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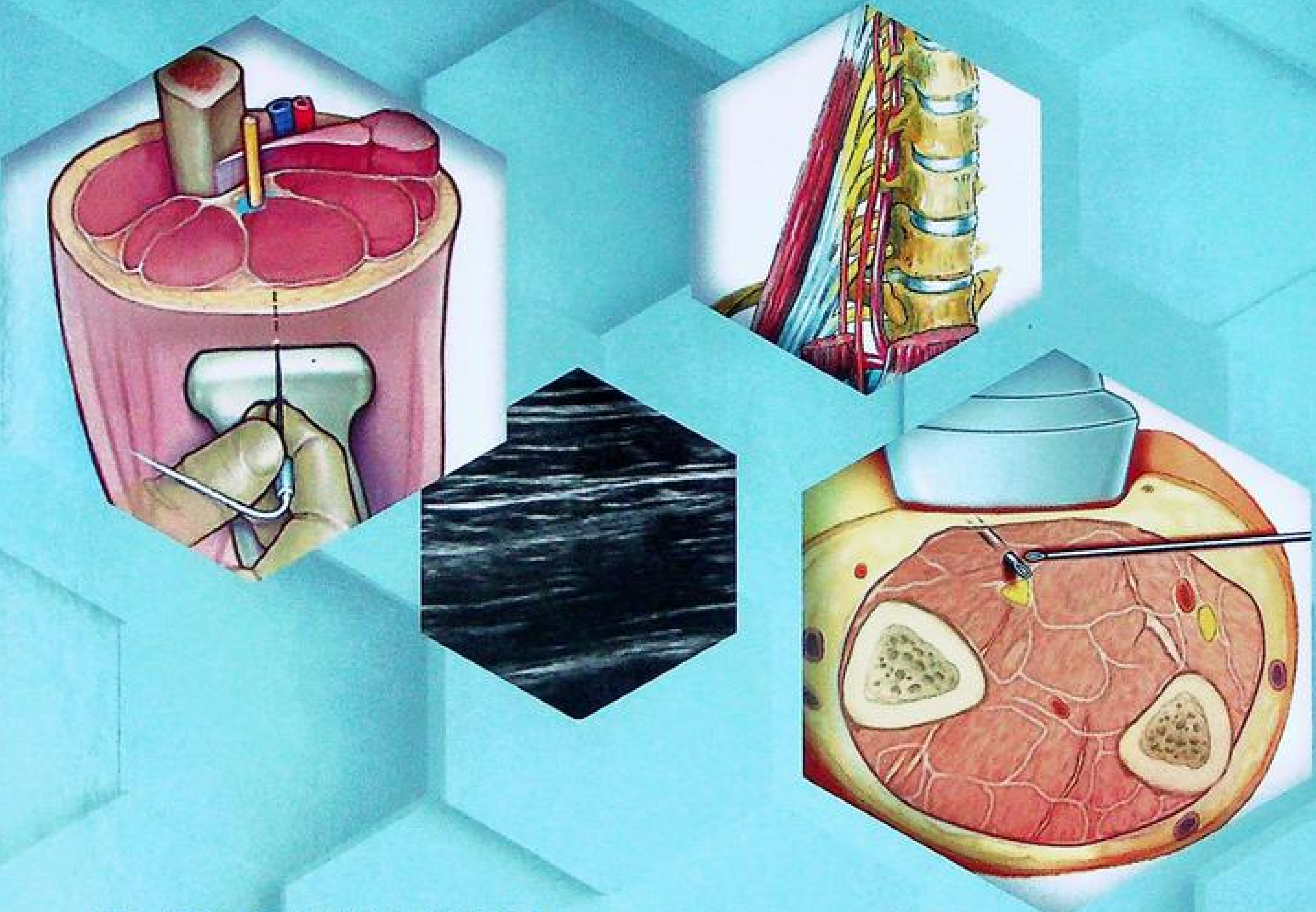

BROWN'S ATLAS OF REGIONAL ANESTHESIA

7TH EDITION

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7TH EDITION

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DEDICATION

To all my family, whose unwavering support and encouragement have been the guiding light on this edition. Your belief in me has made this atlas possible, and I dedicate it to you all.

With heartfelt gratitude,

Ehab Farag

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Foreword

I am deeply honored to write the foreword to the seventh edition of *Brown's Atlas of Regional Anesthesia*, co-edited by Drs. Ehab Farag and Loran Mounir-Soliman.

As a surgeon and chief of staff, I appreciate and value staying up to date with the latest advancements in the field of regional anesthesia, and this atlas has served as a trusted resource for clinicians for decades since its initial publication in 1992. The latest edition, which Ehab and Loran and their impressive roster of expert contributors extensively updated and revised, promises to be an indispensable tool for physicians and trainees alike.

I have had the pleasure of working with both Ehab Farag and Loran Mounir-Soliman in various capacities over the years, and I am continually impressed by their expertise and dedication to their work. Our paths have intertwined as professional colleagues at Cleveland Clinic for nearly 15 years, allowing me to witness their exemplary skills and dedication to patient care. Their exceptional leadership in the field sets them apart and places them at the forefront of regional anesthesia. Both are accomplished anesthesiologists and educators, and their leadership in the field is widely recognized. As you read on, you will soon discover why.

This update represents a substantial overhaul of its predecessors. As you delve into this edition, you will quickly recognize one of its most remarkable attributes—the sheer comprehensiveness it offers. The co-editors and their team have meticulously revised existing chapters and added new ones, covering new blocks to the upper and lower limbs. This version also includes chronic pain blocks that can be performed by acute pain physicians using ultrasound. One unique feature found in this edition for the first time is the ultrasound blocks for upper airway management such as superior laryngeal nerve and recurrent laryngeal nerve blocks.

Another notable feature is that the anatomy chapters have been completely rewritten. Dr. Drake, editor of *Gray's Anatomy for Students*, contributed to the anatomy chapters, adding an essential and invaluable perspective. The added gift of Dr. Drake's expertise enhances an already impressive resource and elevates it to a new level of excellence.

With an eye to inclusiveness, the atlas broadened its reach to encompass dentists who explained dental nerve blocks, providing valuable insights for dentists and enhancing the relevance of this resource across a range of specialties.

An additional standout feature is the incorporation of a unique time-out checklist, designed to be implemented before procedures, ensuring utmost patient safety. Complementing these enhancements, the accompanying videos have been entirely revised, offering a more comprehensive and informative visual learning experience compared with previous versions.

The seventh edition of *Brown's Atlas of Regional Anesthesia* is an impressive accomplishment, reflecting the tireless efforts of both co-editors and an ever-expanding list of contributors. The breadth and depth of coverage make this edition an essential resource for anyone interested in the latest clinical perspectives on regional anesthesia.

Our organization is committed to promoting the highest standards of patient care and believes that this book will advance that goal by providing clinicians with the tools and knowledge they need to provide safe and effective regional anesthesia. I highly recommend this edition to all clinicians, educators, and trainees in the field.

Beri Ridgeway, MD
Chief of Staff
Cleveland Clinic

Preface to the Seventh Edition

It is with great pleasure and enthusiasm that we present this latest edition of *Brown's Atlas for Regional Anesthesia*. In crafting this iteration, we have undertaken a significant transformation, marked by the integration of novel blocks, the enlistment of fresh perspectives through new authorship, and a comprehensive reimagining of the multimedia components within the atlas. This edition stands as a testament to our unwavering commitment to the advancement of regional anesthesia knowledge and practice.

A hallmark of this edition is the incorporation of innovative block techniques, including but not limited to the PENG block, cervical interfacial plane blocks, and axillary nerve blocks, each enhancing the breadth and depth of our coverage. Notably, we have expanded our purview to encompass the intricacies of nerve supply within the shoulder and knee, a distinctive feature that sets this edition apart.

Breaking new ground, this atlas pioneers the inclusion of ultrasound techniques for upper airway blocks, notably addressing the superior laryngeal nerve, recurrent laryngeal nerve, and glossopharyngeal nerve blocks. Furthermore, we embrace a holistic approach by introducing chronic pain blocks, equipping acute pain physicians to perform procedures such as occipital nerve blocks and sacroiliac joint injections with confidence.

In recognition of the symbiotic relationship between dentistry and anesthesia, dental blocks have been authored meticulously by dental professionals, enriching this edition's value for both dentists and physicians engaged in dental anesthesia procedures.

Acknowledging the pivotal role of foundational anatomy knowledge in mastering regional anesthesia, we are privileged to have engaged Dr. Richard Drake, esteemed chief editor of *Gray's Anatomy for Students*, to meticulously rearticulate the anatomy chapters. His specialized expertise has endowed these chapters with a level of clarity and insight unparalleled in the field.

To ensure the currency and relevance of this edition, we have updated existing chapters meticulously, removing unused traditional landmark techniques. The atlas retains its hallmark clarity, ensuring that techniques are not just comprehensible but eminently practicable.

Integral to the multimedia narrative, the videos in this edition have been reenvisioned under the masterful direction of Dr. Escolar from Spain. His artistic acumen has redefined our visual pedagogy, imbuing each video with instructional depth while preserving the accessibility that has defined our atlas.

Aspiring to be more than a reference, this edition transforms into a virtual workshop. Through a synergy of textual elucidation and visual demonstration, it cultivates a comprehensive learning experience, nurturing proficiency from every angle.

Heartfelt appreciation extends to Mr. Joe Kanasz for his consummate artistic talents and unwavering dedication in illustrating the figures that enrich this edition. We also extend our profound gratitude to Kayla Wolfe, Vaishali Singh, Dr. Ambika Kapoor, and the entire publishing team at Elsevier for their tireless commitment and invaluable contributions.

Our ultimate aspiration is for this edition to be a beacon of knowledge and guidance. May it empower readers to glean profound insights, refine their skill sets, and embark upon regional anesthesia procedures with confidence.

Editors
Ehab Farag, MD, FRCA, FASA
Loran Mounir-Soliman, MD

Preface to the Sixth Edition

What nobler employment or more advantageous to mankind than that of the man who correctly instructs the rising generation?

Cicero

In this new edition of *Brown's Atlas of Regional Anesthesia* we have tried our best to make those words of Cicero our motto. Since the last edition, several new blocks, specifically interfascial plane blocks, have been added to our clinical practice, including serratus anterior, PECS, erector spinae blocks, and many more. Therefore, in this edition we tried our best to delve deeper and to add all the nuances in the field of regional anesthesia. Furthermore, we added a new chapter for regional anesthesia written by a world-renowned obstetric anesthesiologist, Dr. Cynthia Wong. We have recruited well-versed authors in the field of regional anesthesia from both the United States and Europe to enrich the content of the text. In this edition, we tried to maintain the theme that characterizes *Brown's Atlas* from its first edition, which is the simplicity and easily performed techniques that can be routinely adopted in everyday clinical practice. All the videos in this edition, as in the previous one, have been performed on real patients in order to transform the atlas into a virtual workshop that can be used by physicians in their clinical practices. Moreover, we not only included the largest library of videos covering virtually every block in the atlas, but we also added an introductory video by Dr. Seif that discusses in detail commonly performed blocks. We hope this new edition will be useful to everyone interested in regional anesthesia from the novice to the master in the field.

We would like to express our gratitude to Drs. John Seif and Vicente Roqués-Escolar for their invaluable help in making the videos of the new edition. We would like to thank Mr. Joe Kanasz and Brandon Stelter for their extraordinary medical illustrations and video production, as well as Mrs. Tanya Smith, our editorial assistant, and Laura Klein and Sarah Barth from Elsevier for their generous help and support during the production process of this new edition.

Editors
Ehab Farag, MD, FRCA, FASA
Loran Mounir-Soliman, MD

Preface to the Fifth Edition

Regional anesthesia is one of the fundamental pillars of modern anesthesia. *The Atlas of Regional Anesthesia* by Dr. David Brown has become a classic textbook for regional anesthesia since its first edition in 1991. Since the last edition published in 2010, the use of ultrasound has changed the map of the practice of regional anesthesia. In this new edition, now *Brown's Atlas of Regional Anesthesia*, we combined the classical techniques from the original atlas with updated techniques and blocks using ultrasound. We believe the eyes do not see what the brain does not recognize. Therefore we felt it was important to include a number of ultrasound images and figures that identify the optimal position of the needle, as well as the best position of the patient and the anesthesiologist during the procedure. We have tried to retain the simplicity of the original atlas through self-explanatory figures and a few purposeful pearls to demonstrate the block performance. We tried to limit the techniques to the most commonly used and routinely adopted in our practice. Moreover, we have added videos of real patients for better clarification, showing real-time blocks performance in addition to advanced techniques using peripheral nerve catheters. Our aim is to transform the atlas into a virtual workshop that enables the reader to feel comfortable with the procedures after reading the text and watching the video. In this new edition we did rewrite all the blocks using ultrasound and added new blocks like subcostal, quadratus lumborum, paravertebral, adductor canal, and many more. We have added new chapters on regional anesthesia pharmacology and on regional anesthesia using ultrasound in pediatric patients. We hope this new edition will be useful to anyone interested in learning regional anesthesia or in mastering regional anesthesia.

We would like to thank Mr. Joe Kanasz for his extraordinary medical illustrations; Mrs. Mariela Madrilejos, our editorial assistant; Ms. Carole McMurray and Mr. William Schmitt from Elsevier for their help and incessant support during the production process of this edition.

Editors
Ehab Farag, MD, FRCA
Loran Mounir-Soliman, MD

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Section VII: Neuraxial Blocks

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The videos accompanying this text can be accessed at eBooks.health.elsevier.com. The videos should be used in conjunction with the text and not as a standalone product.

Video Contents

Please visit eBooks.health.elsevier.com to access your eBook and Video Contents.

Section 1
Introduction

Pharmacology 1

Andrzej P. Kwater and Juan P. Cata

Key Points

- Regional anesthesia is an evolving field that incorporates the use of a variety of local anesthetics, corresponding adjuncts, and extended-release formulations.
- Local anesthetics target voltage-gated sodium channels in order to prevent further transmission of neuronal signals.
- Local anesthetics can be classified based on chemical structure (amino esters and amino amides), duration of clinical effect, and other pharmacodynamic parameters.
- Amino esters: *cocaine, procaine, chloroprocaine, tetracaine,* and *benzocaine*.
- Amino amides: *lidocaine, prilocaine, etidocaine, mepivacaine, ropivacaine*, and *bupivacaine*.
- *Liposomal bupivacaine* is an extended-release formulation and is approved for single-dose infiltration and interscalene brachial plexus blockade in adults.
- Local anesthetic adjuncts are utilized to provide additional clinical benefit, maximize efficacy, and/or prolong the duration of action of a local anesthetic.
- Common adjuncts include vasoconstrictors (epinephrine, norepinephrine, and phenylephrine), buprenorphine, clonidine, dexmedetomidine, and dexamethasone.
- Local anesthetic systemic toxicity (LAST) is an inherent risk and requires timely identification as well as prompt initiation of treatment (lipid emulsion therapy).
- Understanding the pharmacological properties and relative application of local anesthetics allows providers to utilize these agents safely and effectively in the clinical setting.

INTRODUCTION

Regional anesthesia is a field that is constantly evolving as novel techniques and unique local anesthetic formulations are utilized in a wide range of clinical scenarios. The incorporation of regional anesthesia continues to benefit many aspects of patient care, including enhanced analgesia, patient satisfaction, reduced opioid requirements, shortened hospital length of stay, and improved functional outcomes. In fact, regional anesthesia, when indicated and feasible, has become a recommendation in current guidelines for enhanced recovery after surgery. In the perioperative environment, a variety of regional anesthesia techniques can be utilized, including neuraxial anesthesia (spinal, epidural, or caudal), peripheral nerve blocks, fascial plane blocks, and field blocks, as well as intra- or periarticular injections. With the utilization of relevant anatomy, nerve stimulators, and ultrasonography-guided techniques, regional anesthesia has become an effective and reliable tool in the clinical setting.

In the context of regional anesthesia, it is essential to have a thorough understanding of local anesthetics, including their mechanism of action, pharmacokinetics, and relevant application. The use of specific local anesthetic formulations, adjuncts, delayed-release formulations, and continuous catheter systems each have an impact on the effect provided by a particular regional anesthesia intervention. Therefore the appropriate local anesthetic formulation must be considered for each patient scenario, corresponding regional technique, and intended outcome. This chapter will provide detail on these relevant concepts and discuss the important aspects of pharmacology that impact the practice of regional anesthesia.

LOCAL ANESTHETICS

Local anesthetics are classified based on their chemical composition and can vary according to pharmacodynamic parameters, including duration of action. The decision to choose a certain local anesthetic, as well as potential adjuncts, is dictated by the goal of the intervention and the anticipated time of effect. For example, to achieve surgical anesthesia using a peripheral nerve block, it would be ideal to utilize a longer-acting local anesthetic with the highest tolerated concentration to achieve this intended effect. In the context of pain management, understanding the pain trajectory experienced by a patient will determine the type of regional anesthesia intervention performed as well as the choice of local anesthetic and strategies for prolonged analgesia.

In terms of mechanism of action, local anesthetics primarily target voltage-gated sodium channels on the inner surface of the nerve cell membrane during depolarization when the channels are in an open or inactivated state (Fig. 1.1). This mechanism of action prevents further transmission of neuronal signals along myelinated and nonmyelinated fibers.

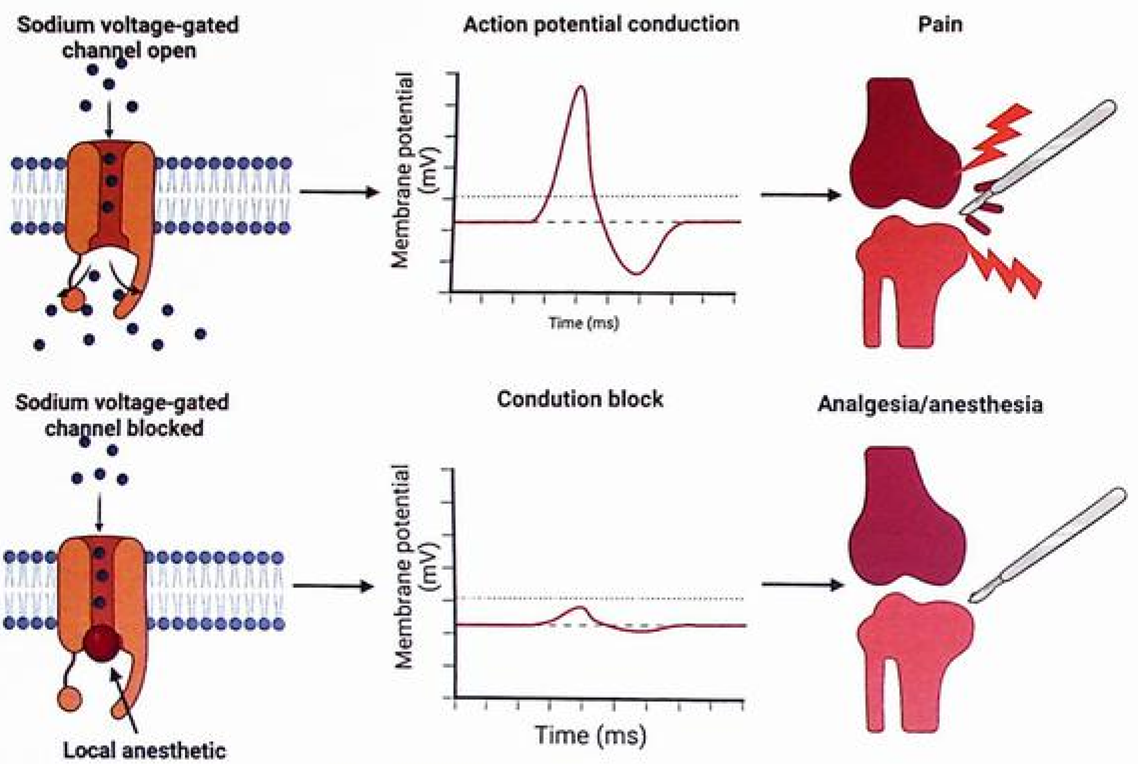


Fig. 1.1 Mechanism of action of local anesthetics.

	Procaine	Chloroprocaine	Lidocaine	Mepivacaine	Tetracaine	Ropivacaine	Etidocaine	Bupivacaine
Infiltration	45–60		75–90					180–360
+ epi	60–90		90–180					200–400
Peripheral			90–120	100–150		360–480		480–780
+ epi			120–180	120–220		480–600		600–900
SAB*	60–75		60		70–90			90–110
+ epi	75–90		75–100		100–150			100–150
phenylephrine†	90–120				200–300			
Epidural		45–60	80–120	90–140		140–200	120–200	165–225
+ epi		60–90	120–180	140–200		160–220	150–225	180–240

*Subarachnoid block.
†For lower extremity surgery.

Fig. 1.2 Local anesthetic duration of action in the context of various regional anesthesia interventions (infiltration, peripheral nerve block, spinal [SAB], epidural). Time measurements are provided in minutes of surgical anesthesia. *Epi*, Epinephrine; *SAB*, subarachnoid block.

The clinical effect provided by local anesthetics varies along a timeline as most agents are generally classified as short-, intermediate-, or long-acting. This distribution of differences among local anesthetics is displayed (Fig. 1.2), in addition to the effects provided by adjuvant drugs (vasoconstrictor agents), for a variety of regional anesthesia interventions.

All local anesthetics share the basic structure of an aromatic end, intermediate chain, and amine end (Fig. 1.3). This basic structure is further subdivided into two classes of local anesthetics: amino esters and amino amides (Fig. 1.4). The amino esters possess an ester linkage between the aromatic end and the intermediate chain. These agents include cocaine, procaine, 2-chloroprocaine, and tetracaine (Fig. 1.5). On the other hand, the amino amides contain an amide link between the aromatic end and the intermediate chain. These local anesthetics include lidocaine, prilocaine, etidocaine, mepivacaine, bupivacaine, and ropivacaine (Fig. 1.5).

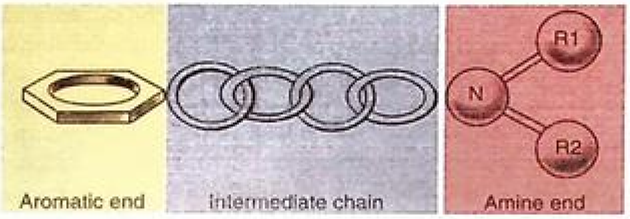


Fig. 1.3 Basic chemical structure of local anesthetic.

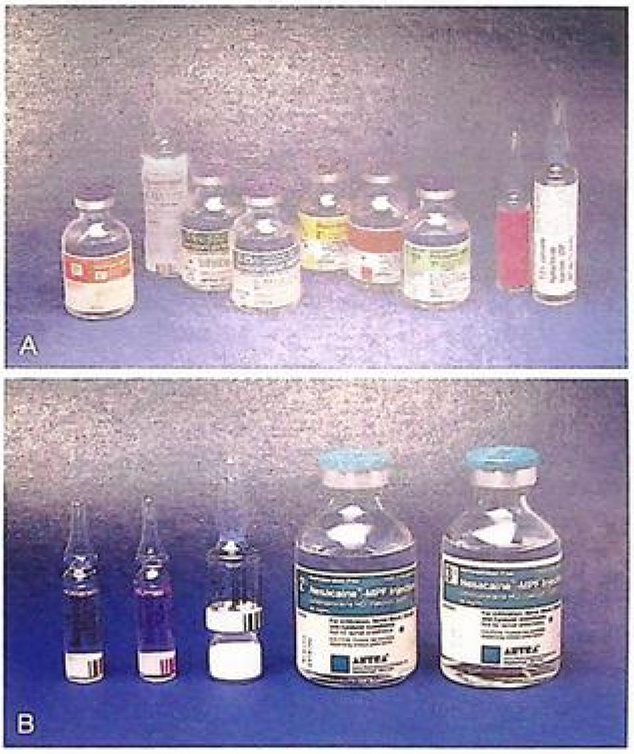


Fig. 1.4 Local anesthetics commonly used in the United States. (A) Amino amides. (B) Amino esters.

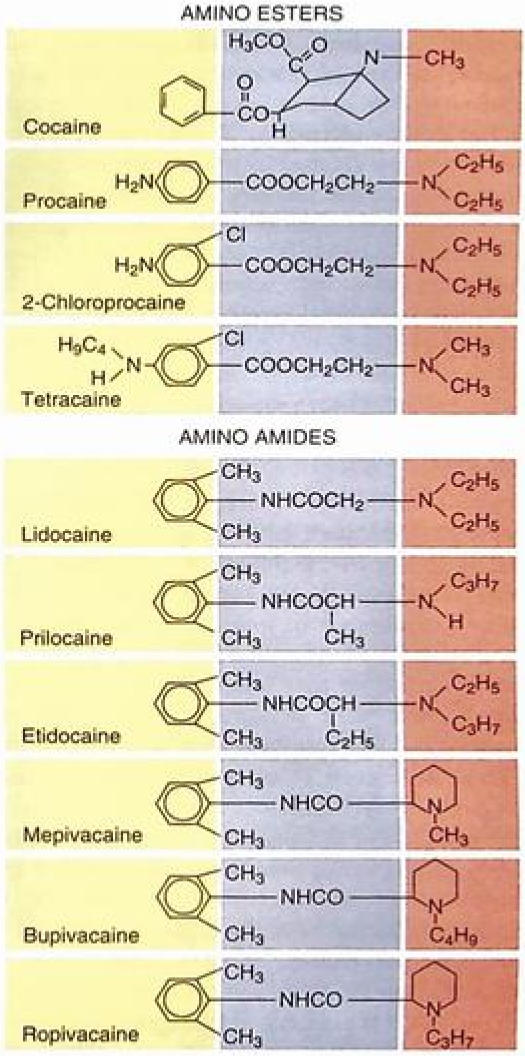
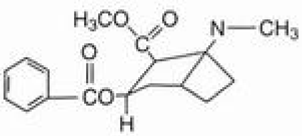


Fig. 1.5 Chemical structure of various amino ester and amino amide local anesthetics.

AMINO ESTERS



Cocaine was the first local anesthetic used clinically and, although limited in utility today, it remains an effective agent for achieving topical anesthesia, such as in transsphenoidal pituitary resections. Due to its unique quality as a vasoconstrictor, cocaine can be used to provide topical anesthesia as well as decrease congestion along mucous membranes during airway management techniques. However, due to its addictive qualities and risk for abuse, cocaine is often substituted with alternative formulations (i.e., lidocaine with phenylephrine) as a way to achieve similar clinical results.

Procaine was synthesized in 1904 by Alfred Einhorn, who at the time was looking for a drug that was superior to cocaine and other solutions. Its qualities include a slow onset, short duration of action, low potency, and limited tissue penetration. Despite it seldom being used for peripheral nerve blocks or epidural anesthesia due to these qualities, it does function as an effective local anesthetic for skin infiltration. In addition, the 10% procaine formulation can be used as a short-acting (i.e., lasting <1 hour) local anesthetic in spinal anesthesia.

Chloroprocaine is characterized by rapid onset and a short duration of action. Its principal use has been in the context of epidural anesthesia for emergent cesarean delivery or short procedures (i.e., lasting <1 hour). Its use declined during the early 1980s after reports of prolonged sensory and motor deficits resulting from unintentional subarachnoid administration. The adverse effects were attributed to its low pH and the use of sodium metabisulfite as a preservative in the solution. As a result of these findings, a newer drug formulation was created using ethylenediaminetetraacetic acid (EDTA) as a preservative. However, even with this substitution, the use of intrathecal chloroprocaine as part of spinal anesthesia is limited.

Tetracaine was first synthesized in 1931 and has become widely used in the United States for spinal anesthesia. It can be used as an isobaric, hypobaric, or hyperbaric solution for spinal anesthesia. Without epinephrine as an additive, tetracaine administered for spinal anesthesia typically lasts 1.5 to 2.5 hours. However, with the addition of epinephrine, its effects can last up to 4 hours, which is beneficial for prolonged cases, such as lower extremity procedures. Tetracaine is also effective for achieving topical anesthesia, although caution must be used due to the potential for systemic side effects. Tetracaine is available as a 1% solution for intrathecal use or as anhydrous crystals that are reconstituted by adding sterile water immediately before use.

Eduard Ritsert synthesized *benzocaine* in 1900. Benzocaine is a derivative of the organic compound para-aminobenzoic acid (PABA). The most common uses of this local anesthetic are dentistry and awake endotracheal intubations because it is available in lozenges, sprays, aerosols, creams, and gels in different concentrations (5%, 10%, and 20%). The maximum recommended dose is 7 mg/kg. Due to its related structure to PABA, benzocaine can cause methemoglobinemia. Thus it is contraindicated in children younger than 2 years of age, patients with a history of methemoglobinemia, and those with glucose-6-phosphate deficiency. Methemoglobinemia results from the ability of the metabolite nitrobenzene to reduce the oxygen-binding capacity of hemoglobin by the oxidation of iron ($Fe2^+$ to $Fe3^+$). Treatment for methemoglobinemia includes the administration of 1% methylene blue and supportive measures (supplemental oxygen).

AMINO AMIDES

Nils Lofgren introduced *lidocaine* in 1948, with it ultimately becoming one of the most widely used local anesthetics due to its many beneficial properties. These attributes include its inherent potency, rapid onset of action, effective tissue penetration, and strength of effect when administered in the setting of infiltration, peripheral nerve blockade, and both epidural and spinal anesthesia. For peripheral nerve blocks, the 1% to 1.5% lidocaine solution is often effective in producing a quick onset of motor and sensory blockade. For epidural anesthesia, the 2% solution is most often utilized to achieve the intended effect. On the other hand, for spinal anesthesia, a 5% lidocaine solution in 7.5% dextrose is most commonly used, although it may also be used as a 0.5% hypobaric solution or a short-acting 2% solution.

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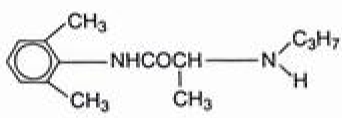

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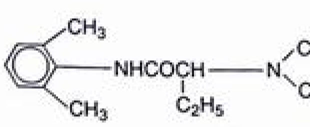

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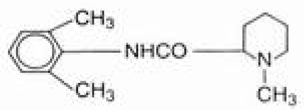

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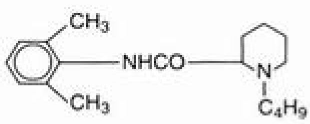

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Cardiotoxicity following systemic reactions with bupivacaine became a concern in the 1980s. Although it is clear that bupivacaine alters myocardial conduction more dramatically than lidocaine, the need for appropriate and rapid resuscitation during any LAST scenario cannot be overemphasized. Of note, levobupivacaine is the single enantiomer (L-isomer) of bupivacaine and is less potent than bupivacaine but more potent than ropivacaine. Levobupivacaine has a lower risk of potential cardiotoxicity than bupivacaine, yet maintains its pharmacokinetic profile and clinical effects similar to those of standard racemic bupivacaine.

Liposomal bupivacaine (Exparel: Pacira BioSciences Inc., Parsippany, NJ, USA) has become clinically available in more recent years. Liposomal bupivacaine is an injectable suspension that provides a slow, continuous release of bupivacaine following initial administration and has a theoretical duration of effectiveness of up to 72 hours. It is approved for single-dose infiltration in patients above the age of 6 years and adult patients undergoing interscalene brachial plexus blockade for postoperative analgesia. Presently, it is not recommended to administer liposomal bupivacaine as part of epidural and intrathecal formulations, intraarticular injections, or regional anesthesia interventions, aside from interscalene brachial plexus blocks. The maximum dose should not exceed 266 mg (20 mL of liposomal bupivacaine solution). The solution can be mixed with plain bupivacaine hydrochloride (no more than 1:2 mg dose ratio, bupivacaine hydrochloride:liposomal bupivacaine) or saline for volume expansion. Additional use of local anesthetics should be avoided for a period of 96 hours following the initial administration of liposomal bupivacaine.

Liposomal bupivacaine has gained significant interest as a strategy to provide a prolonged analgesic effect in the setting of surgical wound infiltration and regional anesthesia interventions. Although initial findings from studies were reassuring, in more recent evaluations, liposomal bupivacaine has not exhibited convincing and/or consistent evidence supporting its use over standard local anesthetic formulations. Therefore strategies for achieving prolonged analgesic effects should focus on the use of catheter-based techniques and the utilization of long-acting local anesthetics in combination with adjuncts. These adjuncts include medications such as dexamethasone, clonidine, and dexmedetomidine, all of which will be discussed in the next section.

Another extended-release formulation, composed of a combination of bupivacaine and meloxicam, is currently approved for soft tissue (i.e., abdominal surgery) and periarticular instillation (i.e., arthroplasty). However, a recent meta-analysis concluded that the added clinical benefit of this combined formulation was marginal when compared to standard bupivacaine.

LOCAL ANESTHETIC ADJUNCTS

The use of adjuncts involves the addition of one or more pharmacologic agents to the local anesthetic formulation. The goal of utilizing these adjuncts is to provide additional clinical benefit, maximize efficacy, and/or prolong the duration of action of a particular local anesthetic solution.

VASOCONSTRICTORS

Vasoconstrictors are often added to local anesthetics to prolong the duration of action, enhance the quality of analgesia, and function as markers of intravascular injection. The mechanism of action of these adjuvant drugs is at least partially attributed to vasoconstriction and delayed systemic absorption in the surrounding tissue. Further, it context of epidural anesthesia for emergent cesarean delivery or short procedures (i.e., lasting <1 hour). Its use declined during the early 1980s after reports of prolonged sensory and motor deficits resulting from unintentional subarachnoid administration. The adverse effects were attributed to its low pH and the use of sodium metabisulfite as a preservative in the solution. As a result of these findings, a newer drug formulation was created using ethylenediaminetetraacetic acid (EDTA) as a preservative. However, even with this substitution, the use of intrathecal chloroprocaine as part of spinal anesthesia is limited.

Tetracaine was first synthesized in 1931 and has become widely used in the United States for spinal anesthesia. It can be used as an isobaric, hypobaric, or hyperbaric solution for spinal anesthesia. Without epinephrine as an additive, tetracaine administered for spinal anesthesia typically lasts 1.5 to 2.5 hours. However, with the addition of epinephrine, its effects can last up to 4 hours, which is beneficial for prolonged cases, such as lower extremity procedures. Tetracaine is also effective for achieving topical anesthesia, although caution must be used due to the potential for systemic side effects. Tetracaine is available as a 1% solution for intrathecal use or as anhydrous crystals that are reconstituted by adding sterile water immediately before use.

Eduard Ritsert synthesized *benzocaine* in 1900. Benzocaine is a derivative of the organic compound para-aminobenzoic acid (PABA). The most common uses of this local anesthetic are dentistry and awake endotracheal intubations because it is available in lozenges, sprays, aerosols, creams, and gels in different concentrations (5%, 10%, and 20%). The maximum recommended dose is 7 mg/kg. Due to its related structure to PABA, benzocaine can cause methemoglobinemia. Thus it is contraindicated in children younger than 2 years of age, patients with a history of methemoglobinemia, and those with glucose-6-phosphate deficiency. Methemoglobinemia results from the ability of the metabolite nitrobenzene to reduce the oxygen-binding capacity of hemoglobin by the oxidation of iron ($Fe2^{+}$ to $Fe3^{+}$). Treatment for methemoglobinemia includes the administration of 1% methylene blue and supportive measures (supplemental oxygen).

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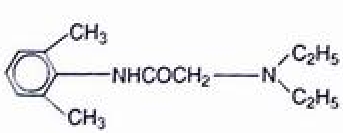

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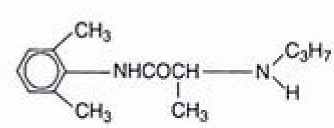

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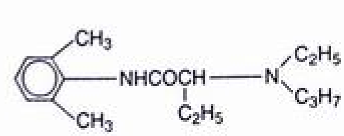

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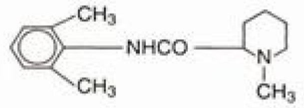

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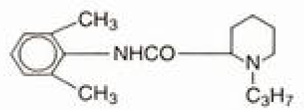

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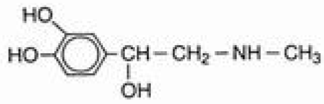
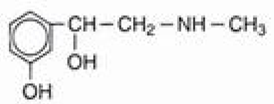


Epinephrine is the most commonly used vasoconstrictor agent, with an effective concentration dose of 1:200,000. When epinephrine is added to a local anesthetic in the commercial production process, it is necessary to add stabilizing agents. Otherwise, epinephrine rapidly loses its potency on exposure to air and light. Phenylephrine serves as another additive agent, principally in the context of spinal anesthesia. Effective prolongation of the analgesic block can be achieved by adding 0.5 to 2 mg of phenylephrine to the chosen spinal anesthetic solution. *Norepinephrine* also has been utilized as a vasoconstrictor for spinal anesthesia, although it does not appear to provide extensive prolongation of action as is seen with other vasoconstrictors. Of note, while the addition of vasoconstrictor agents can prolong the analgesic benefits of local anesthetics, it can also enhance their unwanted effects, such as motor weakness, in situations when not desirable.

OPIOIDS



Buprenorphine functions as a mu (μ) partial opioid receptor agonist and kappa (κ) opioid receptor agonist that can be administered as part of a local anesthetic formulation for peripheral nerve blockade. Following perineural injection, buprenorphine contributes to the inhibition of voltage-gated sodium channels and acts on opioid receptors on neuronal fibers. In a meta-analysis of several randomized controlled trials, it was shown that buprenorphine as an adjunct for peripheral nerve blocks increased the duration of analgesic benefit by approximately 8 hours when compared to local anesthetic alone. Possible side effects associated with buprenorphine include pruritus as well as postoperative nausea and vomiting, with no evidence of neurotoxicity.

α_2-ADRENORECEPTOR AGONISTS

Clonidine functions as an α_2-adrenoreceptor agonist that can be administered perineural as part of a peripheral nerve block. Its mechanism of action is presumed to involve the inhibition of channels on neurons that are responsible for the hyperpolarization phase, thus inhibiting the generation of further action potentials and proper functioning of the nerve. There is also a thought that clonidine can contribute to α_1-adrenoreceptor-mediated vasoconstriction in local tissue. Several randomized controlled trials have demonstrated that when administered as an adjunct with local anesthetics for peripheral nerve blocks, clonidine (30–300 μg) increases the duration of analgesia as well as sensory and motor blockade by approximately 1 to 2 hours. Potential side effects from systemic absorption can include bradycardia, hypotension, and sedation.

Dexmedetomidine is a more highly selective α_2-adrenoreceptor agonist and has a similar mechanism of action to clonidine following perineural administration. In a recent meta-analysis of randomized controlled trials, the use of perineural dexmedetomidine for brachial plexus blocks was associated with a prolongation of analgesia as well as motor and sensory blockade by 3 to 4 hours and a reduction in time of onset of the sensory block as compared to local anesthetic alone. These findings were also identified in lower extremity blocks when dexmedetomidine was added to bupivacaine solutions. Potential side effects are similar to those of clonidine, including hypotension and bradycardia secondary to systemic absorption.

STEROIDS

Dexamethasone serves as a potent long-acting glucocorticoid that has been extensively studied as an adjunct in the setting of regional anesthesia. Its mechanism of action is related to effects on neuronal glucocorticoid receptors that lead to downstream effects of decreased excitability of neurons. However, research findings indicate that dexamethasone primarily acts through systemic and local anti-inflammatory effects.

In the context of peripheral nerve blocks and fascial plane blocks, dexamethasone used as a local anesthetic adjunct has demonstrated an increase in the duration of analgesia for up to 8 hours and of motor blockade by up to approximately 4 hours, most prominently when using long-acting local anesthetics. In these studies, no effect on the time of onset for the blockade was identified. In regard to appropriate dosing with peripheral nerve blocks, perineural dexamethasone appears to exhibit a ceiling effect, with a dose of 4 mg providing the optimal analgesic benefit. Of note, dexamethasone can increase perioperative blood glucose concentration following perineural administration, although it appears to be minimal when compared to the effect following intravenous administration.

LOCAL ANESTHETIC TOXICITY

LAST is an inherent risk when administering local anesthetics in the context of regional anesthesia. Timely identification of signs and symptoms, proper airway and resuscitative interventions, as well as prompt initiation of lipid emulsion therapy all serve as vital components in the management of LAST. The American Society of Regional Anesthesia and Pain Medicine (ASRA) has developed a practice advisory (Table 1.1) with updated guidelines on LAST management. This checklist provides a focused approach to the management and treatment of LAST. Every anesthesia provider involved in regional anesthesia interventions should become familiar with these guidelines to ensure patient safety.

Pharmacology of Local Anesthetics in Pediatrics

2

Rami Edward Karroum and Tarun Bhalla

Key Points

- Neonates and infants are more prone to developing systemic toxicity to local anesthetics (LAs), particularly amide LAs, compared with older children and adults. This is due to reduced plasma concentration of α1-acid glycoprotein with higher unbound fraction and decreased clearance of amide LAs.
- Higher baseline heart rates in neonates and infants predispose them to increased sensitivity for bupivacaine-induced cardiotoxicity compared with adults. This is due to the strong affinity of bupivacaine for the fast sodium channels, resulting in prolonged blockade of these channels in the cardiac conduction system and a profound decrease in ventricular conduction velocity.
- Liposomal bupivacaine (LB) is now approved by the U.S. Food and Drug Administration (FDA) for single-dose surgical site infiltration to produce postsurgical local anesthesia in patients ≥6 years of age.
- Chloroprocaine is the LA of choice for epidural infusion in neonates and small infants due to its very low risk of systemic toxicity and accumulation compared with amide LAs in this age group, as well as easier dosing and pump programming.
- Regional anesthesia is usually performed under general anesthesia, which may mask the earliest signs of systemic toxicity, particularly central nervous system (CNS) signs. Therefore refractory cardiovascular collapse may be the first and only sign in pediatric patients.
- It is recommended that an epinephrine-containing test dose be used in all regional blocks before giving the full bolus dose. The order of sensitivity for detection of unintentional intravascular injection in pediatric patients when a test dose of LAs mixed with epinephrine is given, from most to least sensitive, is:
  - Increase T-wave amplitude and ST segment changes > increase in systolic blood pressure more than 10% > increase in heart rate 10% to 15% above baseline heart rate before administration of test dose.
  - Total doses of LAs should not exceed the maximum allowable dose under any circumstances. The dose should be based on the lean body weight rather than the actual body weight, particularly in obese patients.

INTRODUCTION

LAs are divided into two main chemical compounds: the amides and the esters.

Amide LAs are metabolized exclusively in the liver by cytochrome P450 enzymes. These enzymes reach adult activity levels by 9 months to 1 year of age. Therefore neonates and infants have a decreased clearance of amide LAs. Amide LAs bind to serum proteins. α1-acid glycoprotein (AGP) is the major serum protein that binds amide LAs. Albumin has a very low affinity to bind amide LAs. However, being the most abundant protein in serum, albumin-binding capacity to amide LAs is not insignificant.

Infants have a decreased level of AGP and albumin. Adult levels of protein binding are reached at about 1 year of age. Therefore neonates and infants are more prone to developing toxicity from amide LAs due to a higher serum-free fraction and lower clearance rate. The susceptibility to cardiac toxicity is amplified by increased heart rates. Due to their higher baseline heart rates, neonates and infants are more sensitive than adults to amide LA-induced cardiotoxicity.

Neonates and infants have a relatively larger volume of distribution (VD) of amide LAs compared with adults. Toxicity will be more likely to occur following repeated doses and/or continuous infusion. This can be explained by the fact that larger VD prevents high serum drug concentrations from occurring after a slow incremental injection of a single dose of amide LAs.

Commonly used amide LAs in children include lidocaine, ropivacaine, bupivacaine, its L-enantiomer levobupivacaine, and eutectic mixture of local anesthetics (EMLA) cream.

Ester LAs are degraded in plasma by cholinesterases. Although neonates and infants have a lower level of cholinesterases, this has not been shown to be of clinical significance. Commonly used ester LAs in children include tetracaine and 2% to 3% chloroprocaine. Chloroprocaine use for continuous epidural analgesia in neonates and infants has been on the rise due to its rare incidence of systemic toxicity.

AMIDE LOCAL ANESTHETICS

BUPIVACAINE

This is the most commonly used amide LA for regional blockade in pediatric anesthesia. Its long duration of action is related to its high binding to plasma proteins. Adding epinephrine will not result in further prolongation of the duration of action. However, epinephrine will reduce the rate of systemic absorption and the peak plasma concentration of bupivacaine. Its relatively slow onset of action is due to its high pKa of 8.1. It is a racemic mixture of levorotatory (L) and dextrorotatory (D) enantiomers; the L-enantiomer is the bioactive form, and the D-enantiomer is responsible for its toxicity. Toxicity from bupivacaine can be serious, ranging from CNS excitation to cardiovascular collapse. Direct cardiac toxicity is due to prolonged blockade of the sodium channels in the cardiac conduction system, resulting in a profound decrease in ventricular conduction velocity. This phenomenon is markedly amplified by tachycardia due to the strong affinity of bupivacaine for the fast sodium channels. Stereoselectivity of the sodium channel in the open state, however, has not been demonstrated.

The threshold for toxicity occurs at a bupivacaine level of 2 to 4 μg/mL. The maximum dose of bupivacaine is 2.5 to 3 mg/kg. The most commonly used concentration for single-shot peripheral nerve block and caudal epidural is 0.25% (Table 2.1). After a single administration, analgesia usually lasts for 3 to 4 hours. For an epidural catheter, the loading dose is 0.05 mL/kg/spinal segment or between 0.5 and 1 mL/kg, not to exceed the maximum dose of 2.5 mg/kg. For continuous epidural infusion, a concentration ranging from 0.0625% to 0.125% is used and usually runs at a dose of 0.2 to 0.4 mg/kg/h (Table 2.2).

LIPOSOMAL BUPIVACAINE

The liposome bupivacaine formulation incorporates liposome-encapsulated bupivacaine (DepoFoam) and a small amount of extraliposomal bupivacaine. The liposome-encapsulated component permits bupivacaine release over an extended period. The extraliposomal component allows for rapid release and relatively rapid onset of action.

In March 2021, the U.S. Food and Drug Administration (FDA) approved the use of liposomal bupivacaine (LB) for single-dose surgical site infiltration in patients aged 6 years of age and older to produce postsurgical local analgesia. This approval was based on a multicenter study to evaluate the pharmacokinetics (PK) and safety of LB for postsurgical analgesia in pediatric patients aged 6 to less than 17 years undergoing spine or cardiac surgery (PLAY). Two separate age groups were evaluated (age group 1: patients 12 to <17 years undergoing spine surgery; age group 2: patients 6 to <12 years undergoing spine or cardiac surgery), with randomized allocation of LB 4 mg/kg or bupivacaine hydrochloride (HCl) 2 mg/kg via local infiltration at the end of spine surgery (age group 1); or LB 4 mg/kg via local infiltration at the end of spine or cardiac surgery (age group 2). Results of the study showed that the safety of LB was comparable to bupivacaine. LB was well tolerated for all age groups. Adverse events (AEs) were mild or moderate, and there were no discontinuations due to AEs or deaths. AEs included nausea, vomiting, constipation, hypotension, anemia, muscle twitching, blurred vision, pruritus, and tachycardia. There were no treatment-related cardiac or nervous system AEs in the LB arms. The PK profile of LB in pediatric patients was comparable across age groups and generally consistent with the LB PK profile in adults.

Multiple case reports since then have been published about the use of LB for surgical site infiltration in pediatric anterior cruciate ligament (ACL) reconstruction, posterior spinal fusion with instrumentation for adolescent idiopathic scoliosis, and pediatric tonsillectomy.

LB is still not recommended for:

- Epidural, intrathecal, intravascular or intraarticular use
- Patients <6 years for infiltration

Table 2.1 Single-Shot Caudal Epidural Dose of Local Anesthetics

Local anesthetic	Concentration	Dose (mg/kg)	Dose (mL/kg)
Bupivacaine	0.25% (2.5 mg/mL)	2.5	1
Ropivacaine	0.2% (2 mg/mL)	2	1

Table 2.2 Suggested Epidural Infusion Concentrations and Rates for Pediatric Patients

Local anesthetic	Maximum rate of infusion and suggested infusion concentration (conc.)		
	Neonates and infants up to 6 months	Infants (6 months to 1 year)	Children older than 1 year
Chloroprocaine[a]	Conc. of 2%. Rate of 5 to 15 mg/kg/h.	N/A[c]	N/A[c]
Bupivacaine	Conc. of 0.0625%. Rate of 0.2 mg/kg/h for no more than 48 hours.	Conc. of 0.0625% to 0.125%. Rate of 0.3 to 0.4 mg/kg/h. Reduce the infusion rate 30% after 48 hours and discontinue after 72 hours.	Conc. of 0.0625% to 0.125%. Rate of 0.4 mg/kg/h.
Ropivacaine[b]	Conc. of 0.1%. Rate of 0.2 mg/kg/h for no more than 72 hours. Reduce the infusion rate 30% after 48 hours.	Conc. of 0.1% to 0.2%. Rate of 0.3 to 0.4 mg/kg/h. Reduce the infusion rate 30% after 48 hours.	Conc. of 0.1% to 0.2%. Rate of 0.4 mg/kg/h.

[a] *Chloroprocaine is the first choice for epidural infusion in neonates due to reduced risk of systemic toxicity compared with amide LAs.*
[b] *Ropivacaine is the second choice for epidural infusion in neonates due to its better toxicity profile compared with bupivacaine.*
[c] *N/A, nonapplicable. Chloroprocaine is not usually used in this age group and is replaced by amide LAs.*

- Regional nerve blocks other than interscalene brachial plexus nerve blocks in patients ≥18 years

The recommended dose of LB for patients aged 6 to <17 years old is 4 mg/kg, up to a maximum of 266 mg.

LEVOBUPIVACAINE (L-ENANTIOMER OF BUPIVACAINE)

Levobupivacaine has almost the same blocking properties and PK as its racemic counterpart, bupivacaine. The effect on the cardiac conduction system is stereospecific, with the L-enantiomer having much less of an effect than the D-enantiomer present in the racemic mixture of bupivacaine. As a result, levobupivacaine carries a reduced risk of cardiac toxicity compared with bupivacaine. It is currently unavailable in the United States.

ROPIVACAINE

This exists as an L-enantiomer. It is chemically similar to bupivacaine but differs from it structurally, having a propyl (three-carbon) side chain rather than a butyl (four-carbon) side chain. In an equipotent dose, it carries a lower risk of cardiac and neurological toxicities compared with bupivacaine. This makes ropivacaine an attractive alternative to bupivacaine in pediatric patients. The data available from studies on infants and children do not report greater sparing of motor function following ropivacaine blockade compared with bupivacaine. Adult studies are conflicting in this regard.

The most commonly used concentration for single-shot caudal and single-shot peripheral nerve block is 0.2% (see Table 2.1). For an epidural catheter, the loading dose is 0.05 mL/kg/spinal segment or between 0.5 and 1 mL/kg, not to exceed the maximum dose of 3 mg/kg. For continuous infusion, the concentration range is from 0.1% to 0.2% and usually runs at a dose of 0.2 to 0.5 mg/kg/h (see Table 2.2).

LIDOCAINE

Lidocaine is not commonly used in pediatrics due to its short duration of analgesia. The amides ropivacaine and bupivacaine are more commonly used instead.

EUTECTIC MIXTURE OF LOCAL ANESTHETICS CREAM

This is a eutectic mixture of equal quantities of lidocaine 2.5% and prilocaine 2.5%. It is commonly used to provide transdermal local anesthesia in pediatric patients. Methemoglobinemia has been reported with the use of EMLA cream. Therefore the maximum total surface area to which the cream is applied should be calculated in advance, and the maximum allowable dose should never be exceeded (Table 2.3). This is particularly important in neonates. However, close attention should also be paid to the dose used in infants and toddlers. EMLA cream should be applied only to intact skin, and the dose should be reduced in case it is applied to mucous membranes. Other reported side effects include blanching and rash at the site of application. The duration of action is 1 to 2 hours.

LIDOCAINE AND TETRACAINE (SYNERA) TRANSDERMAL PATCH

This is a combination of lidocaine, an amide LA, and tetracaine, an ester LA. The drug formulation is an emulsion in which the oil phase is a 1:1 eutectic mixture of lidocaine 7% and tetracaine 7%. Each patch contains 70 mg of lidocaine, and 70 mg of tetracaine, and has a total skin contact area of 50 cm and an active drug-containing area of 10 cm^2. The eutectic mixture has a melting point below room temperature, and therefore both LAs exist as a liquid oil rather than as crystals. The patch has a heating component that begins to heat once the patch is removed from the pouch and is exposed to oxygen in the air. It increases skin temperature slightly to increase blood flow into the area and speeds up delivery of LAs to provide anesthesia to a depth of almost 7 mm. It is used to facilitate venipuncture, intravenous (IV) cannulation, and some superficial dermatological procedures. It should be applied only to intact skin. Methemoglobinemia has been reported, and caution should be exercised in patients with congenital or idiopathic methemoglobinemia. Caution should be exercised in patients with pseudocholinesterase deficiency, as they are at greater risk of tetracaine toxicity.

If being used with other products containing an LA, consider the potential for additive effects. The heating component contains iron powder and must be removed before magnetic resonance imaging. Application of the patch for a longer duration than recommended, or simultaneous or sequential application of multiple patches, is not recommended because of the risk for increased drug absorption and possible adverse reactions. Cutting the patch or removing the top cover could cause the patch to heat to temperatures that could result in thermal injury. On the other hand, covering the holes on the top side of the patch could cause the patch not to heat. The most common side effects are local skin reactions such as redness of the skin and swelling; these reactions are generally mild and resolve spontaneously after discontinuation of the patch. Safety and effectiveness of the patch have been established

Table 2.3 Maximum Recommended Doses and Application Areas for EMLA Cream

Body weight and age	Maximum total dose (g)	Maximum surface area (cm^2)
0 to 3 months or <5 kg	1	10
3 to 12 months and 5 to 10 kg	2	20
1 to 6 years and 10 to 20 kg	10	100
7 to 12 years and >20 kg	20	200

EMLA, Eutectic mixture of local anesthetics.

in patients 3 years of age and older. Apply the patch for 20 to 30 minutes prior to venipuncture or IV cannulation. For superficial dermatological procedures such as superficial excision or shave biopsy, apply the patch for 30 minutes prior to the procedure. A topical cream of lidocaine and tetracaine (Pliaglis) also exists but is indicated only for adult use.

ESTER LOCAL ANESTHETICS

TETRACAINE

Tetracaine is the most commonly used LA for spinal anesthesia in children. Some centers use spinal anesthesia with tetracaine as the sole anesthetic for inguinal hernia repair in premature or expremature neonates. This practice is most relevant for those premature neonates who are less than 60 weeks' postconceptual age at the time of surgery. This population is at risk for developing postoperative apnea, and the use of spinal anesthesia may decrease the incidence of this complication.

Neonates have a larger total volume of cerebrospinal fluid (CSF) compared with adults (4 mL/kg compared with 2 mL/kg, respectively). In addition, 50% of the total CSF volume is in the spinal portion of the subarachnoid space, compared with only 25% of the total CSF volume in adults. Neonates also have a more rapid turnover of CSF than adults. As a result, neonates require larger doses of LAs for spinal anesthesia, and the duration of the spinal block is shorter.

Tetracaine is used in a concentration of 1% (10 mg/mL), and the calculated dose is mixed in an equivalent volume of dextrose 10% to make the solution hyperbaric. The final concentration of tetracaine is 0.5% (5 mg/mL). For inguinal hernia repair, neonates less than 5 kg require the largest dose of 0.5 to 0.6 mg/kg. For infants 5 to 15 kg, the dose is 0.3 to 0.4 mg/kg, and for children greater than 15 kg, the dose is 0.2 to 0.3 mg/kg (Table 2.4).

The duration of the block is 90 to 120 minutes. This can be extended by 30% with the addition of epinephrine 1:100,000. If a higher block level is desired in neonates, the dose can be increased up to a maximum of 1 mg/kg. This dose can result in a block that extends to a dermatome height in the mid to upper thoracic region.

CHLOROPROCAINE

Chloroprocaine is increasingly used to provide continuous epidural infusion for postoperative pain control in neonates. It is rapidly metabolized by cholinesterases, with an elimination half-life of a few minutes. Although neonates have a reduced level of plasma esterases compared with adults, this is clinically insignificant. Therefore the incidence of systemic toxicity is rare, and the risk of accumulation is minimal. This safety profile allows better analgesia in neonates as it allows the use of higher infusion rates and thus wider dermatomal coverage compared with amide LAs. Chloroprocaine has a rapid onset of action (5–10 minutes) because of its high tissue penetrance. It has a short duration of action (45 minutes) that can be prolonged to 70 to 90 minutes with the addition of epinephrine. Its potency is 25% that of bupivacaine or tetracaine. Epidural anesthesia is achieved by administering up to 1 mL/kg of 2% to 3% chloroprocaine with epinephrine 1:200,000 (maximum dose of chloroprocaine: 20–30 mg/kg). For continuous epidural analgesia rates, refer to Table 2.2.

TOXICITY OF LOCAL ANESTHETICS

DIRECT NEUROTOXICITY

All LAs are potentially capable of producing direct neurotoxicity. This complication is rare, and conclusive human studies are still lacking in this field. However, animal studies show that the risk is higher in the developing nervous system and is directly related to the concentration of the LA. Therefore neonates and infants are at higher risk because their nervous system is still developing. The recommendation is to avoid the use of a high concentration of LAs in this age group.

SYSTEMIC TOXICITY

Predisposing Factors

Neonates and infants are more prone to developing systemic toxicity to LAs, particularly amide LAs, compared with older children and adults. This is due to the following:

- Reduced plasma concentration of AGP in this age group, resulting in a higher unbound fraction of amide LAs, which is responsible for toxicity.
- Decreased clearance of amide LAs in neonates and infants due to decreased metabolism in the liver by cytochrome P450 enzymes.
- Regional anesthesia is usually performed under general anesthesia, which may mask the earliest

Table 2.4 Tetracaine Dose for Spinal Anesthesia for Inguinal Hernia Repair

Local anesthetic	Age and weight	Dose (mg/kg)	Duration of action
Tetracaine 1% in 10% dextrose (1:1 dilution) (hyperbaric)	Neonates and infants less than 5 kg[a]	0.5 to 0.6	90 to 120 minutes[b]
	Infants and children 5 to 15 kg	0.3 to 0.4	
	Children greater than 15 kg	0.2 to 0.3	

[a]*Maximum dose of 1 mg/kg can be used to achieve mid to high thoracic level dermatomes.*
[b]*Duration can be extended by 30% with the addition of epinephrine.*

signs of systemic toxicity, particularly CNS signs. Therefore refractory cardiovascular collapse may be the first and only sign.

- Higher baseline heart rates in neonates and infants predispose them to increased sensitivity for bupivacaine-induced cardiotoxicity compared with adults.

Clinical Picture

- Systemic toxicity can result from accidental intravascular injection of LAs or secondary to systemic absorption of LAs from the regional block site, particularly when maximum recommended doses are exceeded.
- Systemic toxicity is consistent with signs of CNS and cardiac toxicity.
- Regional anesthesia is usually performed under general anesthesia in pediatric patients. Although general anesthesia with inhalational agents raises the threshold for seizure, it will also lower the threshold for cardiac toxicity. Therefore general anesthesia may confound the diagnosis of systemic toxicity, and the first sign may be cardiovascular collapse.
- The bupivacaine threshold for cardiac toxicity is lower than its CNS toxicity in pediatrics. Therefore in pediatrics, signs of cardiac toxicity may precede signs of CNS toxicity, or may be the only sign of systemic toxicity. This is different from adults, where signs of CNS toxicity usually precede cardiac toxicity.
- Signs of systemic toxicity under general anesthesia may be nonspecific and consist of muscle rigidity, unexplained hypoxemia, unexplained tachycardia, dysrhythmias, and cardiovascular collapse.
- When bupivacaine is mixed with epinephrine (usually in a 1:200,000 dilution), the earliest and most reliable sign of unintentional intravascular injection is an increase in the T-wave amplitude of more than 50% compared with the baseline, with associated ST segment changes. These electrocardiogram (EKG) changes are very sensitive and occur within 60 seconds of injection. If only a small test dose is given, these changes are transient and brief and do not progress to cardiovascular collapse.
- Following a test dose of bupivacaine and epinephrine, tachycardia is not a sensitive sign for unintentional intravascular injection in pediatrics.
- The order of sensitivity for detection of unintentional intravascular injection in pediatrics, from most to least sensitive, is:

Increase T-wave amplitude and ST segment changes > increase in systolic blood pressure more than 10% > increase in heart rate 10% to 15% above baseline heart rate before administration of test dose.

- After the age of 8 years, T-wave changes are less sensitive for the detection of intravascular injection.
- If a bolus dose of bupivacaine is unintentionally injected intravascularly, cardiac arrhythmias and subsequent cardiovascular collapse develop rapidly.

Prevention/Reducing the Risk

- Careful calculation of total doses of LAs administered.
- Total doses of LAs should not exceed the maximum allowable dose under any circumstances (Table 2.5).
- The dose should be based on the lean body weight rather than the actual body weight, particularly in obese patients. Lean body weight can be extrapolated by knowing the actual body weight and the ideal body weight.
- The dose should be reduced in pediatric patients with associated comorbidities such as liver failure or congestive heart failure.
- Decrease bolus dose of amide LAs by 30% for all infants less than 6 months of age.
- Limit the duration of amide LA infusion to no more than 48 hours for bupivacaine and 72 hours for ropivacaine for all infants and neonates less than 6 months of age (see Table 2.2).
- Chloroprocaine is the LA of choice for epidural infusion in neonates and small infants due to its very low risk of systemic toxicity and accumulation compared with amide LAs in this age group.
- When mixing two different LAs, toxicity is additive. Thus when mixing equivalent amounts of two different LAs, the maximum dose for each should be reduced by 50%.
- Using ropivacaine or levobupivacaine instead of bupivacaine may reduce the risk of cardiotoxicity.
- When performing an epidural block, aspiration of blood or CSF through the needle or catheter may indicate that the tip is within a vessel or subarachnoid space, respectively. However, a false-negative aspiration test tends to occur frequently in pediatric patients. This is related to the fact that even the smallest application of negative pressure can result in collapse of the thin-walled vessels.
- The recommendation is to use an epinephrine-containing test dose in all regional blocks before giving the full bolus dose. This will help detect unintentional intravascular injections, as mentioned earlier.
- The only exception for the use of an epinephrine-containing test dose is the block that involves an end artery, such as penile and digital blocks.

Table 2.5 Maximum Recommended Doses of Commonly Used Local Anesthetics

Local anesthetic	Dose (mg/kg)
Bupivacaine	2.5 to 3
Ropivacaine	3
Levobupivacaine	3
Lidocaine/lidocaine + epinephrine	4/7
2-Chloroprocaine	20

- Slow and intermittent injection of all bolus doses should occur over several minutes. Rapid injection can result in systemic toxicity, even if the maximum allowable dose is not exceeded and the injection is not intravascular. This results from a rapid surge of LAs in the blood beyond the protein-carrying capacity of neonates and infants.
- Absorption of LAs from the site of regional block from higher to lower is:

Intercostal > caudal > lumbar epidural > thoracic epidural brachial > femoral > sciatic.

- Ilioinguinal/iliohypogastric nerve blocks, particularly in children weighing less than 15 kg, are associated with alarming levels of bupivacaine in the blood, even when half the maximum recommended dose is used. Therefore this block should be performed under ultrasound guidance as it can limit the required volume needed to perform the block. A volume of 0.2 mL/kg of ropivacaine 0.2% is used in an ultrasound-guided block compared with the anatomic landmark method, which may require the use of up to 1 mL/kg.
- Whenever a regional block is performed in pediatric patients, all resuscitation equipment should be immediately available.

Treatment

Effective Cardiopulmonary Resuscitation

- This is the first line of treatment in conjunction with intralipid administration.
- This includes securing the airway and ensuring adequate breathing and circulation through the performance of quality chest compression.

Intralipid 20%

- This is recommended as the next line of treatment for cardiotoxicity induced by bupivacaine and ropivacaine.
- Give immediately and without delay in conjunction with cardiopulmonary resuscitation (CPR).
- Acts as a "lipid sink" by promoting dissociation of bupivacaine from the myocardium and therefore shortening the duration of bupivacaine-induced asystole.
- The pediatric dose is similar to the adult dose and consists of a bolus of 1.5 mL/kg over 1 minute. A repeat bolus dose can be given in 3 to 5 minutes, with a maximum of 3 mL/kg. This is followed by a maintenance infusion of 0.25 mL/kg/min until the circulation is restored.

Prevention and Treatment of Seizure

- Should occur only after securing the airway and ensuring adequate breathing and oxygenation, because the majority of cases of morbidity that occurs with seizure are related to airway complications such as aspiration and hypoxia.
- Midazolam 0.05 to 0.2 mg/kg IV is the agent of choice.
- Propofol 1 to 2 mg/kg may be also used to control seizures; however, this should be used with caution and in the absence of hypotension or cardiovascular instability.
- Mild hyperventilation can help raise the seizure threshold by inducing respiratory alkalosis.
- Some case reports suggest the use of intralipid 20% to treat CNS toxicity of LAs, even in the absence of cardiotoxicity, and suggest its use as a first line of treatment in this context.

Support the Circulation

- IV fluid bolus with 10 to 20 mL/kg of isotonic fluids such as lactated Ringer.
- Phenylephrine infusion starting at a rate of 0.1 μg/kg/min to support the vascular tone antagonizes the LA-induced vasodilatation.
- Successful use of cardiopulmonary bypass has been also reported.

Suggested Reading

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Equipment and Ultrasound

3

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EQUIPMENT

NEEDLES, CATHETERS, AND SYRINGES

Effective regional anesthesia requires comprehensive knowledge of equipment—that is, the needles, syringes, and catheters that allow the anesthetic to be injected into the desired area. In the early years, regional anesthesia found many variations in the method of joining needle to syringe. Around the turn of the century, Schneider developed the first all-glass syringe for Hermann Wülfing-Luer. Luer is credited with the innovation of a simple conical tip for easy exchange of needle to syringe, but the "Luer-Lok" found in use on most syringes today is thought to have been designed by Dickenson in the mid-1920s. The Luer fitting became virtually universal, and both the Luer slip tip and the Luer-Lok were standardized in 1955.

In almost all disposable and reusable needles used in regional anesthesia, the bevel is cut on three planes. Theoretically, the design creates less tissue laceration and discomfort than the earlier styles did, and it limits tissue coring. Many needles that are to be used for deep injection during regional block incorporate a security bead in the shaft so that the needle can be easily retrieved on rare occasions when the needle hub separates from the needle shaft. Fig. 3.1 contrasts a blunt-beveled, 25-gauge needle with a 25-gauge "hypodermic" needle. Traditional teaching holds that the short-beveled needle is less traumatic to neural structures. There is little clinical evidence that this is so, and experimental data about whether sharp or blunt needle tips minimize nerve injury are equivocal.

Fig. 3.2 shows various spinal needles. The key to their successful use is to find the size and bevel tip that allow one to cannulate the subarachnoid space easily without causing repeated unrecognized punctures. For equivalent needle size, rounded needle tips that spread the dural fibers are associated with a lower incidence of headache than those that cut fibers. The past interest in very small-gauge spinal catheters to reduce the incidence of spinal headache, with the controllability of a continuous technique, faded during the controversy over lidocaine neurotoxicity.

Fig. 3.3 depicts epidural needles. Needle tip design is often mandated by the decision to use a catheter with the epidural technique. Fig. 3.4 shows two catheters available for either subarachnoid or epidural use. Although each has advantages and disadvantages, a single-end-hole catheter appears to provide the highest level of certainty of catheter tip location at the time of injection, whereas a multiple-side-hole catheter may be preferred for continuous analgesia techniques.

Continuous Infusion Dosage

With the advent of ultrasound and better training, more and more continuous nerve block catheters are performed to help patients. Current practice is to limit continuous infusion at 0.4 mg/kg/h (bupivacaine/ropivacaine). See Table 3.1 for specific block recommendations.

NERVE STIMULATORS

In recent years, the use of nerve stimulators has increased from occasional use to common use and is often of critical importance. The growing emphasis on techniques that use either multiple injections near individual nerves or placement of stimulating catheters has provided an impetus for this change. The primary impediment to successful use of a nerve stimulator in clinical practice is that it requires at least a three-handed or two-individual technique (Fig. 3.5), although there are devices allowing control of the stimulator current using a foot control, eliminating the need for a third hand or a second individual. In those situations requiring a second set of hands, correct operation of contemporary peripheral nerve stimulators is straightforward and easily taught during the course of the block. There are a variety of circumstances in which a nerve stimulator is helpful, such as in children and adults who are already anesthetized, when a decision is made that regional block is an appropriate technique, in individuals who are unable to report paresthesias accurately, in performing local anesthetic administration on specific nerves, and in the placement of stimulating catheters for anesthesia or postoperative analgesia. Another group that may benefit from the use of a nerve stimulator is patients with chronic pain in whom accurate needle placement and reproduction of pain with electrical stimulation or elimination of pain with accurate administration of small volumes of local anesthetic may improve diagnosis and treatment.

When nerve stimulation is used during regional block, insulated needles are most appropriate, because the current from such needles results in a current sphere around the needle tip, whereas uninsulated needles emit current at the tip as well as along the shaft, potentially resulting in less

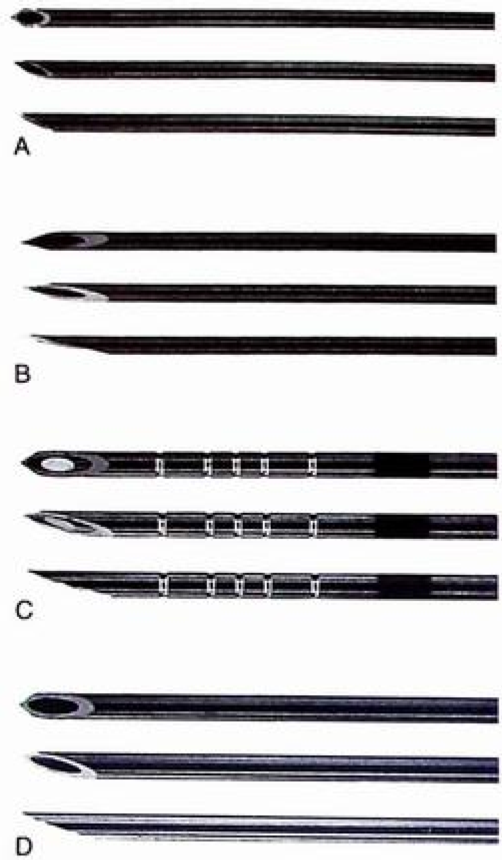


Fig. 3.1 Frontal, oblique, and lateral views of regional block needles. (A) Blunt-beveled, 25-gauge axillary block needle. (B) Long-beveled, 25-gauge ("hypodermic") block needle. (C) 22-gauge ultrasonography "imaging" needle. (D) Short-beveled, 22-gauge regional block needle. (Maheshwari K, Mounir-Soliman L. Equipment and ultrasound, ch 3. In: Farag E, ed. Brown's Atlas of Regional Anesthesia. 6th ed. Elsevier; 2020. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

Fig. 3.2 Frontal, oblique, and lateral views of common spinal needles. (A) Sprotte needle. (B) Whitacre needle. (C) Greene needle. (D) Quincke needle. (Maheshwari K, Mounir-Soliman L. Equipment and ultrasound, ch 3. In: Farag E, ed. Brown's Atlas of Regional Anesthesia. 6th ed. Elsevier; 2020. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

precise needle location. A peripheral nerve stimulator should allow between 0.1 and 10 milliamperes (mA) of current in pulses lasting approximately 200 ms at a frequency of 1 or 2 pulses per second. The peripheral nerve stimulator should have a readily apparent readout of when a complete circuit is present, a consistent and accurate current output over its entire range, and a digital display of the current delivered with each pulse. This facilitates generalized location of the nerve while stimulating at 2 mA and allows refinement of needle positioning as the current pulse is reduced to 0.5 to 0.1 mA. The nerve stimulator should have the polarity of the terminals clearly identified, because peripheral nerves are most effectively stimulated by using the needle as the cathode (negative terminal). Alternatively, if the circuit is established with the needle as anode (positive terminal), approximately four times as much current is necessary to produce equivalent stimulation. The positive lead of the stimulator should be placed in a site remote from the site of stimulation by connecting the lead to a common electrocardiographic electrode (see Fig. 3.5).

The use of a nerve stimulator is not a substitute for a complete knowledge of anatomy and careful site selection for needle insertion. In fact, as much attention should be paid to the anatomy and technique when using a nerve stimulator as when not using it. Large myelinated motor fibers are stimulated by less current than are smaller unmyelinated fibers, and muscle contraction is most often produced before patient discomfort. The needle should be carefully positioned to a point where muscle contraction can be elicited with 0.5 to 0.1 mA. If a pure sensory nerve is to be blocked, a similar procedure is followed; however, correct needle localization will require the patient to report a sense of pulsed "tingling or burning" over the cutaneous distribution of the sensory nerve. Once the needle is in the final position and stimulation is achieved with 0.5 to 0.1 mA, 1 mL of local anesthetic should be injected through the needle. If the needle is accurately positioned, this amount of solution should rapidly abolish the muscle contraction or the sensation with pulsed current.

ULTRASOUND

In the last decade, image-guided peripheral nerve blocks have become the norm for anesthesiologists at the forefront of regional anesthesia innovation. The dominant method of imaging is ultrasonography. Ultrasonographic imaging devices are noninvasive, portable, and moderately priced. Most work has been done using scanning probes with frequencies in the range of 5 to 10 megahertz (MHz). These devices are capable of identifying vascular and bony structures

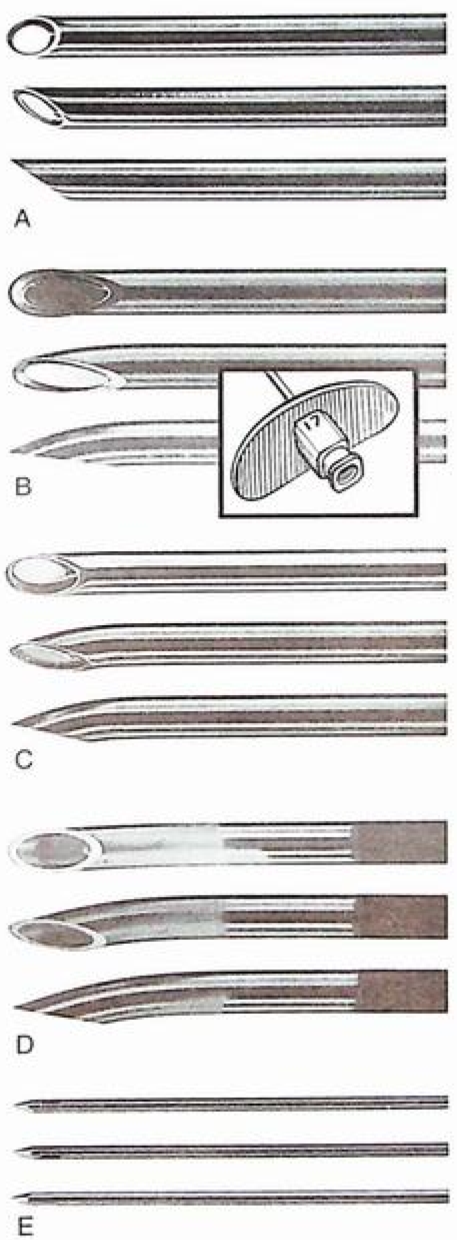


Fig. 3.3 Frontal, oblique, and lateral views of common epidural needles. (A) Crawford needle. (B) Tuohy needle; the *inset* shows a winged hub assembly common to winged needles. (C) Hustead needle. (D) Curved 18-gauge epidural needle. (E) Whitacre 27-gauge spinal needle. *(Maheshwari K, Mounir-Soliman L. Equipment and ultrasound, ch 3. In: Farag E, ed. Brown's Atlas of Regional Anesthesia. 6th ed. Elsevier; 2020. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)*

but not nerves. Contemporary devices using high-resolution probes (12–15 MHz) and compound imaging allow clear visualization of nerves, vessels, catheters, and local anesthetic injection and can potentially improve the techniques of ultrasonography-assisted peripheral nerve block. Use of these devices is limited by their cost, the need for training in their use and familiarity with ultrasonographic image anatomy, and the extra set of hands required. They work best with superficial nerve plexuses and can be limited by excessive obesity or anatomically distant structures. One of the keys to using this technology effectively is a sound understanding of the physics behind ultrasonography. A corollary to understanding the physics is the need for study and appreciation of the relevant human anatomy.

Fig. 3.4 Epidural catheter designs. (A) Single distal orifice. (B) Closed tip with multiple side orifices. *(Maheshwari K, Mounir-Soliman L. Equipment and ultrasound, ch 3. In: Farag E, ed. Brown's Atlas of Regional Anesthesia. 6th ed. Elsevier; 2020. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)*

American Society of Regional Anesthesiologists Recommendations

The following are the American Society of Regional Anesthesiologists recommendations for performing an ultrasonography-guided block:

1. Visualize key landmark structures, including muscles, fascia, blood vessels, and bone.
2. Identify the nerves or plexus on short-axis imaging, with the depth set 1 cm deep to the target structures.
3. Confirm normal anatomy or recognize anatomic variation(s).
4. Plan for the safest and most effective needle approach.
5. Use the aseptic needle insertion technique.
6. Follow the needle under real-time visualization as it is advanced toward the target.
7. Consider a secondary confirmation technique such as nerve stimulation.
8. When the needle tip is presumed to be in the correct position, inject a small volume of a test solution.
9. Make necessary needle adjustments to obtain optimal perineural spread of local anesthesia.
10. Maintain traditional safety guidelines of frequent aspiration, monitoring, patient response, and assessment of resistance to injection.

WAVELENGTH AND FREQUENCY

Ultrasound is a form of acoustic energy defined as the longitudinal progression of pressure changes (Fig. 3.6). These pressure changes consist of areas of compression and relaxation of particles in a given medium. For simplicity, an ultrasound wave is often modeled as a sine wave. Each ultrasound wave is defined by a specific wavelength (l) measured in units of distance, amplitude (h) measured in decibels (dB), and frequency (f) measured in hertz (Hz) or cycles per second. Ultrasound is defined as a frequency of more than 20,000 Hz. Current transducers used for ultrasonography-guided regional anesthesia generate waves in the 3- to 13-MHz range (or 30,000–130,000 Hz).

ULTRASOUND GENERATION

Ultrasound is generated when multiple piezoelectric crystals inside a transducer vibrate rapidly in response to an alternating electric current. Ultrasound then travels into

Table 3.1 Commonly Used Dose and Pump Setting for Continuous Peripheral Nerve Block Infusion

Block type	Local anesthetic[a]	Continuous rate (mL/h)	Bolus dose (mL)	Lock-out interval (min)	Number of bolus per hour
Interscalene	0.25% Bupivacaine or 0.2% ropivacaine	8–10	8–12	60	1
Supraclavicular	0.25% Bupivacaine or 0.2% ropivacaine	8–10	8–12	60	1
Popliteal	0.25% Bupivacaine or 0.2% ropivacaine	8–10	8–12	60	1
Femoral or adductor canal[b]	0.12% Bupivacaine or 0.1% ropivacaine	6–8	0	—	—

[a]*Overall cumulative dose of local anesthetic for any 4-hour period should be less than the toxic dose. Conservative dosage is recommended for elderly and frail patients.*

[b]*Lower dose is recommended to avoid quadriceps weakness.*

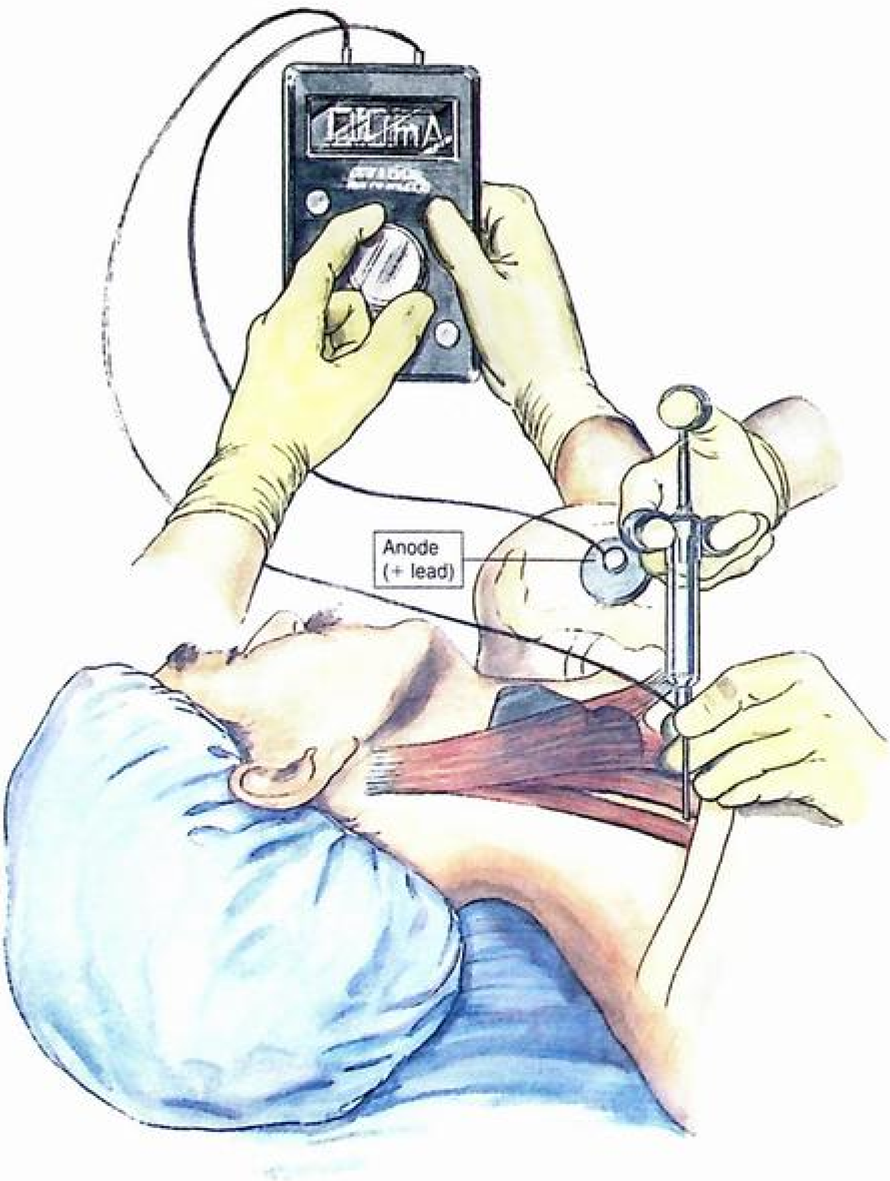
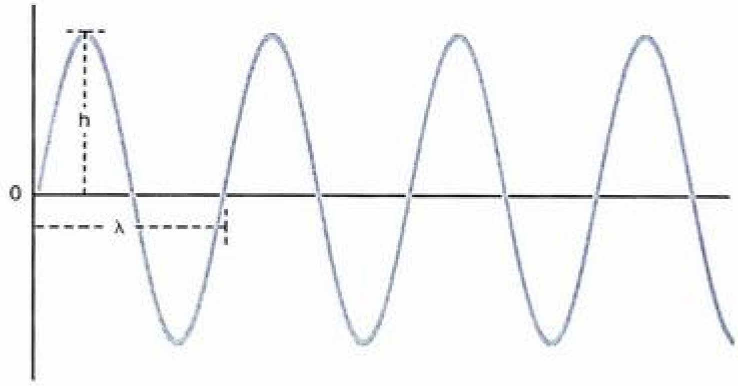


Fig. 3.5 Nerve stimulator technique.



h = height of the wave, or amplitude
λ = wavelength

$$f = \frac{\text{velocity of ultrasound}}{\lambda}$$

Fig. 3.6 Ultrasound wave basics.

the body where, on contact with various tissues, it can be reflected, refracted, and scattered (Fig. 3.7).

To generate a clinically useful image, ultrasound waves must reflect off tissues and return to the transducer. After emitting the wave, the transducer switches to a receive mode. When ultrasound waves return to the transducer, the piezoelectric crystals will vibrate once again, this time transforming the sound energy back into electrical energy. This process of transmission and reception can be repeated over 7000 times per second and, when coupled with computer processing, results in the generation of a real-time, two-dimensional (2D) image that appears seamless. By convention, whiter (hyperechoic) objects represent a larger degree of reflection and higher signal intensities, whereas darker (hypoechoic) images represent less reflection and weaker signal intensities.

CLINICAL ISSUES RELATED TO PHYSICS

Resolution. Resolution refers to the ability to clearly distinguish two structures lying beside one another.

Although there are several different types of resolution, anesthesiologists are mostly concerned with lateral resolution (left-right distinction) and axial resolution (front-back distinction). Ultrasonography systems with higher frequencies have better resolution and can discriminate closely spaced peripheral neural structures effectively. However, because of a process known as *attenuation*, high-frequency ultrasound cannot penetrate into deep tissue (Fig. 3.8). Attenuation is the loss of ultrasound energy, primarily as heat, into the surrounding tissue. For superficial blocks between 1 and 4 cm in depth, frequencies greater than 10 MHz are preferred. For blocks at depths greater than 4 cm, frequencies less than 8 MHz should result in adequate tissue penetration, with a predictable degradation in resolution.

Focus. Although axial resolution is related simply to the frequency of ultrasound, lateral resolution also depends on beam thickness. Any maneuver that generates a narrow beam will increase the lateral resolution. Most ultrasonography machines have an electronic focus that generates a focal point (narrowest part of the beam) that can be placed directly over the target of interest. However, this increases the divergence of the beam beyond the region of the focus point (far field), resulting in image degradation of structures beyond this focal point. Thus the beam focus should be placed at the level of the object that is being assessed to provide the clearest possible picture of the object (Fig. 3.9).

Gain. The overall gain controls allow the operator to increase or decrease the signal intensity for a darker or a brighter image. The time gain compensation (TGC) adjusts gain at specific depths of the image. The goal of TGC is to compensate for the attenuation in the signal as a result of depth. Accordingly, appropriate TGC adjustment allows structures with similar reflecting characters to be seen with similar brightness regardless of depth. Inappropriately low gain settings may result in the apparent absence of an existing structure (i.e., "missing structure" artifact), whereas inappropriately high gain settings can easily obscure existing structures.

Reflection. The sound waves bounce back to the transducer at the interface of tissues with different acoustic impedance (*reflection*). The quantity of energy reflected determines the amplitude (brightness) of the image processed and mainly depends on the nature of the tissue, with bone having the highest impedance and air having the lowest impedance. A large, smooth surface can reflect the beam more effectively than the surrounding tissue; this is called *specular reflection*. When two specular reflectors are close to each other, reverberation of the beam between those surfaces can occur. Clinically, it shows as equally spaced parallel lines, deep to and parallel to the reflecting surfaces (*reverberation artifact*). The comet tail artifact is an example of this reverberation when scanning the two layers of pleura when in proximity with no fluids or air in between. Hyperechoic reverberation is another example of this artifact caused by the two walls of the hollow block needles.

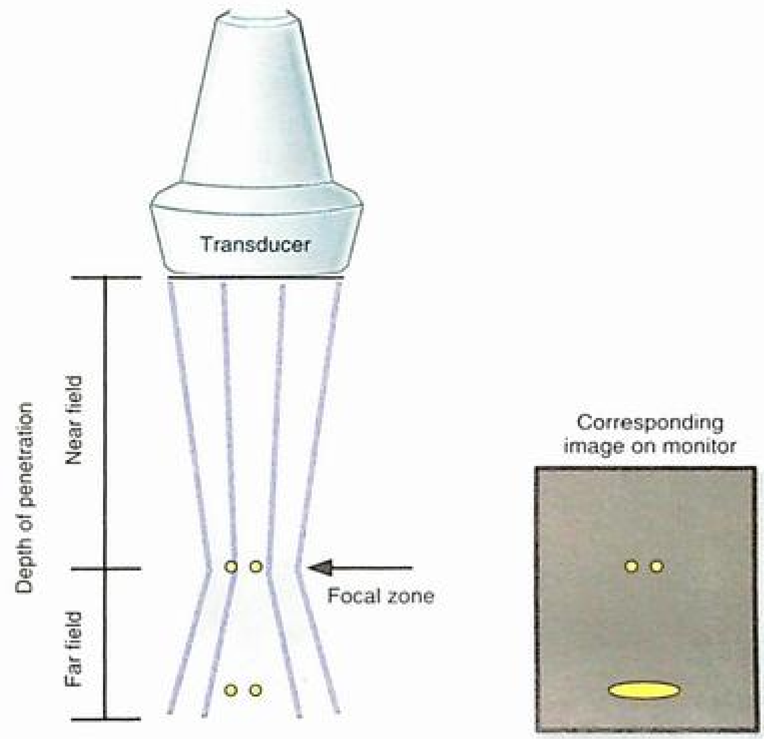


Fig. 3.9 Basics of ultrasonographic probe focusing.

COLOR DOPPLER

Color-flow Doppler ultrasonography relies on the fact that if an ultrasound pulse is sent out and strikes moving red blood cells, the ultrasound that is reflected back to the transducer will have a frequency that is different from the original emitted frequency. This change in frequency is known as the *Doppler shift*. It is this frequency change that can be used in cardiac and vascular applications to calculate both blood flow velocity and blood flow direction. The Doppler equation states that

$$\text{Frequency shift} = 2 \times V \times Ft \times \text{cosine}\Phi / c$$

where V is the velocity of the moving object, Ft is the transmitted frequency, Φ is the angle of incidence of the ultrasound beam and the direction of blood flow, and c is the speed of ultrasound in the medium. The direction of blood flow is not as crucial for regional anesthesia as it is for cardiovascular anesthesia. What is most important is being able to identify blood vessels positively by visualizing color flow. This is especially important when interrogating a projected trajectory of the needle when placing a block. By placing color-flow Doppler over the expected needle path, the clinician should be able to screen for and avoid any unanticipated vasculature.

GENERAL PRINCIPLES OF AN ULTRASONOGRAPHY-GUIDED NERVE BLOCK

During ultrasonographic needle guidance, most nerves are imaged in cross section (short axis). Alternatively, if the transducer is moved 90 degrees from the short-axis view, the long-axis view is generated. The short-axis view generally is preferred, because it allows the operator to assess the lateromedial perspective of the target nerve, which is lost in the long-axis view (Fig. 3.10).

Two techniques have emerged regarding the orientation of the needle with respect to the ultrasound beam (Fig. 3.11). The in-plane approach generates a long-axis view of the needle, allowing full visualization of the shaft and tip of the needle. The out-of-plane view generates a short-axis view of the needle. One disadvantage of the in-plane approach is the challenge of maintaining needle imaging with a very thin ultrasound beam. A limitation of the out-of-plane view is that it generates a short-axis view of the block needle, which may be very hard to visualize. With the out-of-plane view, the operator cannot confirm that the needle tip (rather than part of the shaft) is being imaged; therefore the needle location often is inferred from tissue movement or small injections of solution.

Two main types of ultrasound probes are used for regional anesthesia:

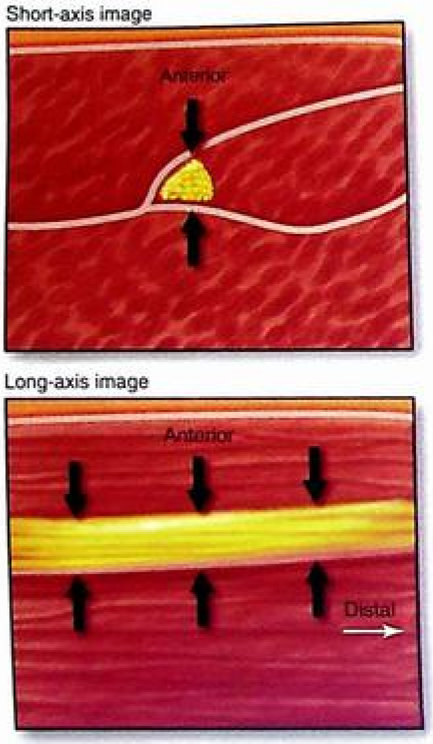


Fig. 3.10 Short-axis *(top)* and long-axis *(bottom)* imaging of the median nerve.

1. Linear probe (usually higher-frequency probe), which allows better resolution and more accurate identification of the margins for the target structure, with a narrower ultrasonographic window.
2. Curvilinear probe (generally with lower frequency), which makes it more suitable for deeper structures, providing a wider view to detect important structures adjacent to the target nerve. The caveat with the curvilinear probe is a lower degree of resolution (Figs. 3.12 and 3.13A and B).

Regardless of the machine or transducer selected, there are four basic transducer manipulation techniques, which can be described as the "PART" of scanning:

Pressure (P): Various degrees of pressure are applied to the transducer that are translated onto the skin.

Alignment (A): Sliding the transducer defines the lengthwise course of the nerve and reference structures.

Rotation (R): The transducer is turned in either a clockwise or counterclockwise direction to optimize the image (either long- or short-axis) of the nerve and needle.

Tilting (T): The transducer is tilted in both directions to maximize the angle of incidence of the ultrasound beam to the target nerve, thereby maximizing reflection and optimizing image quality.

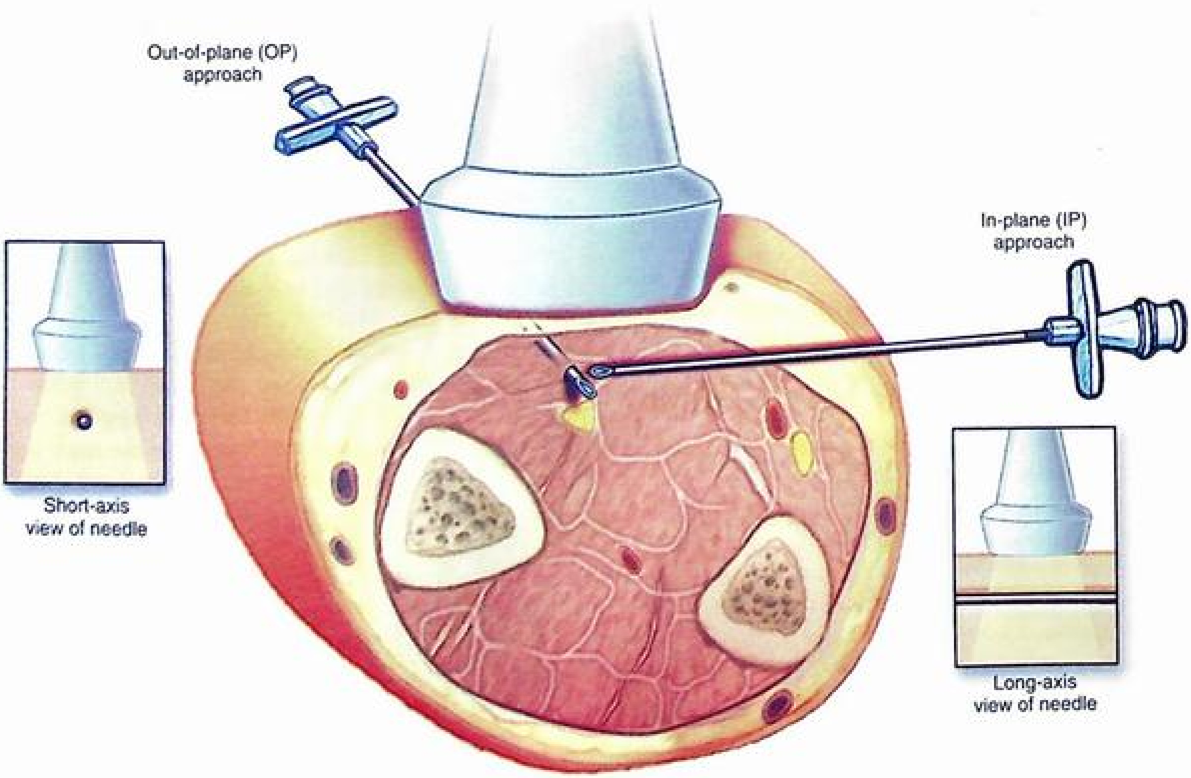


Fig. 3.11 The in-plane *(right)* and out-of-plane *(left)* needle approaches for needle insertion and ultrasonographic visualization.

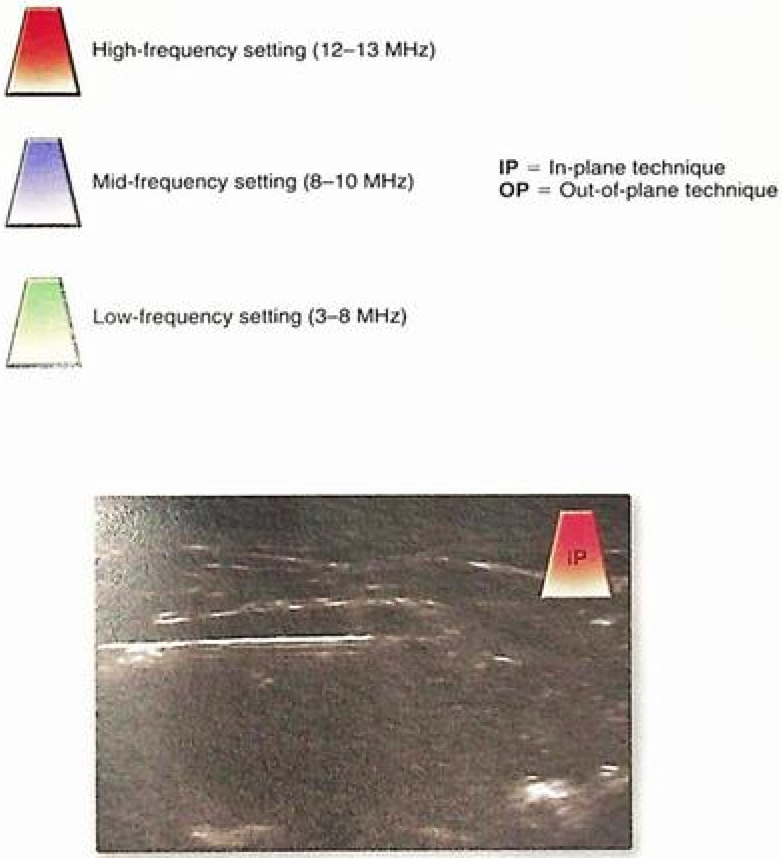


Fig. 3.12 Our system for ultrasonographic needle guidance recommendations. For a block for which we would recommend a high-frequency setting with the in-plane *(IP)* technique of needle visualization, a *red* scan plane with an "IP" inside the plane is shown. For a low-frequency setting with the out-of-plane *(OP)* technique for needle visualization, we show a *green* scan plane with an "OP" in the plane. The mid-frequency setting is indicated by a *blue* scan plane. An example is shown in the upper right of the figure. In this case, we recommend starting with a high-frequency probe setting and an IP technique for needle visualization.

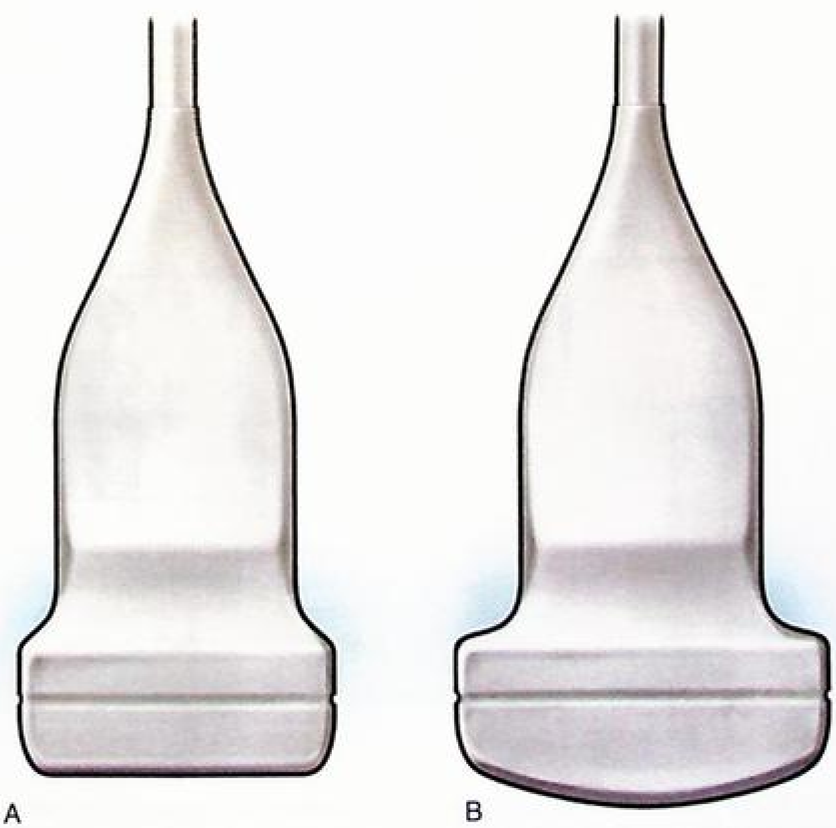


Fig. 3.13 (A) Linear probe. (B) Curvilinear probe.

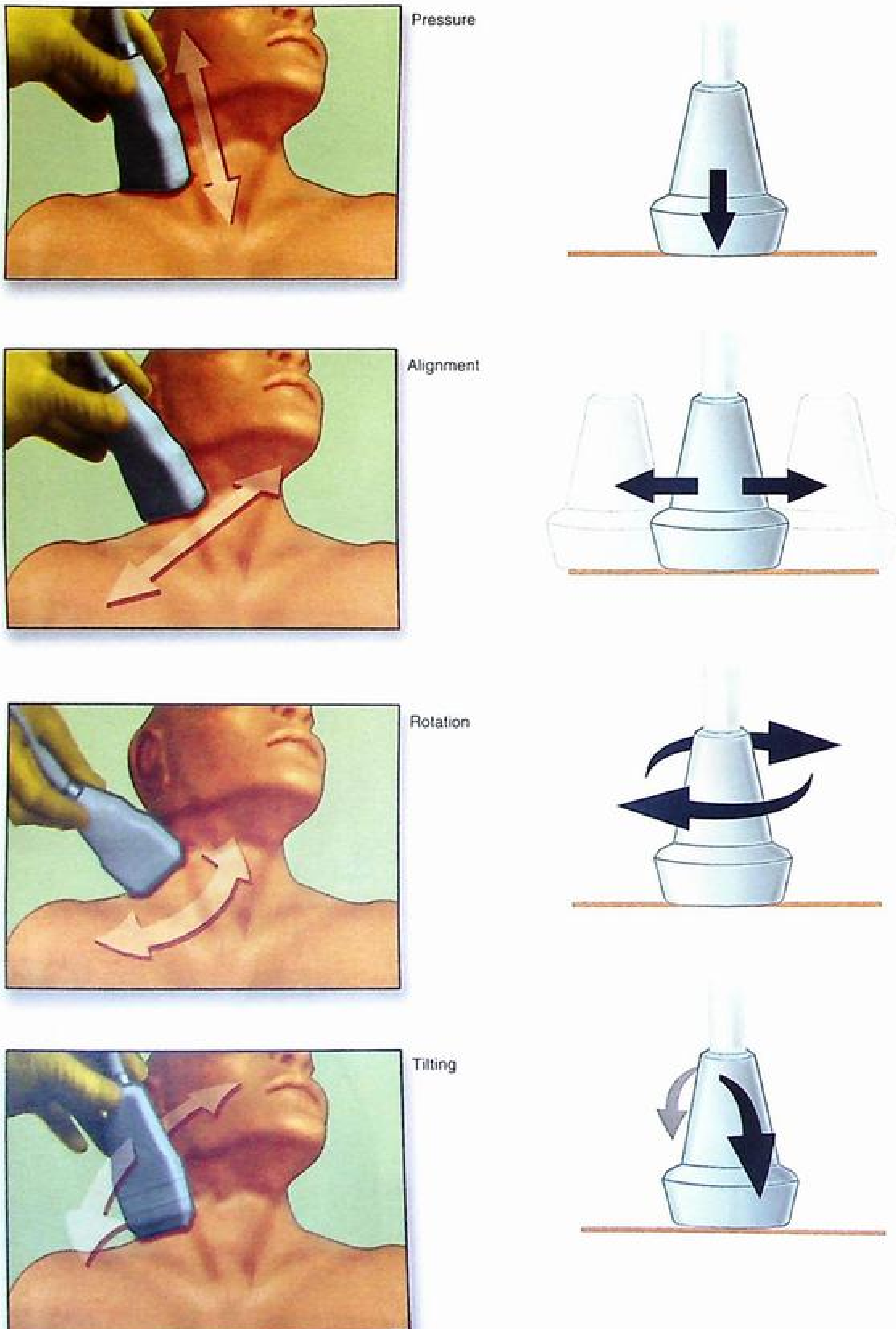


Fig. 3.14 PART maneuvers: pressure, alignment, rotation, and tilting.

The primary objective of PART maneuvers is to optimize the amount of ultrasound that reflects off an object and returns to the transducer (Fig. 3.14).

Constant and frequent manipulations of the probe, mainly rotation and tilting, allow better appreciation of the anatomical structures, particularly nerves and tendons, caused by anisotropy.

This characteristic mainly indicates the change in amplitude of the reflected signal based on the angle of incidence of the beam. Small changes in the angle of the beam striking the object can result in significantly unequal amplitude of the reflected image (anisotropic), with the largest amplitude when this angle is perpendicular to the long axis of the structure in the short-axis view. Clear visualization of the targeted structure versus no visualization at all can be a function of change in this angle of incidence, highlighting the importance of acquiring this hand skill.

ADVANCEMENTS IN ULTRASOUND-GUIDED REGIONAL ANESTHESIA

Ultrasound-guided regional anesthesia has improved the practice of acute pain management. The widespread use of ultrasound for peripheral nerve blocks gained popularity among anesthesiologists, because it improves patient safety and procedural success. This section will explore some of the advancements in ultrasonography that are either available on the market or still under research.

THREE-DIMENSIONAL AND FOUR-DIMENSIONAL TECHNOLOGY

Three-dimensional (3D) and four-dimensional (4D) ultrasound technologies have been used in fetal and cardiac imaging. Three-dimensional imaging combines multiple 2D images, while 4D imaging produces moving or dynamic 3D imaging. In the practice of regional anesthesia, these imaging techniques will allow for better visualization of the needles in multiple planes and from different angles. This will help in first-pass success and prevent injury to surrounding structures. Further, it will allow for the identification of the spread of LA around the target nerve or plane.

ARTIFICIAL INTELLIGENCE USE IN ULTRASOUND

The use of artificial intelligence (AI) to assist practitioners in performing regional anesthesia will add a safety net to daily practice. The goal of its use is to identify anatomical structures and avoid injury to nearby structures, including blood vessels, nerves, and lungs. Incorporating AI algorithms and anatomical ultrasound data will reduce block failure and patient harm. AI can also be used in neuraxial blocks, especially in morbidly obese patients, pediatrics, and patients with vertebral deformities, to perform challenging epidurals properly. For example, the use of AI assistance for the identification of the ligamentum flavum, subarachnoid space, and spinous processes will guide the anesthesiologist to perform an enhanced procedural plan including the depth of the epidural space and the angulation of the needle.

NEEDLE TIP TRACKER

The continuous visualization of the needle tip is a key safety measure in performing ultrasonography-guided nerve blocks. This improves the injection accuracy and prevents unintended nerve or nearby tissue harm. Needle tip tracker technology depends on biomarkers and certain tissue properties that track the needle during injection. This can be utilized in most types of blocks, especially for deeper and more complex blocks, and allows for in-plane and out-of-plane tracking.

MICROULTRASOUND AT THE TIP OF THE NEEDLE

Nerve injury during peripheral nerve blocks remains a feared complication. Intraneural injection and permanent nerve injury should be avoided while performing the blocks. These risks led to the development of different technologies, including microultrasound imaging, to give a better anatomical resolution. This imaging differentiates between subepineural and subperineural needle insertion, allowing for better visualization to prevent intraneural injection and nerve injury.

The continuous evolution of ultrasound technology will guide the future of regional anesthesia. This will lead to safer practice models and more precise nerve block injections. In addition, it will provide more resources for trainees to combine the medical basic sciences with bedside practice in a more interactive way.

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Checklist for the Regional Block 4

Loran Mounir Soliman, Mohamad Ayoub, Hazem Alahwal, and Husien Taleb

Key Points

- Regional anesthesia complications yet are rare but could lead to devastating and life-threatening adverse events.
- Wrong-side block is a never event because it is preventable.
- Comprehensive checklist for regional anesthesia block during time-out helps to prevent and limit most of the complications.

Various complications may occur with regional anesthesia, although they are rare but yet devastating and life-threatening in some cases. Our goal in this chapter is to create a comprehensive checklist during the time-out for any regional anesthesia procedure, addressing risks, potential complications, and measures to prevent complications such as wrong-side blocks, local anesthetic systemic toxicity (LAST), and so on.

The term "Never Event" was first introduced in 2001 by Ken Kizer, MD, former CEO of the National Quality Forum (NQF), in reference to particularly shocking medical errors, such as wrong-site surgery, which should never occur. Over time, the term's use has expanded to signify adverse events that are unambiguous (clearly identifiable and measurable), serious (resulting in death or significant disability), and usually preventable.

Since the initial never event list was developed in 2002, it has been revised multiple times and now consists of 29 "serious reportable events" grouped into seven categories. These categories include surgical or procedural events, product or device events, patient protection events, care management events, environmental events, radiologic events, and criminal events.

Sentinel events are defined as an unexpected occurrence involving death or serious physiological or psychological injury, or the risk thereof. While sentinel events are unexpected, never events usually are preventable.

Wrong-side blocks are unambiguous, serious, and preventable. Hence they are considered to be never events.

Many events that could occur during regional anesthesia are considered sentinel events. Examples include LAST, seizures, inadvertent dural puncture, inadvertent placement of an intrathecal catheter, use of wrong local anesthetic medication, unintended retention of nerve catheter in a patient, and many others.

According to an Agency for Healthcare Research and Quality (AHRQ)-supported study by Kwaan et al., wrong-site surgery occurred at a rate of approximately 1 per 113,000 operations between 1985 and 2004.

In July 2004, The Joint Commission (TJC) enacted a universal protocol that was developed through expert consensus on principles and steps for preventing wrong-site, wrong-procedure, and wrong-person surgery.

The elements of the universal protocol include conducting a preprocedure verification process, marking the procedure site, and performing a time-out.

The universal protocol dictates the minimum requirements physicians must follow to help prevent basic surgical mistakes and is required to be implemented by all accredited hospitals, ambulatory care, and office-based surgical facilities. It is important to note that these checklists are not intended to be comprehensive, and additions and modifications to fit local practice are encouraged.

Additionally, other surgical safety checklists exist, including one by the WHO. It includes aspects to be performed before induction of anesthesia, before skin incision, and before the patient leaves the operating room.

Wrong-site regional anesthetic procedure is considered a never event, with an incidence rate of 7.5 per 7000. It is much more common than the incidence of wrong-site surgery, which is estimated to be approximately 1 event per 100,000.

Besides wrong-site regional anesthetic procedures, there are rare serious complications that may occur with regional anesthesia:

- LAST, with an incidence of 0.03%, or 0.27 episodes per 1000 peripheral nerve blocks
- Infection
- Bleeding
- Nerve injury

Efforts have been made to decrease these adverse events. National guidelines have been developed by TJC and the American Society of Regional Anesthesia and Pain Medicine (ASRA) to reduce the incidence of these complications. A preprocedural checklist was created for performing regional nerve blocks and published in 2014.

Regional Block Preprocedural Checklist

1. Patient is identified, two criteria.
2. Allergies and anticoagulation status are reviewed.
3. Surgical procedure/consent is confirmed.
4. Block plan is confirmed, site is marked.
5. Necessary equipment is present, drugs/solutions are labeled.
6. Resuscitation equipment is immediately available: airway devices, suction, vasoactive drugs, and lipid emulsion.
7. Appropriate ASA monitors are applied; intravenous access, sedation, and supplemental oxygen are provided, if indicated.
8. Aseptic technique is used: hand cleansing is performed, mask and sterile gloves are used.
9. "Time-out" is performed before needle insertion for each new block site if the position is changed or separated in time or performed by another team.

Adapted from Mulroy MF, Weller RS, Liguori GA. A checklist for performing regional nerve blocks [published correction appears in *Reg Anesth Pain Med.* 2014;39(4):357]. *Reg Anesth Pain Med.* 2014;39(3):195-199. https://doi.org/10.1097/AAP.0000000000000075.

Although wrong-site regional anesthesia events, LAST, and other serious complications are rare, the effects can be devastating. By creating a comprehensive checklist (Fig. 4.1) that includes site marking, risk factors for LAST, maximum dose of anesthetic, anticoagulation, and other preventive measures, the goal is to decrease the incidence of complications.

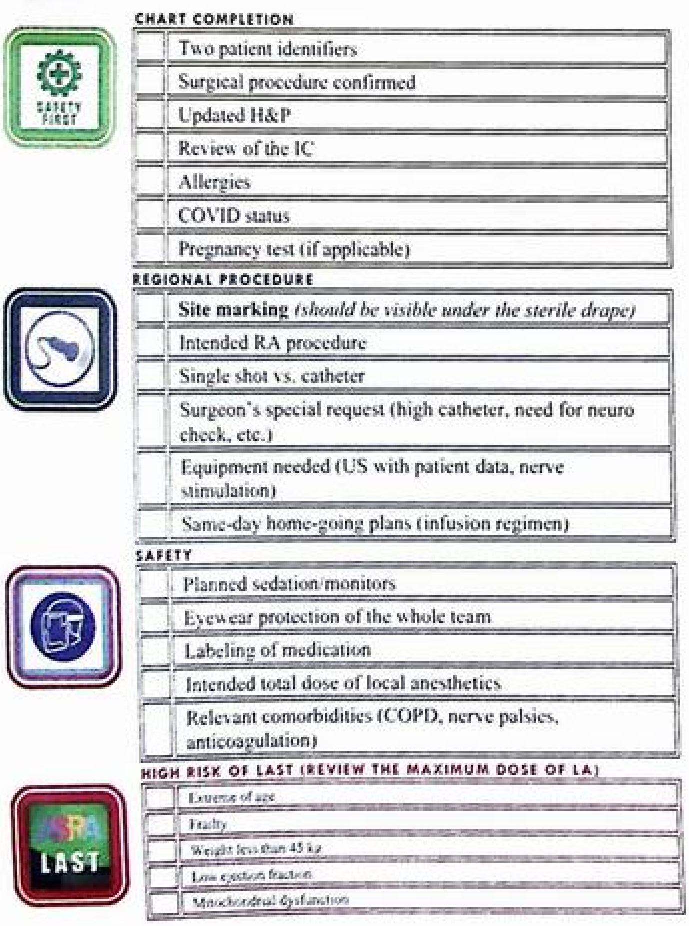

Fig. 4.1 Regional anesthesia procedures time-out protocol. *COPD*, Chronic obstructive pulmonary disease; *H&P*, history and physical; *IC*, informed consent; *LA*, local anesthetic; *LAST*, local anesthetic systemic toxicity; *RA*, regional anesthesia; *US*, ultrasound.

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Section 2
Upper Extremity Blocks

Upper Extremity Block Anatomy 5

Richard L. Drake

The brachial plexus, a somatic nerve plexus, is formed by the anterior rami of cervical nerves 5 to 8 (C5–C8) and the majority of the first thoracic nerve (T1) (Fig. 5.1). It begins in the neck and moves laterally and inferiorly into the axilla. As this occurs, it is divided structurally into various components, that is, roots, trunks, divisions, cords, and terminal nerves (Fig. 5.2). Major nerves innervating the upper limb are from the brachial plexus, primarily from the cords. Regarding relationships with arteries, the most medial/proximal portions are posterior to the subclavian artery, and the most lateral/distal portions surround the axillary artery (Fig. 5.3).

CLINICAL CORRELATION

Nerves supplying the ventral (anterior) part of the upper extremity originate from anterior divisions of the trunks of the brachial plexus, forming the medial and lateral cords (Fig. 5.4).

Nerves supplying the dorsal (posterior) part of the upper extremity originate from posterior divisions of the trunks of the brachial plexus, forming the posterior cord (see Fig. 5.4).

ROOTS

The anterior rami of C5 to C8 and most of T1 are classified as the roots of the brachial plexus (Fig. 5.5). Near the origin of these structures, they receive gray rami communicantes from the sympathetic trunk, which carry postganglionic sympathetic fibers and which the roots distribute to the periphery. The roots pass between the anterior and middle scalene muscles, which places them in the posterior triangle of the neck (Fig. 5.6). With regard to vasculature, the roots are superior and posterior to the subclavian artery.

While there are small branches from the C5 to C8 roots that supply muscles in the neck and a branch of C5 that contributes to the nerve supply to the diaphragm, two major nerves do originate from the roots of the brachial plexus—the dorsal scapular nerve and the long thoracic nerve (see Fig. 5.3).

The dorsal scapular nerve arises from the C5 root, passes posteriorly to the medial border of the scapula, and continues inferiorly along this structure, innervating the rhomboid minor and major muscles. The long thoracic nerve originates from the C5 to C7 roots, passes downward through the neck, enters the axillary inlet, and continues inferiorly on the medial wall of the axilla, supplying the serratus anterior muscle. It is unique in its positioning as it travels on the anterior/superficial aspect of this muscle.

CLINICAL CORRELATION

Interscalene Block (Classic Anterior Approach)

This block is effective for surgery of the shoulder or upper arm because the roots of the brachial plexus are blocked in this technique (Fig. 5.7). Frequently, the ulnar nerve and its distal supply to the hand are spared. It is regarded as ideal for shoulder joint repairs or other procedures that focus on the joint.

TRUNKS

The combining of various roots forms the trunks of the brachial plexus (see Fig. 5.2). The C5 and C6 roots come together to form the superior trunk, the C7 root continues on as the middle trunk, and the C8 and T1 roots form the inferior trunk. With regard to positioning, the inferior trunk is on rib 1 and posterior to the subclavian artery, while the superior and middle trunks are more superior (see Fig. 5.6).

Similar to the branching that occurs from the roots of the brachial plexus, there are only two major nerves that arise from the trunks, and they both take origin from the superior trunk. They are the suprascapular nerve and the nerve to the subclavius muscle (see Fig. 5.3). The suprascapular nerve is a branch of the superior trunk and contains contributions from spinal cord levels C5 and C6. Passing laterally, it moves through the posterior triangle of the neck and enters the posterior scapular region through the suprascapular foramen. It is joined in the lateral part of the neck and in the posterior scapular region by the suprascapular artery and innervates the supraspinatus and infraspinatus muscles. Similarly, the nerve to the subclavius muscle also branches from the superior trunk, thus containing contributions from the C5 and C6 spinal cord levels, moves anteroinferiorly over the subclavian artery and vein, and supplies the subclavius muscle (see Fig. 5.3).

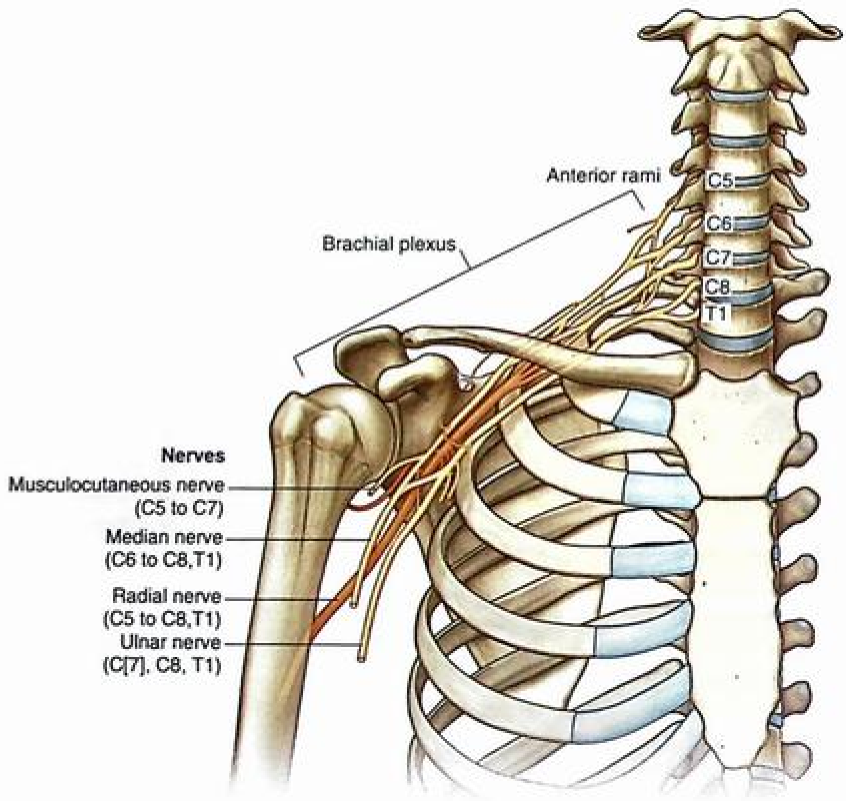


Fig. 5.1 Innervation of the upper limb. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students.* 4th ed. Philadelphia: Elsevier; 2020.)

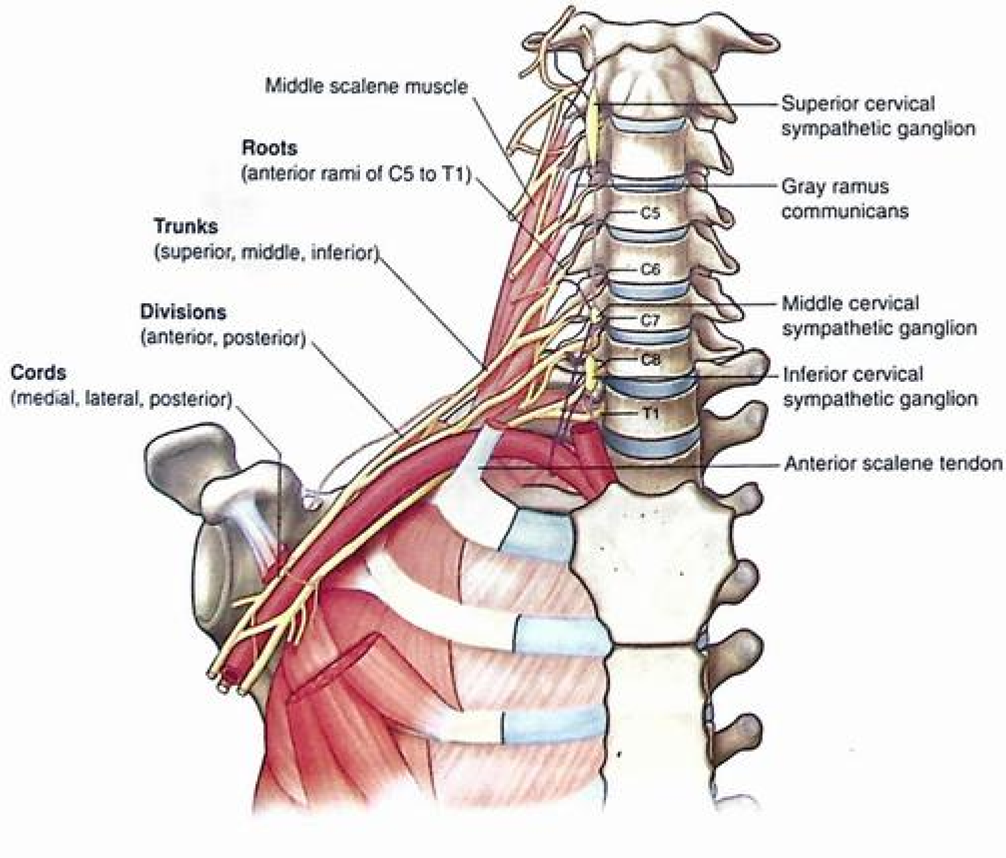


Fig. 5.2 Brachial plexus—major components in the neck and axilla. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students.* 4th ed. Philadelphia: Elsevier; 2020.)

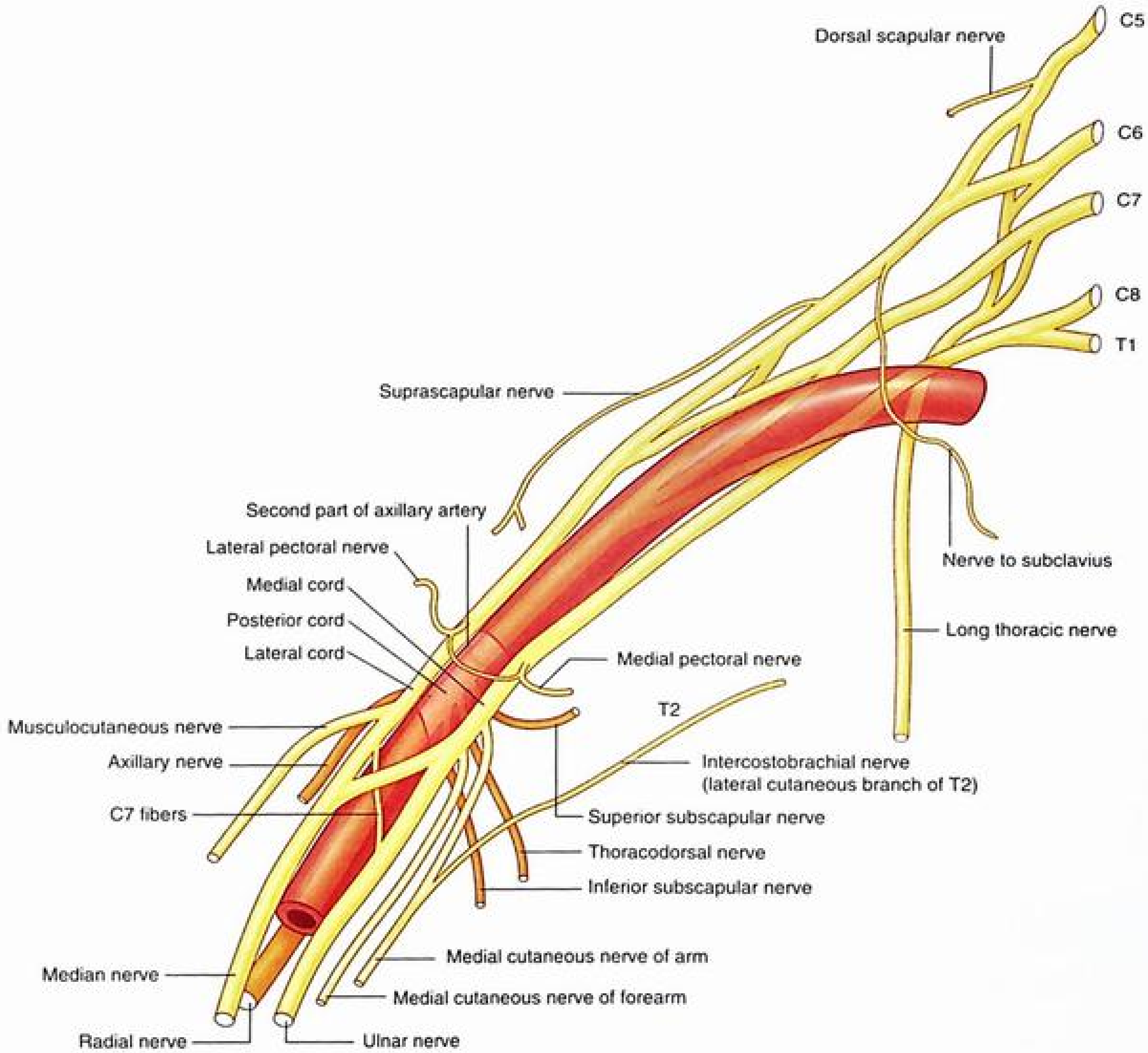


Fig. 5.3 Brachial plexus—relationships to the axillary artery. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

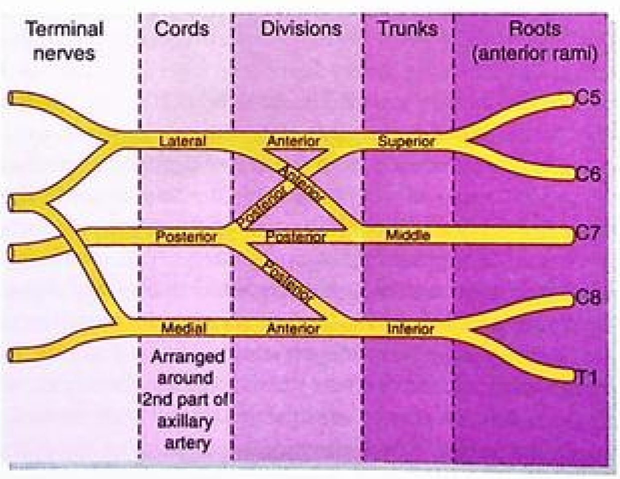


Fig. 5.4 Brachial plexus—schematic showing parts of the brachial plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

CLINICAL CORRELATION

Suprascapular Block

The suprascapular nerve branches from the superior trunk of the brachial plexus after the C5 and C6 nerve roots have joined. It enters the supraspinatus fossa through the suprascapular notch, passing under the superior transverse scapular ligament (Fig. 5.8). The suprascapular nerve innervates nearly 70% of the superior and posterior parts of the shoulder and virtually none of the anterior and inferior regions. This block is primarily used for shoulder surgeries that use a posterior approach.

DIVISIONS

The superior, middle, and inferior trunks each separate into anterior and posterior divisions (see Fig. 5.5). These divisions

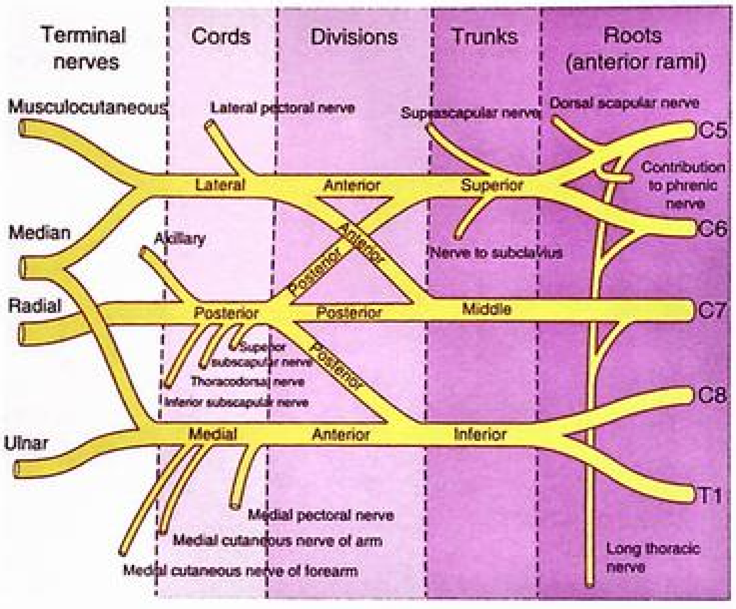


Fig. 5.5 Brachial plexus—schematic showing branches of the brachial plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

ultimately will give rise to the specific nerves. The three anterior divisions will form nerves that are associated with the anterior compartments of the arm and forearm, while the three posterior divisions will form nerves that are associated with the posterior compartments of the arm and forearm.

CLINICAL CORRELATION

Supraclavicular Block

This block is effective for anesthesia of the entire upper extremity and is carried out at the division level of the brachial plexus. The location of this block is in the area where the subclavian artery and divisions of the brachial plexus pass over the first rib between the insertion of the anterior and middle scalene muscles (see Fig. 5.2).

CORDS

The cords form from the divisions (see Fig. 5.5) and are associated with the second part of the axillary artery (see Fig. 5.3). Most of the nerves of the upper limb are branches of the three cords. The lateral cord, named for its positional relationship with the axillary artery, forms from the joining of the anterior divisions of the anterior and middle trunks. The medial cord, occupying a position medial to the axillary artery, is the extension of the anterior division of the inferior trunk. The posterior cord, being posterior to the axillary artery, receives all of the posterior divisions. The majority of terminal nerves branch from the three cords in the brachial plexus.

Medial Cord. The medial cord has five branches (Fig. 5.9). The first and most proximal branch from the medial cord is the medial pectoral nerve. After receiving a communicating branch from the lateral pectoral nerve, the medial pectoral nerve passes anteriorly between the axillary artery and vein. Branching occurs, with some branches passing into the pectoralis minor muscle, innervating it; through this muscle and into the pectoralis major muscle, innervating it; with additional branches passing around the lateral border of the pectoralis minor muscle entering the pectoralis major muscle, innervating it. The next branch, the medial cutaneous nerve of the arm (medial brachial cutaneous nerve), moves through the axilla and into the arm. Thus fibers of this branch innervate the upper medial surface of the arm and floor of the axilla. Moving distally, the medial cutaneous nerve of the forearm (medial antebrachial cutaneous nerve) is the next branch. It moves out of the axilla into the arm supplying the skin over the biceps brachii muscle. Continuing inferiorly, traveling with the basilic vein, it innervates the skin over the anterior surface of the forearm and skin, along the medial surface of the forearm to the wrist. Continuing distally, the medial root of the median nerve is the next branch. Passing laterally, this branch joins with a similar branch originating from the lateral cord, forming the median nerve anterior to the third part of the axillary artery. The final branch of the medial cord is the ulnar nerve. This large branch may receive a communicating branch from the lateral root of the median nerve, consisting of C7 fibers from the lateral cord. The ulnar nerve passes through the arm and forearm, entering the hand. As it passes through the forearm, it innervates the flexor carpi ulnaris and the medial half of the flexor digitorum profundus muscles. In the hand, the ulnar nerve innervates all the intrinsic muscles, excluding the three thenar muscles and the two lateral lumbrical muscles. It also innervates the skin over the palmar side of the little finger, the medial half of the ring finger, parts of the palm and wrist, and the dorsal surface of the medial portion of the hand.

Lateral Cord. The lateral cord has three branches (see Fig. 5.9). The lateral pectoral nerve is the first branch from the lateral cord. It penetrates the clavipectoral fascia,

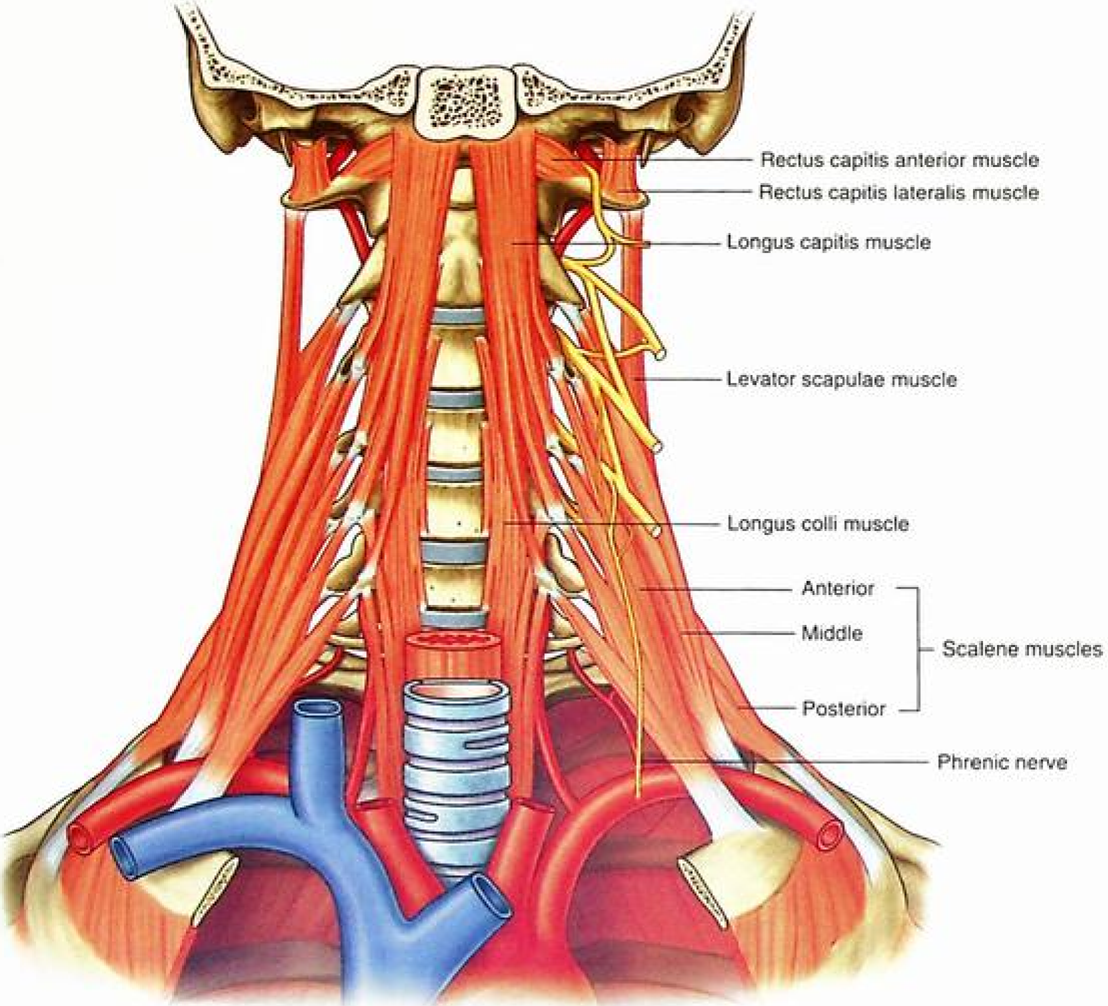


Fig. 5.7 Arteries and nerves associated with gateways in the posterior scapular region. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

ulnar nerve). The median nerve continues into the hand, innervating the three thenar muscles, the two lateral lumbrical muscles involved in movements of the index and middle fingers, the skin on the palmar side of the lateral three-and-one-half digits, and the skin on the lateral side of the palm and middle of the wrist.

Posterior Cord. The posterior cord has five branches, four of which innervate muscles related to movements of the shoulder or the posterior wall of the axilla, while the remaining branch passes into the arm and forearm (Fig. 5.10). Originating in this order, the superior subscapular, the thoracodorsal, and the inferior subscapular nerves pass into muscles contributing to the posterior wall of the axilla. The short superior subscapular nerve supplies the subscapularis muscle; the longer thoracodorsal nerve passes along the posterior axillary wall and enters the latissimus dorsi muscle, innervating it; and, following the same path, the inferior subscapular nerve innervates the subscapularis and teres major muscles. Branching next from the posterior cord is the axillary nerve. This nerve passes inferiorly and laterally along the posterior wall of the axilla and exits through the quadrangular space. It continues passing posteriorly around the surgical neck of the humerus, innervating the deltoid and the teres minor muscles. Additionally, the axillary nerve, after passing through the quadrangular space, has a branch, the superior lateral cutaneous nerve of the arm, which loops around the deltoid muscle to innervate the skin in this region. Finally, the largest branch of the posterior cord, the radial nerve, leaves the axilla, entering the posterior compartment of the arm through the triangular interval (an area between the inferior border of the teres major muscle, the long head of the triceps brachii muscle, and the shaft of the humerus). Traveling with the radial nerve at this point is the profunda brachii artery. The radial nerves innervate muscles in the posterior compartment of the arm and forearm, the skin on the posterior surface of the arm and forearm, the lower lateral surface of the arm, and the dorsolateral surface of the hand. An additional branch of the radial nerve in the axilla, the posterior cutaneous nerve of the arm, innervates the skin on the posterior surface of the arm.

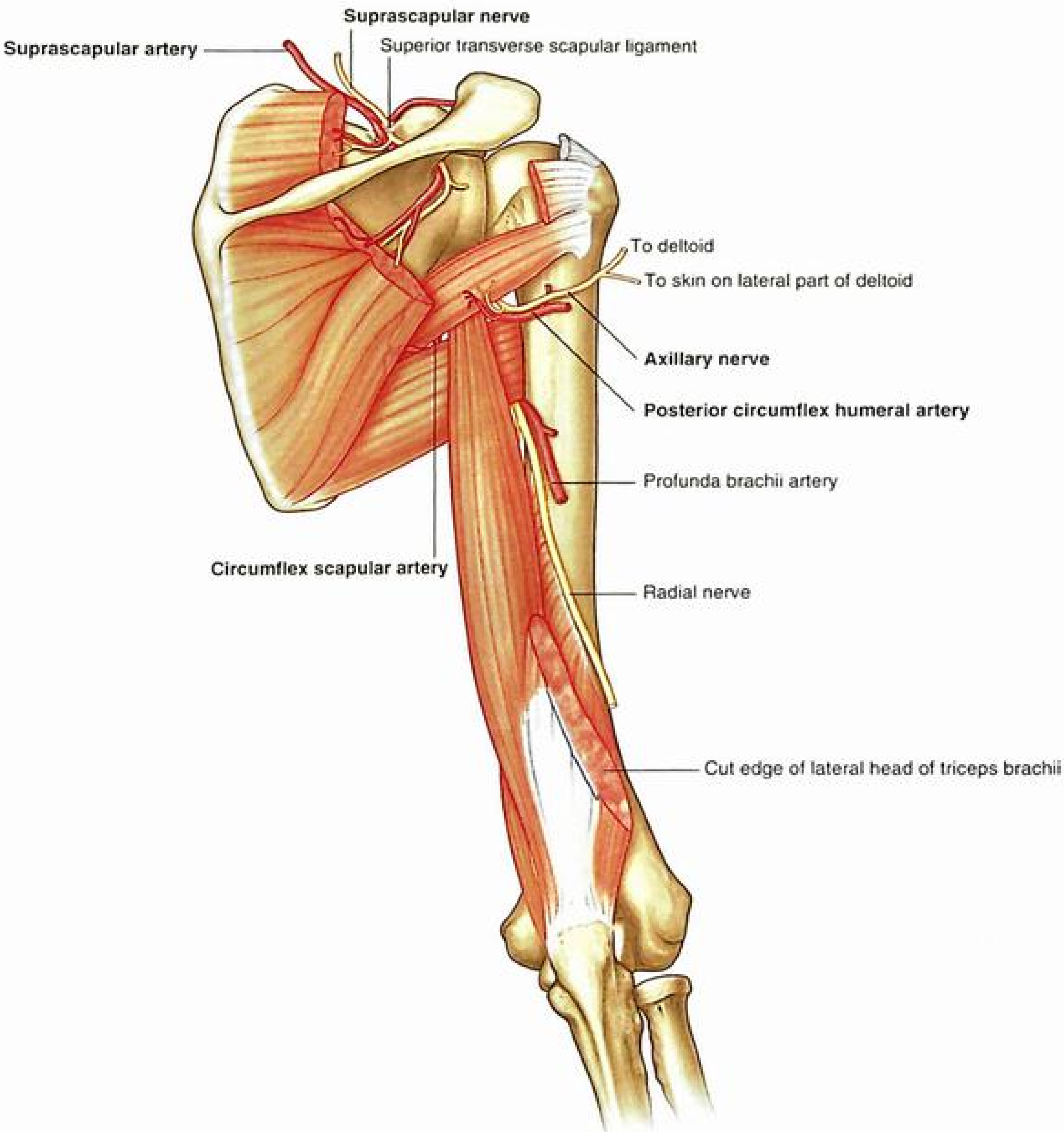


Fig. 5.8 Branches of the lateral and medial cords of the brachial plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

CLINICAL CORRELATION

Infraclavicular Block

The infraclavicular block is useful for single-injection and continuous infusion techniques. Generally, it is referred to as a sensory and motor block and is used for procedures on the elbow, forearm, and hand. The block is performed at the level of the proximal axilla. The axilla is a pyramid-shaped space with an apex formed by the clavicle, scapula, and first rib coming together (Fig. 5.11). The neurovascular structures enter through this apex. The anterior and posterior divisions become cords as they enter the axilla and various nerves leave the cords (see Fig. 5.2).

Axillary Block

This block is used for surgical procedures distal to the elbow, such as hand and forearm surgeries. It is usually done at the level of the distal axilla. The nerves affected are the musculocutaneous, median, ulnar, and radial nerves (see Figs. 5.9 and 5.10).

TERMINAL NERVES

- Median nerve—motor and sensory from medial and lateral cords of BP (Fig. 5.12).
  - Sensory—the skin on the palmar surfaces of the lateral three-and-one-half digits and cutaneous

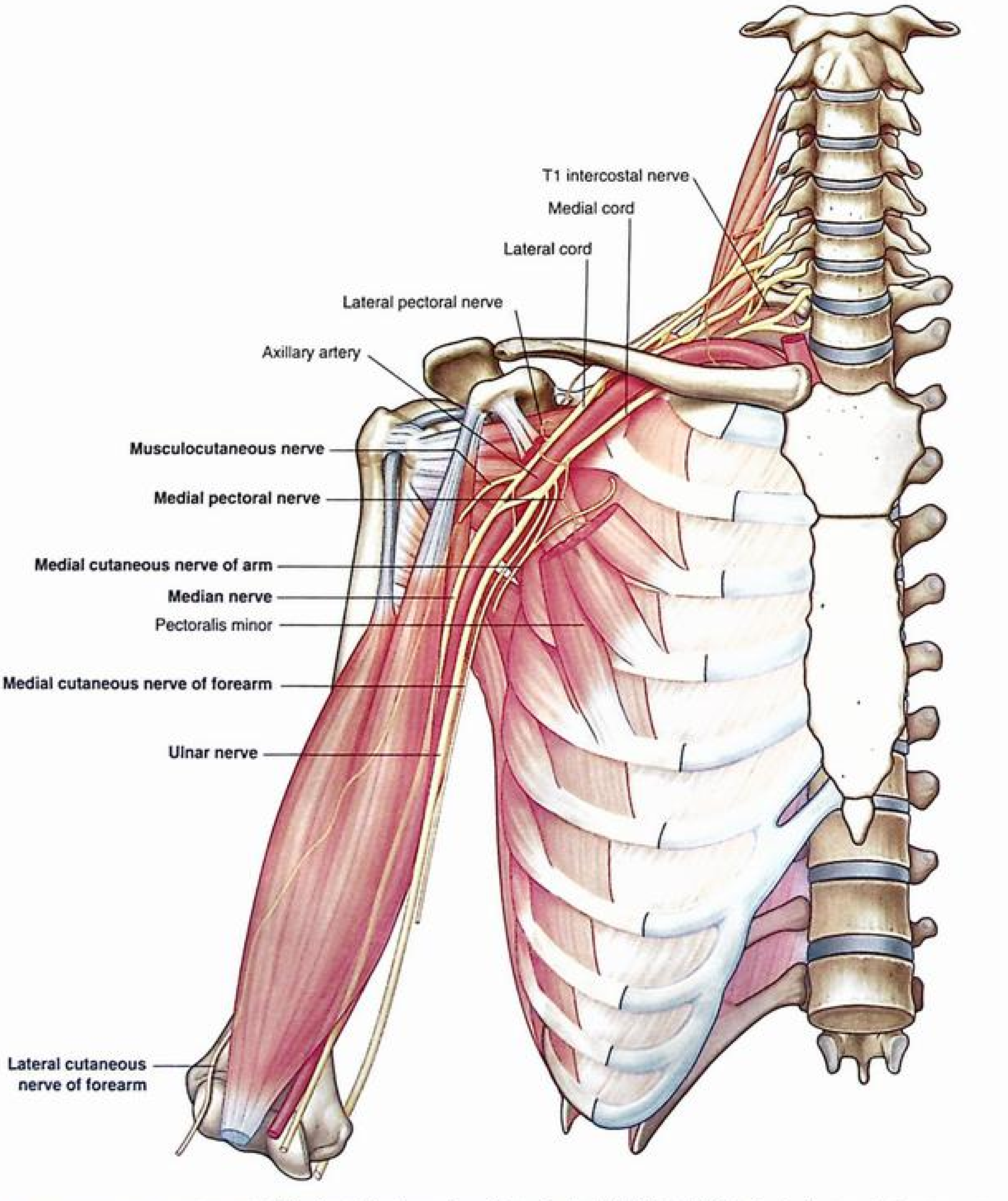


Fig. 5.9 Branches of the posterior cord of the brachial plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier, 2020.)

regions over the dorsal aspects of the distal phalanges (nail beds) of these digits.

- Motor—innervates all muscles of the forearm except the flexor carpi ulnaris and the medial part of the flexor digitorum profundus. In the hand, it innervates the three thenar muscles and the two lateral lumbricals.

- Ulnar nerve—from C8 and T1 nerve roots as the terminal branch of medial cord with motor and sensory components (see Fig. 5.12).
  - Sensory—innervates the skin on the palmar and dorsal surfaces of the little finger and the medial half of the ring finger.
  - Motor—in the forearm, innervates the flexor carpi ulnaris and the medial part of the flexor digitorum profundus. It innervates all intrinsic muscles in the hand except for the three thenar muscles and the two lateral lumbricals.
- Radial nerve—motor and sensory from the posterior cord of BP, with components from C5 to T1 nerve

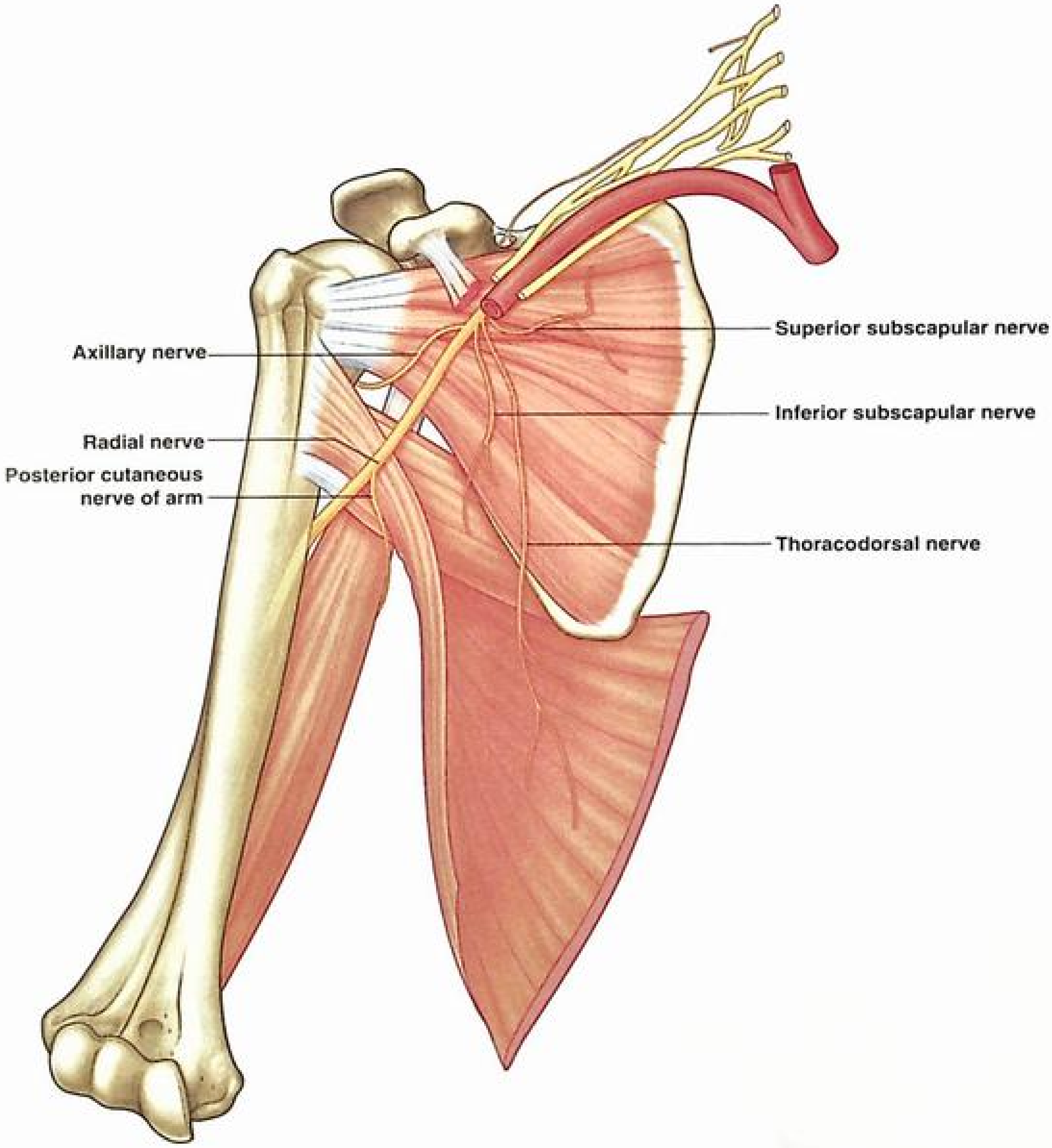


Fig. 5.10 Branches of the lateral and medial cords of the brachial plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

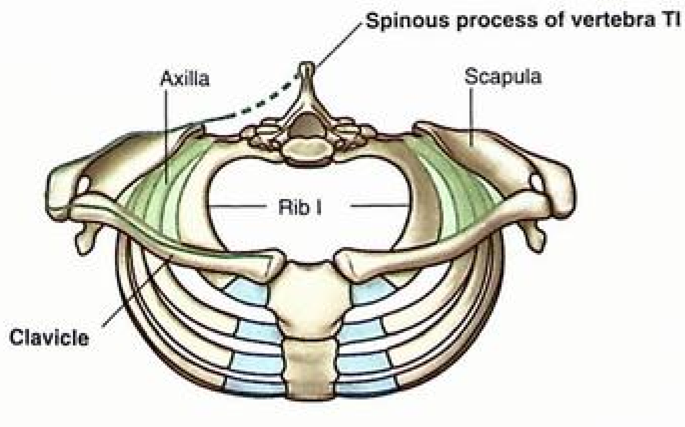


Fig. 5.11 Upper limb—superior view of the shoulder. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

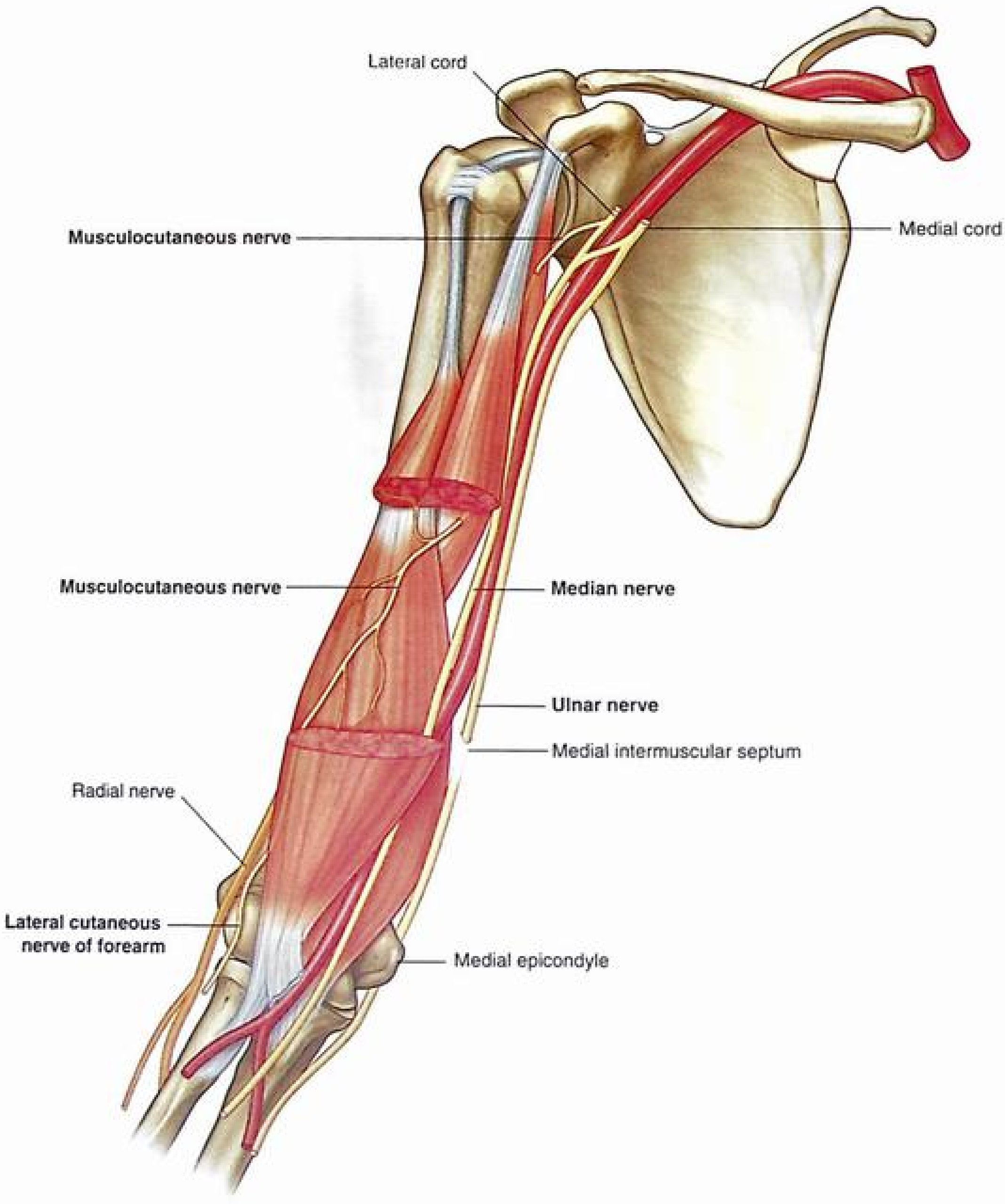


Fig. 5.12 Musculocutaneous, median, and ulnar nerves in the arm. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

roots. At the elbow, it divides into superficial and deep branches (Fig. 5.13).

- Sensory—innervates the skin on the dorsolateral aspect of the hand and the dorsal aspects of the lateral three-and-one-half digits, up to the terminal interphalangeal joints.
- Motor—innervates all of the muscles in the posterior compartment of the forearm.

CLINICAL CORRELATION

Distal Upper Extremity Blocks

These blocks may be performed at various levels, that is, arm, elbow, forearm, and wrist, and are meant to affect the median, ulnar, and radial nerves.

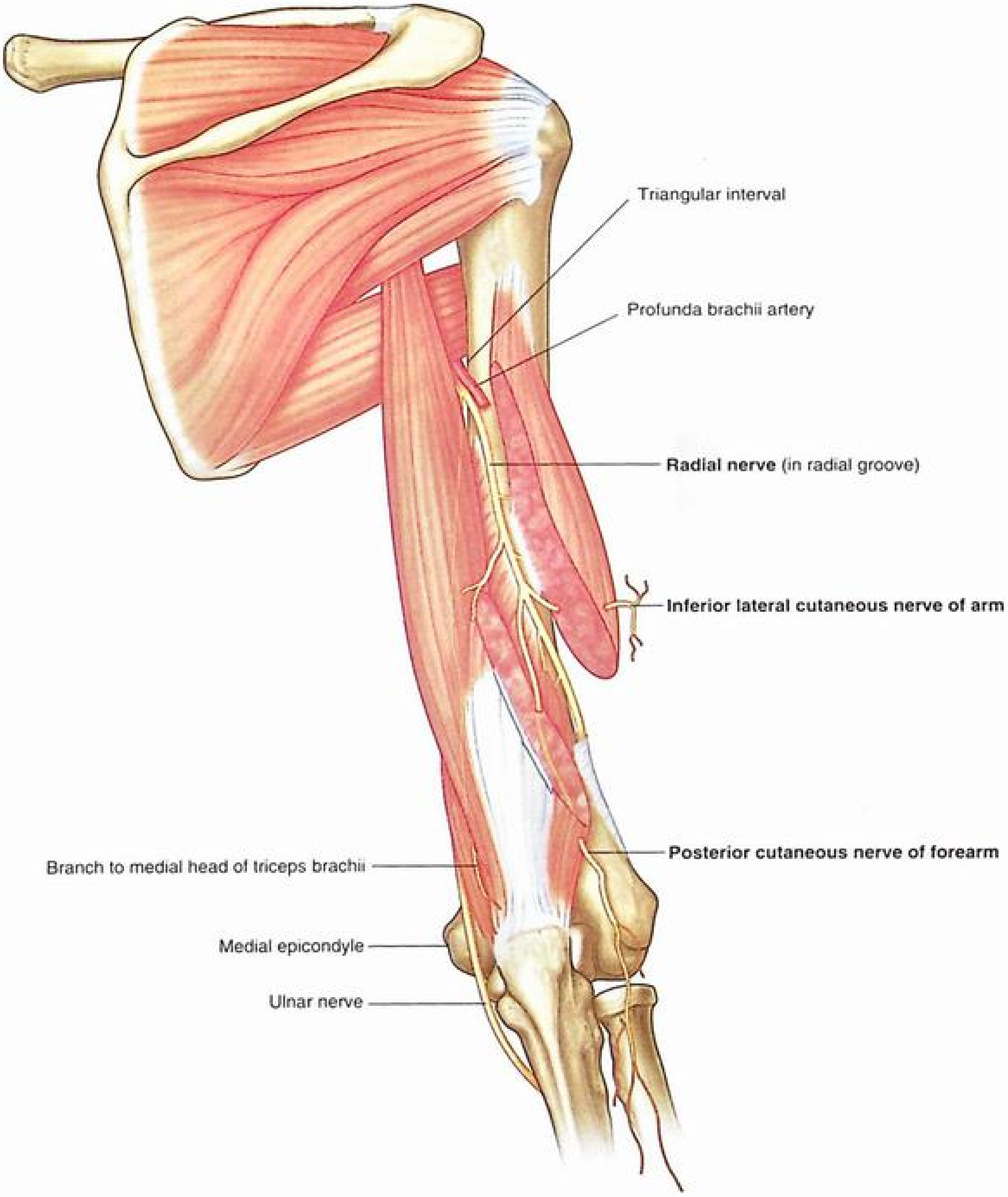


Fig. 5.13 **Radial nerve in the arm.** (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

Shoulder Joint Innervation

The glenohumeral or shoulder joint is in a unique position. It is innervated by nerves arising from three different parts of the brachial plexus—the suprascapular nerve from the superior trunk, the lateral pectoral nerve from the lateral cord, and the axillary nerve, as well as direct branches from the posterior cord. For this reason, various blocks may be used, such as the interscalene or the suprascapular, to achieve the desired result.

Axillary Nerve Block

6

Ehab Farag

Key Points

- The axillary nerve innervates the anterior and posterior parts of the inferior portion of the shoulder joint.
- Axillary nerve blocks can be used for quadrilateral space syndrome.
- Combined axillary nerve and suprascapular nerve blocks could be used for postoperative pain relief after shoulder surgeries in cases where there are contraindications for an interscalene brachial plexus block.
- The in-plane approach is the preferred way for axillary nerve block using ultrasound.
- Identification of the posterior circumflex humeral artery is the key landmark for the axillary nerve block. Visualization of the posterior circumflex humeral artery will be enhanced by utilizing color Doppler ultrasound.

ANATOMY

The axillary nerve branches from the posterior cord (C5–T1) and descends in the axilla posterior to the subscapularis. It emerges from the axilla at the level of the lower border of the subscapularis by traversing the quadrilateral space. This is a space in the posterior scapular region which is bounded by the superior margin of the teres major inferiorly; the inferior margin of the teres minor superiorly; the lateral margin of the long head of the triceps brachii medially and the surgical neck of the humerus laterally. The posterior circumflex humeral artery and vein also run posterior to the axillary nerve in this nerve. The articular branches of the axillary nerve to the shoulder joint arise from three sites: the main trunk, anterior, and posterior divisions. After the axillary nerve enters the quadrilateral space, one or two of the articular branches take off from the main trunk. These articular branches travel with the anterior circumflex humeral artery and pass between the tendons of the subscapularis and latissimus dorsi muscles. At the medial border of the humerus, the articular branches continue superiorly deep to the tendon of the subscapularis muscle. Before they reach the capsule, each split into two main branches that themselves ramify into small nerve bundles within the joint capsule. The axillary nerve innervates the anterior and posterior parts of the inferior portion of the shoulder joint (Fig. 6.1).

SONOANATOMY

The high-frequency linear ultrasound probe is placed in the long-axis orientation over the medial side of the posterior humerus. The hyperechoic margin of the shaft humerus and the adjacent long head of the triceps muscle are identified. The transducer is slowly moved toward the axilla while tracing the hyperechoic margin of the humerus until the hyperechoic margin curves outward as the transducer approaches the inferior head of the humerus. Below the point of this outward curve, the axillary nerve and posterior circumflex humeral artery lie in the quadrilateral space. Color Doppler may be helpful in identifying the posterior circumflex artery.

TECHNIQUE

The patient is usually placed in a sitting position with the forearm resting comfortably on the ipsilateral thigh, allowing identification of the axillary nerve in the quadrilateral space close to the posterior circumflex artery. The needle is placed above the center of the transducer and then is advanced using an in-plane approach under real-time ultrasound guidance till the tip of the needle ultimately rests in proximity to the axillary nerve as it lies in the quadrilateral space. After careful aspiration, 10 mL of either 0.2% ropivacaine or 0.25% bupivacaine is injected around the nerve for a shoulder surgery, or 3 mL of lidocaine 1% for quadrilateral space syndrome (Figs. 6.2 and 6.3, Video 6.1).

PEARLS

- Innervation of the shoulder joint is provided mainly by suprascapular, axillary, lateral pectoral, and lower subscapular nerves.
- The suprascapular nerve provides the greatest contribution to overall shoulder innervation.
- The combined suprascapular nerve and axillary nerve blocks for shoulder surgery are associated with a lower incidence of numbness, tingling, motor weakness, Horner syndrome, and subjective dyspnea compared to interscalene brachial plexus block.
- The motor blockade of combined suprascapular nerve and axillary nerve blocks for shoulder surgery is confined to the deltoid, supraspinatus,

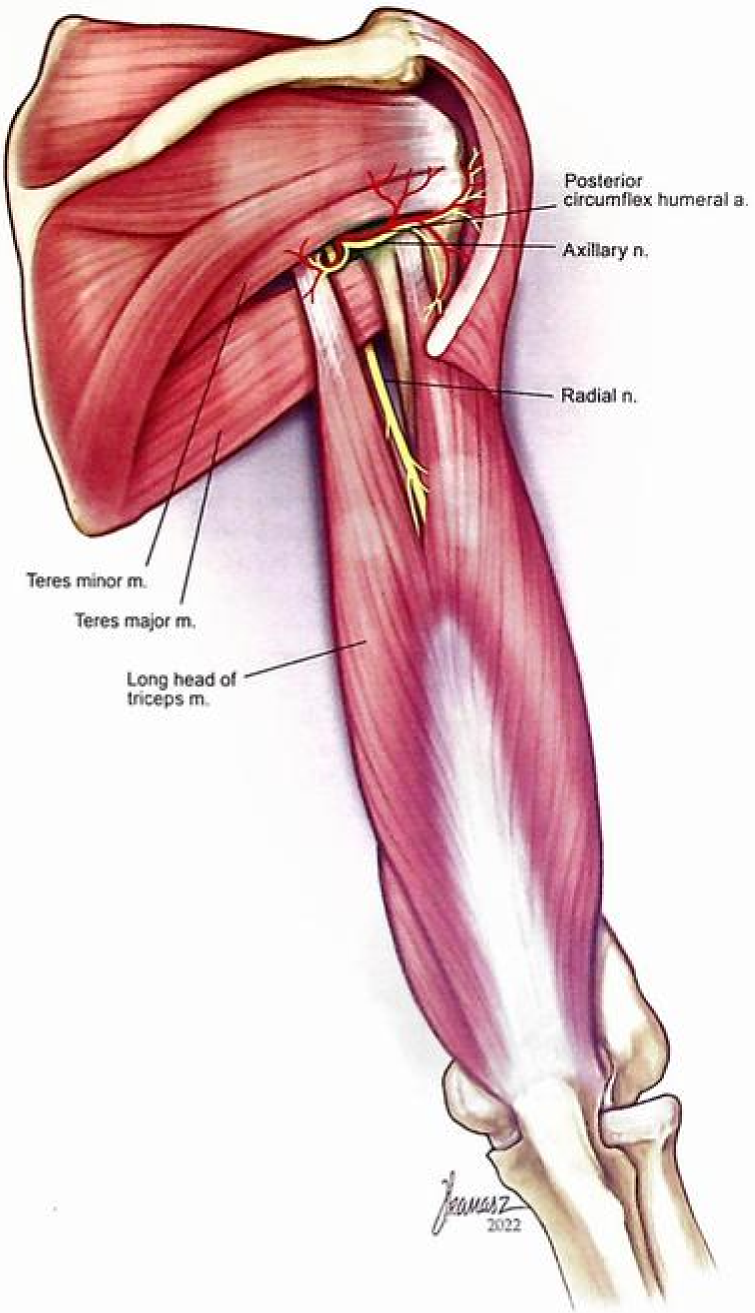


Fig. 6.1 Anatomy of the axillary nerve in the quadrilateral space and its relation to the posterior circumflex artery.

infraspinatus, and teres minor muscles (posterior rotator cuff).

- Interscalene brachial plexus block is contraindicated in patients with contralateral phrenic nerve palsy, severe preexisting respiratory insufficiency due to chronic obstructive pulmonary disease, restrictive pulmonary disease, bronchial asthma, and morbid obesity.

Fig. 6.2 Patient's position for the axillary nerve block. Notice the in-plane needle technique for the block.

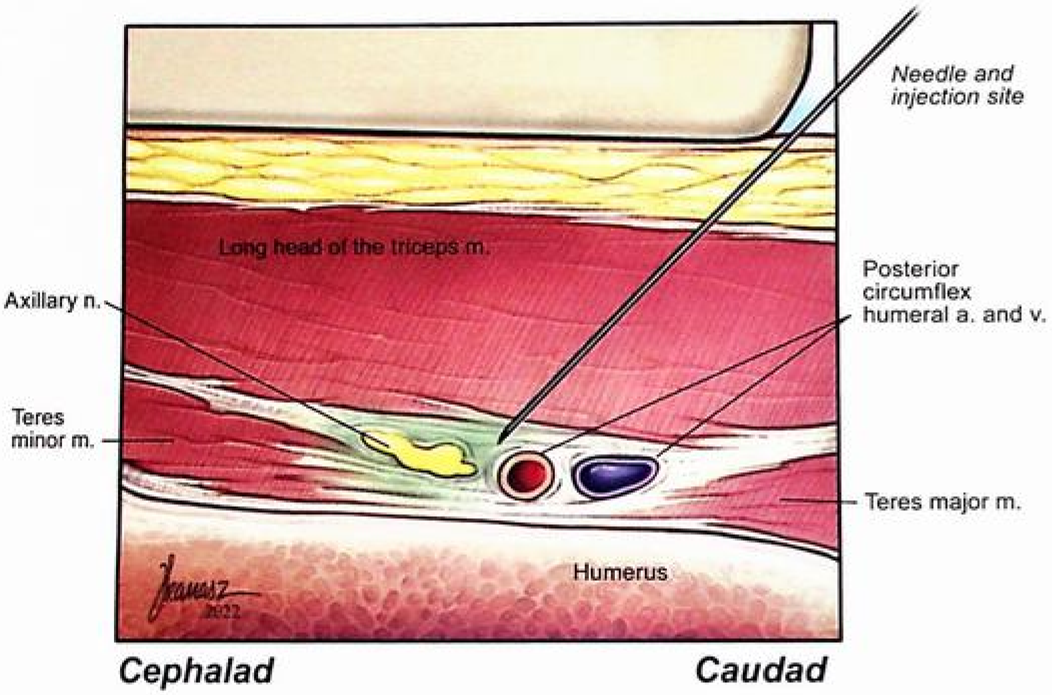


Fig. 6.3 Illustration of the ultrasound image for the axillary nerve block.

Suggested Reading

Dhir S, Sondekppam R, Sharma R, Ganapathy S, Athwal GS. A comparison of combined suprascapular and axillary nerve blocks to interscalene nerve block for analgesia in arthroscopic shoulder surgery. An equivalence study. *Reg Anesth Pain Med*. 2016;41:564–571.

Laumonerie P, Dalmas Y, Tıbbo ME, et al. Sensory innervation of the human shoulder joint: the three bridges to break. *J Shoulder Elbow Surg*. 2020;29:e499–e507.

7 Interscalene and Superior Trunk Blocks

Ehab Farag

Key Points

- The interscalene nerve block remains the most commonly used peripheral nerve block for shoulder surgery.
- The interscalene nerve block provides anesthesia for shoulder joint surgery by blocking the C5 and C6 nerve roots.
- The interscalene nerve block provides excellent analgesia after shoulder surgery while avoiding hand weakness.
- The main complication of the interscalene nerve block is hemidiaphragmatic paralysis. Interscalene nerve blocks are contraindicated in patients with contralateral phrenic nerve palsy, severe preexisting respiratory insufficiency due to chronic obstructive pulmonary disease, and severe restrictive pulmonary disease.
- A small, linear (20- to 25-mm) footprint is preferred for this block.
- The most successful way to perform this block is to visualize the brachial plexus in the supraclavicular region and then scan cephalad to identify the roots that are sandwiched between the anterior scalene and middle scalene muscles.
- Insertion of the needle and the catheter between C5 and C6 or C6 and C7 will help to anchor the catheter properly and ensure good analgesia after shoulder surgery.
- The superior trunk block provides adequate analgesia for shoulder surgery, with less hemidiaphragmatic paralysis.

SENSORY INNERVATION OF THE HUMAN SHOULDER

Innervation of the shoulder joint is provided by the suprascapular nerve, axillary nerve, lateral pectoral nerve, and lower subscapular nerve according to Hilton's law, which states that the nerve supplying the muscles extending directly across and acting at a given joint not only supplies the muscle but also innervates the joint and the skin overlying the muscle.

The suprascapular nerve is the greatest contributor to overall shoulder innervation. It provides sensory innervation to the posterior glenohumeral capsule, subacromial bursa, and coracoacromial and acromioclavicular ligaments.

The axillary nerve provides the sensory innervation to the smaller areas involving the inferior portion of the anterior and posterior glenohumeral capsule. In addition, the axillary nerve provides sensory innervation to the lateral part of the anterior shoulder joint via its articular branches.

The lower subscapular nerve provides the sensory innervation to the medial portion of the shoulder joint.

The long pectoral nerve also provides the sensory innervation to the anterosuperior quadrant of the shoulder, including the anterior edge of the subacromial bursa, coracoacromial ligaments, and glenohumeral capsule.

SONOANATOMY

The interscalene block is performed in the posterior triangle (Figs. 7.1–7.6), which lies between the posterior border of the sternocleidomastoid muscle and the trapezius muscle, next to the sixth and seventh cervical vertebrae. In the interscalene block, the brachial plexus is made up of nerve roots (C5, C6, and C7) or trunks. The brachial plexus in the interscalene block appears as hypoechogenic nodules (due to the high ratio of neural/nonneural tissue in this region) located between the anterior and middle scalene muscles under the prevertebral fascia. The dorsal scapular and long thoracic nerves of the brachial plexus are frequently located in the middle scalene muscle at less than 1 cm posterior to the plexus. The nerves appear as hyperechoic structures containing a hypoechoic center.

INDICATIONS

- The principal indication for interscalene block is surgery of the shoulder. Local anesthetic spread after the block includes the supraclavicular (nonbrachial plexus) nerve (C3–C4), which supplies sensory innervation to the cape of the shoulder.
- The interscalene block can be used for surgery on the humerus neck; however, it is not sufficient for hand surgeries, as it misses the lower roots and the trunk of the plexus.

TECHNIQUE

The patient position is usually either supine with the head turned to the opposite side to be blocked or in the lateral

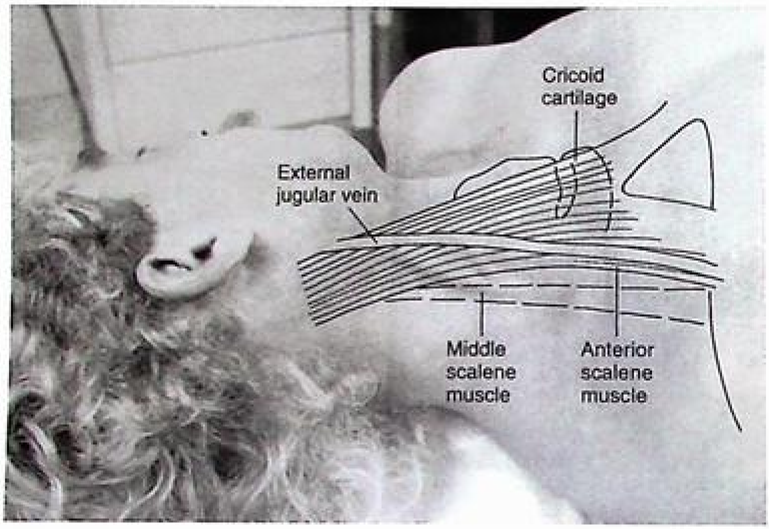


Fig. 7.1 Interscalene block: surface anatomy.

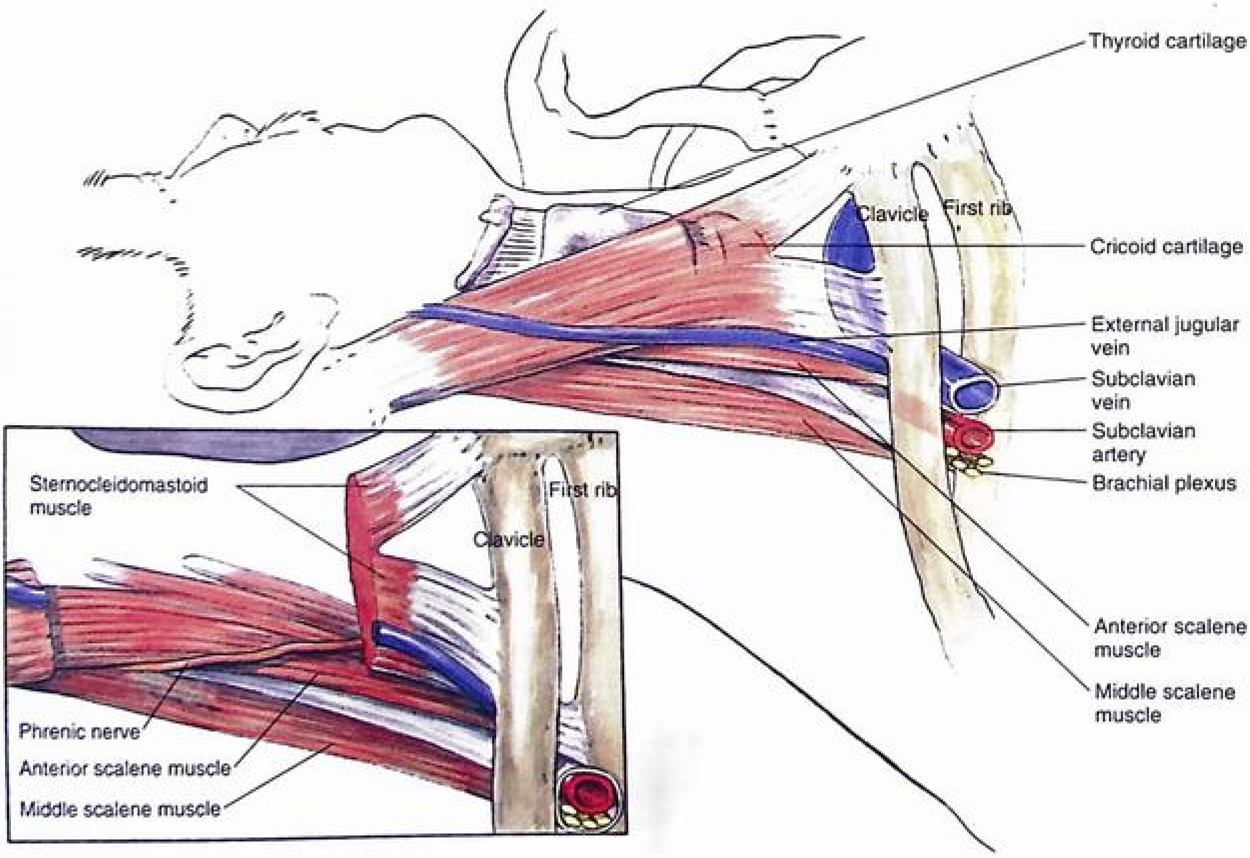


Fig. 7.2 Interscalene block: the anatomy of the scalene muscles and their relationship to the brachial plexus.

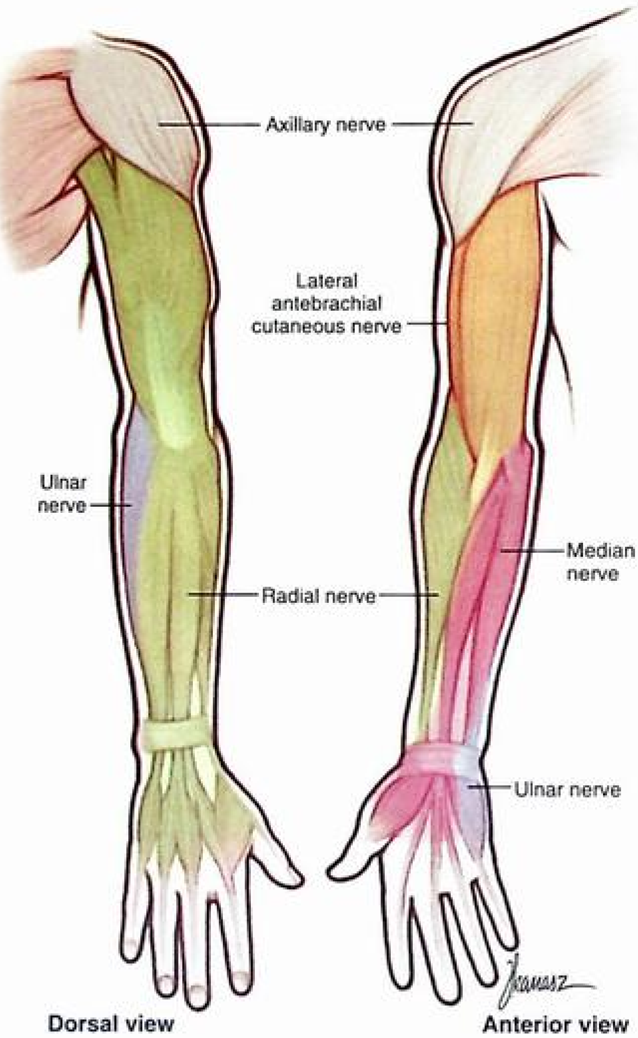


Fig. 7.5 The myotome innervation of the upper limb.

We prefer to use ropivacaine 0.2% for this block, as it results in a relatively reduced motor blockade.

SUPERIOR TRUNK BLOCK

The ventral rami of C5 and C6 unite to form the superior trunk. The suprascapular nerve and the nerve to the subclavius arise from the superior trunk. Of note, the trunks of the brachial plexus pass between the anterior and middle scalene muscles.

The superior trunk block has been described recently as an alternative to the interscalene block. The superior trunk block could provide similar analgesic effects but with reduced rates of hemidiaphragmatic paralysis compared with the interscalene block.

TECHNIQUE

The patient's position is usually either supine with the head turned to the opposite side to be blocked or in the lateral decubitus position.

After identifying the cervical roots and scalene muscles, as in the interscalene block, the linear probe will be moved distally until the suprascapular nerve branches off the

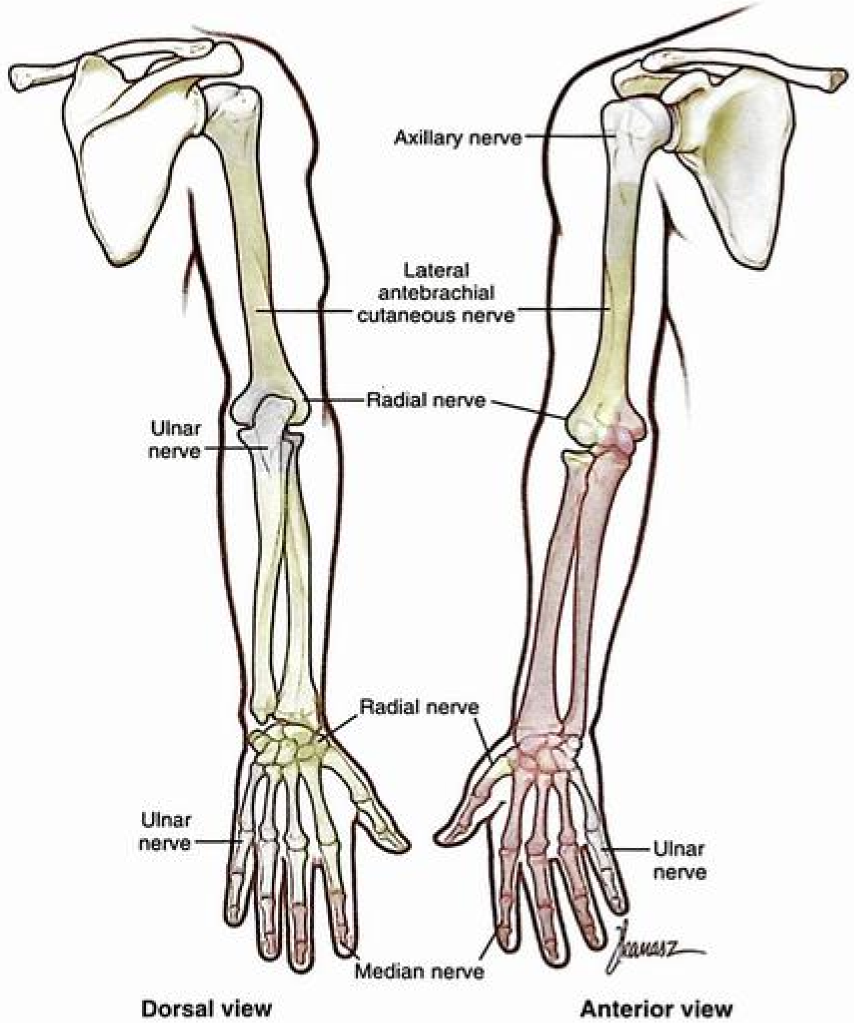


Fig. 7.6 Sclerotome innervation of the upper limb.

superior trunk are seen. The targeted level of insertion for the injection should be immediately before the branching-off point of the suprascapular nerve. The needle will be inserted from lateral to medial, using an in-plane technique. The tip of the needle will be placed posterior/inferior to the trunk. In the single-shot technique, we usually inject 20 mL of 0.2% ropivacaine. In the catheter technique, we use a Tuohy needle for catheter insertion. Ideally, the catheter should be posterior/inferior to the superior trunk (Fig. 7.15).

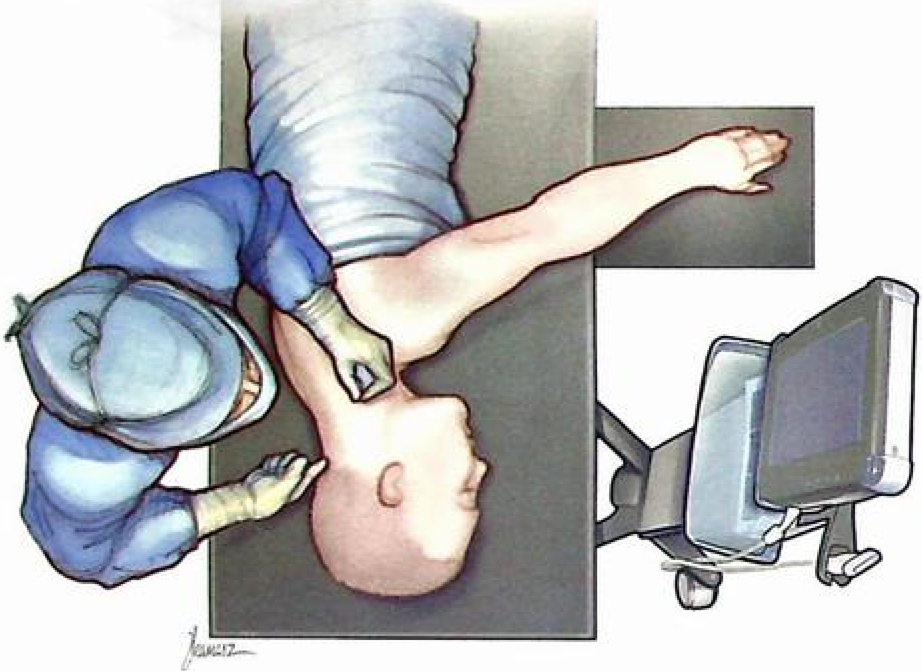


Fig. 7.7 The lateral decubitus position (posterior approach) for the interscalene block.

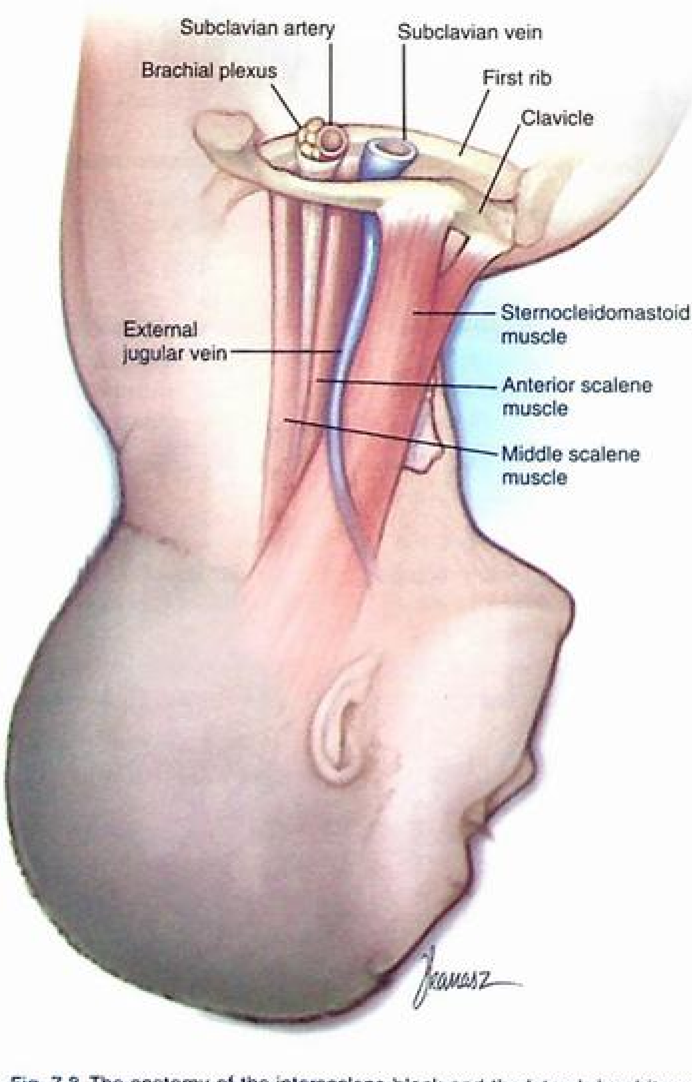


Fig. 7.8 The anatomy of the interscalene block and the lateral decubitus position.

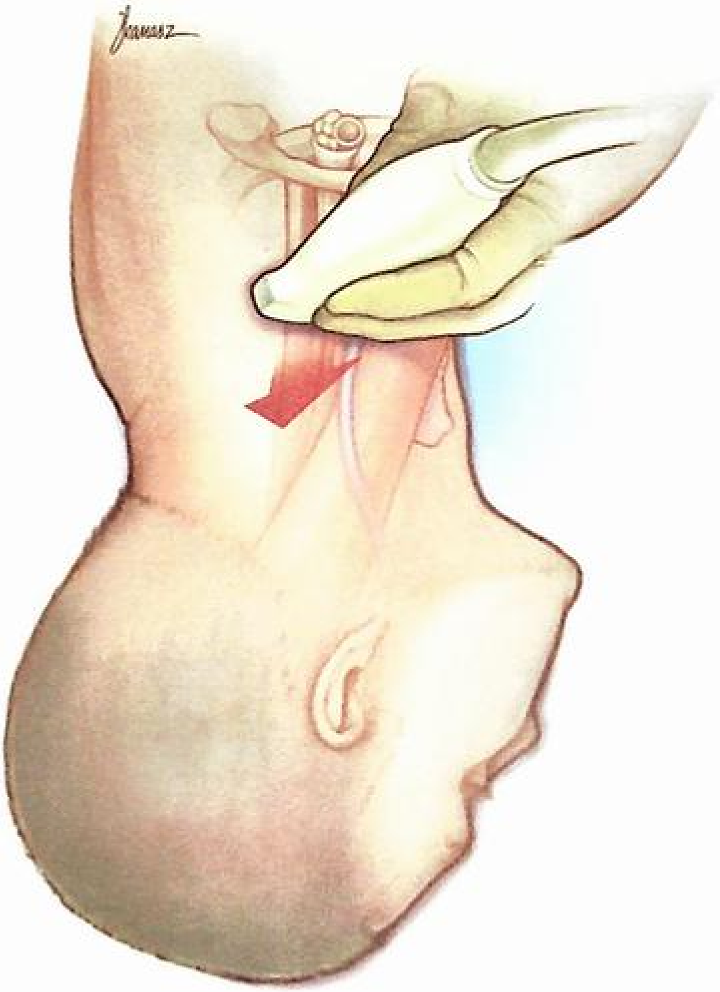


Fig. 7.9 The brachial plexus is scanned in the cephalad direction from the supraclavicular region to identify the roots of the brachial plexus in the interscalene region between the anterior and middle scalene muscles.

NERVE BLOCKS FOR SHOULDER SURGERY WITH PHRENIC-SPARING EFFECTS

The three nerve blocks for shoulder surgery with phrenic-sparing effects are the superior trunk, suprascapular nerve, and combined suprascapular and axillary nerve blocks. The anterior suprascapular approach provides noninferior analgesia compared to the interscalene nerve block while preserving the pulmonary function. There is spread of the local anesthetic in the anterior approach of the suprascapular nerve block to the posterior division of the superior trunk from which the axillary and subscapular nerves arise, making a separate axillary nerve block redundant.

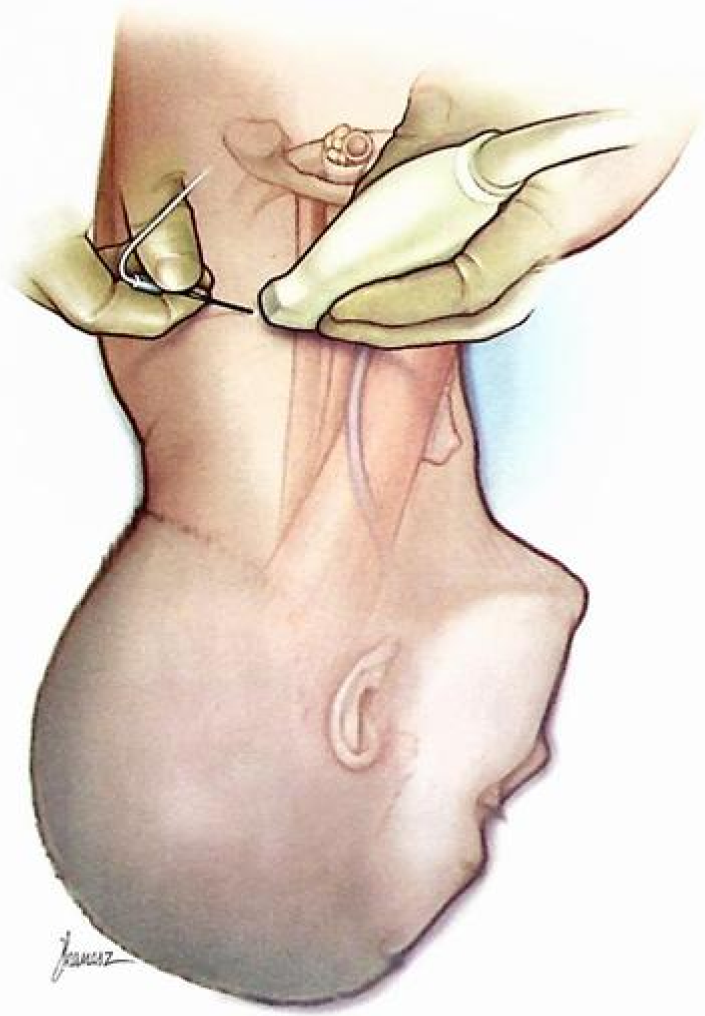


Fig. 7.10 In-plane technique for interscalene block with the needle direction from posterior to anterior in the lateral decubitus position.

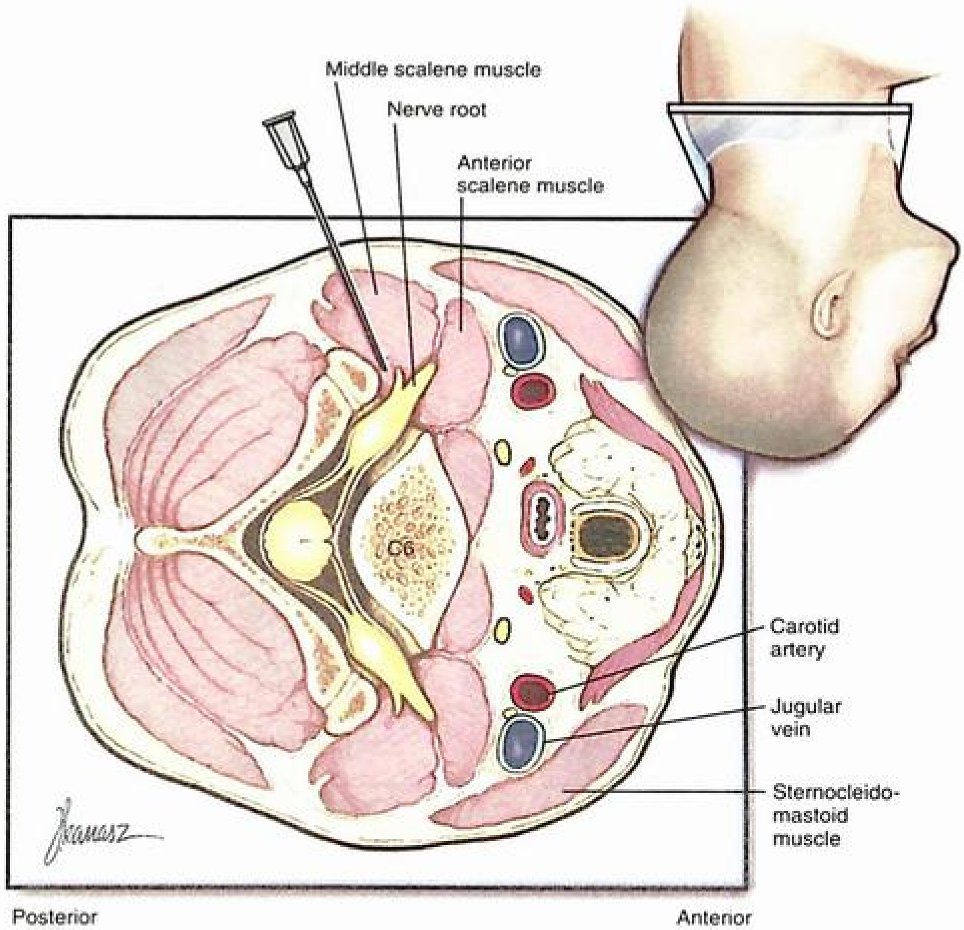


Fig. 7.11 Interscalene block. Notice the needle has to pass through the middle scalene muscle to reach the roots of the brachial plexus in the interscalene groove.

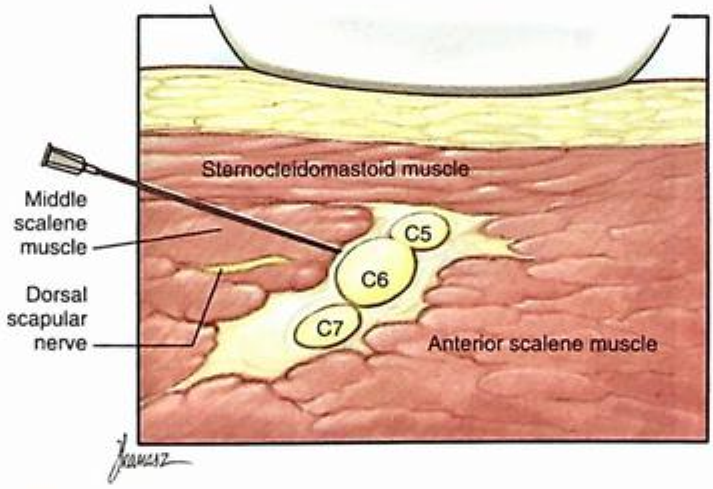


Fig. 7.12 The needle position between *C5* and *C6* roots of the brachial plexus.

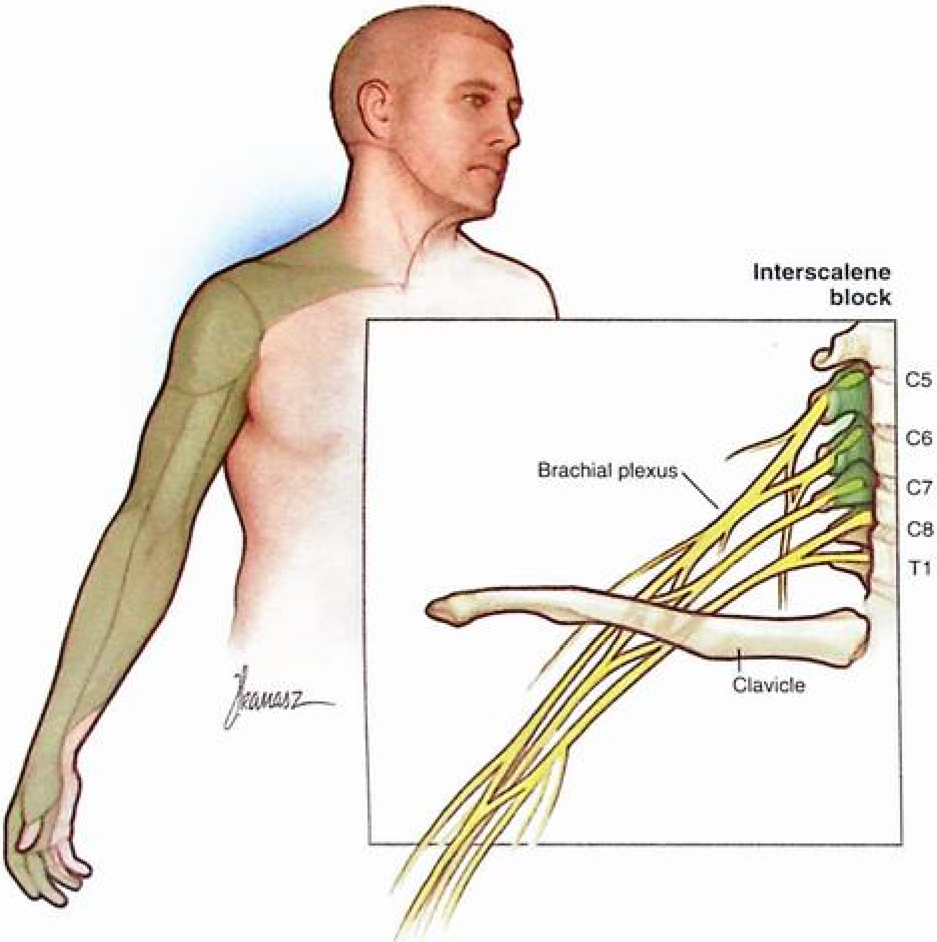


Fig. 7.13 The anatomy of the interscalene block. Note that the roots are blocked in this technique.

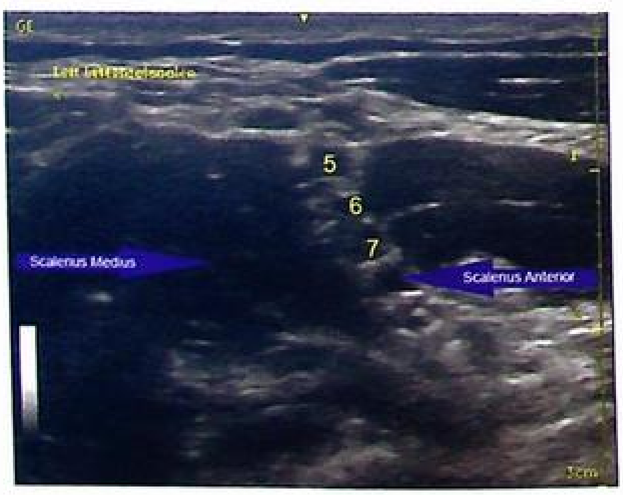


Fig. 7.14 Ultrasound of the interscalene. Note that the roots of the brachial plexus are sandwiched between the scalenus anterior and the scalenus medius.

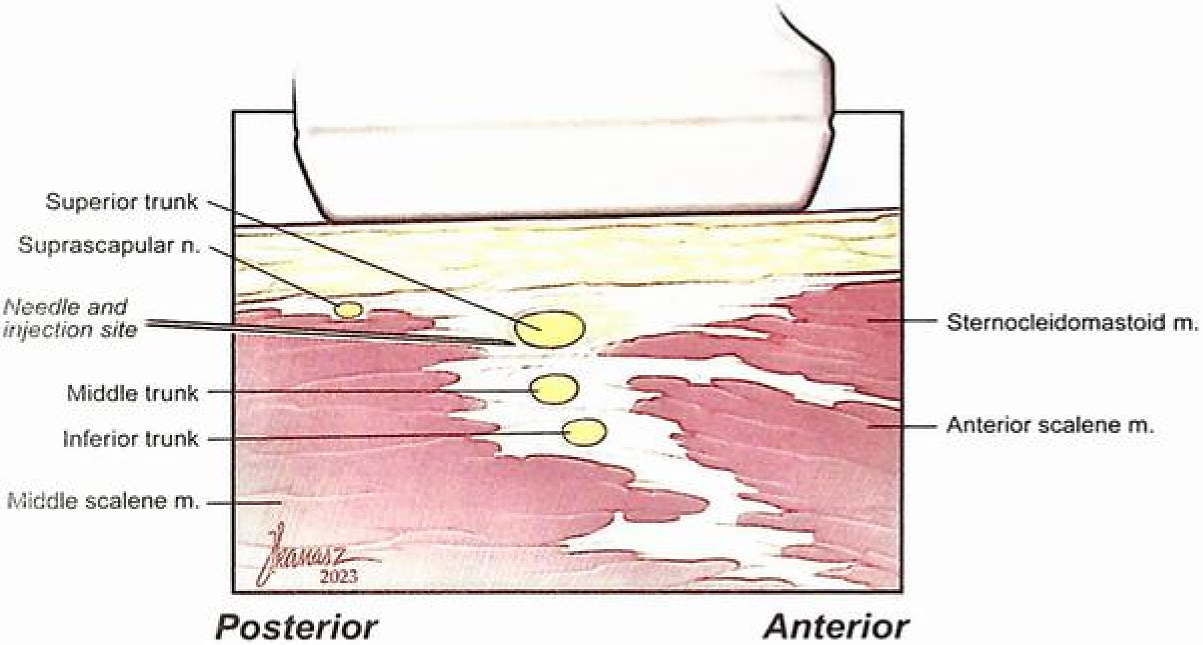


Fig. 7.15 The superior trunk and suprascapular nerve block. Note that the suprascapular nerve emerges from the superior trunk. The needle position is beneath the superior trunk and suprascapular nerve.

8 Supraclavicular Block

Ehab Farag

Key Points

- A small, linear (20- to 25-mm footprint) transducer is preferred for this block.
- Try to identify the cervical pleura and keep the needle direction in a parallel position to the first rib to avoid injuring the pleura and to prevent the development of pneumothorax.
- For catheter insertion, the Tuohy needle is usually used. The catheter is typically inserted superior to the subclavian artery in the case of shoulder surgery, or in the corner pocket between the artery and the first rib in the case of hand surgery. The correct position of the catheter can be confirmed under ultrasound by either injecting local anesthetic or 1 mL of air via the catheter and observing its distribution in relation to the plexus.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

The brachial plexus in the supraclavicular region is composed mainly of three trunks: superior, middle, and inferior. These trunks pass across the upper surface of the first rib, where they lie posterior and superior to the subclavian artery. The trunks then divide into anterior and posterior divisions behind the clavicle. With ultrasonography, the six divisions can be seen compactly arranged and located superior and posterior to the subclavian artery as the artery passes over the first rib. Practically, in the supraclavicular approach for the brachial plexus, the trunks and the divisions appear as a compact group of nerves (like a bunch of grapes) lying superior and posterior to the artery (Figs. 8.1–8.3).

INDICATIONS

- The supraclavicular block is very efficient for upper limb and hand surgeries.
- This block can be used for shoulder surgery; however, it can miss the suprascapular nerve, which supplies the sensory innervation to the glenohumeral joint. Therefore the block could fail to

TECHNIQUE

The patient could be in either a semisitting position (beach-chair position) by elevating the head of the bed 45 degrees, or a supine position with the patient's head turned to the opposite side to be blocked. The first position is preferable in obese patients. The usual probe position is in the coronal oblique plane behind the midpoint of the clavicle to obtain the short-axis view. Scan the supraclavicular fossa to identify the subclavian artery and brachial plexus in the short-axis view. The first rib and the cervical pleura should be identified in this view as well. We prefer to use the in-plane approach for this technique, and the needle will be inserted from the posterior to the anterior direction (Figs. 8.4–8.7, Video 8.1).

PEARLS

- For hand surgery, the local anesthetic should be inserted in the corner pocket between the subclavian artery and the first rib to avoid missing the lower trunk/divisions and therefore the ulnar nerve.
- For shoulder surgeries, try to visualize the suprascapular nerve by scanning more proximal, away from the artery.
- If the patient experiences chest pain and cough during the procedure, they might have developed pneumothorax. The procedure should be abandoned and a chest x-ray should be ordered to confirm the diagnosis.
- Try to examine the anterior chest wall by ultrasound after every supraclavicular block to confirm the absence of pneumothorax by visualizing the intact pleura (sliding sign).
- Injury to the suprascapular nerve following supraclavicular block usually presents with severe shoulder pain followed by weakness in the supraspinatus and infraspinatus muscles. To prevent this complication, try not to inject above the plexus to avoid exposing the nerve to toxic high concentrations of local anesthetics. In addition, avoiding injection above the plexus might decrease the incidence of phrenic nerve palsy after the block.
- Parsonage-Turner syndrome has the same physical presentations as suprascapular nerve injury. However, Parsonage-Turner syndrome is often idiopathic in its etiology, although its onset has been

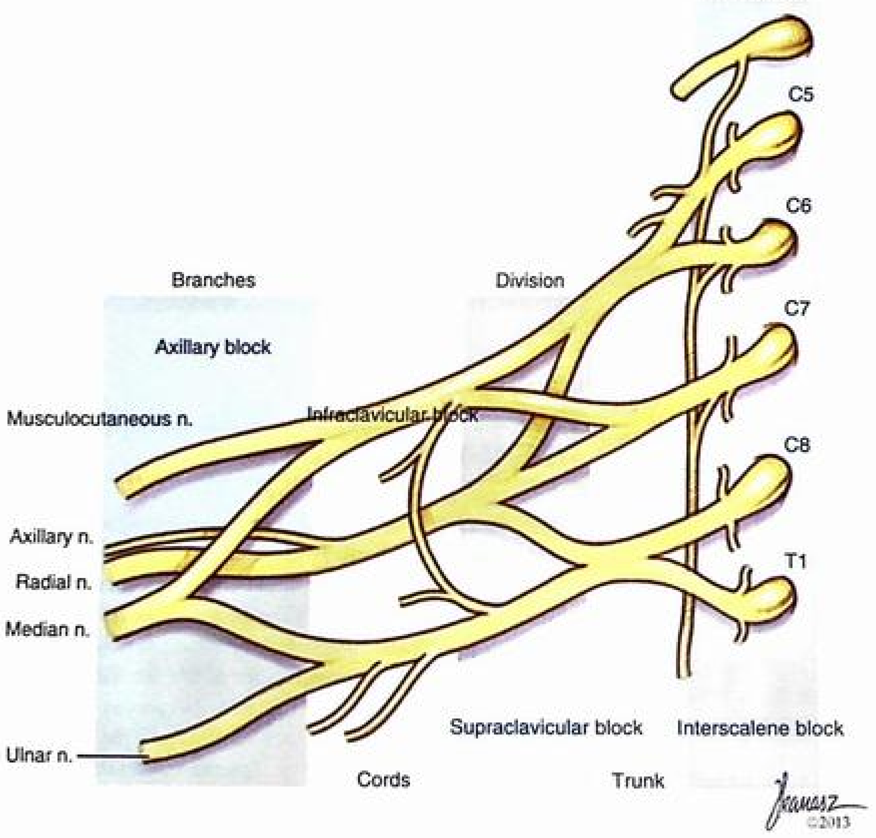


Fig. 8.1 Comparing the anatomy of different techniques of the brachial plexus block.

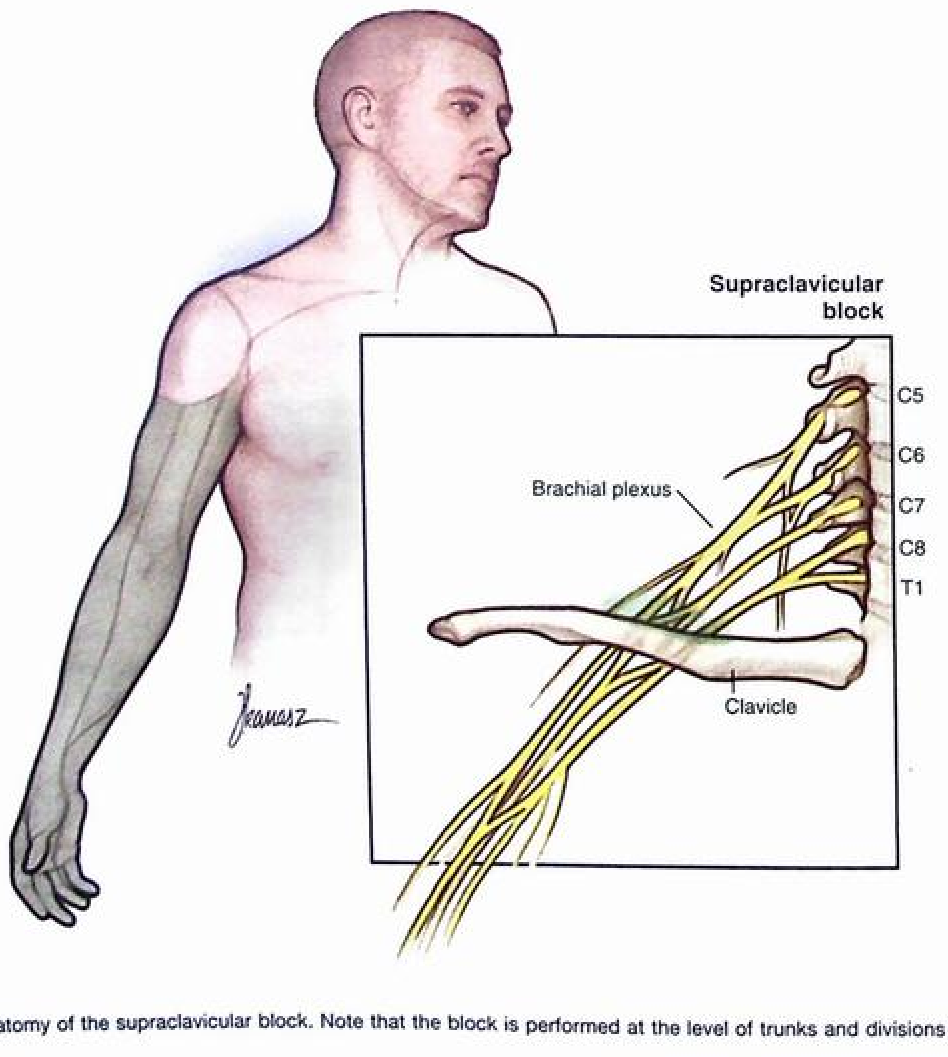


Fig. 8.2 The anatomy of the supraclavicular block. Note that the block is performed at the level of trunks and divisions of the brachial plexus.

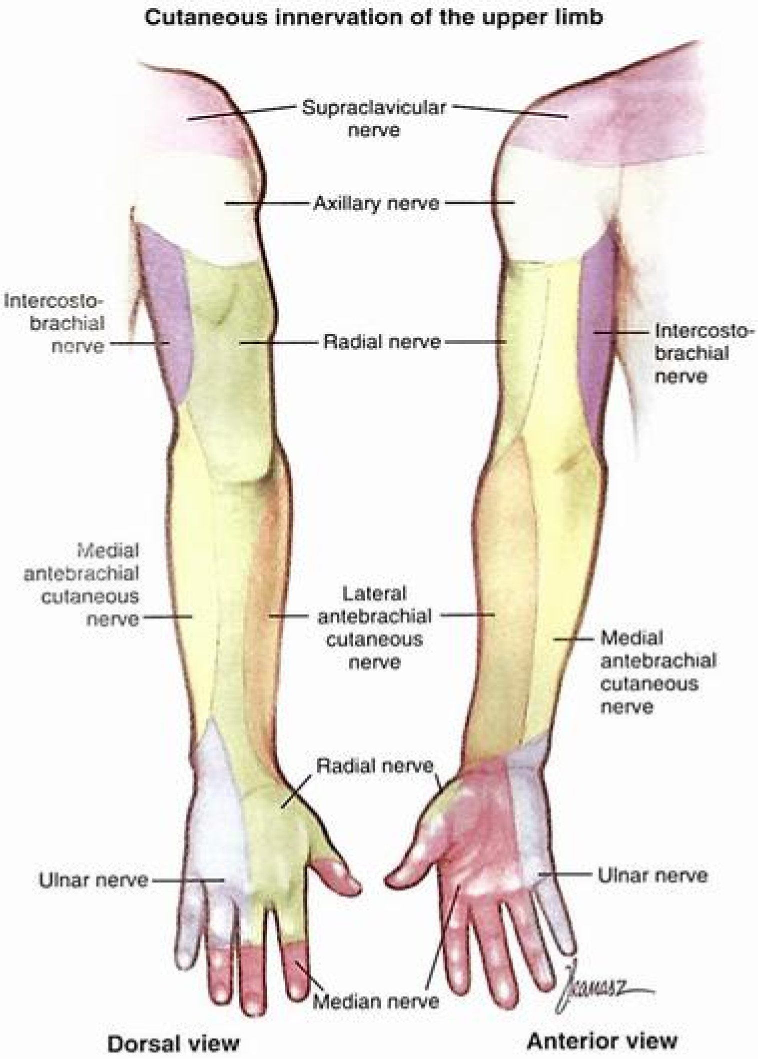
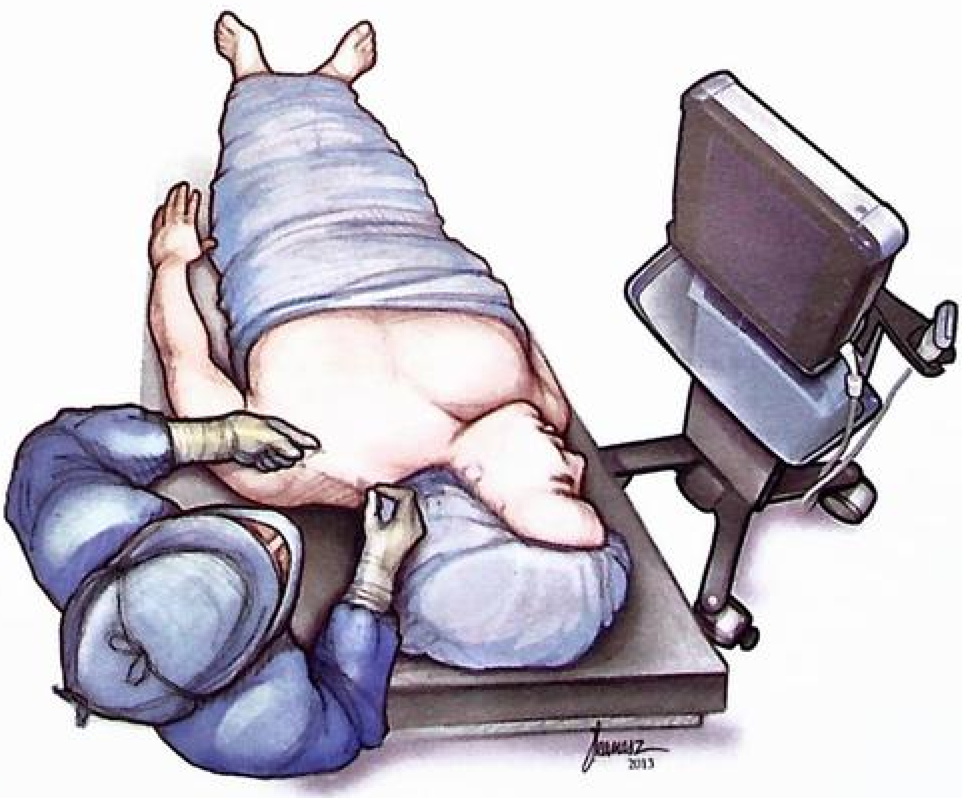


Fig. 8.3 The sensory and motor distribution of the supraclavicular block.



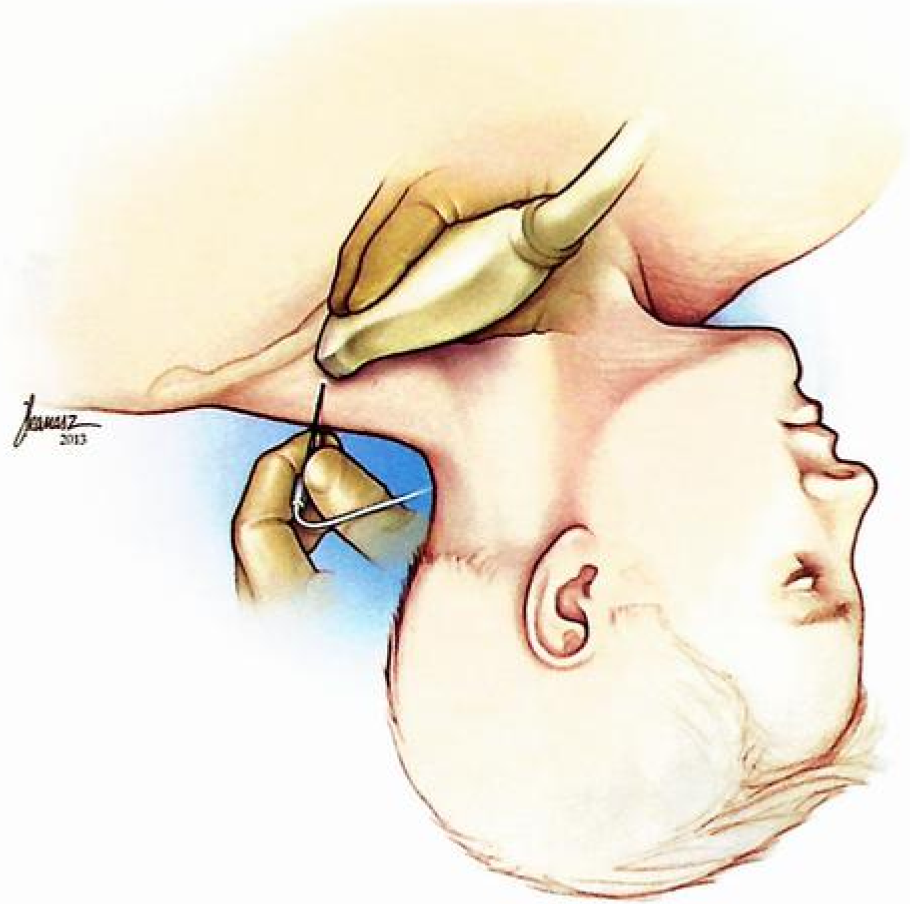


Fig. 8.5 The probe is in the coronal oblique plane. Note the in-plane position of the needle with the direction of the needle from posterior to anterior.

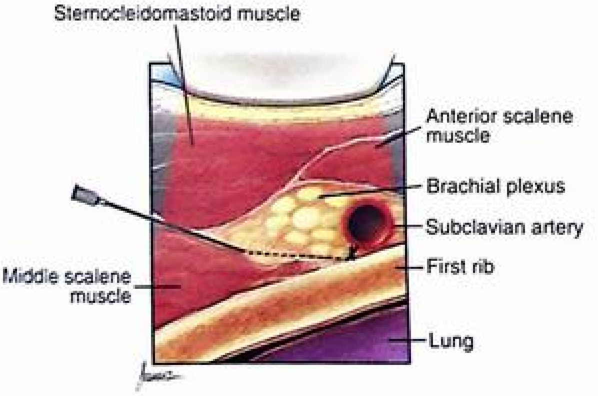


Fig. 8.6 The needle position beneath the brachial plexus parallel to the first rib.

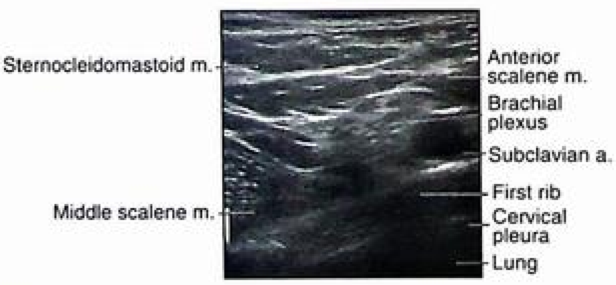


Fig. 8.7 Ultrasound image of Fig. 8.6. Visualization of the first rib and cervical pleura is crucial to avoid inducing pneumothorax while performing the block.

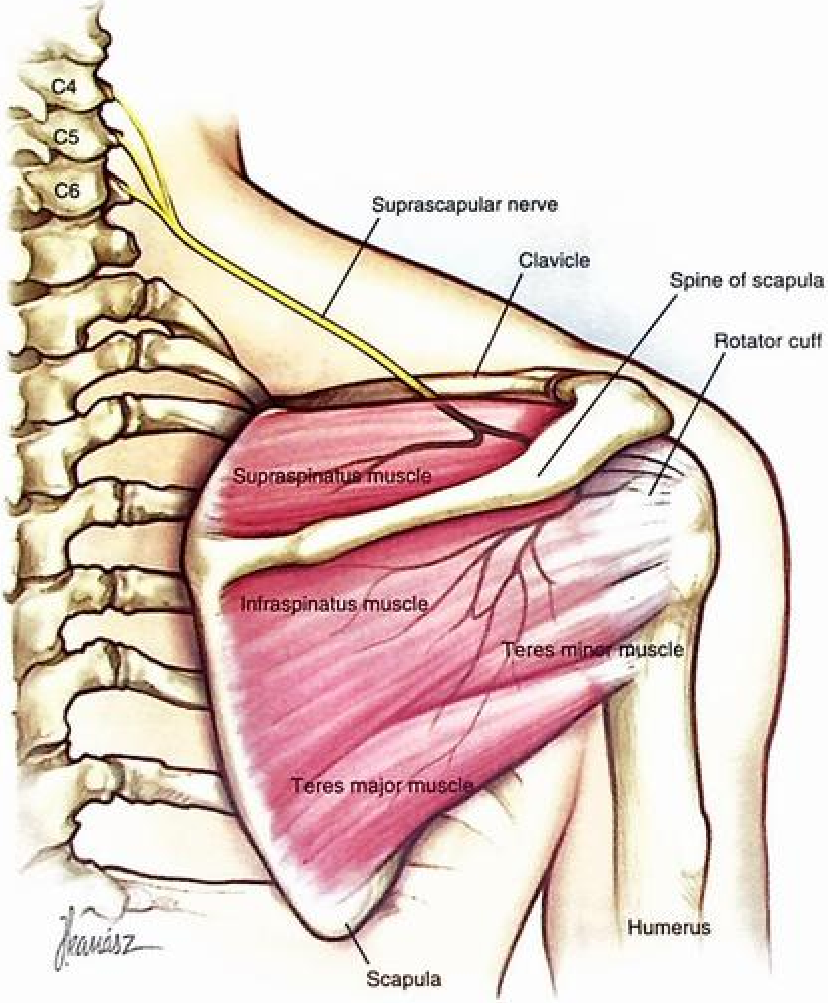


Fig. 9.1 Anatomy of the suprascapular nerve.

moves laterally under the belly of the omohyoid muscle. The SSN will be seen as a hyperechoic structure lateral to the BP. The echoic needle is advanced using the in-plane technique from lateral to medial. The end point for injection is an ultrasound image demonstrating the needle tip in proximity to the SSN deep to the inferior belly of the omohyoid muscle, and the tip is positioned next to the fascial plane of the SSN.

Care should be taken when advancing the needle to avoid puncturing the omohyoid muscle. Tracing the SSN from its origin (nerve root C5) can facilitate its identification (Fig. 9.2).

There are some data showing that the anterior blockade of the SSN block is noninferior to the interscalene peripheral nerve block, which is the gold standard block for shoulder surgeries.

SUPRASCAPULAR BLOCK POSTERIOR APPROACH

This approach was first described in 1941 as a treatment for chronic shoulder pain.

Ideally, the patient should be placed in a sitting position, and the operator should be behind the patient, with the ultrasound machine in front of the patient and facing the operator. This allows an uninterrupted field of view of the ultrasound screen. The ultrasound transducer should be placed parallel to the scapular spine. A transverse plane of imaging is optimum for the ultrasound-guided SSN block. By moving the transducer cephalad, the suprascapular fossa can be identified. While imaging the supraspinatus muscle and the bony fossa underneath, the ultrasound transducer should be moved slowly laterally to locate the suprascapular notch. The SSN should be seen as a round, hypoechoic structure beneath the transverse scapular ligament in the scapular notch. Also, with the application of color Doppler, the SSN can be visualized medial to the pulsation of the suprascapular artery as an oval or a round, slightly hyperechoic structure. We prefer to use the in-plane approach for this technique. The echoic needle should be advanced using the in-plane approach medial to lateral to visualize the whole length of the needle (Fig. 9.3). The end point for injection is an ultrasound image demonstrating the needle tip in proximity to the SSN in the suprascapular notch below the transverse

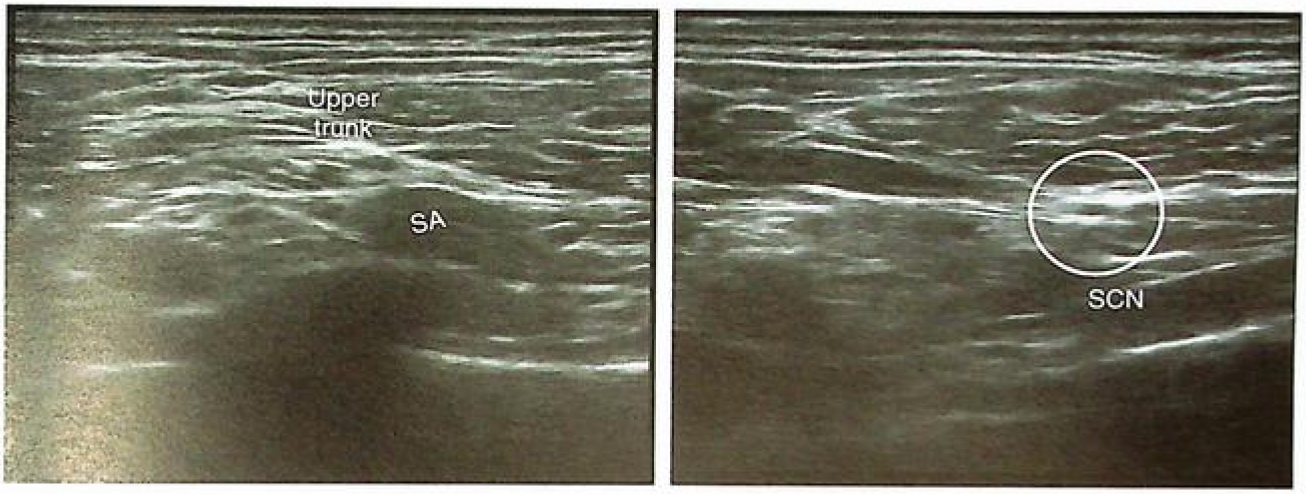


Fig 9.2 Suprascapular block, anterior approach.

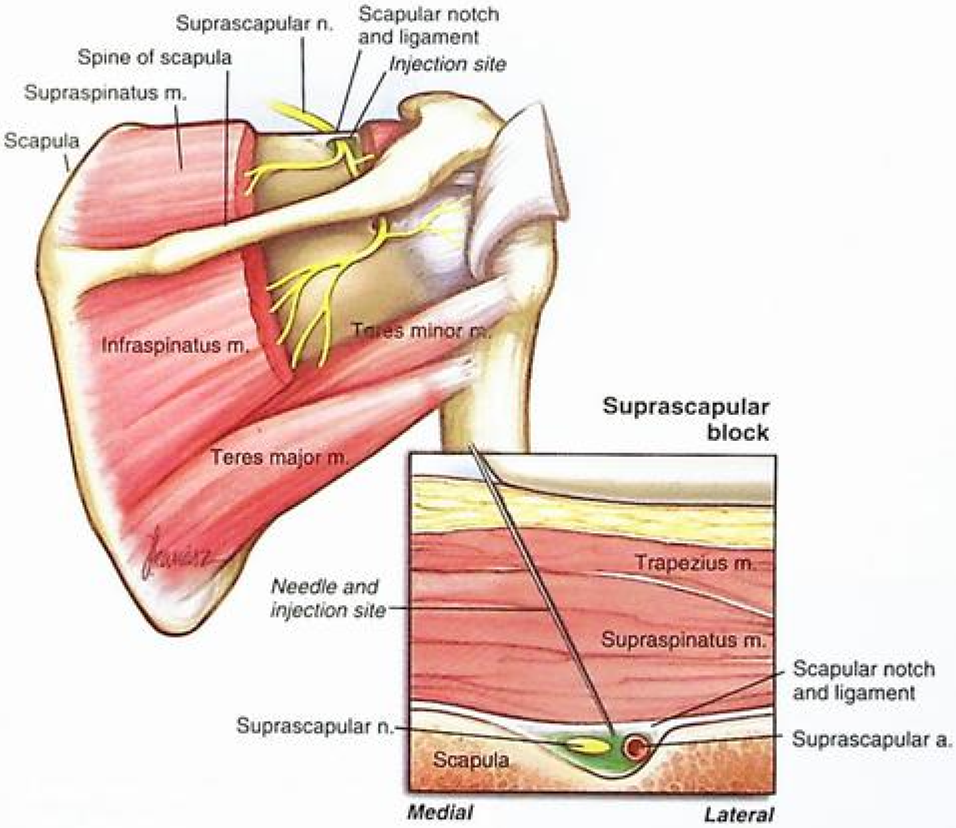


Fig. 9.3 In-plane technique for suprascapular block. The needle direction is from medial to lateral.

scapular ligament, and the spread of the LA confirmed as a separation between the supraspinatus muscle and the spine of the scapula (Figs. 9.4 and 9.5, Video 9.1).

Both techniques can spare the phrenic nerve blockage. The anterior approach is quite sufficient for postoperative pain control for shoulder surgery, as the SSN arises close to the origin of the axillary nerve. However, in the posterior approach, an axillary nerve block is required, in addition to the SSN block, to ensure proper analgesia after shoulder surgery.

PEARLS

- Adjust the focal point to the suprascapular notch to get a better image when performing the posterior approach.
- If possible, ask the patient to adduct the arm and move it forward, thus bringing the nerve more superficially.
- Using color Doppler can be very helpful, as the SSN usually lies medial to the suprascapular artery.

Fig. 9.4 Position of the patient and the ultrasound machine.

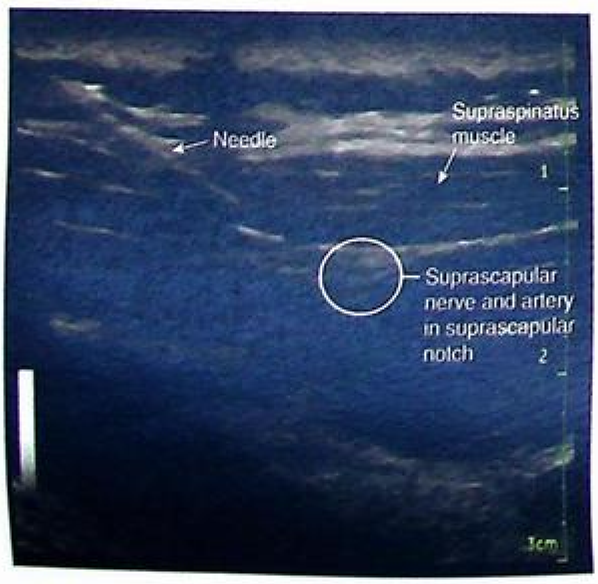


Fig. 9.5 Ultrasound image of a 22-gauge needle directed toward the suprascapular nerve.

- The block is painful, as the needle will pass through muscles, so prepare your patient with LA, midazolam, and fentanyl.
- Always use echogenic needles, as visualization of the needle is difficult due to the steep angle used in performing this block. You also can reduce the needle angle by using an insertion point as far as possible from the ultrasound probe while still maintaining an in-line approach and visualization of the entire needle during the block.
- The SSN can be blocked using a small volume of LA (average 4–5 mL).

The advantages of the SSN block over the interscalene block are a marked decrease in the incidence of Horner syndrome and phrenic nerve blockade.

Suggested Reading

Auyong DB, Hanson NA, Joseph RS, Schmidt BE, Slee AE, Yuan SC. Comparison of anterior suprascapular, supraclavicular, and interscalene nerve block approaches for major outpatient arthroscopic shoulder surgery: a randomized, double-blind, noninferiority trial. *Anesthesiology.* 2018;129(1):47–57.

Martinez-Barenys C, Busquets J, de Castro PE, et al. Randomized double-blind comparison of phrenic nerve infiltration and suprascapular nerve block for ipsilateral shoulder pain after thoracic surgery. *Eur J Cardiothorac Surg.* 2011;40(1):106–112.

Siegenthaler A, Moriggl B, Mlekusch S, et al. Ultrasound-guided suprascapular nerve block, description of a novel supraclavicular approach. *Reg Anesth Pain Med.* 2012;37(3):325–328. https://doi.org/10.1097/AAP.0b013e3182409168.

Infraclavicular Block 10

Kenneth C. Cummings III

Key Points

- A linear or small curved transducer is preferred for this block to minimize the transducer footprint.
- The axillary artery is usually 4 to 5 cm below the skin in a typical patient.
- Because of the steep angle of needle insertion relative to the ultrasound beam, direct visualization of the needle may be difficult.
- Approximately 15 to 30 mL of local anesthetic typically is sufficient to provide a complete block of the plexus. A single injection at the 6 o'clock position commonly suffices, but multiple injections may be required to ensure spread around the three cords.
- Unlike an axillary block, the medial brachial and antebrachial cutaneous nerves are blocked with this technique. The intercostobrachial nerve (arising from T2) may be separately blocked under the arm, if desired.
- For catheter insertion, a Tuohy needle is usually used. The catheter is usually inserted posterior to the axillary artery and advanced 2 to 3 cm past the needle tip. The correct position of the catheter can be confirmed under ultrasound by injecting either local anesthetic or 1 mL of air via the catheter and observing its distribution relative to the plexus.
- Catheters are typically coiled on the skin over the insertion site and covered with a transparent sterile dressing.

PERSPECTIVE

The infraclavicular brachial plexus block is useful for both single-injection and continuous infusion techniques. Originally described in the early 1900s, the technique was not widely used until popularized in the latter part of the 20th century. This technique results in a sensory and motor block similar to a traditional axillary approach, but it has certain advantages. Thus it is most useful for procedures on the elbow, forearm, or hand. Like the axillary approach, this technique is carried out distant from both the neuraxial structures and the lung, minimizing complications associated with proximity to those structures.

Patient Selection. There are fewer contraindications to infraclavicular block than with more proximal blocks such as the supraclavicular or interscalene approaches. Because of the very low risk of phrenic nerve block, this approach is appropriate for patients with pulmonary disease or contralateral diaphragmatic paralysis. Patients on anticoagulant therapy or who have coagulopathies should be considered on a case-by-case basis because of the relative inability to compress the relevant vascular structures. To undergo an infraclavicular block, the patient need not abduct the arm at the shoulder, as is required for the axillary approach, and thus the technique is preferable to an axillary block in patients who cannot abduct their arms due to pain or other limitations. However, abduction of the arm at the shoulder elevates the clavicle and pulls the plexus anteriorly, usually improving the ease of the procedure.

Choice of Anesthetic Drugs. Because postoperative analgesia requires less motor block than is needed for surgical anesthesia, the concentration of local anesthetic can be decreased during postoperative analgesia regimens. Appropriate drugs for infusion are bupivacaine 0.1% to 0.15% or ropivacaine 0.2%, both administered at initial rates of 8 to 12 mL/h. If a single-injection technique is used, appropriate drugs are lidocaine (1%–1.5%), mepivacaine (1%–1.5%), bupivacaine (0.5%), or ropivacaine (0.5%–0.75%). Lidocaine and mepivacaine produce 2 to 3 hours of surgical anesthesia without epinephrine and 3 to 5 hours with the addition of epinephrine. These drugs are useful for less involved procedures or outpatient surgical procedures. For more extensive surgical procedures (or where a longer block is desired), longer-acting agents such as bupivacaine or ropivacaine are appropriate. Plain bupivacaine and ropivacaine produce surgical anesthesia lasting 4 to 6 hours; the addition of epinephrine may prolong this period to 8 to 12 hours. With the addition of adjuvants such as dexamethasone, blocks lasting as long as 18 to 24 hours are possible with higher concentrations of ropivacaine or bupivacaine.

TRADITIONAL BLOCK TECHNIQUE

PLACEMENT

Anatomy. At the level of the proximal axilla, where the infraclavicular block is performed, the axilla is a pyramid-shaped space with an apex, a base, and four sides (Fig. 10.1A). The base is the concave armpit, and the anterior wall is composed of the pectoralis major and minor muscles and their accompanying fasciae. The posterior wall of the axilla is formed by the scapula and the scapular musculature, the subscapularis, and the teres major. The latissimus dorsi muscle abuts the teres major muscle to form the

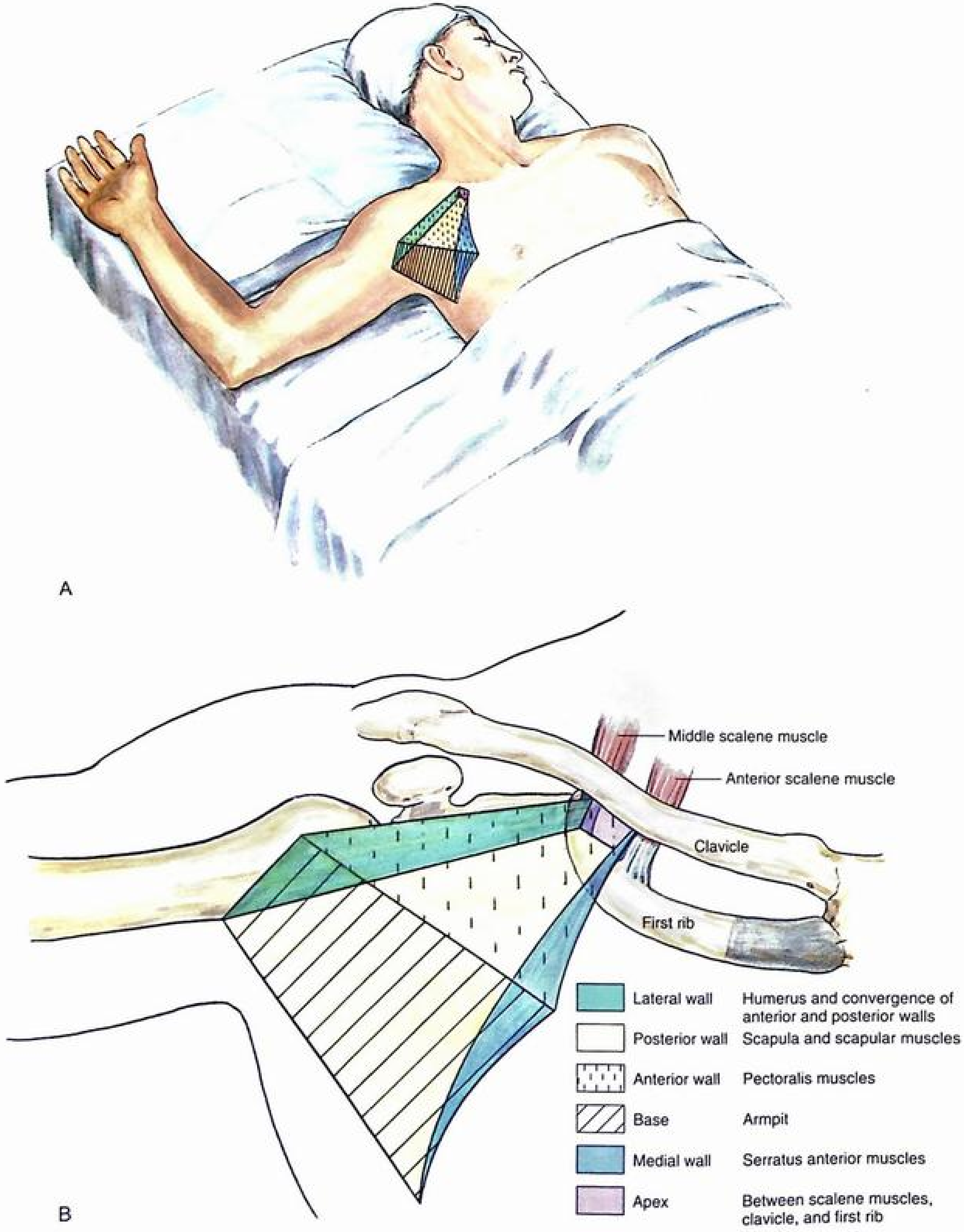


Fig. 10.1 (A) The surface anatomy of the infraclavicular block. (B) The concept of the pyramid-shaped axilla is important for infraclavicular block.

inferior aspect of the posterior wall of the axilla (Fig. 10.1B). The medial wall of the axilla is composed of the serratus anterior muscle and its fascia, and the lateral wall is formed by the converging muscle and tendons of the anterior and posterior walls as they insert into the humerus (see Fig. 10.1B). The apex of the axilla is triangular and is formed by the convergence of the clavicle, the scapula, and the first rib. The neurovascular structures of the limb pass into the pyramid-shaped axilla through its apex (Fig. 10.2A).

The contents of the axilla are blood vessels and nerves—the axillary artery and vein and the brachial plexus,

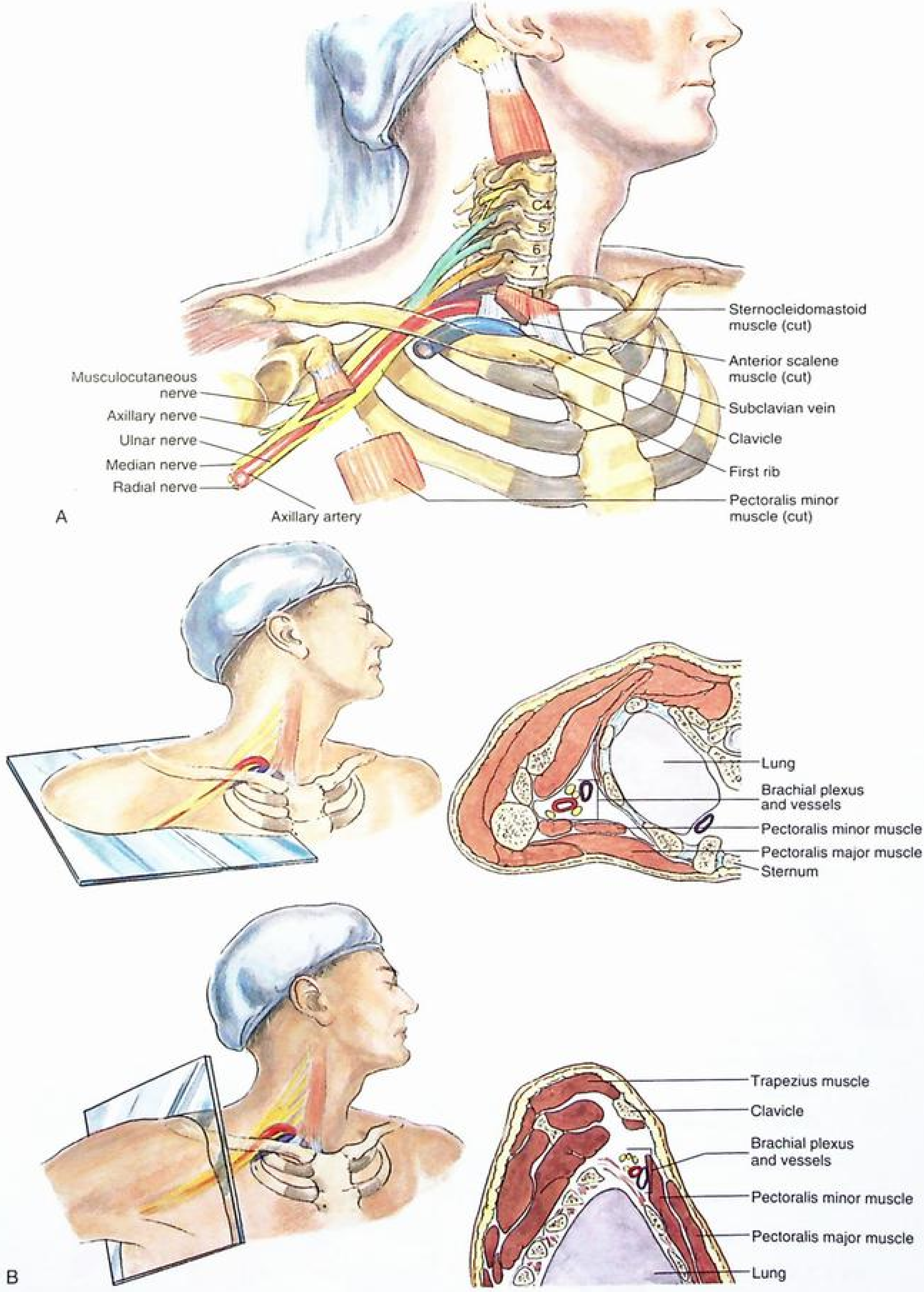
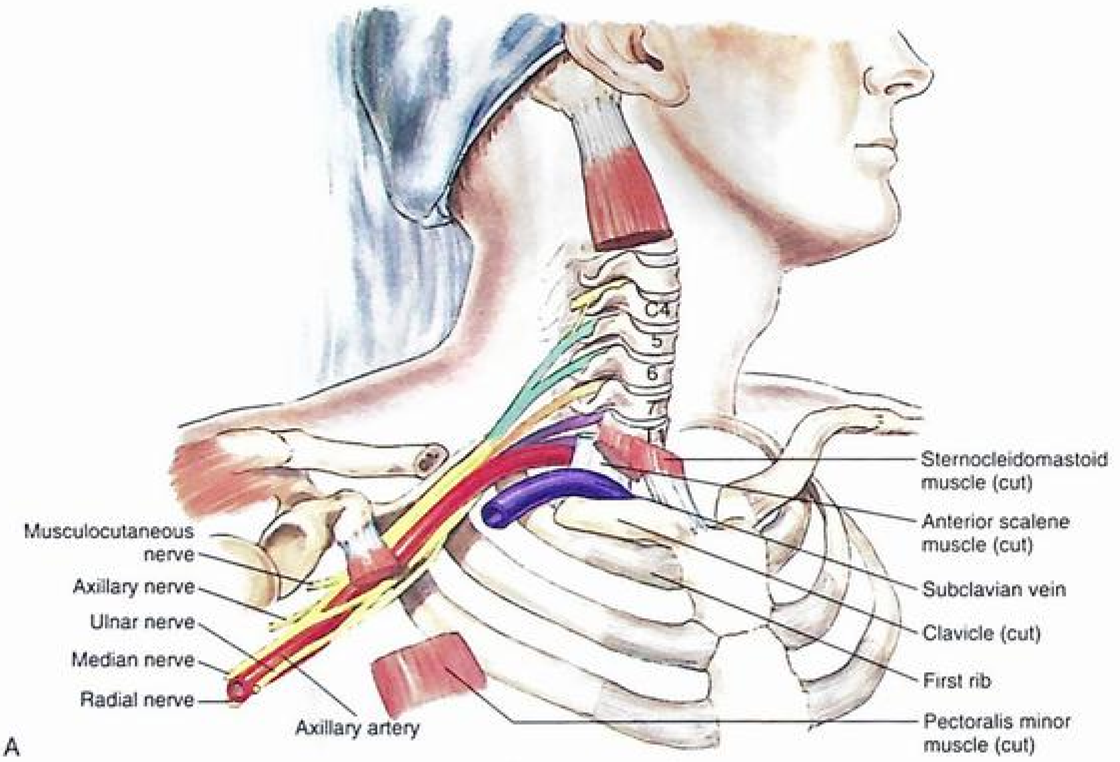


Fig. 10.2 Anatomy important for infraclavicular block. **(A)** Muscles, bones, and neurovascular structures. **(B)** Cross-sectional *(top)* and parasagittal *(bottom)* anatomy.

respectively—as well as lymph nodes and loose areolar tissue. The neurovascular elements are enclosed within the anatomically variable, multipartitioned axillary sheath, a fascial extension of the prevertebral layer of cervical fascia covering the scalene muscles. The axillary sheath adheres to the clavipectoral fascia behind the pectoralis minor muscle and continues along the neurovascular structures until it enters the medial intramuscular septum of the arm (Fig. 10.2B).

The brachial plexus divisions become cords as they enter the axilla. The posterior divisions of all three trunks unite to form the posterior cord, the anterior divisions of the superior and middle trunks join to form the lateral cord, and the anterior division of the inferior trunk forms the medial cord. These cords are named according to their relationship to the second part of the axillary artery (Fig. 10.3). From these cords, the nerves to the subscapularis, pectoralis major and minor, and latissimus dorsi muscles leave the brachial plexus. The medial brachial cutaneous, medial antebrachial cutaneous, and axillary nerves also leave the brachial plexus at the level of the cords.



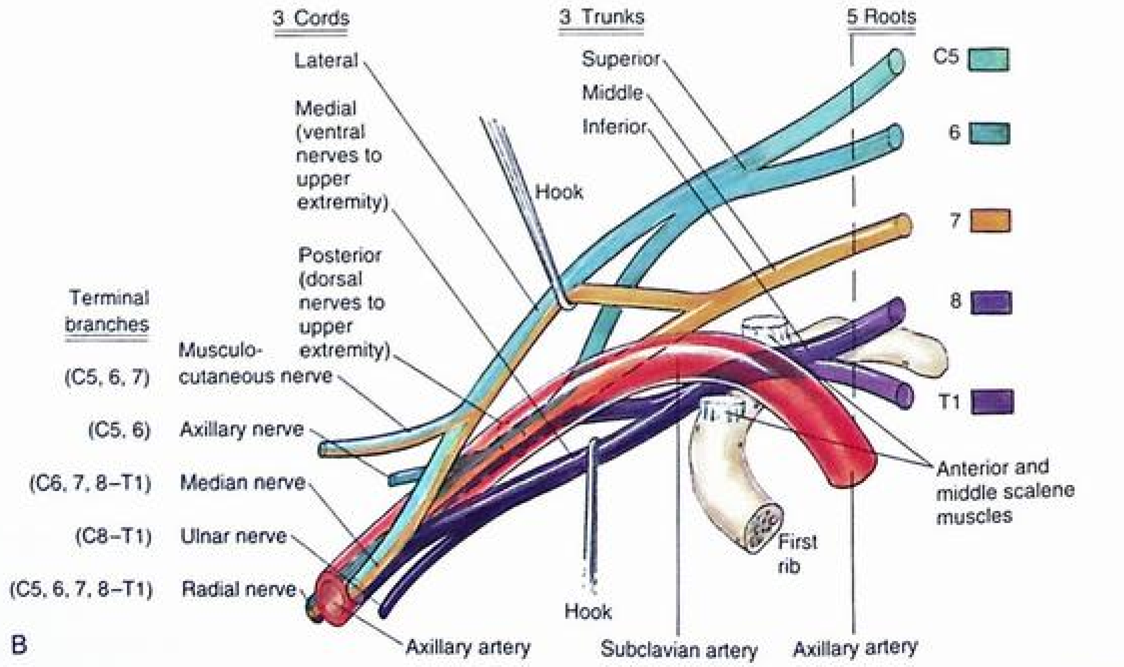


Fig. 10.3 Brachial plexus anatomy important for infraclavicular block. (A) Regional anatomy. (B) Detailed infraclavicular anatomy.

At the lateral border of the pectoralis minor muscle (which inserts onto the coracoid process), the three cords reorganize to give rise to the peripheral nerves of the upper extremity. In a simplified scheme, the branches of the lateral and medial cords are all "ventral" nerves to the upper extremity. The posterior cord, in contrast, provides all "dorsal" innervation to the upper extremity. Thus the radial nerve supplies all the dorsal muscles in the upper extremity below the shoulder. The musculocutaneous nerve supplies muscular innervation in the arm and provides cutaneous innervation to the forearm. In contrast, the median and ulnar nerves are nerves of passage in the arm, but in the forearm and hand, they provide the ventral musculature with motor innervation. These nerves can be further categorized: the median nerve innervates more heavily in the forearm, whereas the ulnar nerve innervates more heavily in the hand.

Position. The patient is placed supine, with the arm to be blocked abducted at the shoulder at a 90-degree angle, if possible. If pain prevents this, the arm can be left at the patient's side and adjustments can be made with skin markings. The anesthesiologist can stand on the ipsilateral or the contralateral side of the patient, depending on their preference and the patient's body habitus. We prefer to stand on the ipsilateral side of the patient.

Traditional Approach. The coracoid process is identified by palpation and a skin mark placed at its most prominent portion. The skin entry mark is then made at a point 2 cm medial and 2 cm caudal to the previously marked coracoid process (Fig. 10.4A). Deeper infiltration is then performed with a 25-gauge, 5-cm needle while the needle is directed from the insertion site in a vertical parasagittal plane. Then a 7- to 9.5-cm, 20- to 22-gauge needle is inserted in a direction similar to that taken by the infiltration needle. If a paresthesia technique is used, a distal upper extremity paresthesia is sought; if a nerve stimulator technique is used, a distal upper extremity motor response is sought. If needle redirection is needed to achieve either a paresthesia or a motor response, the needle should be redirected only in a cephalocaudad arc (Fig. 10.4B). To avoid inadvertent entry into the thorax, it is critical not to direct the needle path medially. The depth of the brachial plexus depends on body habitus and needle angulation; it ranges from 2.5 to 3 cm in slender patients and from 8 to 10 cm in larger individuals.

Once adequate needle position has been achieved, either the single-injection dose of local anesthetic is administered incrementally, or 20 mL of preservative-free normal saline solution (5% dextrose if a stimulating catheter is used) is injected before threading the continuous brachial plexus catheter. For a single-injection technique, the block can be administered in a manner similar to that used in either a supraclavicular or an axillary block.

POTENTIAL PROBLEMS

An infraclavicular block should not cause neuraxial or pulmonary complications. Although vascular compromise (puncture of the axillary artery or vein) is theoretically possible, in our experience this occurs infrequently. If a continuous catheter technique is

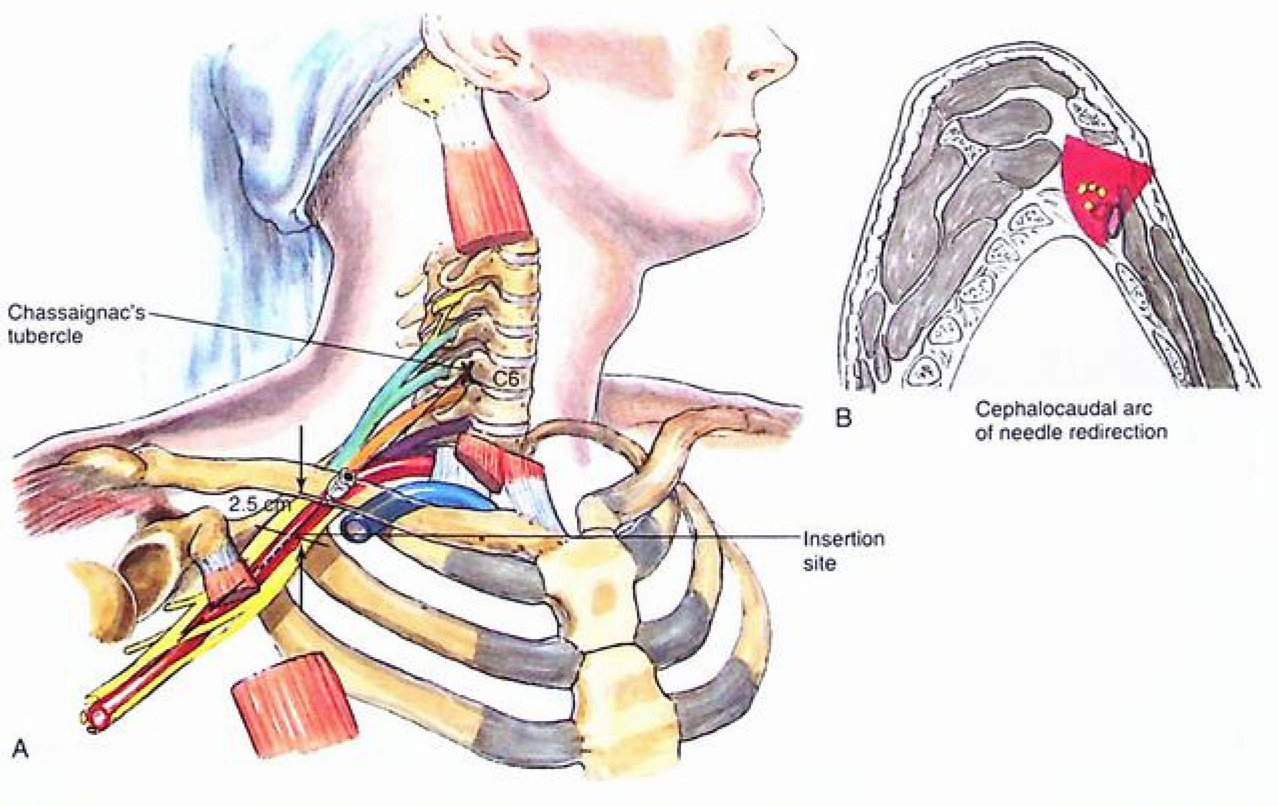


Fig. 10.4 The technique of the infraclavicular block. (A) Surface markings for the block. (B) Parasagittal view showing the arc of needle redirection.

chosen, there is the possibility that despite adequate initial needle position, the catheter may be threaded too far away from the plexus to result in an effective block. However, the use of stimulating catheters has decreased this concern.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

The brachial plexus in the infraclavicular region consists of three cords, each named for its classical position relative to the second portion of the axillary artery: medial, lateral, and posterior. There is, however, significant anatomic variation. The cords and axillary vessels lie deep to the pectoralis major and minor muscles, just below the fascia of the pectoralis minor. The ultrasound transducer should be placed in a parasagittal orientation caudal to the coracoid process, roughly perpendicular to the clavicle, so that the plane of the ultrasound beam cuts the brachial plexus cords and axillary vessels in the short-axis view. The axillary artery is seen in cross-section as a hypoechoic, noncompressible pulsatile structure, whereas the axillary vein usually lies inferior and/or superficial to the artery. With the left side of the screen oriented cephalad, the lateral, posterior, and medial cords are often found at 9 to 10 o'clock, 6 to 7 o'clock, and 4 to 5 o'clock relative to the artery, respectively. The cords are often difficult to identify distinctly, emphasizing the importance of placing the local anesthetic deep into the pectoral fascia (Fig. 10.5). Depending on how medially the

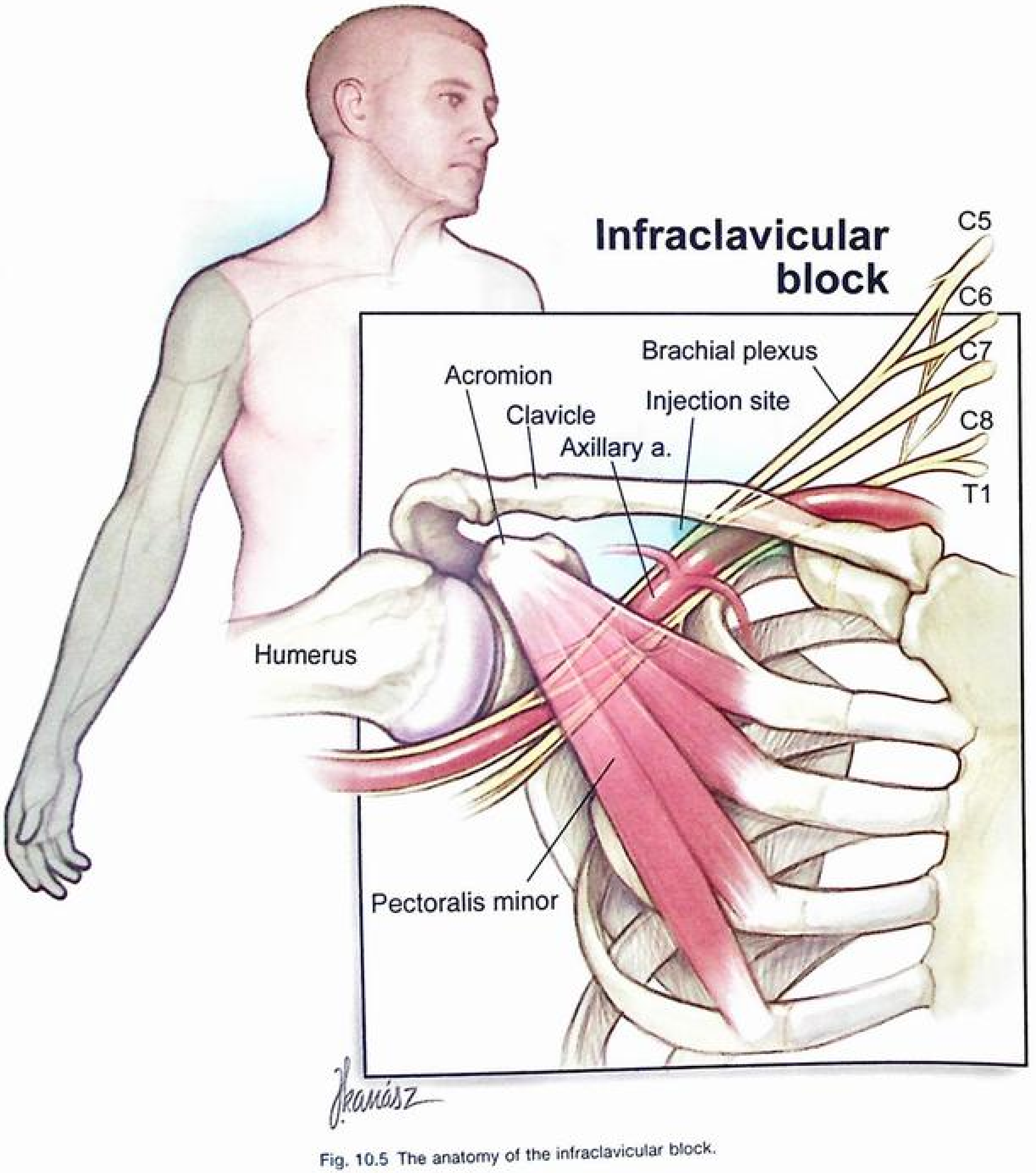


Fig. 10.5 The anatomy of the infraclavicular block.

transducer is placed, the ribs and/or pleura may be identified in the inferior part of the image.

INDICATIONS

- Infraclavicular blocks are very effective for arm, elbow, forearm, and hand surgeries.
- Both single-shot and continuous techniques are possible. Continuous infraclavicular nerve blocks may provide superior analgesia compared with other techniques.

TECHNIQUE

The patient may be placed either supine or semisitting. The patient's head should be turned away from the side to be blocked. In the classic technique for the infraclavicular block, the arm is adducted to the side; therefore it is called the lateral infraclavicular technique. However, to improve visualization of the cords, we prefer to use the medial infraclavicular approach in which the arm is abducted 110 degrees, externally rotated, and the elbow is flexed 90 degrees. This will bring the cords closer together, superior to the axillary artery, and they may lie closer to the skin. The puncture site is made at the apex of the deltopectoral groove in the parasagittal plane. An in-plane approach is recommended from the cephalad end of the probe along its long axis. In the case of catheter insertion, we first prefer to use a 22-gauge needle to inject the local anesthetics around the three cords separately; then we use the Tuohy needle to place the catheter beneath the posterior cord (Figs. 10.6–10.8, Video 10.1).

ALTERNATIVE APPROACHES

Costoclavicular Block

The costoclavicular space lies deep to the clavicle and superficial to the second rib. In this space, the cords of the brachial plexus are more closely positioned and are typically

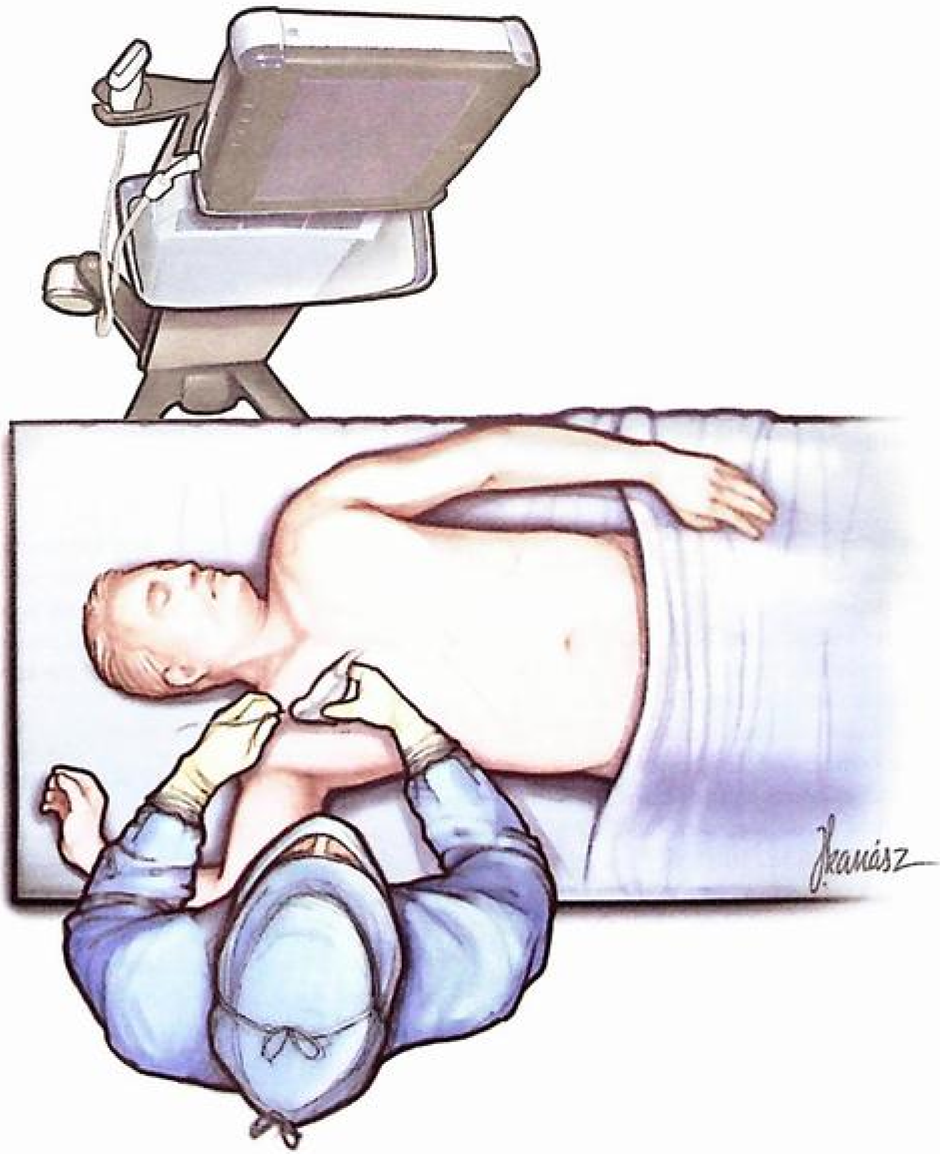


Fig. 10.6 The medial approach for the infraclavicular block. Note that the arm is abducted.

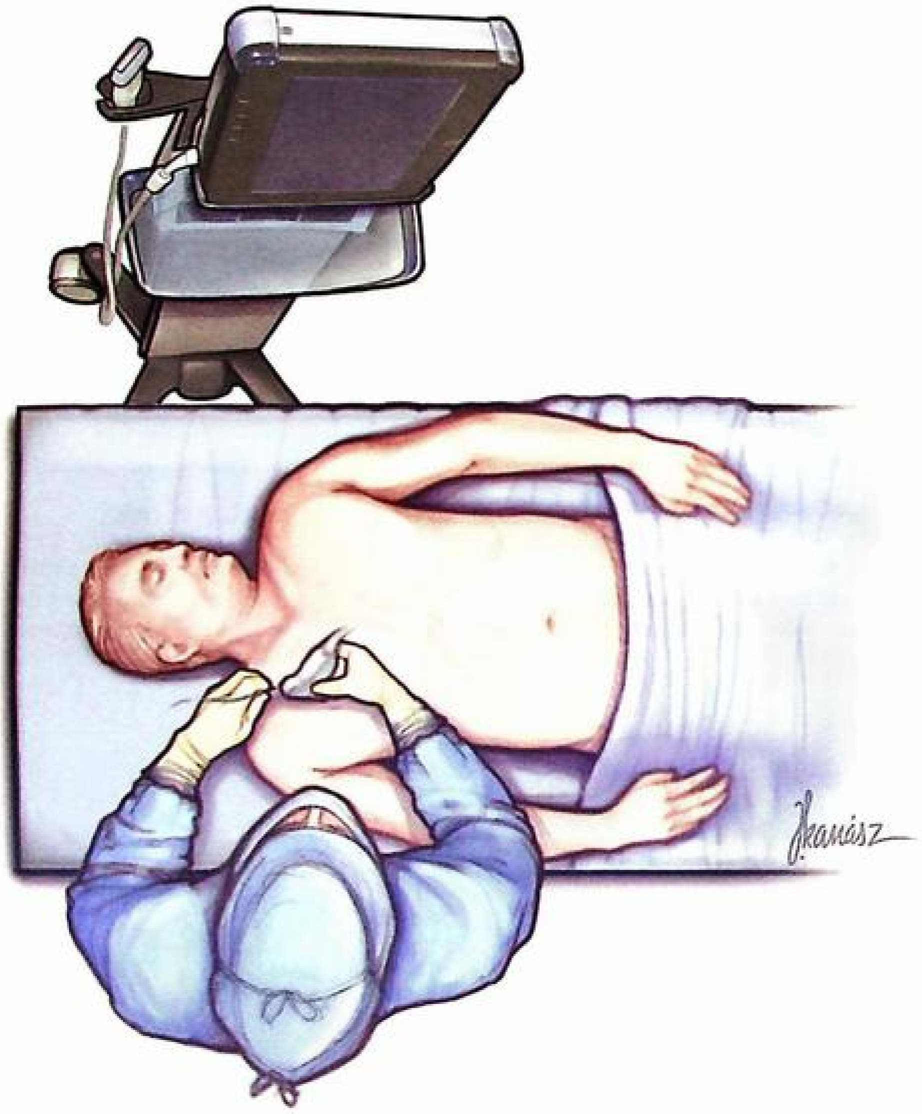


Fig. 10.7 The lateral approach for the infraclavicular block. Note that the arm is adducted. The in-plane technique is used for both, with the needle direction from proximal to distal.

lateral to the axillary artery. This allows the use of lower doses of local anesthetic (20 mL has been reported as an effective volume). The patient is placed supine, with the arm abducted at the shoulder and with the head turned slightly away. The transducer is placed immediately caudad to and parallel with the clavicle in the midclavicular line. The transducer is angled slightly caudally to direct the plane of the ultrasound beam cranially, underneath the clavicle. Using an in-plane technique, the needle path is lateral to medial, with the target location between the three cords, just lateral to the axillary artery (Figs. 10.9 and 10.10, Video 10.1). In principle, this should show the neurovascular structures in the short axis. However, the transducer may be rotated relative to the clavicle to optimize the short-axis view. As with any block closer to the thorax, this block carries the risk of pneumothorax.

Retroclavicular Block

An alternative approach has been proposed in which the needle entry point is superior to the clavicle, rather than between the clavicle and transducer. This allows easier visualization of the needle as it approaches the plexus due to a more perpendicular orientation relative to the ultrasound beam. We do not endorse this approach due to the inability to visualize the needle as it passes posterior to the clavicle and the close proximity of the suprascapular nerve to the needle path.

Subcoracoid Tunnel Approach

A recently described approach is somewhat similar to the costoclavicular approach but is performed further laterally. In this approach, the ultrasound transducer is placed in an oblique longitudinal axis along an imaginary line drawn from C6 to the axillary artery pulsation in the axilla. The nerves are visualized in long axis in the subcoracoid tunnel parallel to the axillary artery, and slight angulation can put the artery out of the field of view. The needle is then advanced from a caudal to a cranial direction. In one case series of 20 patients, 16 patients had successful surgical blocks. This technique may prove useful but needs further study.

Fig. 10.10 Ultrasound image of the brachial plexus and needle path using the costoclavicular approach. (Image courtesy Ehab Farag MD, FRCA.)

PEARLS

- If visualization of all three cords is not possible, typically it is sufficient to ensure that local anesthetic spreads in a "U" shape surrounding the axillary artery. The contrast provided by the local anesthetic commonly improves visualization of the cords during the block.
- A reverberation artifact from the axillary artery may lead to the incorrect impression of a nerve structure deep to the artery.
- Because of the acute needle-to-transducer angle, it may be necessary to rely on indirect signs of needle location such as hydrodissection with normal saline or tissue movement while jiggling the needle. Textured ("echogenic") needles may be easier to visualize with this approach.
- Excessive transducer pressure may occlude veins and increase the chance of inadvertent intravenous injection or hematoma formation.
- Placing the transducer as laterally as possible (but still medial to the coracoid process) increases the distance to the pleura and provides a larger margin of safety.
- Because of the greater distance between the plexus structures at this level, a larger volume of local anesthetic is commonly needed compared with more proximal brachial plexus blocks. Larger patient-controlled or programmed boluses (8–12 mL once per hour in our practice) via an indwelling catheter are also often needed to provide adequate analgesia.
- The infraclavicular location is particularly appealing for continuous blocks because the insertion site is away from the patient's head and neck, and passing through the pectoral muscles stabilizes the catheter.
- In contrast to the interscalene or supraclavicular approaches to the brachial plexus, the infraclavicular approach does not produce phrenic nerve paralysis. This characteristic makes infraclavicular blocks an appealing option in patients with compromised pulmonary function.

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Axillary Brachial Plexus Block

11

Wael Ali Sakr Esa and Chelsea Skinner

Key Points

- A high-frequency 38-mm broadband linear array transducer is preferred for the axillary brachial plexus block.
- Use between 20 and 25 mL total of 0.5% ropivacaine or bupivacaine to inject around the four nerves of the axillary brachial plexus block.
- We usually block the nerves around the axillary artery first—the median, ulnar, and radial nerves—then the needle is withdrawn to the biceps muscle and redirected toward the musculocutaneous nerve (a hypoechoic, flattened oval within the body of the coracobrachialis muscle).
- To visualize the intercostobrachial nerve after performing the axillary brachial plexus block, slide the ultrasound probe posteriorly until the intercostobrachial nerve appears posterior and superficial to the axillary vessels.
- Use between 3 and 5 mL of 0.5% ropivacaine or bupivacaine to inject around the intercostobrachial nerve.

PERSPECTIVE

The axillary brachial plexus block is effective for surgical procedures distal to the elbow. The axillary brachial plexus block is named for the approach in the axilla and, in fact, does not target the axillary nerve. Rather, the block targets the median, ulnar, radial, and musculocutaneous nerves and results in anesthesia of the upper extremity from the midarm down to and including the hand. To review, the lateral cord of the brachial plexus divides into the musculocutaneous nerve and the lateral portion of the median nerve. The medial cord divides into the ulnar nerve and medial portion of the median nerve. The posterior cord divides into the radial nerve and the axillary nerve. In the axilla, the median, ulnar, and radial nerves travel with the axillary artery in a neurovascular bundle medial to the humerus. The musculocutaneous nerve travels separately and usually lies in the plane between the biceps and coracobrachialis muscles or in the body of the coracobrachialis.

The median nerve provides cutaneous innervation to the medial forearm, palm, first three digits of the hand, and the lateral half of the fourth digit, as well as motor innervation to the thenar eminence, lumbricals of the second and third digits, and most of the flexor muscles of the anterior forearm. The ulnar nerve provides cutaneous innervation to the fifth digit, medial half of the fourth digit, and the medial palmar aspect of the hand, as well as motor innervation to the flexor carpi ulnaris, half of the flexor digitorum profundus, and most of the intrinsic muscles of the hand. The radial nerve provides cutaneous innervation to the anterolateral arm, posterior forearm, and posterolateral hand, as well as motor innervation to the triceps brachii and extensor muscles of the posterior forearm. The musculocutaneous nerve provides innervation to the radial aspect of the forearm as well as motor innervation to the biceps brachii, brachialis, and coracobrachialis muscles of the anterior arm.

The axillary brachial plexus block is appropriate for hand and forearm surgery; thus it is often the most appropriate technique for outpatients in a busy hand surgery practice. Some anesthesiologists find the axillary brachial plexus block suitable for procedures on the elbow or lower humerus, but strong consideration should be given to a supraclavicular block for those requiring more proximal procedures. Because this block is carried out distant from both the neuraxial structures and the lung, complications associated with those areas are avoided. Further, the axillary artery is readily compressible at the level of the axillary brachial plexus block (unlike the infraclavicular block), so bleeding complications are rare, even in patients receiving anticoagulation.

Anatomy. At the level of the distal axilla where the axillary brachial plexus block is undertaken (Fig. 11.1), the axillary artery can be visualized as the center of a four-quadrant neurovascular bundle. It is important to note that anatomical variations exist, but the most common anatomy relative to the axillary artery is as follows: the median nerve is found in the superficial lateral quadrant, the ulnar nerve is in the superficial medial quadrant, the radial nerve is in the deep medial quadrant, and the musculocutaneous nerve is in the deep lateral quadrant in the substance of the coracobrachialis muscle or in the fascial layer between the biceps brachii and coracobrachialis muscles (see Fig. 11.2). Multiple injections during the axillary brachial plexus block result in more acceptable clinical anesthesia versus injection at a single site. The block does not need to be performed in the axilla; in fact, needle insertion in the middle to lower portion of the axillary hair patch or even more distal is effective. It is clear from the

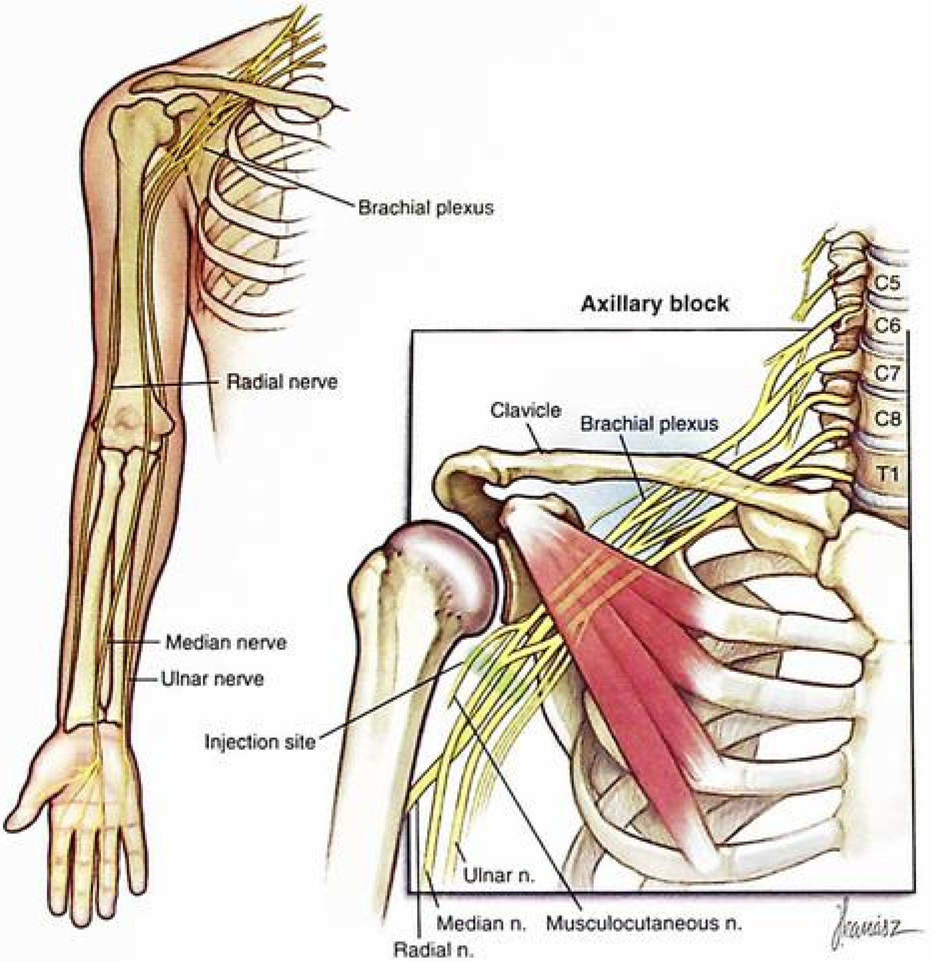

Fig. 11.1 Anatomy of the axillary approach of brachial plexus block.

radiographic and anatomic study of the brachial plexus and the axilla that separate and distinct sheaths are associated with the plexus at this point. Keeping this concept in mind will help decrease the number of unacceptable blocks performed. This more distal approach to the axillary brachial plexus block is similar to the midhumeral brachial plexus block.

Patient Selection. To undergo an axillary brachial plexus block, a patient must be able to abduct the arm at the shoulder. As the experience of the operator increases, the need for abduction decreases, but this block cannot be carried out with the arm at the side. Because the block is most appropriate for forearm and hand surgery, it is rare that a patient with a surgical condition at those sites cannot abduct the arm as needed.

Pharmacologic Choice. Because hand and wrist procedures often require less motor blockade than procedures on the shoulder, the concentration of local anesthetic (LA) needed for the axillary brachial plexus block usually can be slightly less than that needed for the supraclavicular or interscalene block. Appropriate drugs are lidocaine (1%–2%), mepivacaine (1%–2%), bupivacaine (0.5%), and ropivacaine (0.5%). Lidocaine and mepivacaine produce 2 to 3 hours of surgical anesthesia without epinephrine and 3 to 5 hours with the addition of epinephrine. These drugs can be useful for less involved procedures or outpatient surgical procedures. For more extensive surgical procedures requiring hospital admission, a longer-acting agent such as bupivacaine can be used. Plain bupivacaine and ropivacaine produce surgical anesthesia that lasts from 4 to 6 hours; the addition of epinephrine may prolong this period to 8 to 12 hours. The LA timeline must be considered when prescribing a drug for an outpatient axillary brachial plexus block, because blocks lasting as long as 18 to 24 hours can result from higher concentrations of bupivacaine with added epinephrine.

Dexmedetomidine at concentrations of approximately 1 μg/kg may be added to the LA to shorten the time to onset by up to 4 minutes, prolong the duration of analgesia by up to 6 hours, and improve the overall quality of the block. The operator must be mindful of potential adverse effects, such as hypotension and bradycardia, with the use of dexmedetomidine, although these effects seem less common with perineural injection versus systemic administration. Magnesium sulfate may also be added to the LA to shorten the time to onset by up to 1 minute, prolong the duration of analgesia by up to 2.5 hours, and improve postoperative analgesia. Dexamethasone

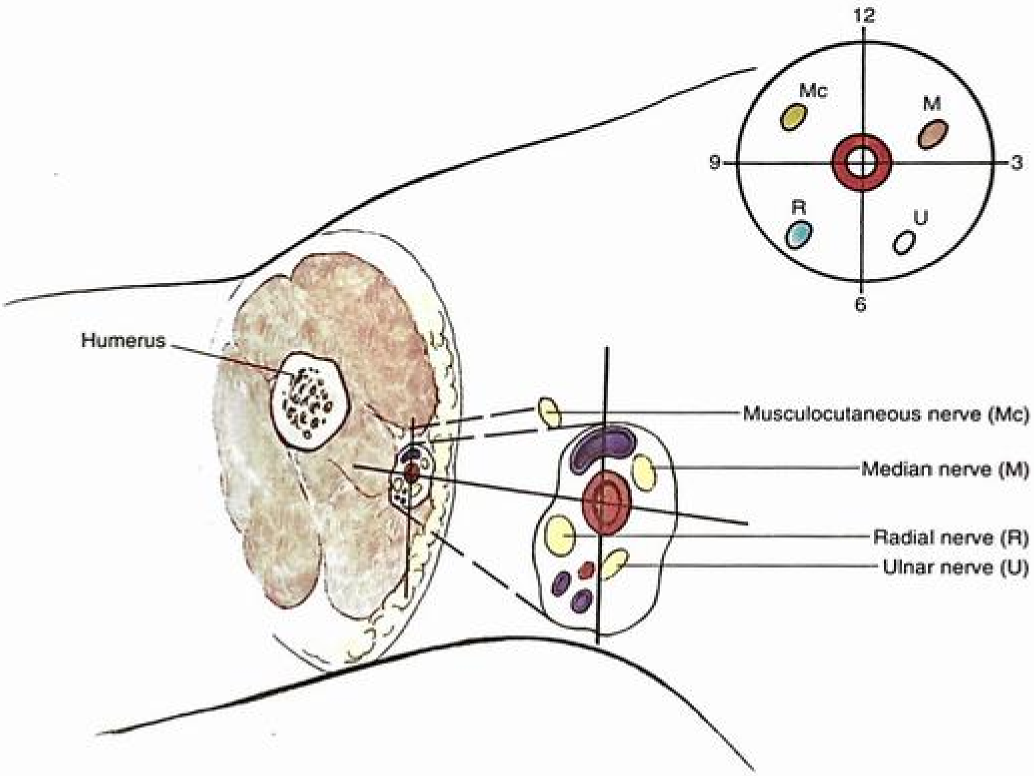

Fig. 11.2 Axillary brachial plexus block: functional quadrant anatomy of the distal axilla.

administered perineurally (4–10 mg) and intravenously (8 mg) has also been studied as a potential adjunct to prolong the duration of the axillary brachial plexus block and improve overall postoperative analgesia with promising results.

With continuous catheter techniques used for postoperative analgesia or chronic pain syndromes, 0.1% bupivacaine or 0.2% ropivacaine may be used, and even lower concentrations of these drugs may be used.

POTENTIAL PROBLEMS

Problems with the axillary brachial plexus block are infrequent because of the distance of this block from neuraxial structures and the lung, as well as the compressibility of the axillary artery at this level. One occasional complication is systemic toxicity, which can be minimized by using multiple injections rather than a fixed needle; use of a single immobile needle to inject large volumes of an LA increases the potential for systemic toxicity relative to the use of smaller volumes of LA injected at multiple sites. Another potential problem with the axillary brachial plexus block is the development of postoperative neuropathy, but one should not assume that the axillary brachial plexus block is the cause of all neuropathy after upper extremity surgery. One must follow a logical and systematic approach when seeking the cause of neuropathy to understand the true incidence and causes of this condition after brachial plexus block and upper extremity surgery.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

The axillary artery and target nerves are superficial (1–3 cm) from the skin surface of the anteromedial aspect of the proximal arm. The median nerve is located superficial and lateral to the artery. The ulnar nerve is superficial and medial to the artery. The radial nerve is posterior and either lateral or medial to the artery.

On ultrasound, the median, ulnar, and radial nerves can be seen as round, hyperechoic structures, or they can have a honeycomb appearance. The musculocutaneous nerve is usually seen on ultrasound as a hypoechoic, flattened oval with a bright hyperechoic border.

INDICATIONS

- Surgery on the midarm down to the elbow (brachiobasilic fistula and elbow fixation).
- Surgery on the hand and wrist.

TECHNIQUE

Ideally, the patient should be placed in the supine position with the arm abducted 90 degrees and externally rotated so the dorsum of the hand rests on the bed (see Fig. 11.3).

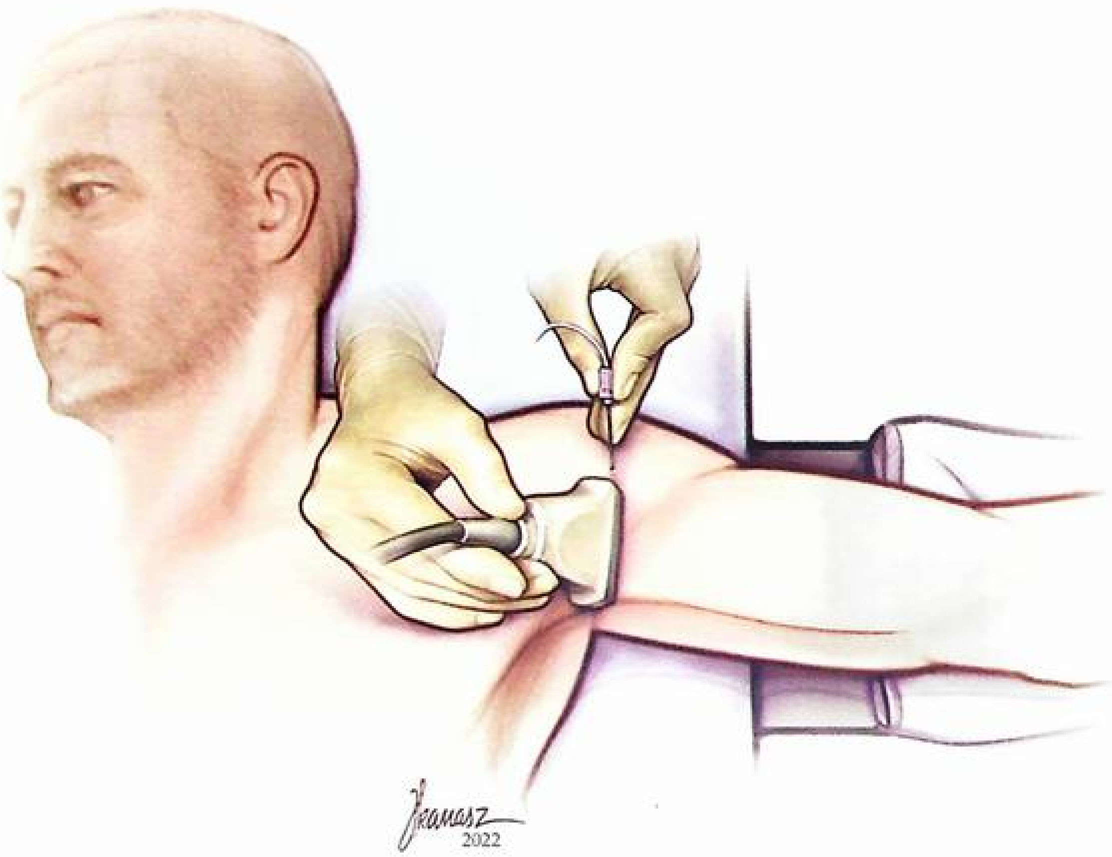

Fig. 11.3 Patient position with the arm abducted 90 degrees and externally rotated.

Preferably, the operator should be positioned behind the patient with the ultrasound machine in front of the patient and facing the operator (see Fig. 11.4A). Injured extremities should be well supported during positioning. The ultrasound probe is placed transversely on the proximal medial upper aspect of the arm with the leading edge facing laterally in order to view the axillary artery and surrounding nerves in the short-axis view (Fig. 11.4B). This starting point should place the ultrasound transducer over both the biceps and triceps muscles. Then the operator will slide the ultrasound transducer across the axilla until the thick-walled, pulsatile axillary artery and the hyperechoic surrounding nerves are visualized. We prefer to use the in-plane approach with a 4-inch, 22-gauge echogenic needle. The needle is inserted in-plane from the cephalad aspect and directed to the location of the median, ulnar, and radial nerves, using careful hydrodissection with a small amount of LA. Finally, the needle is withdrawn to the biceps muscle and redirected toward the musculocutaneous nerve in the body of the coracobrachialis muscle (see Fig. 11.5A and B, Video 11.1). If the individual nerves are difficult to identify, it is reasonable to inject LA around the axillary artery at multiple sites to achieve circumferential spread.

One may choose to supplement the axillary brachial plexus block with the intercostobrachial nerve block. The intercostobrachial nerve provides cutaneous innervation to the medial aspect of the upper arm and the axilla. It originates from the second thoracic nerve root (T2) and thus is not anesthetized in any brachial plexus block. The nerve enters the axilla, crosses over the anterior aspect of the latissimus dorsi muscle, and terminates in the subcutaneous tissue of the medial arm. To identify the intercostobrachial nerve on ultrasound, the transducer is placed over the posteromedial axilla with the leading edge facing laterally. The nerve is a small honeycomb-appearing structure posterior to the axillary artery and vein, just deep to the superficial fascia of the axilla. The needle is inserted in-plane and advanced toward the target nerve while avoiding the axillary vessels, and LA is injected around the nerve.

PEARLS

- A reverberation artifact deep to the artery is often misinterpreted for the radial nerve. When in doubt, one can use nerve stimulation to confirm the location of the nerve.
- The axillary nerve is not blocked, because it departs from the posterior cord high up in the axilla; that is why the deltoid muscle is not anesthetized by the axillary brachial plexus block.
- To avoid toxicity, always aspirate before injection and watch the spread of LA on the ultrasound monitor to ensure that it is not deposited intravascularly.
- When scanning, use minimal pressure with the ultrasound transducer to avoid obliteration of the veins, which can render the veins invisible

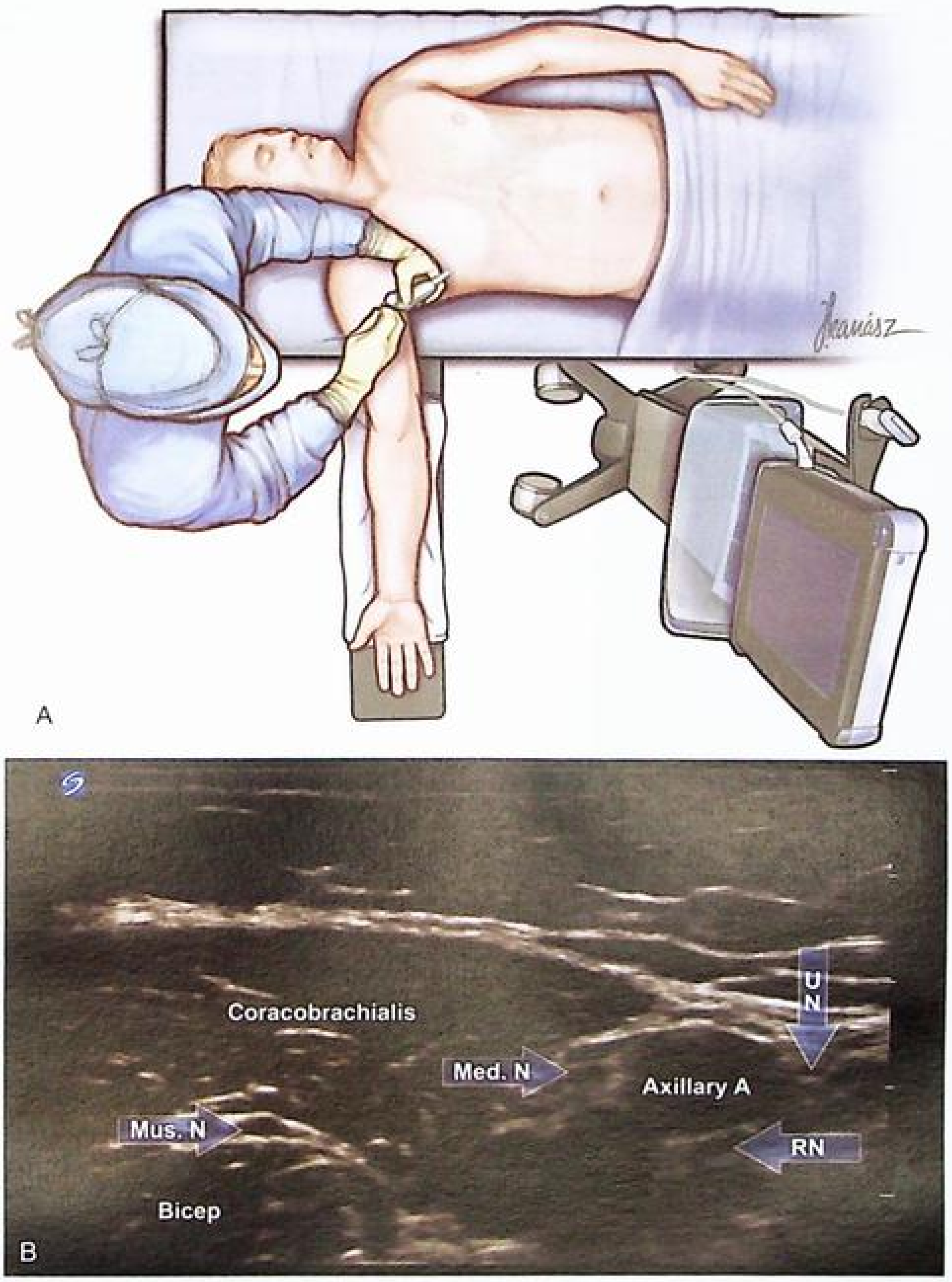

Fig. 11.4 (A) Operator positioned behind the patient with the ultrasound machine facing the operator. (B) Sonoanatomy for the axillary brachial plexus block. *Med. N*, Median nerve; *Mus. N*, musculocutaneous nerve; *RN*, radial nerve; *UN*, ulnar nerve.

and easily prone to being punctured with the needle.

- Unintentional multiple punctures of the veins surrounding the axillary artery can predispose the patient to LA toxicity.

AXILLARY BRACHIAL PLEXUS CATHETER TECHNIQUE

The axillary brachial plexus catheter technique is performed by first targeting the median, ulnar, radial, and musculocutaneous nerves with a single-shot injection to speed the onset of the block. A 4-inch, 22-gauge needle is used to avoid vascular punctures with a Tuohy needle. From the same entry point, the 19-gauge catheter is then placed using a 3-inch, 17-gauge Tuohy needle, and the catheter is threaded around the targeted nerves for the surgical procedure. For example, if the operation involves the little finger, then we thread the catheter around the ulnar nerve. If the operation involves the whole hand, then we thread the catheter between the median and ulnar nerves, and the LA usually spreads to the radial nerve. Then we tunnel the catheter 2 to 3 inches under the skin away from the axilla to decrease catheter migration and risk of infection. We use an adhesive dressing with built-in slow-releasing chlorhexidine to prevent infection. See Fig. 11.6 for the axillary brachial plexus catheter tunneling technique used at our institution. We use an infusion of ropivacaine 0.2% at a basal rate of 5 mL per hour with a 5-mL per hour demand rate, using an automated

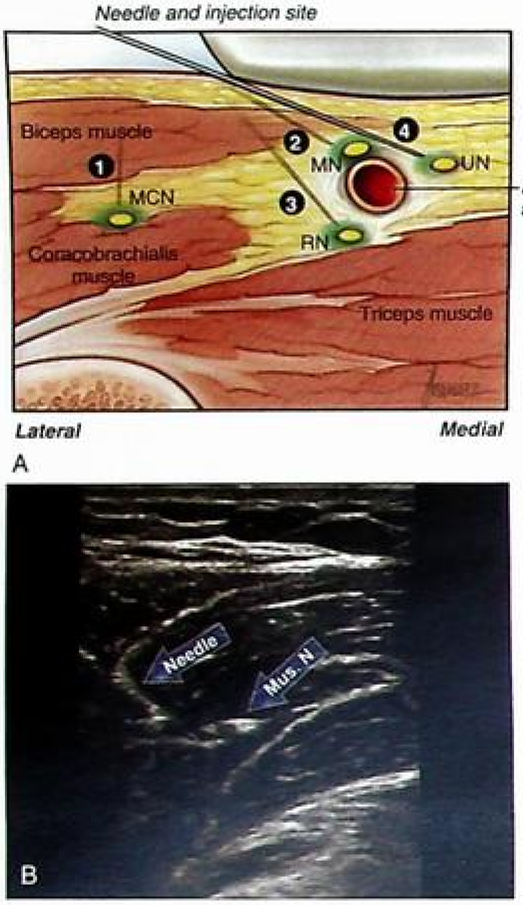

Fig. 11.5 (A) In-plane technique for axillary brachial plexus block. Note the multiple injections of LA around the musculocutaneous nerve *(MCN)*, median nerve *(MN)*, radial nerve *(RN)*, and ulnar nerve *(UN)*. (B) Ultrasound image for musculocutaneous nerve *(Mus. N)* injection. Notice the needle in close proximity to the nerve.

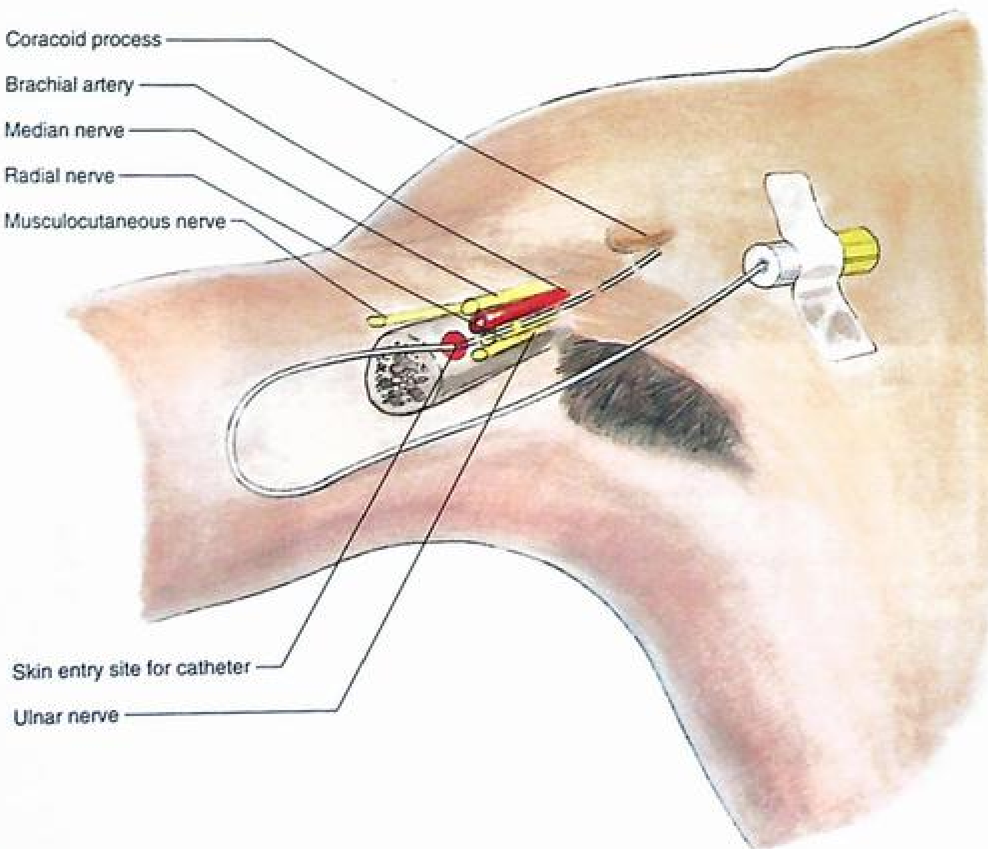

Fig. 11.6 Tunneling technique used for the axillary brachial plexus catheter.

programmed pump to deliver the medication in the hospital and when the patient is at home. The catheter usually is kept in place for 5 days after surgery. Then the catheter is removed, either by the patient or a family member, or by the surgeon at their office during the patient's postoperative visit.

If there are multiple vessels around the axillary artery and between the nerves, an infraclavicular or supraclavicular block may be a better option for surgery on the hand, forearm, and elbow.

INDICATIONS FOR AXILLARY BRACHIAL PLEXUS CATHETER

- Operations on the hand, forearm, and elbow.
- Patients with morbid obesity (difficulty obtaining a good ultrasound image for an infraclavicular block and concern about the patient's tolerance of phrenic nerve blockade from a supraclavicular block).
- Patients with severe chronic obstructive pulmonary disease, sleep apnea, asthma, phrenic nerve palsy on the contralateral side of the planned operation, those on home oxygen, and those who refuse to have an infraclavicular block.

COMPLICATIONS OF AXILLARY BRACHIAL PLEXUS CATHETER

- Infection.
- Hematoma.
- Partial block.
- Catheter migration and dislodgement.

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12 Dental Local Anesthesia

Rebecca Farag and Keith Schneider

Key Points

- The goal of dental local anesthesia is to provide comfort and pain relief for patients.
- 2% Lidocaine HCl, 1:100,000 epinephrine is the anesthetic of choice for most dental injections.
- The typical dosing of anesthetic is 2 to 4 mL.
- An aspirating syringe and basic injection technique are utilized for all dental injections.
- Due to bony architecture, maxillary teeth are amenable to profound anesthesia through infiltration, while blocks are needed for mandibular teeth.
- The inferior alveolar block is a critical dental block and can be mastered through anatomical study and repetition.

TYPES OF ANESTHETICS

The most commonly used dental anesthetics are listed in Table 12.1, based on duration of pulpal action. They are all amides, consisting of a hydrophilic amino terminal, intermediate chain, and lipophilic aromatic terminal. There are many other varieties of anesthetics, but these four are standard for most dental applications.

ARMAMENTARIUM

The equipment needed for dental local anesthesia is the syringe, needle, and local anesthetic cartridge. The most common type of syringe is the breech-loading, metallic, cartridge-type, aspirating syringe. The piston with harpoon inserts into the rubber of the anesthetic cartridge. When negative pressure is exerted by the clinician onto the thumb ring, blood may enter and become visible in the cartridge. This occurs if the needle has entered a blood vessel. Positive pressure then pushes local anesthetic into the patient's tissues. The mechanism of aspiration is a vital tool for clinicians and ensures that vasculature has not been affected during injection. Malamed found in a survey of 209 dentists that 63.2% always aspirate prior to injection for an inferior alveolar block.

Connected to the syringe is the needle. Most dental needles are stainless steel and disposable. The tip of the needle is beveled and is described as long, medium, or short. The gauge of the needle refers to the needle diameter. The most used needle gauges are 25-, 27-, and 30-gauge, which can be found in the dental practice with red, yellow, and blue caps, respectively.

Held within the syringe is the anesthetic cartridge, consisting of a glass tube, stopper, aluminum cap, and diaphragm. The harpoon of the syringe is embedded into the stopper with finger pressure at the thumb ring of the syringe. The aluminum cap opposes the stopper and holds the diaphragm. The diaphragm is a semipermeable membrane into which the needle forms a tight seal. These three components are the main armamentarium of dental injections; other instruments may be recommended based on the type of injection.

ANATOMICAL CONSIDERATIONS

Pain control in dentistry is mostly related to second and third divisions of the trigeminal nerve, which controls sensory innervation for the maxilla, mandible, skin, mucosa, and surrounding tissue. V_2 exits the cranium through the foramen rotundum into the upper portion of the pterygopalatine fossa. V_3 travels downward through the skull with the motor root of the trigeminal nerve to exit through the foramen ovale and form one nerve trunk entering the infratemporal fossa. Teeth receive sensory trigeminal innervation through the sensory nerves of the pulpal tissue, the innermost layer in the anatomy of a tooth. The pulp of the tooth is composed of soft connective tissue, vascular, lymphatic, and nervous elements, which occupy the central cavity of each tooth.

The osteology of the maxilla and mandible plays an important role for appropriate anesthesia. Bone

Table 12.1 Type of Anesthetics

Anesthetic	Duration of pulpal infiltration
4% Prilocaine HCl, no epinephrine	10–15 minutes
2% Lidocaine HCl, 1:100,000 epinephrine	55–65 minutes
4% Articaine HCl, 1:200,000 epinephrine	60 minutes
0.5% Bupivacaine HCl, 0.5% 1:200,000 epinephrine	Up to 7 hours

surrounding maxillary teeth is more porous and of the cancellous variety. Therefore this area is more receptive to profound anesthesia through infiltrative anesthetic techniques in comparison with the dense cortical bone found surrounding mandibular dentition.

BASIC INJECTION TECHNIQUE

No matter the type of regional block administered, the clinician's priority is the comfort and pain management of the patient. There are several steps that will be done with every injection to provide atraumatic and profound local anesthesia.

1. **Ensure the needle is sterile and sharp.** Disposable stainless steel needles are standard and may be painless upon injection when used properly. However, after three to four injections, these needles become dull, causing unnecessary trauma to mucosa.
2. **Confirm flow of anesthetic from cartridge to needle prior to injecting.** This can be done by allowing a few drops of anesthetic to run through the needle before approaching the patient.
3. **Position and communicate with the patient.** This is both for accuracy of injection and to prevent syncope in the patient. Talk to the patient throughout the injection process to calm them. Syncope is the most common emergency in dental practice. Anxiety during local anesthesia exacerbates these symptoms. It is optimal to place the patient in a supine position with raised legs to prevent this occurrence.
4. **Apply topical anesthetic.** The most used topical anesthetic is the ester benzocaine. The tissue should be dried prior to application. Topical anesthetic need only be applied at the area of needle penetration. It will anesthetize ~1 to 2 mm of mucosa and requires at least 1 minute of application for effect.
5. **Establish hand rest.** Stabilize injection by utilizing a finger rest or elbow rest. Depending on the type of injection, the patient's chin, lip, or chest can be used for stabilization. Do not use a patient's arm or shoulder or attempt to inject without syringe support.
6. **Stretch the tissue.** The injection site must be stretched taut for accuracy. This can be done using a gloved finger, mirror, tongue depressor, or similar instrument. Some clinicians opt to couple this with distractors, such as jiggling the upper lip. This is not mandatory but can be helpful with some patients, especially children.
7. Insert the needle. To avoid increased anxiety, the needle should be passed away from the eyeline of the patient. After confirming the hand rest and tissue is prepared, the needle can be inserted with the bevel of the needle pointed toward bone.
8. **Slowly inject anesthesia.** Before releasing the cartridge of solution, deposit several drops and adjust to ensure the correct anatomy has been reached. Aspirate to confirm the needle tip is not in a blood vessel. Do not move the tip of the needle when aspirating. Once in position, continue to inject in a slow and controlled manner. This rate is defined as one full cartridge per 2 minutes.
9. **Withdraw the needle.** Once the injection is finished, slowly remove the needle so as to not injure adjacent structures. Cap the needle immediately using the scoop technique or built-in cap holder. Do not have an assistant aid in capping the needle.
10. **Observe and communicate with the patient.** The patient should not be left unattended following local anesthesia, for most adverse drug interactions occur 5 to 10 minutes after injection.
11. **Record in patient chart.** Type and amount of anesthetic injected must be documented in the patient's record.

MAXILLARY INJECTIONS

Supraperiosteal Injection

Commonly referred to as a local infiltration or buccal infiltration, the supraperiosteal injection is the most frequently used injection for reaching profound pulpal anesthesia in the maxillary arch. When done correctly, it will anesthetize the entire region innervated by the large terminal branches of the dental plexus. This includes the pulp, root of the tooth, buccal periosteum, connective tissue, and mucous membrane. This injection has a high success rate, for it is technically simple and atraumatic. It is contraindicated for multiple teeth in one quadrant, for it requires multiple injections and a high volume of anesthetic. A dental block should be considered if multiple teeth require anesthesia.

Local infiltration can be accomplished in a similar manner with mandibular teeth. As will be discussed later, due to the anatomy of the mandibular arch, blocks are required for profound anesthesia in the area. However, infiltration is often used supplementary to a block or for less invasive dental procedures. Research has also found that the use of 4% articaine 1:100,00 epinephrine over traditionally used 2% lidocaine 1:100,000 in the mandibular molar area provides profound anesthesia for 70 minutes after buccal infiltration.

Supraperiosteal Procedure (Fig. 12.1)

1. Short needle is recommended (25- or 27-gauge).
2. Clean tissue site with sterile gauze. Apply topical anesthetic.
3. Orient needle bevel toward bone, with syringe parallel to the long axis of the tooth.
4. Lift lip, stretch tissue at injection site.
5. Insert needle 2 to 3 mm into the buccal sulcus adjacent to the desired maxillary tooth—height of mucobuccal fold. The target area of anesthesia is the apex of the tooth of treatment.
6. Advance slowly and aspirate. If aspiration is negative, inject ~⅓ of cartridge per 20 seconds. When done correctly, this injection is painless to the patient.
7. Slowly withdraw needle.

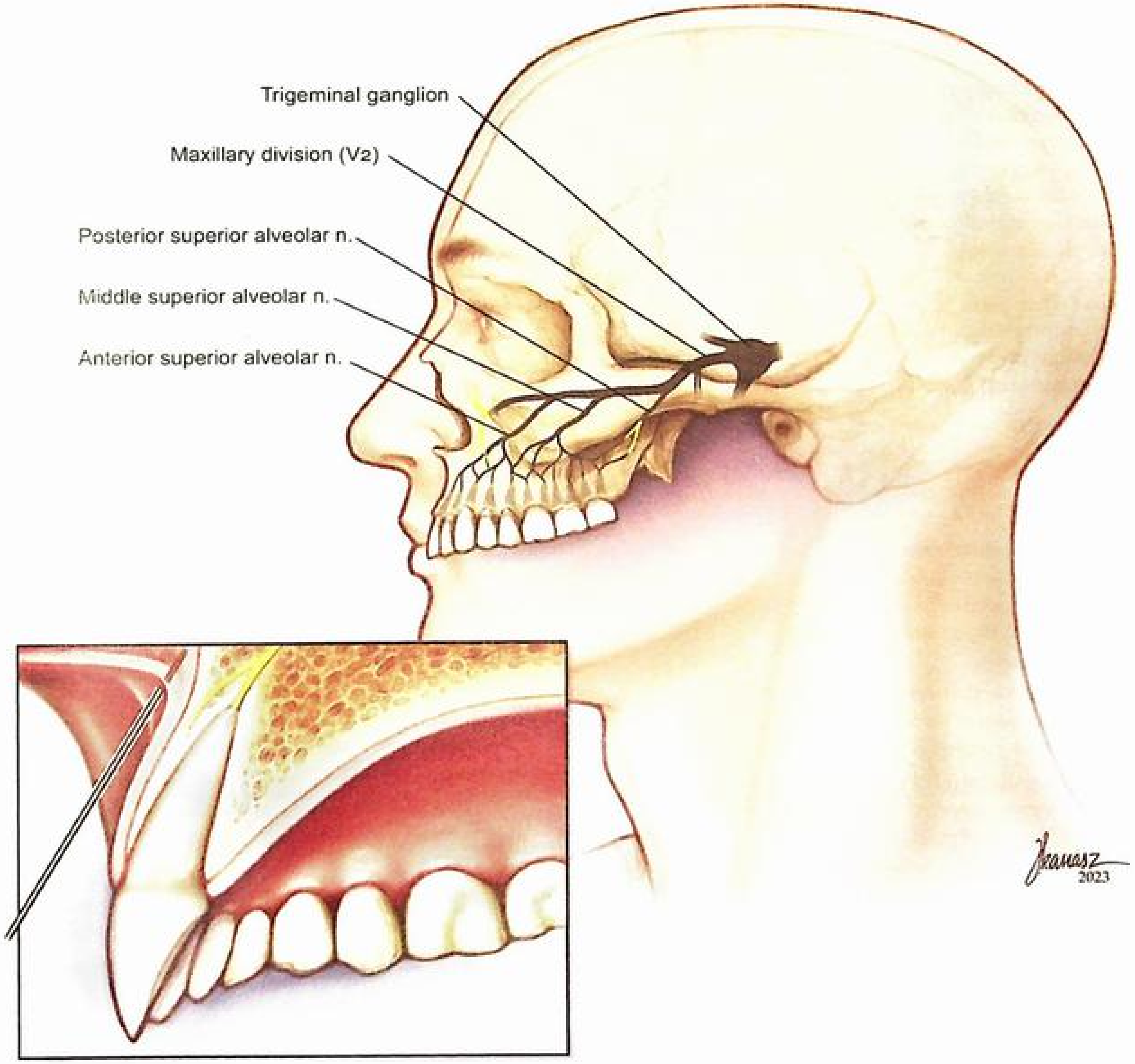

Fig. 12.1 This illustration outlines the branches of the maxillary division of the trigeminal nerve that are targeted through maxillary anesthesia. As noted in the focused view, the needle in the supraperiosteal or infiltration technique is aimed at the apex of the maxillary dentition.

Posterior Superior Alveolar Nerve Block

The posterior superior alveolar nerve (PSAN) is a sensory branch of the maxillary division of the trigeminal nerve. The PSAN block provides pulpal and soft tissue anesthesia to the area of the maxillary first through third molars, excluding the mesiobuccal root in ~25% of patients. This block has been found to be 85% to 100% successful, but possible complications include hematoma, transient diplopia, blurred vision, and in rare cases, temporary blindness and Bell palsy. The PSAN block has the second highest positive aspiration at ~3%, the first being the inferior alveolar nerve (IAN) block. The use of a short needle (25- to 27-gauge) has been recommended to avoid the complications. Additionally, aspiration is crucial to ensure a vessel has not been inadvertently entered.

Posterior Superior Alveolar Nerve Block Procedure

1. Clean tissue site with sterile gauze. Apply topical anesthetic.
2. Orient needle bevel toward bone.
3. Retract cheek on side of injection. Insert needle 2 to 3 mm into buccal sulcus (height of mucobuccal fold) above maxillary second molar.
4. Inject slowly superiorly, medially, and posteriorly at a 45-degree angle. If bone is felt, angulation toward the midline is too great. Aspirate. If aspiration is negative, inject cartridge of anesthetic. This injection is usually atraumatic.
5. Slowly withdraw needle.

Anterior Superior Alveolar Nerve/ Infraorbital Nerve Block

This block is not as popular as the PSAN but is very effective at anesthetizing pulpal and buccal tissues from maxillary central incisors through premolars in ~72% of patients. Most clinicians opt for multiple supraperiosteal injections, although a successful anterior superior alveolar nerve (ASAN) block would require fewer injections and less anesthetic solution if multiple teeth are targeted. The infraorbital nerve, like the PSAN, is a sensory branch of the maxillary division of the trigeminal nerve. This block is indicated when infection or inflammation is present, causing infiltration to be potentially less effective. Complications of the ASAN block include bleeding, hematoma, unintentional intravascular injection, and edema.

Anterior Superior Alveolar Nerve Block Procedure

1. Long needle recommended. Short needle may be indicated for children.
2. Localize infraorbital foramen and feel for the infraorbital notch. Once it is located, the palpating finger should remain in place so that landmarks are not lost. Clean tissue site with sterile gauze. Apply topical anesthetic.
3. Retract the lip and cheek with noninjecting thumb and insert needle at level of mucobuccal fold above maxillary first premolar.
4. Maintain needle parallel to long axis of tooth. Advance slowly. Approximate depth of needle penetration is 16 mm in adults.
5. Aspirate. If aspiration is negative, slowly inject anesthetic, ensuring needle has not deviated laterally.
6. Slowly withdraw needle.

Greater Palatine Nerve Block

Though a palatal injection is not indicated for all dental procedures, palatal anesthesia is valuable for dental procedures involving palatal soft tissues. The greater palatine nerve is a branch of the maxillary division of the trigeminal branch, contributing to the pterygopalatine ganglion. The greater palatine nerve block is indicated for teeth distal to the maxillary canine. Due to the dense fibrous anatomy of the palatal tissues, this injection tends to be uncomfortable for patients, but a minimum volume of solution still provides profound anesthesia in this area.

Greater Palatine Nerve Block Procedure

1. Short gauge needle recommended.
2. Instruct patient to open mouth widely and extend neck to visualize palate.
3. Localize greater palatine foramen with cotton-tipped applicator. Applicator will "fall" into depression distal to maxillary second molar bilaterally.
4. Clean tissue site with sterile gauze. Apply topical anesthetic.
5. Apply pressure to foramen. Note blanching of area.
6. Insert needle into area of foramen. Direct syringe from opposing side for straight access into foramen.
7. Slowly advance needle until palatine bone is reached. Aspirate. If aspiration is negative, slowly inject up to one-third cartridge of anesthetic solution.
8. Slowly withdraw needle.

Nasopalatine Nerve/Incisive Nerve Block

Another branch of the maxillary division of the trigeminal nerve, the nasopalatine nerve, provides sensory function to the anterior palate. Though an invaluable injection, the nasopalatine nerve block is a distinctly painful injection, warranting adherence to technique for atraumatic procedure. It anesthetizes the soft and hard tissues of the anterior portion of the hard palate mesial of the first premolars bilaterally.

Nasopalatine Nerve Block Procedure

1. Short gauge needle recommended.
2. Instruct patient to open mouth widely and extend neck to visualize the incisive papilla.
3. Clean tissue site with sterile gauze. Apply topical anesthetic.
4. Apply pressure to papilla with cotton-tipped applicator. Insert needle into papilla.
5. Slowly advance needle toward incisive foramen until bone is contacted. Aspirate. If aspiration is negative, slowly inject up to one-fourth cartridge of anesthetic solution.
6. Slowly withdraw needle.

MANDIBULAR INJECTIONS

Inferior Alveolar Nerve Block

Commonly but inaccurately referred to as the mandibular nerve block, the IAN block is one of the most frequently used and possibly the most important blocks in dentistry. When done correctly, this block anesthetizes the terminal branches of the inferior alveolar nerve, incisive and mental nerves, and commonly, the lingual nerve. It anesthetizes all mandibular teeth to the midline of the mandible, body of the mandible, inferior portion of the ramus, anterior two-thirds of the tongue, and lingual soft tissues on its respective side.

However, it is considered one of the most frustrating due to anatomic variations among patients and the need to identify specific anatomical landmarks to ensure accurate injection. Clinical failure of the IAN block is one of the highest of all dental blocks at ~15% to 20%. Profound anesthesia is accomplished in the mandible by blocks above supraperiosteal injection (infiltration) due to the mineral density of the bone and anatomical variation. Buccal nerve, supraperiosteal, and periodontal ligament (PDL) injections can be used in conjunction with an IAN block for soft tissue anesthesia. Bilateral administration of the IAN block is usually avoided in dental treatment due to patient

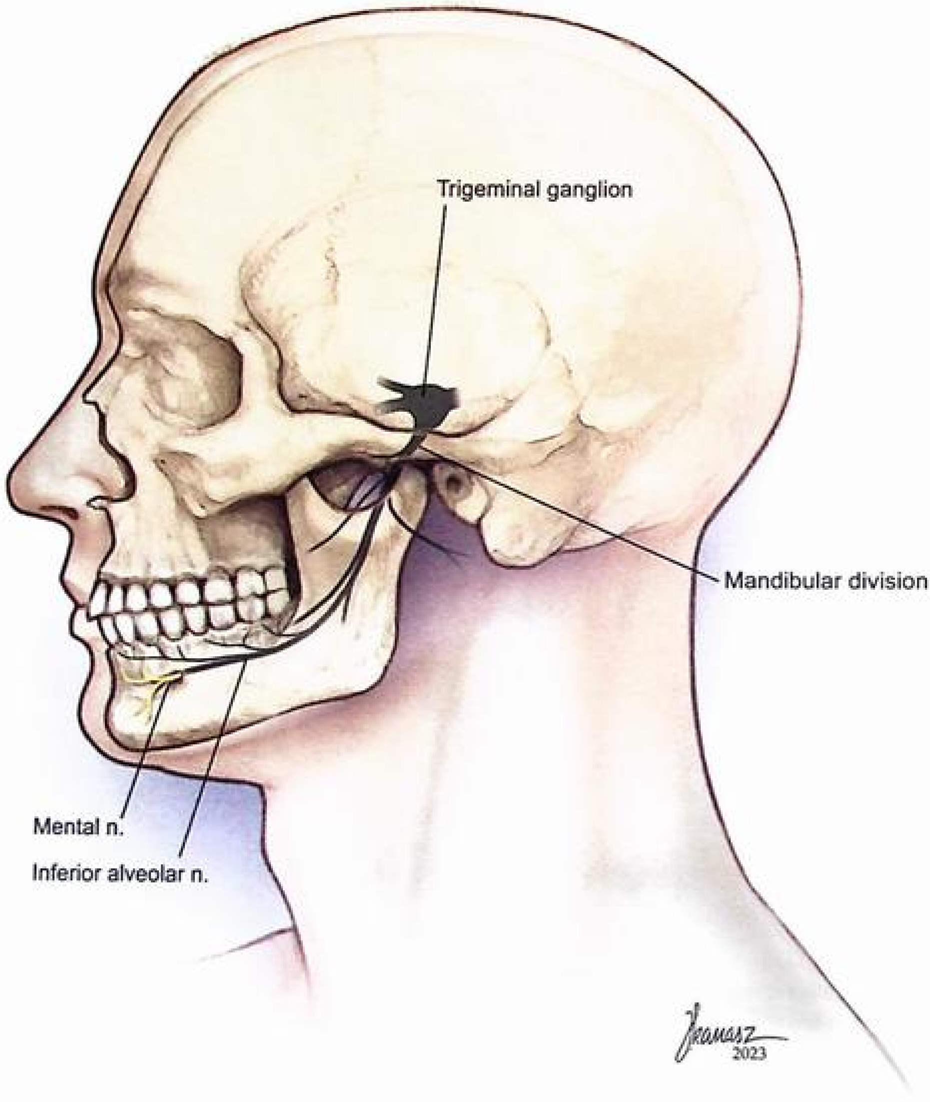

Fig. 12.3 As illustrated, the Gow-Gates technique involves a landmark closer to the mandibular head. When done correctly, this approach will provide profound anesthesia to all branches of the trigeminal ganglion. The traditional inferior alveolar nerve block is directed at the ramus of the mandible to anesthetize only the inferior alveolar nerve.

midline. It additionally touts a 2% positive aspiration compared with the 10% to 15% for traditional IAN block.

Gow-Gates Technique Procedure

1. 25- or 27-gauge long needle recommended for adult patients.
2. Position the patient in a supine or semisupine position. Instruct the patient to open widely to visualize the pterygomandibular raphe.
3. Clean tissue site with sterile gauze. Apply topical anesthetic.
4. Place syringe barrel near contralateral mandibular canine or premolars while the patient keeps mouth open as wide as possible. The needle tip should be inserted just below the mesial cusp of the maxillary second molar.
5. Slowly advance needle until bone is contacted at neck of condyle. Ideal depth of penetration is approximately 25 mm (variation is possible due to patient anatomy).
   a. Once bone is contacted, withdraw ~1 mm to prevent subperiosteal injection. Aspirate. If aspiration is negative, slowly inject full cartridge of anesthetic over minimum of 60 seconds.
   b. Slowly withdraw needle.

Vazirani-Akinosi (Closed-Mouth) Mandibular Block

In 1977, Dr. Joseph Akinosi reported this closed-mouth approach to mandibular anesthesia. The Vazirani-Akinosi block is an anesthetic method targeting the mandibular branch of the trigeminal nerve, like the Gow-Gates mandibular nerve block. Although this technique can be used whenever mandibular anesthesia is desired, it is especially useful in case of anatomical variation, including accessory innervation. This method is commonly used when there is trismus or difficulty in finding soft tissue landmarks, such as during abscess or acute infection of a mandibular molar.

Vazirani-Akinosi (Closed-Mouth) Mandibular Block Procedure

1. 25- or 27-gauge long needle recommended for adult patients.
2. Position the patient in a supine or semisupine position. Instruct the patient to open.
3. Place thumb or index finger on coronoid notch to reflect the soft tissues on the medial border of the ramus laterally.
4. Clean tissue site with sterile gauze. Apply topical anesthetic.
5. Insert needle at the height of the mucogingival junction of the maxillary posterior teeth, between the maxillary tuberosity and coronoid process.
6. Slowly advance needle 25 mm into tissue (distance measured from maxillary tuberosity). Aspirate. If aspiration is negative, slowly deposit full cartridge of anesthetic over minimum of 60 seconds.
7. Slowly withdraw needle.

Buccal Nerve Block

A branch of the anterior division of the mandibular branch of the trigeminal nerve, the buccal nerve, or the long buccal nerve, is not usually anesthetized during an IAN block. The buccal nerve provides sensory innervation to the buccal soft tissue of the mandibular molars only. This block is not required for dental treatment in mandibular molars but is indicated when soft tissue is manipulated (e.g., rubber dam placement). Because the buccal nerve is located immediately below mucosa, this block has close to 100% success rate.

Buccal Nerve Block Procedure

1. 25- or 27-gauge long needle recommended.
2. Position the patient in a supine or semisupine position. Instruct the patient to open.
3. Clean tissue site with sterile gauze. Apply topical anesthetic.
4. With index finger, retract buccal soft tissues tightly for an atraumatic needle insertion.
5. Insert needle distal and buccal to the last molar, with syringe parallel with the occlusal plane of the side of injection.
6. Slowly advance needle until mucoperiosteum is contacted. Depth of penetration is usually ~2 mm. Aspirate. If aspiration is negative, slowly deposit ~one-eighth of cartridge of anesthetic solution.
7. Slowly withdraw needle.

Mental Nerve Block

The mental nerve is the terminal branch of the IAN, providing sensory innervation to the buccal soft tissue around the mandibular premolar area. The mental nerve block, like the buccal nerve block, is often used supplementary to an IAN block.

Mental Nerve Block Procedure

1. Short needle recommended.
2. Position the patient in a supine or semisupine position. Instruct the patient to open.
3. Area of insertion is the mental foramen, which is usually found between the apices of the two premolars bilaterally. This can be confirmed on a radiograph prior, if available.
4. Clean tissue site with sterile gauze. Apply topical anesthetic.
5. With index finger, retract lower lip and buccal soft tissues. Insert needle into mucous membrane, directing needle toward mental foramen. Aspirate. If aspiration is negative, slowly deposit ~one-third of cartridge of anesthetic solution.
6. Slowly withdraw needle.

SUPPLEMENTARY INJECTION

Periodontal Ligament Injection

The nerves supplying mandibular teeth and periodontal tissue are encased in the bone, limiting the effectiveness of infiltration. The PDL anesthetic technique, also referred to as the intraligamentary injection, uses high injection pressure to force local anesthetic solution through the PDL into the cancellous bone surrounding a tooth. This technique can also be used on maxillary teeth, but it is not as often utilized due to the efficiency of the supraperiosteal injection in this arch. The PDL injection is indicated for pulpal anesthesia for one to two teeth in a quadrant. This technique avoids anesthesia of the lip, tongue, and other soft tissue.

Periodontal Ligament Injection Procedure

1. 27-gauge short needle recommended.
2. Position the patient in a supine or semisupine position. Instruct the patient to open.
3. Direct syringe long axis of root to be anesthetized with bevel facing the root of the tooth. Advance needle apically until resistance is met. Slowly deposit 0.2 mL of anesthetic solution in approximately 20 seconds. Significant resistance will be felt at the deposition of solution.
4. Slowly withdraw needle.

LOCAL ANESTHESIA TOXICITY

Dental local anesthetics are very safe and commonly used. However, any drugs can cause adverse reactions in some patients. Proper dosing of the local anesthetic is crucial, for local anesthetic overdose may cause dizziness, nervousness, tingling of the extremities, visual disturbances, drowsiness, metallic taste, and loss of consciousness. The management of an overdose is based on the severity of the reaction. In most cases, the reaction is mild and self-limiting and can be managed by administering oxygen and terminating dental treatment. In severe cases that include loss of consciousness with or without seizure, the use of basic life support with anticonvulsant therapy would be necessary and the injection of intralipid as recommended by the Society of Regional Anesthesia and Pain Management.

Understanding the maximum recommended doses (MRDs) for each of the local anesthetic drugs is critical to avoid complications. The dosage of anesthetic is also dependent on the patient's weight and health conditions. For example, the MRD for lidocaine without epinephrine is 4.4 mg/kg with an absolute maximum of 300 mg.

PEARLS

- For successful dental anesthesia, it is imperative to become acquainted with the landmarks for injection and practice great patient care.
- Intentional injection technique with negative aspiration will ensure that the correct anatomy is receiving anesthesia.
- Blocks, along with supplemental injections, are great tools for profound anesthesia.
- Bone surrounding maxillary teeth is more porous and of the cancellous variety and lends better to infiltrative anesthetic technique compared with the dense cortical bone found surrounding mandibular dentition.
- Proper dosing of local anesthesia is integral at preventing adverse reactions or toxicity.

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13 Distal Upper Extremity Blocks

Sree Kolli and Husien Taleb

Key Points

- Blockade of peripheral nerves of the upper extremity is often accomplished by brachial plexus approaches. However, conditions such as infections to brachial plexus sites, coagulopathy, single nerve distribution—minor procedures (not requiring a tourniquet), and rescue supplementations of a brachial plexus block may require individual nerve blockade.
- Distal nerve blocks provide potential benefits compared with proximal approaches, including avoiding the injury to important structures such as lungs, major vessels, and the phrenic nerve. Moreover, these blocks preserve motor function in the fingers, especially in hand surgeries where the digits' movements are tested.
- Distal peripheral nerve blocks are associated with a slightly higher likelihood of nerve injury, possibly because of the anatomical location of these sites, where the nerve is contained within bony and ligamentous surroundings.
- As most distal forearm and hand surgery procedures are performed using a tourniquet, patients may require deeper sedation to tolerate the high tourniquet inflation pressures, because the cutaneous sensation of the upper arm is innervated by multiple nerves, including musculocutaneous, intercostobrachial, medial, and posterior cutaneous nerves of the arm.
- A high-frequency linear array transducer is preferred for these peripheral nerves; also, it is easier to locate a nerve in the short axis at a determined landmark and then follow in a cranial to caudal direction.
- Continuous nerve catheters are not recommended, perhaps because these nerves are confined in a tight space and carry the risk of compartment syndromes. Additionally, there is no literature available for its use in prolonged analgesia. Nevertheless, if prolonged analgesia is needed, axillary continuous catheters may be considered.

DISTAL NERVE BLOCKS OF THE UPPER LIMB

The three major peripheral nerves of the upper extremity, namely median, radial, and ulnar, may be blocked at various levels, that is, arm, elbow, forearm, and wrist.

MEDIAN NERVE

ANATOMY

The median nerve originates from the C5, C6, C7, C8, and T1 nerve roots. It is composed of both motor and sensory components derived from the medial and lateral cords of the brachial plexus.

It is bounded in a neurovascular bundle in the upper arm, where it accompanies the brachial artery. At the elbow, the median nerve courses medial to the brachial artery and lies between the humeral and ulnar heads of the pronator teres muscle. At the midforearm, the median nerve separates from the ulnar artery and is sandwiched between the muscle of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) before entering through the carpal tunnel at the wrist.

Motor branches (anterior interosseous nerve) supply the deep volar muscles in the forearm and thenar eminence of the hand, whereas sensory distribution is limited to the radial aspect of the hand. Notably, the median nerve does not provide any sensory distribution to the forearm; however, it innervates all muscles of forearm except the flexor carpi ulnaris (FCU) and the ulnar aspect of the flexor carpi radialis.

TECHNIQUE

Landmark Technique. At the level of the elbow—antecubital crease, the median nerve is located 1 cm medial to the pulsation of the brachial artery, approximately 1 to 2 cm deep. The needle is inserted at 45 degrees cephalad, and a resistance click of bicipital aponeurosis may be felt at 1 to 2 cm to the skin. At this point, paresthesia may be achieved and, after confirming, 5 to 10 mL of local anesthetic (LA) can be injected.

Ultrasound Technique. Distal to the elbow, at the level of the midforearm, the median nerve is found as a hyperechoic structure embedded in hypoechoic FDS and FDP (Fig. 13.1). The nerve should be confirmed by fanning the probe along its course. Using an in-plane view with a high-frequency linear probe, the needle tip is advanced toward the base of the median nerve, and 2 to 3 mL of LA is injected. The needle is then readjusted to the superior border of the nerve, effectively surrounding the nerve completely with LA. The total volume should be limited to 5 to 7 mL (Video 13.1).

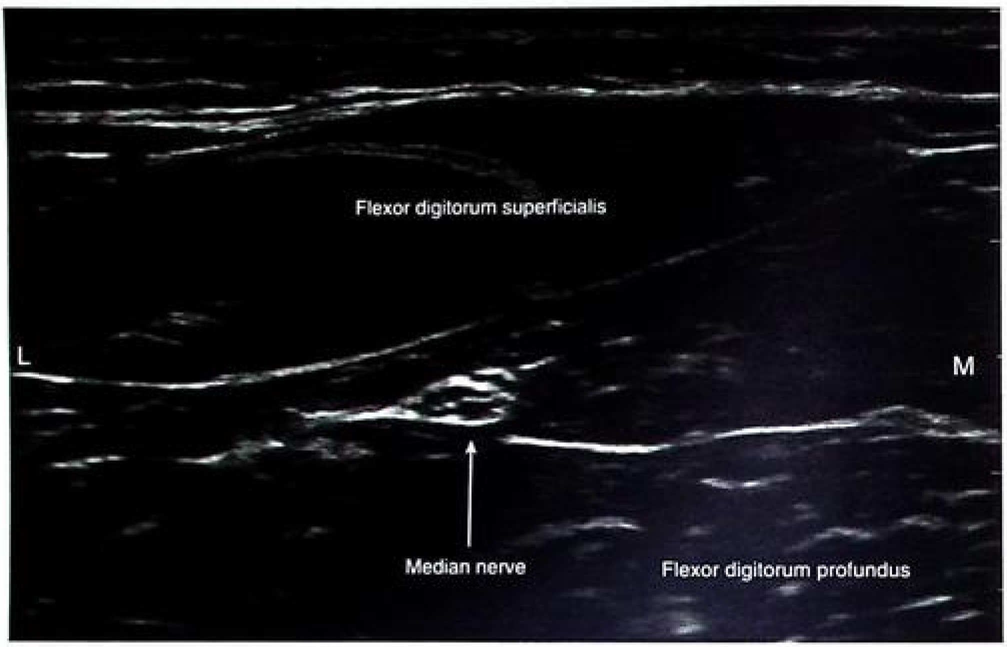

Fig. 13.1 Midforearm nerve blocks: median nerve.

INDICATIONS

The median nerve block provides anesthesia to the volar aspect of the thumb, index finger, middle finger, and the radial aspect of the ring finger, in addition to the radial half of the palm. It can be used as the sole anesthetic technique in several hand surgeries, including lacerations, incision and drainage of an abscess or a cyst, and in the repair of bony dislocations.

ULNAR NERVE

ANATOMY

The ulnar nerve originates from the C8 and T1 nerve roots as the terminal branch of the medial cord of the brachial plexus. It has mixed motor sensory components.

At the level of the arm, the ulnar nerve is medial to the axillary artery and posterior to the brachial artery and median nerve. It does not provide any motor or sensory innervation at this level. However, in the midarm, it descends along the posteromedial aspect and passes between the olecranon process and the medial epicondyle to enter the forearm, where it lies superficial to the FDP and medial to the ulnar artery. At the forearm, the ulnar nerve can be located medial to the ulnar artery in close proximity, hence facilitating sonographic determination. At the level of the wrist, the nerve runs lateral to the FCU and enters the hand superficial to the flexor retinaculum.

TECHNIQUE

Landmark Technique. At the level of the elbow, the ulnar nerve can be accessed by midrange flexion and abduction. Identification of the ulnar groove and medial epicondyle landmarks are made, followed by insertion of the needle 1 to 2 cm deep and proximal to the medial epicondyle at 45 degrees cephalad to the skin (Fig. 13.2). After appropriate paresthesia is achieved, 3 to 5 mL of LA can be injected. Within the ulnar groove, the nerve is immobile, and care must be taken to restrict the total volume (preferably less than 5 mL) injected and pressure neurapraxia.

Ultrasound Technique. We suggest ulnar nerve block at the level of midforearm—(1) easily discoverable at the ulnar artery landmark, (2) the nerve starts to separate and the risk of arterial puncture may be avoided at somewhat distal location, (3) low risk of compartment syndrome, and (4) ability to cover the dorsal and volar terminal branches of ulnar nerves, which divide distal to this location. After the nerve is located (Fig. 13.3), the confirmation is made by fanning the probe along a proximal to distal direction. Using in-plane view with a low-frequency probe, the needle is inserted along the ulnar side of transducer and the nerve is surrounded with not more than 3 to 5 mL of LA (Video 13.1).

The ulnar nerve can also be blocked at the elbow, where it can be easily identified medial to the pulsatile brachial artery, appearing as a bright, hyperechoic oval structure.

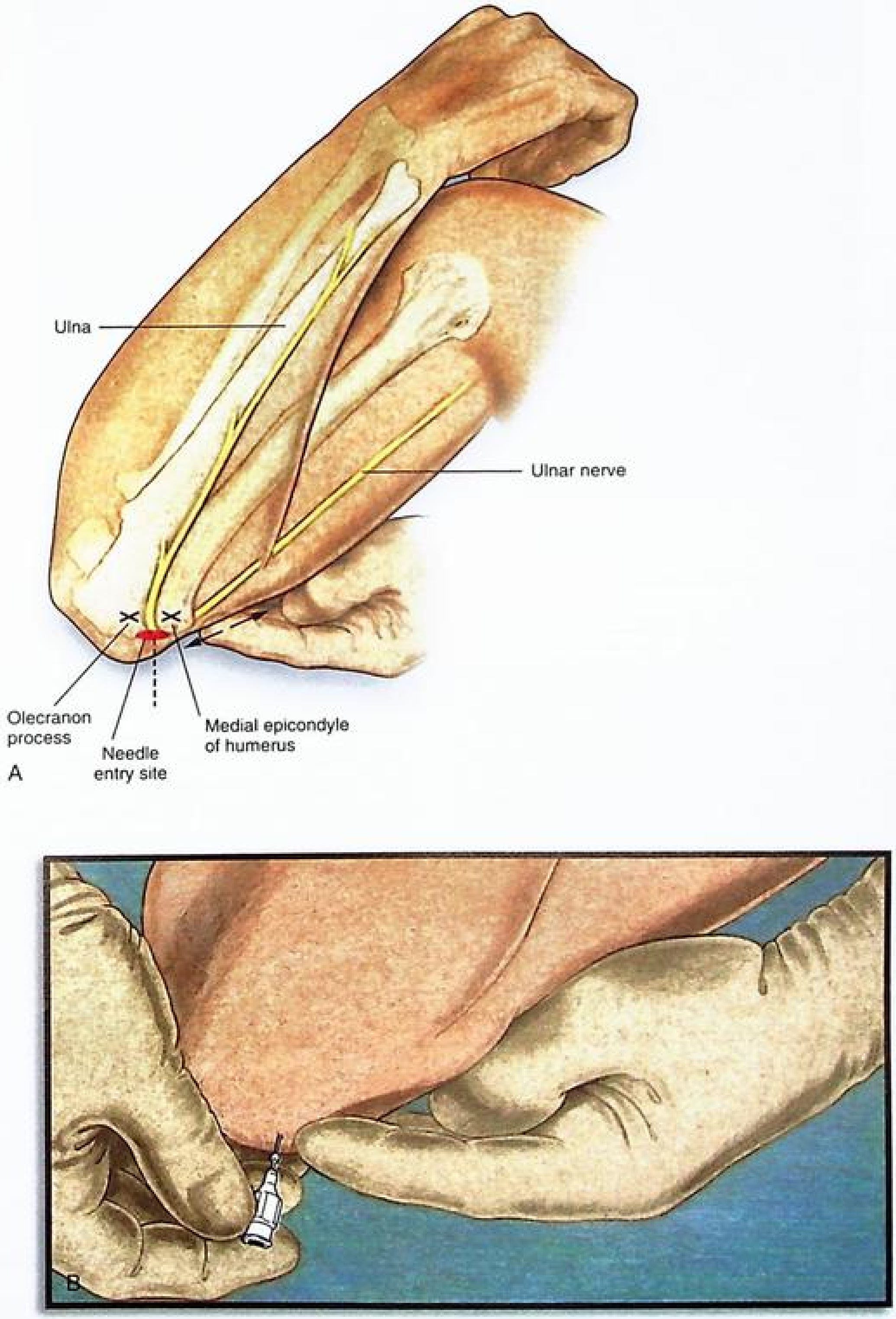

Fig. 13.2 Ulnar nerve block. (A) Positioning. (B) Palpation of the ulnar groove and needle position.

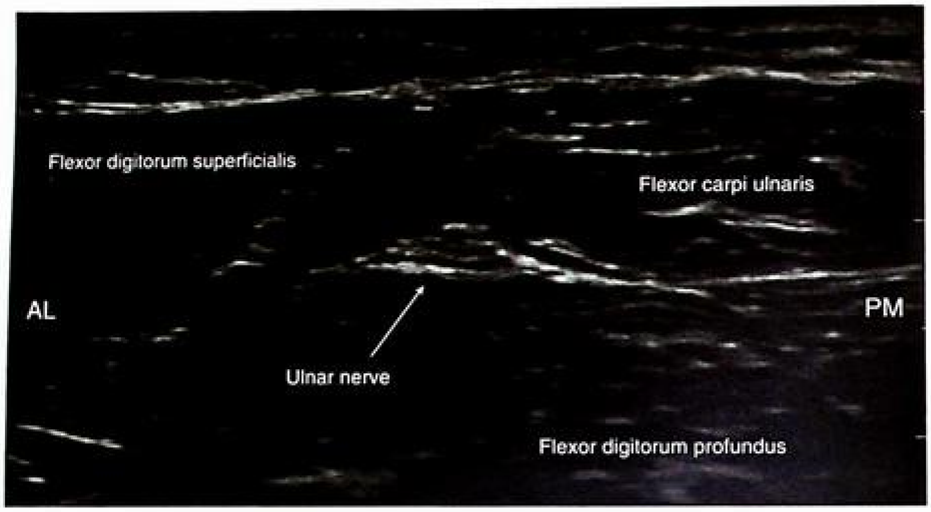

Fig. 13.3 Midforearm nerve blocks: ulnar nerve.

INDICATIONS

The ulnar nerve block is suitable for surgical procedures of the little finger or fifth metacarpal. This involves lacerations; reduction of fractures, including boxer's fractures; and analgesia for burns involving the little finger. In addition to that, it can be used as a rescue block for a failed brachial plexus block. A diagnostic ulnar nerve block is also done before the implantation of a peripheral nerve stimulator in chronic pain patients with ulnar nerve neuropathy.

RADIAL NERVE

ANATOMY

The radial nerve originates from the posterior cord of the brachial plexus via C5 to the T1 nerve roots. It is a mixed motor sensory nerve. It travels from medial to lateral within the spiral groove of the humerus and descends further along the medial and lateral heads of the triceps muscle to lie anterior to the lateral epicondyle in the elbow. At this level, the nerve divides into superficial and deep branches.

TECHNIQUE

Landmark Technique. At the level of the elbow, the antecubital crease, medial epicondyle, lateral epicondyle, biceps, and brachioradialis tendon are identified. The median nerve is located within the groove of the brachioradialis and biceps tendon. An imaginary line can be drawn connecting the medial and lateral epicondyles, and the needle is inserted 2 to 4 cm deep to the skin. After appropriate paresthesia (wrist extension) is achieved, 5 to 10 mL of LA can be injected.

Ultrasound Technique. We recommend blocking the nerve at the level of the upper arm, which theoretically ensures broader coverage. This technique involves placing a low-frequency probe in an out-of-plane view in a transverse direction, approximately between the upper and middle one-third of the arm over the triceps muscle as it crosses the humerus shaft. At this level, the radial nerve and deep brachial artery are visible. Color Doppler may be helpful in visualization. Scanning more distally, just above the elbow, the nerve may be seen sandwiched between the brachioradialis and brachialis muscle. Further distal to this point, it divides into superficial and deep branches (Video 13.1). The radial nerve also may be traced from the cubital fossa more proximally to the midhumeral level. However, the nerve is more superficial proximally, and the chance of vascular injury may be decreased when the injection is done at the cubital fossa. It can also be blocked at the midforearm level (Fig. 13.4) but does not get the benefit of blocking higher up in the midhumeral or at the level of elbow.

INDICATIONS

Radial nerve blocks can be used for surgical anesthesia along the distribution of the radial nerve in forearm and hand procedures, including incision and drainage, foreign body removal, and finger amputation. It also can be used in certain painful conditions, including radial tunnel syndrome and Wartenberg syndrome. It also can be used as a rescue block for a failed brachial plexus block.

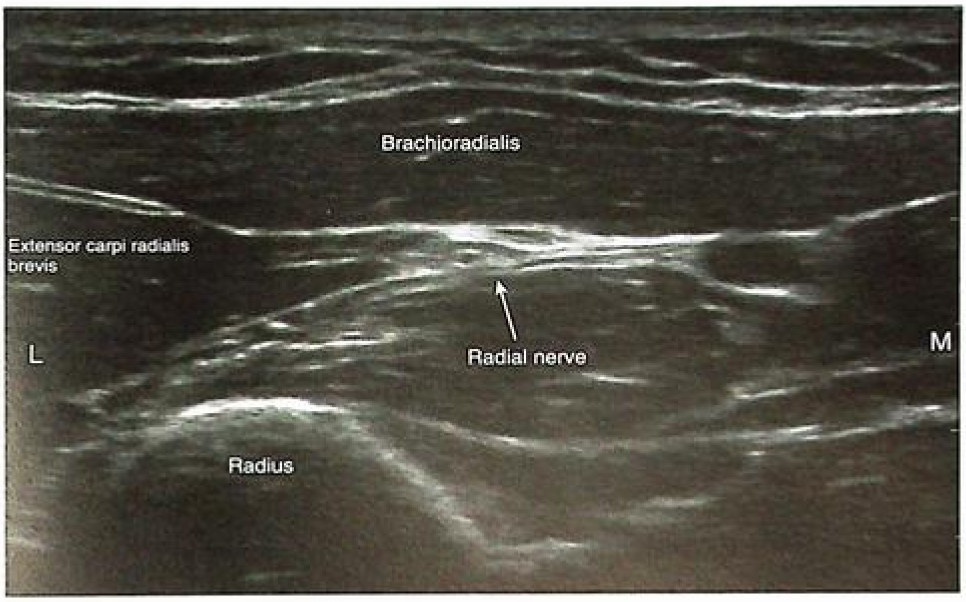

Fig. 13.4 Midforearm nerve blocks: radial nerve.

WRIST BLOCK

At the level of wrist (See Fig. 13.5)	Median nerve	Ulnar nerve	Radial nerve
Landmark technique *Position of wrist*: supine	Located between the tendons of the palmaris longus and the flexor carpi radialis. The palmaris longus is the most prominent of these two and present in 85% of the population. The median nerve is blocked by inserting the needle at 45 degrees to skin, 1–1.5 cm deep when a fascial click is felt. At this level, paresthesia (thumb or index finger) can be achieved, and 3–5 mL of LA is injected.	Located between flexor carpi ulnaris and ulnar artery. Blocked by inserting needle at a depth of 1-1.5 cm, insertion site is 5–10 mm away from the flexor carpi ulnaris tendon toward the radial border of the wrist, close to the ulnar styloid. 3–5 mL of LA is injected after achieving appropriate paresthesia.	LA is injected subcutaneously between the radial styloid and the midpoint of the dorsum of the wrist.
Ultrasound technique *Probe position*: transverse at level of wrist	The nerve appears as an oval, hypoechoic structure beneath the flexor retinaculum, confirmed by scanning proximally 5–10 cm. The needle is inserted in-plane and 3–5 mL of LA is injected in circumferential pattern.	The nerve appears as a triangular, hyperechoic structure medial to the ulnar artery. A hyperechoic ulnar bone shadow also is seen posteriorly. Following negative aspiration, 3–5 mL of LA is injected around the nerve.	At this level, a subcutaneous field block around the radial styloid process is used. This structure is identified as lateral to the radial artery.

DIGITAL BLOCK

The most common use of the digital block in the emergency room is to repair lacerations and drainage of digital abscesses. It can also be used in certain elective digital surgeries.

The nerves appear to traverse laterally on a cross section of a digit. The digital nerves are the distal continuations of both the median and ulnar nerves (Fig. 13.6). They provide anesthesia distal to the distal interphalangeal joint.

Many techniques for performing a digital nerve block have been described. With the hand pronated, the block is performed with a 27-gauge needle, slowly injecting laterally into base of digit—1 cm distal to web space, along the side of the periosteum. Angle the needle toward the palmar and dorsal surface and inject 1.5 to 2 mL of LA; visible small subcutaneous swelling is observed. Repeat on the opposite side.

PEARLS

- Caution should be observed when injecting LA into the olecranon fossa. The ulnar nerve is located in a confined, tight space at this location. To prevent intraneural injection, preferably use less than 5 mL.

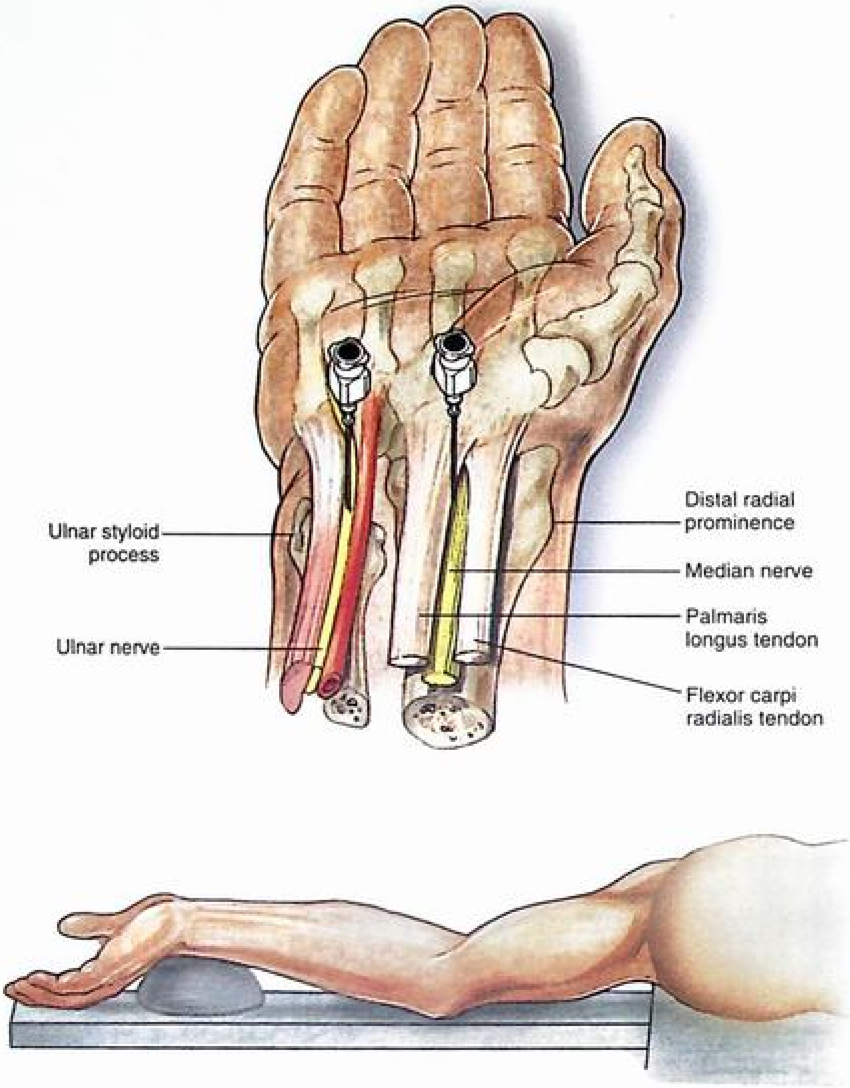

Fig. 13.5 Wrist nerve blocks: functional anatomy, needle insertion, and arm positioning.

of anesthetic, ensure that injection pressure is not high, and avoid overflexing the elbow.

- Color Doppler may be helpful in identifying and distinguishing the brachial artery and the radial nerve in the proximal third of the upper arm as well as the forearm.
- In morbidly obese patients, it can be difficult to identify individual nerves. Therefore we recommend determining the arterial location first and following its course, finally confirming the location of the nerve with a peripheral nerve stimulator.
- Inadvertent vascular injection can be avoided by applying firm pressure to the vascular structure via a transducer.
- When using an out-of-plane technique, injecting a small amount of normal saline may be helpful in determining location of tip of needle.
- At times, the median nerve can be confused with the muscle tendon; asking the patient to flex fingers and wrist may be helpful in distinguishing.
- Advantages of blocking terminal nerves 5 to 10 cm proximal to wrist—more room for maneuverability, wider coverage can be ensured by additional blockage of the palmar branches of the median and ulnar nerves, and the risk of neurapraxia may be reduced by avoiding injection in tight structures at the wrist.
- Never use LA with epinephrine for digital nerve blocks. Digital arteries are end arteries and may cause ischemia and potentially necrosis.

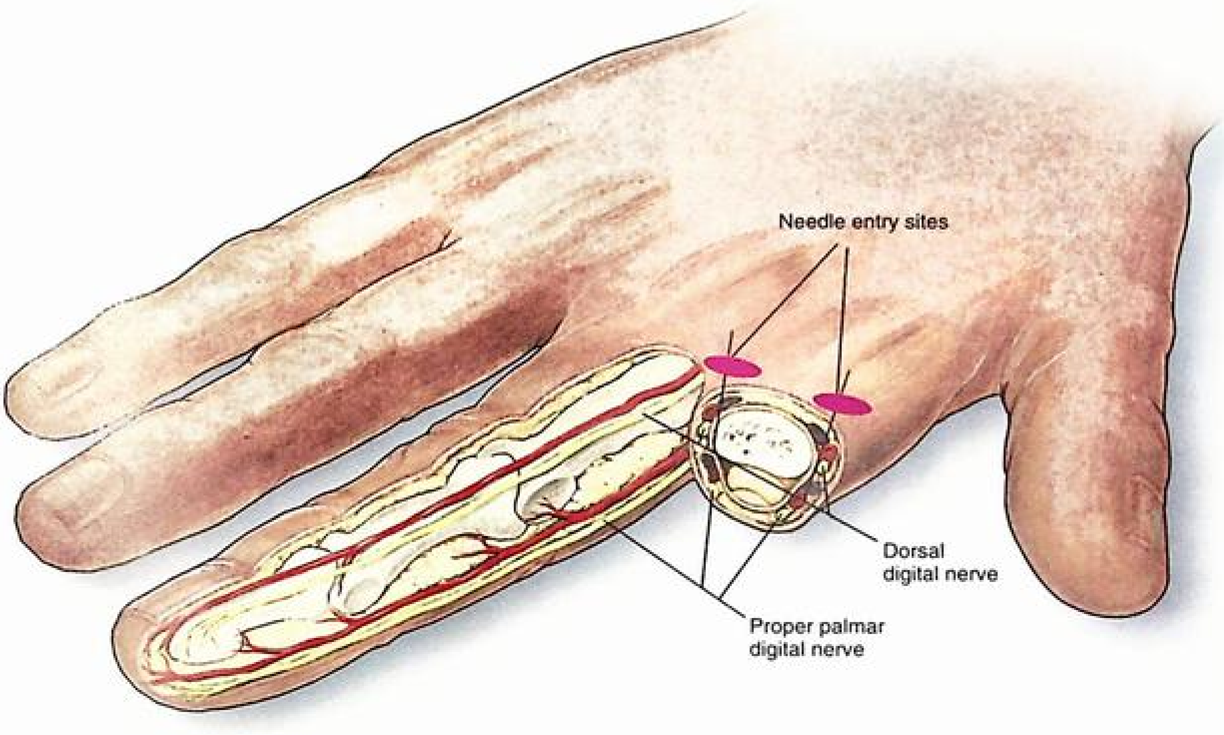

Fig. 13.6 Digital nerve block: anatomy and needle insertion.

Suggested Reading

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Intravenous Regional Block

14

David L. Brown and Ehab Farag

Key Points

- Intravenous (IV) regional anesthesia is usually achieved using dilute lidocaine 0.5%; 50 mL of prilocaine has also been used successfully.
- The IV regional block is useful for procedures lasting 90 to 120 minutes. This time limit is due to tourniquet time constraints rather than diminution of the local anesthetic effect.

PERSPECTIVE

Intravenous (IV) regional anesthesia was introduced by Bier in 1908. As illustrated in Fig. 14.1, in the initial description, a surgical procedure was required to cannulate a vein, and both proximal and distal tourniquets were used to contain the local anesthetic in the venous system. After its introduction, the technique fell into disuse until the less-toxic amino amides became available in the mid-20th century. This technique can be used for a variety of upper extremity operations, including both soft tissue and orthopedic procedures, primarily in the hand and forearm. The technique has also been used for foot procedures with a calf tourniquet.

Patient Selection. The technique is best suited for patients in whom there is no disruption of the venous system of the involved upper extremity, because the technique relies on an intact venous system. It can be used for distal orthopedic fractures and soft tissue operations. IV regional block may not be appropriate for patients in whom movement of the upper extremity causes significant pain, because movement of the upper extremity is required to exsanguinate blood adequately from the venous system.

Pharmacologic Choice. The most commonly used agent for IV regional anesthesia is a dilute concentration of lidocaine; however, prilocaine has also been used successfully. Lidocaine is used in a 0.5% concentration; approximately 50 mL is used for an upper extremity IV regional block.

PLACEMENT

Anatomy. The only anatomic detail necessary for clinical use of the IV regional block is the identification of a peripheral vein; one must be cannulated in the involved extremity.

Position. The patient should be resting supine on the operating table with an IV tube already established in the nonsurgical arm. The involved arm should be extended on an arm board near available supplies (Fig. 14.2).

Needle Puncture. Before placement of the IV catheter in the operative extremity, a tourniquet, either double or single, should be placed around the upper arm of the patient. An IV cannula is then inserted in the operative extremity as distally as possible, most commonly in the dorsum of the hand (Fig. 14.3). There are two methods for exsanguinating the venous blood from the operative extremity. The traditional technique requires wrapping an Esmarch bandage from distal to proximal (Fig. 14.4). When the Esmarch bandage is not available or the patient is in too much pain to allow its placement, another method is to raise the arm for 3 to 4 minutes to allow gravity to exsanguinate the operative upper extremity (Fig. 14.5). After the blood has been exsanguinated from the upper extremity, the tourniquet is inflated. If a double tourniquet is used, only the upper tourniquet is inflated. Recommendations for tourniquet inflation pressures range from 50 mm Hg above systolic blood pressure with a wide cuff to a cuff pressure double the systolic blood pressure to 300 mm Hg, regardless of blood pressure. Until more information is available, I caution against using pressures greater than 300 mm Hg during upper extremity block.

If an Esmarch bandage has been used, the elastic bandage is then unwrapped, and in the average adult, 50 mL of 0.5% lidocaine without a vasoconstrictor is injected. The onset of the block usually occurs within 5 minutes; the block is effective for procedures lasting as long as 90 to 120 minutes. This time limit is due to tourniquet time constraints rather than diminution of the local anesthetic effect. The IV cannula is removed before preparation for operation. The block persists as long as the cuff is inflated and disappears shortly after deflation.

POTENTIAL PROBLEMS

The principal disadvantage of IV regional anesthesia is that physicians unfamiliar with treating local anesthetic toxicity may use the technique when appropriate resuscitation measures are not available. Although some workers report successful use of IV regional anesthesia for lower extremity surgery, especially if a calf tourniquet is used for foot surgery, its use is not widespread. During upper extremity use, a considerable number of patients complain about tourniquet pressure even

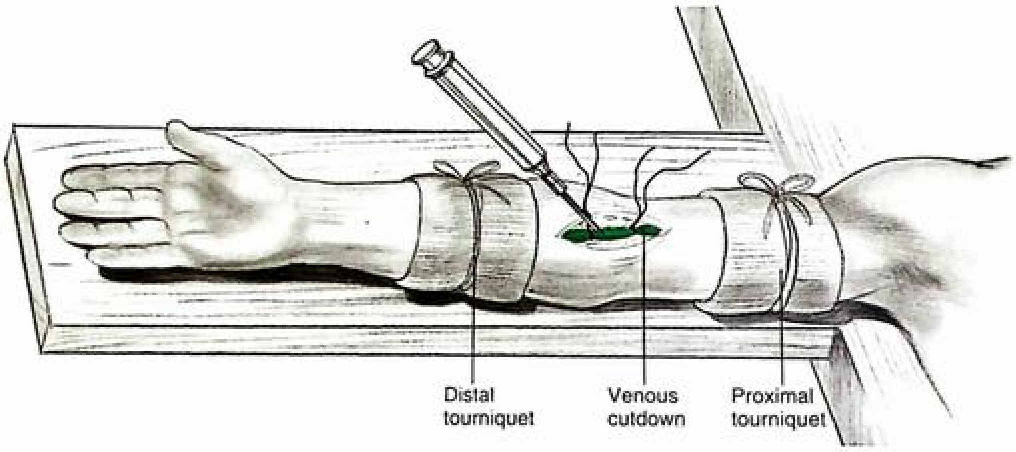

Fig. 14.1 Early Bier block: surgical technique.

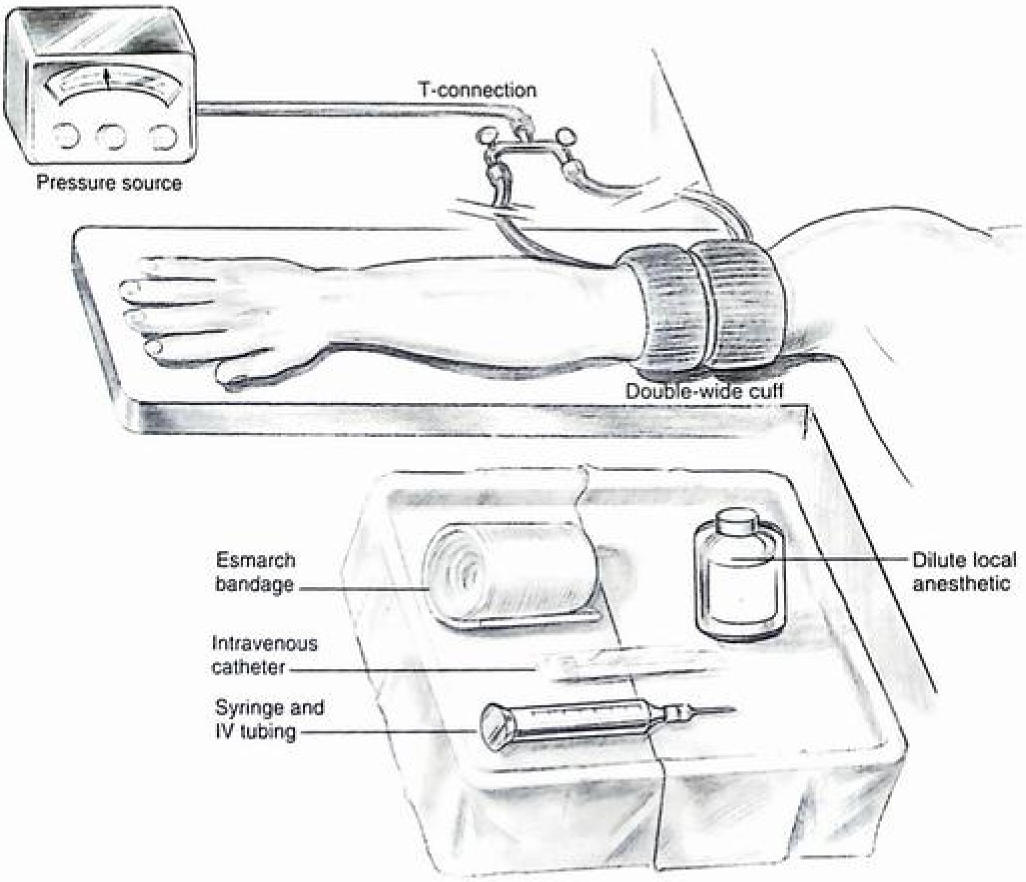

Fig. 14.2 Intravenous regional block: equipment.

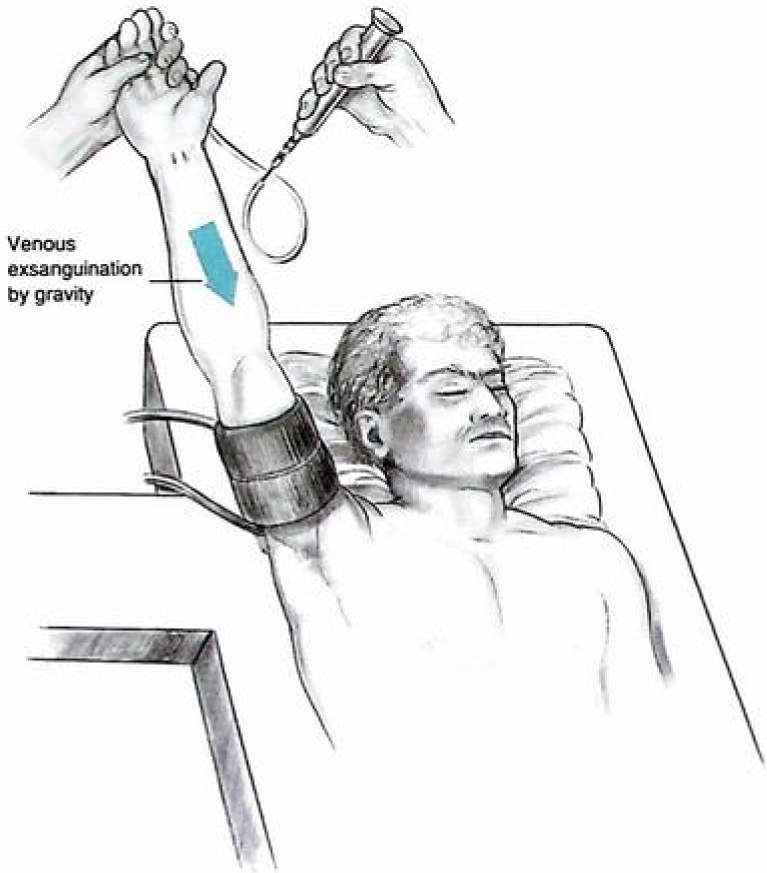

Fig. 14.5 Intravenous regional block: venous exsanguination by gravity.

when a double tourniquet is used, and this is often the clinically limiting feature of this technique. Appropriate use of IV sedatives is important for patient comfort.

PEARLS

Fig. 14.6 illustrates the two complementary theories of how IV regional anesthesia produces block. The figure conceptualizes local anesthetic entering the venous system and producing block by blocking the peripheral nerves running with the venous structures. It also outlines a theory that may be complementary—that is, the local anesthetic leaves the veins and blocks small distal branches of peripheral nerves. It is likely that both of these theories are operative. If IV regional anesthesia is to be used successfully, all members of the operating team should understand the importance of tourniquet integrity because the most significant problems with the technique involve unintentional deflation of the tourniquet.

Section 3
Lower Extremity Blocks

Lower Extremity Block Anatomy 15

Richard L. Drake

The lower extremity receives its innervation from two nerve plexuses. The lumbar plexus supplies nerves that primarily innervate the ventral aspect of the lower extremity, and the lumbosacral plexus supplies nerves that primarily innervate the dorsal aspect of the lower extremity.

LUMBAR PLEXUS

The lumbar plexus forms from the ventral rami of L1, L2, L3, and part of L4 (Fig. 15.1). This occurs anterior to the transverse processes of the lumbar vertebrae in the psoas major muscle. The upper portion of the plexus, L1, and usually a small portion of T12, splits into superior and inferior branches. The superior branch splits into the iliohypogastric and ilioinguinal nerves, while the inferior branch continues, unites with a small branch from L2, and forms the genitofemoral nerve. Arising from the lower portion of the plexus, L2, L3, and part of L4 are three major nerves—the lateral femoral cutaneous nerve, which provides cutaneous innervation to the lateral buttock distal to the greater trochanter and to the proximal two-thirds of the lateral thigh; the obturator nerve, which supplies the adductor muscles, the hip and knee joints, and the skin on the medial aspect of the thigh above the knee; and the femoral nerve, which supplies the muscles and skin of the anterior thigh, knee, and hip joints.

FEMORAL TRIANGLE AND FEMORAL SHEATH

The femoral triangle is a wedge-shaped depression formed by muscles in the upper thigh between the anterior abdominal wall and the lower limb (Fig. 15.2).

- The base of the triangle is the inguinal ligament.
- The medial border is the medial margin of the adductor longus muscle.
- The lateral border is the medial margin of the sartorius muscle.
- The floor is formed medially by the pectineus and adductor longus muscles and laterally by the iliopsoas muscle.
- The apex of the triangle points inferiorly and is continuous with the adductor canal.

The femoral nerve, artery, vein, and lymphatics pass between the abdomen and lower limb, under the inguinal ligament, and into the femoral triangle (Fig. 15.3). From lateral to medial, the structures in the femoral triangle are the femoral nerve, femoral artery, femoral vein, and lymphatic vessels.

In the femoral triangle, the femoral artery and vein and the lymphatic vessels are surrounded by a funnel-shaped sleeve of fascia—the femoral sheath (Fig. 15.3). It is continuous superiorly with the transversalis fascia and iliac fascia of the abdomen and merges inferiorly with the connective tissue associated with the vessels. The femoral nerve is lateral and is not contained in the femoral sheath.

RELATIONSHIP—FASCIA ILIACA, FASCIA LATA, AND THE FEMORAL NERVE

Fascia iliaca—this fascia is simply the fascial layer covering the anterior surface of the iliacus muscle, which is a large, triangular-shaped muscle covering the inner surface of the ilium (Fig. 15.4). The iliacus muscle is associated with the posterior abdominal wall and joins the psoas major muscle, forming the iliopsoas muscle as it descends into the anterior compartment of the thigh under the inguinal ligament. The nerves deep to the fascia iliaca are the femoral, obturator, and lateral femoral cutaneous nerves.

Fascia lata—the outer layer of deep fascia in the lower limb forms a stocking like membrane covering the limb beneath the superficial fascia (Fig. 15.5A and B). This fascia is thickened in the thigh and is termed the fascia lata. Its line of attachment superiorly, the inguinal ligament and pubic bone, defines the upper margin of the lower limb, and it is continuous inferiorly with the deep fascia of the leg.

HIP JOINT INNERVATION

The hip joint is innervated by nerves arising from both the lumbar and the lumbosacral plexus (Fig. 15.1). The femoral, obturator, and accessory obturator nerves, branches of the lumbar plexus, supply the anterior capsule. Similarly, the sciatic and superior gluteal nerves, and nerve to the quadratus femoris, branches of the lumbosacral plexus, supply the posterior capsule.

ADDUCTOR CANAL

Beginning at the apex of the femoral triangle, the adductor (or subsartorial) canal continues down the medial side of the thigh (Fig. 15.6). It is bounded anterolaterally by the

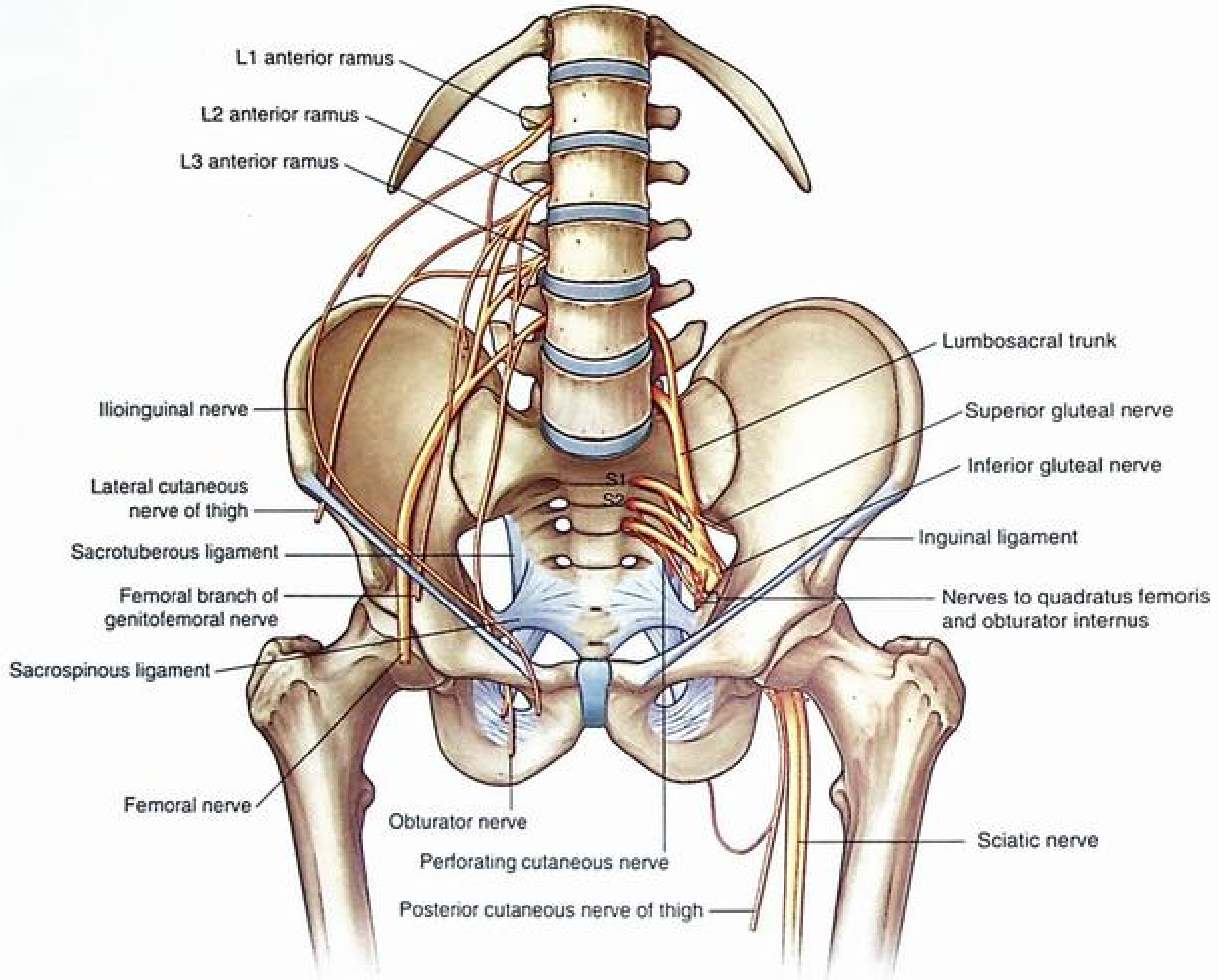

Fig. 15.1 The branches of the lumbosacral plexus. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

vastus medialis, posteromedially by the adductor longus, and distal to this muscle by the adductor magnus. The anteromedial boundary, or roof, is a strong, dense fascia extending from the medial surface of the vastus medialis to the medial edge of the adductor longus and magnus, covering the femoral vessels. This fascia, being covered by the sartorius muscle, is sometimes called the subsartorial fascia. The canal continues, moving posteriorly, to pass through an opening in the lower end of the adductor magnus muscle to enter the popliteal fossa behind the knee (Fig. 15.7).

SUBSARTORIAL PLEXUS

The subsartorial plexus forms at the lower border of the adductor longus muscle, where the anterior branch of the obturator nerve sends branches that join with the medial femoral cutaneous and saphenous branches of the femoral nerve, forming the subsartorial plexus. This plexus innervates the skin on the medial side of the thigh (Fig. 15.8).

KNEE JOINT INNERVATION

Similar to the hip joint, the knee joint is also innervated by branches of the lumbar plexus and the lumbosacral plexus. Muscular branches from the femoral nerve supply articular branches, while an articular branch from the obturator nerve is a terminal branch. Similarly, genicular branches from the tibial and common fibular nerves accompany genicular arteries into the joint.

CLINICAL CORRELATIONS

LUMBAR PLEXUS BLOCK

This block is appropriate for hip surgeries and surgeries above the knee. The lumbar plexus block is based on the idea that local anesthetic injected near the femoral nerve will follow the fascial plane between the anterior two-thirds of the psoas major muscle and the posterior one-third of this muscle, reaching the area of the roots of the lumbar plexus (Fig. 15.9). Using this approach, the three major branches of the lumbar plexus (the femoral, obturator, and lateral femoral cutaneous nerves) will be affected.

FEMORAL BLOCK

This block is a useful block for procedures involving the superficial and deep anterior thigh, hip joint replacement,

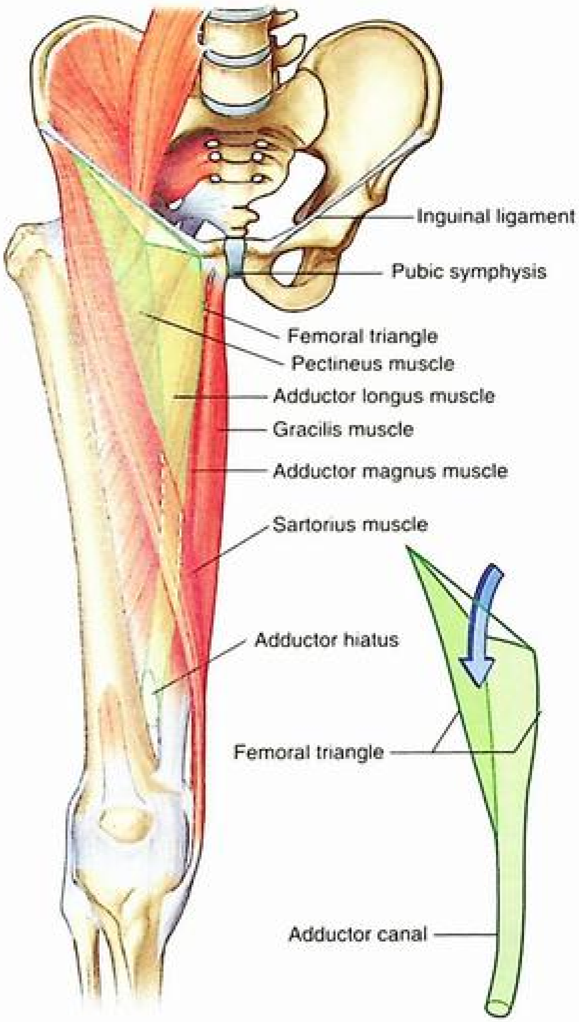

Fig. 15.2 The boundaries of the femoral triangle. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

knee joint surgeries, and fractures of the neck and shaft of the femur. It may be used with other lower limb blocks for operations on the leg and foot. The femoral nerve passes through the pelvis in a groove anterior to the iliacus and psoas major muscles and deep to the iliacus fascia (Fig. 15.9). The injection should be made into this groove. The femoral nerve continues in this groove, passing into the thigh under the inguinal ligament and lateral to the femoral vessels.

FASCIA ILIACA COMPARTMENT BLOCK

This block provides a sensory block covering the medial, anterior, and lateral thigh and can be used instead of the lumbar plexus block. It targets the femoral, obturator, and lateral femoral cutaneous nerves, which lie in the iliac fascia. The suprainguinal approach seems to result in increased cranial spread of the anesthetic compared with the traditional infrainguinal procedure.

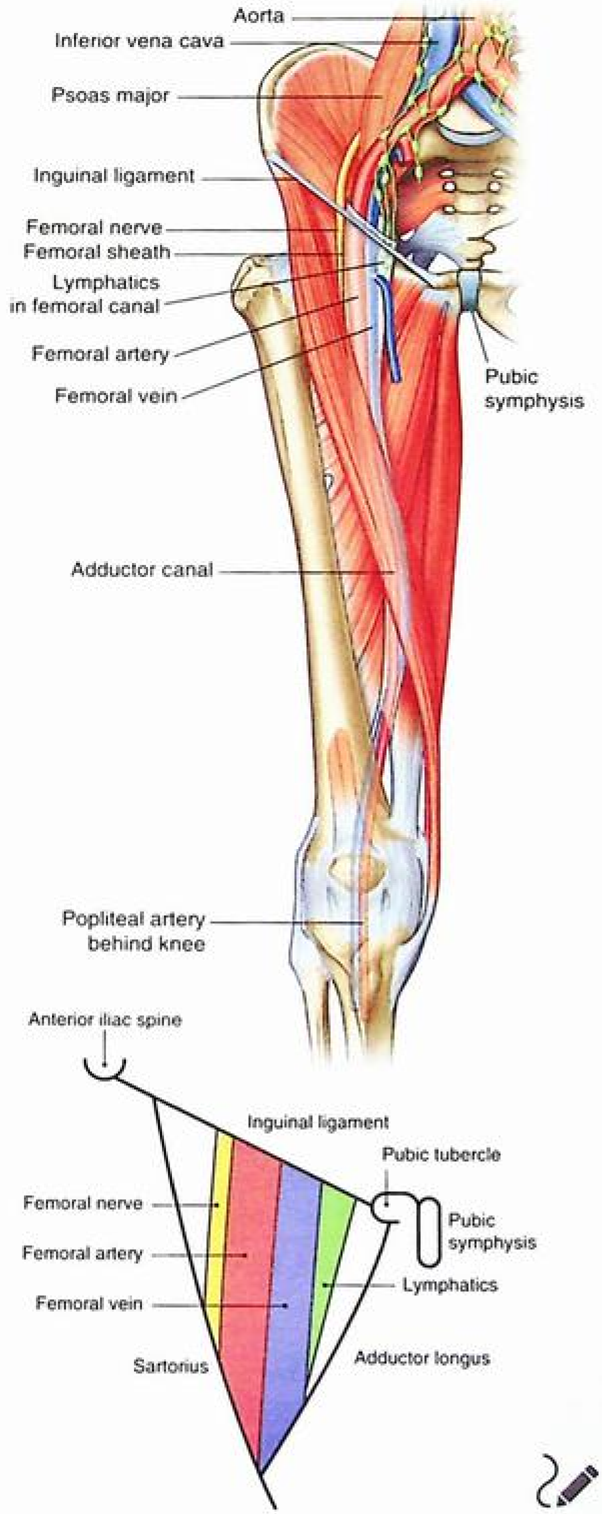

Fig. 15.3 The contents of the femoral triangle. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

INGUINAL REGION BLOCK

The targets of this superficial block are the ilioinguinal and iliohypogastric nerves, which supply the inguinal region. It is usually given between the anterior abdominal wall

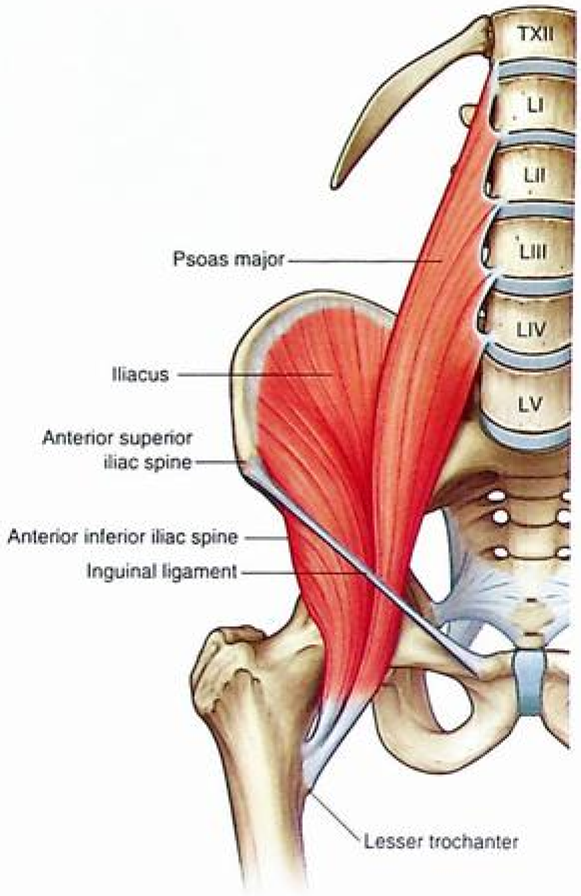

Fig. 15.4 The psoas major and iliacus muscles. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

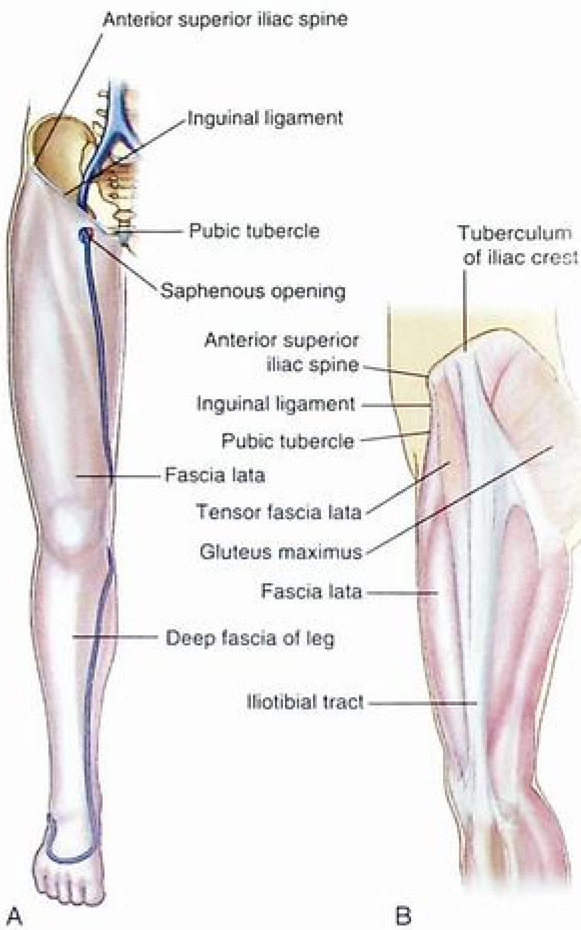

Fig. 15.5 The fascia lata. (A) Right limb, anterior view. (B) Lateral view. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

muscle layers medial and inferior to the anterior superior iliac spine. This block provides for anesthesia of the groin and may be combined with other blocks affecting the iliohypogastric and genitofemoral nerves.

LATERAL FEMORAL CUTANEOUS NERVE BLOCK

This superficial block is used to relieve pain postoperatively following hip surgery and upper lateral thigh skin grafting. Combined with other lower limb blocks, it decreases discomfort during lower limb procedures. The target of this block is the purely sensory lateral femoral cutaneous nerve. This nerve exits the pelvis under the inguinal ligament medial to the anterior superior iliac spine and supplies the skin on the anterolateral and lateral thigh (Fig. 15.1).

OBTURATOR BLOCK

Combined with the femoral, lateral femoral cutaneous, and sciatic blocks, this block is used during surgical procedures on the lower limb. It can also be used to relieve hip pain. The obturator nerve passes over the pelvic brim, continues along the lateral wall of the pelvis, and exits the pelvis through the obturator foramen (Fig. 15.9). At this point, the nerve immediately divides into anterior and posterior branches (Fig. 15.8). In the thigh, the anterior branch continues toward the knee between the adductor longus and the adductor brevis muscles, while the posterior branch continues toward the knee between the adductor brevis and adductor magnus muscles. The injection point is just lateral and inferior to the pubic tubercle, and success of the block depends on the spread of anesthetics in the fascial planes superficial and deep to the adductor brevis muscle.

SAPHENOUS BLOCK

The saphenous block is an additional block used for foot and ankle surgeries. Two possible approaches are used when administering this block. In one procedure, the injection is placed just distal to the medial surface of the tibial condyle, while in the second approach, the needle is inserted medially at the superior level of the patella, deep to the sartorius muscle and in the plane between the sartorius and vastus medialis muscles (Fig. 15.10).

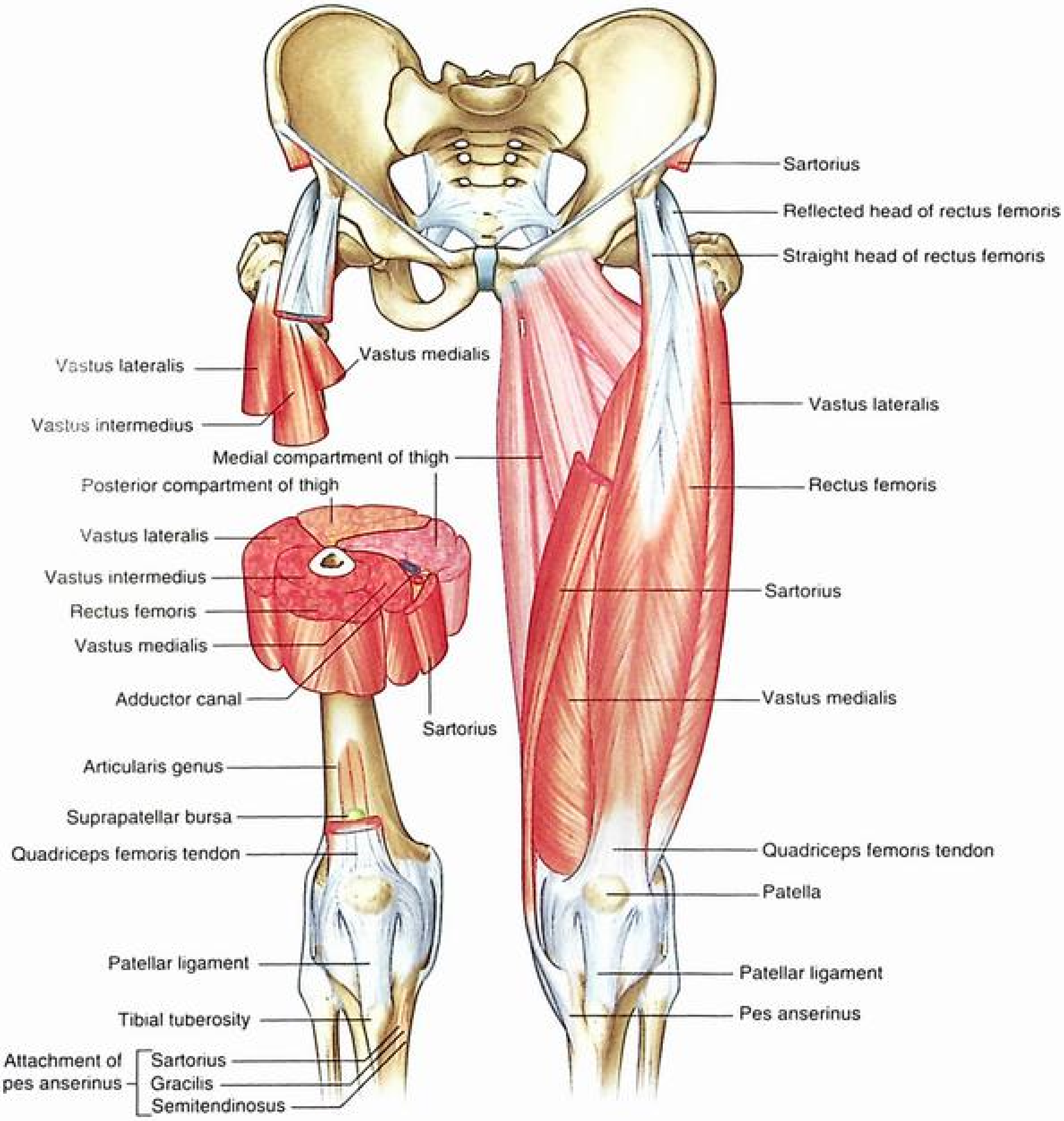

Fig. 15.6 The muscles of the anterior compartment of thigh. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier, 2020.)

ADDUCTOR CANAL BLOCK

This block is thought to be the most effective and straightforward when blocking the saphenous nerve is the goal. Traveling in the adductor canal, the saphenous nerve is sensory to the medial, anteromedial, and posteromedial regions of the lower limb from the distal thigh to the medial malleolus (Fig. 15.10). Leaving the adductor canal, it gives off an infrapatellar branch before continuing inferiorly along the medial tibial border with the saphenous vein, providing sensory innervation to the medial aspect of the leg, ankle, and foot. The injection point for this block is the midthigh, halfway between the anterior superior iliac spine and the patella.

LUMBOSACRAL PLEXUS

The lumbosacral plexus forms from the ventral rami of L4, L5, S1, S2, and S3. The major nerve coming from this plexus is the sciatic nerve (Fig. 15.11). It consists of two major trunks, the tibial nerve and the common fibular (peroneal) nerve, which both continue into the leg and foot. The division of the sciatic nerve usually occurs at the superior border of the popliteal fossa but can occur within the pelvis (Fig. 15.12). The tibial nerve innervates all of the muscles in the posterior compartment of the thigh, except for the short head of the biceps femoris muscle, the muscles in the posterior compartment of the leg, and the sole of the foot, except for the first two dorsal interossei

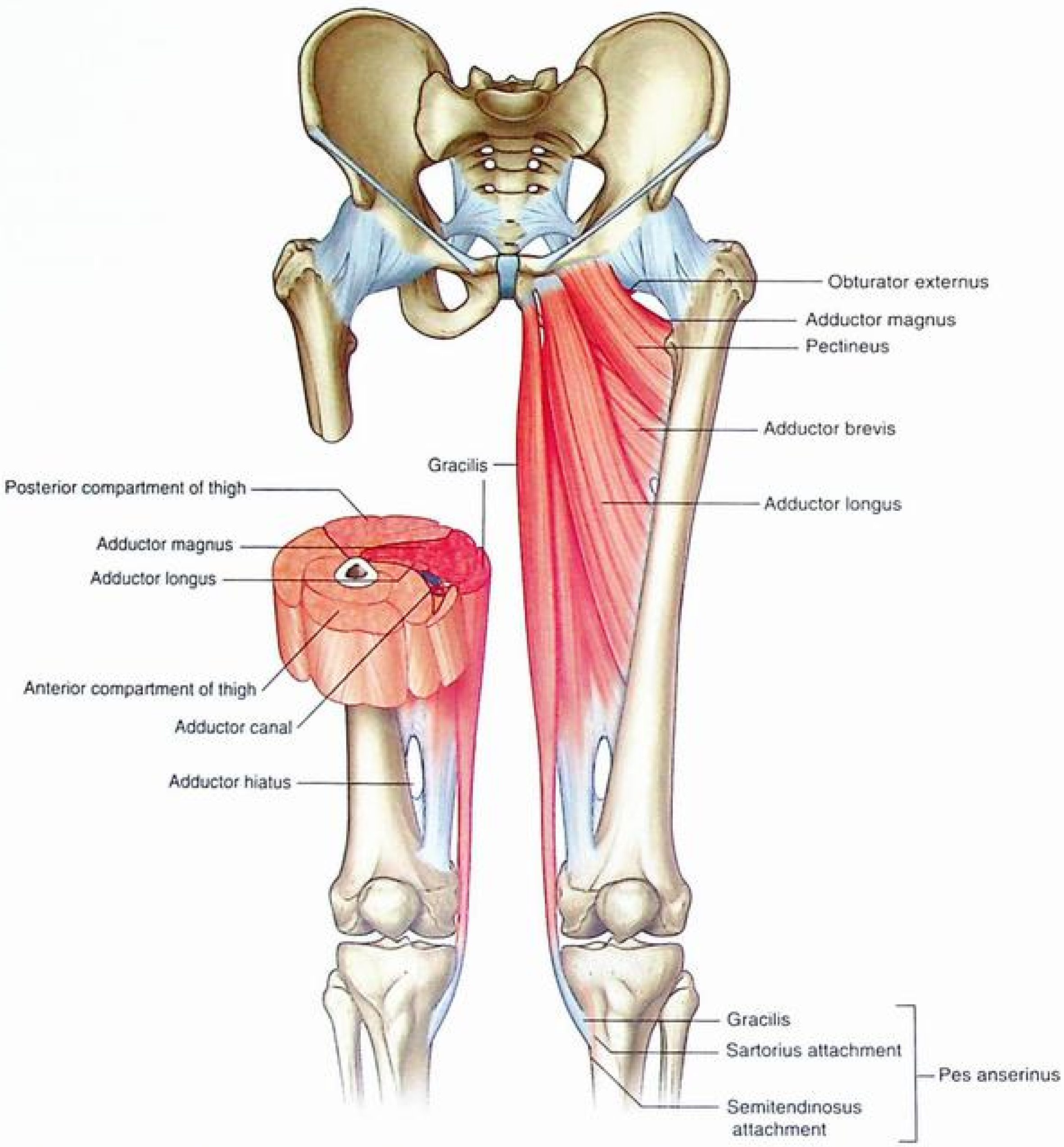

Fig. 15.7 The muscles of the medial compartment of thigh. Anterior view. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

muscles. It also innervates the skin on the posterolateral side of the lower half of the leg; on the lateral side of the ankle, foot, and little toe; and on the sole of the foot and the toes. The common fibular nerve innervates the short head of the biceps femoris muscle in the posterior compartment of the thigh, all the muscles in the anterior and lateral compartments of the leg, the extensor digitorum brevis on the dorsal aspect of the foot, the first two dorsal interossei muscles in the sole of the foot, and the skin on the lateral aspect of the leg and ankle and over the dorsal aspect of the foot and toes.

ANKLE JOINT INNERVATION

Innervation of the ankle joint involves a variety of nerves. Branches from the deep fibular, saphenous, sural, and tibial (or medial and lateral plantar nerves) and sometimes a branch from the superficial fibular all contribute to the innervation of this complex joint.

CLINICAL CORRELATIONS

SCIATIC BLOCK

Since few surgical procedures of the lower extremity can be performed using the sciatic block alone, it is usually combined with femoral, obturator, or lateral femoral cutaneous blocks. Additionally, combining this block with the lumbar plexus block provides the anesthesia necessary for all lower limb procedures. Injection approaches commonly used for the sciatic block are the subgluteal and midthigh.

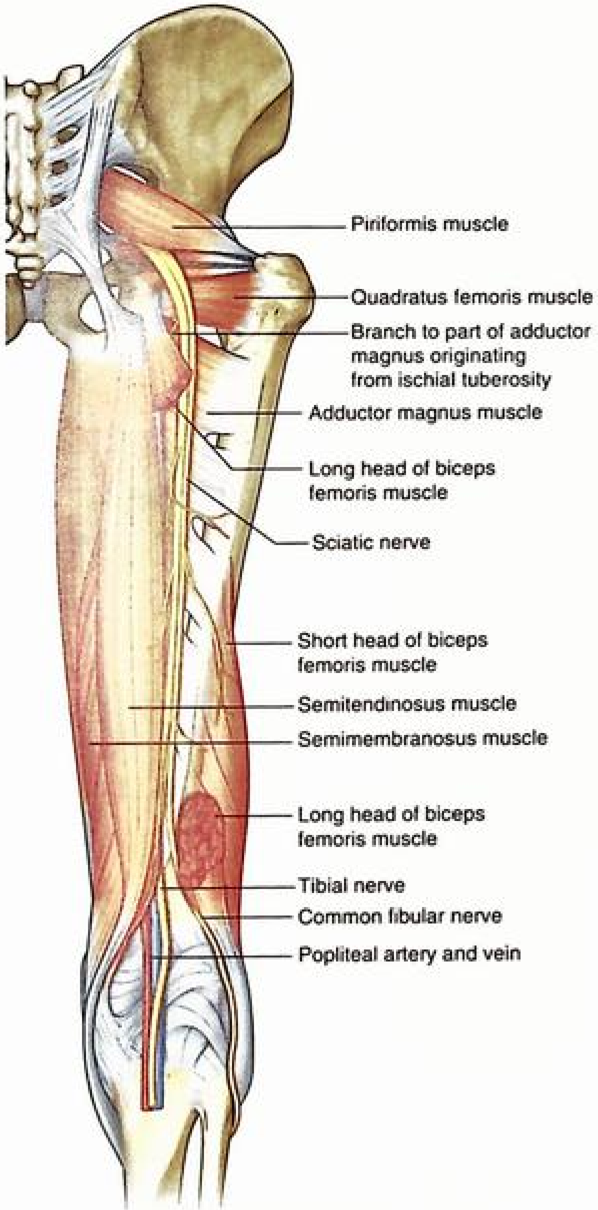

Fig. 15.8 The sciatic nerve. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

POPLITEAL BLOCK

This block, used for distal leg, foot, and ankle surgeries, is administered in the upper lateral quadrant of the popliteal fossa (Fig. 15.12). As the sciatic nerve enters the fossa, it quickly divides into the tibial and common fibular (peroneal) nerves. The goal is to block the sciatic nerve before it divides. A saphenous block can also be included, which improves patient comfort.

ANKLE BLOCK

The ankle block is primarily used for surgical procedures on the foot. The nerves blocked in this procedure are the terminal branches of the tibial division of the sciatic nerve, the posterior tibial and sural nerves, and the terminal branches of the common fibular (peroneal) division of the sciatic nerve, the superficial and deep fibular (peroneal) nerves (Fig. 15.13). The femoral nerve also supplies its terminal branch, the saphenous nerve. Since these five nerves supply superficial and deep structures, the usual approach is to block the nerves traveling beneath the deep fascia first, the posterior tibial and deep fibular (peroneal), then block the nerves in the superficial fascia, the sural, superficial fibular (peroneal), and the saphenous.

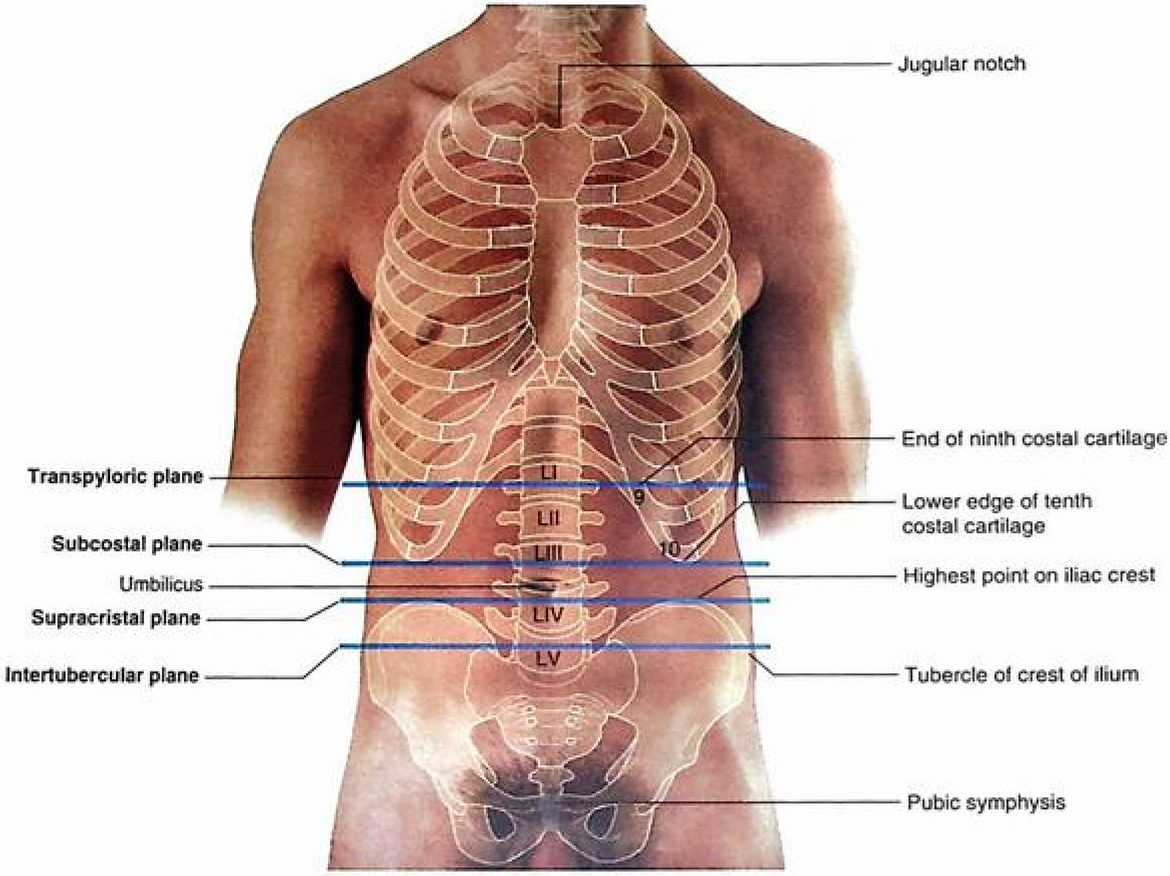

Fig. 15.9 The landmarks used for establishing the positions of the lumbar vertebrae are indicated. Anterior view of the abdominal region of a man. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

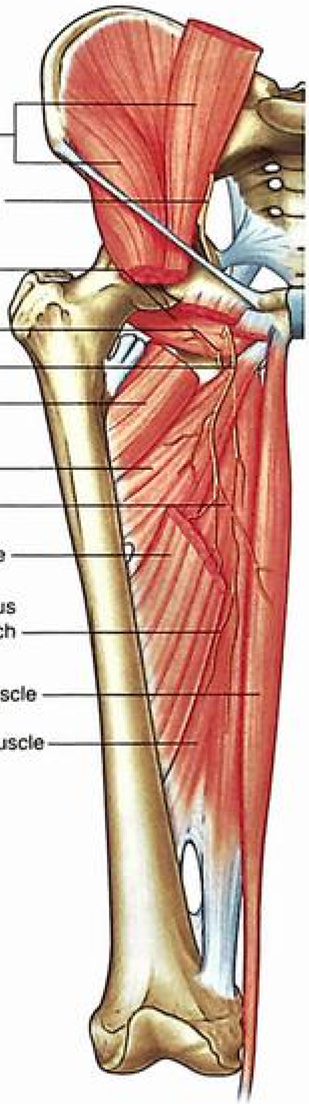

Fig. 15.10 The obturator nerve. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

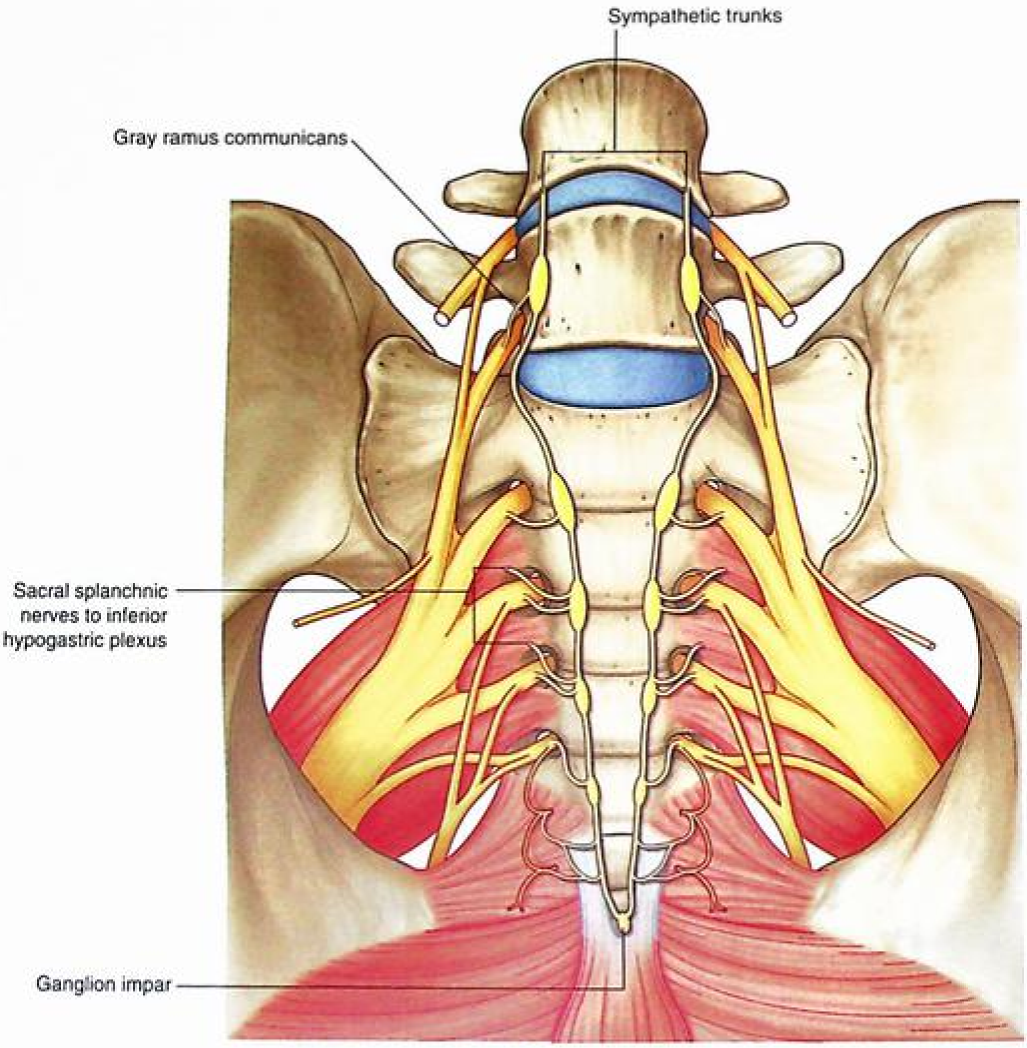

Fig. 15.11 **The sympathetic trunks in the pelvis.** (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

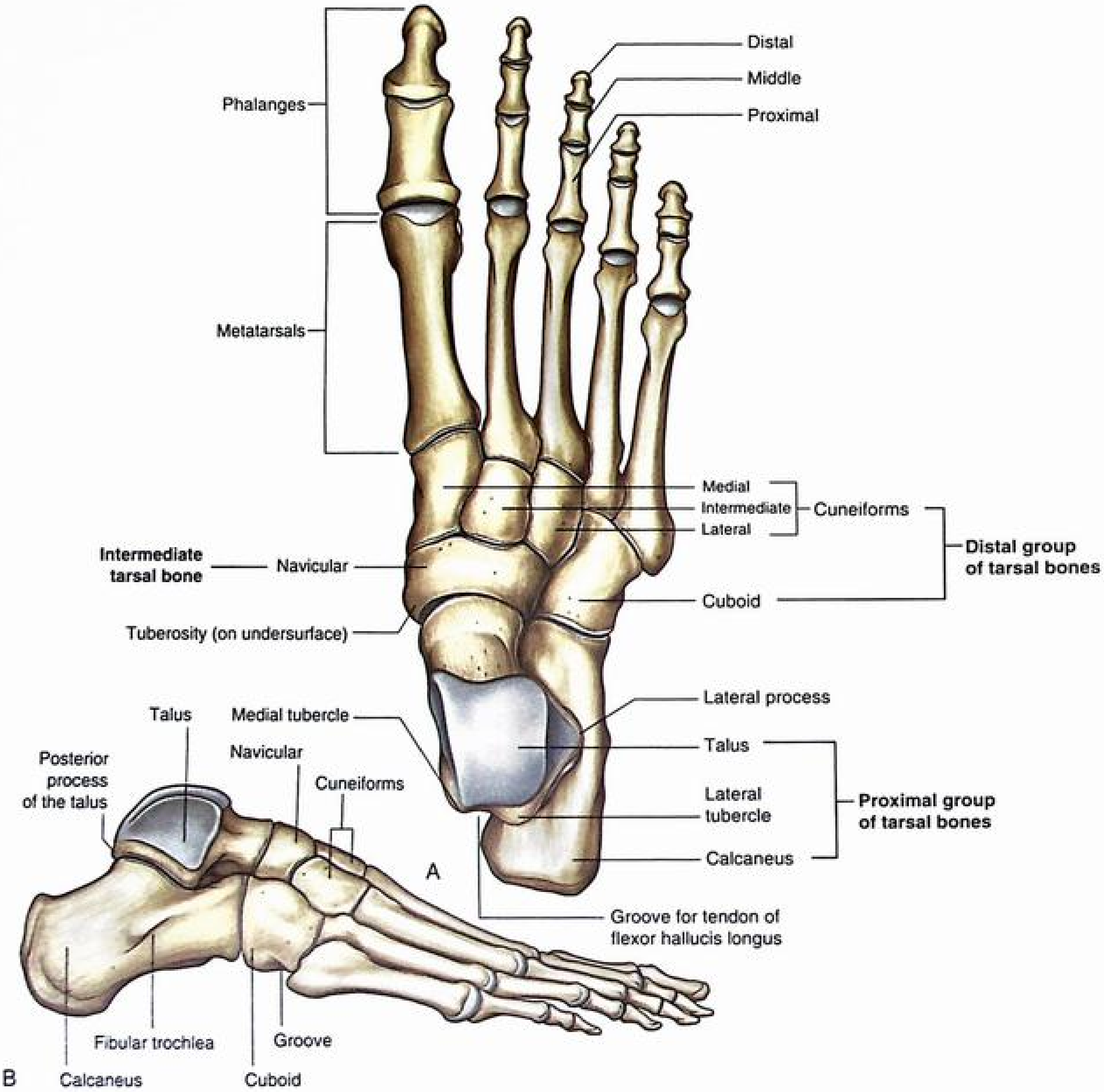

Fig. 15.13 The bones of the foot. (A) Dorsal view, right foot. (B) Lateral view, right foot. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

16 Lumbar Plexus Block

Loran Mounir-Soliman and David L. Brown

Key Points

- The lumbar plexus block is a deep block that makes it difficult to appreciate the difference in the echogenicity of the anatomic structures, especially in obese and elderly patients.
- The use of nerve stimulation is necessary to identify the lumbar plexus.
- Identification of small lumbar arteries is hard to visualize at deeper scan, and the block should be avoided in patients with coagulation disorders or who are at risk of bleeding.
- The spread of local anesthetic (LA) at the posterior surface of the psoas muscle is satisfactory.

INGUINAL PERIVASCULAR BLOCK (THREE-IN-ONE BLOCK)

PERSPECTIVE

The inguinal perivascular block is based on the concept of injecting LA near the femoral nerve in an amount sufficient to track proximally along fascial planes to anesthetize the lumbar plexus. The three principal nerves of the lumbar plexus pass from the pelvis anteriorly: the lateral femoral cutaneous, the femoral, and the obturator nerves. As illustrated in Fig. 16.1, the theory behind this block presumes that the LA will track in the fascial plane between the iliacus and the psoas muscles to reach the region of the lumbar plexus roots.

Patient Selection. As outlined, lower extremity block is often most effectively and efficiently performed with neuraxial blocks. Nevertheless, in some patients, avoidance of bilateral block or sympathectomy may make an alternative approach necessary.

Pharmacologic Choice. LAs should be selected by deciding whether a primarily sensory or a sensory and motor block is needed. Any of the amino amides can be used. It has been suggested that the volume of LA needed for an adequate lumbar plexus block from this approach can be estimated by dividing the patient's height in inches by three. That number is the volume of LA in milliliters that theoretically will provide lumbar plexus block.

PLACEMENT

Anatomy. The concept behind this block is that the only anatomy one needs to visualize is the extension of sheath like fascial planes that surround the femoral nerve.

Position. The patient should be placed supine on the operating table, with the anesthesiologist standing at the patient's side in position to palpate the ipsilateral femoral artery.

Needle Puncture. A short-beveled, 22-gauge, 5-cm needle is inserted immediately lateral to the femoral artery, caudal to the inguinal ligament in the lower extremity to be blocked. It is advanced with cephalad angulation until femoral paresthesia occurs. Alternatively, nerve stimulation or ultrasonographic guidance is used to identify the correct perineural location of the needle tip. At this point, the needle is firmly fixed and, while the distal femoral sheath is digitally compressed, the entire volume of LA is injected.

POTENTIAL PROBLEMS

Our clinical experience suggests that the principal problem with this technique is a lack of predictability. In addition, whenever a large volume of LA is injected through a fixed "immobile" needle, the risk of systemic toxicity is increased. If the technique is used, incremental injection of LA, accompanied by frequent aspiration for blood, should be carried out.

PEARLS

This block should be used when the goal is lower extremity analgesia, not anesthesia during an operation. We do not believe one needs to master this technique to provide comprehensive regional anesthesia care.

PSOAS COMPARTMENT BLOCK

PERSPECTIVE

In theory, the psoas compartment block produces block of all lumbar and some sacral nerves, thus providing anesthesia of the anterior thigh. Based on the anatomical site and

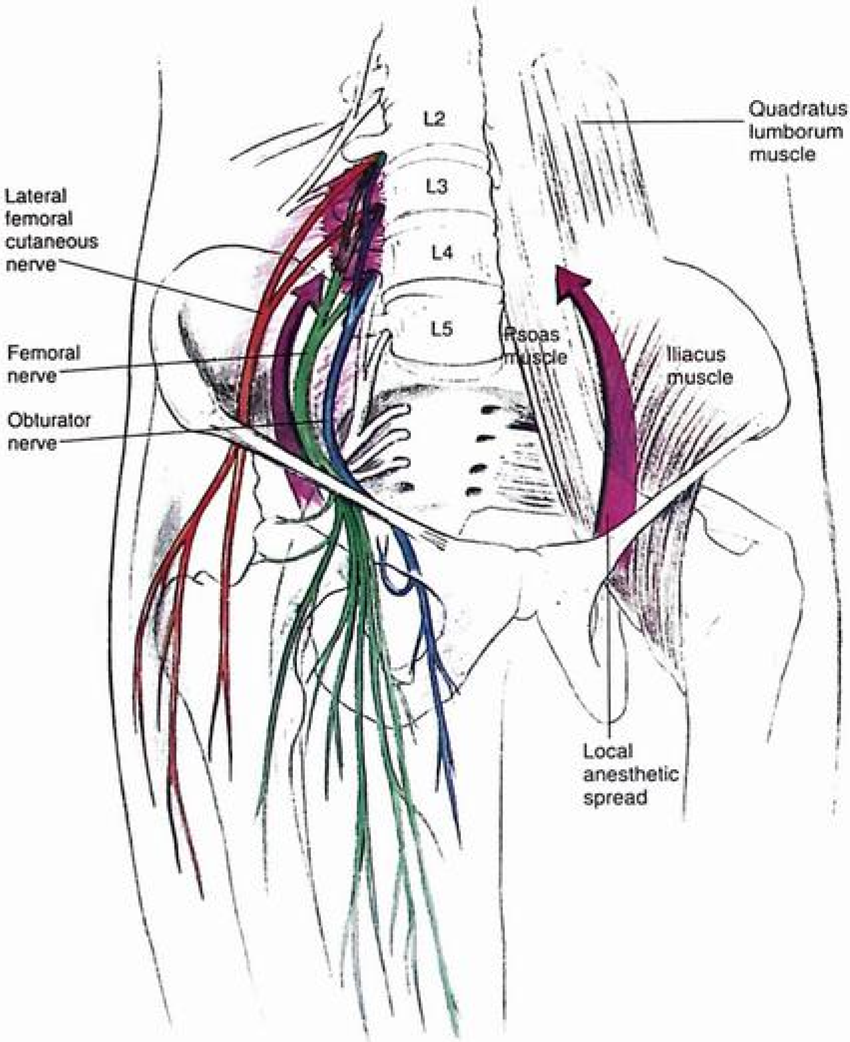

Fig. 16.1 Lumbar plexus anatomy: proposed mechanism of proximal LA spread.

the expected end result of this block, it is sometimes described as a *lumbar paravertebral block*.

LUMBAR PLEXUS BLOCK

RELEVANT ANATOMY OF THE LUMBAR PLEXUS

The lumbar plexus is formed by the ventral rami of the first three lumbar nerves and the greater part of the ventral ramus of the fourth nerve. The first lumbar nerve, frequently supplemented by the 12th thoracic nerve, splits into an upper branch that divides into the iliohypogastric and ilioinguinal nerves. The lower branch unites with a branch from the second lumbar to form the genitofemoral nerve.

From the remains of the second lumbar nerve, the third and fourth nerves separate into ventral and dorsal divisions. The anterior divisions unite to form the obturator nerves, and the dorsal divisions form the lateral femoral cutaneous nerve and the larger femoral nerve.

The lumbar plexus and its branches are formed within the psoas major muscle, in front of the transverse processes of the lumbar vertebrae. The anterior two-thirds of the psoas muscle originate from the anterolateral aspect of the vertebral body, and the posterior one-third of the muscle originates from the anterior aspect of the transverse processes, creating a fascial plane between both compartments of the muscle that hosts the lumbar plexus.

It is important to appreciate that the lumbar plexus is located anterior to the transverse processes of the lumbar vertebrae and posterior (embedded in the post wall) of the psoas muscle. The erector spinae muscle covers the lumbar spine posteriorly medially and the quadratus lumborum muscle laterally.

Appreciation of the relationships among the different muscles and spinal anatomy, as well as the sonographic characteristics of these structures, is crucial to perform the block.

TECHNIQUE

The lumbar plexus block is a deep block that requires a lower-frequency (2–5 MHz), curvilinear ultrasound probe.

A 4- to 6-inch (10–15 cm) needle is used, depending on body habitus. Two techniques to perform the block are described.

Paramedian Longitudinal Scanning Technique

With the patient in the prone position (this can also be performed in the lateral position with the side blocked upward), the ultrasound probe is placed parallel to the long axis of the sacrum to identify its flat surface. The probe is moved cephalad to identify the intervertebral space between L5 and S1 as an interruption of the sacral line continuity. The probe is moved 3 to 4 cm laterally (keeping the same orientation) to identify the transverse process of L5. The transverse processes of the other lumbar vertebrae are identified by cephalad scan in ascending order. The acoustic shadow of the transverse processes has a characteristic appearance, often referred to as a *trident sign*.

The psoas muscle is imaged through the acoustic windows between the hyperechoic shadows of the transverse processes. The lumbar plexus can be identified as hyperechoic striations in the posterior wall of the psoas muscle. However, appropriate identification of the plexus is confirmed by inducing quadriceps contraction or adduction when applying nerve stimulation to the insulated needle. The needle can be introduced using both the in-plane and out-of-plane techniques in the middle of the probe or using the in-plane technique from the lower edge of the probe (Fig. 16.2A–D, Video 16.1).

Transverse Oblique Scanning Technique

This technique can be also used in the prone or lateral position with the side blocked up. The L3 to L4 transverse processes are identified by the same technique described earlier (scanning from the sacrum upward). Once identified, the ultrasound probe is rotated horizontally parallel to the transverse processes. Next, it is directed slightly medially to scan the midline structures (transverse oblique orientation). The target structures of the ultrasound beam are:

- Quadratus lumborum (lateral) and erector spinae muscles (medial).
- Deeper to the muscles, the transverse processes of L3 to L4 and the anterolateral surface of the vertebral bodies can be scanned as hyperechoic structures with underlying drop-down shadows.
- The psoas muscle appears slightly hypoechoic, with multiple hyperechoic striations deeper to the transverse processes.
- Slowly adjust the probe in the acoustic window between the transverse processes, allowing for visualization of the intervertebral foramen, and the

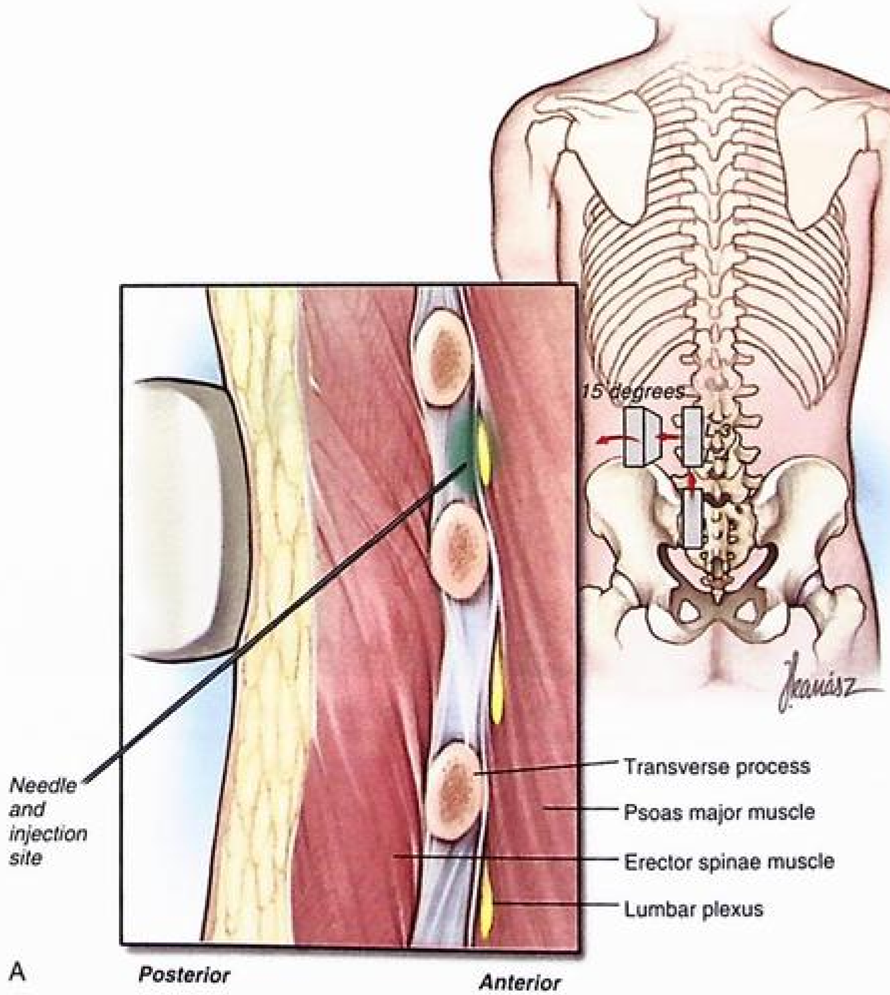

Fig. 16.2 (A) Anatomy of the paramedian longitudinal technique for lumbar plexus block.

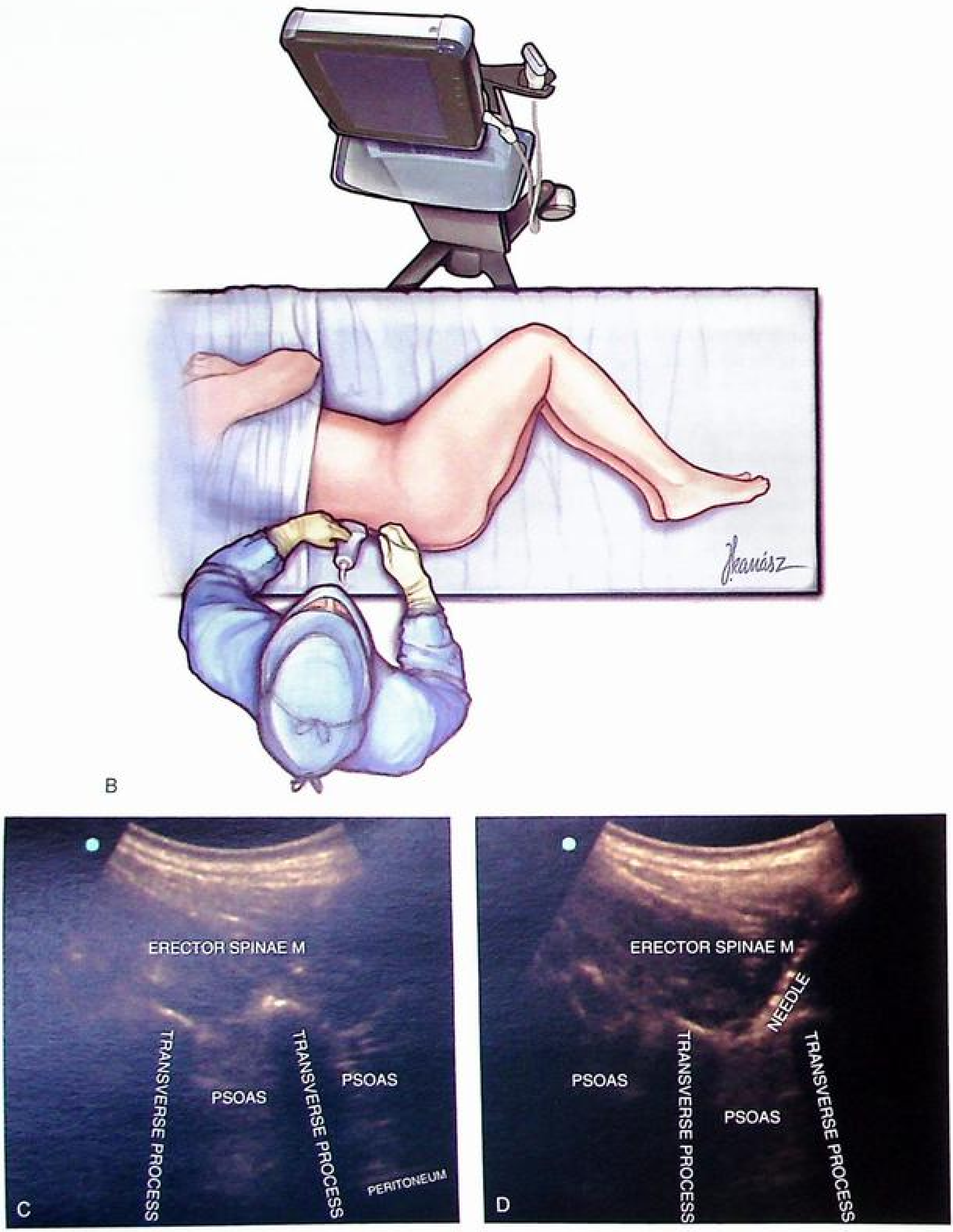

Fig. 16.2, cont'd (B) Position of the patient and probe orientation for the paramedian longitudinal technique. Note the in-plane technique for the paramedian longitudinal approach. (C) and (D) Ultrasound images for the paramedian approach for the lumbar plexus that show the transverse processes, psoas muscle, and the needle position.

articular process facet joint with the roots of the lumbar plexus as it emerges from the intervertebral foramen. The roots appear as hyperechoic structures adjacent to the posterior wall of the psoas muscle.

The lumbar plexus is approached with the needle in the plane with the ultrasound beam from the lateral side of the probe (the approach from the medial side is also described), targeting the posterior border of the psoas muscle at the level of the intervertebral foramen. Using nerve stimulation is very helpful to confirm the proximity of the needle to the lumbar plexus and to avoid intramuscular injection where local psoas contraction is induced. Care should be taken to avoid advancing the needle too medially to reduce the risk of injury of the lumbar artery or its branches and to avoid spread of LA into the neuraxial space (Fig. 16.3A–D, Video 16.1).

INDICATIONS

- The lumbar plexus block is the most proximal approach to the lumbar plexus, providing the most reliable block of its major branches (femoral, obturator, and lateral femoral cutaneous nerves).
- The block is ideal for hip surgeries and surgeries above the knee.
- When combined with sciatic nerve block, it provides complete unilateral lower limb anesthesia, suitable for lower extremity surgeries.
- Continuous catheterization can be used for prolonged analgesia (Fig. 16.4).

PEARLS

- The lumbar plexus block is a technically advanced procedure with major potential for complications. Experience with ultrasound anatomy, scanning skills, and needle manipulations is necessary before attempting an ultrasound-guided lumbar plexus block.
- The lumbar plexus is embedded within the body of the psoas muscle; hence the name *psoas block* is synonymous with lumbar plexus block.

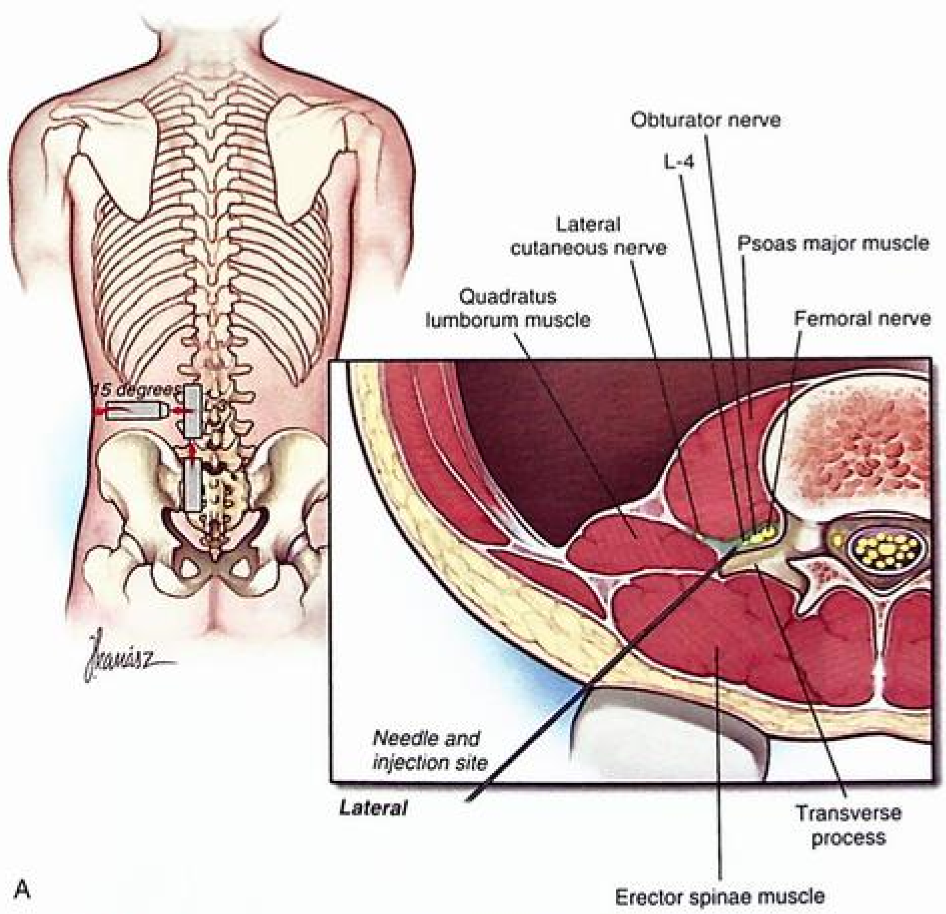

Fig. 16.3 (A) Anatomy of the transverse oblique technique for lumbar plexus block.

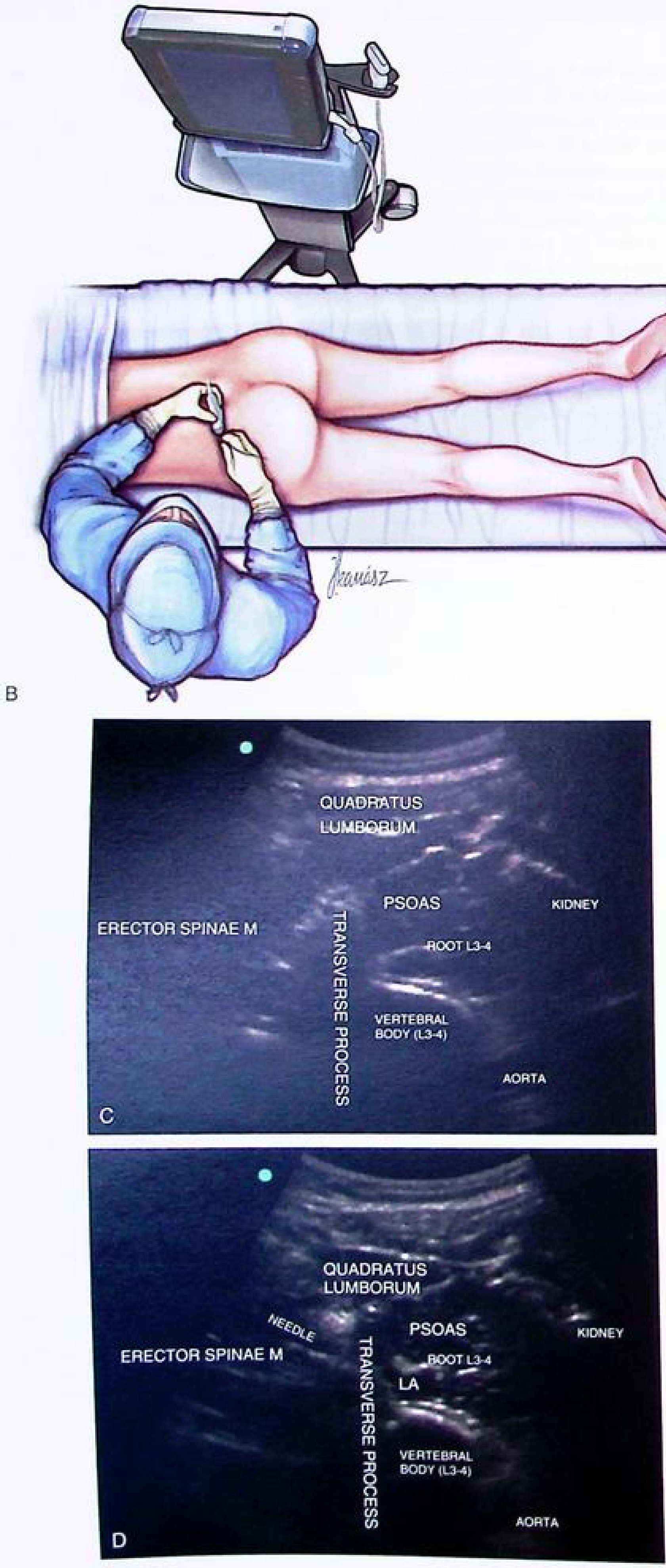

Fig. 16.3, cont'd (B) Position of the patient for the transverse technique; note the in-plane technique used for the block. (C) and (D) Ultrasound images for the transverse technique for the lumbar plexus block; note the position of the needle in the psoas muscle deep to the quadratus lumborum muscle.

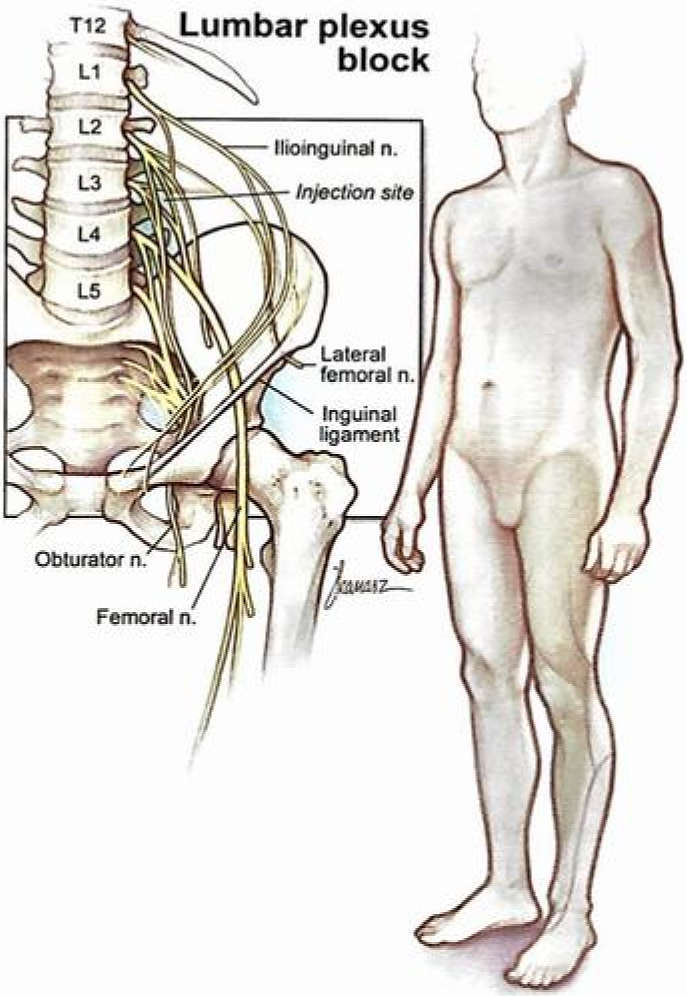

Fig. 16.4 Anatomical distribution of lumbar plexus block.

- The block can be performed in the prone and lateral positions. The advantage of the prone position is that it provides a more stable resting hand position and allows more precise scanning and manipulations.
- At the level of L2 to L3, the kidney can be visualized as a hypoechoic structure that moves with respiration.
- Care should be taken to do frequent repeated aspiration and to inject the LA in small increments to detect epidural or spinal spread early.
- The lumbar paravertebral space is a vascular and to muscular space, which leads to significant systemic absorption of the LA and potentially high plasma levels.

17 Sciatic Block

Ehab Farag and David L. Brown

Key Points

- Subgluteal and midthigh approaches are the most commonly used techniques for sciatic nerve block using ultrasound.
- Short axis with in-plane approach with lateral to medial needle direction is the preferred ultrasound technique for both subgluteal and midthigh sciatic blocks.
- Using a nerve stimulator is very helpful to confirm the identification of the sciatic nerve in the subgluteal approach, especially in obese patients.

PERSPECTIVE

The sciatic nerve is one of the largest nerve trunks in the body, yet few surgical procedures can be performed with sciatic block alone. It is combined most often with femoral, lateral femoral cutaneous, or an obturator nerve block. The block is also effective for analgesia of the lower leg and may provide pain relief from ankle fractures or tibial fractures before operative intervention.

Patient Selection. This block may be indicated for patients needing analgesia before transport for definitive orthopedic surgical repair of lower leg or ankle fractures. For patients in whom it may be desirable to avoid the sympathectomy accompanying neuraxial block, sciatic block combined with femoral nerve block often allows ankle and foot procedures to be carried out. One group of patients in whom this block is often useful is those undergoing distal amputations of the lower extremity who have vascular compromise based on diabetes or peripheral vascular disease.

Pharmacologic Choice. Sciatic nerve block requires from 20 to 25 mL of local anesthetic solution. When this volume is added to that required for other lower extremity peripheral blocks, the total may reach the upper end of an acceptable local anesthetic dose range. Conversely, uptake of local anesthetic from these lower extremity sites is not as rapid as with epidural or intercostal block; thus a larger mass of local anesthetic may be appropriate in this region. If motor blockade is desired with this block, 1.5% mepivacaine or lidocaine may be necessary, whereas 0.5% bupivacaine or 0.5% to 0.75% ropivacaine will be effective.

TRADITIONAL BLOCK TECHNIQUE

PLACEMENT

Anatomy. The sciatic nerve is formed from the L4 through S3 roots. These roots of the sacral plexus form on the anterior surface of the lateral sacrum and are assembled into the sciatic nerve on the anterior surface of the piriformis muscle. The sciatic nerve results from the fusion of two major nerve trunks. The "medial" sciatic nerve is functionally the tibial nerve, which forms from the ventral branches of the ventral rami of L4 to L5 and S1 to S3; the posterior branches of the ventral rami of these same nerves form the "lateral" sciatic nerve, which is functionally the peroneal nerve. As the sciatic nerve exits the pelvis, it is anterior to the piriformis muscle and is joined by another nerve—the posterior cutaneous nerve of the thigh. At the inferior border of the piriformis, the sciatic and posterior cutaneous nerves of the thigh lie posterior to the obturator internus, the gemelli, and the quadratus femoris. At this point, these nerves are anterior to the gluteus maximus. Here, the nerve is approximately equidistant from the ischial tuberosity and the greater trochanter (Figs. 17.1–17.3). The nerve continues downward through the thigh to lie along the posteromedial aspect of the femur. At the cephalad portion of the popliteal fossa, the sciatic nerve usually divides to form the tibial and common peroneal nerves. Occasionally, this division occurs much higher, and sometimes the tibial and peroneal nerves are separate through their entire course. In the popliteal fossa, the tibial nerve continues downward into the lower leg, whereas the common peroneal nerve travels laterally along the medial aspect of the short head of the biceps femoris muscle.

CLASSIC APPROACH

Position. The patient is positioned laterally, with the side to be blocked nondependent. The nondependent leg is flexed and its heel placed against the knee of the dependent leg (Fig. 17.4). The anesthesiologist is positioned to allow insertion of the needle, as shown in Fig. 17.4.

Needle Puncture. A line is drawn from the posterior superior iliac spine to the midpoint of the greater trochanter. Perpendicular to the midpoint of this line, another line is extended caudomedially for 5 cm. The needle is inserted through this point (Fig. 17.5). As a cross-check

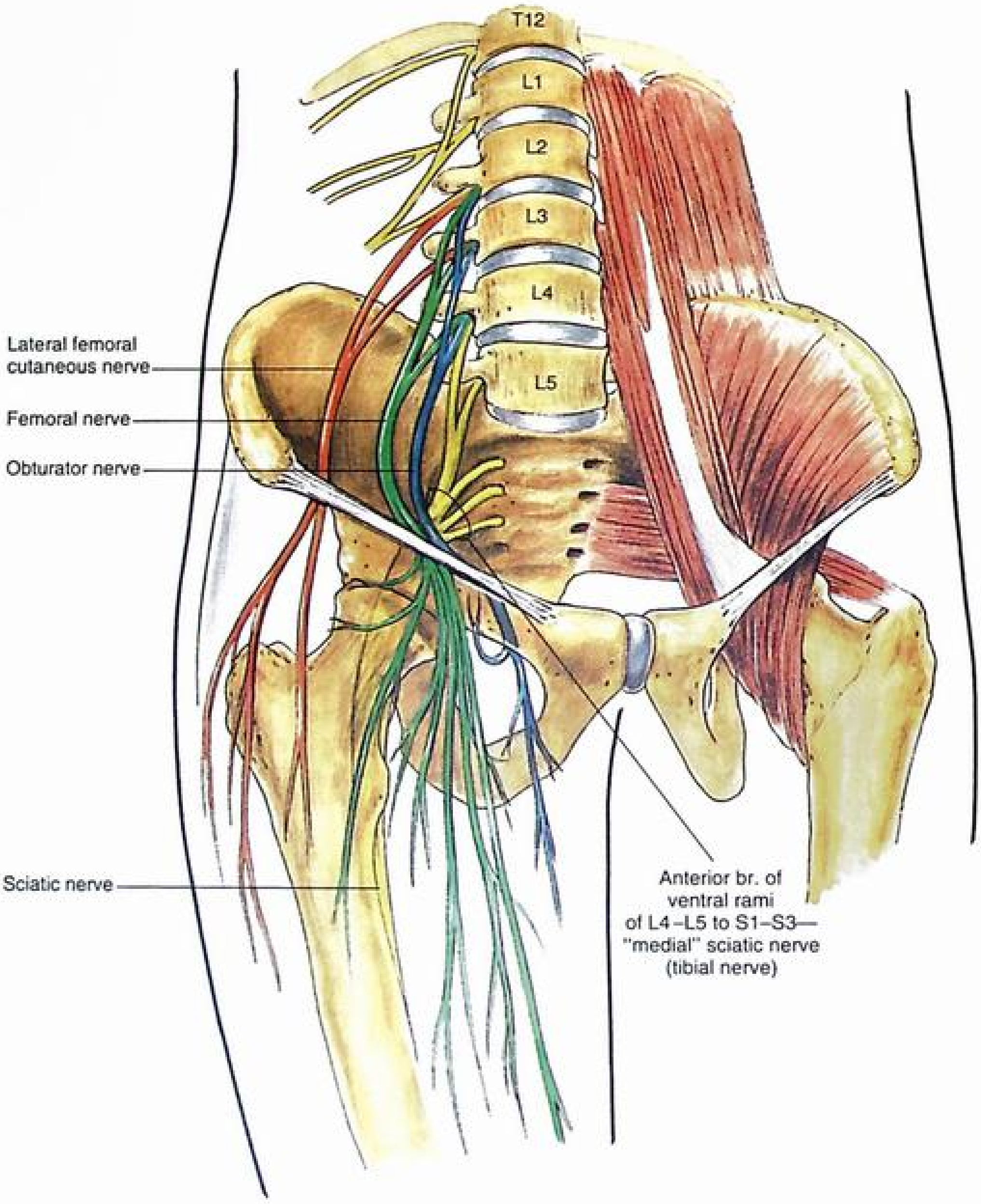

Fig. 17.1 Sciatic nerve anatomy: anterior oblique view.

for proper placement, an additional line may be drawn from the sacral hiatus to the previously marked point on the greater trochanter. The intersection of this line with the 5-cm perpendicular line should coincide with the needle insertion site.

At this site, a 22-gauge, 10- to 13-cm needle is inserted, as illustrated in Fig. 17.4. The needle should be directed through the entry site toward an imaginary point where the femoral vessels course under the inguinal ligament. The needle is inserted until paresthesia is elicited or until bone is contacted. If bone is encountered before paresthesia is elicited, the needle is redirected along the line joining the sacral hiatus and the greater trochanter until paresthesia or a motor response is elicited. During this redirection, the needle should not be inserted more than 2 cm past the depth at which bone was originally contacted, or the needle tip will be placed anterior to the site of the sciatic nerve. Once paresthesia or a motor response is elicited, 20 to 25 mL of local anesthetic is injected.

ANTERIOR APPROACH

Position. The anterior block of the sciatic nerve can be carried out in the supine patient whose leg is in the neutral position. The anesthesiologist should be at the patient's side, similar to positioning during femoral nerve block.

Needle Puncture. In the supine patient, a line should be drawn from the anterior superior iliac spine to the pubic

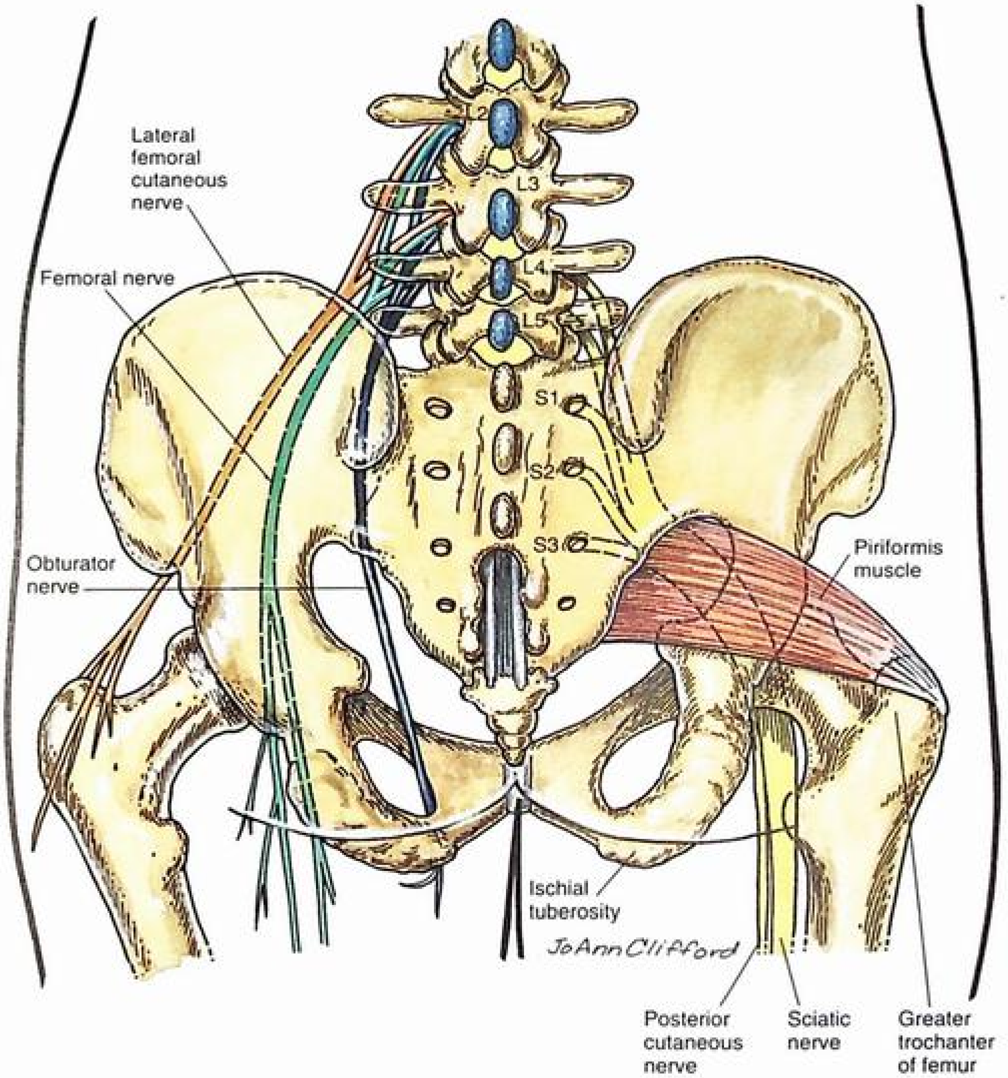

Fig. 17.2 Sciatic nerve anatomy: posterior view.

tubercle. Another line should be drawn parallel to this line from the midpoint of the greater trochanter inferomedially, as illustrated in Fig. 17.6. The first line is trisected and a perpendicular line is drawn caudolaterally from the juncture of the medial and middle thirds, as shown in Fig. 17.6. At the point where the perpendicular line crosses the more caudal line, a 22-gauge, 13-cm needle is inserted so that it contacts the femur at its medial border. Once the needle has contacted the femur, it is redirected slightly medially to slide off the medial surface of the femur. At approximately 5 cm past the depth required to contact the femur, paresthesia or a motor response should be sought to ensure successful block (Fig. 17.7). Once paresthesia or a motor response is obtained, 20 to 25 mL of local anesthetic is injected.

POTENTIAL PROBLEMS

In patients in whom the block is being used for an injury to the lower extremity, the classic position is sometimes difficult to use. This block can also be of long duration, and patients should be warned of this before surgery. Although it is unsubstantiated, some consider that dysesthesia may be more common after this block than after other peripheral blocks. The same problems pertaining to the classic approach should be considered with the anterior approach.

PEARLS

CLASSIC APPROACH

The keys to making this block work are adequate positioning of the patient and a systematic redirection of the needle until paresthesia is obtained.

ANTERIOR APPROACH

Although the anterior approach is conceptually simple, we are able to produce anesthesia using it slightly less often

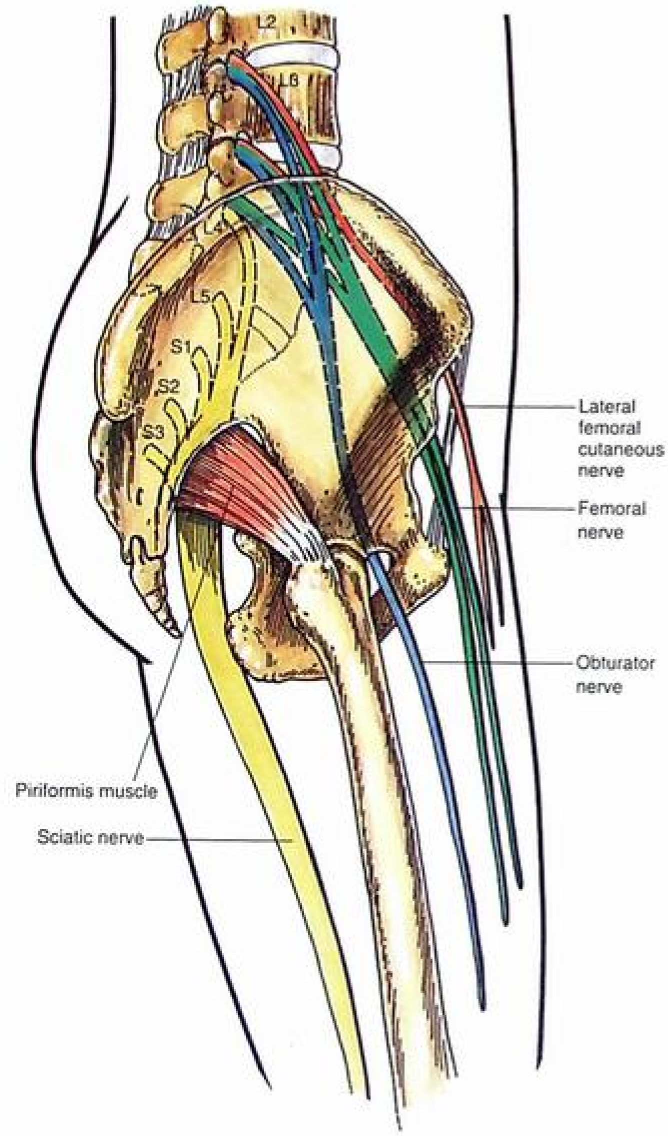

Fig. 17.3 Sciatic nerve anatomy: lateral view.

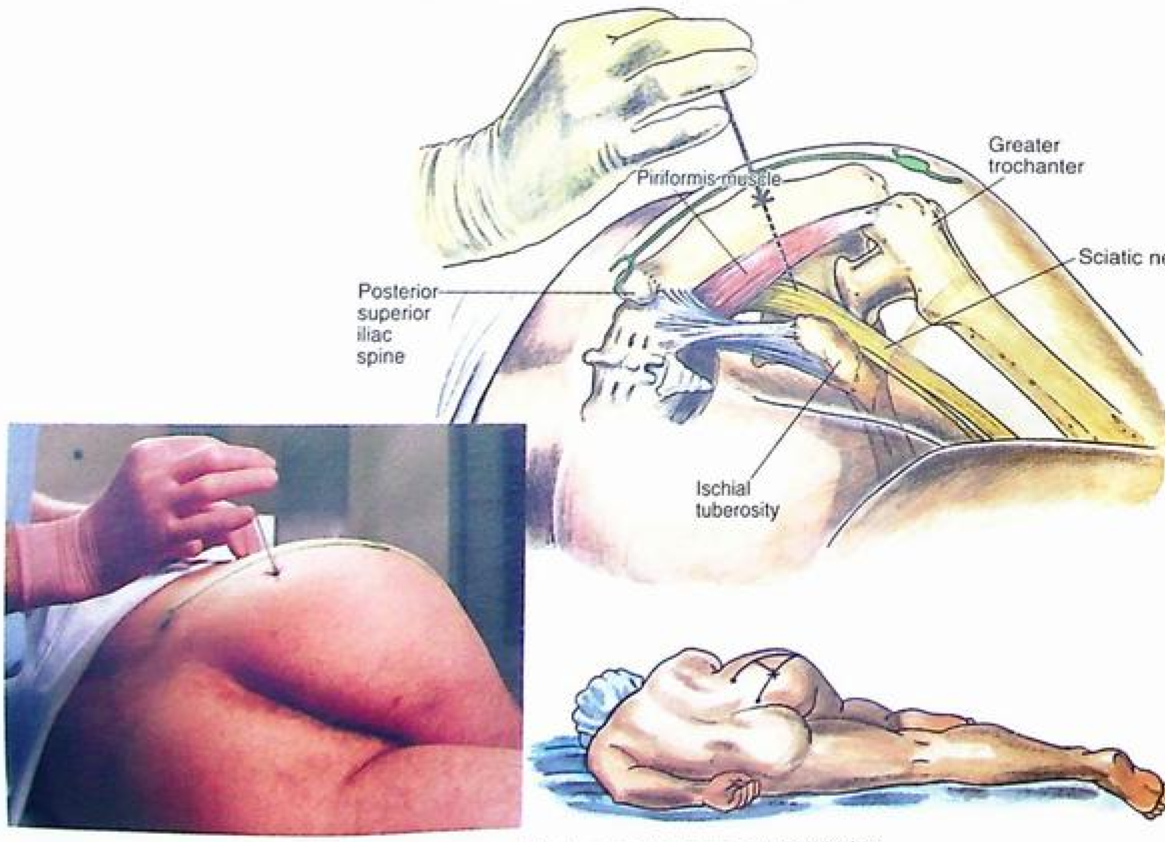

Fig. 17.4 Sciatic nerve block: classic technique and positioning.

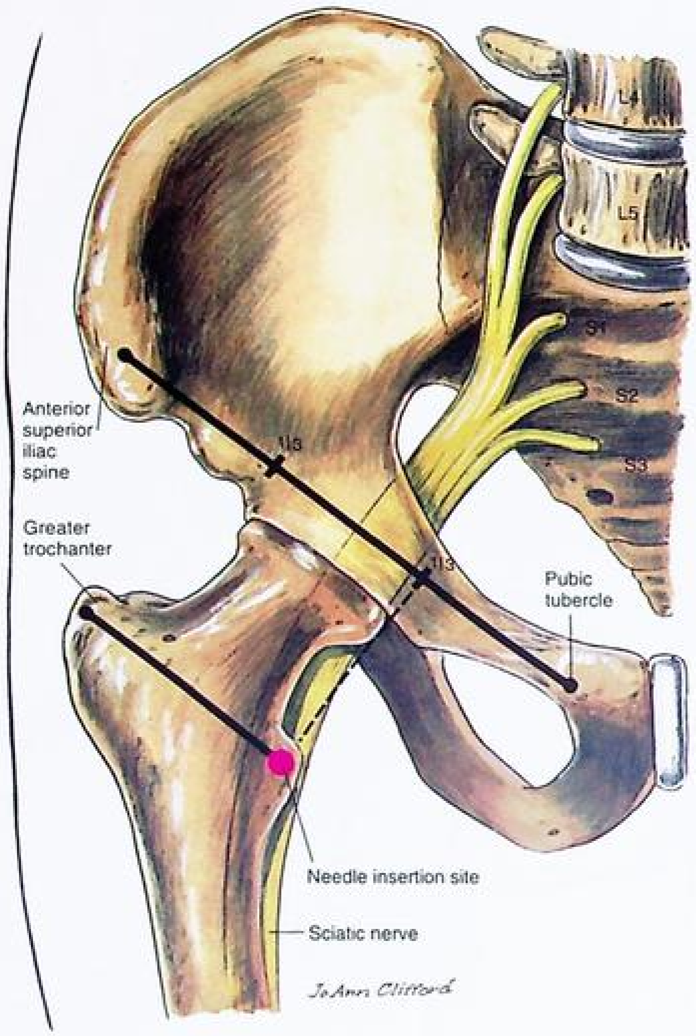

Fig. 17.6 Sciatic nerve block: anterior technique.

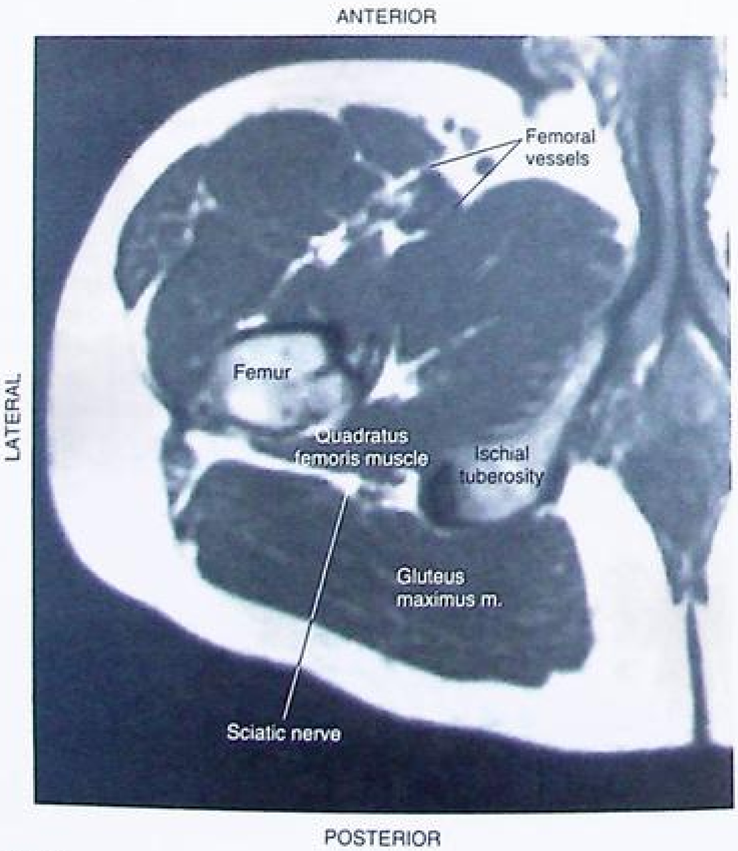

Fig. 17.7 Magnetic resonance image (cross-sectional) at level of anterior sciatic nerve.

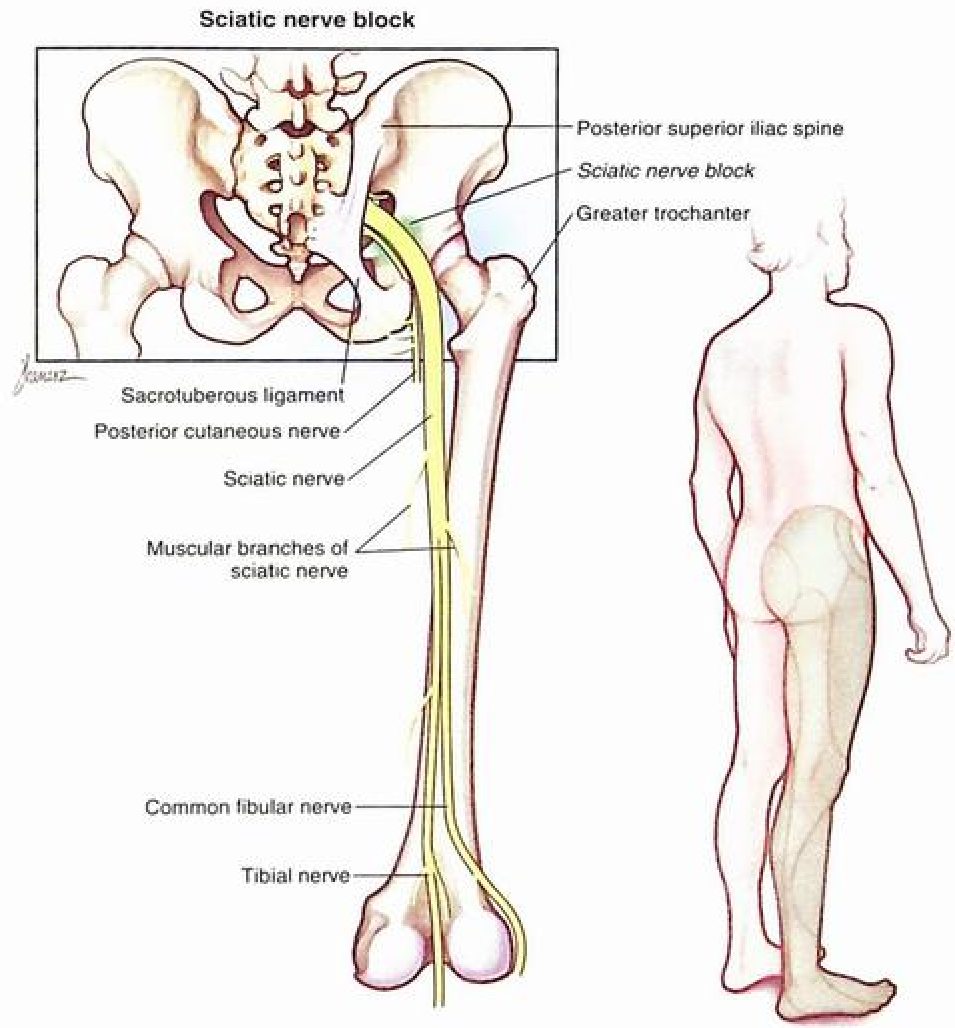

Fig. 17.8 Anatomy of the subgluteal sciatic nerve block.

a hyperechoic structure between the greater trochanter and ischial tuberosity. The in-plane approach will be used with the needle direction from medial to lateral in the prone position; however, in the lateral position, the needle direction preferably should be from posterior to anterior (Video 17.1, Video 17.2, Video 17.3 and Video 17.4). The use of nerve stimulation, in addition to the ultrasound, is preferred in this technique to confirm the nerve identification, especially in obese patients. The medium-frequency linear 50-mm footprint is used for the midthigh approach block for the sciatic nerve block. The continuous block can be performed using a catheter threaded through a Tuohy needle. The catheter tip position can be identified by injecting local anesthetic and observing its distribution using ultrasound or by injecting 1 mL of air, which appears as a hyperechogenic artifact (Figs. 17.9–17.11).

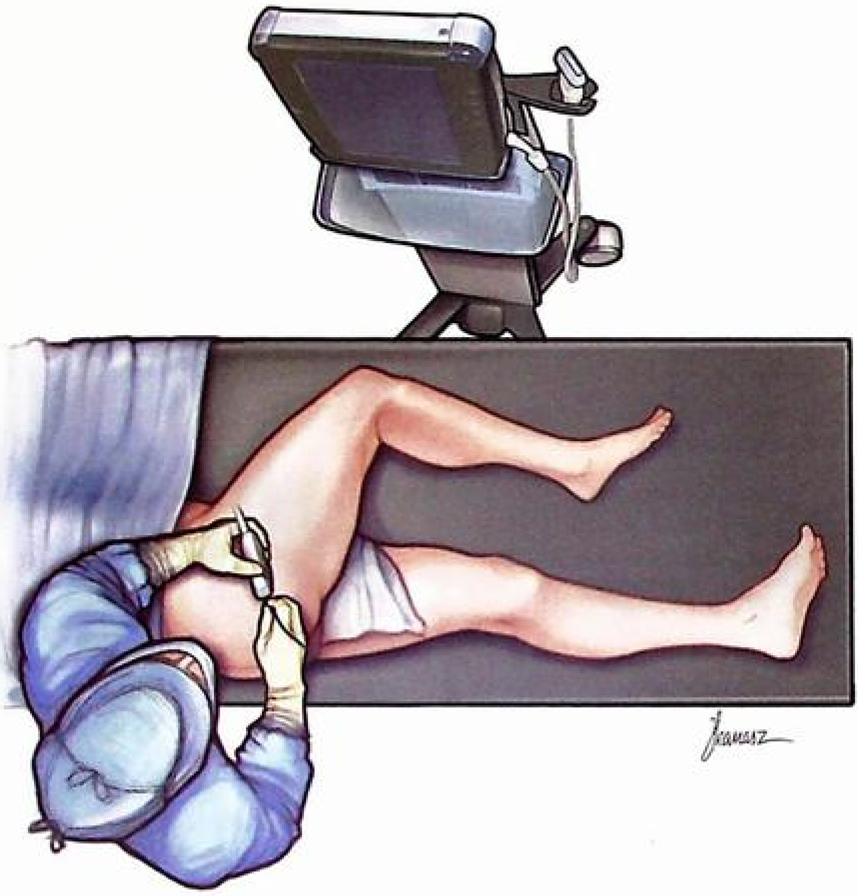

Fig. 17.9 Patient in lateral position. Note the in-plane approach with posterior to anterior needle direction.

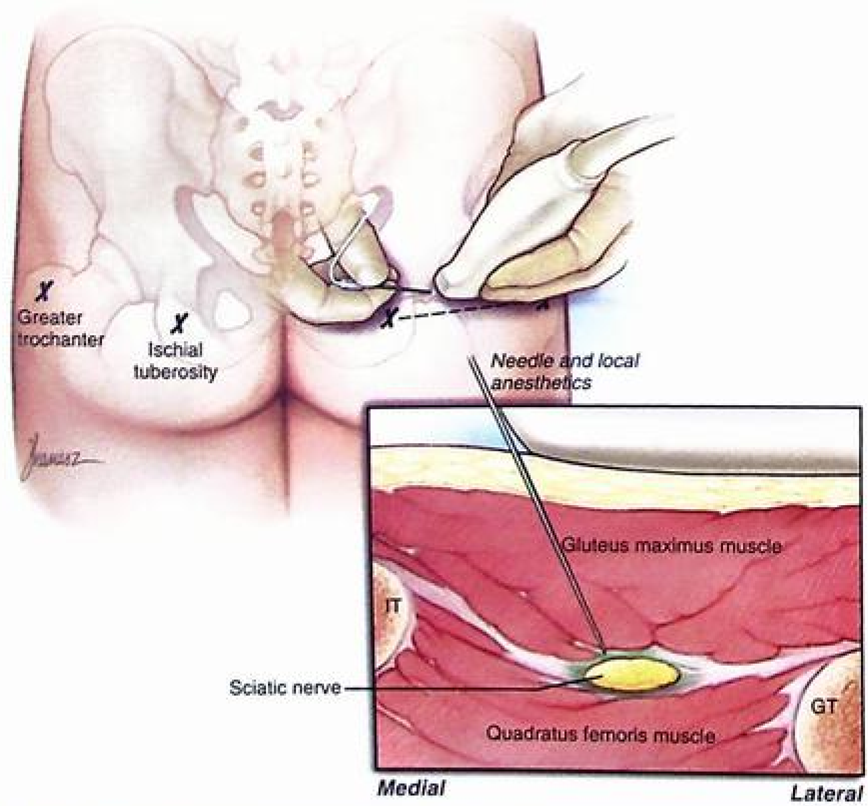

Fig. 17.10 In-plane technique for subgluteal sciatic nerve block in prone position. Note the medial to lateral needle direction.

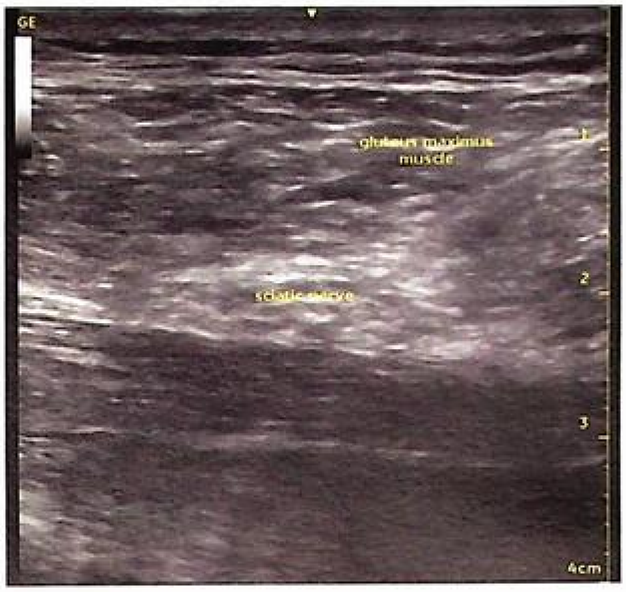

Fig. 17.11 Ultrasound still of sciatic nerve block.

CLINICAL PEARLS

- Continuous sciatic block is very helpful for managing phantom limb pain after either below-knee or above-knee amputations.
- Single-shot sciatic block using 0.1% ropivacaine is very helpful to manage posterior knee pain after total knee arthroplasty without affecting the motor power and/or neurological examination of the lower limb after total knee arthroplasty.
- Combined femoral and sciatic blocks are quite sufficient for lower limb procedures, especially in high-risk patients in whom general and/or neuraxial anesthesia can disturb their hemodynamic stability, such as very tight aortic stenosis or heart failure.

Femoral Block 18

Ehab Farag and David L. Brown

Key Points

- High-resolution linear ultrasound (30- to 40-mm footprint) is preferred for the femoral nerve block.
- In some patients, the femoral nerve at the inguinal crease is already branched into superficial and deep divisions, along with femoral artery division into femoral deep profunda femoris branches. Therefore it is better to scan proximally to place the probe at the common femoral artery in order to ensure blocking the main trunk of the femoral nerve.
- For catheter insertion, the Tuohy needle is used. The proper position of the tip of the needle beneath the fascia iliaca can be identified by injecting 2 to 3 mL of saline, which appears laterally to the artery and in the vicinity of the nerve. Then the catheter will be inserted 3 to 4 cm beyond the tip of the needle. For further confirmation of the location of the catheter tip, a small volume of air, which appears as a hyperechoic artifact, can be injected through the catheter.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

The femoral nerve is the largest branch of the lumbar plexus and usually consists of the roots of segments L2 to L4. It runs distally to the inguinal region, typically positioned in the groove formed by the iliac and lateral psoas muscles posteriorly and covered by the iliac fascia anteriorly. At this level, the iliac fascia, along with the internal aspect of the iliopsoas, thickens to form the iliopectineal band that separates the femoral vein and femoral artery from the nerve. The femoral nerve is often visualized distal to the inguinal ligament within a triangular hyperechoic region lateral to the femoral artery and superficial to the iliopsoas muscle. The nerve may be thin and flat in this region as it may divide into terminal branches. However, it can be visualized as a biconvex or oval hyperechoic structure. Therefore from superficial to deep, the fascia lata is first encountered, then the fascia iliaca, as a hyperechoic line (Figs. 18.1–18.3).

INDICATIONS

- Analgesia for fractured neck/shaft of femur.
- Analgesia after hip joint replacement.
- Analgesia after knee joint surgeries, such as total knee arthroplasty or anterior cruciate ligament repair.
- It can be combined with popliteal block to provide anesthesia for lower leg or foot surgeries.

TECHNIQUE

While the patient is in a supine position, the ultrasound probe will be parallel to the inguinal crease to obtain the short axis of the nerve within the triangular hyperechoic region. The in-plane technique is most commonly used for this block. In this technique, the needle will be inserted in-plane and advanced from lateral to medial in the transverse plane of the image. After piercing the fascia iliaca, inject 2 to 3 mL of saline to ensure the needle tip is beneath the fascia and the saline is spreading lateral to the femoral artery and in the vicinity of the nerve before injecting the local anesthetics (Figs. 18.4–18.9, Video 18.1).

PEARLS

- The femoral nerve can be confused in the short-axis view with inguinal lymph nodes, which also appear hyperechoic.
- If you are not able to identify the femoral nerve, injection in the hyperechoic triangle lateral to the femoral artery will suffice to produce a successful block.
- After inserting the catheter through the Tuohy needle, keep the needle in situ and inject through the catheter 2 to 3 mL of saline or local anesthetic solution to identify the position of the catheter tip. This technique will help modify the catheter position by readjusting the needle and ensuring the catheter position is in the vicinity of the nerve.
- The concentration of local anesthetic used in this block usually depends on the aim. For analgesic purposes, ropivacaine 0.1% to 0.2% is quite sufficient; however, ropivacaine 0.5% is ideal for anesthetic purposes.

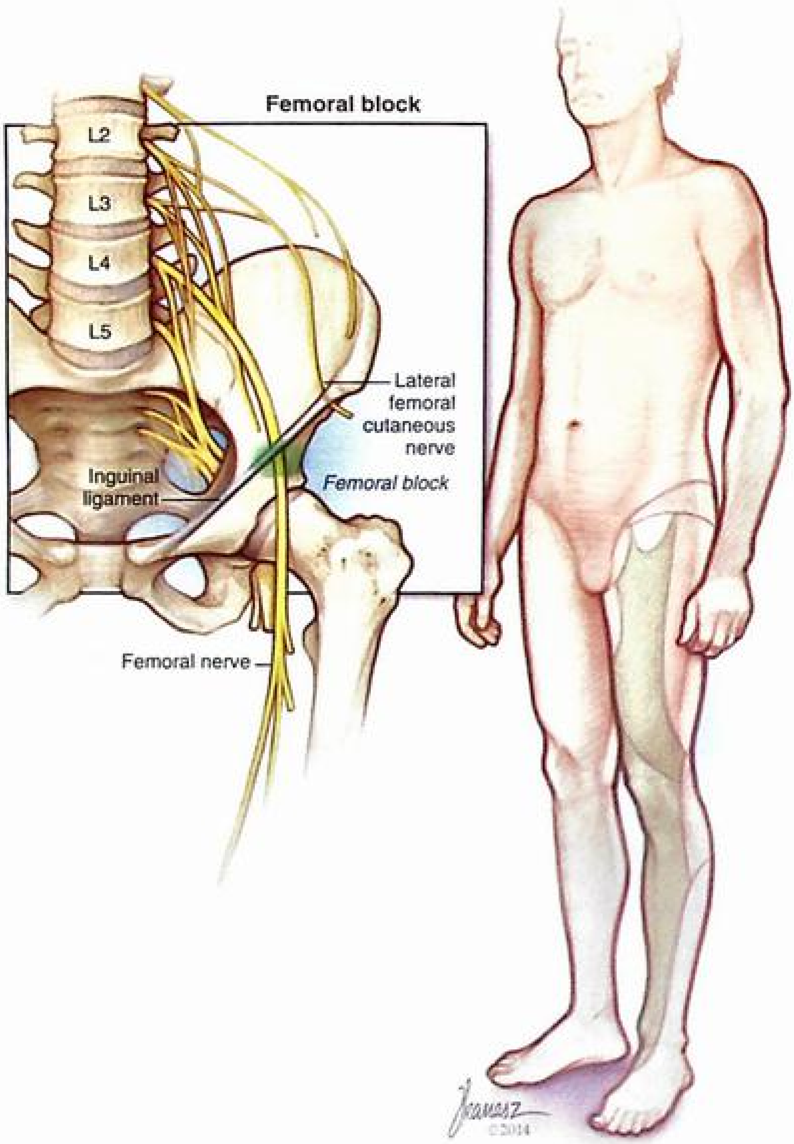

Fig. 18.1 Femoral nerve sensory innervation.

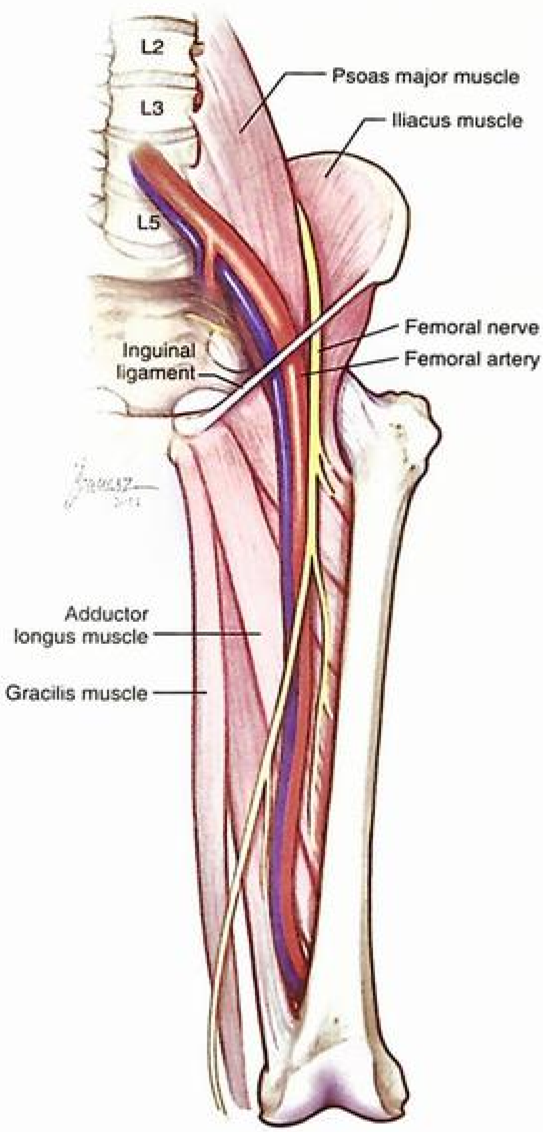

Fig. 18.2 This figure shows the relation of the femoral nerve to femoral artery at the groin below the inguinal ligament.

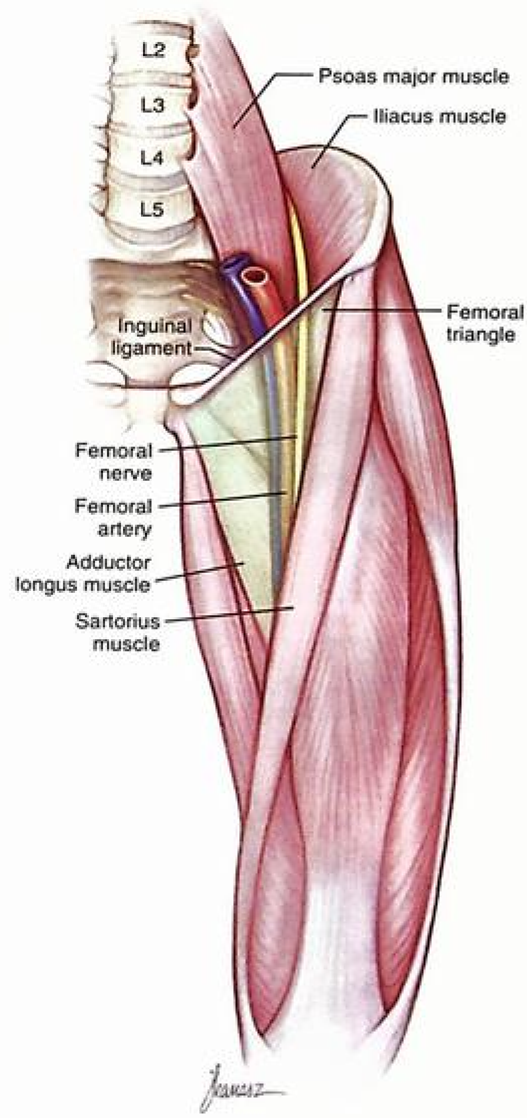

Fig. 18.3 This figure shows the components of the femoral sheath from medial to lateral (vein, artery, nerve) in the femoral triangle.

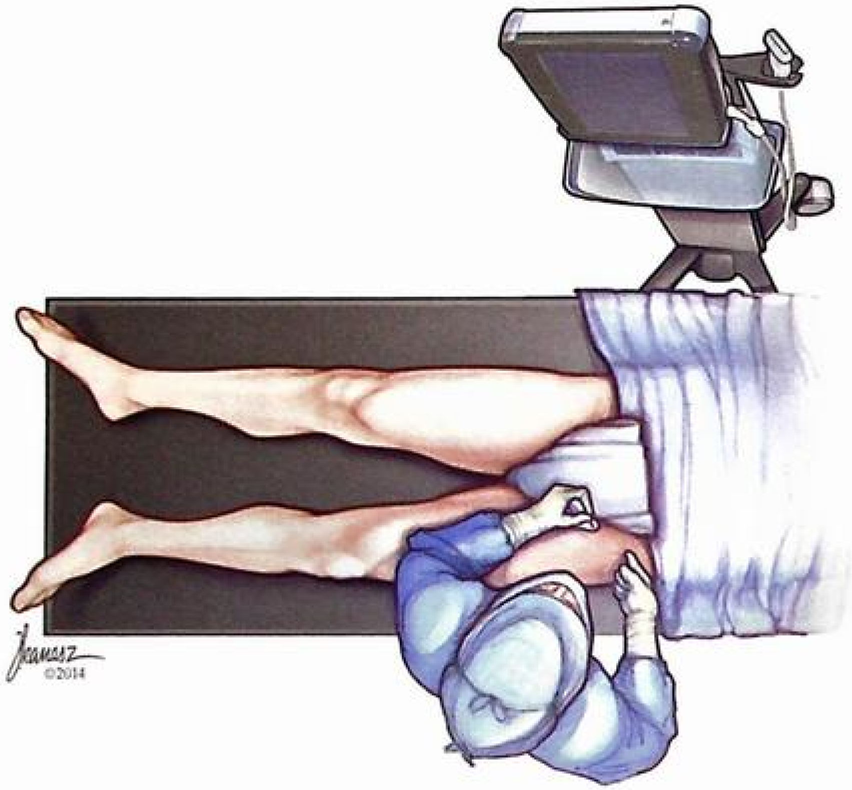

Fig. 18.4 Position of the patient and the ultrasound machine.

Fig. 18.5 Note the needle in-plane and the needle direction from lateral to medial.

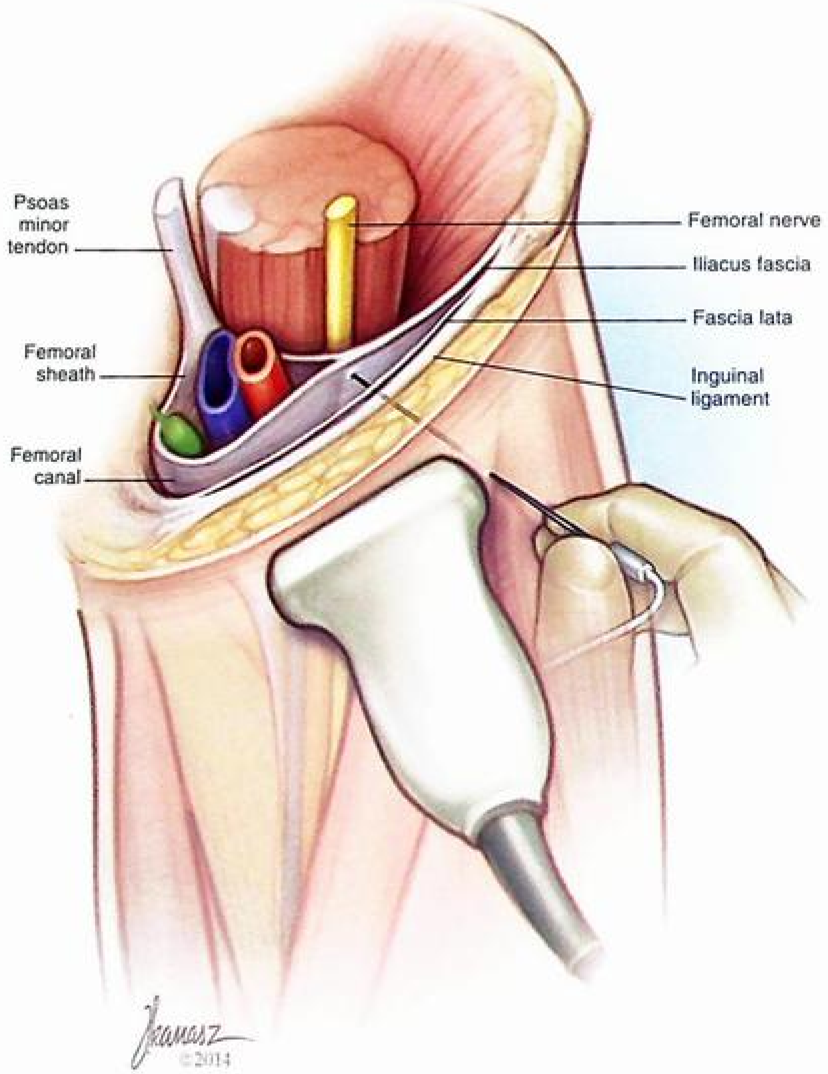

Fig. 18.6 The needle should pierce the iliacus fascia to have a successful block.

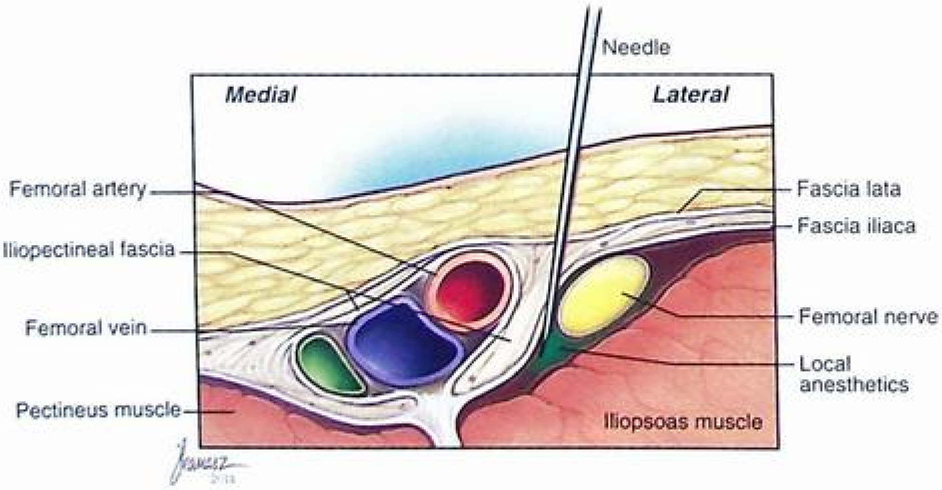

Fig. 18.7 The needle and the local anesthetics are beneath the fascia iliaca.

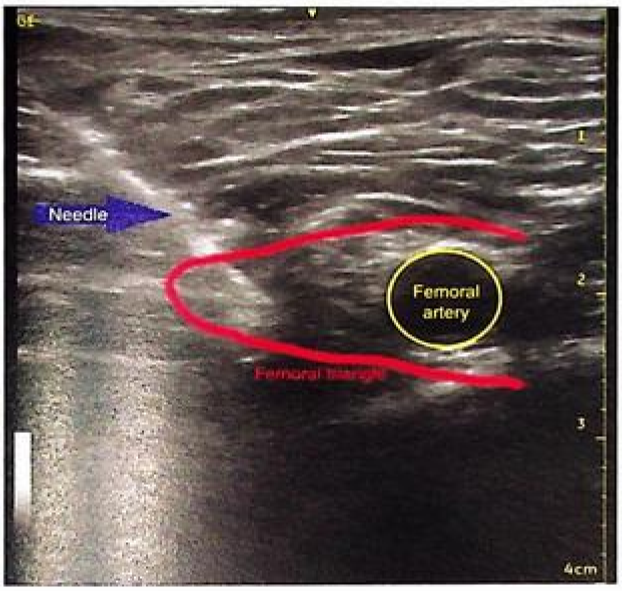

Fig. 18.8 Ultrasound still of the femoral block procedure.

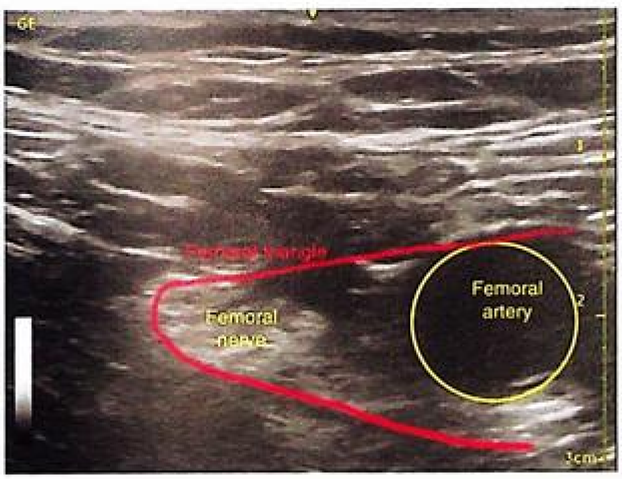

Fig. 18.9 Ultrasound still of the anatomy of femoral block.

Pericapsular Nerve Group (PENG) Block 19

Emily Barney Hall and Jeff Gadsden

Key Points

- The PENG block is a motor-sparing approach for analgesia of the hip joint.
- A curved transducer is recommended as it provides a wider (and deeper) field of view.
- The PENG block is relatively simple to both image and perform because the endpoint for needle advancement is bony contact.

PERSPECTIVE

The PENG block is a regional anesthesia technique designed to anesthetize a number of small articular nerve branches that supply the anterior and medial joint capsule as well as much of the articular surfaces of the femur and acetabulum. The principal advantage of the PENG block over other techniques that are used for hip joint analgesia (i.e., fascia iliaca or femoral nerve block) is sparing of the motor fibers of the lumbar plexus, which allows patients to ambulate and bear weight safely on the affected lower extremity. It was originally described in 2018 as an analgesic technique for hip fracture but has since been used for a variety of other hip-related indications, including elective procedures such as total hip arthroplasty, hip arthroscopy, and pediatric correction of congenital hip dysplasia. The PENG block has also been used as a palliative ablative technique for patients with hip fracture who are nonoperative, as well as for pain relief during sickle cell vaso-occlusive crises. Because the technique involves advancing a needle until bony contact is made on the pelvic brim, it is a reasonably simple one to teach and learn. This, along with its demonstrated analgesic efficacy and sparing of motor nerves, explains its rapid growth in popularity.

ANATOMY AND SONOANATOMY

The hip capsule is richly innervated by nerve branches that originate from both the lumbar and sacral plexuses. The anterior portion is largely supplied by the femoral nerve and muscular branches that originate from the femoral (e.g., nerve to pectineus, nerve to rectus femoris). These articular branches leave the proximal femoral nerve in the pelvis and course over the brim of the pelvis deep to the iliopsoas muscle before continuing on to supply the anterior capsule (Fig. 19.1). The obturator nerve is responsible for innervation of most of the medial joint capsule. Finally, in 10% to 30% of individuals, an accessory obturator nerve crosses superficial to the superior pubic ramus to innervate part of the anterior and anteromedial capsule. These small articular branches descend as far as the intertrochanteric line and therefore the PENG block is not suitable for fractures and/or surgery on the femur distal to that line; a femoral or fascia iliaca block should be considered. The posterior aspect of the joint capsule is supplied by small branches from the sacral plexus and anatomically and functionally is less relevant for hip analgesia than the anterior and anteromedial capsule. All of these articular branches innervate the outer fibrous capsule before penetrating into the joint space and innervating the synovium and periosteal structures.

The principle of the PENG block is to deposit local anesthetic on the pubic ramus, immediately deep to the iliopsoas muscle. Injectate placed at that location will spread along the bony brim of the pelvis as well as distally over the hip joint capsule itself to anesthetize the small articular branches of the femoral, obturator, and accessory obturator nerves. Importantly, because the plane of injection is deep to the bulk of the iliopsoas muscle, the femoral nerve proper, which travels superficial to the muscle, is spared, preserving quadriceps motor function. Similarly, the PENG technique does not block any cutaneous branches, and supplemental blocks of relevant cutaneous nerves (e.g., lateral femoral cutaneous nerve) are often performed in concert in order to provide analgesia for incisional pain.

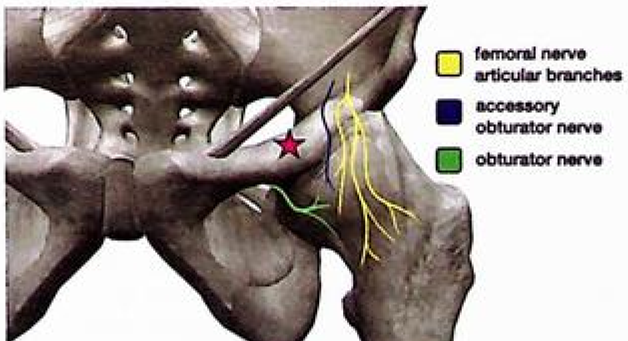

Fig. 19.1 Innervation of the anterior and medial hip joint capsule relevant to the pericapsular nerve group (PENG) block showing the location of the femoral nerve articular branches *(yellow)*, obturator nerve *(green)*, and accessory obturator nerve *(blue)*. The *star* indicates the target for needle advancement on the pubic ramus.

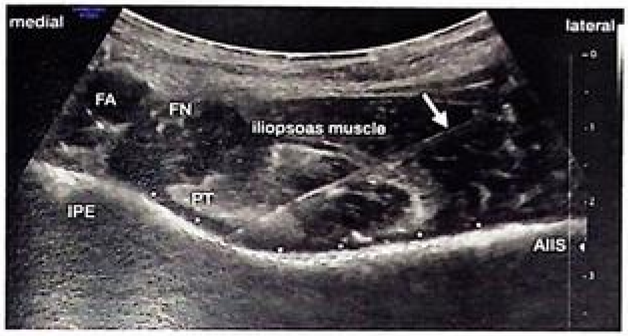

Fig. 19.4 Sonogram showing local anesthetic deposition *(asterisks)* immediately superficial to the pubic ramus, elevating the iliopsoas muscle and psoas tendon *(PT)*. Note the extent of medial and lateral spread with a single injection and the absence of intramuscular injectate *(arrow)*. The needle *(arrow)* can be visualized contacting the pubic ramus. *AIIS*, Anterior inferior iliac spine; *FA*, femoral artery; *FN*, femoral nerve; *IPE*, iliopubic eminence.

visualize intramuscular spread as evidenced by injectate traveling superficially within the muscle fibers; the needle is advanced and/or twisted by the operator to pop through the final epimysial layer. Once confirmed in the correct plane, 20 mL of local anesthetic solution is deposited slowly with the aim of visualizing the elevation of the iliopsoas off the bony brim. The injectate should be observed spreading medially toward the IPE and laterally toward the AIIS. The needle is then withdrawn (Video 19.1).

A variety of local anesthetic solutions and concentrations have been used, but in general, the target nerves are small articular branches and therefore do not require the use of highly concentrated solutions. In our experience, a concentrated solution does not add significantly to the efficacy or duration of the block and only increases the likelihood that the patient will experience inadvertent quadriceps weakness (see Potential Problems later). Because the PENG block is typically being performed to relieve moderate-severe bony pain, a long-acting solution is indicated. We frequently use ropivacaine 0.2% with 2.5 µg/mL of epinephrine, with or without an adjuvant such as dexamethasone. An alternative is a mixture of liposomal bupivacaine and 0.25% bupivacaine (10 mL of each to make 20 mL total) in order to extend the block out to 48 hours and beyond.

Continuous PENG catheters have also been used. Case studies have demonstrated excellent postoperative pain control without muscle weakness in patients undergoing total hip arthroplasty. Many of these catheters were performed in geriatric patients at high risk for delirium who would greatly benefit from reduced opioid or opioid-free pain management. Preoperative catheters have also been reported, improving pain scores as early as 20 minutes after PENG catheter placement and lasting up to 48 hours. The benefits of continuous catheter infusion are prolonged blockade and the ability to titrate/bolus local anesthetic as indicated by patient symptoms. One consideration with a catheter technique is the presence of a dressing and the catheter itself in the inguinal crease, which may interfere with surgical skin preparation and/or incision. We have placed PENG catheters in the emergency department as part of our clinical pathway for hip fracture analgesia. When the patient presents to the operating room for surgical fixation over the next 12 to 36 hours, the catheters are typically bolused with an additional 10 to 15 mL and then discontinued. An appropriate infusion regimen for PENG catheters involves ropivacaine 0.2% at 8 mL/h. The use of an intermittent bolus technique (i.e., 20 mL every 3 hours) has been advocated for in fascial plane blocks, rather than a continuous background rate, and while this is attractive intuitivel, there are scant data to date suggesting any advantage to this for PENG blocks.

Block success can be somewhat challenging to determine objectively since there are no cutaneous nerves or myotomes to test. Patients who have received a PENG block for hip fracture analgesia or as a rescue technique postoperatively do typically report a reduction in pain intensity over the 10 to 20 minutes following administration of the local anesthetic. PENG blocks should be considered an analgesic technique and are not used for surgical anesthesia.

POTENTIAL PROBLEMS

1. *High injection pressure/inability to inject.*

   High injection pressures are frequently encountered during PENG block and may represent a needle tip firmly apposed to (or within) the periosteum of the pubic ramus or the psoas tendon. A slight withdrawal (<1 mm) of the needle usually corrects this and results in immediate visualization of injectate spreading deep to the iliopsoas muscle. Care should be taken to not withdraw too much so that the needle tip is intramuscular. This is the crux of the needle technique with the PENG block—to be effective, the tip must be advanced with sufficient force to pass through the iliopsoas muscle but not be lodged within the periosteum. Even when the needle is in the correct plane, the poor compliance of the tight muscular compartment can make injection feel very firm, and careful observation of the pattern of spread is critical to ensure successful deposition.

2. *Block failure due to intramuscular administration of local anesthetic.*

   PENG block is a fascial plane block that relies on the spread of local anesthetic within the submuscular plane of the iliopsoas. An intramuscular injection may anesthetize one or more branches associated with that muscle but in general (and in our experience), it will not produce the desired block effect.

3. *Quadriceps weakness.*

   Weakness of the quadriceps muscle group has been reported and represents inadvertent spread of local anesthetic to the femoral nerve proper. In our experience, this occurs in one of two circumstances. First, an intramuscular injection can easily lead to local anesthetic migrating superficially toward the femoral nerve and should be avoided. Second, a large dose of local anesthetic—even if placed in the correct plane—may overcome the barrier effect of the iliopsoas muscle and produce a femoral nerve block, especially if the patient is elderly, frail, and/or sarcopenic. As mentioned earlier, the target nerves are small and easily blocked with low concentrations of local anesthetic (e.g., ropivacaine 0.2% or bupivacaine 0.25%); concentrated solutions of 0.5% ropivacaine or bupivacaine are simply unnecessary and may just provoke a femoral nerve block. In both clinical and cadaveric studies, 20 mL of injectate appears to be more than enough to spread to the anterior and anteromedial joint capsule and effect a block of the target nerves. Increasing the volume past 20 mL may increase the risk of femoral blockade.

PEARLS

- The injection plane can feel quite tight; withdrawing the needle slightly can improve spread by reducing pressure against the periosteum.
- Occasional reports of quadriceps weakness following a PENG block seem to correspond to intramuscular injection; beware of inadvertent femoral nerve involvement with intramuscular injection!
- Small amounts (15–20 mL) of dilute local anesthesia are enough to produce an effective block with these small nerves.
- Consider adding a lateral femoral cutaneous nerve block for lateral thigh skin coverage.

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Ultrasound for Fascia Iliaca and Inguinal Region Blocks 20

Mohammed Faysal Malik and Chihiro Toda

Key Points

- A high-frequency linear transducer is preferred for this block.
- The fascia iliaca compartmental block (FICB) can be used as an alternative anterior approach to the lumbar plexus block, targeting the femoral, obturator, and lateral femoral cutaneous nerves.
- The suprainguinal approach to the FICB is associated with better cranial spread of local anesthetic (LA) and more complete sensory blockade of the anterior, medial, and lateral thigh compared with the traditional infrainguinal approach.
- The traditional infrainguinal approach required great volumes of LA to achieve adequate cephalad spread. The suprainguinal approach requires less volume to achieve adequate sensory blockade.

PERSPECTIVE

The FICB can be used to provide complete sensory blockade of the medial, anterior, and lateral thigh. This block has been used effectively for postoperative analgesia following hip and knee surgery. It can be used as an alternative to a traditional lumbar plexus block by targeting the femoral nerve, obturator, and lateral femoral cutaneous nerves, which lie deep to the fascia iliaca. It can also provide adequate analgesia for hip and proximal femur fractures as well as for total hip arthroplasty. As with any fascial plane block within the fascia iliacus plane, blockade of the femoral, obturator, and lateral femoral cutaneous nerves is achievable with a large enough volume of LA. Traditionally, the fascia iliaca block was performed using a "double-pop" technique as the needle traversed the fascia lata and fascia iliaca. This was associated with a significant block failure rate, as high as 10% to 37%. However, with advancements in ultrasound and the use of direct needle visualization under continuous ultrasound guidance, the success rate and consequently the popularity of this block is beginning to regain favor.

ANATOMY

The iliacus muscle lies over the ilium. It is a large, flat, triangular-shaped muscle that joins with the psoas major muscle to form the anisotropic hypoechoic iliopsoas muscle. The iliopsoas is covered by the hyperechoic broad ligament and fascia iliaca. The iliopsoas muscle then travels beneath the inguinal ligament, exits the pelvis, winds around the proximal neck of the femur, and inserts into the lesser trochanter of the hip, functioning as a powerful hip flexor.

The fascia iliaca is located anterior to the iliacus muscle, bound superiorly and laterally by the iliac crest, and merges with the overlying psoas muscle fascia medially. The femoral nerve descends through the psoas major muscle, passing through its lateral border and coursing between psoas and the iliacus muscle deep to the fascia iliaca.

The obturator nerve crosses the iliacus muscle deep to the fascia, innervating the distal medial thigh. The lateral femoral cutaneous nerve emerges from the lumbar plexus and courses inferiorly just lateral to the psoas muscle before crossing the iliacus just deep to the fascia iliaca (Fig. 20.1).

SONOANATOMY

TECHNIQUE

The FICB has been traditionally performed below the level of the inguinal ligament. However, substantial clinical evidence and radiological studies suggest that the infrainguinal approach does not block the femoral, obturator, and lateral femoral cutaneous nerves reliably. Indeed, block failure rate has been described as high as 10% to 37%.

An alternative technique, the suprainguinal approach, has been gaining favor because of improved outcomes in terms of median pain scores in hip fracture patients, and it has a more consistent spread of LA to the lumbar plexus. A recent study identified improved cranial spread of LA with the suprainguinal approach compared with a more caudal spread with the traditional infrainguinal injection. The suprainguinal approach has been shown to provide comparable analgesic efficacy to periarticular infiltration for total hip arthroplasty.

Typical injectate volumes include 20 mL of LA solution such as 0.5% ropivacaine for hip fractures and lower concentrations for postoperative analgesia following hip or knee surgery to minimize motor block.

The patient is positioned supine and a high-frequency linear probe is placed in the inguinal crease to identify the femoral artery. Typical depths are 3 to 4 cm from the skin. The probe is moved laterally to identify the sartorius

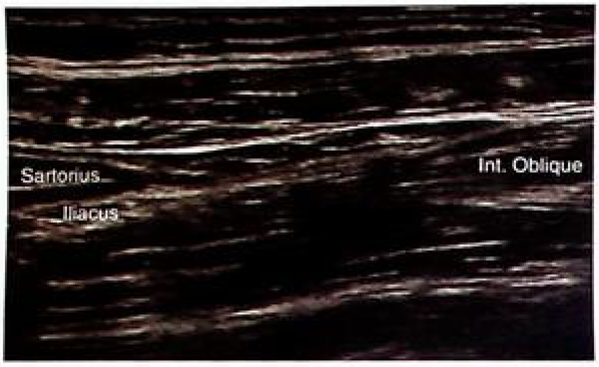


Fig. 20.1 Sonoanatomy of the fascia iliaca compartmental block.

muscle, which is then traced cephalad to its insertion point over the anterior superior iliac spine (ASIS). The ASIS can easily be identified by its hump like hypoechoic shadow. Moving the probe 2 to 3 cm medial to the shadow identifies the iliacus muscle, which covers the ilium. The bright hyperechoic band covering the iliacus is the fascia iliaca.

The probe is then rotated in a slight parasagittal plane such that the medial end points toward the umbilicus. At this position, the anterior abdominal muscles may be identified from superficial to deep as the internal oblique muscle, transversus abdominis, and the fascia iliaca overlying the iliacus muscle. The curve of the ilium will be identified on the inferior caudal side of the ultrasound image, with the iliacus muscle overlying it. With this view, the classical "bow-tie" appearance may be appreciated (Fig. 20.2, Video 20.1).

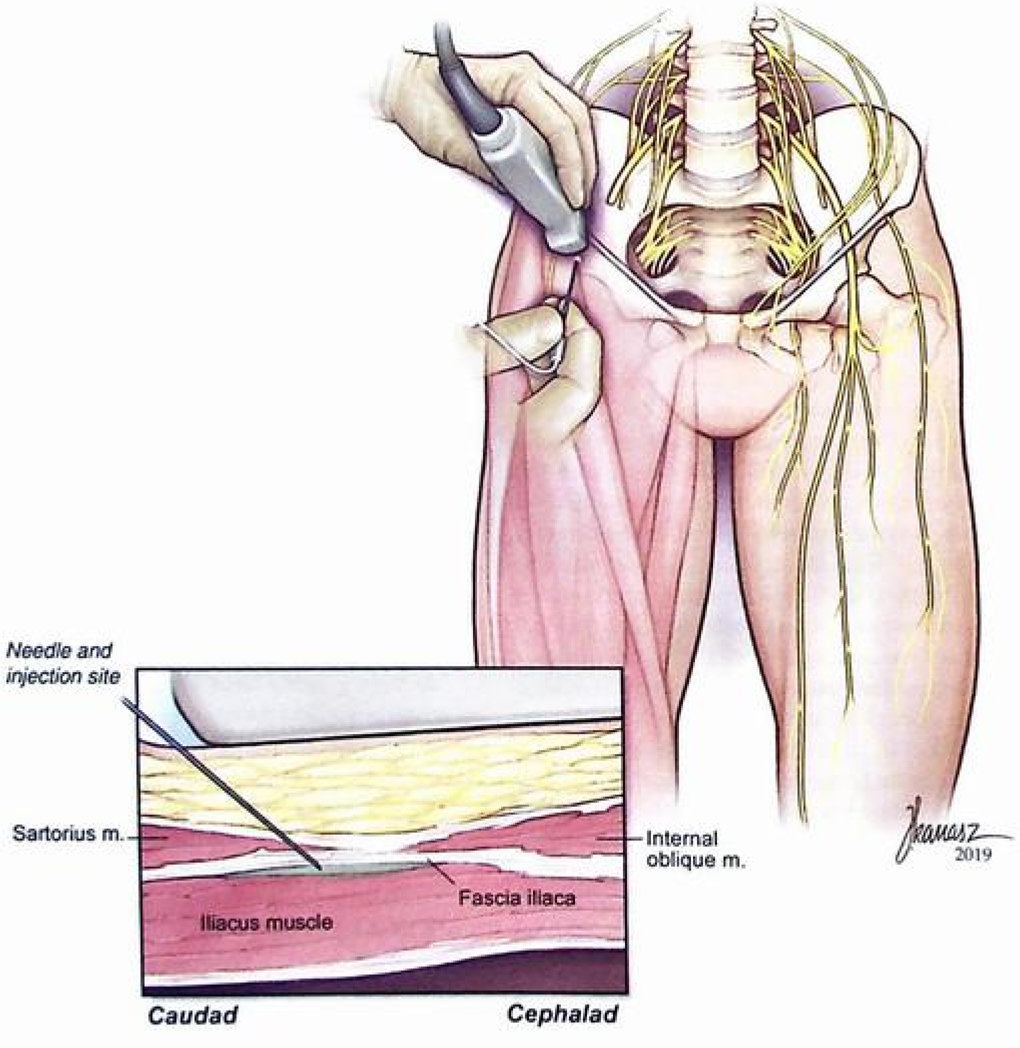


Fig. 20.2 The fascia iliaca compartmental block.

The block needle is inserted and advanced caudad to cephalad such that it traverses the sartorius muscle above the inguinal ligament. It is then advanced in-plane just deep to the fascia iliaca. After piercing the fascia, 1 to 2 mL of LA is injected to confirm adequate spread cranially and peeling of the fascial layers, lifting the fascia off the superficial layer of the iliacus muscle. Then 20 to 30 mL of the block solution is deposited superficial to the iliacus muscle and deep to the fascia iliaca. Adequate spread of LA will expand the space between the iliacus muscle and fascia iliaca in a cephalad direction toward the superior edge of the iliacus muscle. In order to improve the spread of LA superiorly, the needle tip may be advanced superiorly into the space created by the injectate.

Although the FICB has enjoyed renewed interest and is deemed a safe and effective block, complications that have been described include bladder perforation and inadvertent puncture of the deep circumflex iliac artery, inferior epigastric artery, external iliac artery, spermatic cord, and hernia contents. Careful use of real-time ultrasound and maintaining an in-plane needle approach should help mitigate these potential complications.

INGUINAL REGION BLOCKS

Key Points

- The ilioinguinal and the iliohypogastric nerves supply the inguinal area and are the targets of the block.
- It is a superficial block, and a high-frequency linear probe is used for ultrasound guidance.
- The LA should be given between the muscle layers of the abdominal wall near the iliac crest for a successful block.
- The provider should keep in mind that the surgeon may give an LA intraoperatively as well and so should avoid injecting a total amount of LA that would exceed the toxic dose.

INDICATION

The ilioinguinal nerve block provides surgical anesthesia for groin surgery, primarily inguinal herniorrhaphy. It is often combined with iliohypogastric and genitofemoral nerve blocks.

ANATOMY

Innervation of the inguinal region arises from the lumbar plexus nerves. The ilioinguinal and iliohypogastric nerves originate from the first lumbar nerve and emerge from the upper part or the lateral border of the psoas major muscle. The genitofemoral nerve originates from the first and second lumbar nerves. These peripheral extensions of the lumbar plexus and the 12th thoracic nerve follow a circular course. As they course anteriorly, they pass near the ASIS. The 12th thoracic nerve and iliohypogastric nerves run between the internal and external oblique muscles near the ASIS. The ilioinguinal nerve runs between the transverse abdominis muscle and the internal oblique muscle and then penetrates the internal oblique muscle medial to the ASIS. All these nerves continue anteriorly in a medial orientation and become superficial as they terminate in the skin and muscles of the inguinal region. The genitofemoral nerve follows a different course from other nerves and often requires a supplemental intraoperative block to make this regional block effective for inguinal herniorrhaphy.

BLOCK TECHNIQUE

Anatomical Landmark Technique

The patient is placed in the supine position. The ASIS should be identified. A point approximately 3 cm medial and inferior from the ASIS should be marked. After preparing the skin, a needle is inserted in a cephalolateral direction. LA is injected as the needle is withdrawn through the layers of the abdominal wall. Then the needle should be inserted again at a steeper angle until it penetrates all three muscle layers of the abdominal wall. As the needle is withdrawn, 10 to 20 mL of LA is injected. Patients who are obese or muscular may need another injection. The injection is extended from the previously placed skin wheal toward the umbilicus and creates a subcutaneous field block.

Ultrasonography-Guided Technique

The patient is placed supine and the ASIS is identified as for the landmark technique. Draw a line from the ASIS to the umbilicus. A high-frequency linear ultrasound probe is placed along the line, superior and medial to the ASIS (Fig. 20.3). The ilioinguinal and iliohypogastric nerves are seen in the fascia plane, either between the internal oblique muscles and transverse abdominis or between the internal oblique and external oblique muscles. These two nerves are often seen as a hypoechoic structure. Below the transverse abdominis is the peritoneal cavity. It is common to see small blood vessels close to these nerves. Color Doppler is helpful in identifying blood vessels. After identifying the anatomy, a needle is inserted in-plane. A 10 to 20 mL volume of LA is injected into the fascia plane (Video 56.1).

MEDICATION

Lower concentrations of intermediate- to long-acting LAs, such as 1% lidocaine, 1% mepivacaine, 0.25% bupivacaine, and 0.2% ropivacaine, can be chosen. The anesthesiologist should keep in mind that the surgeon may need an additional intraoperative injection of LA and so limit the dose of the initial injection to allow an additional injection without concern for LA systemic toxicity.

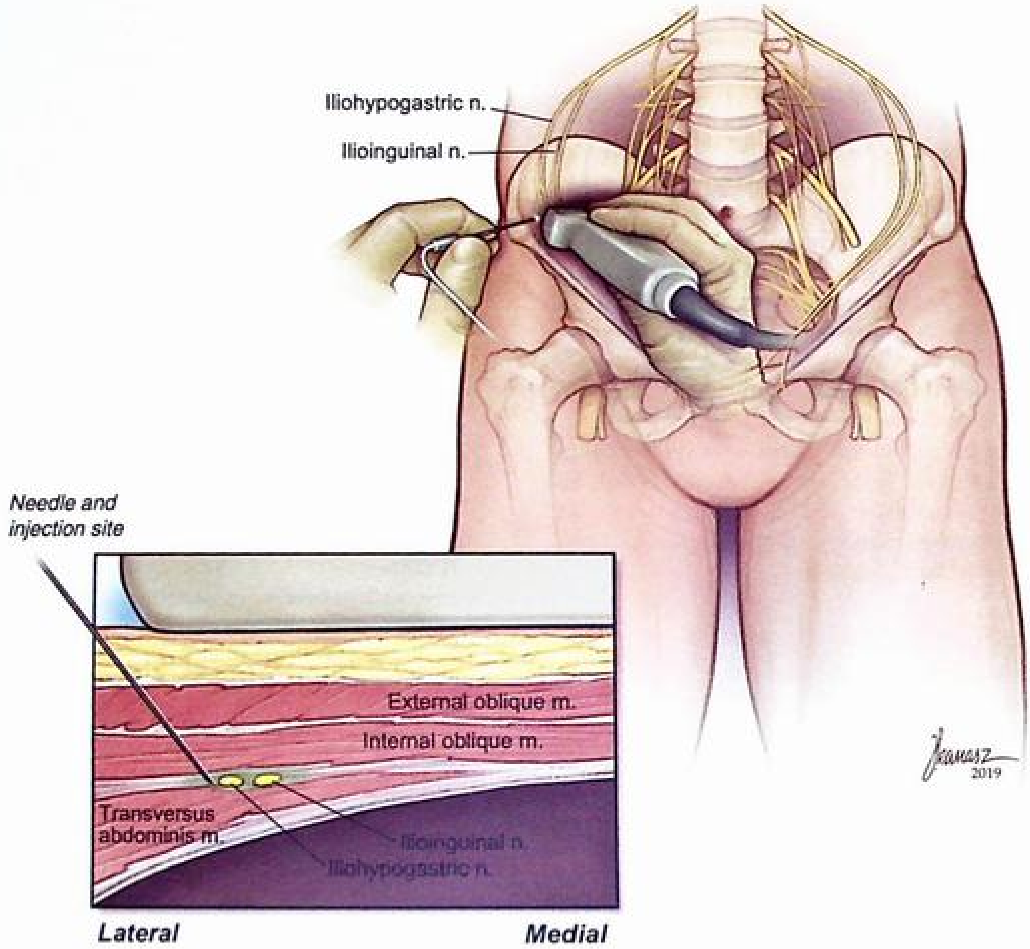


Fig. 20.3 Ilioinguinal-iliohypogastric block.

COMPLICATIONS

The ilioinguinal block is a superficial block and has only a few major complications. These include postblock ecchymosis and hematoma formation in the region of the spermatic cord. This may make it difficult for the surgeon to perform an adequate surgical dissection. If a needle is advanced too deep and enters the peritoneal cavity, perforation of the colon could occur.

Lateral Femoral Cutaneous Nerve Block 21

Sree Kolli and Nour El Hage Chehade

Key Points

- This block can be used to provide postoperative analgesia following hip surgery, upper lateral thigh skin grafting, and neurolysis for refractory meralgia paresthetica.
- Combined with other lower extremity blocks, it reduces the discomfort with a tourniquet during procedures on lower leg.
- This is a very superficial block; hence a high-frequency transducer is preferred for this block.

ANATOMY

The lateral femoral cutaneous nerve (LFCN) of the thigh is a pure sensory nerve and a derivative of posterior branches of the lumbar plexus, namely L2 and L3 spinal nerves. It travels downward along the lateral border of the psoas muscle heading inferior-lateral toward anterior superior iliac spine (ASIS) where it angulates acutely, and exits the lesser pelvis under the inguinal ligament and arrives over the sartorius muscle into the thigh. As the nerve nears the inguinal ligament, it is covered with fascia lata. Furthermore, the nerve divides into anterior (main trunk) and posterior branches as it crosses the inguinal ligament. Importantly, it has several distinct patterns of division—the most common being caudal to inguinal ligament. The anterior branch is roughly 7 to 10 cm below the ASIS and supplies the skin over the anterolateral aspect of the thigh, while the posterior branch runs through fascia lata more proximal to the division of the anterior branch and supplies the lateral thigh from greater trochanter to the midthigh.

LANDMARK TECHNIQUE

With the patient in the supine position, the ASIS is marked and the block needle inserted at a point 2 cm medial and 2 cm caudal to the ASIS, as shown in Fig. 21.1. The needle is advanced until a "pop" is felt as the needle passes through the fascia lata. Local anesthetic (LA) is then injected in a fanlike manner from medial to lateral, as illustrated in Fig. 21.2.

SONOANATOMY

Under sonogram, the nerve is accessible for visualization before it exits the pelvis. The image of the nerve appears as a hyperechoic rimmed structure, seated roughly 0.5 to 1 cm below the skin surface subfascially (not subcutaneously) and 1 to 2 cm inferior and medial to the ASIS. It is found within a fat-filled space sandwiched between the two muscles, namely the sartorius and tensor fascia lata. The orientation of the nerve and its branches is lateral with respect to the obliquely and medially placed sartorius muscle. The nerve can also be confirmed in a sagittal plane by visualizing the deep circumflex iliac artery. In this view, the artery is perpendicular to the course of the nerve and can be seen as a pulsating dot. In some cases, when the nerve has an aberrant course, the area under the medial aspect of the inguinal ligament and immediately lateral to the ASIS should be searched.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

Three ultrasonography-guided techniques were described to block the LFCN: the classic nerve targeting technique, the subinguinal technique, and block of the LFCN in a flat-filled flat tunnel (FFFT).

NERVE TARGETING TECHNIQUE AND SUBINGUINAL TECHNIQUE

While placing the patient in supine position, the ASIS is palpated, and the lateral end of a high-frequency transducer is positioned immediately inferior to the ASIS in line with the inguinal ligament—angled slightly in a caudal direction. The inguinal ligament can be seen as a linear hyperechoic structure running from the pubic tubercle to the ASIS. At this level, we can find an image showing the inguinal ligament, the ASIS, and the anterior inferior iliac spine (AIIS). The subinguinal technique consists of performing the block at this level below the inguinal ligament where the nerve courses without directly visualizing the nerve. The needle is inserted out of plane, and 5 mL of LA is injected medial to the ASIS.

Also, we can keep moving the probe further medial-caudad until locating the nerve. The nerve can be visualized in a

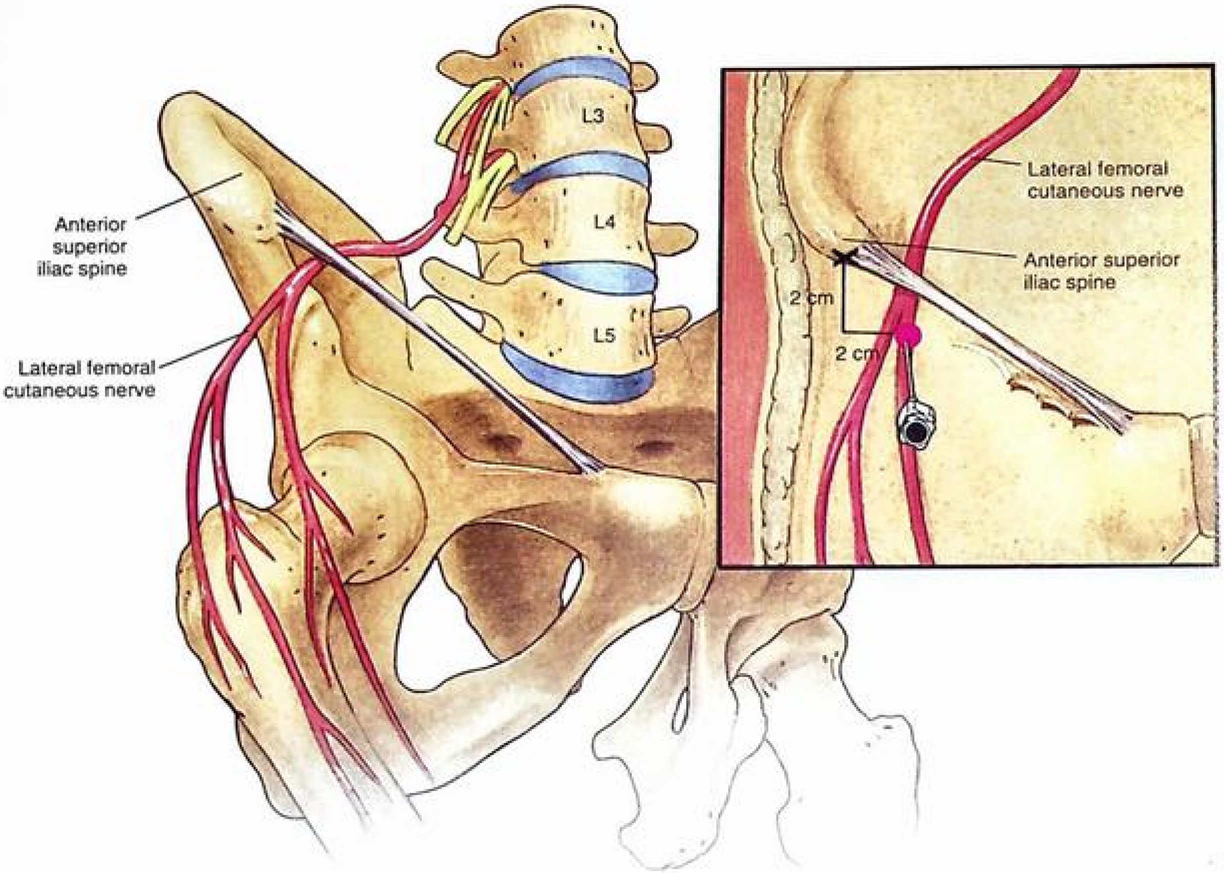


Fig. 21.1 Lateral femoral cutaneous nerve: anatomy.

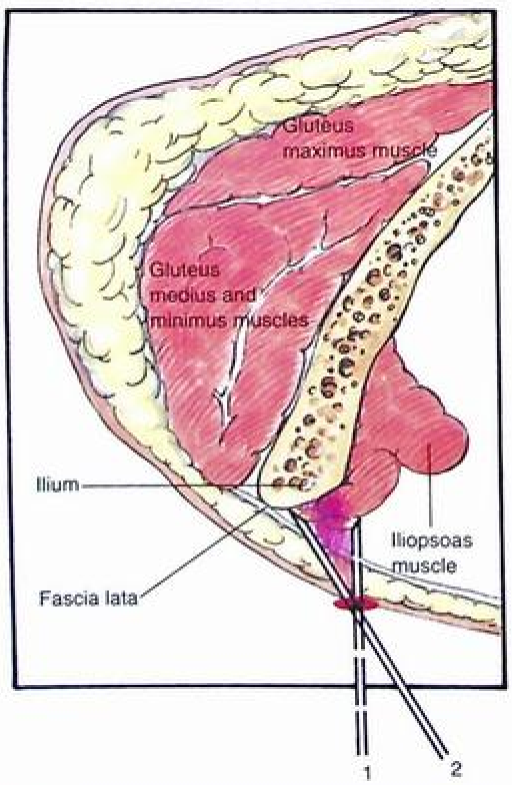


Fig. 21.2 Lateral femoral cutaneous nerve block: technique.

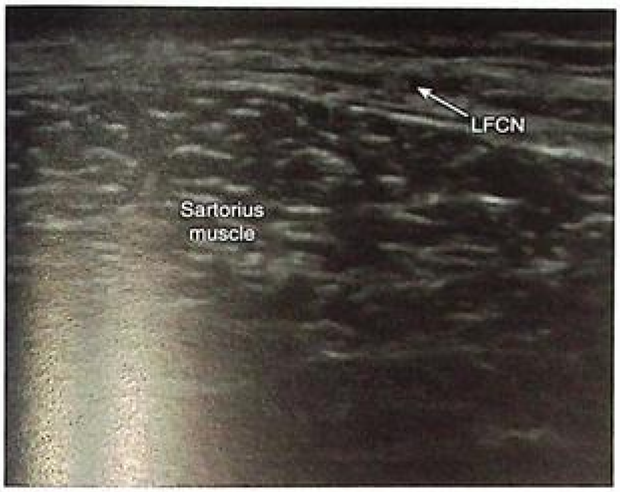


Fig. 21.3 Sonoanatomy for LFCN block.

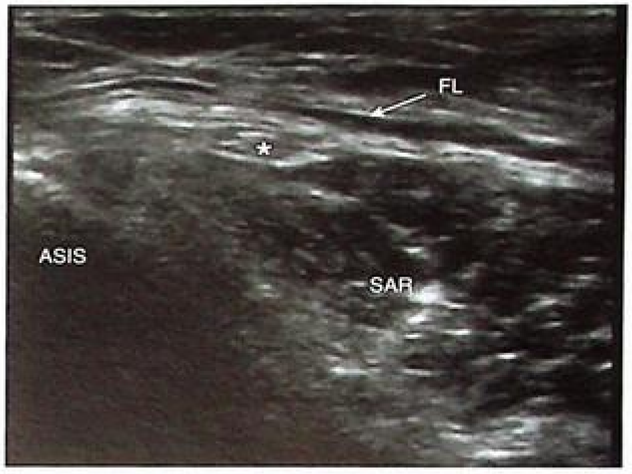


Fig. 21.4 Ultrasound-guided LFCN block.

fat-filled space between medially located sartorius and laterally tensor fascia lata. Once the nerve is found in the transverse plane, it should be traced proximally and distally (Figs. 21.3 and 21.4). Confirmation of the nerve can also be done in the sagittal plane by visualizing the deep circumflex vessels (via Doppler) that course parallel to the inguinal ligament and perpendicular to the course of the nerve. It is essential to confirm the nerve by either method described because it is not uncommon to mistake the hyperechoic tendinous part of the sartorius as the nerve. After confirmation, the needle is inserted in a lateral to medial fashion via the in-plane technique, and 5 mL of LA can be injected subfascially or perineurally. However, visualization of the nerve might be difficult sometimes. Both techniques could be easily performed with similar outcomes (Video 21.1).

LFCN BLOCK IN THE FFFT

A novel, recently described technique involves identifying the LFCN in the FFFT formed by the double layer of the fascia lata between the sartorius and the tensor fascia lata muscle, about 10 cm from the ASIS. The transducer can be placed in a transverse direction on the thigh to find the sartorius muscle. The transducer is moved cranially toward the ASIS. The target area is where we localize the sartorius muscle and the tensor of the fascia lata, along with the ASIS. The gap between the two muscles is formed by a fat-filled tunnel, seen as a hyperechoic area between the two muscles where the LFCN can be localized. The needle is inserted using the in-plane technique into the FFFT, and 10 mL of LA is injected intermittently while simultaneously advancing the needle tip inside the FFFT toward the ASIS and while tracking the needle tip with ultrasonography in real time.

PEARLS

- This block can be used in lieu of a lumbar plexus block after hip surgery. However, an injection of a high volume of LA in the fascia iliaca can spread as far as the anterior and posterior divisions of the femoral nerve.
- The block can be performed just below the inguinal ligament medial to the ASIS, with or without visualizing the nerve on ultrasound.
- The nerve appears as a small hyperechoic structure containing hypoechoic vesicles and must be differentiated from the hyperechoic tendinous part of the sartorius muscle by scanning the course of the nerve. Hydrodissection of fascia iliaca and tensor facia lata may also help improve visualization of the nerve.
- It is not uncommon to see variations in the course of the nerve. It is sometimes helpful to locate the nerve more distally, between the sartorius and tensor facia lata, then tracing up proximally toward the ASIS at the insertion site of the sartorius. Also, the deep circumflex artery landmark may be useful.
- Because of the superficial nature of this block, apply light pressure and plenty of ultrasound gel for better nerve visualization.
- Peripheral nerve catheters are not studied with this block.

Suggested Reading

Hara K, Sakura S, Shido A. Ultrasound-guided lateral femoral cutaneous nerve block: comparison of two techniques. *Anaesth Intensive Care*. 2011;39:69–72.

Nielsen TD, Moriggl B, Barckman J, et al. The lateral femoral cutaneous nerve: description of the sensory territory and a novel ultrasound-guided nerve block technique. *Reg Anesth Pain Med*. 2018;43(4):357–366.

Obturator Block 22

Loran Mounir-Soliman and David L. Brown

Key Points

- The success of the block depends on the appropriate spread of local anesthetics (LAs) in the appropriate fascial planes superficially and deeply to the adductor brevis muscle.
- Care should be taken to confirm the spread in the intermuscular fascial planes, not intramuscular.
- Change in adductor strength is the best assessment method for the block, because the sensory distribution is variable.
- With a successful block, some residual adductor strength is secondary to the formal innervation to the pectineus as well as some sciatic innervation to the adductor magnus.

PERSPECTIVE

This block is most often combined with the sciatic, femoral, and lateral femoral cutaneous nerve blocks to allow surgical procedures on the lower extremities. If an operation on the knee using these peripheral blocks is planned, the obturator block is often essential. Another use for this block is in patients who have hip pain. It can be used diagnostically to help identify the cause of pain, because the obturator nerve block may provide considerable pain relief if the nerve's articular branch to the hip is involved in pain transmission. The block also may be useful in the evaluation of lower extremity spasticity or chronic pain syndromes.

Patient Selection. As with femoral and lateral femoral cutaneous nerve blocks, elicitation of paresthesia is not essential for the obturator block. Any patient able to lie supine is a candidate.

Pharmacologic Choice. Motor blockade most often is not necessary for surgical patients receiving obturator nerve block; thus lower concentrations of LAs are appropriate for obturator block: 0.75% to 1.0% lidocaine or mepivacaine, 0.25% bupivacaine, or 0.2% ropivacaine.

PLACEMENT

Anatomy. The obturator nerve emerges from the medial border of the psoas muscle at the pelvic brim and travels along the lateral aspect of the pelvis, anterior to the obturator internus muscle and posterior to the iliac vessels and ureter. It enters the obturator canal cephalad and anterior to the obturator vessels, which are branches from the internal iliac vessels. In the obturator canal, the obturator nerve divides into anterior and posterior branches (Fig. 22.1). The anterior branch supplies the anterior adductor muscles and sends an articular branch to the hip joint and a cutaneous area on the medial aspect of the thigh. The posterior branch innervates the deep adductor muscles and sends an articular branch to the knee joint. In 10% of patients, an accessory obturator nerve may be found.

Position. The patient should be supine, with the legs in a slightly abducted position. The genitalia should be protected from antiseptic solutions.

Needle Puncture. The pubic tubercle should be located and an "X" marked 1.5 cm caudad and 1.5 cm lateral to the tubercle (Fig. 22.2). The needle is inserted at this point, and at a depth of approximately 1.5 to 4 cm, it contacts the horizontal ramus of the pubis. The needle is then withdrawn, redirected laterally in a horizontal plane, and inserted 2 to 3 cm deeper than the depth of the initial contact with bone. The needle tip now lies within the obturator canal (see Fig. 22.2). With the needle in this position, 10 to 15 mL of an LA solution is injected while the needle is advanced and withdrawn slightly to ensure development of a "wall" of LA in the canal.

POTENTIAL PROBLEMS

The obturator canal is a vascular location, thus the potential exists for intravascular injection or hematoma formation, although these are more theoretical than clinical concerns.

PEARLS

This block, even in trained hands, has a variable success rate. Our experience suggests that one must rely on the volume of anesthetic delivered rather than on absolute accuracy of needle position. Fortunately, use of an obturator block with the other lower extremity peripheral nerve blocks is not an absolute requirement for most surgical procedures. If this block is used diagnostically for patients with chronic pain, it is helpful to use a nerve stimulator to guide needle placement. This will minimize diagnostic confusion when pain relief is produced with a small volume

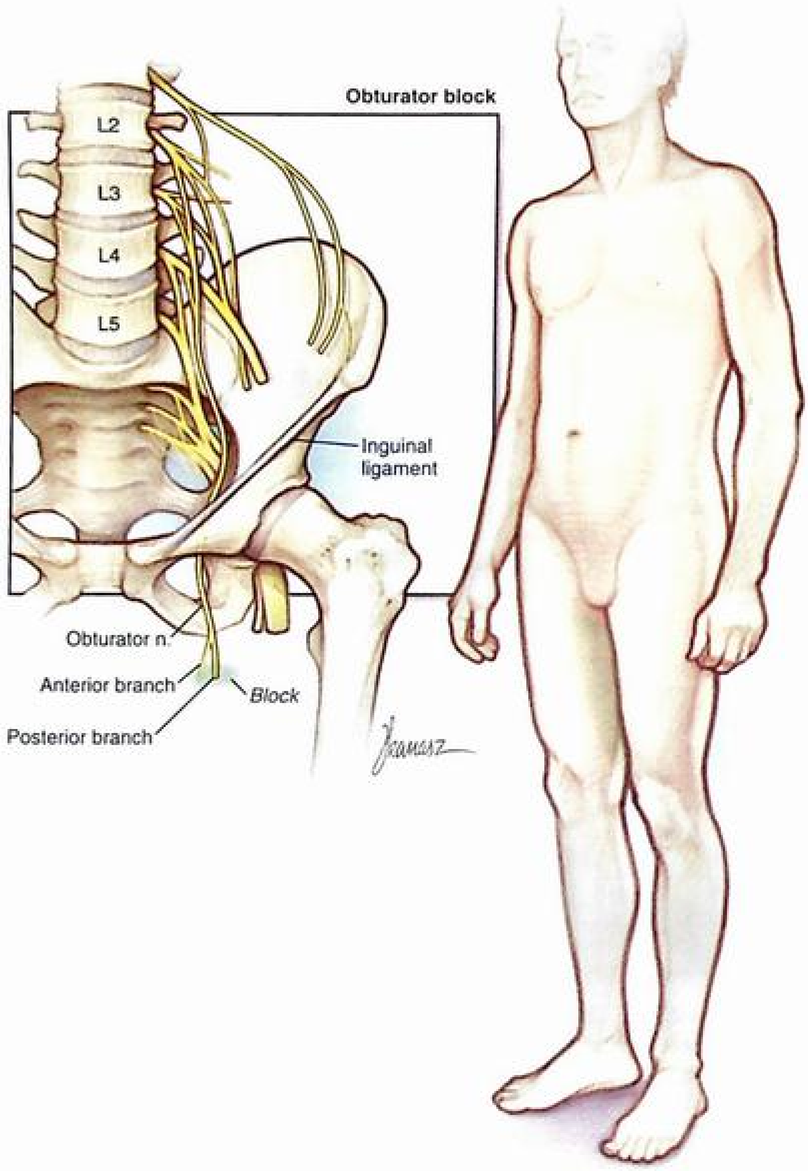


Fig. 22.1 Obturator nerve: functional anatomy.

of LA. Large-volume injections (approximately 15 mL) are performed with this block for many surgical procedures.

SONOANATOMY

The obturator nerve is formed from the anterior primary rami of the L2 to L4 roots as a branch of the lumbar plexus within the psoas muscle. The nerve exits the pelvis through the obturator foramen, then typically divides into an anterior and posterior branch before entering the thigh. The anterior branch provides sensory supply to a variable area of the medial aspect of the thigh as well as motor fibers to the adductor muscles. The posterior branch provides primarily motor fibers to the adductor muscles and occasional articular sensation to the medial aspect of the knee joint. Notably, the articular branch of the hip joint provided by the obturator nerve usually originates from the main obturator nerve before division.

In the thigh, the two nerves run within the adductor compartment and medial to the femoral compartment. The anterior branch has a more superficial course between the fascia of the pectineus and adductor brevis muscles, whereas the posterior branch runs at a deeper level between the adductor brevis and adductor magnus muscles (Fig. 22.3).

INDICATIONS

- Avoid adductor muscle contractions during transurethral bladder surgery under spinal anesthesia or when administration of muscle relaxants is undesirable.

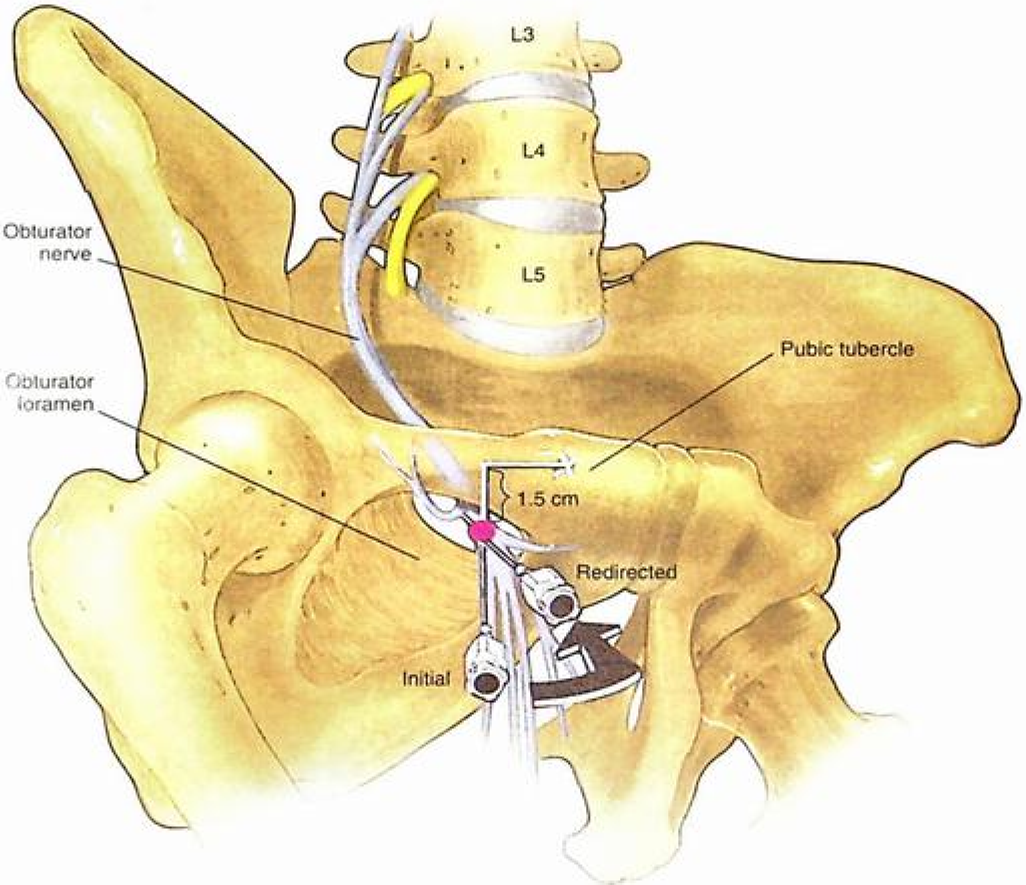


Fig. 22.2 Obturator nerve block: technique.

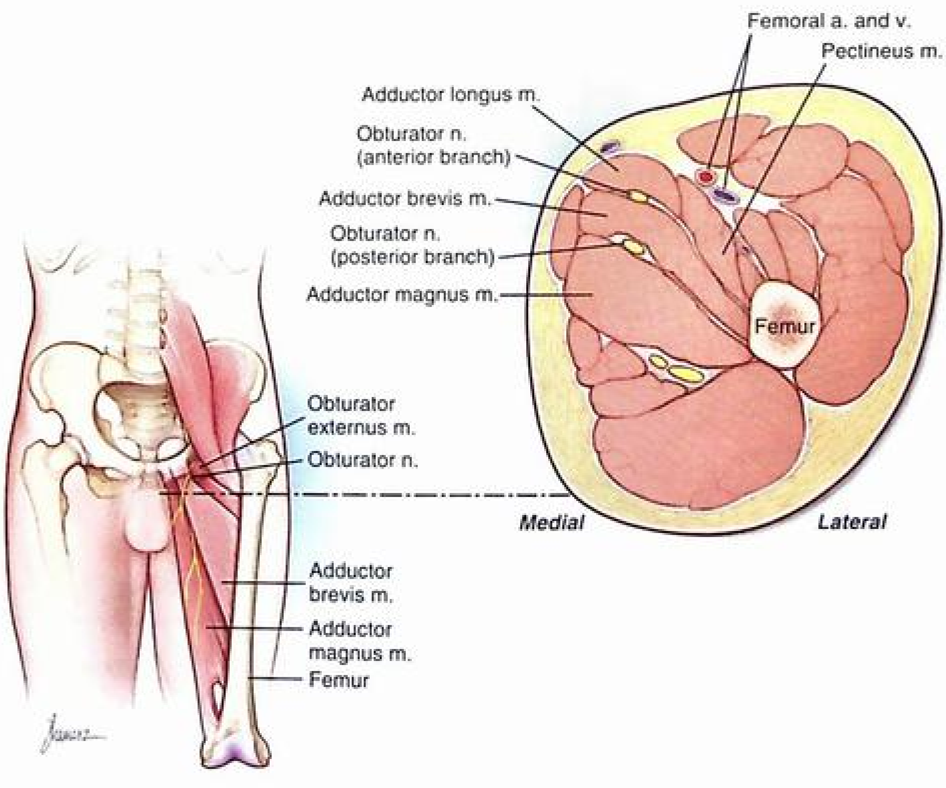


Fig. 22.3 Obturator anatomy.

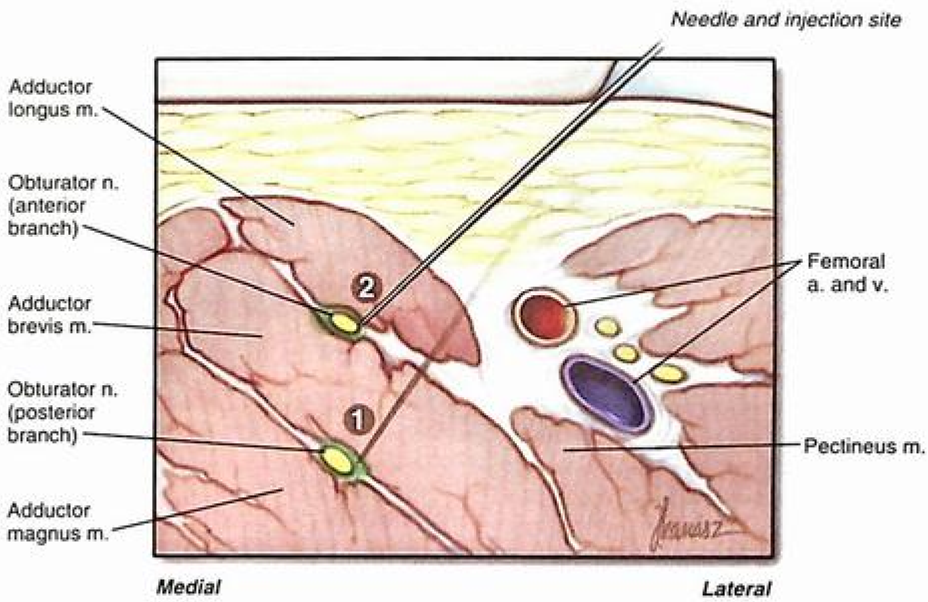


Fig. 22.5 Obturator nerve block technique.

Popliteal and Saphenous Block 23

Maria Yared and David L. Brown

Key Points

- Use a linear transducer probe (8–13 MHz), starting at a depth of 4 cm.
- For a single-shot nerve block, use a 21-gauge, 4-inch or 100-mm needle (stimulating or nonstimulating).
- For local anesthetic solution in a single-shot nerve block, bupivacaine or ropivacaine 0.5% 20 mL (for ultrasound-guided approach) and 30 to 40 mL (for anatomic approach alone) can be used.
- For a continuous nerve block, use a 17-gauge, 3.5-inch or 89-mm Tuohy needle with a 20-gauge catheter (stimulating or nonstimulating). You can inject ropivacaine 0.2% or bupivacaine 0.25% 20 mL and use a bag of solution containing ropivacaine 0.2% running at 8 mL per hour with a 8- to 12-mL bolus every 60 minutes.
- Confirm local anesthetic injection is subparaneural by tracking the local anesthetic spread proximally and distally from the site of injection around the nerves.
- If you are having trouble finding the artery, use color Doppler (the artery pulsates and is hypoechoic).

PERSPECTIVE

The nerves blocked in the popliteal fossa—the tibial and peroneal nerves—are extensions of the sciatic nerve. The principal use of this block is for foot and ankle surgery. The addition of a saphenous nerve block improves comfort because medial lower leg and ankle sensory blockade make tourniquets and medial ankle surgery more comfortable.

Patient Selection. To use the classic form of this block, the patient must be able to assume the prone position. Elicitation of paresthesia or a motor response is desirable but not essential; however, block effectiveness decreases without these endpoints.

Pharmacologic Choice. The principal use of these blocks is to provide sensory analgesia; thus lower concentrations of a local anesthetic (LA) are practical in contrast to situations in which motor blockade is essential. Concentrations of 1% lidocaine, 1% mepivacaine, 0.25% to 0.5% bupivacaine, and 0.2% to 0.5% ropivacaine are effective.

TRADITIONAL BLOCK TECHNIQUE

PLACEMENT

Anatomy. As illustrated in Fig. 23.1, the cephalad popliteal fossa is defined by the semimembranosus and semitendinosus muscles medially and the biceps femoris muscle laterally. Its caudad extent is defined by the gastrocnemius muscles both medially and laterally. If this quadrilateral area is bisected, as shown in Fig. 23.1, the area of interest to the anesthesiologist is the cephalolateral quadrant (hatched area), where both a tibial and common peroneal nerve block is possible. The tibial nerve is the larger of these two nerves; it separates from the common peroneal nerve at the upper limit of the popliteal fossa and sometimes higher. The tibial nerve continues the straight course of the sciatic nerve and runs lengthwise through the popliteal fossa immediately under the popliteal fascia. Inferiorly, it passes between the heads of the gastrocnemius muscles. The common peroneal nerve follows the tendon of the biceps femoris muscle along the cephalolateral margin of the popliteal fossa, as illustrated in Fig. 23.2. After the common peroneal nerve leaves the popliteal fossa, it travels around the head of the fibula and divides into the superficial peroneal and deep peroneal nerves.

Position. The patient is placed in a prone position, and the anesthesiologist stands at the patient's side to allow palpation of the borders of the popliteal fossa.

Needle Puncture. With the patient in the prone position, they are asked to flex the leg at the knee, which allows more accurate identification of the popliteal fossa. Once the popliteal fossa has been defined, it is divided into equal medial and lateral triangles, as shown in Fig. 23.1. An "X" is placed 5 to 7 cm superior to the skin crease of the popliteal fossa and 1 cm lateral to the midline of the triangles, as shown in Fig. 23.1. Through this site, a 22-gauge, 4- to 6-cm needle is advanced at an angle of 45 to 60 degrees to the skin while being directed anterosuperiorly (Fig. 23.3). Paresthesia or a motor response is sought; when obtained, 30 to 40 mL of LA is injected.

When a saphenous block is added for foot and ankle surgery, the patient's knee is bent at approximately a 45-degree angle and the medial aspect of the leg is exposed. Two primary techniques are used for a saphenous block. A superficial ring of LA may be injected just distal to the medial surface of the tibial condyle. Often,

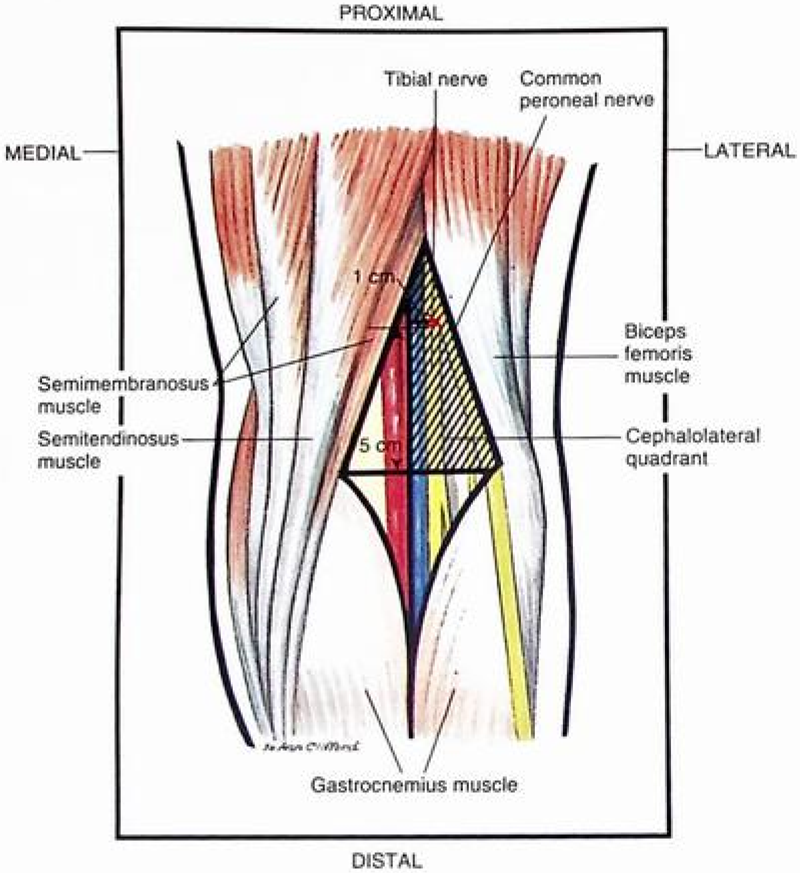


Fig. 23.1 Popliteal fossa: surface anatomy and technique for the popliteal block.

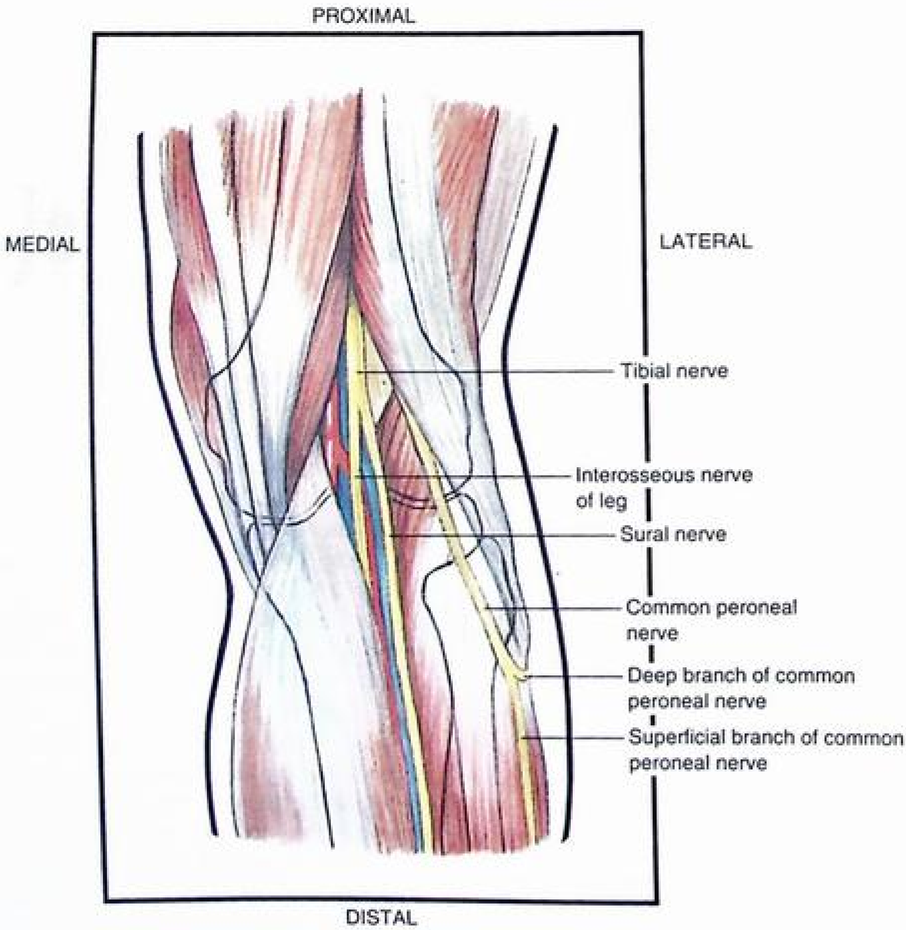


Fig. 23.2 Popliteal fossa: neural anatomy.

5 to 10 mL of LA is needed. Conversely, a more proximal technique at the cross-sectional level of the superior border of the patella is possible (Fig. 23.4). In this case, a 22- to 25-gauge, 3- to 4-cm needle is inserted immediately deep to the sartorius muscle in the plane between the vastus medialis and the sartorius muscles, and 10 mL of LA is injected.

POTENTIAL PROBLEMS

Although vascular structures also occupy the popliteal fossa, intravascular injection should be infrequent if the usual precautions are taken. Hematoma formation is possible.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

The sciatic nerve courses through the popliteal fossa, where it is blocked. It is beneficial to use ultrasound for this block because the division of the sciatic nerve into posterior tibial and common peroneal nerves occurs at variable distances from the popliteal crease. The goal is to block the sciatic nerve before it divides and inject the LA within the paraneurium that surrounds both branches. This allows for a more consistent blockade of both divisions and use of lower volumes of LA. The same anatomic landmarks that are used for the nerve stimulator-guided technique are also used for the

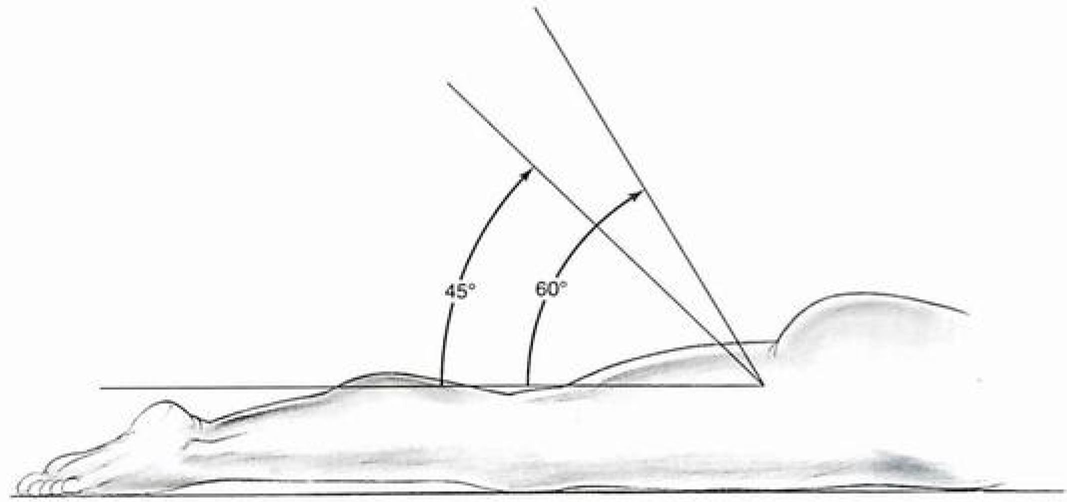


Fig. 23.3 Popliteal fossa: needle angle technique for the popliteal block.

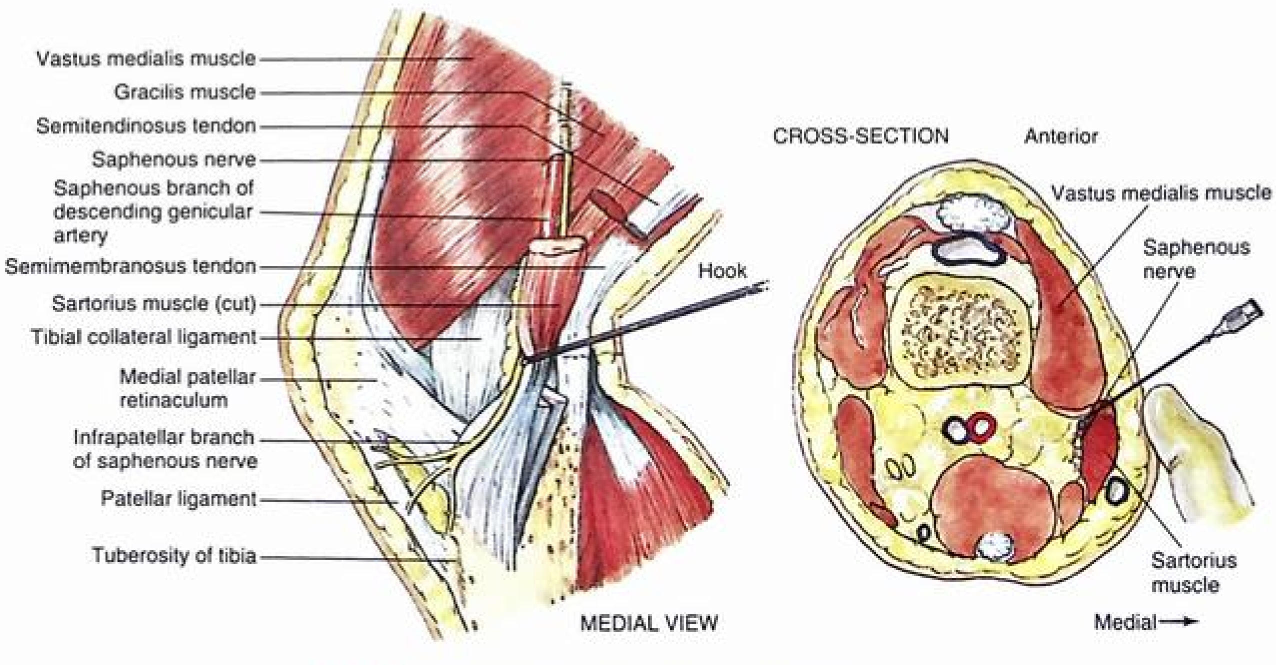


Fig. 23.4 Saphenous nerve block: anatomy and proximal technique.

ultrasound-guided block. However, with the ultrasound, the goal is to find the popliteal vessels first (Figs. 23.5 and 23.6).

INDICATIONS

The sciatic nerve block at the popliteal fossa is done when the goal is to block the distal leg and foot (S2–S4) for the following:

- Tibia or fibula repair
- Achilles tendon repair
- Calf tourniquet pain
- Ankle and toe surgeries
- Below-the-knee amputations
- Posterior knee pain

To have full surgical anesthesia of the area below the knee, one must also block the saphenous nerve, which is the terminal branch of the femoral nerve and innervates the skin of the medial portion of the lower leg.

TECHNIQUE

The popliteal block can be done with the patient in the prone, lateral decubitus, or supine position. We find the prone position to be easiest because it allows us to easily rest and stabilize the hand that is holding the ultrasound probe on the patient's leg once the desired image has been achieved, especially when placing a nerve catheter (Fig. 23.7). However, if the patient has a cast, external fixation device, or fracture, making positioning difficult, then it may be preferable to place the patient in lateral

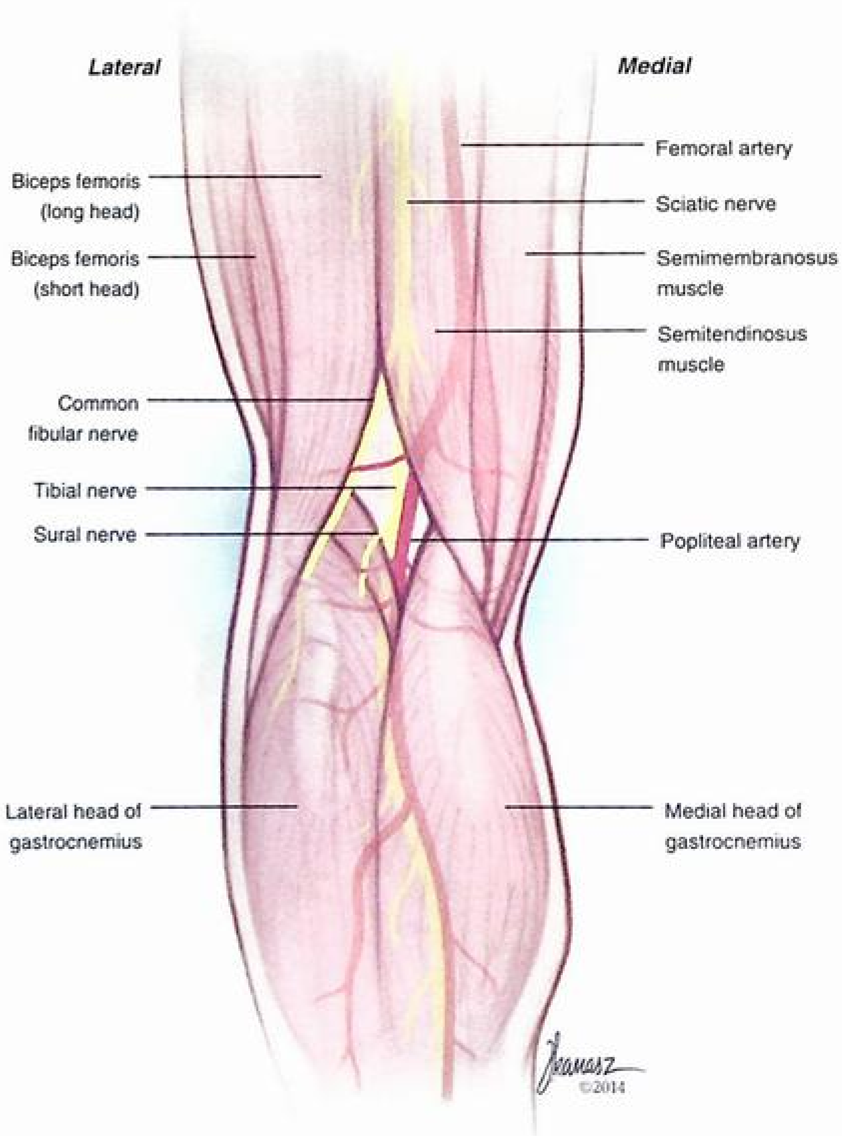


Fig. 23.5 Anatomy of the popliteal fossa.

decubitus (the operative site being superior and placing pillows between the knees), or supine (hip and knee are flexed with blankets serving as a foot rest). Whichever approach you decide to use, the ultrasound image will be the same; it is the needle path that changes (Fig. 23.8).

After identifying the popliteal fossa, place the linear ultrasound probe, which is 8 to 13 MHz, in the transverse position at the crease and ensure that the left side of the screen corresponds to the lateral side of the patient (where the biceps femoris muscle will lie). Then scan medially and laterally to find the popliteal artery, which tends to be about 4 cm deep. The popliteal vein, which is a compressible hypoechoic structure, can be lateral or deep to the artery. The posterior tibial nerve usually lies superficial and lateral to the artery. The posterior tibial nerve will be a hyperechoic oval with a honeycomb interior. Once the posterior tibial nerve is identified, slowly move the ultrasound probe cephalad. Adjust the probe as you scan to maintain a good view of the nerves. As you move cephalad, the popliteal artery tends to course deeper (more anteriorly) and may disappear from the ultrasound view. The common peroneal nerve, usually smaller in size than the tibial nerve, will emerge laterally and move medially to join the posterior tibial nerve until they are enveloped within a common epineural sheath. Their unity forms the sciatic nerve and usually occurs around 5 to 10 cm from the crease, but the distance varies (Fig. 23.9).

We usually prefer the in-line approach when performing this block (Figs. 23.10–23.12). For a single-shot nerve block, after the posterior tibial and common peroneal nerves join, we usually move the probe 1 to 2 cm more cephalad to ensure that the injected LA will surround both nerves. If obtaining an ideal image cephalad to the bifurcation is challenging due to patient anatomy, an alternative is to

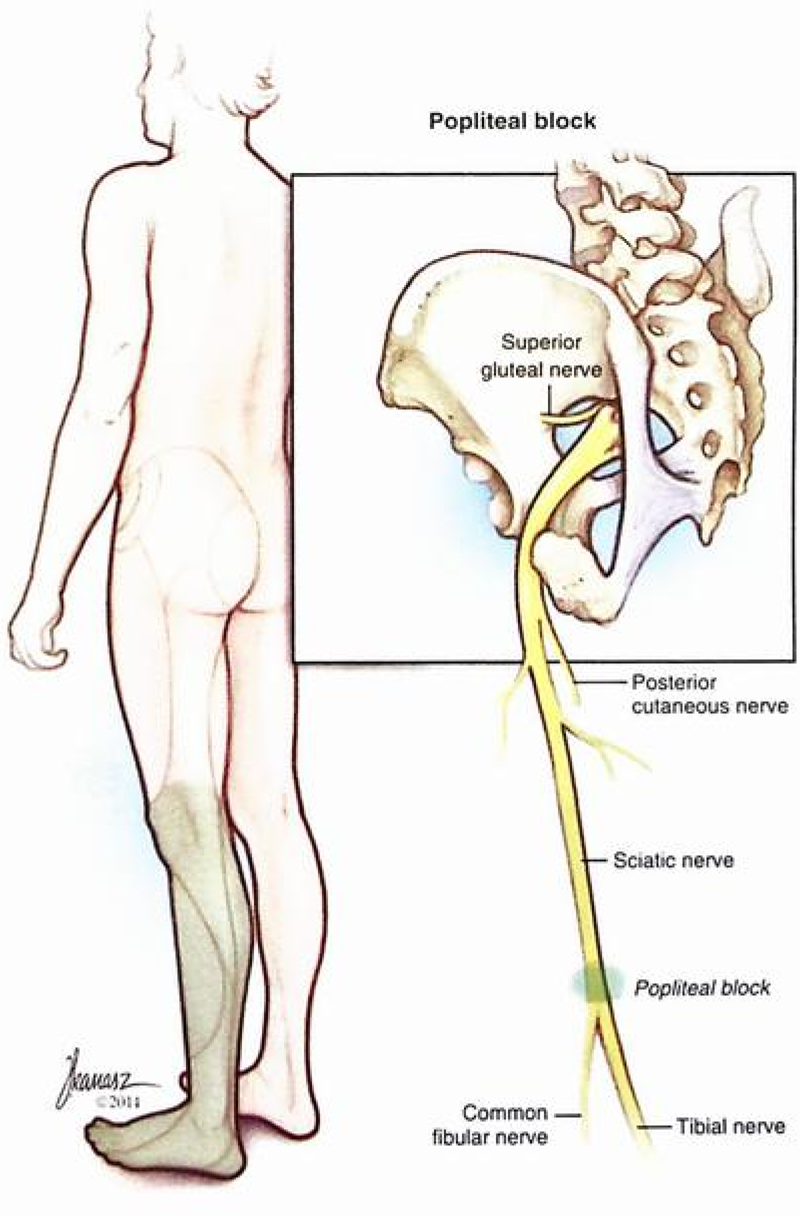


Fig. 23.6 Anatomy of the popliteal block and dermatomal coverage.

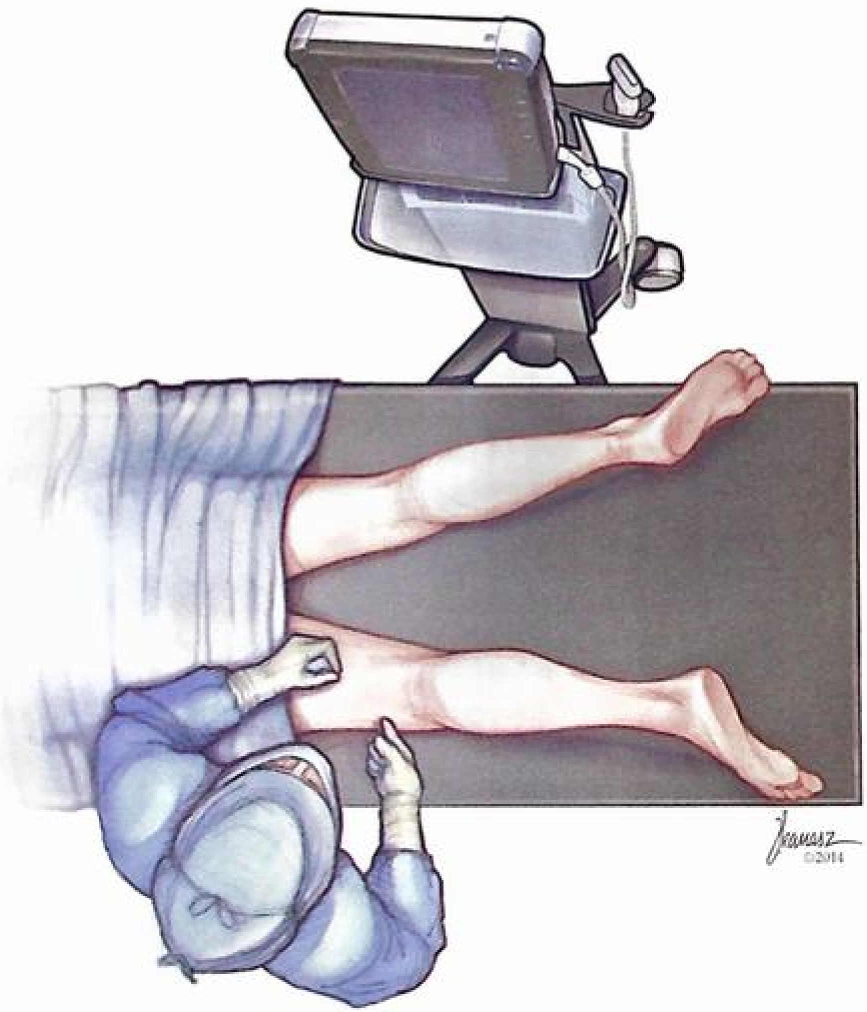


Fig. 23.7 Patient position and ultrasound machine for the popliteal block in prone position.

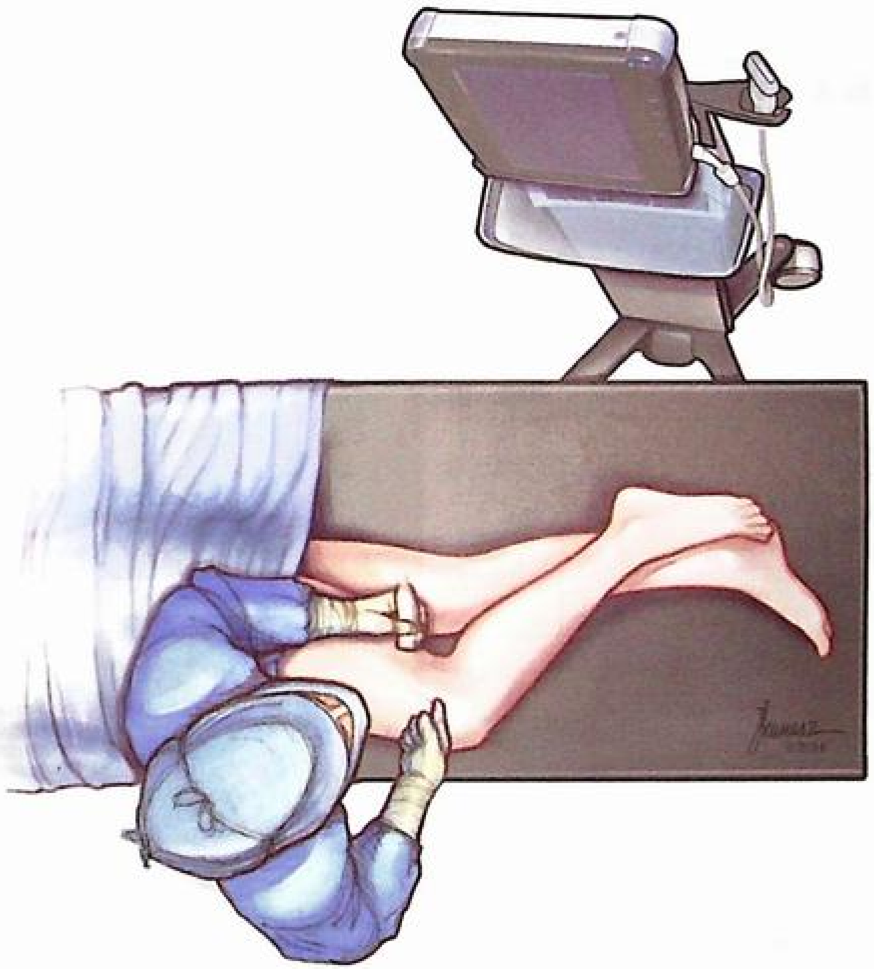
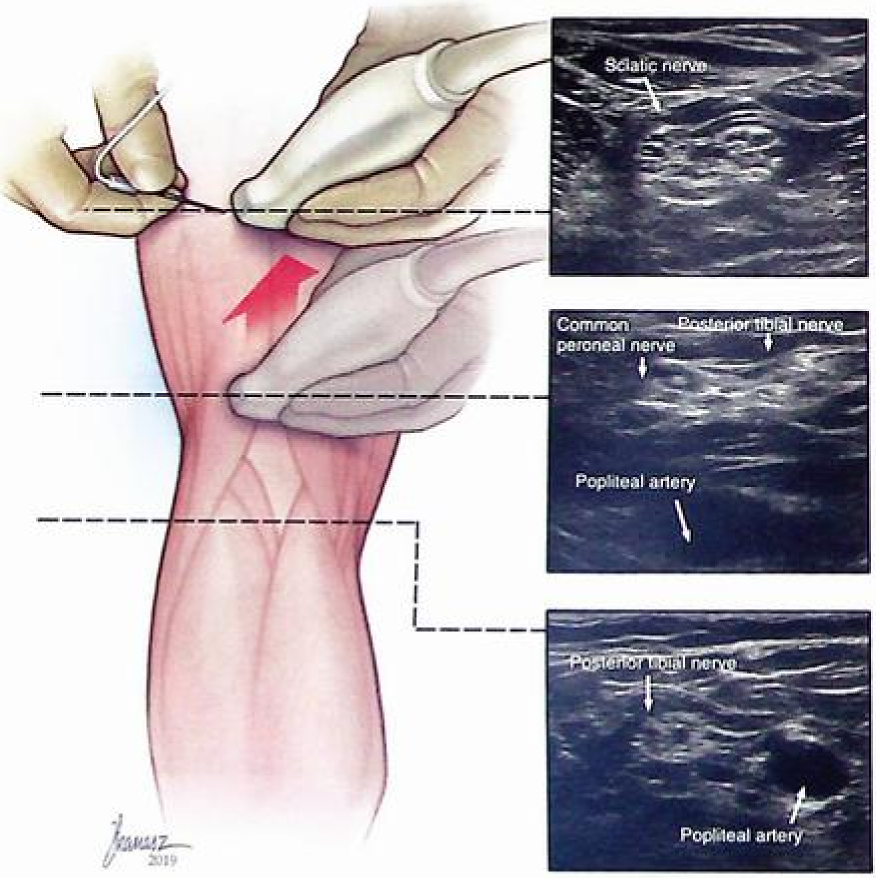


Fig. 23.8 Patient position and ultrasound machine for the popliteal block in lateral position.



Further cephalad, the "dumbbell sign" disappears because the nerves unite and are enveloped within a common epineural sheath, forming the sciatic nerve. It is at this point, or preferably 1 to 2 cm above the division of the sciatic nerve, that local anesthetic is injected. A halo of hypoechoic fluid surrounding the hyperechoic, honeycomb-appearing sciatic nerve indicates appropriate local anesthetic spread.

As you move the ultrasound probe cephalad, the popliteal artery tends to course deeper and may disappear from view. The common peroneal nerve comes into view from the lateral /left side of the screen. As it merges with the posterior tibial nerve, they create the "dumbbell sign," with each nerve resembling the weight portion of the dumbbell and the connective tissue in between the nerves resembling the bar. This sign helps you find the nerves on the ultrasound image.

At the popliteal crease, the popliteal artery tends to be about 4 cm deep; however, it may be deeper in patients who are morbidly obese. The popliteal vein is often compressed by the pressure of the ultrasound probe and can be lateral or deep to the artery. The posterior tibial nerve usually lies superficial and lateral to the artery.

Fig. 23.9 This illustration demonstrates the movement of the ultrasound probe as you move it cephalad from the popliteal crease. Within the popliteal fossa, the popliteal artery and the sciatic nerve's two main terminal branches (posterior tibial and common peroneal nerves) are visualized. One scans proximally/cephalad until the two branches unite together to form the sciatic nerve. Note that the ultrasound probe is in the transverse position; also note the in-plane technique, with the needle directed from lateral to medial, parallel to the ultrasound probe.

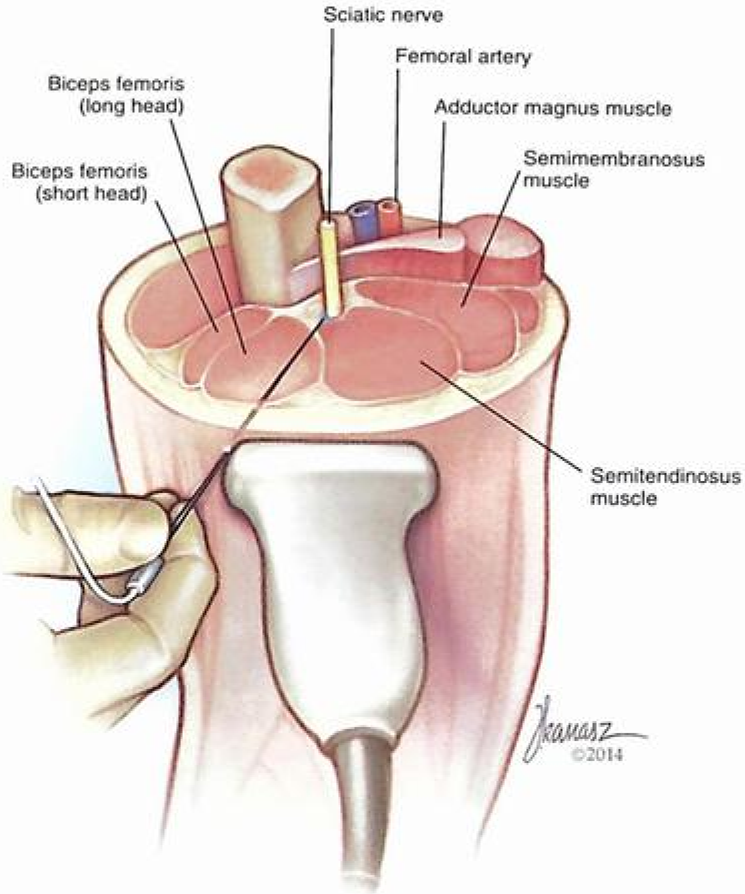


Fig. 23.10 In-plane technique for the popliteal block with needle from lateral to medial.

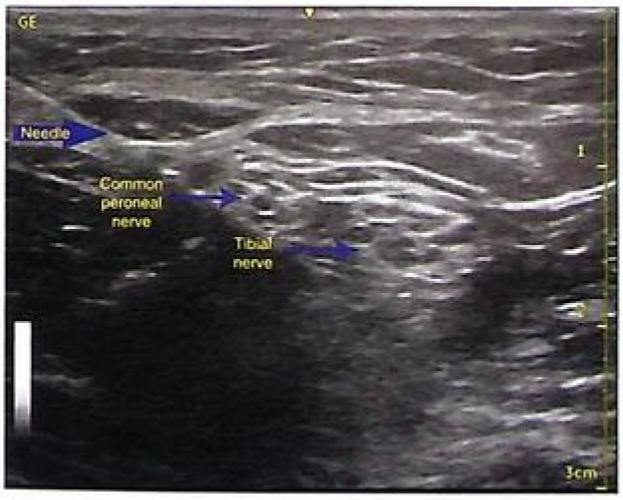


Fig. 23.11 Ultrasound still of the popliteal block procedure. Note the needle is in-plane, thus visualizing the entire needle shaft.

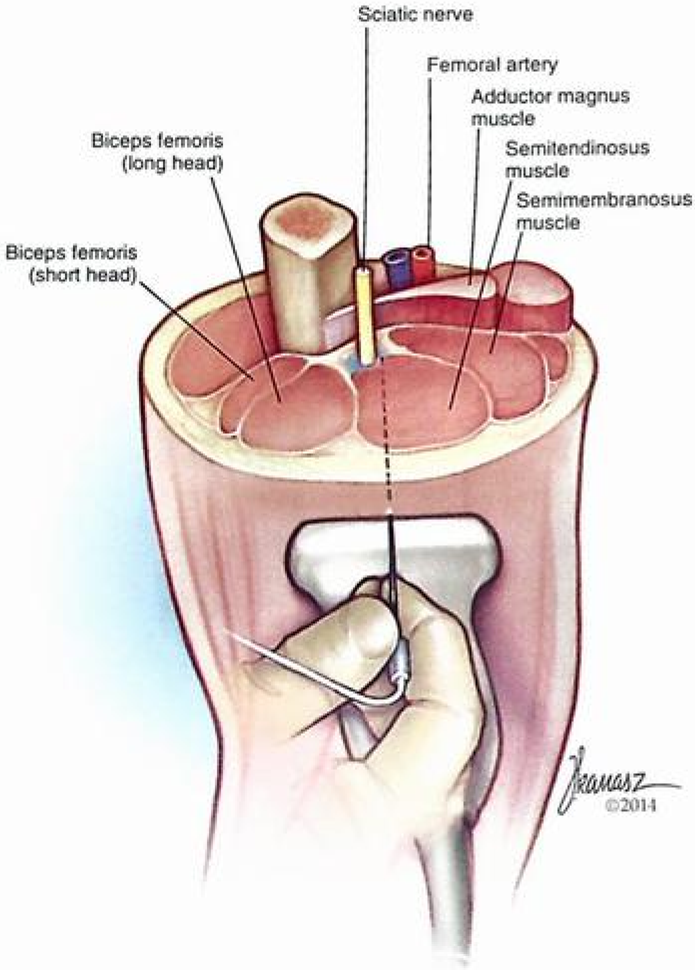


Fig. 23.12 Out-of-plane technique for the popliteal block.

inject LA circumferentially around each individual nerve; however, the subparaneural technique has better block success rate and onset (Video 23.1). When placing a continuous nerve catheter, we insert a 17-gauge Tuohy needle. Once the tip is located near the 6 o'clock position in relation to the nerve, we insert the catheter through the Tuohy needle and follow its trajectory by visualizing the catheter or tissue movement caused by the catheter in order to ensure that it does not migrate. Insert the catheter 5 cm beyond the tip of the Tuohy needle (Fig. 23.11). Please refer to Chapter 24 for a review of the ultrasound-guided adductor canal block.

PEARLS

- If you are having trouble getting a good image of the nerves, try tilting the ultrasound probe caudad to ensure that the ultrasound beams are hitting the nerves at a 90-degree angle.
- As you move the probe cephalad and the nerve tracks deeper, it may be more difficult to visualize the nerve and needle tip despite various attempts at probe manipulation. In this scenario, using the combined technique of ultrasound and nerve stimulation is helpful, or try hydrodissecting with dextrose.
- Muscle tendons may be mistaken for nerves. As you track the course of the tendon cephalad, it will disappear as it turns into muscle. Nerves will stay constant. Furthermore, asking the patient to dorsiflex the ankle will make the nerves rotate or move in relation to their surroundings.

Adductor Canal Block 24

Ehab Farag

Key Points

- A high-frequency transducer is preferred for this block.
- This approach is the most effective and easiest one for saphenous nerve block.
- It can be used in lieu of femoral nerve block after total knee arthroplasty to avoid quadriceps muscle weakness.
- It can be used as a block for the saphenous nerve after surgeries in the medial side of the foot and the ankle.

SONOANATOMY

The saphenous nerve, a terminal branch of the posterior division of the femoral nerve, provides sensory innervation to the medial, anteromedial, and posteromedial aspects of the lower extremity from the distal thigh to the medial malleolus. It travels along the lateral aspect of the superficial femoral artery in the proximal artery within the adductor canal (Hunter canal). It then crosses over the superficial femoral artery anteriorly just proximal of the lower end of the adductor magnus muscle and runs medially alongside the superficial femoral artery until emerging from the canal with the saphenous branch of the descending genicular artery. After leaving the adductor canal, the saphenous nerve divides into the infrapatellar branch, which provides a sensory branch to the peripatellar plexus of the knee, and the sartorial branch, which perforates the superficial fascia between the gracilis and sartorius muscles and emerges to lie in the subcutaneous tissue below the knee fold. It then descends along the medial tibial border with the saphenous vein giving cutaneous branches to the medial aspect of the leg, ankle, and the forefoot. The nerve to the vastus medialis is also a branch of the posterior division of the femoral nerve. It travels lateral to the superficial femoral artery within the adductor canal, sending multiple branches to the vastus medialis, and supplies the anteromedial portion of the knee capsule.

The adductor canal is an aponeurotic tunnel in the middle third of the thigh. It courses between the anterior-medial compartment of the thigh and is covered by strong aponeurosis, the vastoadductor membrane. The canal contains the superficial femoral artery, vein, saphenous nerve, nerve to the vastus medialis, and the terminal nerve endings of the posterior branch of the obturator nerve.

The short-axis ultrasound image of the adductor canal at the midthigh usually shows the sartorius muscle and the saphenous nerve as a hyperechoic structure which lies lateral to the artery and anterior to the vein. The vastus medialis muscle lies laterally to the saphenous nerve, and the adductor longus and adductor magnus muscles are on its medial side (Figs. 24.1 and 24.2).

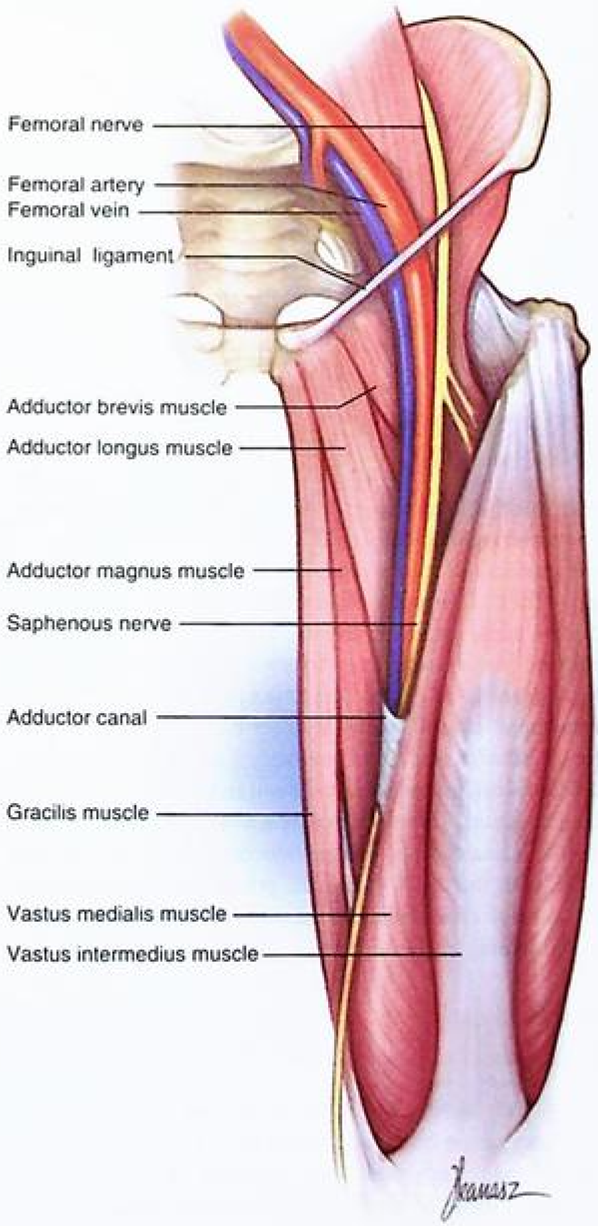


Fig. 24.1 Anatomy of the adductor canal.

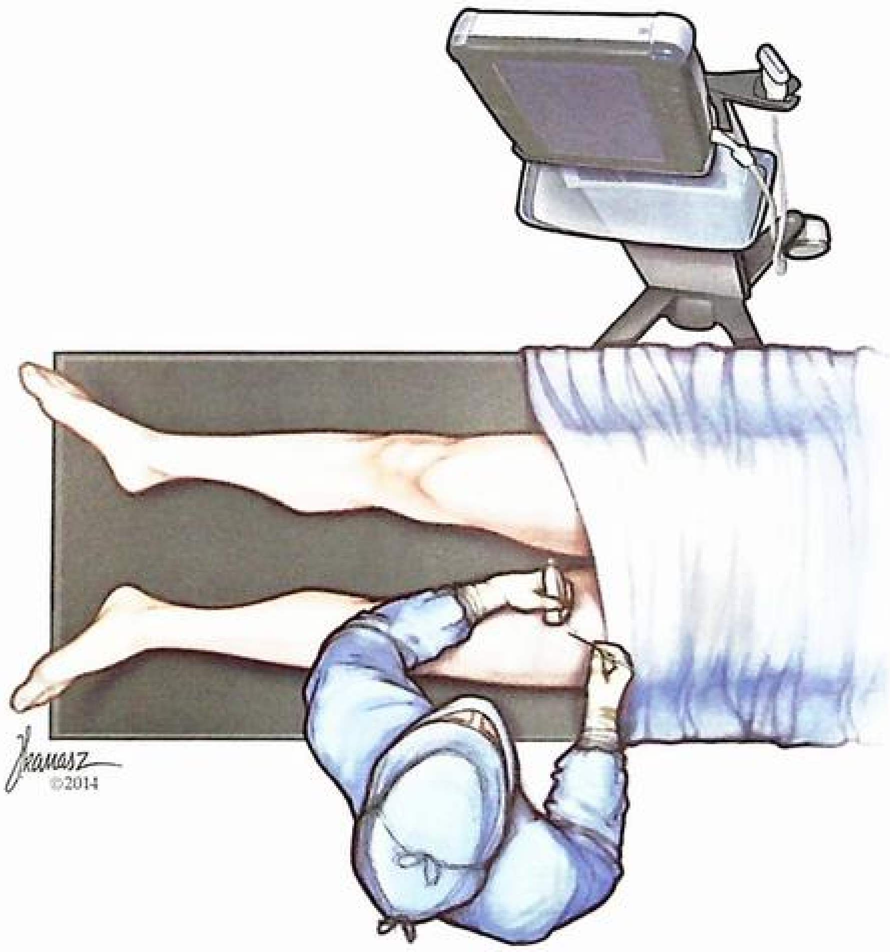


Fig. 24.3 Position for the patient and the ultrasound machine.

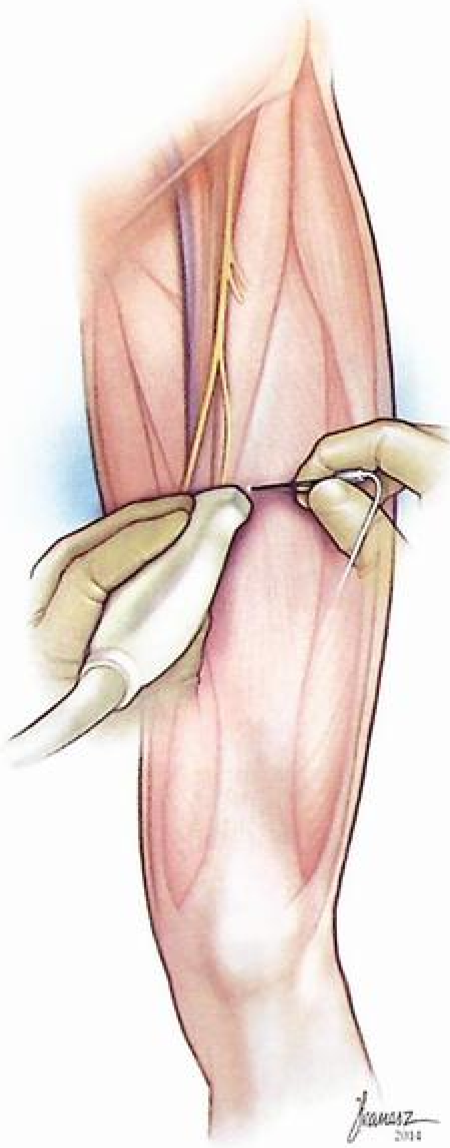


Fig. 24.4 In-plane technique with needle direction from lateral to medial.

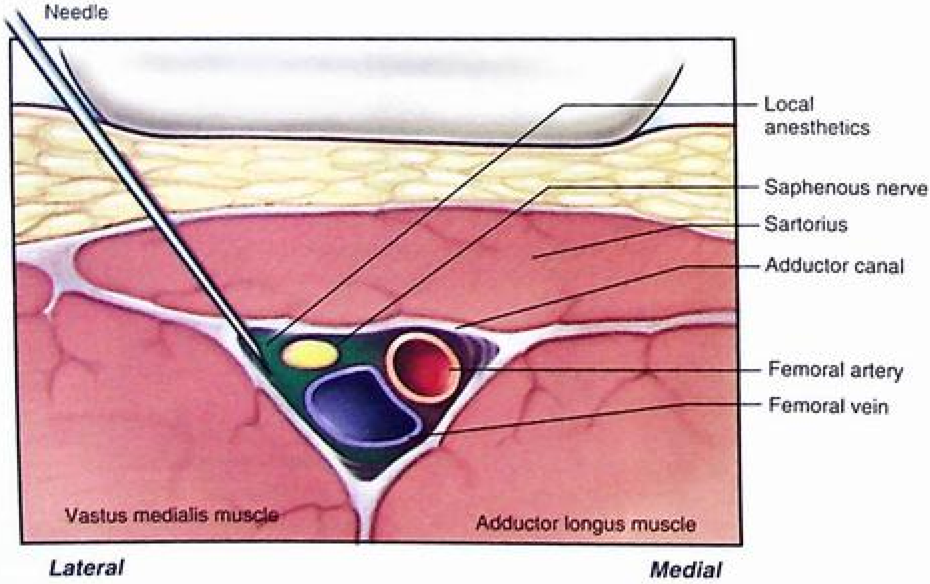


Fig. 24.5 Position of the needle with local anesthetic in the adductor canal. Note that there should be separation of the artery from the fascia by the local anesthetic.

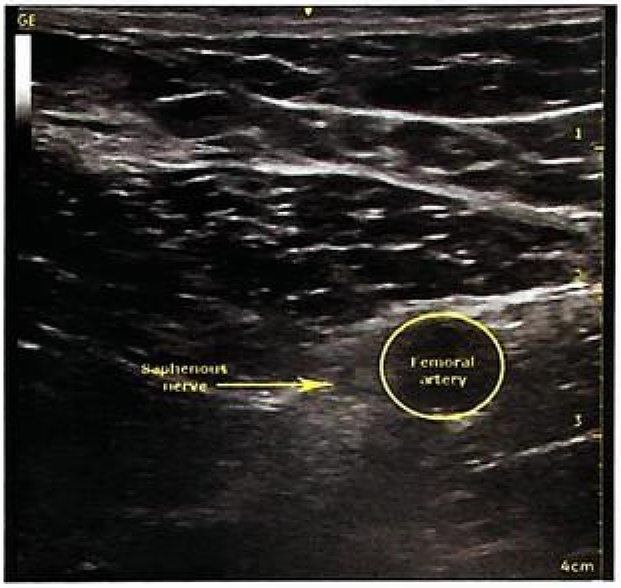


Fig. 24.6 Ultrasound image of the adductor canal.

of normal saline under ultrasound guidance until an expansion between the fascia that separates the sartorius muscle from the adductor canal and the vessels is visualized. After negative aspiration for blood through the catheter, the local anesthetic can be injected.

- Because the femoral artery lies above the vein in the adductor canal, the author usually applies firm pressure with the ultrasound transducer to occlude the vein for better nerve visualization and to decrease the incidence of inadvertent vascular injection.

Femoral Triangle Block 25

Ehab Farag

Key Points

- The femoral triangle block is considered a modified technique of the adductor canal block.
- The femoral triangle block can be used to provide postoperative analgesia after total knee arthroplasty while preserving quadriceps muscle strength.
- The femoral triangle block can be administered as a single-shot or continuous catheter infusion technique.
- The adductor canal block provides better analgesia and preserves more quadriceps strength than the femoral triangle block.

SONOANATOMY

The femoral triangle (FT) block is performed at the midthigh level, which usually lies at 1 to 2 cm proximal to the apex of the FT. Sonoanatomy of this region shows the adductor longus muscle posteromedially, vastus medialis muscle anterolaterally, and sartorius muscle anteromedially. The apex of the FT can be identified under ultrasound, where the medial borders of the adductor longus muscle and sartorius muscle overlie, forming a figure of "3," also called the "kissing sign." In this region, there is no vastoadductor membrane forming the roof of the adductor canal. The saphenous nerve lies just lateral to the femoral artery, whereas the nerve to the vastus medialis lies lateral to the saphenous nerve in the intermuscular fascial planes between the sartorius and vastus medialis muscles. The local anesthetic injected in this block will spread distally into the adductor canal along with the vessels. Most of the drug spreads distally under the sartorius muscle and above the vastoadductor membrane in the adductor canal. The distal spread above the vastoadductor membrane will involve the subsartorial plexus, which is sandwiched between the sartorius muscle and the vastoadductor membrane (Fig. 25.1).

TECHNIQUE

The block is performed at the midthigh level after identifying the apex of the FT using the kissing sign, and the linear probe is moved 1 to 2 cm proximally. The landmarks of the block will be the sartorius muscle above, the vastus medialis muscle anterolaterally, and the adductor longus muscle posteromedially. The saphenous nerve lies lateral to the femoral artery and appears as a hyperechoic structure under ultrasound.

In-plane approach is the preferred technique with lateral to medial approach. After confirming the proper needle tip position lateral to the femoral artery and negative aspiration, 10 to 20 mL of local anesthetic for a single-shot technique will be injected. In the continuous catheter infusion, use a Tuohy needle to place the catheter in proximity of the femoral artery and saphenous nerve. It is preferred to use ropivacaine 0.2% to provide more sensory than motor blockade. Of note, injecting a higher volume of local anesthetic could spread proximally to include the femoral nerve and its branches, thus obviating the motor-sparing effect of this block (Fig. 25.2, Video 25.1).

PEARLS

- The femoral lies in proximity to the femoral artery in the FT and it is better to be occluded while performing the block to avoid inadvertent vascular injection.
- In the single-shot technique, the local anesthetic should be injected in aliquots (3–5 mL) after careful aspiration to avoid inadvertent vascular injection.
- In the continuous catheter technique, the local anesthetic infusion should be started only after careful aspiration through the catheter.

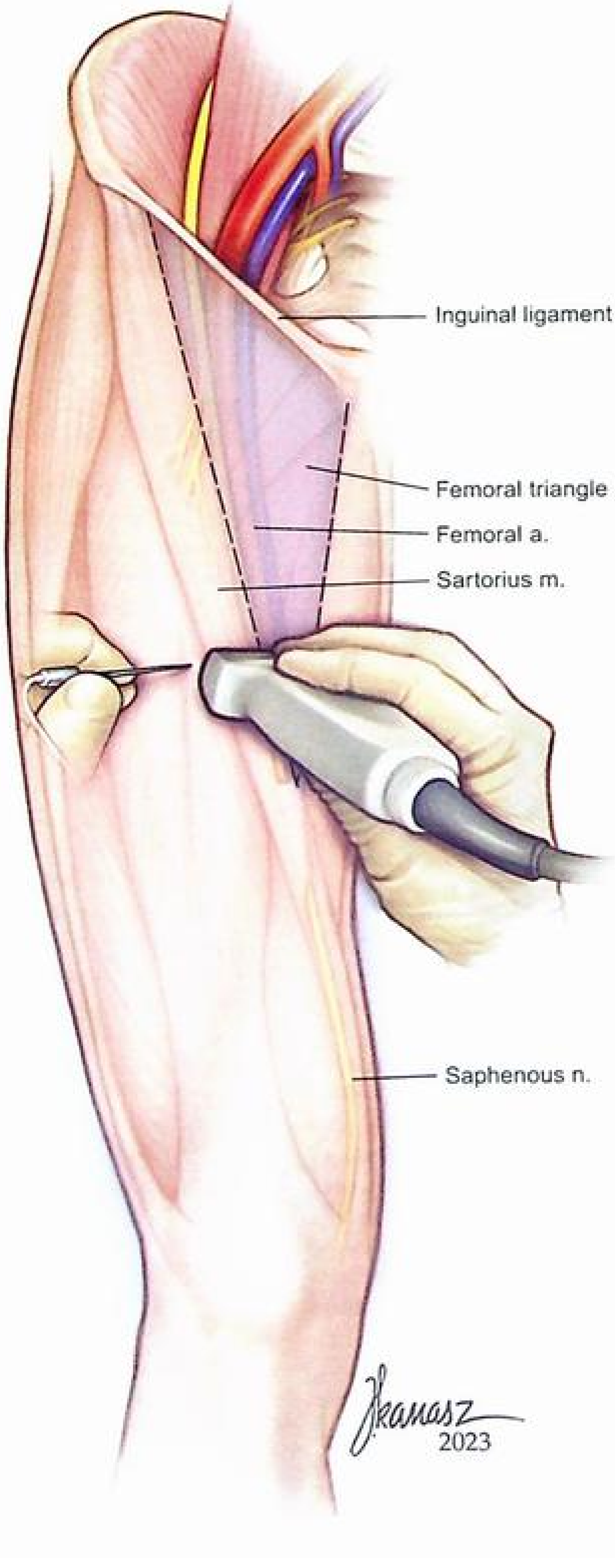


Fig. 25.1 Femoral triangle block anatomy.

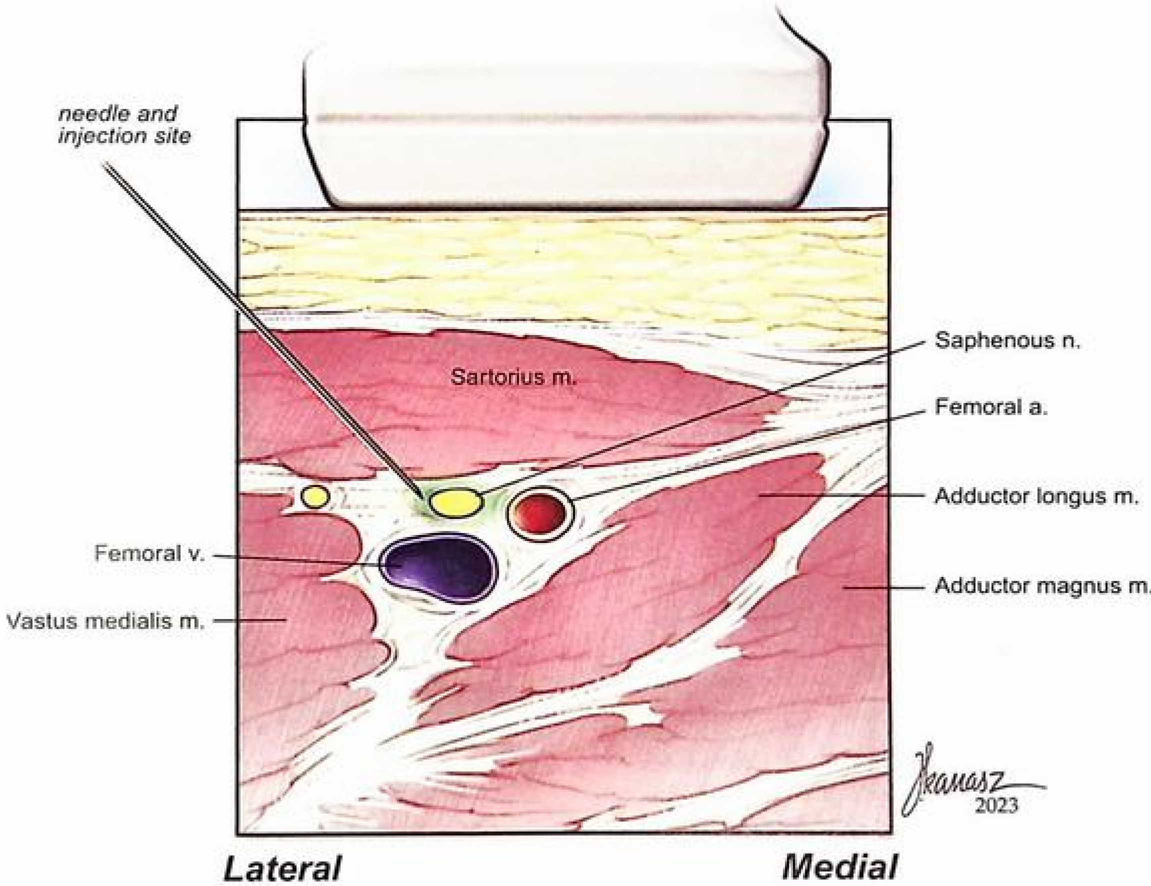


Fig. 25.2 Ultrasound technique for femoral triangle block. Note the figure 3 or kissing sign between Sartorius muscle and Adductor longus muscle.

Suggested Reading

Sonawane K, Dixit H, Mistry T, Balavenkatasubramanian J. Anatomical and technical considerations of "dual subsartorial block," a novel motor-sparing regional analgesia technique for total knee arthroplasty. *Open J Orthrop Rheumatol.* 2021;6(1):046–056.

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iPACK Block 26

Stefan Trela and Harsha Nair

Key Points

- A curved low-frequency transducer is preferable for this block because of the depth of the target.
- This block can be combined with the adductor canal block to provide both anterior and posterior knee analgesia without having to reposition or sterilize the field again.
- The iPACK block results in less risk of lower extremity motor weakness compared with the sciatic nerve block.

INTRODUCTION

The iPACK block, or *i*nfiltration between *p*opliteal *a*rtery and *c*apsule of the *k*nee, is performed to provide pain relief for posterior knee pain following total knee arthroplasty. The block targets articular branches of the tibial, common peroneal, and obturator nerves in the popliteal region behind the knee. The main advantage of the iPACK block over performing a sciatic nerve block is avoidance of motor blockade of the lower extremity caused by sciatic nerve blockade. When combined with the adductor canal block, the iPACK block can be utilized to provide optimal postoperative pain control for both the anterior and posterior knee. Other indications for the iPACK block include surgical procedures involving the posterior knee, such as anterior cruciate ligament repair.

SONOANATOMY

With the patient positioned supine and the knee slightly flexed, place a curved low-frequency ultrasound transducer transversely over the medial surface of the distal thigh, approximately one finger breadth above the patella. Slide the transducer proximally and distally to identify the distal femoral shaft and the femoral condyles anteriorly and the popliteal artery located posterior to the femur. Once the femoral condyles are visualized as two discontinuous, curved hyperechoic lines, scan proximal just until the condyles disappear and the shaft of the femur appears as a continuous hyperechoic line. Identify the location of the posterior capsule of the knee between the femoral shaft anteriorly and the popliteal artery posteriorly. The tibial and common peroneal nerves are not always seen, but the tibial nerve can be identified as superficial to the popliteal artery, with the common peroneal nerve located laterally on the screen.

TECHNIQUE

Insert the needle in-plane from an anteromedial to posterolateral direction. Adjust the transducer more posteriorly to keep the femoral shaft at the edge of the screen to allow a clear path for the needle. Note that the needle insertion angle can be very steep. Keep the needle next to the femoral shaft continuously during needle advancement while avoiding the popliteal vessels. Stop the needle once the tip is located between the posterior capsule and the popliteal artery. Use color Doppler to confirm the position of the popliteal artery and vein if necessary. Inject a total of 10 to 15 mL of local anesthetic. Note that local anesthetic injection too deep past the popliteal artery may reach the sciatic nerve (Figs. 26.1A,B and 26.2, Video 26.1).

PEARLS

- Color Doppler can be used to avoid and identify popliteal vasculature during block.
- A medial-to-lateral approach requires a steep needle angle to avoid nerve and vessel injury.
- A curved array offers larger coverage without the need to slide the probe continually, because all structures will be visible in image.
- Often, this is placed in tandem with an adductor canal block—plan out allotment of local anesthetic prior to placement.
- Morbidly obese patients may have significantly challenging anatomy.

A

Fig. 26.1 (A) and (B) Medial ultrasound orientation and approach to iPACK, or *i*nfiltration between *p*opliteal *a*rtery and *c*apsule of the *k*nee.

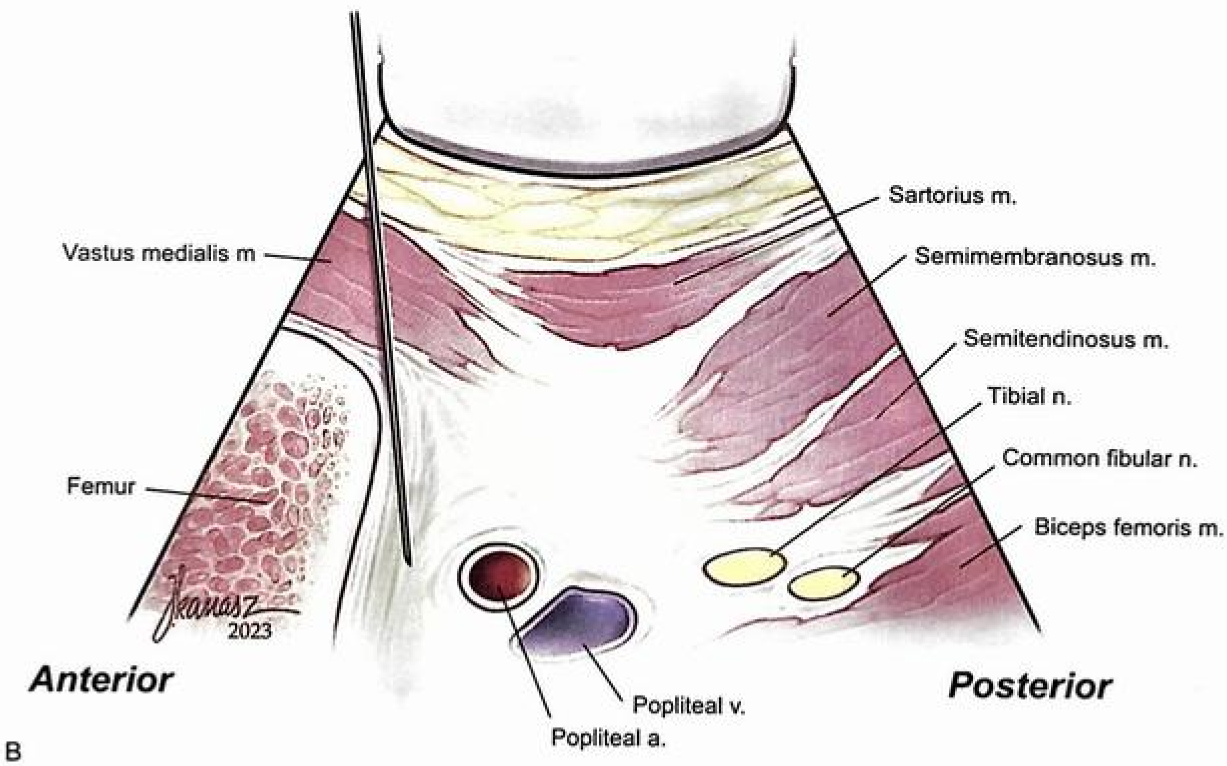

Fig. 26.1—cont'd

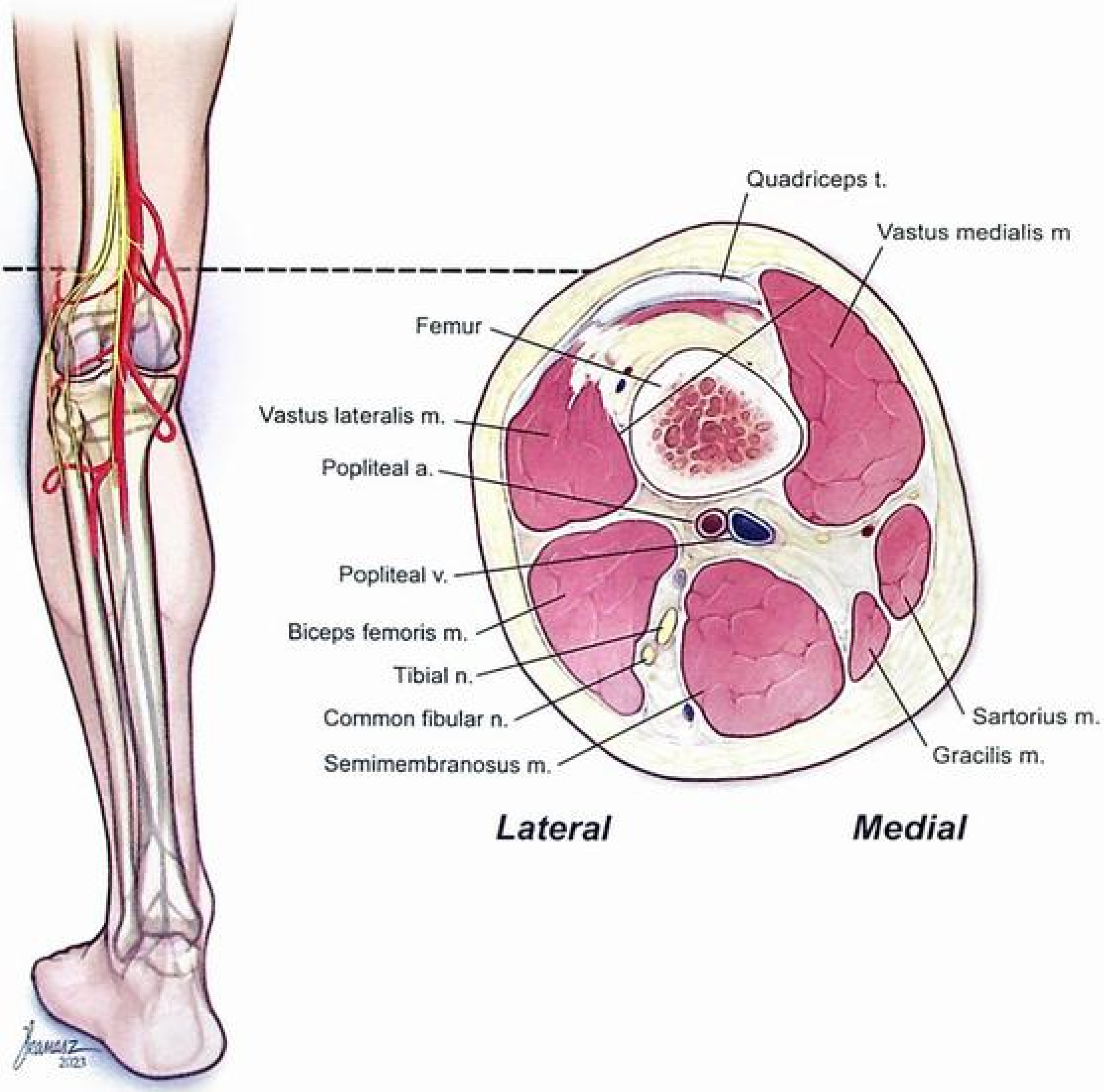

Fig. 26.2 Schematic cross section of posterior knee.

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Chan E, Howle R, Onwochei D, et al. Infiltration between the popliteal artery and the capsule of the knee (IPACK) block in knee surgery: a narrative review. *Reg Anesth Pain Med.* 2021;46:784–805.

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Sinha S, Abras J, Sivasenthil D. Use of ultrasound guided popliteal fossa infiltration to control pain after total knee arthroplasty: a prospective randomized observer-blinded study. In: ASRA 37th Annual Regional Anesthesia Meeting and Workshops. March 15–18, San Diego, CA; 2012.

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27 Dual Subsartorial Block

Vicente Roqués-Escolar and Javier Cubillos

Key Points

- Dual subsartorial block (DBS) is used as a motor-sparing block for knee surgery.
- The first injection of 10 to 20 mL (distal femoral triangle block) will target the saphenous nerve and the nerve to the vastus medialis directly. The distal spread of the local anesthetic under the sartorius muscle but above the vastoadductor membrane will also reach the subsartorial plexus.
- The second injection of 10 to 20 mL of local anesthetic will go into the adductor canal, below the vastoadductor membrane, and will travel along with the femoral vessels to enter the adductor hiatus and reach the posterior aspect of the knee joint, targeting the popliteal plexus (articular branches from the posterior division of the obturator nerve, tibial, common peroneal, and sciatic nerve).
- This novel block must be considered as a procedure-specific component of multimodal analgesia protocols, allowing early mobilization and discharge.

PERSPECTIVE

Multiple regional anesthesia techniques have been described for total knee arthroplasty (TKA) surgery. The goal has always been to choose a procedure-specific, motor, and opioid-sparing modality as part of a well-established multimodal analgesia protocol to improve postoperative recovery, with early mobilization and efficient discharge after surgery.

The first described motor-sparing block was the adductor canal block, which allowed postoperative recovery improvement in terms of mobility without losing analgesic benefit. The adductor canal block can be performed at three different levels: proximal, midpoint, and distal. A slightly different block site at the level of the distal femoral triangle was later described, with the aim of improving analgesic results without losing motor functional preservation by making sure that the saphenous nerve is covered, together with the subsartorial plexus. The subsartorial plexus is formed by an infrapatellar branch from the saphenous nerve, the anterior division of the obturator nerve, the medial femoral cutaneous nerve, and, very importantly, the nerve to the vastus medialis.

The iPACK block (*i*nfiltration between *p*opliteal *a*rtery and *c*apsule of the *k*nee) was described as another motor-sparing block, with the objective of targeting innervation of the posterior capsule of the knee, an area that seemed not to be blocked by the adductor canal block. Nevertheless, some authors recently have demonstrated that after injections inside the adductor canal, there is some distal diffusion of volume toward the posterior aspect of the popliteal fossa.

Very recently, in 2021, Dr. Kartik Sonawane described the dual subsartorial block (DSB) technique as a novel precision, motor-sparing, opioid-sparing, and procedure-specific block that targets specific nerves using standardized volumes and concentration by injecting local anesthetic in two different locations, the femoral triangle and the adductor canal.

The *first injection* aims to block the innervation of the anterior capsule of the knee and is performed 1 to 2 cm proximal to the apex of the femoral triangle, targeting the saphenous nerve and the subsartorial plexus, including the nerve to the vastus medialis. The local anesthetic injected will show a distal spread under the sartorius muscle but above the vastoadductor membrane in the adductor canal region.

The *second injection* aims to block the saphenous nerve directly and then the popliteal plexus formed by the articular branches from the posterior division of the obturator nerve, tibial, and common peroneal innervation of the posterior capsule of the knee. It is performed by injecting 1 to 2 cm distal to the femoral triangle apex inside the proximal adductor canal. Nevertheless, authors have suggested that the injection can also be in the mid or distal canal. Simply depositing the drug around the vasculature and under the vastoadductor membrane is sufficient to obtain the desired outcome. The local anesthetic will travel along with the femoral vessels dissecting a fascial plane and will enter the adductor canal hiatus to reach the popliteal plexus in the posterior aspect of the knee joint, as it has been demonstrated in previous cadaveric and clinical studies.

Another innovative technique also described by Dr. Sonawane in 2022 is the Hi-PAC (*Hi*-volume *p*roximal *a*dductor *c*anal) block that consists of injecting larger volumes of local anesthetic (30–40 mL) in the proximal adductor canal with the objective of covering the saphenous nerve directly and the sciatic nerve plexus indirectly. Nevertheless, it is a technique that originally was recommended by the authors to be used mainly for analgesia of below-the-knee surgeries.

INDICATIONS

The DSB is a newly introduced motor-sparing regional technique for TKA surgeries but also other knee procedures, with a medial parapatellar, midvastus, or subvastus approach that may benefit from this analgesic block.

The DBS may not work in TKA surgeries with other approaches. Similarly, it may not provide complete analgesia in revision TKA surgeries or knee debridement surgeries as the incision is not always medial parapatellar.

PHARMACOLOGIC CHOICE

Long-acting local anesthetics (bupivacaine, levobupivacaine, or ropivacaine) are used at concentrations of 0.2% of ropivacaine or 0.125% of bupivacaine or levobupivacaine. Authors in the original description of the DSB used a total volume of 20 to 40 mL of local anesthetic solution to adequately cover all the innervation of the postoperative pain-generating components of the TKA surgery; 10 to 20 mL for femoral triangle block and 10 to 20 mL for distal adductor canal block. The exact volume and concentration of local anesthetic to be used in DSB is not well established, and further randomized controlled studies are necessary to determine the optimal dosing and volumes. Adding adjuvants to local anesthetic can potentially prolong and improve the quality of the block, but specific evidence will still need to be collected in future research.

Anatomy. The adductor canal (Hunters canal/subsartorial canal) is a narrow conical tunnel located in the thigh. It is approximately 15 cm long, extending from the apex of the femoral triangle above to the adductor hiatus, the tendinous opening in the adductor magnus muscle. The canal serves as a passageway from structures moving between the anterior thigh and posterior leg.

The adductor canal is triangular in shape in a cross section and is bounded anterolaterally by the vastus medialis muscle and posteromedially by the adductor longus muscle in the proximal aspect, followed by the adductor magnus muscle distally. The vastoadductor membrane is a strong, fibrous membrane located anteromedially, joining the anterior and posterior walls. The adductor canal roof is formed by the skin, subcutaneous tissue, sartorius muscle, and the vastoadductor membrane (Fig. 27.1).

The sartorius muscle is a common landmark for both femoral triangle and adductor canal blocks; therefore the area under the sartorius in these regions can also be called a subsartorial area. Consequently, the femoral triangle block and adductor canal block can be considered variants of the subsartorial blocks. The regional block effects in these subsartorial areas differ from each other due to the varied neurovascular anatomy.

The subsartorial plexus lies in this region and is packed between the sartorius muscle and the vastoadductor membrane. It is formed by an infrapatellar branch from the saphenous nerve, anterior division of the obturator nerve, medial femoral cutaneous nerve, and the nerve to the vastus medialis. It supplies the skin over the anteromedial aspect of the knee joint, retinaculum, collateral ligaments, and capsule of the knee joint (Fig. 27.2).

The adductor canal has three foramina; superior, anterior, and inferior. The femoral vessels and the saphenous nerve enter the adductor canal through the superior foramen. The saphenous nerve and descending genicular vessels exit the adductor canal through the anterior foramen, piercing the vastoadductor membrane in at the distal third of the canal. Finally, the femoral vessels exit the canal via the inferior foramen, also called the adductor hiatus. After exiting, femoral vessels become the popliteal artery and vein.

Position. The DSB is typically performed with the patient in the supine position, with the thigh abducted and externally rotated to allow access to the medial thigh.

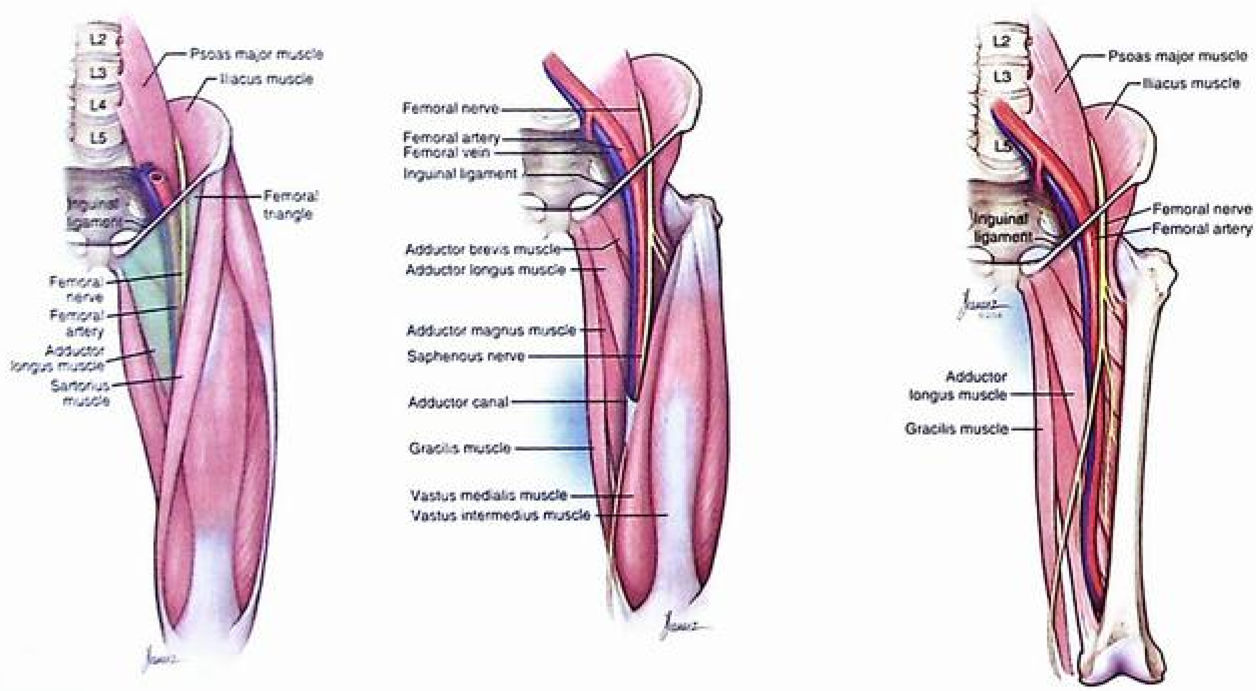


Fig. 27.1 Lower limb anatomy.

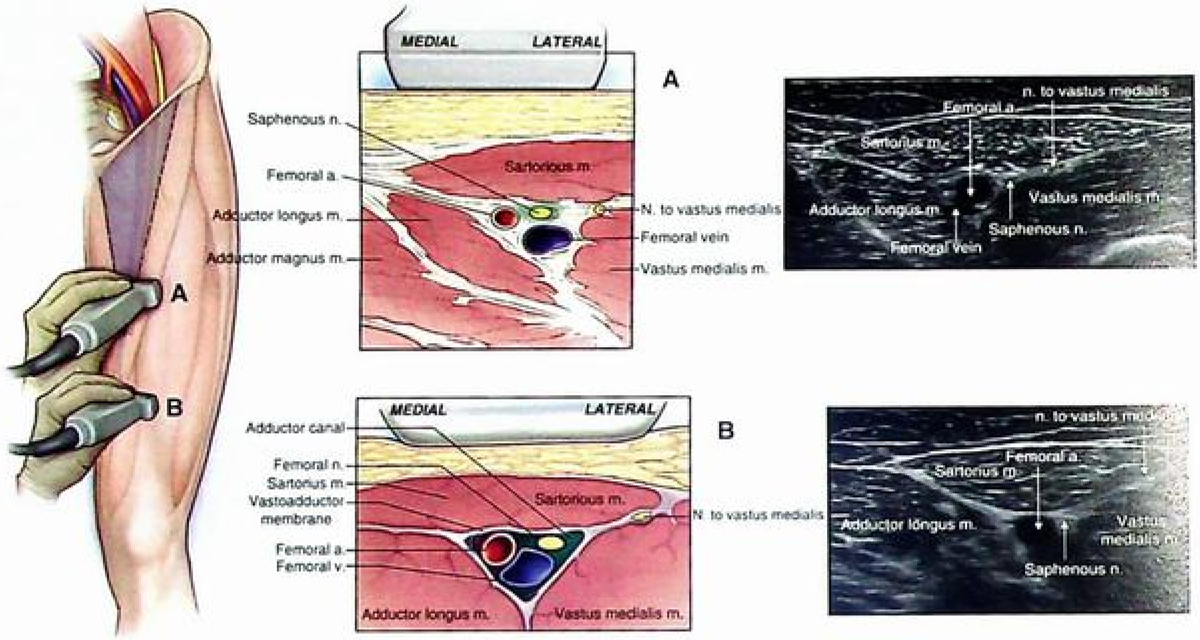


Fig. 27.3 Sonography of (A) femoral triangle and (B) adductor canal.

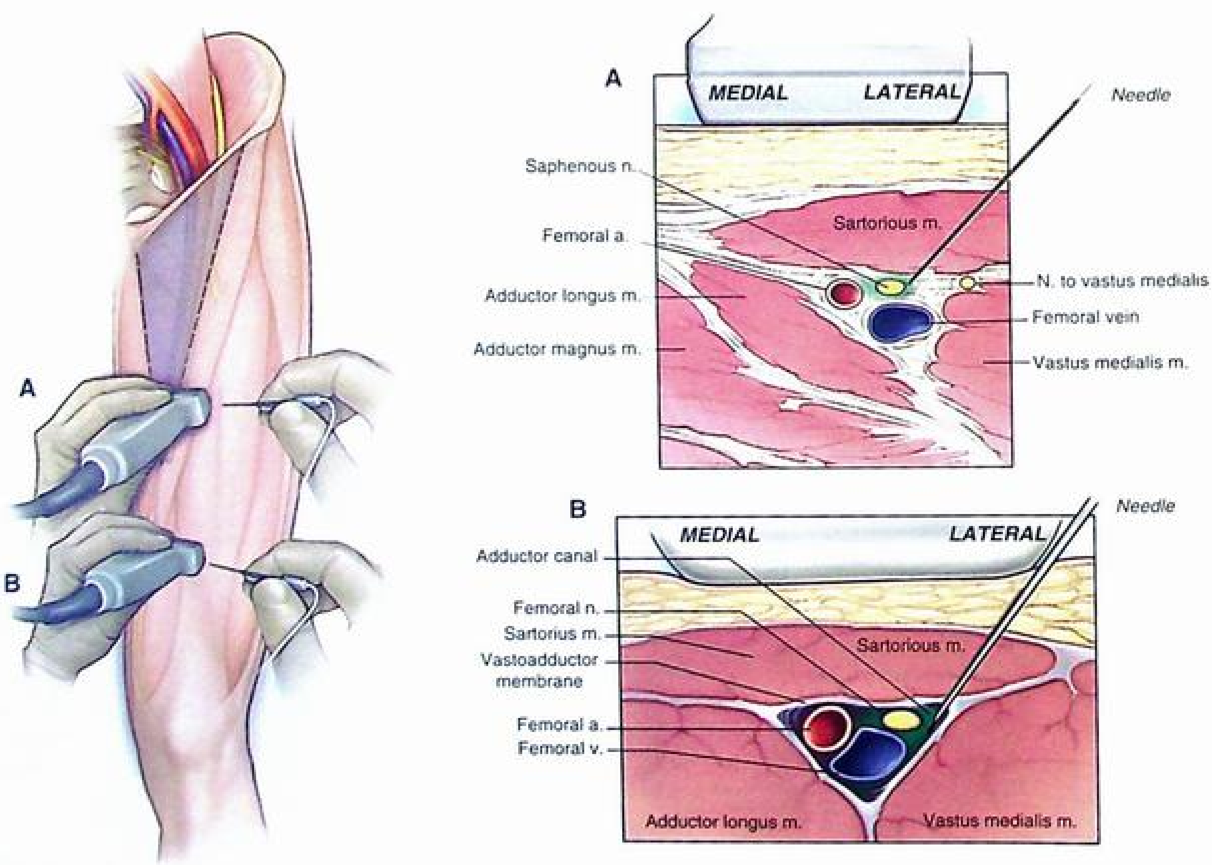


Fig. 27.4 Injection in two steps. (A) Femoral triangle injection. (B) Adductor canal injection.

femoral artery and vein are identified. Color Doppler can be used for orientation if needed.

- Initial ultrasound examination and precise identification of the anatomical landmarks of the femoral triangle and adductor canal are mandatory to obtain the desired analgesic results successfully.
- Vastus medialis nerve identification can be confirmed by neurostimulation to ensure the correct needle position.
- After careful aspiration to avoid intravascular injection, 1 to 2 mL of local anesthetic is injected to confirm the ideal perivascular spread.
- During the first injection, the goal is to place the needle tip immediately adjacent to the nerve to the vastus medialis and saphenous nerve in the intermuscular plane between the vastus medialis and sartorius muscles. During the second injection, the goal is to place the needle tip below the vastoadductor membrane, distal to the apex of the femoral triangle, immediately adjacent to the superficial femoral artery.

Ankle Block 28

Maria Yared

Key Points

- Use a linear transducer probe (8–18 MHz), starting at a depth of 2 cm.
- Use a 22- to 25-gauge, 4-inch or 100-mm needle (stimulating or nonstimulating) and 10-mL syringes to ease injection effort.
- Either bupivacaine or ropivacaine 0.5% 20 to 30 mL without epinephrine may be used. Avoid epinephrine because circumferential injections might cause vasoconstriction and ischemia.
- Three 10-mL syringes are needed to block all five nerves, injecting about 5 mL per nerve.
- There is a low risk of systemic complications. However, patient may have residual paresthesias. Small nerves are more sensitive to intraneural injections. It is preferable not to repeat deep nerve injections.
- Bleeding risk is mainly from the greater saphenous vein, located at the level of the medial malleolus.
- This block should not be chosen if high tourniquet pressures are required to carry out the surgical procedure.

PERSPECTIVE

This block is often used for surgical procedures carried out on the foot, especially for those not requiring high lower leg tourniquet pressure.

Patient Selection. The ankle block is principally an infiltration block and does not require elicitation of paresthesia. Thus patient cooperation is not mandatory. Although the block is most efficient for the anesthesiologist if the patient can assume both the prone and supine positions, this is not essential.

Pharmacologic Choice. Because motor blockade is not often needed for procedures carried out during ankle block, lower concentrations of local anesthetics (LAs) may be used. Practical choices are 1% lidocaine, 1% mepivacaine, 0.25% to 0.5% bupivacaine, and 0.2% to 0.5% ropivacaine. Many physicians suggest that epinephrine not be used during ankle block, especially if injection is circumferential.

TRADITIONAL BLOCK TECHNIQUE

PLACEMENT

Anatomy. The peripheral nerves requiring block are derived from the sciatic nerve, with the exception of a terminal branch of the femoral nerve—the saphenous nerve. The saphenous nerve is the only branch of the femoral nerve below the knee; it courses superficially anterior to the medial malleolus, providing cutaneous innervation to an area of the medial ankle and foot. The remaining nerves requiring block at the ankle are terminal branches of the sciatic nerve—the common peroneal and tibial nerves. The tibial nerve divides into the posterior tibial and sural nerves, which provide cutaneous innervation as outlined in Figs. 28.1 and 28.2. The common peroneal nerve divides into its terminal branches—the superficial and deep peroneal nerves—in the proximal portion of the lower leg. Their cutaneous innervation is also illustrated in Fig. 28.2. Fig. 28.3 identifies the locations of these nerves in a cross-sectional view at the level of ankle block.

Needle Puncture: General. It is often helpful (although not necessary) to have the patient in the prone position initially to facilitate block of the posterior tibial and sural nerves. Once these two nerves have been blocked, the patient assumes the supine position so that block of the saphenous and peroneal nerves can be carried out. The block can be performed with the patient in the supine position if the lower leg is placed on a padded support, and this position facilitates appropriate intravenous sedation.

Needle Puncture: Posterior Tibial Nerve. With the patient in the prone position, the ankle to be blocked is supported on a pillow. A 22-gauge, 4-cm needle is directed anteriorly at the cephalad border of the medial malleolus, just medial to the Achilles tendon, as shown in Fig. 28.3. The needle is inserted near the posterior tibial artery and, if paresthesia is obtained, 3 to 5 mL of LA is injected. If paresthesia is not obtained, the needle is allowed to contact the medial malleolus, and 5 to 7 mL of LA is deposited near the posterior tibial artery.

Needle Puncture: Sural Nerve. The sural nerve is blocked with the patient positioned as for the posterior tibial nerve block. As illustrated in Fig. 28.3, the sural nerve is blocked by inserting a 22-gauge, 4-cm needle anterolaterally immediately lateral to the Achilles tendon at the cephalad border of the lateral malleolus. The sural nerve (lateral ankle) is found in a more superficial position relative to the malleolus than is the tibial nerve (medial ankle). If paresthesia is not obtained, the needle is allowed to contact the lateral malleolus, and 5 to 7 mL of LA is injected as the needle is withdrawn.

Needle Puncture: Deep Peroneal, Superficial Peroneal, and Saphenous Nerves. After the patient assumes the supine position, the anterior tibial artery pulsation is located at the superior level of the malleoli. A 22-gauge, 4-cm needle is advanced posteriorly and immediately lateral to this point (see Figs. 28.3 and 28.4). An alternative is to insert the needle between the tendons of the anterior tibial and the

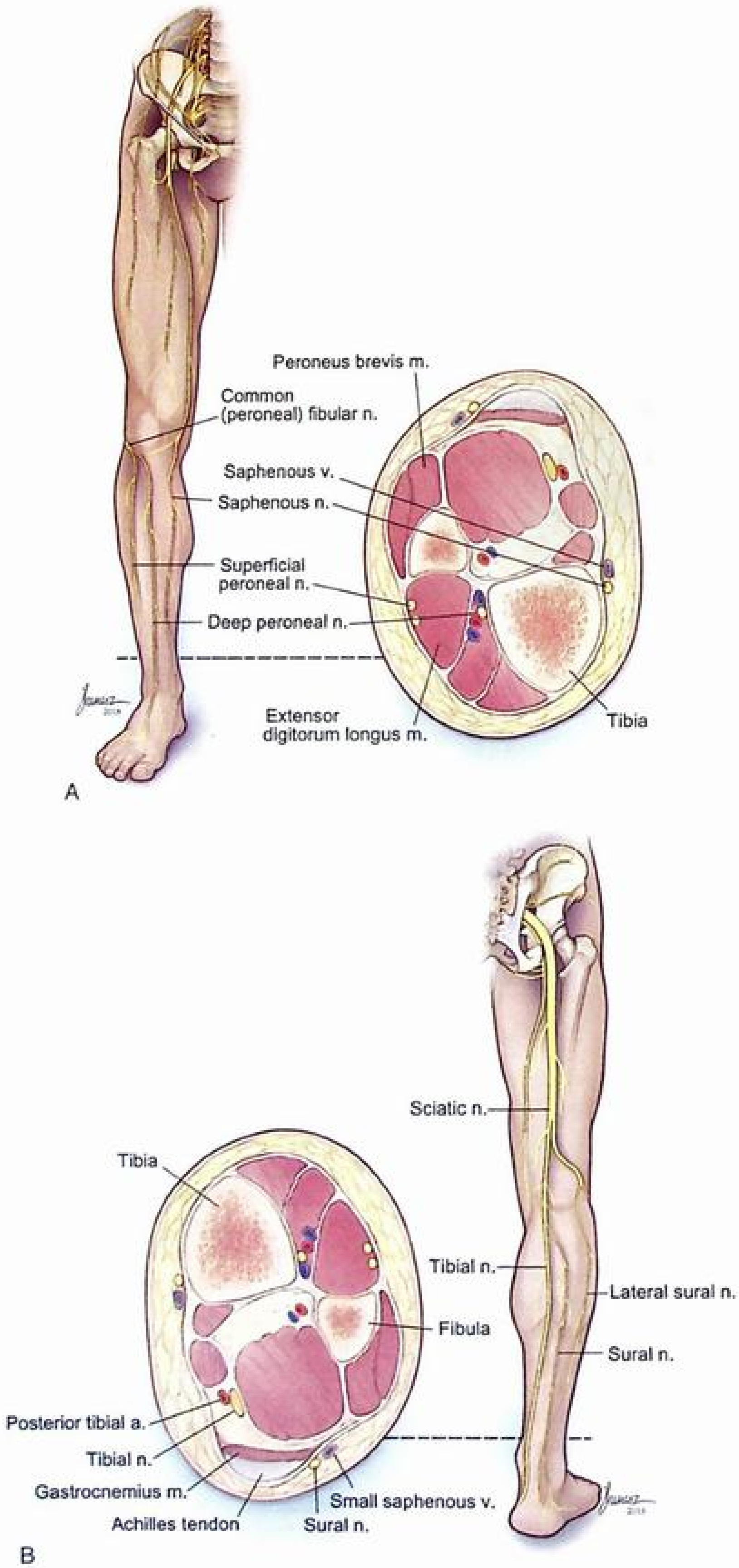


Fig. 28.1 Image of the (A) anterior and (B) posterior leg showing the course of the nerves, each with a cross section of the leg showing the location of the nerves in relationship to arteries, veins, muscles, and bones. The tibia is medial and anterior, and the fibula is lateral.

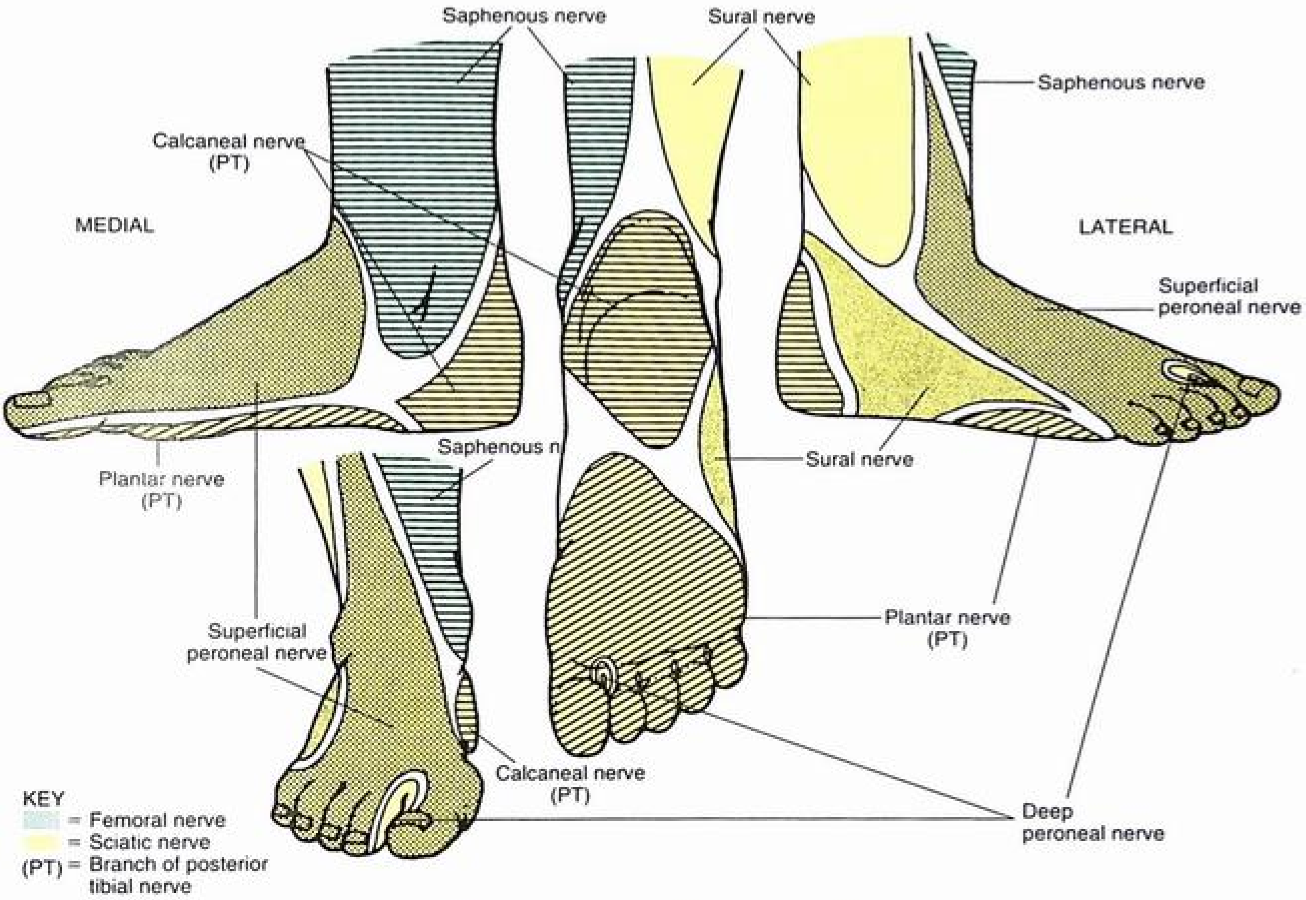


Fig. 28.2 Ankle block: peripheral innervation.

extensor hallucis longus muscles. Approximately 5 mL of LA is injected into this area to block the deep peroneal nerve. From this midline skin wheal, a 22-gauge, 8-cm needle is advanced subcutaneously laterally and medially to the malleoli, injecting 3 to 5 mL of LA in each direction. These lateral and medial approaches block the superficial peroneal and saphenous nerves, respectively.

ULTRASONOGRAPHY-GUIDED TECHNIQUE

SONOANATOMY

Ankle blocks have a variable success rate because of the variable positions of the nerves and multiple branches of the superficial nerves. The tibial and deep peroneal nerves supply deep structures of the foot and therefore must be blocked beneath the deep fascia of the ankle. Under ultrasound guidance, these two nerves are hyperechoic but small and may be difficult to visualize or distinguish from tendons; thus identifying the associated artery or muscle is beneficial. The recommendation is to block these first since subcutaneous injection of the superficial nerves can change the appearance of structures under ultrasound. The remaining nerves supply sensory innervation to the skin and can be blocked superficially by making a circular wheal from the lateral Achilles tendon to the medial Achilles tendon. As a reminder, the distal end of the tibia forms the medial malleolus, while the distal end of the fibula forms the lateral malleolus of the ankle.

INDICATIONS

- Toe and metatarsal foot surgeries (amputation, debridement, and podiatric surgery) that do not require calf tourniquet pressure.
- It does not block the ankle itself.
- Preserves motor function of the leg, thus not impacting postoperative ambulation.

TECHNIQUE

The ankle block can be done using anatomical landmarks as described earlier in the chapter and/or under ultrasound guidance. There are five nerves to the ankle, two that are deep beneath the fascia of the ankle—tibial and deep peroneal nerves—and three superficial ones—sural, saphenous, and superficial peroneal nerves. If the superficial/sensory nerves are difficult to visualize under ultrasound, which is not uncommon, block them subcutaneously, making a skin wheal, using anatomic landmarks.

When performing the ankle block under ultrasound, the patient can be positioned supine, with a foot rest or pillow under the calf. While performing the block, the leg may need to be rotated internally or externally, depending on

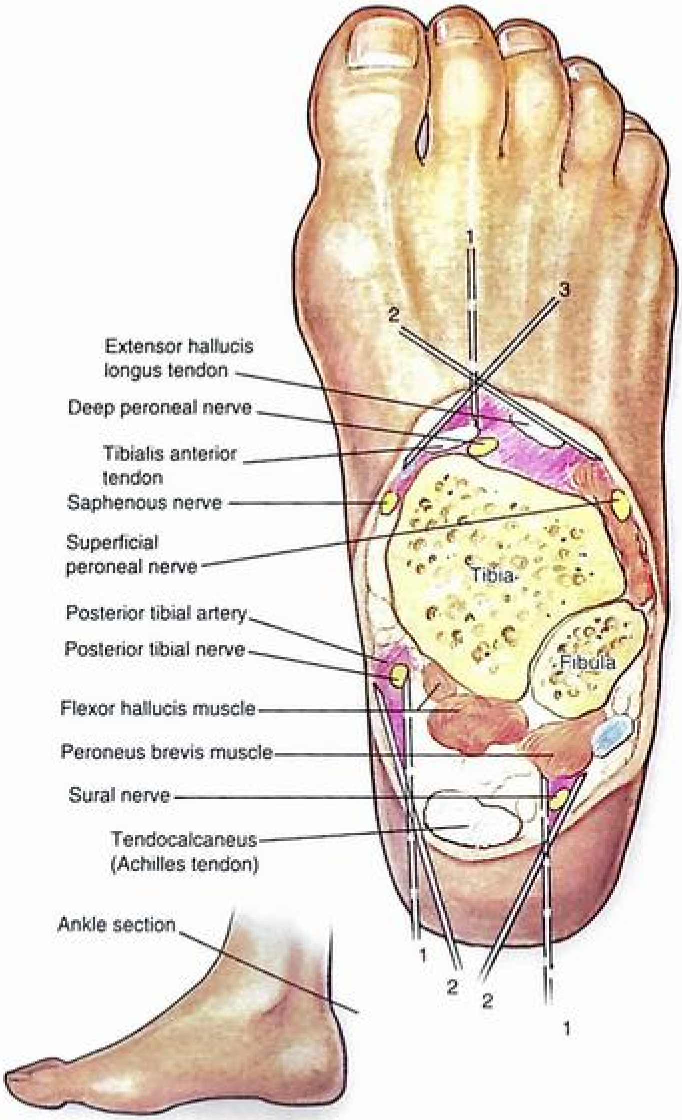


Fig. 28.3 Ankle block: cross-sectional anatomy and technique.

the nerve being blocked. It may be efficient for the proceduralist to walk around the foot as the block is performed. The entire foot should be cleaned and a linear transducer used. The needle can be in-plane or out-of-plane, depending on the patient's position. These nerves are so small that injecting 3 to 5 mL of LA per nerve is usually effective.

Tibial Nerve

Using a combination of anatomic landmarks, ultrasound, and neurostimulation (note plantarflexion of the toes) will maximize the chance of a successful block. To block this nerve, the foot may need to be externally rotated. A linear ultrasound transducer (high frequency, 10–15 MHz) is placed transversely just proximal/cephalad to the medial malleolus. Behind the medial malleolus, identify the posterior tibial artery (with or without the help of color Doppler), and the nerve is posterior to the artery, about halfway between the medial malleolus and the Achilles tendon (Fig. 28.5). The nerve is hyperechoic, with a honeycomb pattern. The tibialis posterior tendon, flexor digitorum longus tendon, and flexor hallucis longus tendon are also in the vicinity and can be distinguished from the nerve by tracking the tendons and seeing them turn into a muscle; they also move with ankle flexion (Video 28.1).

Deep Peroneal Nerve

The linear ultrasound transducer probe is placed transversely/horizontally at the intermalleolar level of the ankle, across the anterior surface of the tibia and extensor retinaculum. The nerve is on the surface of the tibia and lateral to the dorsalis pedis artery (also referred to as the anterior tibial artery) the majority of the time, although occasionally it is located medial to it (Fig. 28.6). It is a small nerve and may be difficult to identify; thus LA injection around the artery may create enough contrast to make the nerve visible. Another landmark is created when dorsiflexing the toes, with the nerve lying between the tibialis anterior tendon and extensor hallucis longus

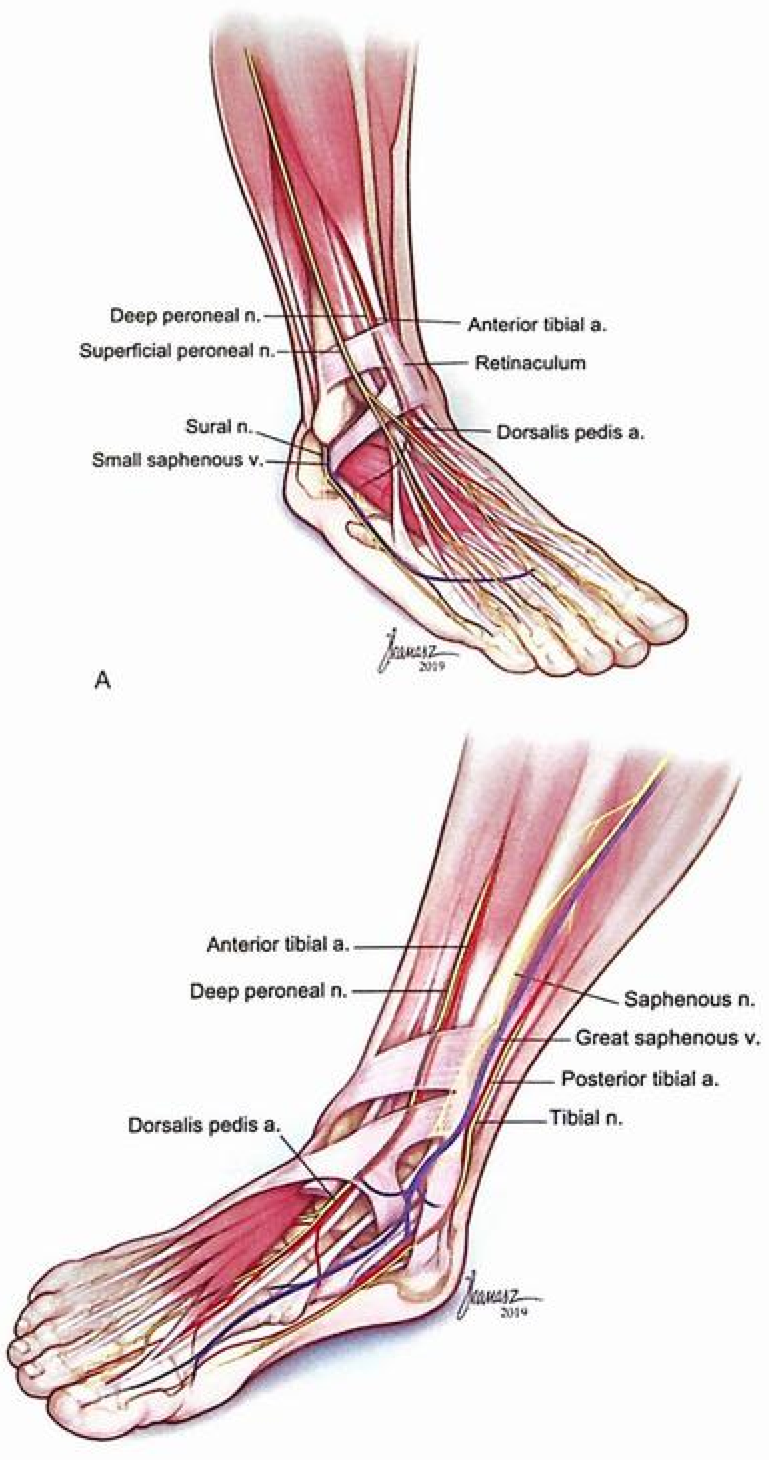


Fig. 28.4 Image of the (A) lateral and (B) medial ankle showing the course of the nerves in relation to arteries and veins.

tendon. LA is injected, 2 to 4 mL, on both sides of the artery. From this landmark on the tibia, the needle can be advanced laterally toward the lateral malleolus to block the superficial peroneal nerve and then advanced medially toward the medial malleolus to block the saphenous nerve. As the needle is moved, it should stay at the level of the ankle, making an imaginary horizontal line across the upper borders of both malleoli, while avoiding the great saphenous vein (Video 28.1).

Superficial Peroneal Nerve

Under ultrasound guidance, the linear transducer probe is placed transversely on the lower leg 5 to 10 cm above the lateral malleolus. Although this nerve is hyperechoic, it is small and may have already branched and be difficult to see in the subcutaneous tissue superficial to the fascia. Thus the probe may have to be moved cephalad, 10 to 20 cm from the ankle along the anterolateral surface of the leg, to find the

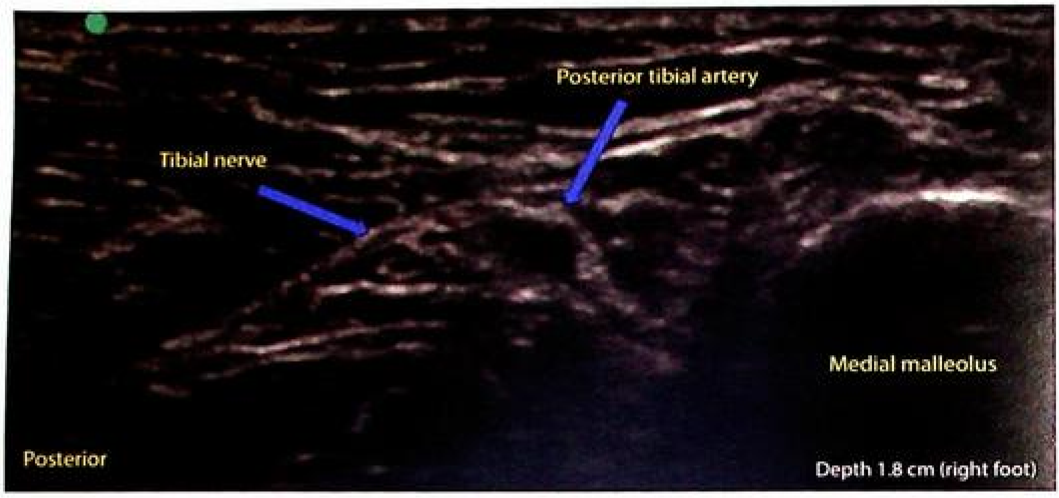


Fig. 28.5 Ultrasound still of the tibial nerve and surrounding anatomy.

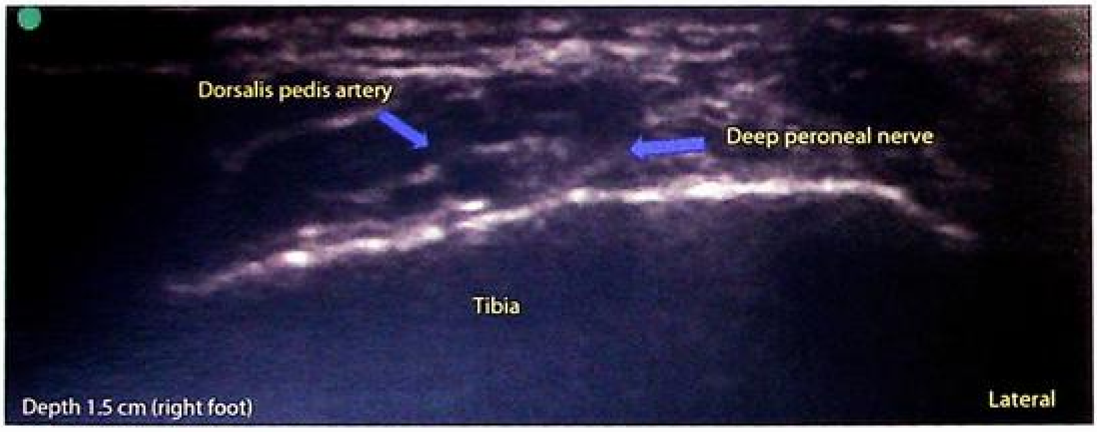


Fig. 28.6 Ultrasound still of the deep peroneal nerve and surrounding anatomy.

nerve prior to its division into branches. The superficial peroneal nerve can be visualized in the intermuscular septal groove created by the extensor digitorum longus and peroneus brevis muscle (Fig. 28.7). At this level, the nerve is now deep to the fascia but lying above the muscles. The nerve can be blocked at this level or traced back distally and blocked at the ankle (Video 28.1).

Saphenous Nerve

Again, the linear transducer probe is placed transversely on the lower leg. The saphenous nerve is best seen 10 to 15 cm cephalad and anterior to the medial malleolus. It can be tracked, traveling down the medial leg with the great saphenous vein. A calf tourniquet can help increase the size of the vein. The nerve is anterior to the saphenous vein and superficial to the medial malleolus. If the nerve is difficult to identify on ultrasound, surround the vein with LA (Fig. 28.8, Video 28.1).

Sural Nerve

The linear transducer probe is placed just cephalad to the lateral malleolus, and the nerve is near the small saphenous vein, which can be easily compressed/collapsed by the pressure exerted on the transducer by the proceduralist. The nerve is between the superior border of the lateral malleolus and the Achilles tendon (Fig. 28.9). If needed, the nerve can be traced along the posterior aspect of the leg, midline and superficial to the gastrocnemius muscles. A calf tourniquet can also help increase the size of the vein. Similar to the saphenous nerve, if the nerve is difficult to image, surround the vein with LA (Video 28.1).

PEARLS

- Patients should be adequately sedated during this block because it is primarily a "volume" block requiring several different needle insertions and superficial injection of LA, which can be uncomfortable. An alert patient is not essential for the block.
- When injecting LA to block superficial nerves, make sure to see a wheal to ensure that the needle is in the correct superficial plane.
- Both the posterior tibial and deep peroneal nerves are deep to fascia.
- When used for outpatient foot surgery, ankle block allows most patients to walk with assistance, thus facilitating earlier discharge from the surgery center.

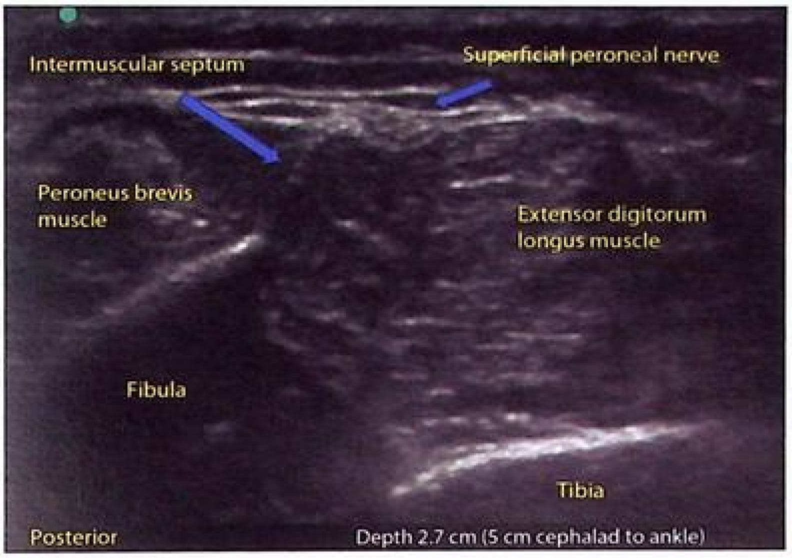


Fig. 28.7 Ultrasound still of the superficial peroneal nerve and surrounding anatomy.

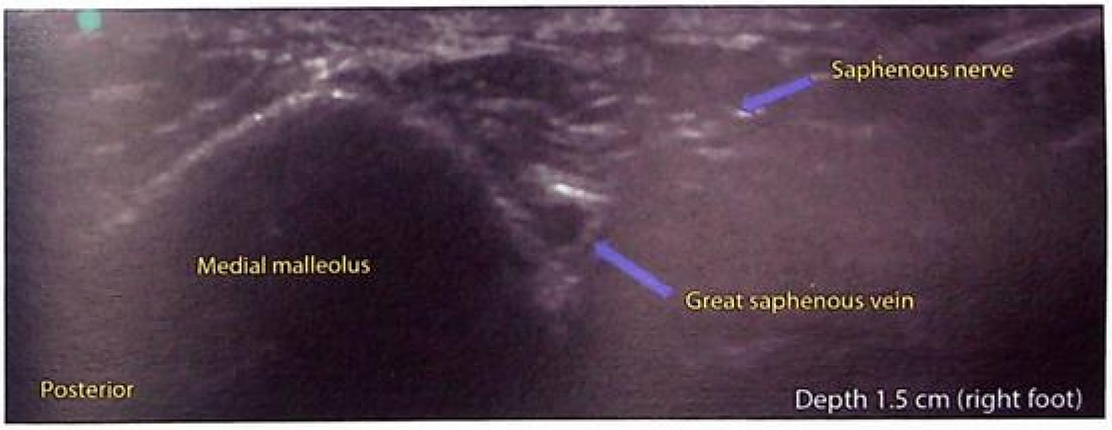


Fig. 28.8 Ultrasound still of the saphenous nerve and surrounding anatomy.

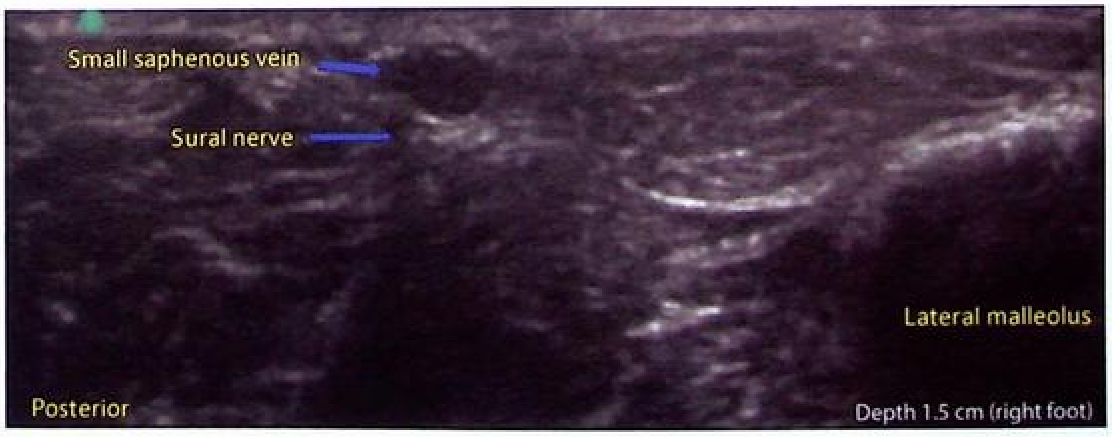


Fig. 28.9 Ultrasound still of the sural nerve and surrounding anatomy.

Section 4
Head and Neck Blocks

Retrobulbar (Peribulbar) Block 29

David L. Brown and Ehab Farag

Key Points

- The most common complication of the retrobulbar block is hematoma formation, which can be minimized by using a needle shorter than 31 mm or performing a peribulbar approach.
- Sudden apnea may happen secondary to unexpected spinal anesthesia—related to injection within the optic nerve sheath.
- Additional block of the facial nerve is essential to produce an immobile eye by blocking the orbicularis oculi muscle.

PERSPECTIVE

This block is performed more often by ophthalmologists than by anesthesiologists. The combination of retrobulbar anesthesia and block of the orbicularis oculi muscle allows most intraocular surgery to be performed. This regional block is most useful for corneal, anterior chamber, and lens procedures.

Patient Selection. Patients who require retrobulbar (peribulbar) anesthesia are principally older patients who are undergoing ophthalmic operations.

Pharmacologic Choice. If retrobulbar block is used, 2 to 4 mL of local anesthetic is all that is required to produce adequate retrobulbar anesthesia. Conversely, if the peribulbar approach is chosen (i.e., the needle tip is not purposely inserted through the cone of extraocular muscles), slightly larger volumes—4 to 6 mL—may be necessary. Almost any of the local anesthetic agents are applicable, with many ophthalmic anesthetists using combinations of bupivacaine and lidocaine.

PLACEMENT

Anatomy. Sensation to the eye is provided by the ophthalmic nerve through the long and short posterior ciliary nerves. Autonomic innervation is provided by the same nerves, and sympathetic fibers traveling with the arteries and parasympathetic fibers carried by the inferior branch of the oculomotor nerve provide additional autonomic innervation. Because the innervation of the orbicularis oculi muscle is through the facial nerve, blockade of these fibers is required to ensure a quiet eye during ophthalmic operations. The ciliary ganglion, measuring approximately 2 to 3 mm in length, lies deep in the orbit just lateral to the optic nerve and medial to the lateral rectus muscle. From this ganglion, the long and short ciliary nerves extend forward in the orbit. Immediately posterior to the ciliary ganglion, the ophthalmic artery can be found at the lateral side of the optic nerve as it crosses superior to it and passes forward medially (Fig. 29.1).

Position. Patients are placed in the supine position and are instructed to maintain their primary gaze directly ahead, not "up and in," as in earlier recommendations. With the globe in primary gaze, the optic nerve position minimizes potential intraneural injection. The anesthesiologist is positioned for the injection as illustrated in Fig. 29.2.

Needle Puncture. While the patient's gaze is directed cephalad and opposite to the site of injection, a 27-gauge, 31-mm sharp-beveled needle is inserted at the inferolateral border of the bony orbit and directed toward the apex of the orbit, as illustrated in Fig. 29.3. The needle should be oriented so that the bevel opening faces toward the globe. A "pop" may be appreciated as the needle tip traverses the bulbar fascia and enters the orbital muscle cone. Before 2 to 4 mL of local anesthetic is injected, careful needle aspiration should be carried out. After retrobulbar block, 5 to 10 minutes should be allowed to pass before the operation is started. This helps avoid operating on patients who develop retrobulbar hematomas. During these 5 to 10 minutes, the anesthesiologist can apply gentle pressure to the globe, principally to facilitate lowering the intraocular pressure. If a peribulbar technique is chosen, needle insertion begins like that used for retrobulbar (inferotemporal) injection; however, the operator inserts the needle parallel and lateral to the lateral rectus muscle and bulbar fascia, rather than making an effort to puncture it. Many practitioners also now suggest making a second injection of 3 to 5 mL for a peribulbar block either in the superomedial orbit or at the extreme medial side of the palpebral fissure. To complete the local block for ocular surgery, the orbicularis oculi muscle must be blocked to produce an immobile eye. This is carried out by blocking the facial nerve fibers that innervate the muscle.

There are many ways of performing blocks of these facial nerve fibers, and the method illustrated in Fig. 29.4 is the example of the van Lint block. In this block, a 25-gauge, 4-cm needle is inserted at *needle position 1* until the lower inferolateral orbital rim is reached. When the needle tip contacts the bony surface, 1 mL of local anesthetic is injected. Through this skin wheal, the needle is repositioned

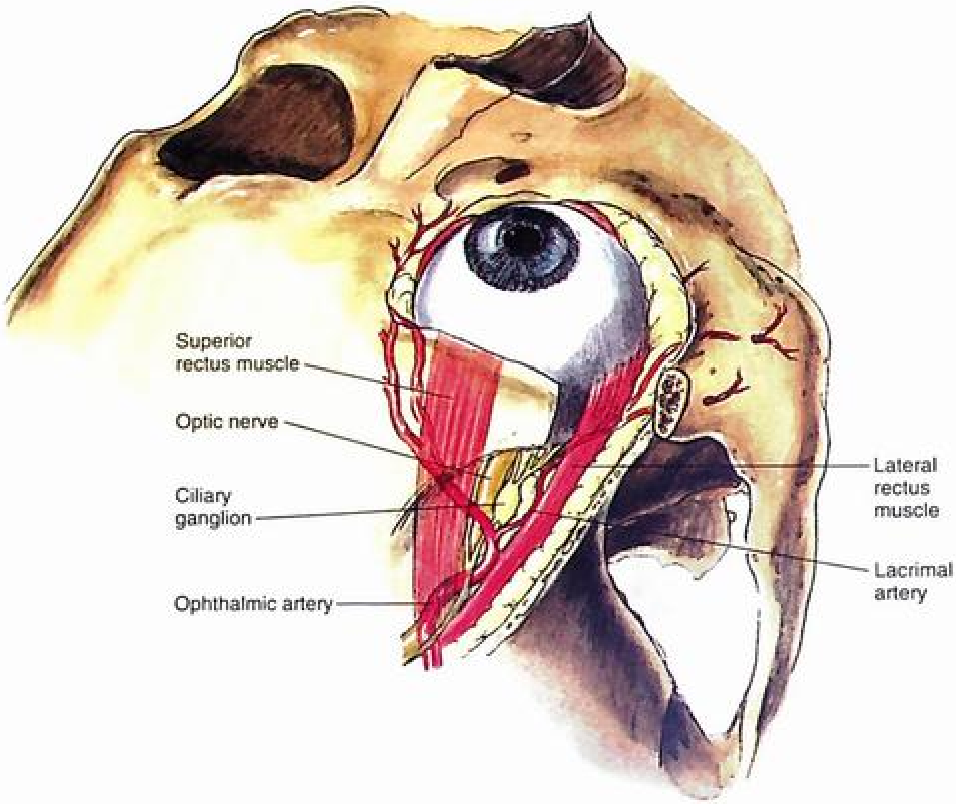


Fig. 29.1 Orbital anatomy.

Fig. 29.2 Retrobulbar (peribulbar) block: position.

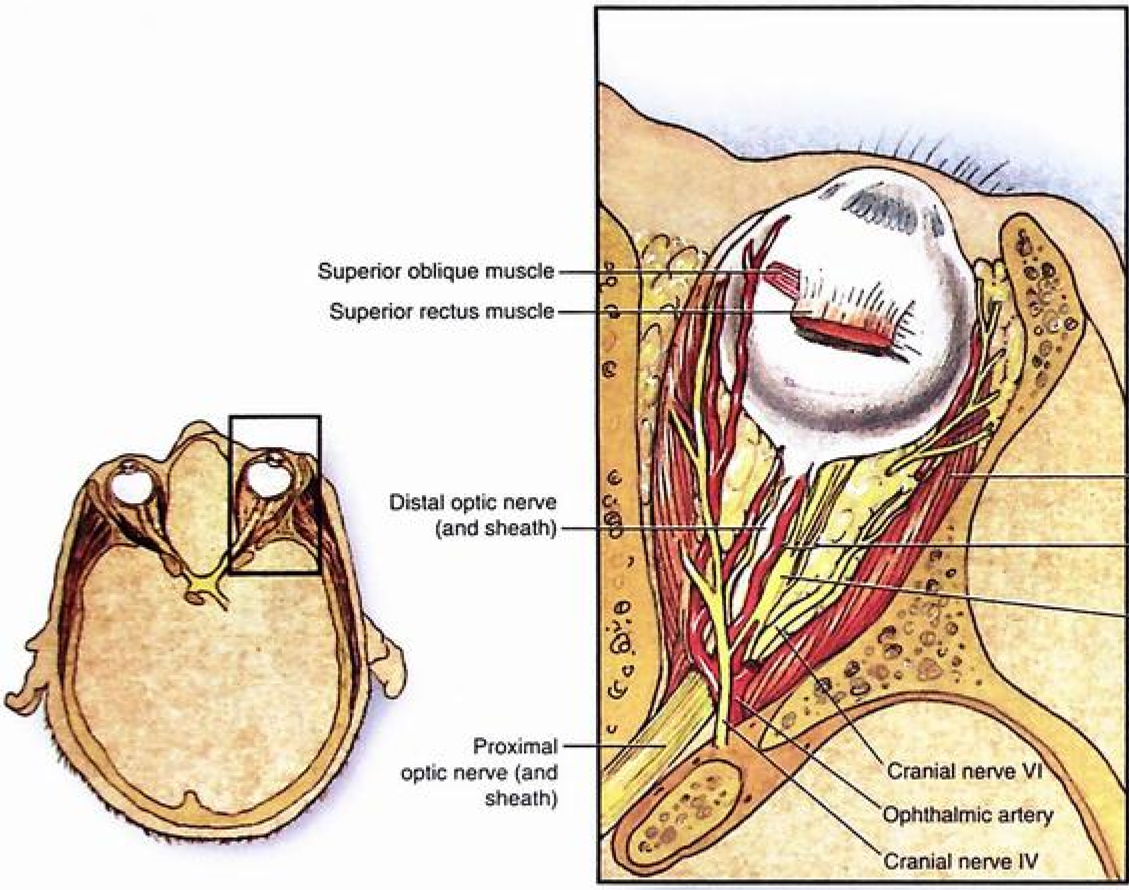


Fig. 29.5 Orbital functional anatomy.

along the lateral and inferior margins of the orbit (*needle positions 2 and 3*), and 2 to 3 mL of local anesthetic is injected along each needle path.

POTENTIAL PROBLEMS

The most common complication with retrobulbar block is hematoma formation. This can be minimized by using a needle shorter than 31 mm. Hematoma formation is more likely if a longer needle is used and the needle tip rests in the vicinity of the ophthalmic artery as it crosses the optic nerve. Hematoma can also be minimized by using a peribulbar approach. Other complications that can accompany retrobulbar block include local anesthetic toxicity, development of the oculocardiac reflex, and cases of sudden apnea and obtundation after retrobulbar injection. The latter two results are probably related to injection within the optic nerve sheath, resulting in unexpected spinal anesthesia, or intravascular injection affecting the respiratory centers in the midbrain, as illustrated in Fig. 29.5.

PEARLS

If anesthesiologists carry out retrobulbar anesthesia, they must work with ophthalmologists who are supportive and willing to share this part of their practice. Theoretically, many of the complications of retrobulbar anesthesia can be avoided if a peribulbar block is carried out. This can be produced by placing the needle along the muscular cone of extraocular muscles, rather than within the muscular cone. Although slightly larger volumes of local anesthetic are required with this technique, most of the major complications can be avoided.

Cervical Plexus Block 30

Aaron Hawke and Samantha Stamper

Key Points

- A high-frequency transducer is preferred for this block due to the shallow nature of the cervical plexus.
- This approach is for the superficial and intermediate cervical plexus nerve blocks, which aim to spare the motor components and avoid serious complications that are more associated with the deep cervical plexus block.
- This block can be used for surgeries such as a carotid endarterectomy, thyroid and superficial neck surgery, lymph node dissection, vascular access surgery, and excision of thyroglossal duct cysts or brachial cleft cysts.

SONOANATOMY

The cervical plexus, which originates from the anterior rami of the cervical vertebrae 2 to 4, provides sensory innervation to the ipsilateral neck, jaw, occiput, and anterior supraclavicular area (Fig. 30.1). It begins at the level of the first cervical vertebra, anterior to the levator scapulae and middle scalene muscles, before piercing the platysma muscle near the posterior border of the sternocleidomastoid muscle. The cervical plexus divides into four terminal cutaneous branches: the lesser occipital nerve, greater auricular nerve, transverse cervical nerve, and supraclavicular nerve (Fig. 30.2). Before the cutaneous branches, the cervical plexus also divides to supply motor innervation to the phrenic nerve, the ansa cervicalis (innervation to the geniohyoid and infrahyoid muscles), components of the accessory nerve to sternocleidomastoid and trapezius muscles, and direct branches to the prevertebral muscles of the neck. The location of the division of the motor and sensory components is at the posterior border of the sternocleidomastoid. The fascia planes at this location allow for selective sensory blockade without compromising the neck and accessory muscles. Several authors use these planes to divide the cervical plexus block into superficial, intermediate, and deep blocks. This chapter focuses on the superficial and intermediate cervical plexus blocks, neither of which have been associated with the degree of motor blockade or the complication rate that is seen with the deep block. The technique to correctly place a superficial or intermediate cervical plexus block is easy and safe, and provides most anesthetic goals. For either block technique, local anesthetic (LA) is injected above the deep cervical fascia.

TECHNIQUE

The posterior border of the sternocleidomastoid muscle should be located. This can be a challenge in obese patients. For those in whom identification of the sternocleidomastoid muscle is difficult, asking the patient to raise their head off the bed can help identify the muscle belly. Drawing a line between the mastoid process and the clavicular head of the sternocleidomastoid can also identify the posterior border. Halfway along this line approximates the fourth cervical vertebra and the site of injection.

Using ultrasound, with the patient in a supine or sitting position, the head is turned slightly away from the operative site. With the probe in a transverse short-axis position, a small collection of nodules are identified (dark oval structures) deep to the sternocleidomastoid border at the posterior border of the halfway point of the sternocleidomastoid (Fig. 30.3). The target nerves lie above the prevertebral fascia. Attention is given to avoid injection below the prevertebral fascial plane in order to avoid a motor block. LA is injected between the cervical and prevertebral fascia to achieve an intermediate block, while injection above the cervical fascia and below the posterior border of the sternocleidomastoid will result in a superficial block. Local permeation along the nerve fibers into the intermediate space may explain the similar reported efficacy between these two blocks. By advancing the needle in an in-plane fashion, approximately 5 to 10 mL can be used for either block following careful aspiration (Fig. 30.4A,B). In the illustration, the needle passes lateral to the sternocleidomastoid muscle to pierce the cervical fascia in the intermediate approach, but it does not penetrate below the deeper prevertebral fascia for either approach. Classically, the superficial block is performed without ultrasound but by using a superficial, fanning-needle injection just below the border of the posterior sternocleidomastoid (Video 30.1).

POTENTIAL PROBLEMS

The risk of complications is highest with deeper LA infiltration. Care must be taken to avoid inadvertent vertebral or carotid artery injection, which increases the risks of hematoma formation and LA toxicity. Spinal anesthesia is a

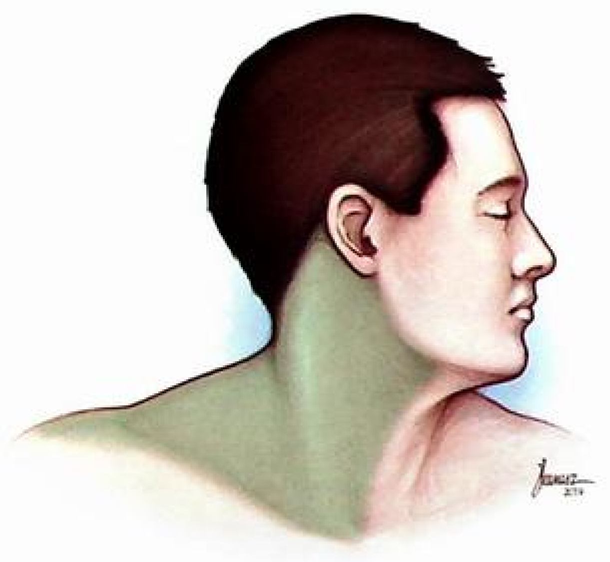


Fig. 30.1 A representation of the sensory distribution of the cervical plexus.

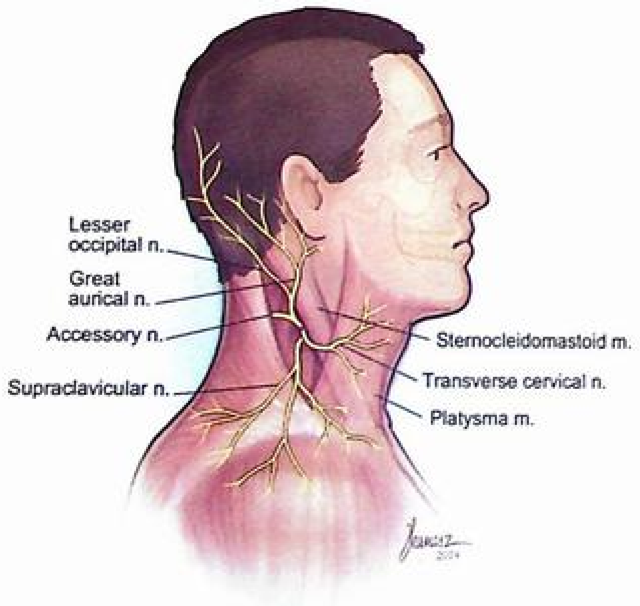


Fig. 30.2 The anatomy of the cervical plexus is seen as it emerges from the posterior border of the sternocleidomastoid muscle.

potential complication arising from inadvertent injection into the dural sleeve. Motor blockade of the phrenic nerve must be considered in patients with respiratory compromise. Complications are exceedingly rare with superficial and intermediate cervical plexus blocks, and direct ultrasound visualization of the plexus helps to ensure safe and effective injection.

PEARLS

- The blocks described are very useful and easily performed, even without ultrasound; however, the deep cervical plexus block is considered an advanced procedure and can have serious or even life-threatening complications.
- Visualization of the cervical plexus is not required for a successful block placement. Proper identification of the posterior border of the sternocleidomastoid and injection immediately posterior to this muscle will result in a successful block.
- If identification of the fascial planes proves difficult near C4, scanning caudad to the level of the sixth cervical vertebra may elucidate tissue planes.

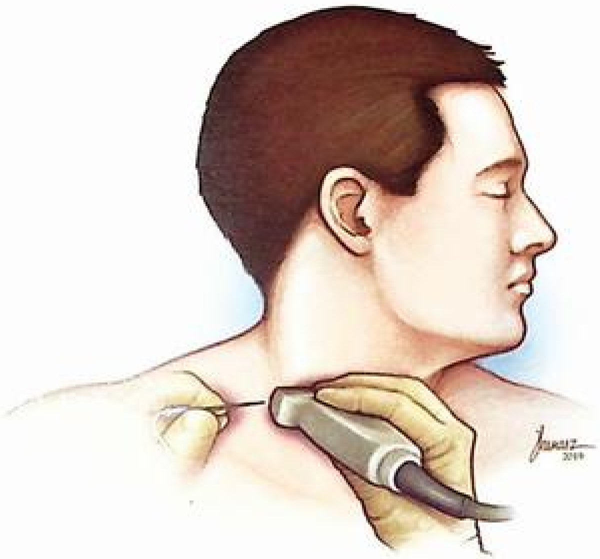
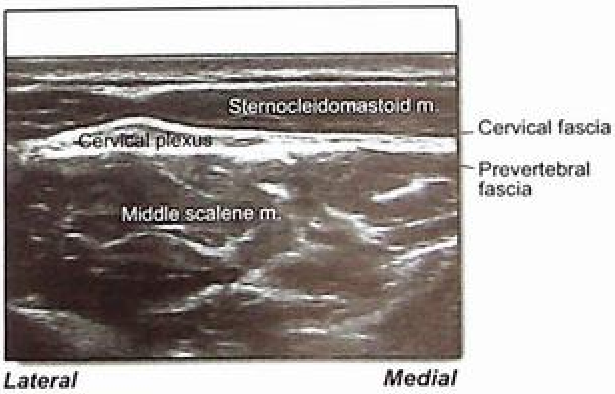


Fig. 30.3 Proper positioning of the patient showing the preferred technique to perform a right-sided cervical plexus block.



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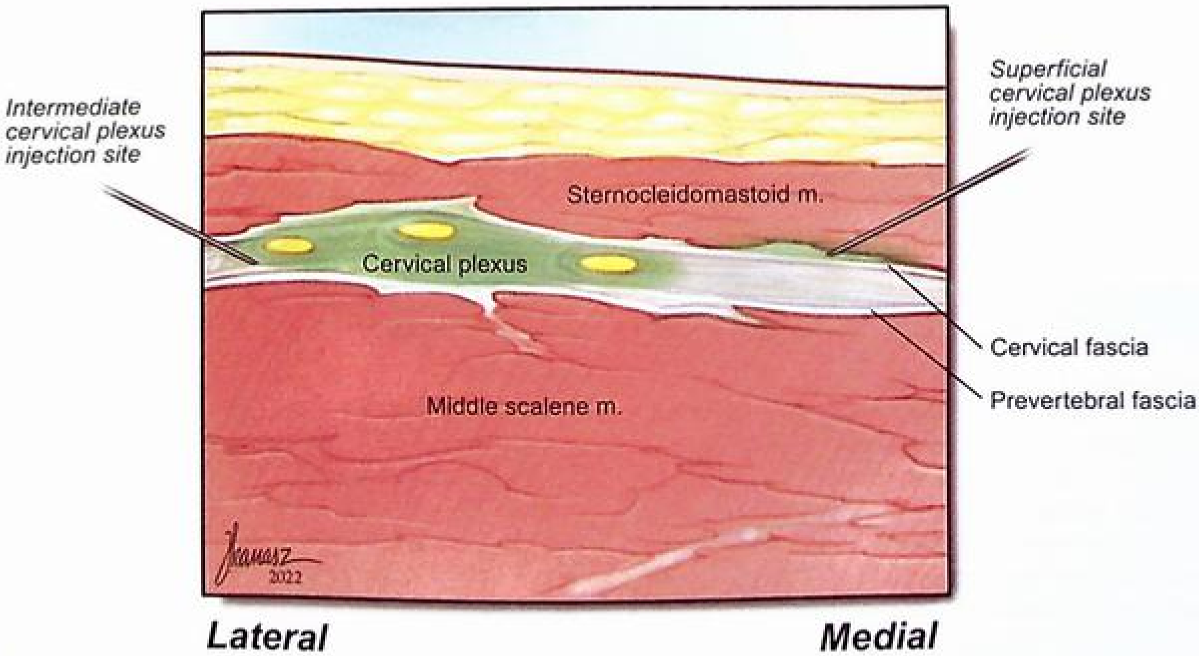


B

Fig. 30.4 (A) A comparison of an actual ultrasound image and (B) an illustrated example.

31 Greater Occipital Nerve Block

Dmitri Souza, John Das, and Christian Seif

Key Points

- Greater occipital nerve block (GONB) can be used to treat acute severe migraines.
- It also can be beneficial for treating acute episodes or exacerbations of chronic occipital neuralgia, cervicogenic headaches, cluster headaches, and some other primary and secondary headache disorders such as postdural puncture headaches and posttraumatic headaches.
- GONB typically provides rapid pain relief that lasts hours to days or even weeks to months.
- GONB can be utilized as a diagnostic tool for occipital neuralgia.
- The evidence of occipital nerve blocks' utility for stable chronic headache disorders is limited. However, there are reports of successful GONB for patients with trigeminal neuralgia, hemicrania continua, and new daily persistent headache.
- GONB can be done using anatomical landmarks at the level of the occipital ridge, but ultrasound guidance is recommended. The procedure is relatively easy to perform and usually well tolerated.
- GONB works on nociceptive afferent fibers distributed over the upper neck and head, including the frontal area.
- GONB is exceptionally safe if performed correctly.

PERSPECTIVE, INDICATIONS, AND CONTRAINDICATIONS

Headache disorders, especially migraine headaches, are exceedingly prevalent in the population and can negatively impact a patient's function, interactions, and overall quality of life. GONB has increased in popularity as a treatment for acute episodes or exacerbations of primary and secondary headaches. Specifically, GONB can be used for migraine headaches (including status migrainosus), cluster headaches, and occipital neuralgia (as a primary condition or secondary to entrapment neuropathy of the greater occipital nerve [GON]). GONB was utilized to treat trigeminal neuralgia, hemicrania continua, postdural puncture headache, new daily persistent headache, and posttraumatic headache. GONB can help with the weaning process in patients with medication overuse headaches and for patients experiencing polypharmacy. It can also be considered in patients with limited pharmacological options, including geriatric patients and pregnant women. Detailed evaluation of risks and benefits and special informed consent are of utmost importance prior to performing an occipital nerve block.

The analgesia experienced by patients after GONB is thought to be due to an effect on peripheral and central pain modulation resulting from the blockade of nociceptive afferent fibers distributed over the upper neck and head, including the frontal area. GONB typically produces rapid analgesia that lasts hours to days or even weeks to months at times. It is frequently used in patients not responding to more conservative treatment such as pharmacologic measures. GONB can also be utilized as a diagnostic tool for occipital neuralgia.

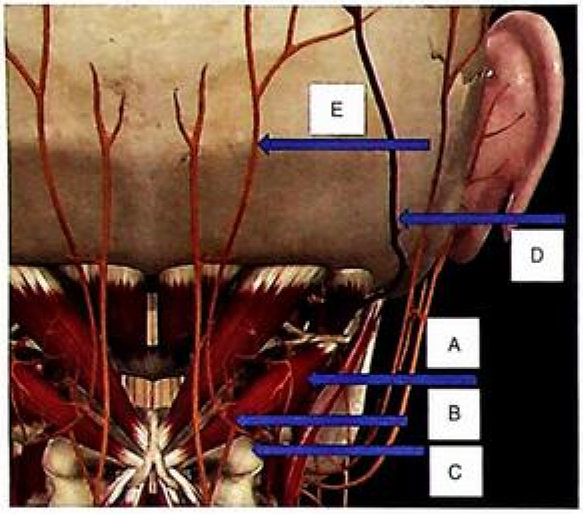
Contraindications to GONB are infections at the injection site. It should also not be performed on patients with known allergies to local anesthetics (LAs) or steroids if they are planned to be used. The presence of an occipital nerve stimulator is not a contraindication for the GONB. However, x-ray is recommended to locate the device before the nerve block to avoid contact of the needle with the leads and/or receiver. Anticoagulation or antiplatelet therapy conventionally is not a contraindication for GONB.

Patients with previous mastoidectomy or craniotomy may be left with skull defects. GONB performed using landmark technique is contraindicated in these patients. However, GONB can be done for patients with previous head surgery using real-time ultrasonography.

CLINICAL ANATOMY

The GON originates from the dorsal primary ramus of the second cervical nerve root. It emerges underneath the inferior oblique muscle and then rises to meet the semispinalis capitis muscle. It runs across the muscles over the neck and posterior occiput, including the trapezius muscle and its aponeurosis. The GON then runs upward and can be identified roughly 2 cm laterally to the superior nuchal line. Then GON turns laterally and toward the vertex. The occipital artery can be detected medial to the GON.

It innervates mainly the posterior occiput but also gives branches to the sides of the head and travels up to the vertex. Two smaller nerves also contribute to the innervation of the posterior and lateral head, including the lesser occipital nerve (located lateral to the GON) and the third occipital nerve,



A, Inferior oblique muscle
B, GON at the level of C2
C, Axis
D, Occipital Artery
E, GON at the level of the occipital protuberance

Fig. 31.1 Greater occipital nerve (GON) anatomy.

typically situated medial to the GON. The frequent sites of GON entrapment include areas of GON penetration of semispinalis capitis and trapezius (including its aponeurosis) (Fig. 31.1)

TECHNIQUES

Conventionally, a 5- to 10-mL syringe and a 25- to 27-gauge, 3–4 cm needle are prepared to inject 1 to 10 mL of the anesthetic solution alone (the volume depends on the technique) or its mixture with a corticosteroid to prolong the therapeutic effect of the GONB. Either 1% lidocaine or 0.5% bupivacaine is used. Nonparticulate corticosteroid is recommended to avoid possible embolization of small vessels with corticosteroid particles. We suggest using 25 to 125 mg of methylprednisolone or 3 to 5 mg of dexamethasone. The half-life of methylprednisolone and dexamethasone is similar: 18 to 36 and 36 to 54 hours, respectively, although the value of adding corticosteroids to the injectate for the GONB remains the subject of debate.

The patient is situated in a sitting or prone position and has to communicate any unexpected sensations during the procedure. We do not recommend sedation for this procedure. An absence of light touch in the dermatome of the blocked nerve followed by an analgesic effect indicates the procedure's success.

The GONB can be done blindly based on anatomic landmarks, or with real-time ultrasonographic guidance. We recommend ultrasound guidance for proper needle advancement while avoiding vessels and other nerves to decrease the risk of complications.

LANDMARK-BASED TECHNIQUE

Landmark-based GONB technique was commonly used in the past. The occipital artery should be palpated in the

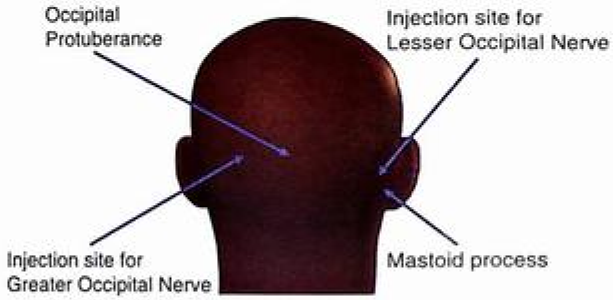


Fig. 31.2 Landmarks for the anatomy-based GONB. *A*, Inferior oblique muscle; *B*, GON at the level of C2; *C*, axis; *D*, occipital artery; *E*, GON at the level of the occipital protuberance.

occipital area. If it is not easily palpated in the back of the head, it can be found caudal to the superior occipital protuberance, about 1 to 1.5 inches laterally to the midline. The GON is commonly situated medial to the occipital artery at the level of the occipital protuberance, around 0.8 inches laterally to the midline (Fig. 31.2).

Tenderness, or possibly headache on palpating this area, may help to guide the GONB. Depending on the patient's symptoms, the GONB can be done unilaterally or bilaterally. It is recommended to palpate the occipital artery prior to creating a skin wheal with LA to avoid trauma or injection to the occipital artery. Make sure that the needle is placed medially to the pulsating occipital artery. A 7 to 10 mL volume of the injectate may be required when performing a GONB without ultrasonographic guidance because of the variations in the anatomy of the GON.

With the blind injection technique, the needle is advanced toward the periosteum until the bony periosteum is encountered or the patient reports paresthesia. Injection into the periosteum will likely make the patient quite uncomfortable. To avoid that, the needle has to be withdrawn gently. After negative aspiration, an LA, with or without corticosteroid, should be injected into the detected tender point. Additional injections can be done in a fanlike fashion. They likely will produce a field block that likely would contribute to the injection's benefit. Some of the third occipital nerve and lesser occipital nerve branches also likely will be blocked with a field block because of their proximity to the GON (Fig. 31.3).

ULTRASONOGRAPHY-GUIDED TECHNIQUE

The GON, surrounding fascial planes, muscles, and vessels can be accurately located with ultrasound, and it helps to visualize the size of the nerve. The increased cross section of the GON may indicate neuritis secondary to entrapment. Therefore real-time ultrasonography can reveal the entrapment of the GON in the muscles or fascia and compression by the vessel, a mass, or anything else. In addition, ultrasonographic guidance helps to visualize the tip of the needle during the advancement toward the nerve and allows visualization of the injection and the injectate. In our assessment, utilizing ultrasonography for GONB

Fig. 31.3 Greater occipital nerve block (GONB) using the anatomic landmark technique. The patient is in the sitting or prone position. Palpate the occipital artery in the occipital area. If it is not easily palpated in the back of the head, it can be found caudal to the superior occipital protuberance, about 1 to 1.5 inches laterally to the midline. Please note that the GON is commonly situated medially to the occipital artery at the level of the occipital protuberance, around 0.8 inches laterally from the midline.

Fig. 31.4 GONB using real-time ultrasonography technique. The patient is in the sitting or prone position. The *blue arrow* highlights the orientation of the ultrasound probe for the GONB with ultrasound guidance.

can contribute to safer and more effective interventions. Ultrasound-guided GONB can be done at the same level as the landmark-based technique or lower, at the C2 level (Fig. 31.4). Ultrasound-guided GONB is typically done with the patient in a prone or sitting position, with the head and neck flexed. An ultrasound transducer is set in the midline to locate the external occipital protuberance. Then it should be placed caudally to identify atlas and axis. Then the ultrasound transducer should be moved laterally to identify the inferior obliquus capitis muscle. It is on top of this muscle that the GON lies, typically in the fascial plane between the inferior obliquus capitis muscle and the semispinalis capitis muscle (Fig. 31.5).

The ultrasonographically guided GONB can be performed using either out-of-plane or in-plane techniques. It is important not to advance the needle if the tip is not seen. Hydrolocalization or other needle visualization techniques can be used to localize the tip of the needle. After negative aspiration, 1 to 3 mL of the injectate is injected around the nerve (but not in the nerve) or another target, including the surrounding muscles.

POSSIBLE COMPLICATIONS

The fact that the occipital nerve is located near vital anatomical structures (such as the vertebral artery, arachnoid space, and spinal cord) creates the opportunity for potential complications. Nonguided GONB has a complication rate of 9% to 16%, with complications including gait instability, numbness, dizziness, and pain.

Scalp necrosis, hyperpigmentation, lipodystrophy, hair loss, and hair discoloration can happen with unintentional intraarterial injection of LA or corticosteroid, especially with a particulate corticosteroid such as triamcinolone. This may occur, however, even without intraarterial injection.

Patients who have had posterior or lateral cranial surgery have decreased protection of the skull and should not undergo the landmark-based procedure. However, ultrasonography-guided injections can typically be safely performed. Longer monitoring times of the intervention should be offered for these patients.

Pain from injection in or around the periosteum is a common observation with the landmark-based technique. Ultrasound-guided GONB has been associated with reduced postprocedural pain scores.

Local myotoxicity has been described with bupivacaine.

Patients receiving corticosteroids, either orally or as frequent injections, are at risk for developing adrenal insufficiency or Cushing syndrome. Physicians should ask patients actively about the use of corticosteroids because they frequently do not report this before the procedure.

Risks, benefits, and alternatives to the GONB should be discussed in detail with pregnant women.

GONB should not be done in patients with a history of allergic reactions to the LA of the same class as the planned injectate to avoid anaphylactic reaction.

The possibility of these potential complications should be discussed with the patient in advance, and detailed informed consent should be obtained.

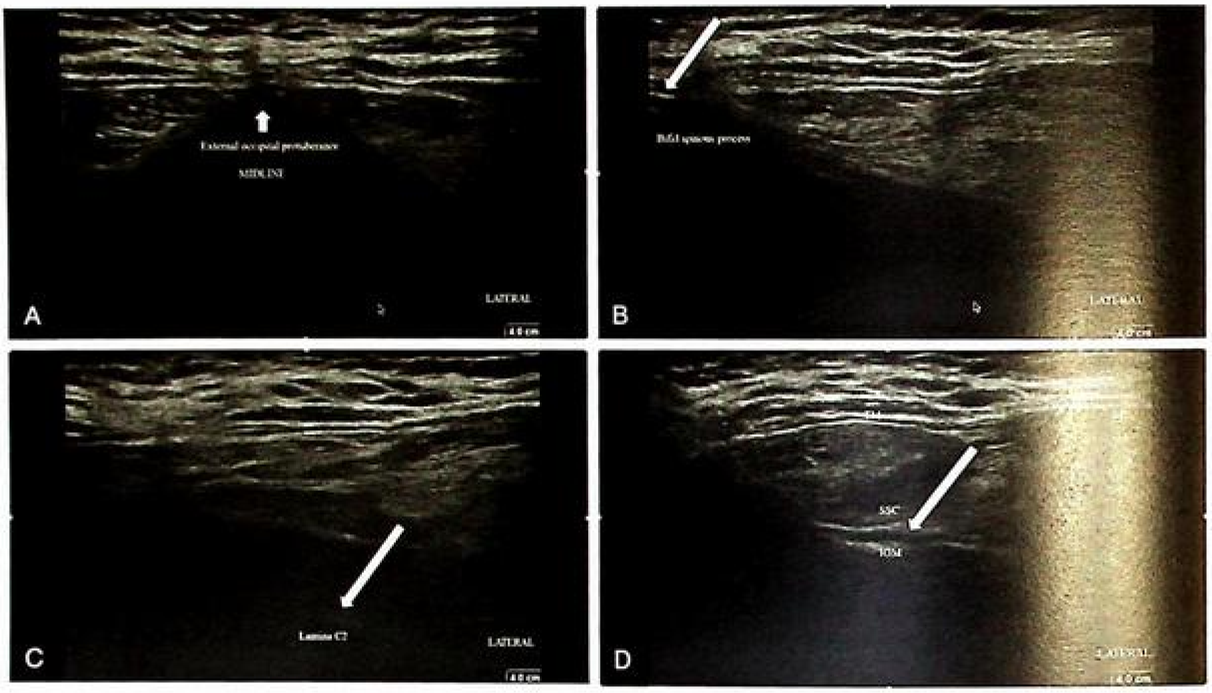


Fig. 31.5 Ultrasound-guided GONB. **(A)** Initial ultrasound probe position, midline at the external occipital protuberance *(arrow)*. **(B)** The ultrasound transducer should be moved caudally until the bifid spinous process is seen *(arrow)*. **(C)** The lamina of C2 should be visualized *(arrow)*. **(D)** *Arrow* points toward injectate around the GON in the fascial plane between the semispinalis capitis muscle (SSC) and the inferior oblique muscle (IOM). *SC*, Splenius capitis muscle; *TM*, trapezius muscle.

PEARLS

- Hydrolocalization, rotation of the needle tip's bevel, and some other techniques for enhanced needle visualization can be utilized during ultrasonographically guided GONB. The needle should not be advanced without real-time visualization of the tip.
- Another needle visualization technique, wiggling the needle, should be avoided because it likely would be very uncomfortable for the patient.
- The GONB can be performed for patients on antiplatelet or anticoagulation therapy. Pressure should be applied to prevent hematoma production in patients with bleeding disorders or on anticoagulation.
- A detailed discussion of risks, benefits, and alternatives to GONB is of utmost importance.

Stellate Ganglion Block 32

Vicente Roqués-Escolar and Ana Isabel Sánchez-Amador

Key Points

- Used for treatment or diagnosis of complex regional syndrome as well as upper limb vascular syndromes.
- Ultrasound allows for a more effective and precise sympathetic block.
- Long-lasting local anesthetics with steroid are commonly used.
- The C7 transverse process and longus colli muscle must be located with a high-frequency linear transducer (6–13 MHz).
- The needle should be directed in-plane from lateral to medial toward the prevertebral fascia located over the longus colli muscle and below the carotid artery.
- A total of 5 mL of local anesthetic is then injected, with real-time visualization of spread, avoiding intravascular injection.

PERSPECTIVE

This is also called a cervicothoracic sympathetic block and has been used since the 1920s for treatment or diagnosis of complex regional syndrome. It has also been used to treat refractory angina, phantom limb pain, vascular insufficiency, and other pain and vascular syndromes.

Stellate ganglion blocks raditionally have been performed blindly by palpating the anterior tubercle of the transverse process of C6 (Chassaignac tubercle) and infiltrating as much as 20 mL of local anesthetic. This method has a relatively high failure rate, with numerous significant and even potentially fatal adverse effects.

Ultrasound allows for a more effective and precise sympathetic block, with the use of a small injectate volume. It may also improve the safety of the procedure by real-time visualization of vascular structures and soft tissue structures.

INDICATIONS

Table 32.1 describes indications for the stellate ganglion block.

Pharmacologic Choice. Even during diagnostic use of the stellate ganglion block, it is often desirable to produce a long-lasting block. Therefore a solution of 0.25% bupivacaine or 0.2% ropivacaine with epinephrine is often used. Steroid coadjutants are frequently added in this technique.

Thermal and pulsed radiofrequency have been successfully used in some cases and can be considered an option in the treatment of these patients to prolong the effects of the blockade.

PLACEMENT

Anatomy. The sympathetic chain is each of the pair of ganglionated longitudinal cords of the sympathetic nervous system, situated on either side of the vertebral column. The sympathetic trunk travels from the base of the skull to the coccyx, just lateral to the vertebral bodies. The cervical portion of the chain extends from the base of the skull to the first rib, below which it becomes continuous with the thoracic part of the chain. In the neck, the cervical sympathetic chain lies embedded in the deep fascia between the carotid sheath and the prevertebral layer of deep fascia. The cervical sympathetic chain is composed of three ganglia: the superior cervical ganglion, immediately below the skull; the middle cervical ganglion, at the level of carotid cartilage; and the inferior cervical ganglion, between the first rib and the transverse process of the seventh cervical vertebra. In most people, the inferior cervical ganglion is fused with the first thoracic ganglion and forms the stellate ganglion (Fig. 32.1).

Table 32.1 Indications for the Stellate Ganglion Block

Pain syndromes	Vascular insufficiency
Complex regional pain syndrome of the head and upper limbs	Raynaud syndrome
Refractory angina	Scleroderma
Phantom limb pain	Frostbite
Herpes zoster	Obliterative vascular disease Vasospasm Trauma Emboli
Intractable angina	Hyperhidrosis
Refractory cardiac arrhythmias	
Posttraumatic stress disorders	

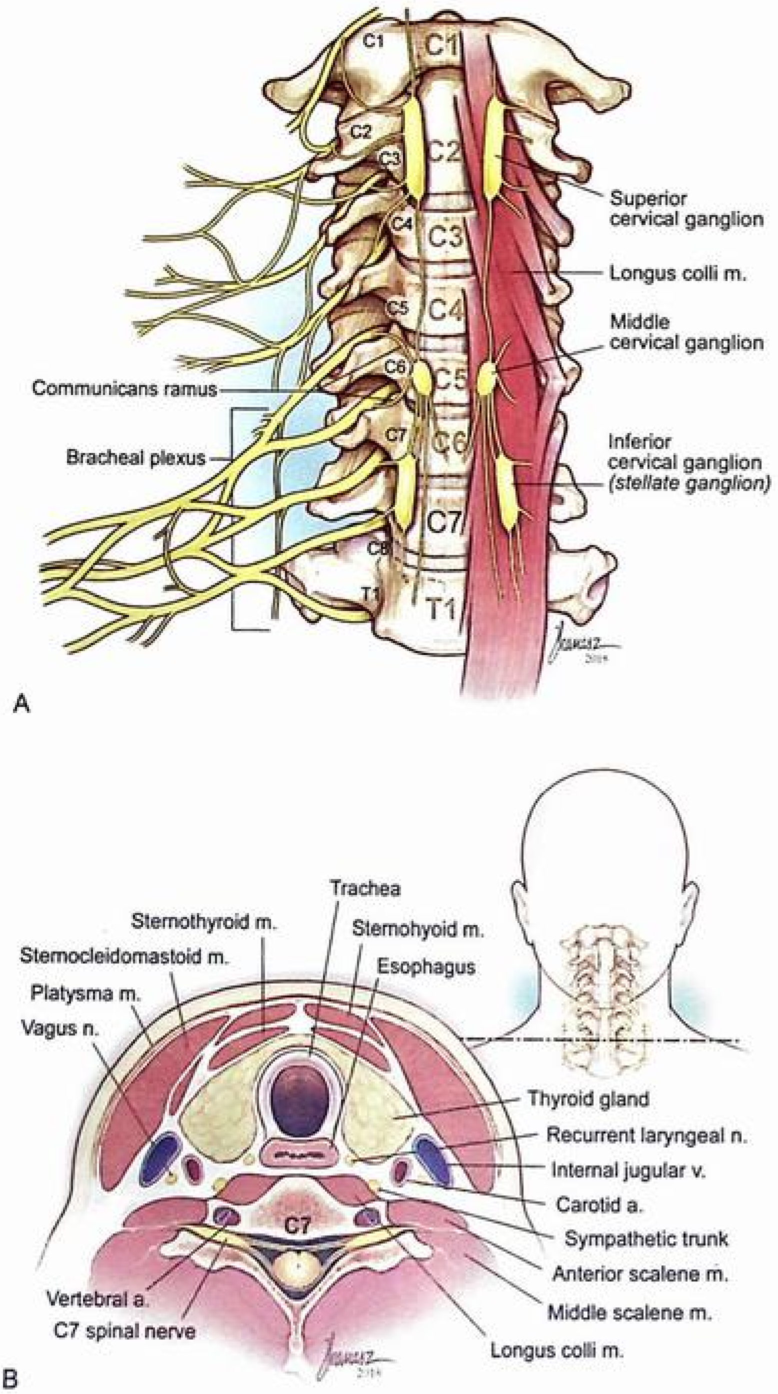


Fig. 32.1 (A) Stellate ganglion block: sympathetic chain anatomy. (B) Cross-sectional anatomy at C7 level.

Position. The patient is placed in the supine position, with the neck slightly extended and the head rotated slightly to the opposite side of the block. This is often facilitated by removing the patient's pillow before positioning.

Ultrasound-Guided Injection Technique. A high-frequency linear transducer (6–13 MHz) is placed at the level of C6 to allow visualization of the anterior and posterior tubercle of the transverse process. At that level, the longus colli muscle, prevertebral fascia, carotid artery, and jugular vein, as well as thyroid gland, trachea, and esophagus, must be located clearly.

The transducer is displaced slightly caudally until the C7 transverse process is located, with a single posterior tubercle and its root in oval form giving origin to the middle trunk. At that point, the vertebral artery and vein must clearly be identified. Color Doppler should be used to detect the position of the vessels.

For the lateral approach over this scanning plane, the needle should be directed in-plane from lateral to medial toward the prevertebral fascia located over the longus colli muscle and below the carotid artery (Fig. 32.2). After aspiration, 5 mL of a local anesthetic is injected until the fluid

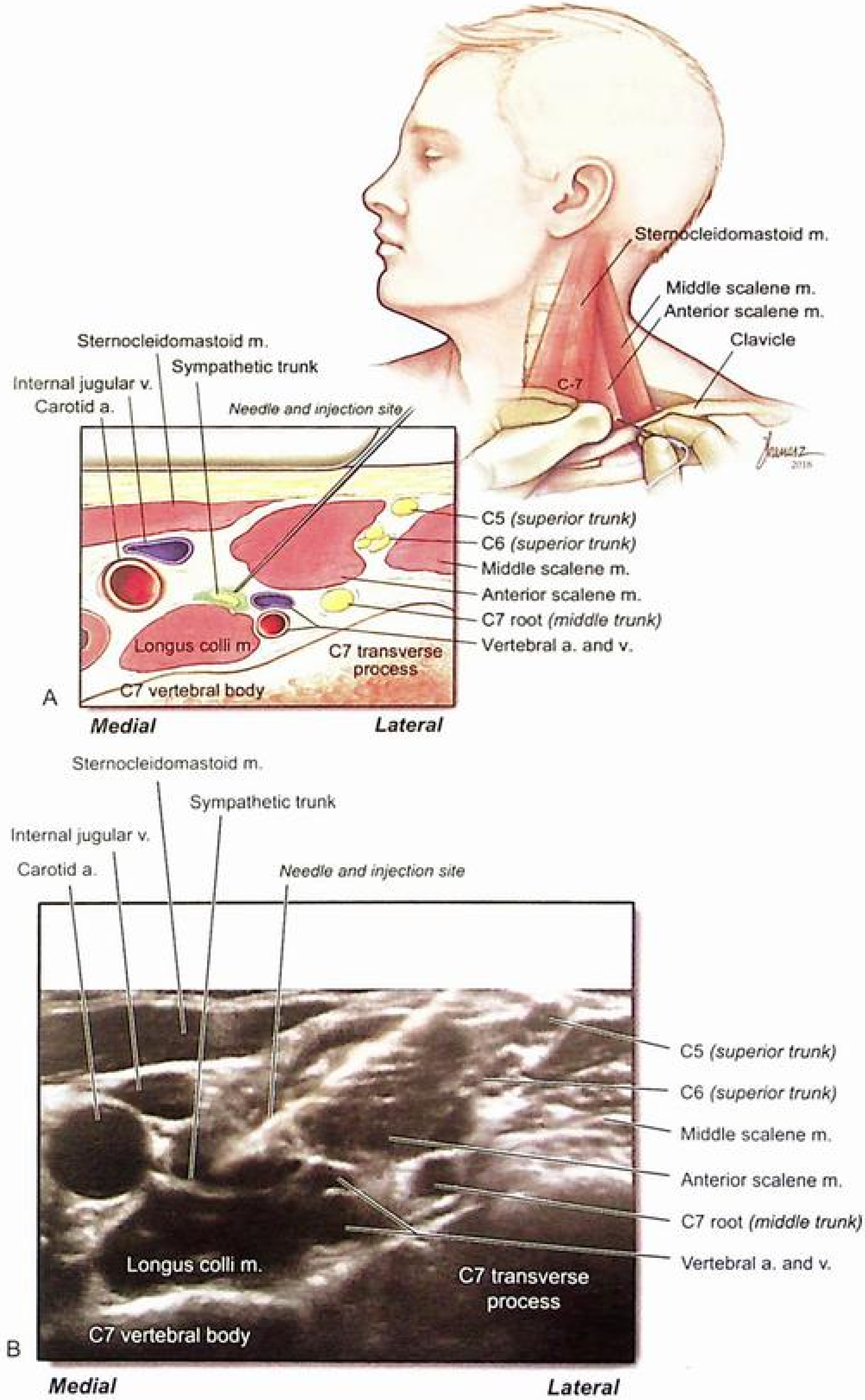


Fig. 32.2 Ultrasound-guided stellate ganglion block. **(A)** Transducer position and needle insertion point. Axial cross section over C7 level. **(B)** Sonoanatomy for ultrasound-guided stellate ganglion approach.

spreads along the paravertebral fascia to the stellate ganglion (Video 32.1).

POTENTIAL COMPLICATIONS

Complications have been described due to malposition of the needle:

- Hematoma caused by carotid, jugular, or vertebral artery trauma.
- Neural injury in case of vagus or brachial plexus root trauma.

Complications due to the spread of local anesthetic:

- Intravascular injection.
- Neuraxial or brachial plexus spread.
- Phrenic nerve or recurrent laryngeal nerve palsy.
- Infection caused by esophageal perforation or meningitis.

PEARLS

- Possible postprocedural effects should be explained to the patient, including ptosis, miosis, blurred vision, enophthalmos, anhidrosis, facial and conjunctival flushing, upper extremity numbness or weakness and sense of dyspnea, dysphagia, or a lump in the throat.
- It is crucial to identify potential dangerous structures such as the vertebral artery and vein, esophagus, trachea, and brachial plexus roots prior to puncture.
- A constant and real-time view of the needle trajectory and distribution of the local anesthetic over the longus colli muscle should be maintained at all times.

33 Airway Block Anatomy

Richard L. Drake

Airway blocks involve three specific cranial nerves: the trigeminal (CN III), the glossopharyngeal (CN IX), and the vagus (CN X) (Figs. 33.1 and 33.2). Any procedures related to the nasal cavities, such as nasal intubation, will involve dealing with the branches of the maxillary division of the trigeminal nerve. Procedures related to the pharynx and posterior third of the tongue must consider the involvement of the glossopharyngeal nerve. This would include sensory nerves to the pharyngeal mucosa, nerves supplying the tonsillar region and parts of the soft palate, and nerves to the posterior third of the tongue. Any procedures distal to the epiglottis will require blocking branches of the vagus nerve. Branches of this nerve would include those supplying sensory fibers from the epiglottis past the vocal cords to the upper trachea and include muscles in this region.

TRIGEMINAL NERVE

The trigeminal nerve (CN V) is the major sensory nerve of the head and innervates muscles that move the lower jaw. Before exiting the cranial cavity, it divides into the ophthalmic nerve, the maxillary nerve, and the mandibular nerve (Fig. 33.3A,B). The ophthalmic nerve exits the cranial cavity and enters the orbit through the superior orbital fissure. This nerve provides sensory innervation to various structures in the orbit, upper portion of the nasal cavity, upper eyelid, dorsum of the nose, and the anterior part of the scalp (Fig. 33.4). The maxillary nerve exits the cranial cavity through the foramen rotundum. It provides sensory innervation to the nasopharynx, palate, nasal cavity, teeth in the upper jaw, maxillary sinus, and skin covering the middle portion of the face, cheek, and upper lip (Fig. 33.4). The mandibular nerve exits the cranial cavity through the foramen ovale and enters the infratemporal fossa. Motor fibers innervate the muscles of mastication, while sensory fibers innervate the lower part of the face, anterior portion of the ear, anterior two-thirds of the tongue, and teeth of the lower jaw (Fig. 33.4).

CLINICAL CORRELATIONS

Upper Airway Block

The upper airway is regarded as the airway associated with the nasal cavity. Therefore if a nasal intubation is to be attempted, the maxillary branches of the trigeminal nerve must be blocked (Fig. 33.5A,B).

GLOSSOPHARYNGEAL NERVE

The glossopharyngeal nerve (CN IX) carries a variety of functional components. For this discussion, the sensory fibers are the most relevant. This nerve exits the cranial cavity through the jugular foramen (Fig. 33.6) and provides sensory innervation to the posterior third of the tongue, palatine tonsils, oropharynx, middle ear, and mastoid air cells (Fig. 33.7).

CLINICAL CORRELATIONS

Glossopharyngeal Block

This block is used for procedures involving the posterior third of the tongue, preventing the gag reflex, and the mucosa in the tonsillar region of the pharynx and soft palate. It can be administered either intraorally (Fig. 33.8) or externally, near the styloid process (Fig. 33.9A,B).

VAGUS NERVE

The vagus nerve (CN X) also carries a variety of functional components. For this discussion, the sensory and motor fibers are the most relevant. This nerve exits the cranial cavity through the jugular foramen (Fig. 33.6) and provides sensory innervation through the superior laryngeal nerve to the mucosa from the epiglottis to the vocal cords (Fig. 33.10). This nerve also innervates the cricothyroid muscle. Similarly, the recurrent laryngeal nerve provides sensory innervation to the larynx and trachea below the vocal cords (Fig. 33.11) and some motor innervation to muscles in the tongue, soft palate, pharynx, and larynx.

CLINICAL CORRELATIONS

Superior Laryngeal Block

In this block, the superior laryngeal nerve is reached at the lower border of the hyoid bone, providing airway

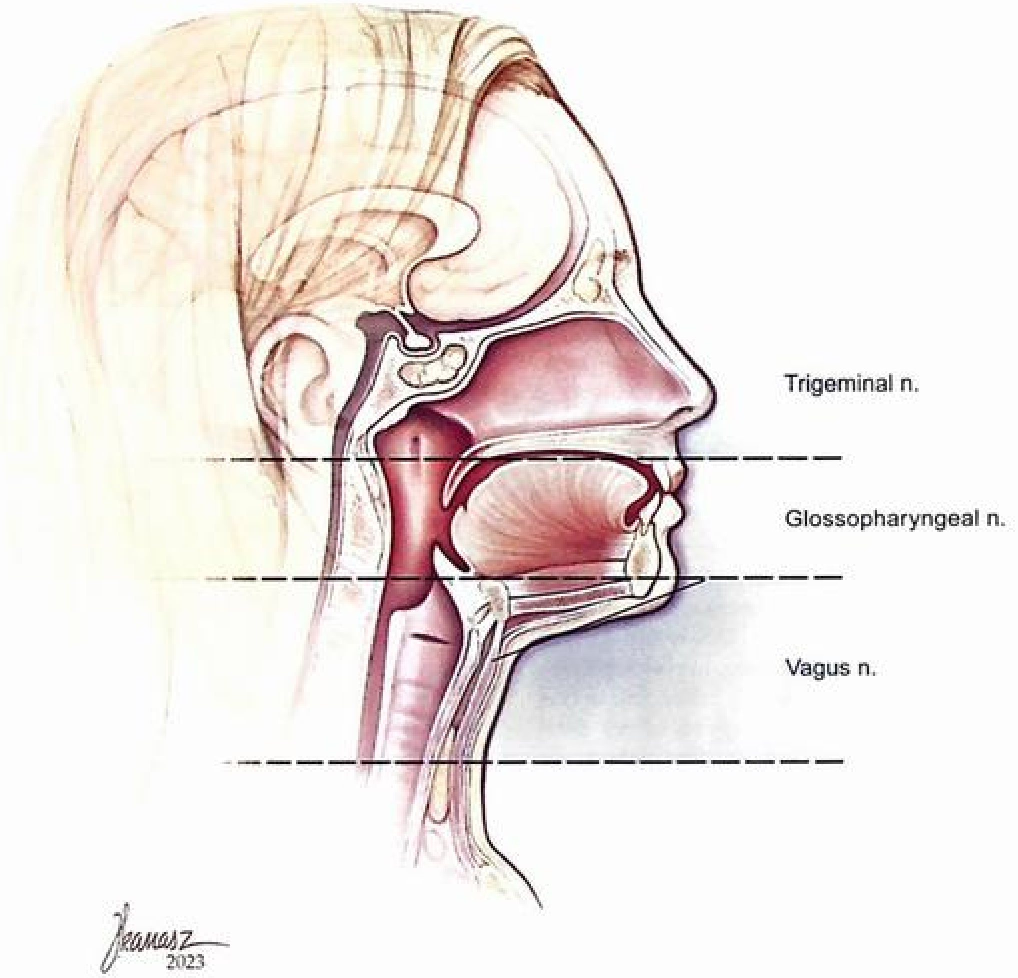


Fig. 33.1 Cranial nerve innervation of the upper airways.

anesthesia (Fig. 33.10). Affected areas will reach from the epiglottis to the level of the vocal cords (Fig. 33.12).

Translaryngeal Block

This block is used to provide numbing to the laryngeal and tracheal mucosa innervated by branches of the vagus nerve. Injection through the cricothyroid membrane allows the solution to spread over the tracheal region and "coughed" onto the more superior laryngeal areas (Figs. 33.13 and 33.14, Video 33.1).

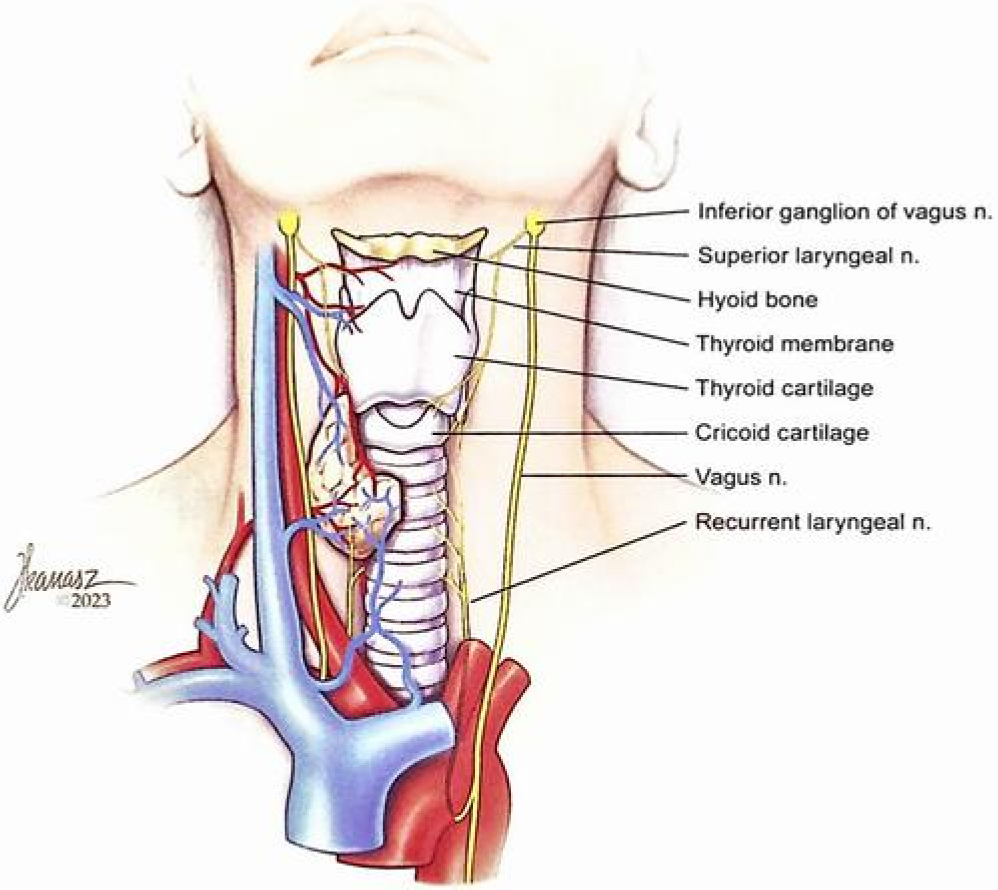


Fig. 33.2 Cranial nerve innervation of the middle airways.

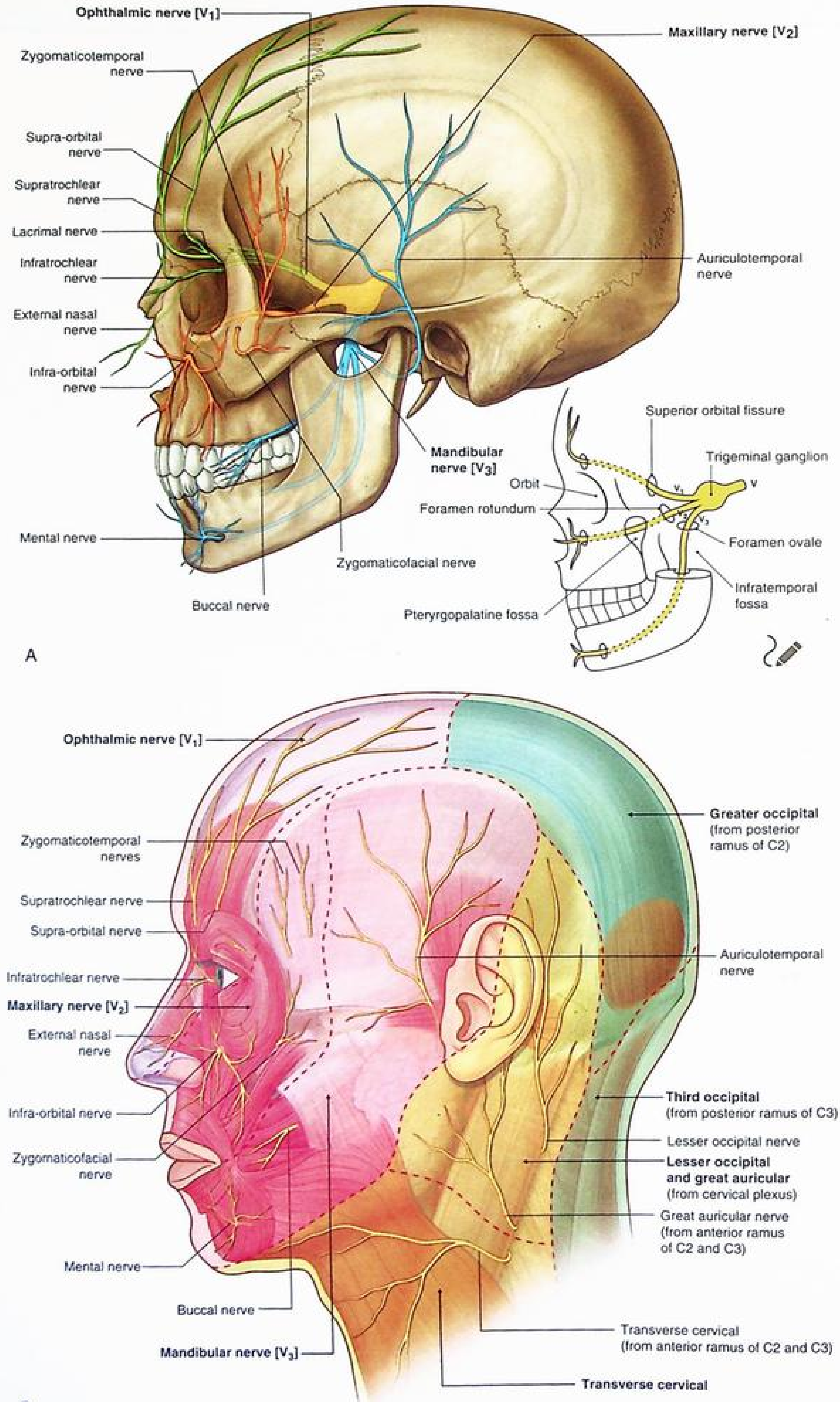


Fig. 33.3 Vasculature of the face. (A) Lateral view. (B) Branches of the maxillary artery. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

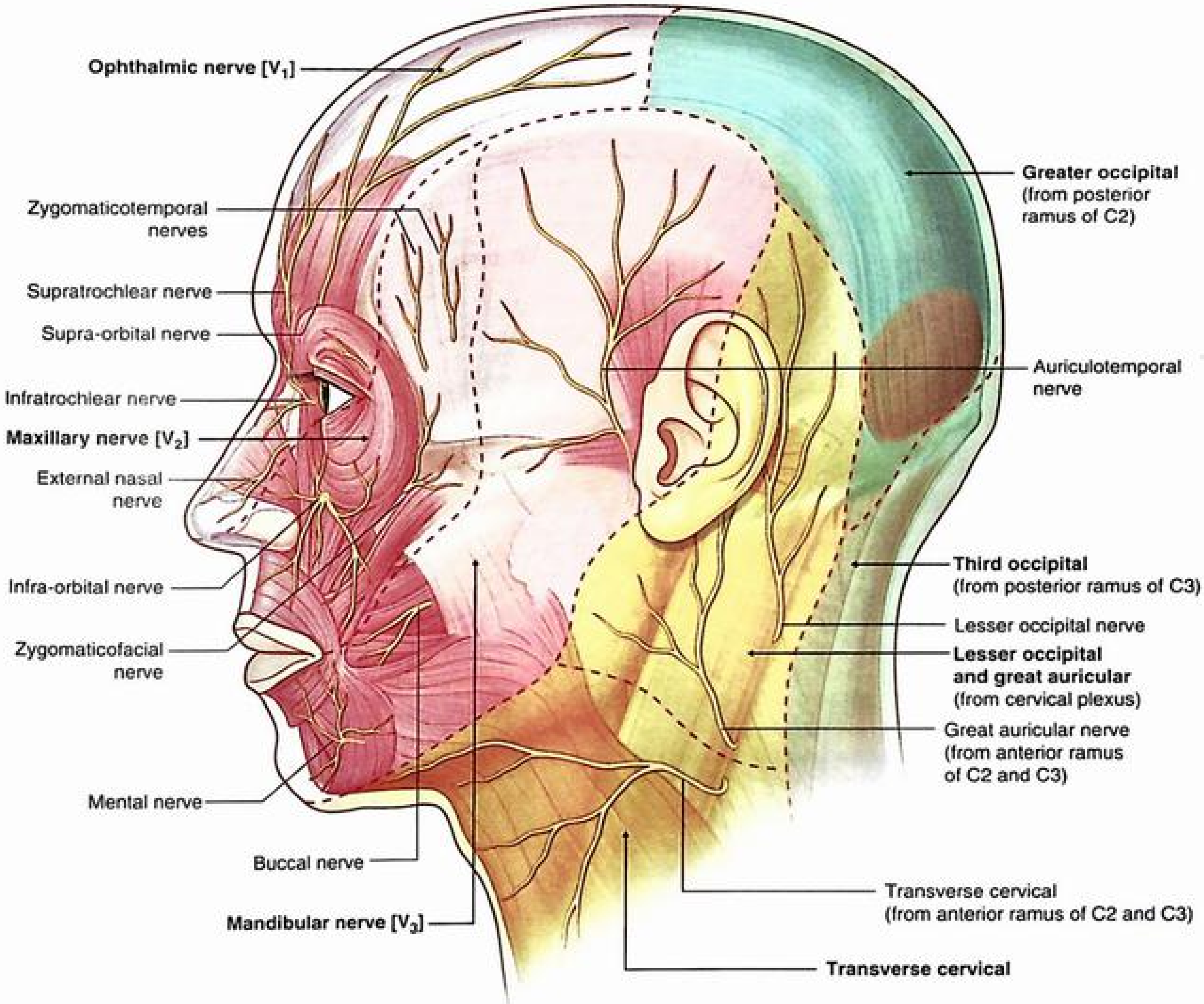


Fig. 33.4 **Intracranial venous connections.** (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

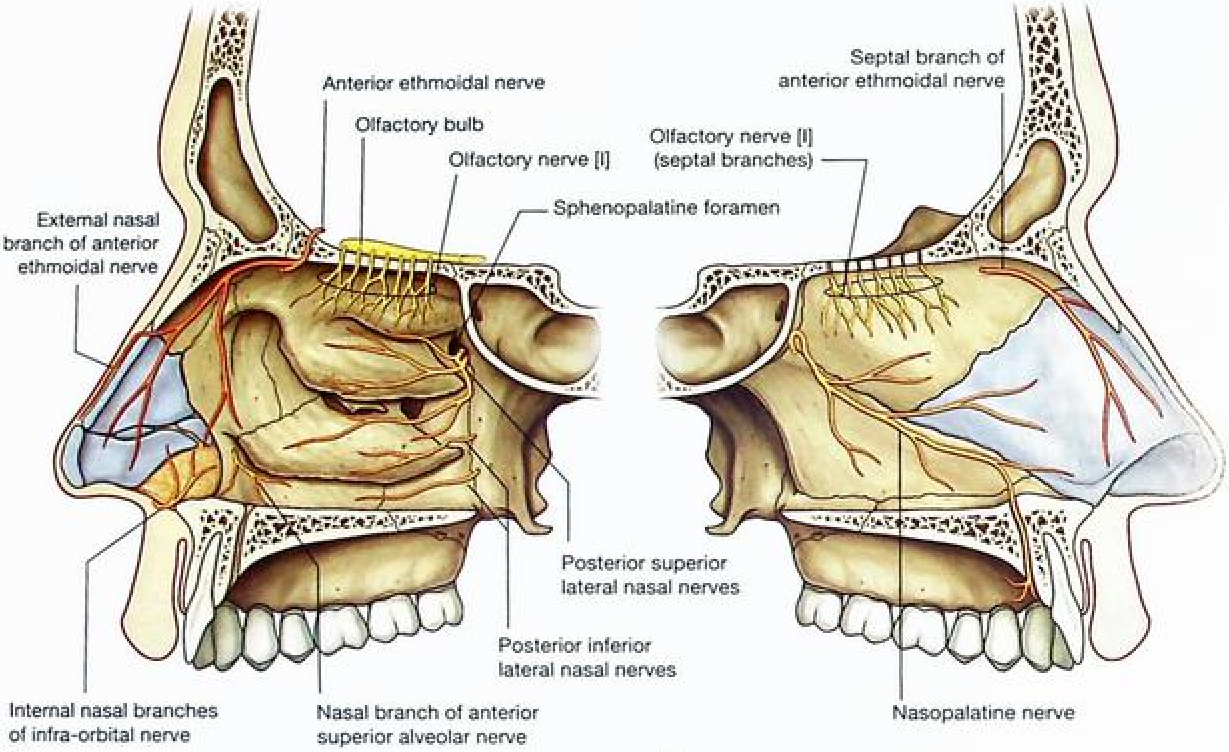


Fig. 33.5 Base and lateral aspects of the skull. (A) Features in the base of the skull related to structures associated with the oral cavity. (B) Styloid process of the temporal bone. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier, 2023.)

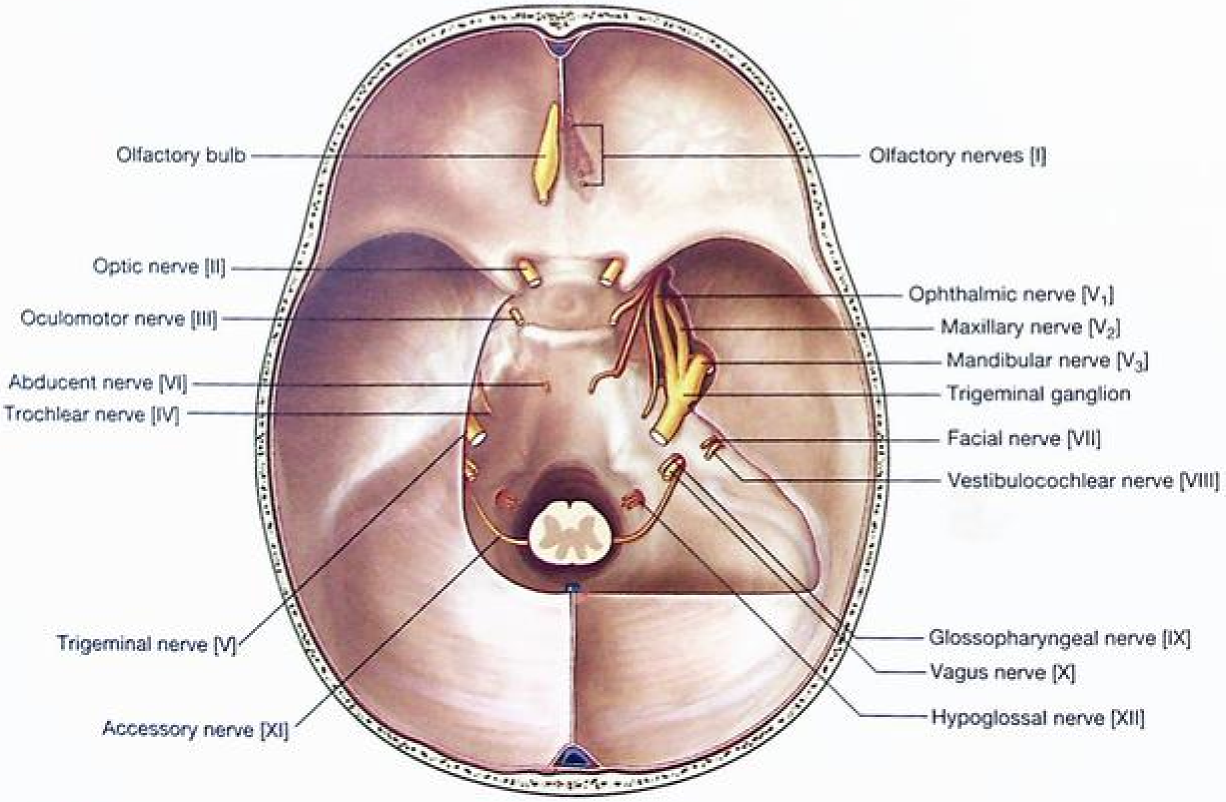
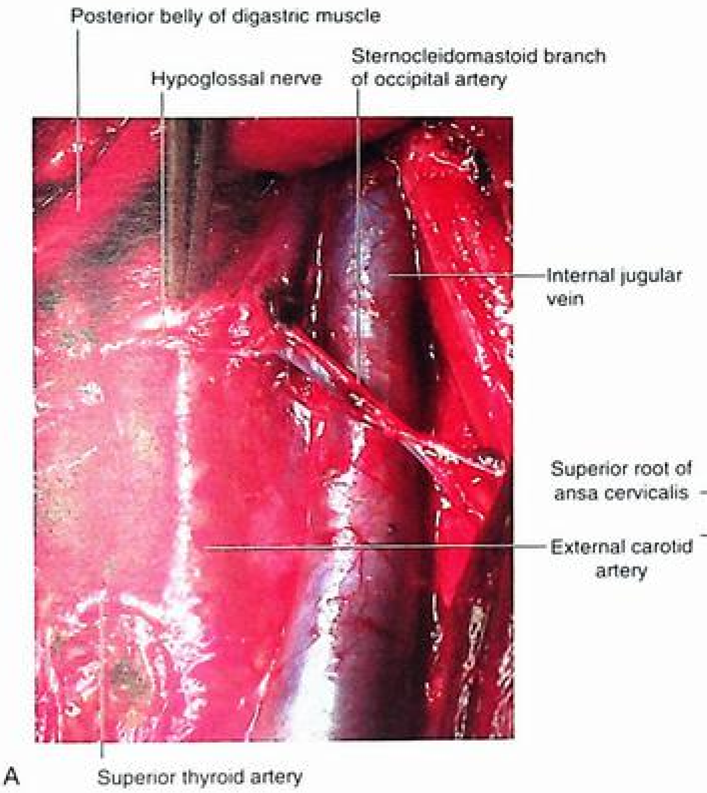


Fig. 33.6 Facial muscles. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)



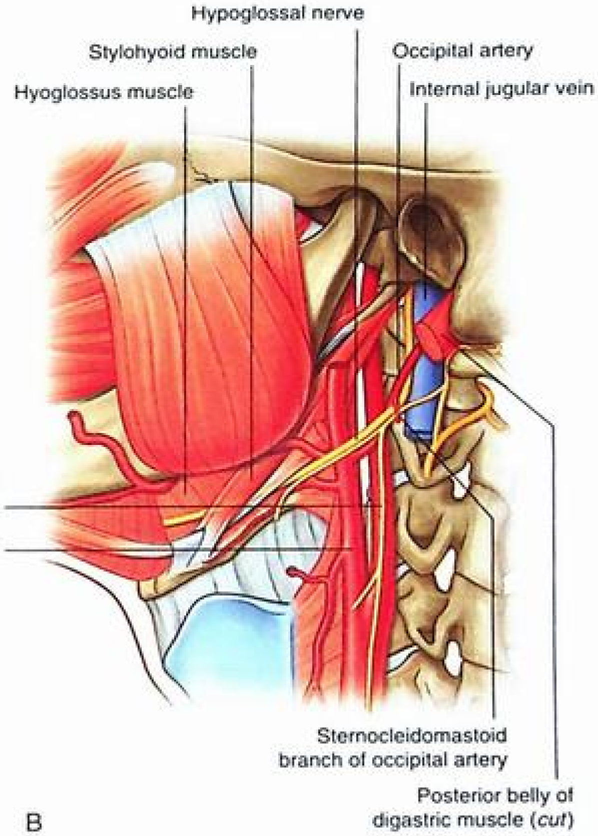


Fig. 33.7 Hypoglossal nerve [XII]. (A) Surgical view of hypoglossal nerve in anterior triangle of the neck. (B) Diagram. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

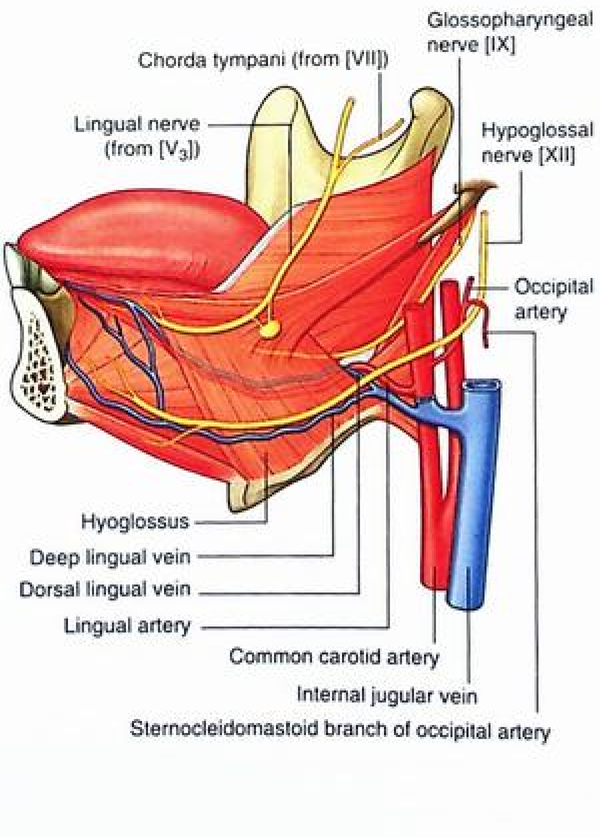


Fig. 33.8 Hypoglossal nerve and C1 fibers. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 5th ed. Philadelphia: Elsevier; 2023.)

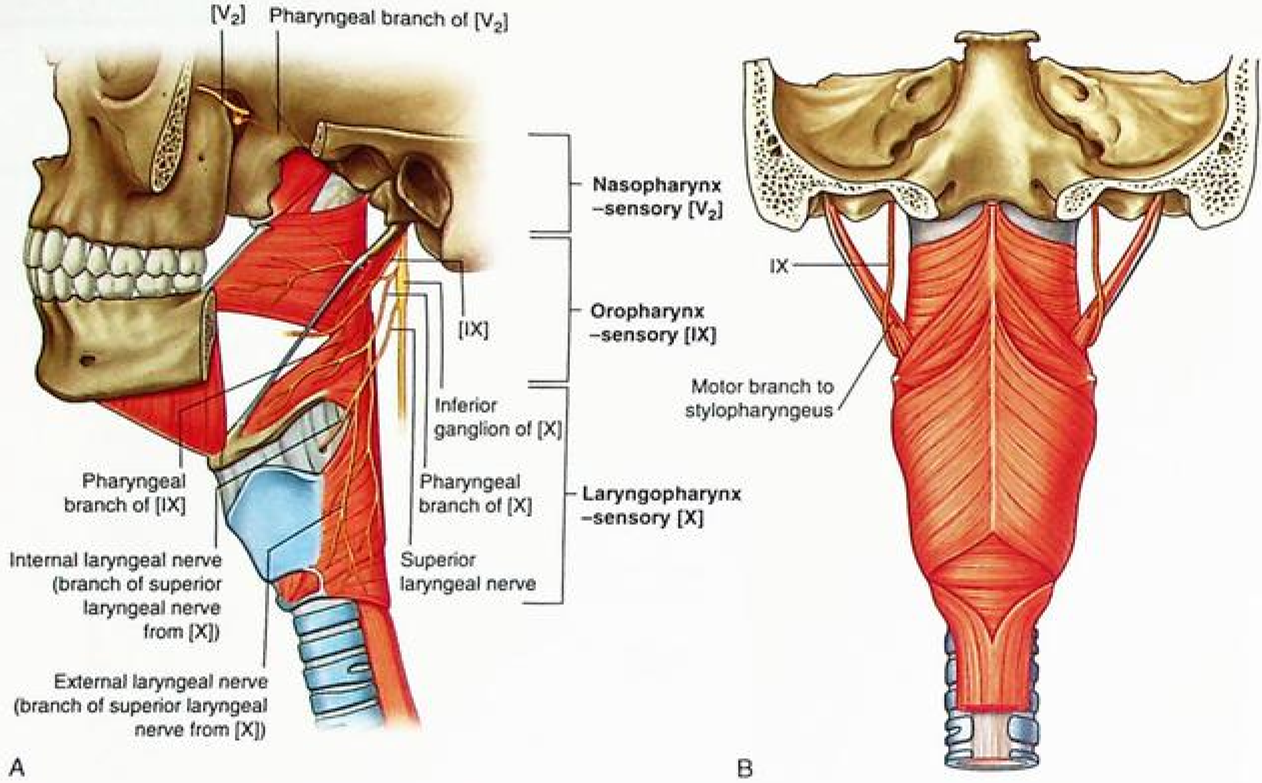


Fig. 33.9 Thyroid cartilage. **(A)** Anterolateral view. **(B)** Superior view. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

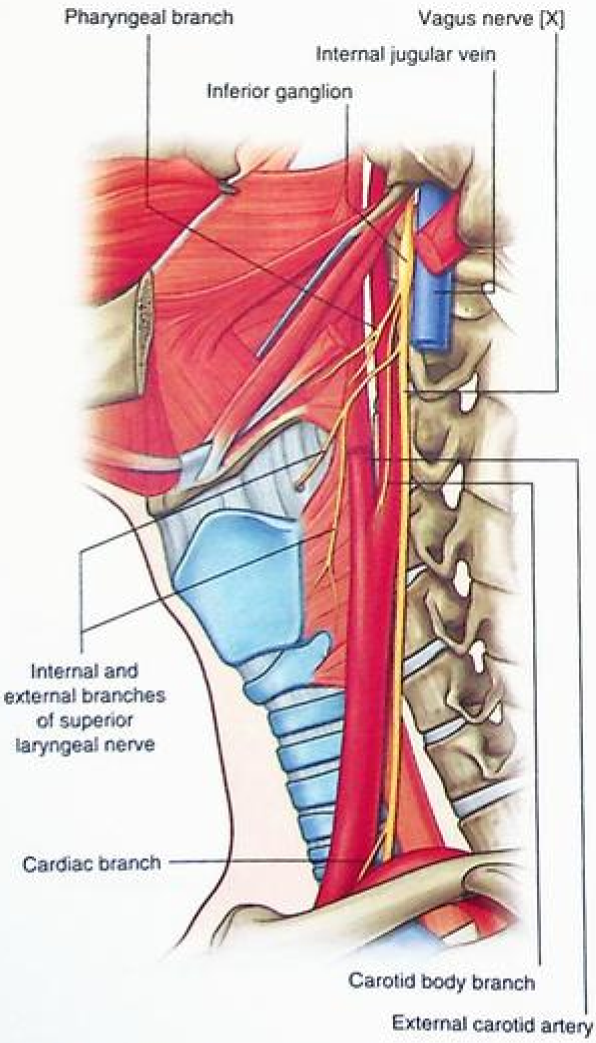


Fig. 33.10 Transverse cervical nerve in the anterior triangle of the neck. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

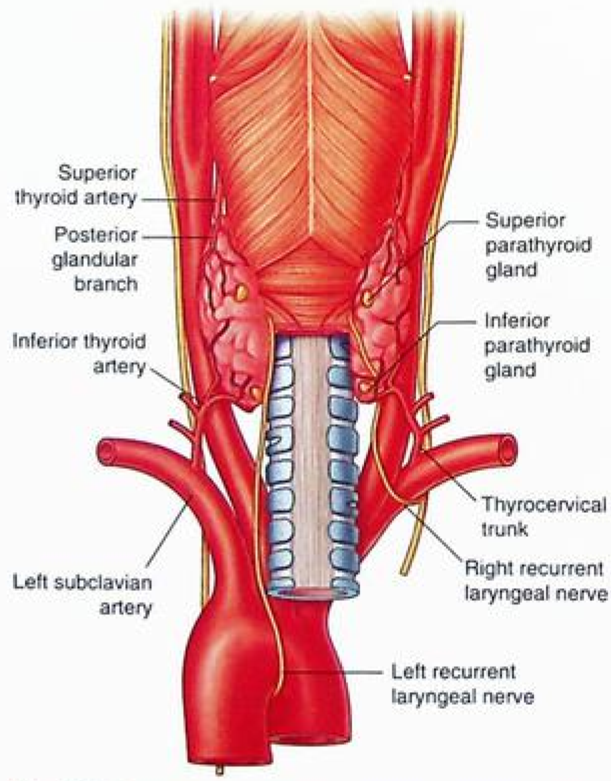


Fig. 33.11 Borders of the posterior triangle of the neck. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

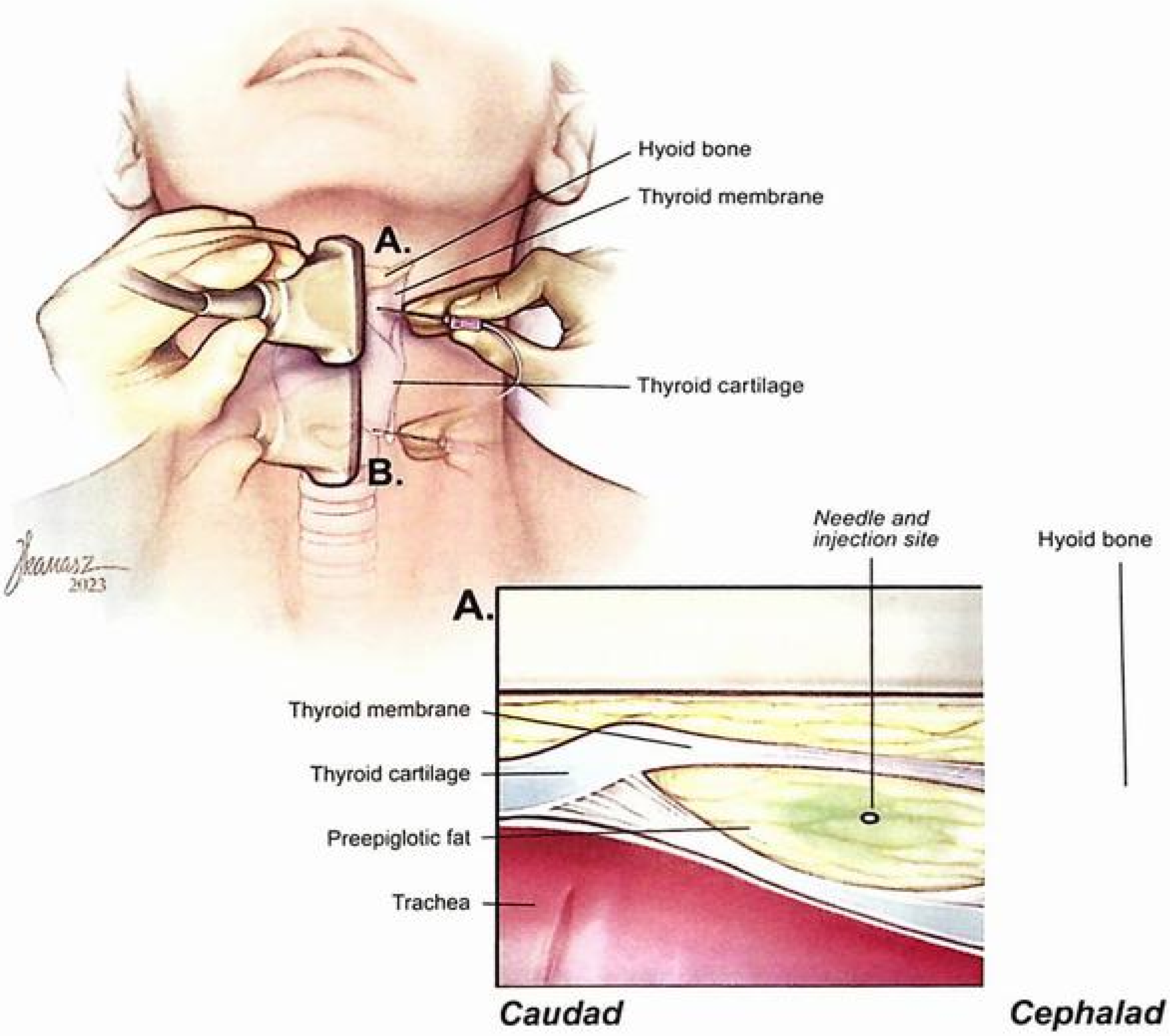


Fig. 33.12 Ultrasound technique for superior laryngeal nerve block. Notice the position of the probe above the thyrohyoid membrane between the hyoid bone and the thyroid cartilage. Notice the out-of-plane technique to inject the local anesthetic beneath the thyrohyoid membrane for blocking the deep branch of superior laryngeal nerve.

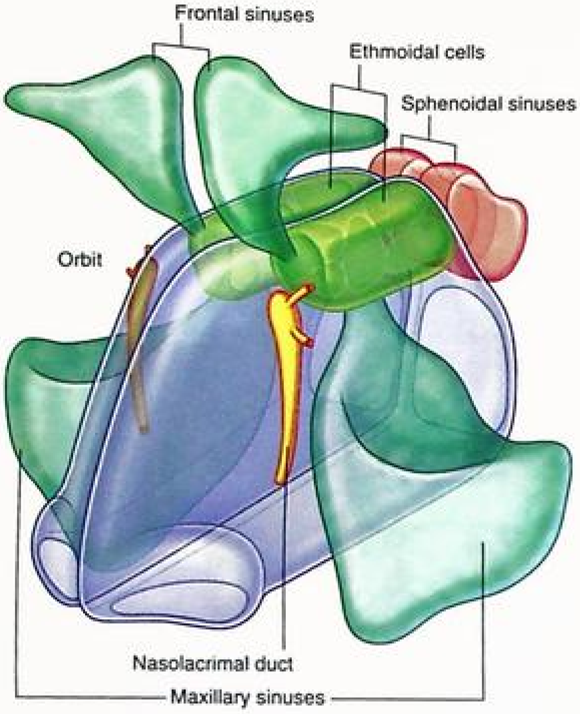


Fig. 33.13 Paranasal sinuses and nasolacrimal duct. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 4th ed. Philadelphia: Elsevier; 2020.)

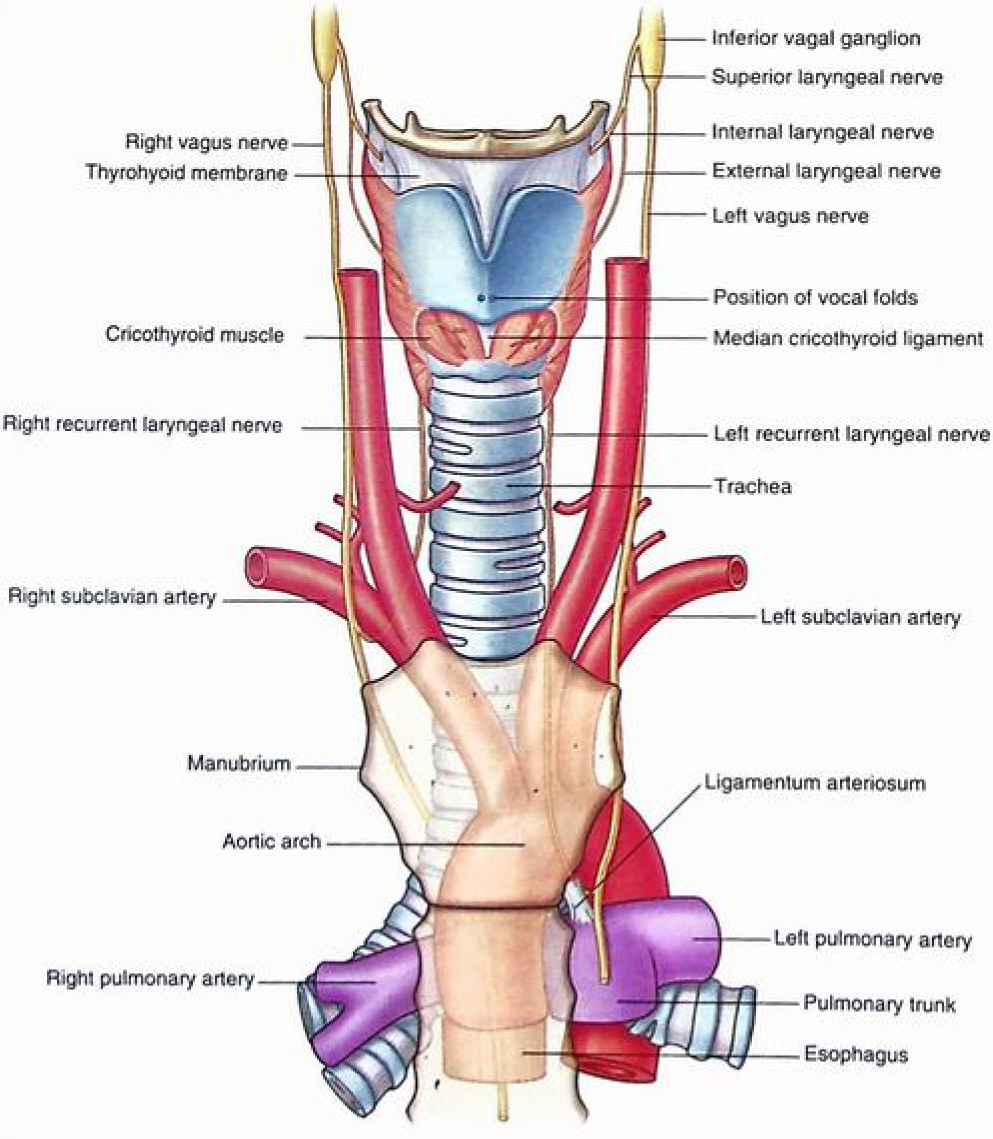


Fig. 33.14 Ultrasound technique to block the recurrent laryngeal nerve. Notice the position of the probe above the cricothyroid membrane between the thyroid and the cricoid cartilage. Notice the out-of-plane technique to inject the local anesthetic beneath the cricothyroid membrane.

Glossopharyngeal Block 34

Ehab Farag, Michael Chepanoske, and Stefan Trela

Key Points

- Glossopharyngeal nerve (GPN) block is crucial to block the gag reflex during the awake fiberoptic intubation.
- GPN block is very helpful in the treatment of chronic nonmalignant and malignant pain in the oropharynx, tongue, and the upper airway.
- GPN block could be used in the treatment of Eagle syndrome.
- Ultrasound-guided GPN block is very helpful to ensure the success and the safety of the block.

SONOANATOMY AND TECHNIQUE

The patient will be placed in the supine position with the head turned to the contralateral side from the side to be blocked. A line will be drawn between the mandibular angle and the tip of the mastoid process. Another line will be drawn 1.5 cm above the posterior edge of the mandibular angle to the tip of the mastoid process. The linear high-frequency probe will be placed on the second line to visualize the styloid process. The scanning sequence will be parallel to the second line, moving up and down to visualize the styloid process. Color flow Doppler will be used to identify the internal carotid artery and the internal jugular vein below or behind the styloid process. A 22-gauge needle will be directed using the in-plane approach under ultrasound guidance from posterior into anterior direction (mastoid toward mandibular angle). Once the needle tip gets in contact of the styloid process, it walks off the process to reach its back. After careful aspiration, 1.5 mL of lidocaine 2% will be injected (Figs. 34.1 and 34.2).

PEARLS

- The in-plane technique is the preferred technique to visualize the needle and to avoid inadvertent vascular injection.
- Walking off the styloid process is very helpful to ensure a successful block.

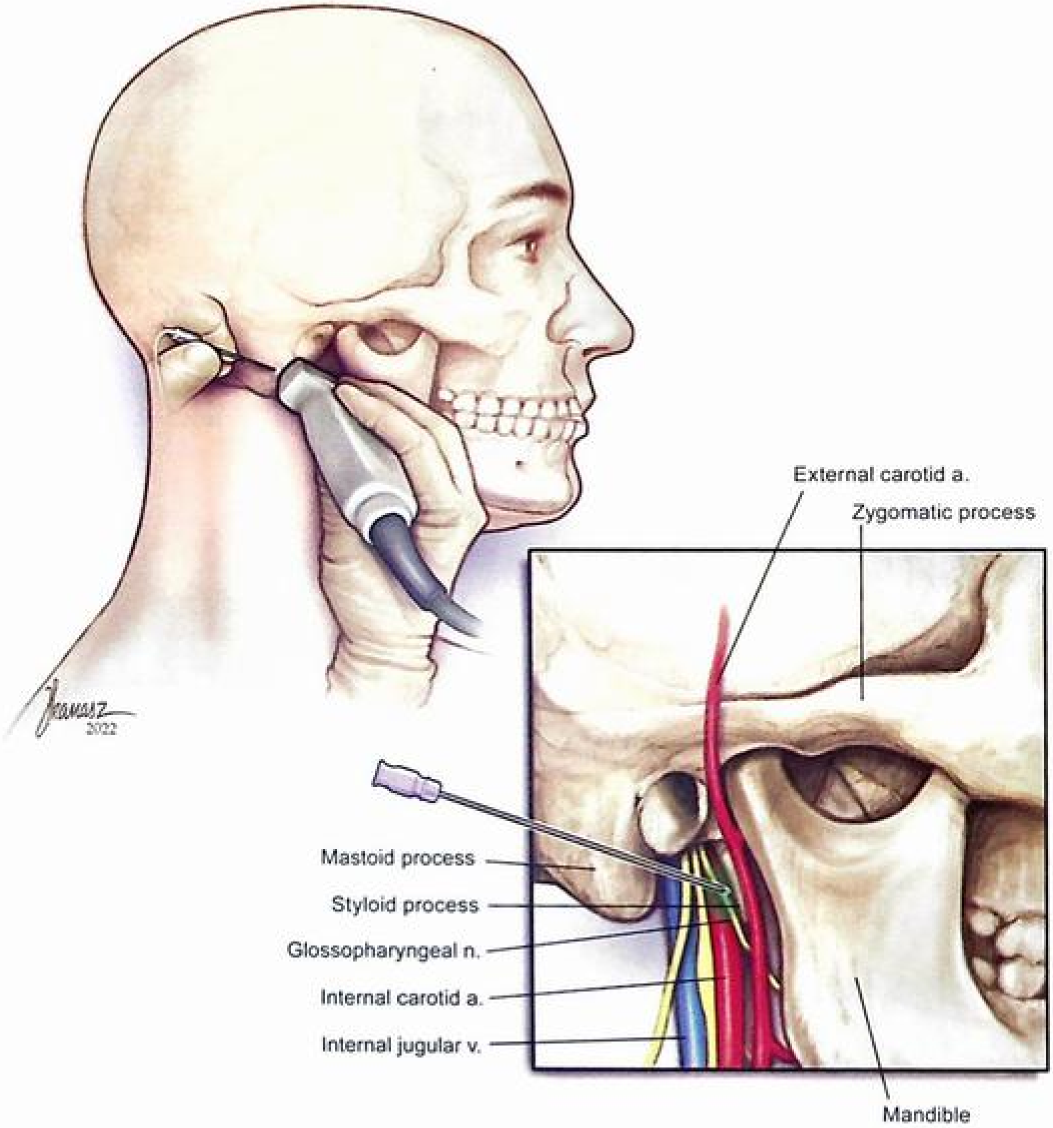


Fig. 34.1 Anatomy of the glossopharyngeal nerve. Note the position of the ultrasound probe between the mastoid process and the angle of the mandible.

Superior Laryngeal Nerve Block 35

Ehab Farag, Michael Chepanoske, and Stefan Trela

Key Points

- The bilateral block of the internal branch of the superior laryngeal nerve is very helpful for awake fiberoptic intubation.
- The hyperechoic hyoid bone, thyroid cartilage, and thyrohyoid membrane are important landmarks for the block.

ANATOMY

The bilateral internal branch of the superior laryngeal nerve block can be used to obtain airway anesthesia. The superior laryngeal nerve arises from the vagus nerve. At the greater horn of the hyoid bone, it divides into external and internal branches. The internal branch provides sensory innervation of the mucous membranes of the larynx above the level of the vocal cords and the base of the tongue and epiglottis. The internal branch passes inferior to the greater horn of the hyoid bone and pierces the thyrohyoid membrane. The external branch provides motor supply to the cricothyroid muscle (Fig. 35.1).

TECHNIQUE AND SONOANATOMY

The internal branch of superior laryngeal nerve passes into the larynx through the hyperechoic thyrohyoid membrane, which is located between the hyoid bone cephalad and the thyroid cartilage caudally. Both structures appear as hyperechoic structures on ultrasound.

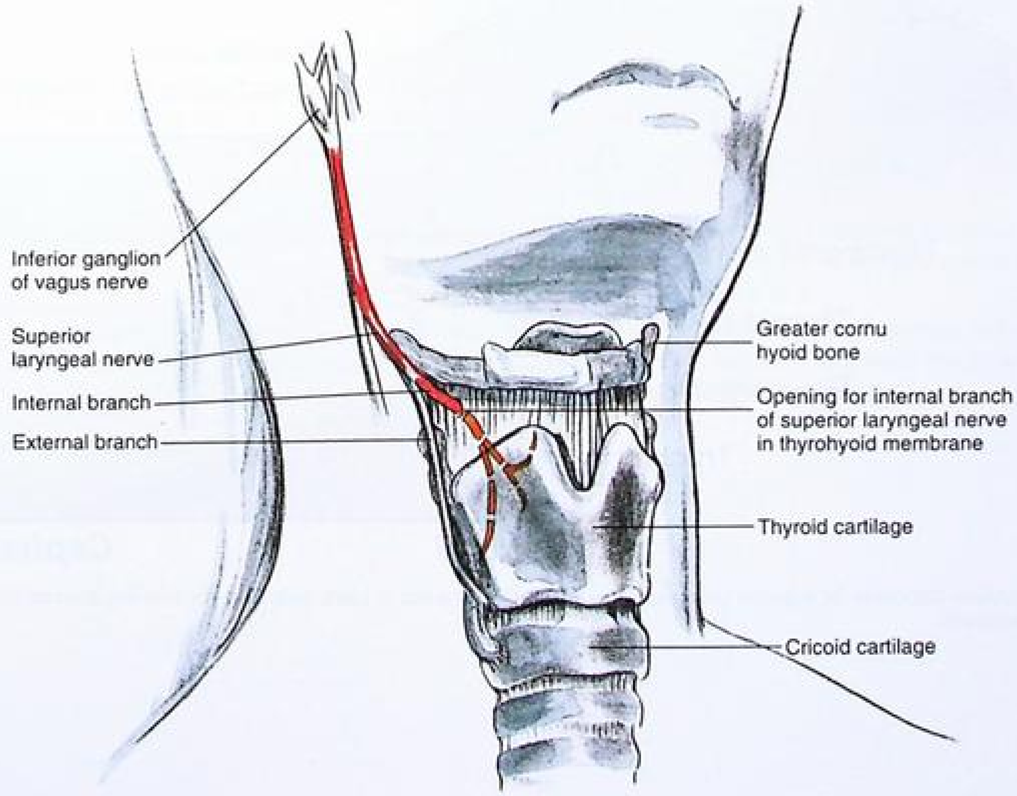


Fig. 35.1 Anatomy of the superior laryngeal nerve.

A linear high-resolution probe (12–15 MHz) is placed on the midline in the submandibular area to visualize the hyoid bone and the thyroid cartilage. The probe is then moved laterally to visualize the larynx hypoechoic thyrohyoid muscle (inserted on the hyoid bone and passing over the thyroid cartilage) and the hyperechoic thyrohyoid membrane. The thyrohyoid membrane appears hyperechoic due to the air-mucosa interface between the hypoechoic preepiglottis space, the luminal surface, and the superficial mucosae of the larynx. A 22-gauge needle can be inserted using the out-of-plane technique to the probe through the thyrohyoid membrane on both sides. A 1.5 mL volume of lidocaine 2% can be injected on each side after careful aspiration (Fig. 35.2).

PEARLS

- If the nerve is not visualized, the easiest way to block is to inject the local anesthetics beneath the thyrohyoid membrane.
- The out-of-plane approach is the preferred method for the block.
- Using small footprint linear probe is helpful, especially in patients with short necks.

Suggested Reading

Barberet G, Henry Y, Tatu L, et al. Ultrasound description of a superior laryngeal nerve space as an anatomical basis for echoguided regional anaesthesia. *Br J Anaesth*. 2012;109(1):126–128.

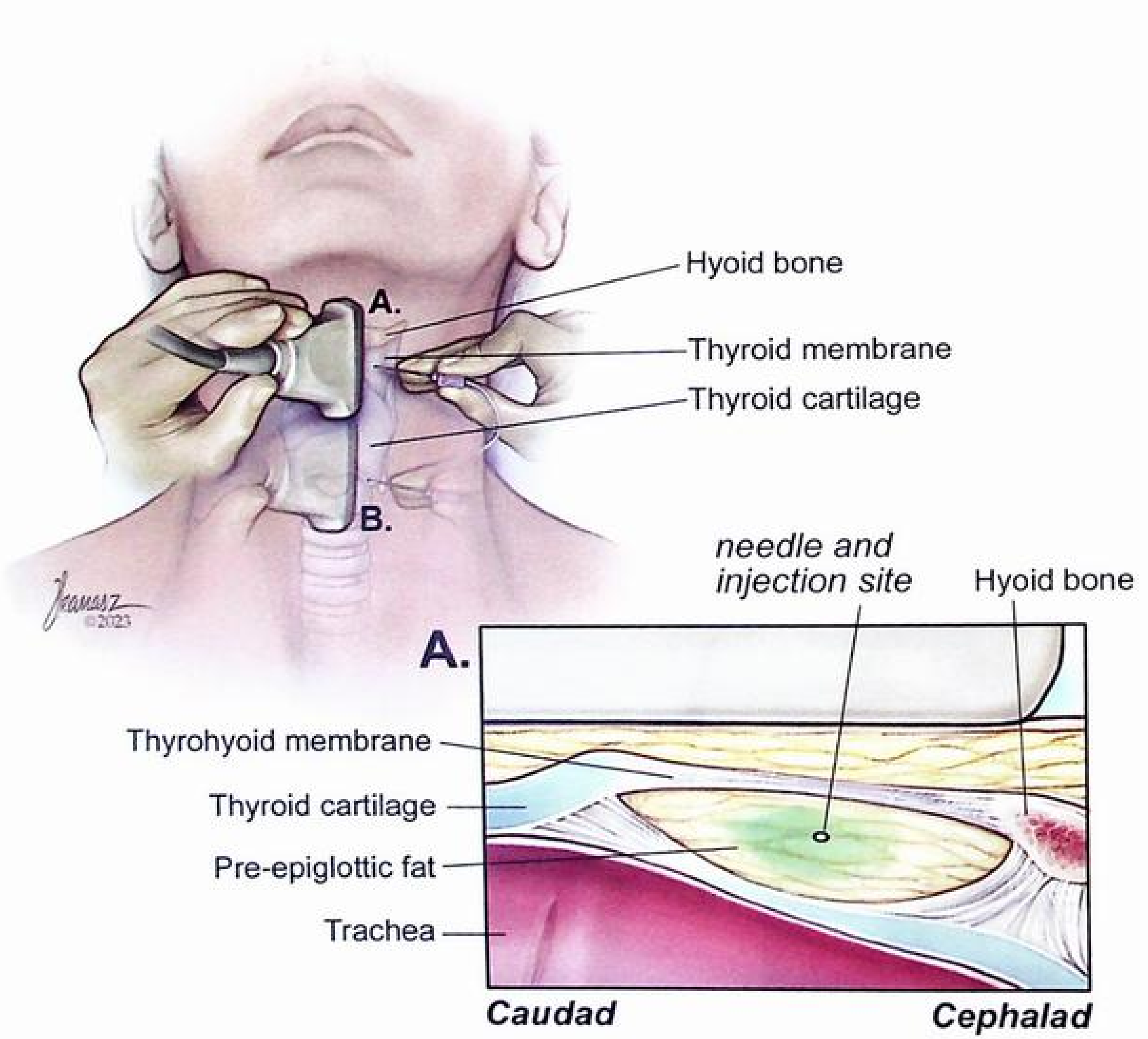


Fig. 35.2 Ultrasound technique for superior laryngeal nerve block. Note the out of plane technique for inserting the needle through the thyrohyoid membrane.

36 Recurrent Laryngeal Nerve Block

Ehab Farag

Key Points

- Using ultrasound for cricothyroid membrane identification is more accurate than the landmark technique.
- Identification of the cricothyroid membrane using ultrasound can be used for transtracheal injection for recurrent laryngeal block or cricothyroidotomy.

ANATOMY AND TECHNIQUE

The recurrent laryngeal nerve supplies the sensory innervation to the laryngeal mucosa below the level of vocal cords and the trachea (Fig. 36.1). Blocking the recurrent laryngeal nerve facilitates comfortable passing of the endotracheal tube into the trachea. Combined transtracheal recurrent laryngeal nerve block with bilateral internal branch of the superior laryngeal nerve is crucial for proper upper airway sensory block during awake fiberoptic intubation.

Ultrasound is an accurate method for the localization of the cricothyroid membrane (CTM) (Fig. 36.2). The success rate for correctly identifying the CTM by a landmark technique varies from 32% to 39% compared with the accuracy of ultrasound. Average CTM dimensions are 8 mm by 11 mm. Transtracheal injection for recurrent laryngeal nerve block can be performed with real-time ultrasound using the "string of pearls" technique. A linear array high-frequency transducer (12–15 MHz) is used for this technique. The transducer should be placed in the transverse short-axis view on the patient's neck, just above the suprasternal notch, to visualize the trachea. This can be seen as an inverted U hypoechoic structure, with hyperechoic reverberation artifacts posteriorly.

The transducer should be rotated 90 degrees to visualize the tracheal rings in the long-axis view. The tracheal rings will appear as hypoechoic rings anterior to a hyperechoic white air-mucosa (A-M) interface line, reminiscent of a string of pearls. The transducer should be moved cephalad in the long-axis view on the midline until the cricoid cartilage, cuboidal in shape, is visualized. The transducer should be moved further cephalad to identify the thyroid cartilage. The echogenic CTM will be visualized between the upper border of the cricoid and lower border of the thyroid cartilages. Next, a 22-gauge needle will be inserted, using real-time ultrasound imaging through the CTM. After aspiration of air, 3 to 5 mL of 2% lidocaine will be injected for the recurrent laryngeal nerve block.

Identification of CTM during an emergency could be a lifesaving procedure in situations when the patient cannot be oxygenated and intubated. It can be performed in a similar way (Fig. 36.3).

PEARLS

- Visualization of CTM is essential for a successful procedure.
- Aspiration of air before injecting the local anesthetics is crucial to ensure the proper needle position in the trachea.
- The patient's coughing after injection of local anesthetics is a sign of successful block; in addition, it disperses the local anesthetic.

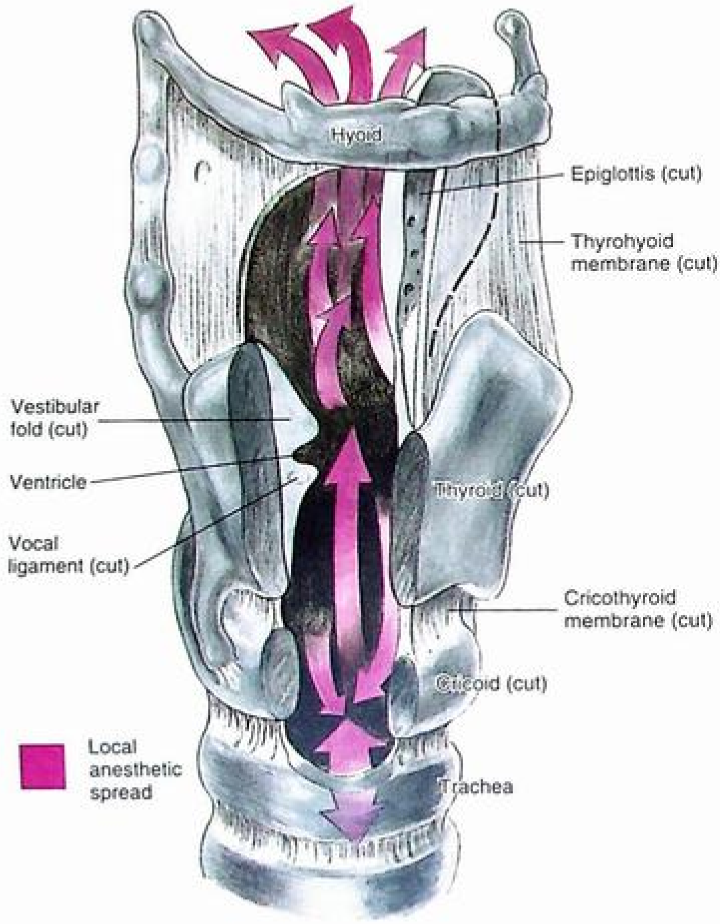


Fig. 36.1 Anatomy of the upper airway.

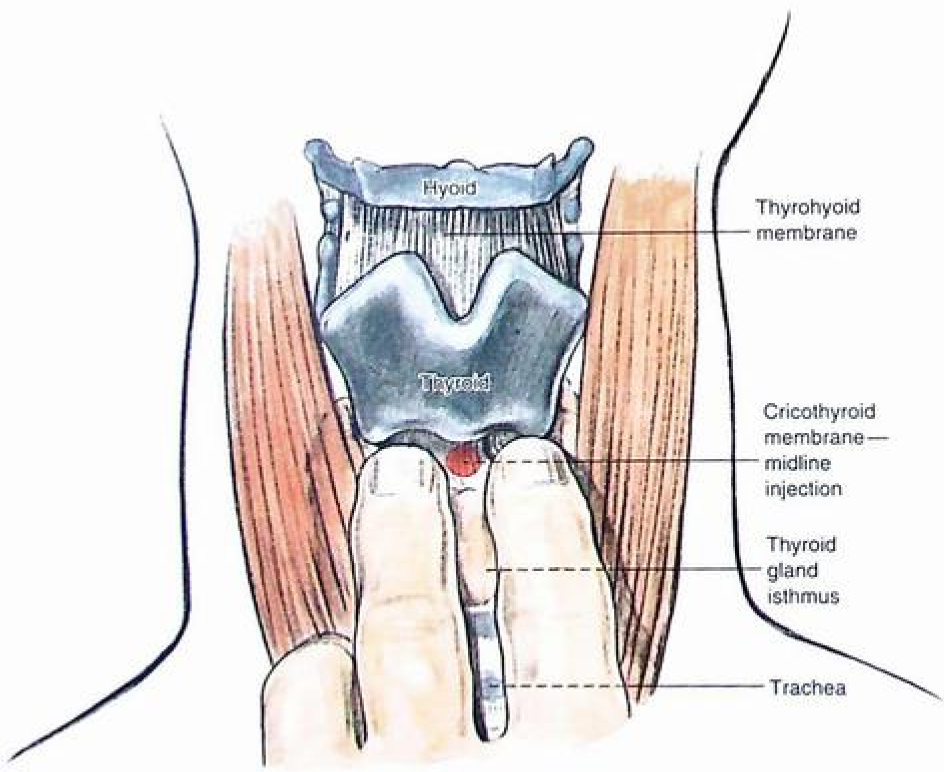


Fig. 36.2 Anatomy of the cricothyroid membrane.

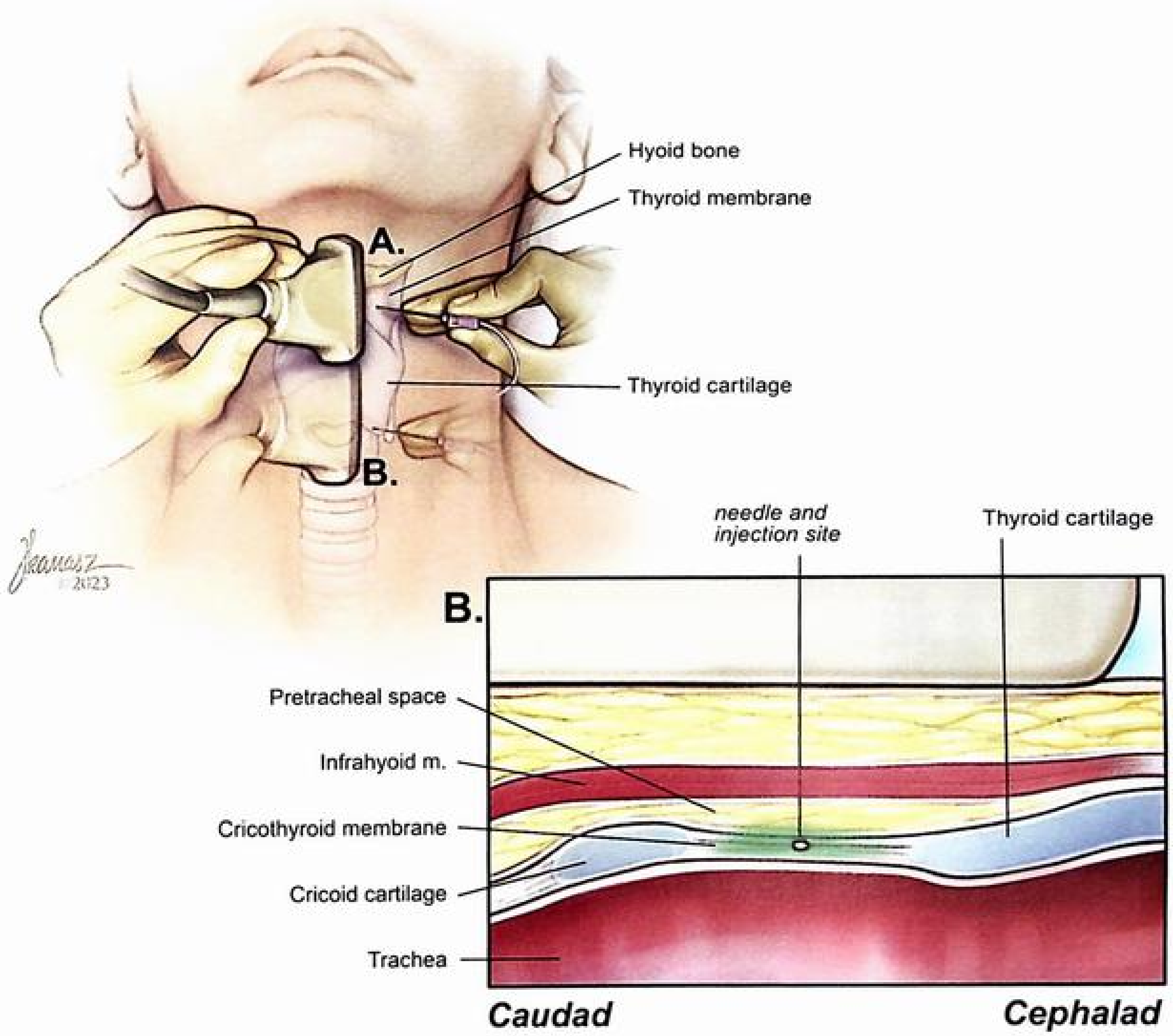


Fig. 36.3 Ultrasound technique for recurrent laryngeal nerve block. Note the out of plane technique for inserting the needle through the cricothyroid membrane.

Section 6
Truncal Blocks

37 Truncal Block Anatomy

Richard L. Drake

Innervation of the thoracic and abdominal walls, generally referred to as the trunk, involves the thoracic and lumbar spinal nerves. These truncal/paravertebral blocks affect somatic innervation and generally avoid affecting the sympathetic nervous system. Additionally, while most major surgical procedures are unable to be performed using only truncal blocks, they are useful in a variety of situations.

PECTORAL NERVE (PECS) AND PECTOINTERCOSTAL BLOCKS

These anterior chest wall fascial plane blocks are an option instead of thoracic epidural and paravertebral blocks. The landmarks for these blocks are the pectoralis major, pectoralis minor, and serratus anterior muscles in the area of the third to fifth ribs.

PECS 1 BLOCK

This block is administered in the fascial plane between the pectoralis major and pectoralis minor muscles in the area of the third and fourth ribs (Fig. 37.1). It targets the medial and lateral pectoral nerves, which innervate the pectoralis major and pectoralis minor muscles, and is used for surgeries involving the pectoralis major muscle.

PECS 2 BLOCK

This block is administered in the fascial plane between the pectoralis minor and serratus anterior muscles in the area of the fourth and fifth ribs. It targets intercostal nerves, intercostobrachial nerves, and the long thoracic nerve, and is used for mastectomies and axillary dissections.

PECTOINTERCOSTAL BLOCK

This block is administered in the fascial plane between the pectoralis major and intercostal muscles on both sides of the sternum (Fig. 37.2). It targets the anterior cutaneous branches of the intercostal nerves.

SERRATUS ANTERIOR BLOCK

The serratus anterior block is appropriate for anterolateral chest wall incisions. The serratus muscle arises as a number of muscular slips from the lateral surfaces of ribs 1 to 9 and the deep fascia covering the related intercostal spaces (Fig. 37.3A,B). The muscle is a flat sheet passing posteriorly around the wall of the thorax to insert on the medial border of the scapula. This muscle pulls the scapula forward over the thoracic wall, keeping the costal surface opposed to the thoracic wall. It is innervated by the long thoracic nerve (branches from C5–C7 nerve roots), which passes through the axilla along the medial wall, and continues down the serratus muscle on its external surface (Fig. 37.3C).

INTERCOSTAL MUSCLE BLOCK

This block is performed for the treatment of pain affecting the thoracic and upper abdominal regions. The three layers of intercostal muscles (external, internal, and innermost) and their tendons are partial and do not completely fill an intercostal space (Figs. 37.4 and 37.5). Additionally, the neurovascular bundle in each space is between the internal and innermost layers in a rib structure described as the costal groove (Fig. 37.4).

PARAVERTEBRAL BLOCK

The paravertebral block can be used for unilateral procedures such as thoracotomies, nephrectomies, rib fractures, and breast surgeries. It is placed in a triangular space located immediately lateral to the intervertebral foramen, which contains the spinal nerves (anterior and posterior rami and rami communicantes) as they exit the vertebral canal (Fig. 37.6). This space is bounded anteriorly by the parietal pleura, posteriorly by the superior costotransverse ligament (this ligament attaches the superior surface of the neck of the rib to the transverse process of the vertebra above), and medially by the vertebral body, the intervertebral disc, and the intervertebral foramen.

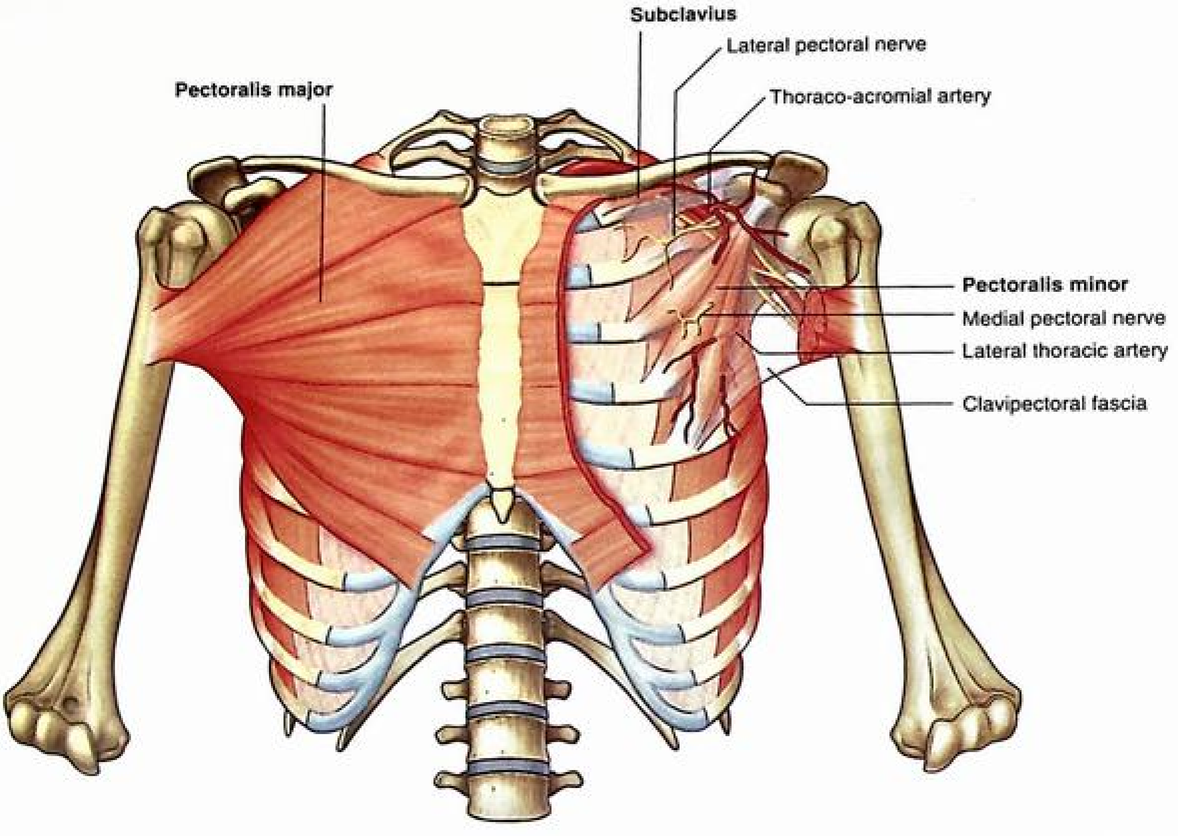


Fig. 37.1 Muscles and fascia of the pectoral region. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier, 2023.)

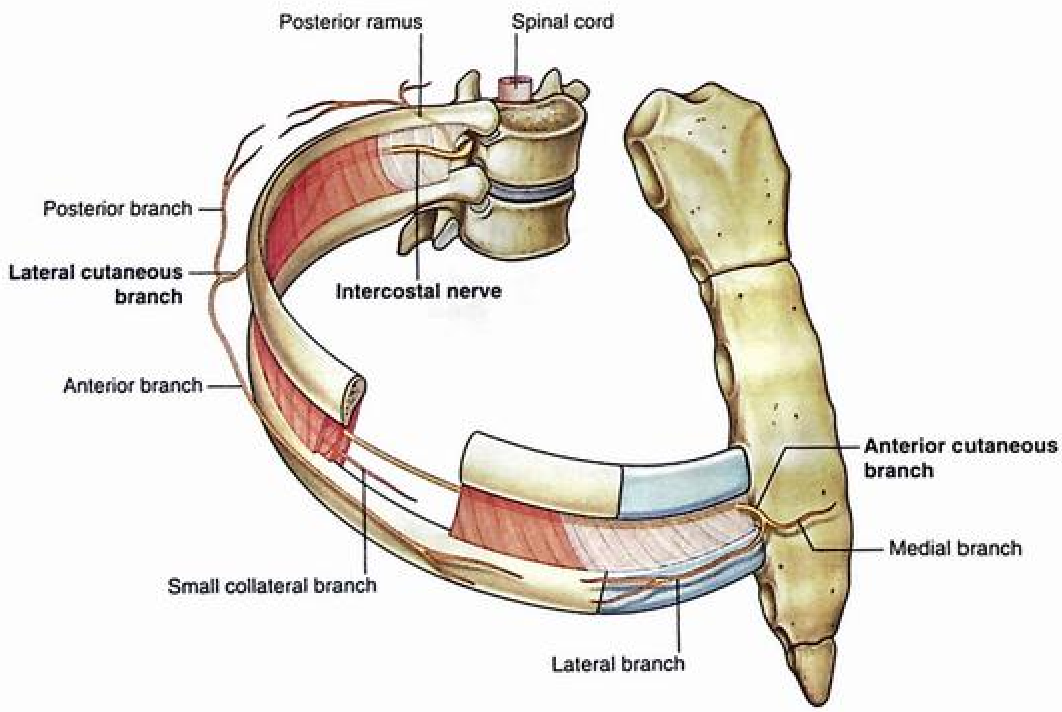


Fig. 37.2 Intercostal nerves. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier, 2023.)

ERECTOR SPINAE PLANE BLOCK

This block is generally used for acute and chronic thoracoabdominal pain. The target of the block is the erector spinae plane, an area between the anterior surface of the erector spinae muscle and the posterior surface of the transverse process of each vertebra (Fig. 37.7). Essentially, the injection is over the transverse process and under the erector spinae muscle. The solution spreads cranially and caudally, covering multiple vertebral levels and, by a not so well described process, also reaches the paravertebral space.

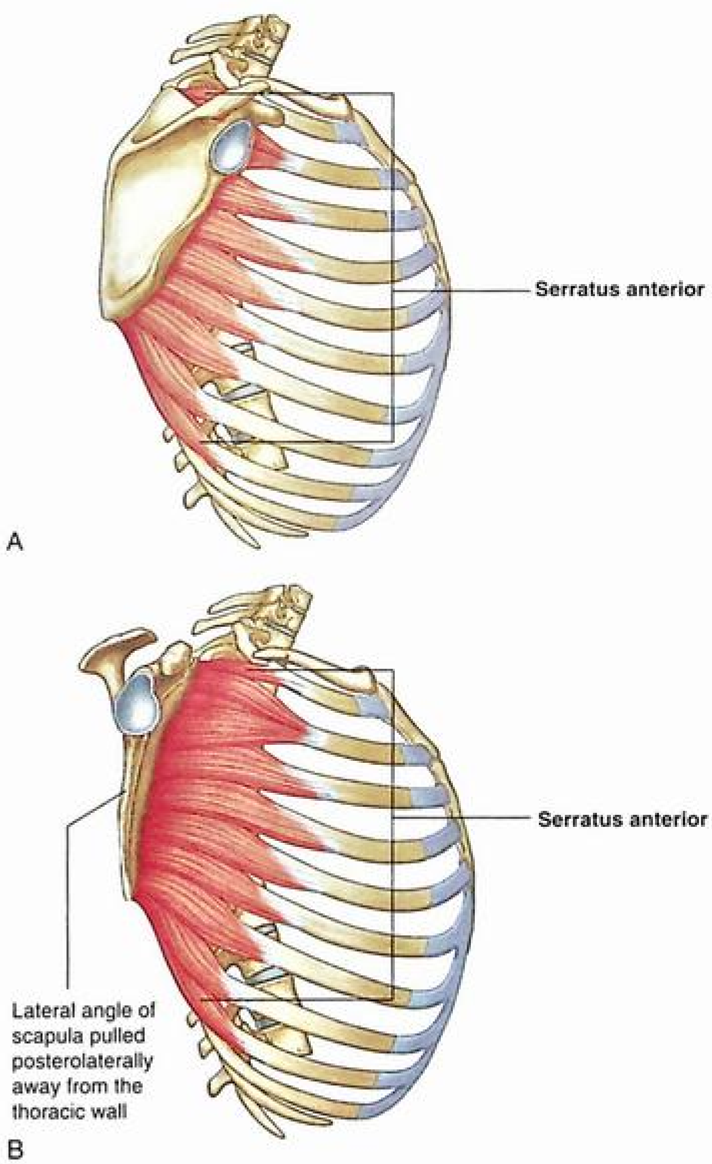


Fig. 37.3 Medial wall of the axilla. (A) Lateral view. (B) Lateral view with lateral angle of scapula retracted posteriorly.

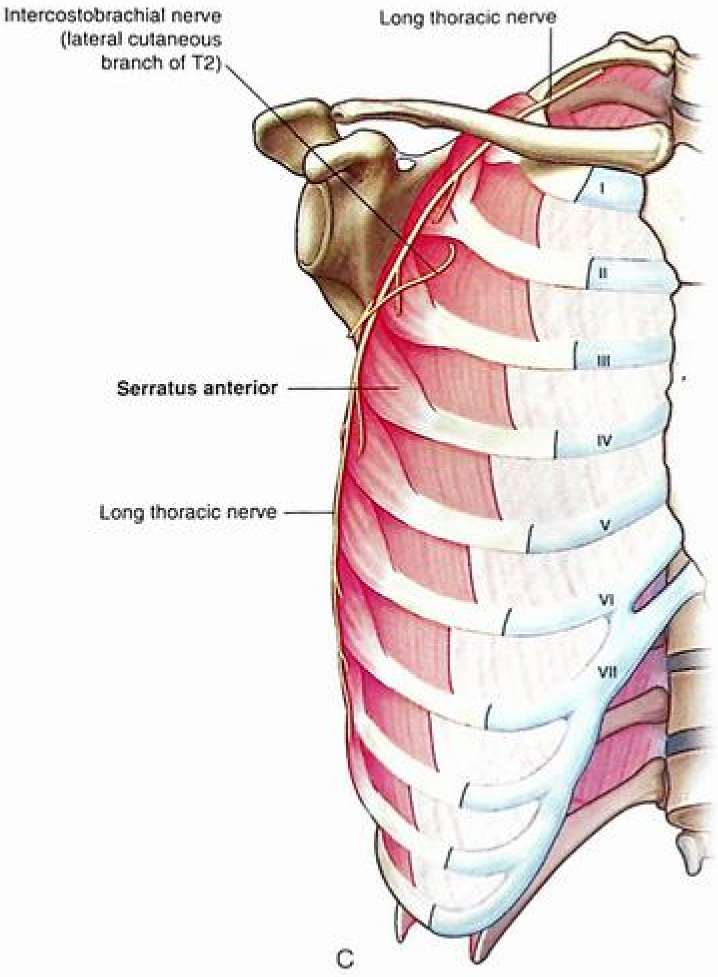


Fig. 37.3, cont'd (C) Anterior view. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 4th ed. Philadelphia: Elsevier; 2020.)

RECTUS SHEATH BLOCK

This block is useful for surgeries around the umbilicus and periumbilical region. It is administered at or slightly above the umbilicus, affecting nerves from spinal cord levels T9 to T11 (Fig. 37.8). At the lateral border of the rectus abdominis muscle, the aponeuroses of the three lateral abdominal muscles (external oblique, internal oblique, and transversus abdominis) initially form a common aponeurosis that splits into an anterior and posterior aponeurosis, enclosing the rectus abdominis muscle and the nerves innervating this muscle (Fig. 37.9A,B). At the midline, the aponeuroses from both sides come together, forming a thick, fibrous band of fascia, the linea alba. The block is performed by placing the needle just deep to the rectus muscle. Since the spinal nerves innervating the muscle do not cross the midline due to the presence of the linea alba, a bilateral block is necessary for some procedures (Fig. 37.10).

EXTERNAL OBLIQUE INTERCOSTAL BLOCK

This block is useful for upper abdominal surgeries. It is administered in the lower thoracic/upper abdominal area in the midclavicular line between the external oblique muscle and the intercostal muscles.

TRANSVERSUS ABDOMINIS PLANE BLOCK

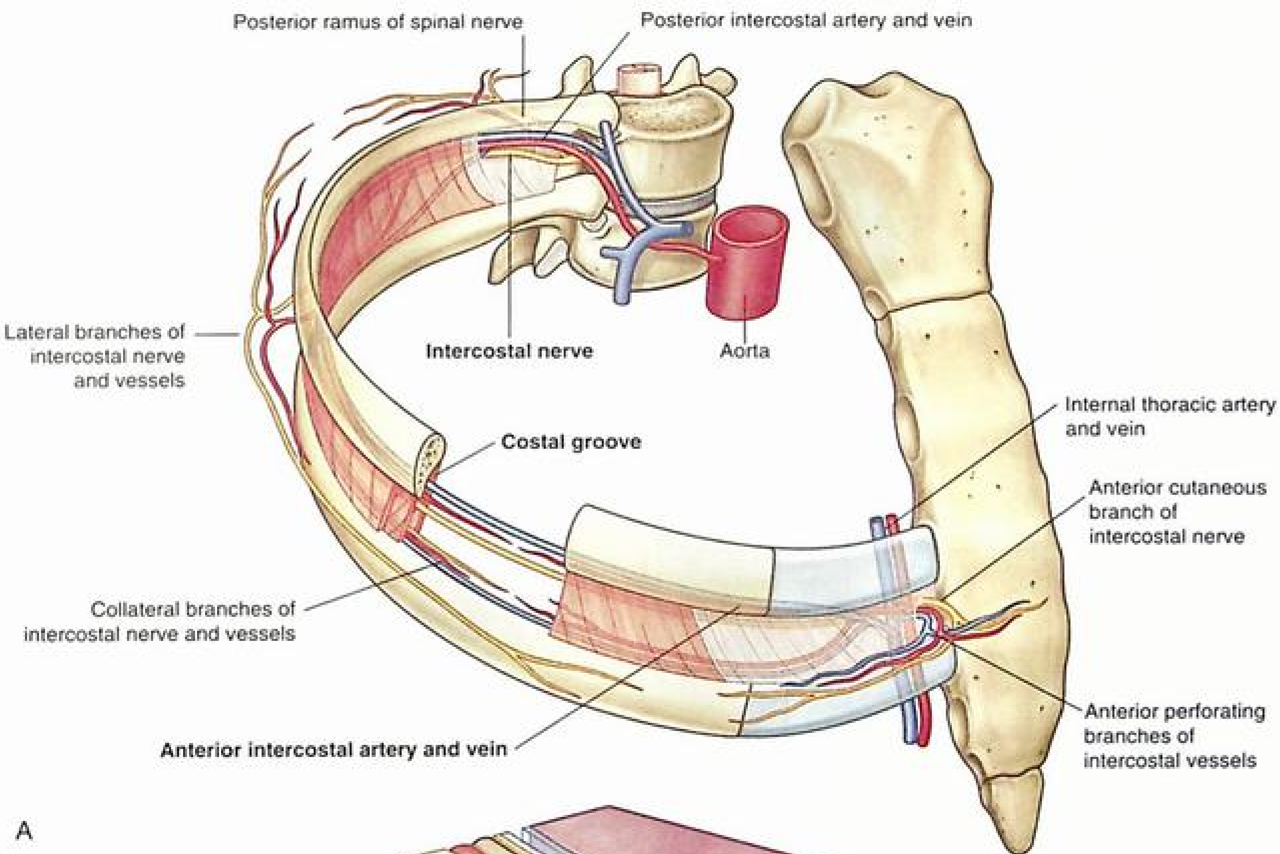
The ventral/anterior rami of spinal nerves T7 to L1 leave the vertebral canal through an intervertebral foramen and enter a fascial plane between the internal oblique and transversus abdominis muscles. Continuing around the body in the appropriate intercostal space, associated with blood vessels, the spinal nerves give off lateral cutaneous branches at the midaxillary line and finally, an anterior cutaneous branch (Fig. 37.11). The block is administered in the interfascial space between the internal oblique and transversus abdominis muscles. For midline procedures, bilateral blocks are necessary.

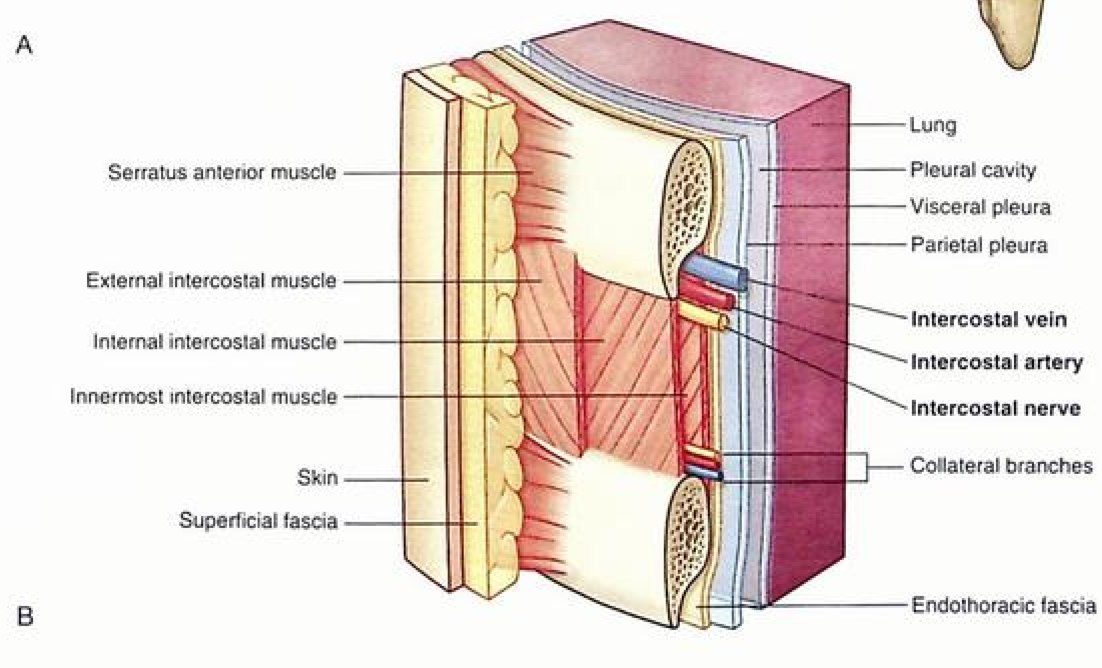
SUBCOSTAL TRANSVERSUS ABDOMINAL PLANE BLOCK

This block is useful for supraumbilical procedures. To administer this block properly, the fascial plane between the rectus abdominis and the transversus abdominis muscles must be identified (Fig. 37.10). As the external oblique, internal oblique, and transversus abdominis muscles move around the body, becoming more medial, the muscle fibers disappear and an aponeurosis, or flat tendon, appears. Using ultrasound, the change is apparent, and the fascial plane between the rectus abdominis muscle and the transversus abdominis muscle is identifiable.

QUADRATUS LUMBORUM BLOCK

This block is intended to be used on individuals dealing with postoperative pain from abdominal or hip surgeries. The thoracolumbar fascia consists of anterior, middle, and posterior layers (Fig. 37.7). The posterior layer surrounds the erector spinae muscles. The middle layer passes between the erector spinae muscles and the quadratus lumborum muscle. The thin anterior layer lies anterior to both the quadratus lumborum and the psoas major muscles. The goal of this block is to place the anesthetic in the space between the quadratus lumborum muscle and the thoracolumbar fascia.





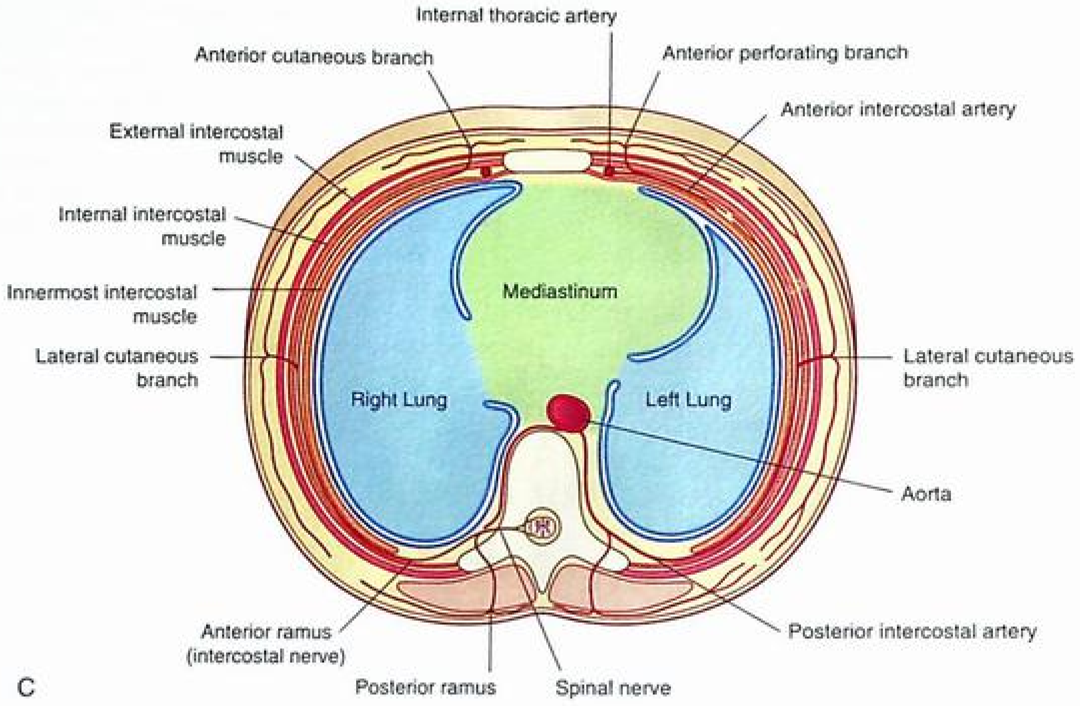


Fig. 37.4 Intercostal space. (A) Anterolateral view. (B) Details of an intercostal space and relationships. (C) Transverse section. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

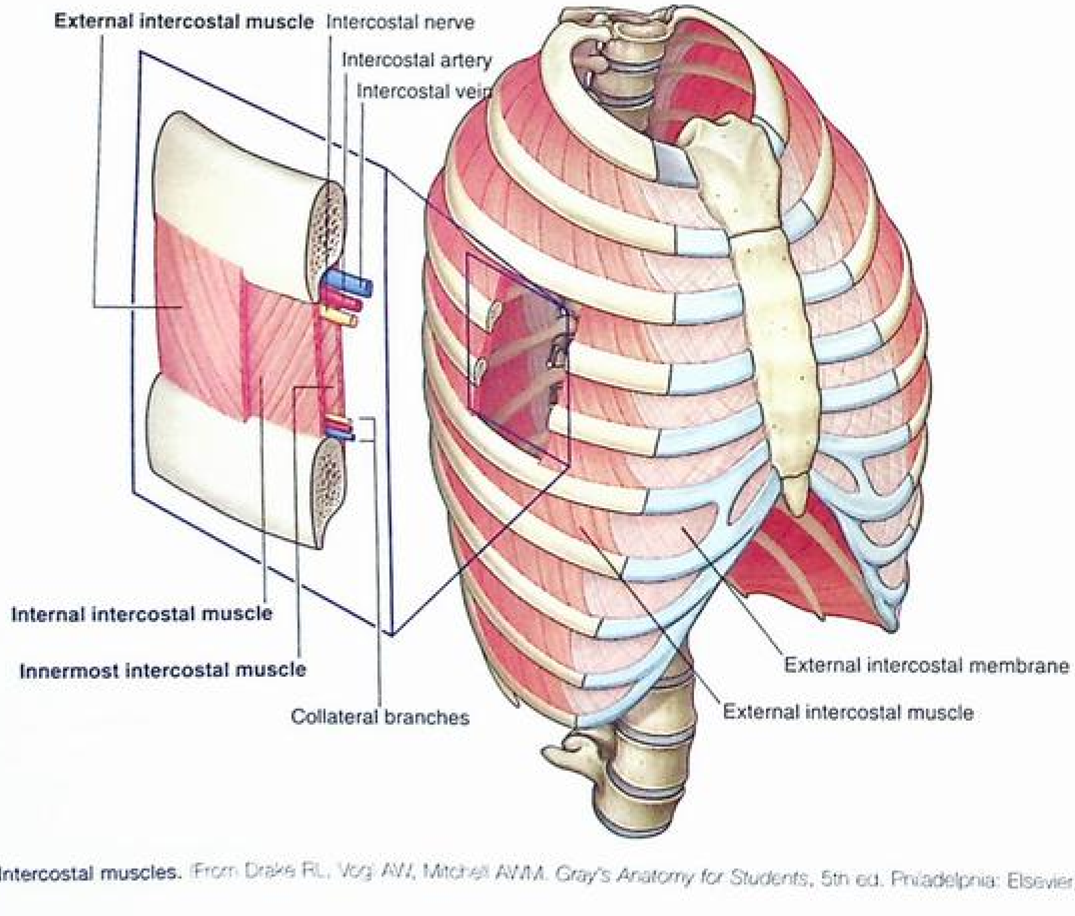


Fig. 37.5 Intercostal muscles. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 5th ed. Philadelphia: Elsevier; 2023.)

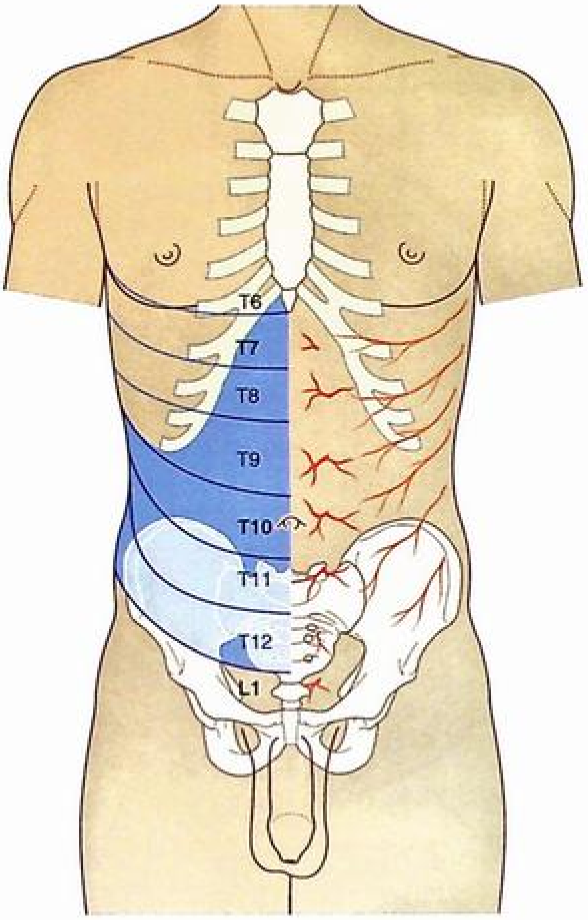


Fig. 37.8 Innervation of the anterior abdominal wall. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

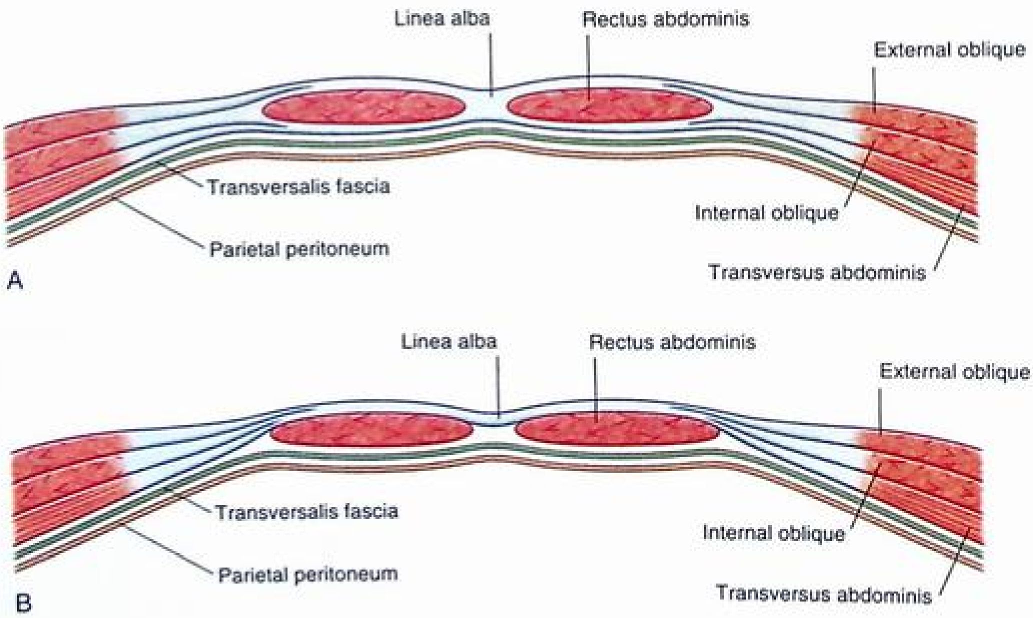


Fig. 37.9 Organization of the rectus sheath. (A) Transverse section through the upper three-quarters of the rectus sheath. (B) Transverse section through the lower one-quarter of the rectus sheath. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*. 4th ed. Philadelphia: Elsevier; 2020.)

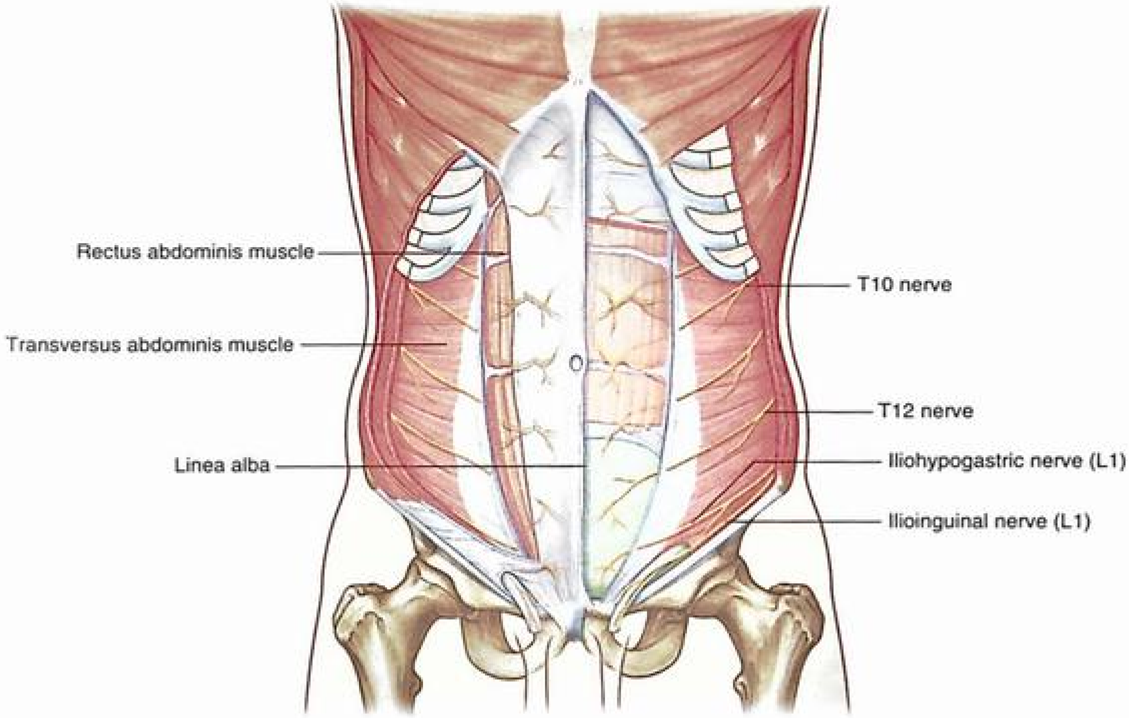


Fig. 37.10 Path taken by the nerves innervating the anterolateral abdominal wall. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 4th ed. Philadelphia: Elsevier; 2020.)

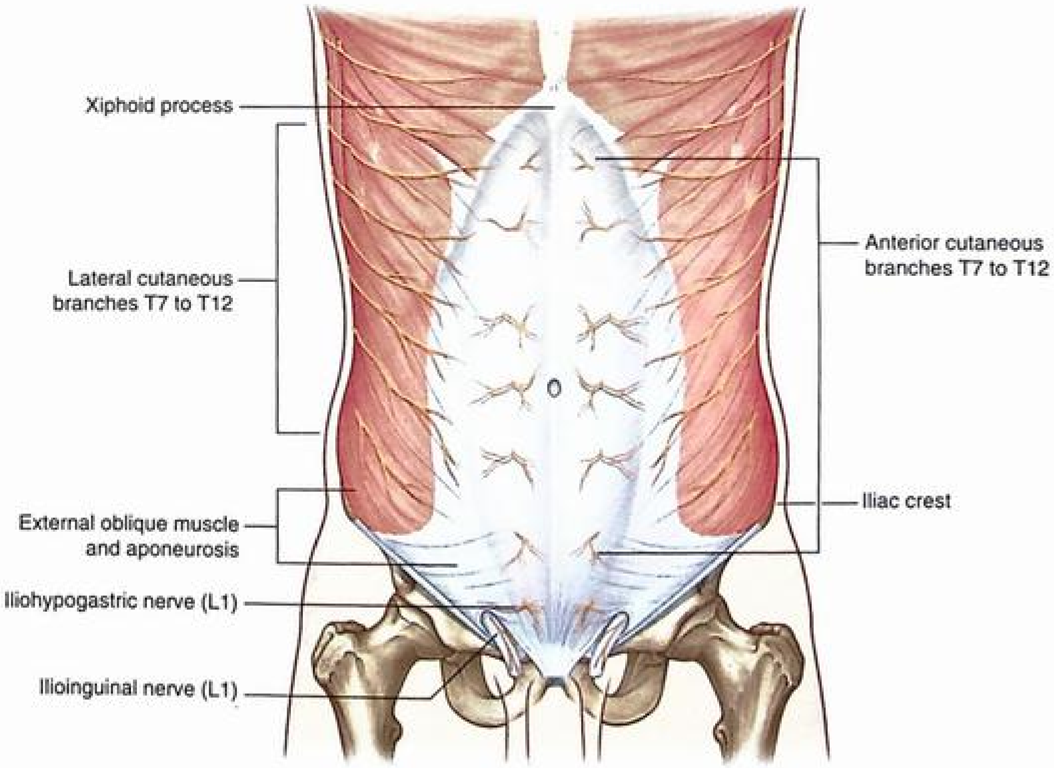


Fig. 37.11 Innervation of the anterolateral abdominal wall. (From Drake RL, Vogl AW, Mitchell AWM. *Gray's Anatomy for Students*, 4th ed. Philadelphia: Elsevier; 2020.)

Pectoral Nerve (PECS) and Pectointercostal Blocks 38

Loran Mounir-Soliman and Nour El Hage Chehade

Key Points

- Anterior chest wall blocks are used as alternatives to thoracic epidurals and paravertebral blocks for breast surgeries and procedures involving the anterior chest walls.
- Serratus plane blocks and supraclavicular blocks may be required for more extensive surgeries.
- The pectoralis major, pectoralis minor, and serratus anterior muscles are the main landmarks for the PEC blocks at the level of the fourth and fifth ribs.
- Bilateral pectointercostal blocks are required for sternal wound incisions.
- All fascial plane blocks need ultrasound guidance, skill with ultrasound-guided procedures, and larger volumes of local anesthetics (LA).

PERSPECTIVE AND BACKGROUND

The introduction of ultrasound to regional anesthesia allowed the identification of various interfascial planes between the different muscles, including the chest wall musculature. Some of the interfascial planes (between the investing fascias of the muscles) are considered neurovascular potential spaces, hosting the different nerves and vessels supplying the chest wall.

Along the course of the intercostal nerves, they branch and communicate with the adjacent intercostal nerves as well as other pectoral nerves when crossing between those different interfascial planes.

The ventral rami of the thoracic spinal nerves (T2–T9) pierce the intercostal muscles, giving lateral and anterior cutaneous branches that further divide into posterior, anterior, medial, and lateral branches, providing sensory innervations to the anterior and lateral aspects of the chest wall, including the breast (T4–T5–T6). The apex of the axilla is innervated by the intercostobrachial nerve, a branch of the T2 spinal nerve. These multiple divisions of the spinal nerves communicate with the branches of the adjacent spinal nerves through the neurovascular planes existing between the muscles of the chest wall, mainly the pectoralis major, pectoralis minor, and serratus anterior muscles, bounded by the fascial layers covering the muscles (interfascial planes). Those planes also host branches of the brachial plexus along their course in the chest, mainly the medial pectoral nerve (C8–T1), lateral pectoral nerve (C5–C7), long thoracic nerve (C5–C7), and thoracodorsal nerve (C6–C8) (Figs. 38.1–38.4).

PEC blocks were first introduced by Blanco in 2011.

INDICATIONS

- Breast surgery (these blocks were introduced as an alternative to paravertebral blocks)
- Pacemaker insertion
- Any surgery involving the upper anterior chest wall

PECTORAL NERVE (PECS) 1 BLOCK

This block is performed at the level of the upper anterior chest wall. Injection of LA in the interval between the pectoralis major and minor muscles at the level of the third to fourth ribs is viewed as PECS 1 block. This block targets the pectoral nerves, the medial (C8–T1) and lateral pectoral (C5–7) nerves that pass along this plane and can be anesthetized by injecting a relatively large volume of LA. This block targets surgeries involving the pectoralis major muscle, for example, expander insertion, port-a-cath placement, and implantable cardiac devices (Fig. 38.5).

PECS 2 BLOCK

For more extensive surgeries of the anterior chest wall, including mastectomies, sentinel node biopsies, and axillary dissections, blockade of the intercostal nerves and intercostobrachial nerves, as well as the long thoracic nerves, is necessary. It is achieved through injection of the LA at a deeper level between the pectoralis minor and serratus anterior muscles at the level of the fourth to fifth ribs (PECS 2 block). Typically, the PECS 1 block is performed as part of the PECS 2 block through the same entry point during the passage of the needle between the pectoralis major and pectoralis minor muscles (Fig. 38.6).

PECTOINTERCOSTAL BLOCK

For a sternal wound, the anterior cutaneous branches of the intercostal nerves can be blocked by infiltrating LA in the fascial plane between the pectoralis major and intercostal muscles on both sides of the sternum (pectointercostal block) (Figs. 38.7 and 38.8).

ULTRASOUND-GUIDED INJECTION TECHNIQUE

The technique was described by Blanco. The patient is usually positioned supine for the PECS and pectointercostal blocks, with the anesthesiologist standing at the head of the patient and the arm abducted. Ideally, the ultrasound machine should face the anesthesiologist across from the patient, allowing them to view the screen as well as the needle entry point and needle direction within the same visual field.

PECS 1 and 2. A high-frequency linear probe is best suited for these superficial blocks to better identify the different fascial planes and borders of the chest wall muscles.

A high-frequency ultrasound probe is placed under the clavicle at the midclavicular line to locate the axillary artery and vein under the pectoralis major and minor muscles. The probe is then moved distally and laterally toward the axilla as you visualize the ribs. Starting at the first rib, count until you reach the third rib. At the level of the third and fourth ribs, you will be able to see three muscle layers: the pectoralis major, pectoralis minor, and serratus anterior muscles. Another way is to start the scanning by placing the probe parallel to the long axis of the body (cephalocaudad direction) medial to the coracoid process, visualizing the axillary artery and the cords of the brachial plexus surrounding it deep to the pectoralis major muscle. At this point, tilting the probe medially will allow visualization of the second rib and pleura. Scanning caudad will enable viewing of the pectoralis minor deeper to the pectoralis major, especially when angulating the leading edge of the probe slightly lateral at the same time toward the axilla and lateral edge of the pectoralis muscle (see Fig. 38.2). The probe is usually turned oblique to the long axis of the body to allow the needle path from a cephalomedial to a caudal and lateral direction. The target of infiltration of LA is between the pectoralis minor and serratus (PECS 2), followed by the interval between the pectoralis major and pectoralis minor (PECS 1) at those two levels. It is easier to perform the deeper block first when doing both blocks with a single needle path. That will also avoid obliteration of the deeper fascial ultrasound identification if air is injected accidentally during the first injection. Care should be taken to avoid vascular punctures of the multiple small branches of the thoracoacromial vessels hosted within the

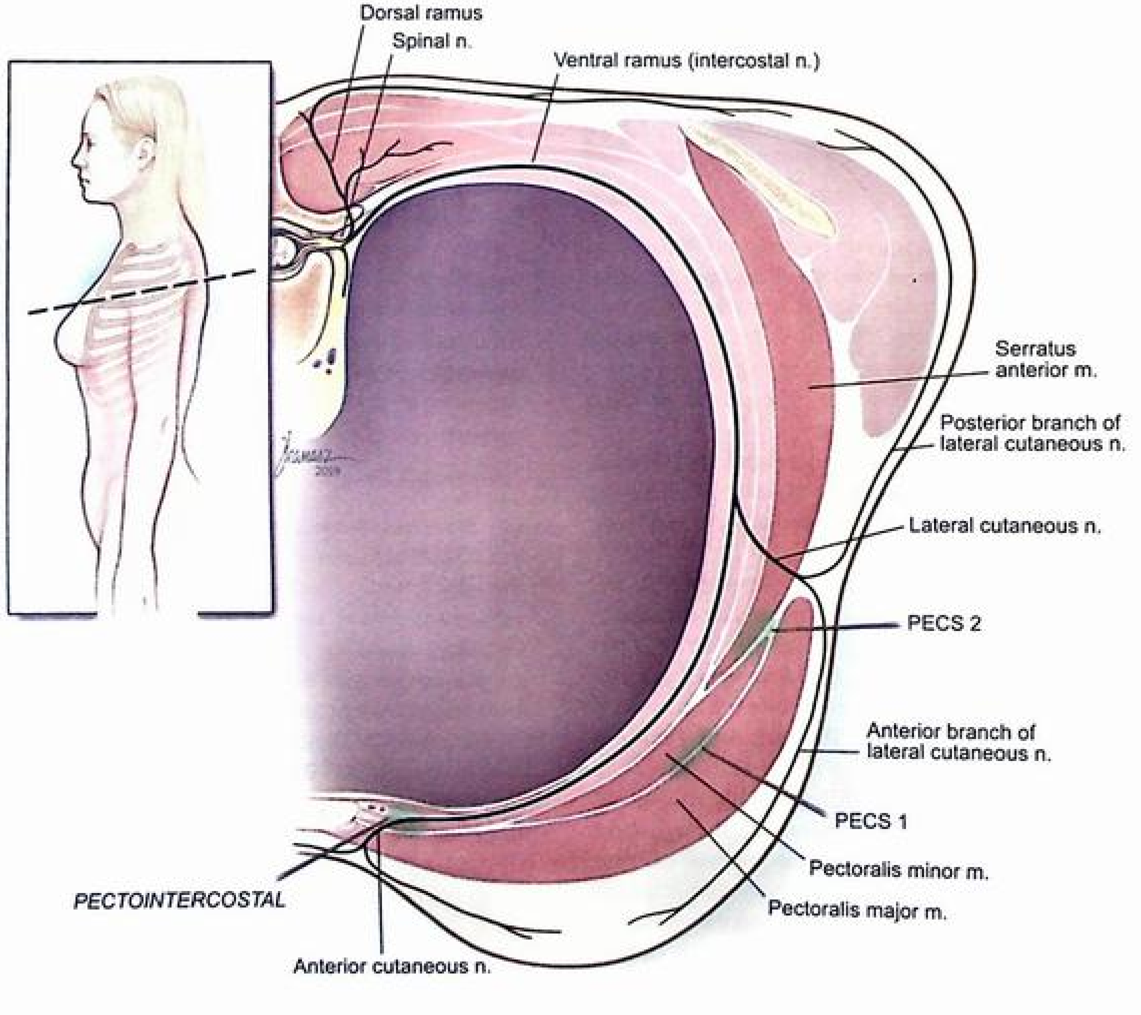


Fig. 38.1 Cross-section showing the muscles of the chest wall, indicating the correct interfascial planes for PECS 1 and 2 blocks.

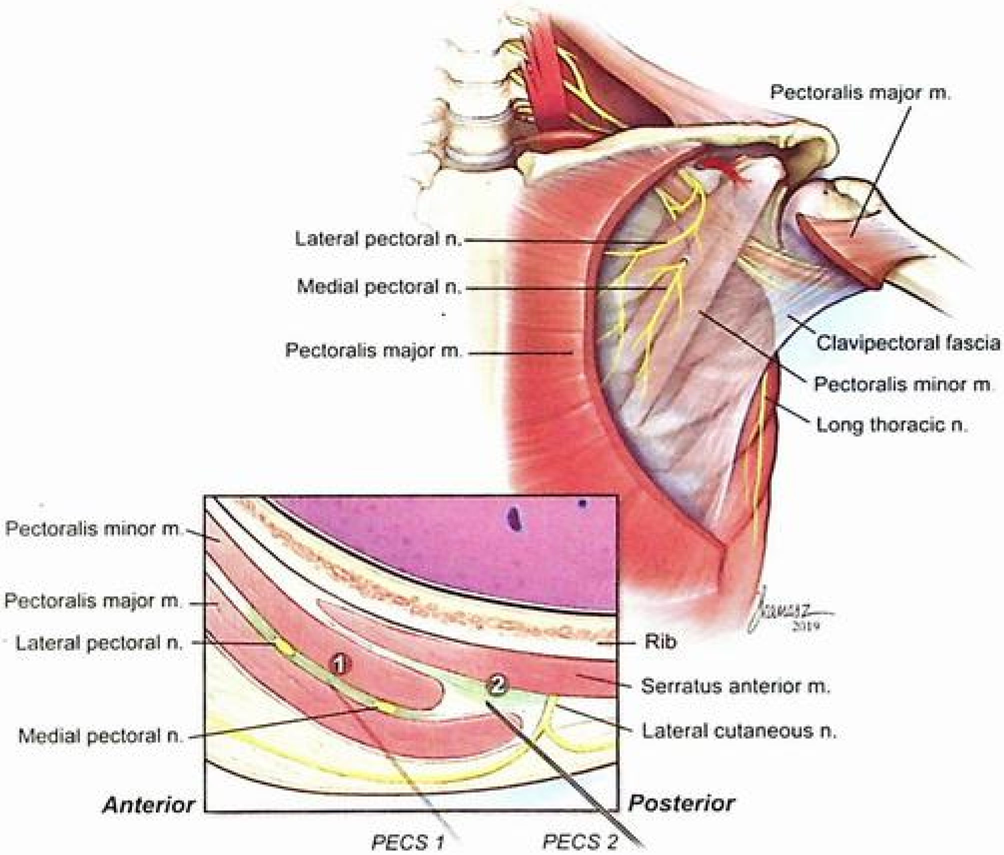


Fig. 38.2 Anatomy of the anterior chest wall with a cross-section showing the correct interfascial planes for PECS 1 and 2.

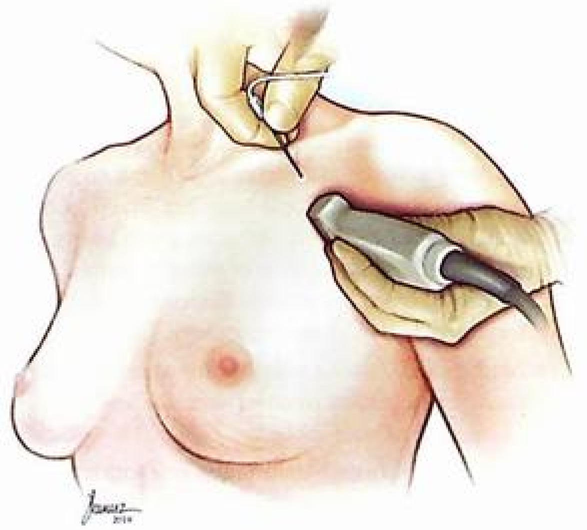


Fig. 38.3 Probe position for PECS 1 and 2. Note the in-plane technique for the block.

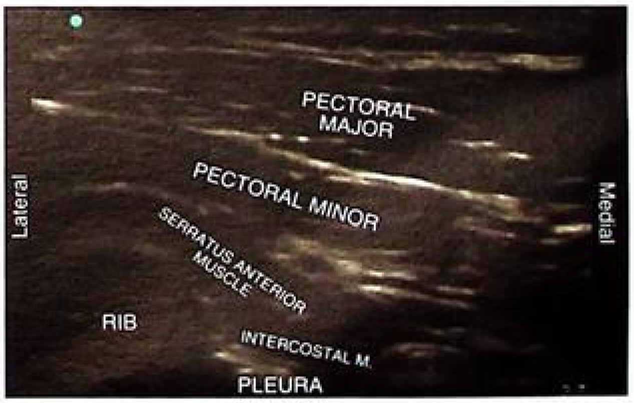


Fig. 38.4 Ultrasound image for PECS 1 and 2 shows the muscles.

same targeted planes (neurovascular fascial planes) (Figs. 38.4–38.6, Video 38.1).

Pectointercostal. The probe is placed an inch lateral and parallel to the long axis of the sternum in a longitudinal orientation. The level of injection is typically at the level of the midsternum. With this view, multiple ribs can be visualized with the intercostal muscles between them and the pleura underneath both. The pectoralis major muscle is the only muscle covering the ribs and the intercostal muscles. The interfascial interval between the pectoralis muscle and the underlying ribs and intercostal muscles is the target of infiltration of LA in order to block the anterior cutaneous branches for sternal incisions. Care should be taken to avoid vascular injuries of the branches of the internal thoracic artery (Figs. 38.7 and 38.8).

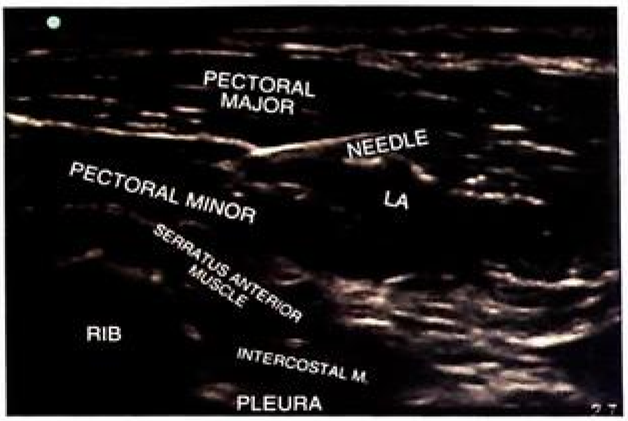


Fig. 38.5 Ultrasound image for PECS 1 shows the position of the needle deep to the pectoralis major muscle.

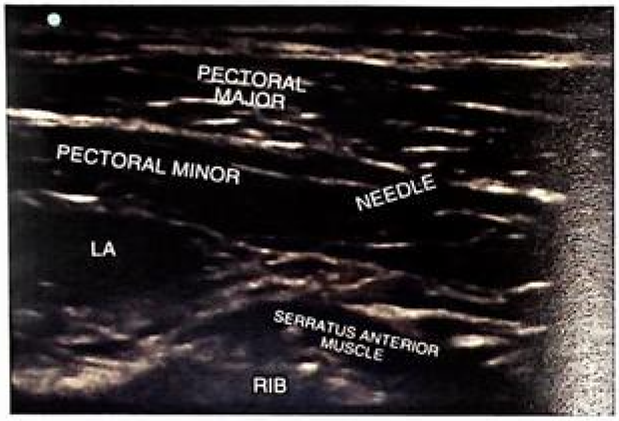


Fig. 38.6 Ultrasound image of PECS 2 shows the position of the needle and the LA deep to the pectoralis minor muscle.

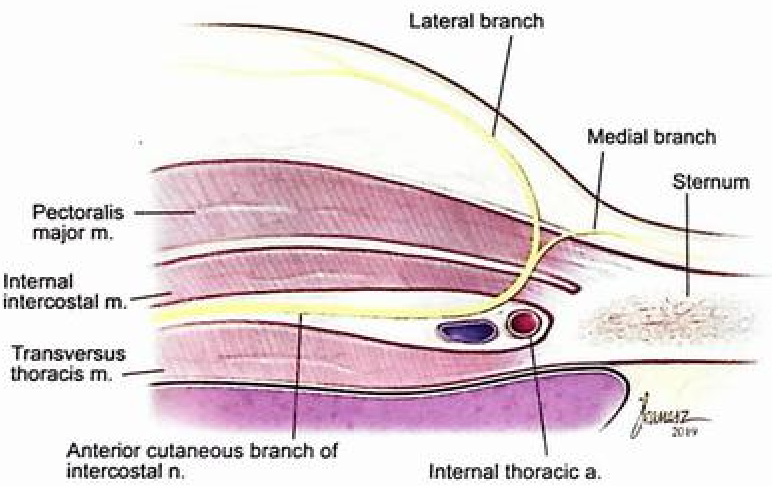


Fig. 38.7 Cross-section showing the anatomical course of the anterior cutaneous branches of the intercostal nerves.

POTENTIAL COMPLICATIONS

Intramuscular hematoma and pleural puncture can be possible complications of this block; however, these are rare. Care should be taken to visualize the needle the entire time it is advanced underneath the ultrasound beam to avoid vascular or pleural puncture.

Multiple encounters of the surface of the ribs are unnecessary, can be painful to patients, and should be minimized.

PEARLS

- Injection of LA underneath the pectoralis major high up in the chest (at the level of the second rib) can lead to an accidental block of the brachial plexus.
- Like most fascial plane blocks, the target is not a specific nerve as much as a plexus of nerves formed by the communication of multiple branches. The injection of a large volume (20–30 mL) is necessary to have a wider spread and to block most of those branches. Care should be taken to calculate the maximum dose of LA injected to avoid systemic toxicity.
- Combining PECS blocks with the serratus anterior block may be necessary to cover anterior and anterolateral chest wall incisions.
- For continuous infusion techniques, intermittent bolus programming may provide better spread and a more effective block.
- The area immediately below the clavicle and the upper part of the breast is supplied by the supraclavicular nerve (C3–C4) and nerve to subclavius (C5–C6). The typical injection for PECS 1 and 2 blocks does not provide coverage to this

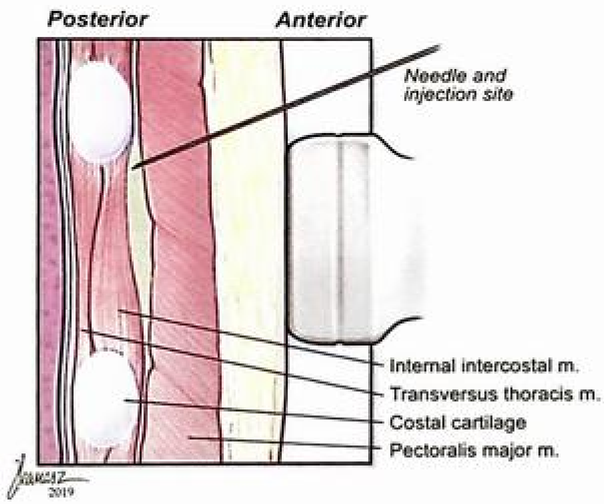


Fig. 38.8 Anatomy and needle position for the pectointercostal block. Note the needle and LA deep to the pectoralis major and superficial to the intercostal muscles.

area. Separate injection of the supraclavicular nerve (superficial injection above the clavicle) and nerve to subclavius (superficial injection below the clavicle) may be needed as a supplement if the incision extends high up in the chest toward the clavicle.

- Original hydrodissection can be achieved by saline to limit the total dose of LA used.

Serratus Anterior Block and Catheters

39

Loran Mounir-Soliman and Nour El Hage Chehade

Key Points

- The serratus anterior block is indicated for anterolateral chest wall incisions, targeting the lateral and postcutaneous branches of upper and middle thoracic dermatomes.
- The block has been used for different thoracoscopic and open chest wall incisions as well as chest tube placements and rib fractures.
- The long thoracic nerve is included in the serratus anterior block.
- Injection of local anesthetic (LA), either superficial or deep to the serratus anterior muscle, leads to similar results clinically.
- The optimal point of injection should be posterior to the midaxillary line, at the level of the fifth or sixth ribs. This allows better identification of the muscle as well as better spread of the medication.

RELEVANT ANATOMY

The serratus anterior muscles originate from the anterior surface of the first to eighth ribs at the lateral chest wall and insert along the entire anterior length of the medial border of the scapula, as well as the ventral aspect of its inferior angle. It consists of multiple serrated tendinous projections connecting the ribs, with the costal margin of the scapula pulling the scapula forward around the chest (protraction), especially when pushing forward. It also helps with upward rotation of the scapula, adding to the trapezius muscle action. The muscular serrations are thinner at their origin (anteriorly) and get bigger along their course posteriorly.

The serratus anterior receives its nerve supply from the long thoracic nerve, also called the nerve to serratus anterior; it originates from the roots of the brachial plexus (C5–C7). Its injury results in "winging" of the scapula. It has multiple sensory and motor branches and typically runs in a course between the middle and posterior axillary lines.

Anterior to the anterior axillary line, the serratus anterior muscle is covered by the pectoralis muscles. Along its dorsal course, starting at the level of the fifth rib, the serratus anterior is covered by the latissimus dorsi muscle. Accordingly, posterior to the midaxillary lines, there are two potential fascial planes: superficial and deep to the serratus muscle. Superficial to the serratus anterior, the fascial plane is bounded by the deep surface of the latissimus dorsi, and deep to the serratus, the plane is bounded by the ribs and intercostal muscles.

The lateral and posterior cutaneous branches of the T2 to T9 intercostal nerves, along with the long thoracic nerve, travel across those two fascial planes: superficial and deep to the serratus anterior muscle posterior to the midaxillary line. Clinical results indicate that injection of LA along both planes results in similar outcomes, mainly blocking upper and midthoracic dermatomes of the lateral chest wall (Fig. 39.1).

INDICATIONS

- Multiple rib fractures, especially lateral rib fractures
- Chest tube pain
- Surgery involving the lateral or posterior chest wall in the dermatomal area T2 to T9

ULTRASOUND-GUIDED INJECTION TECHNIQUE

Typically, a high-frequency linear probe is used for the serratus anterior block to better identify the superficial and deep boundaries of the muscle. However, a curvilinear probe can be more useful in morbidly obese patients to allow deeper penetration and a broader visual window. This block is performed in the axillary region. The landmarks of this block are the latissimus dorsi and the serratus anterior muscles. Ideally, the patient is positioned laterally, with the side to be blocked uppermost. Transverse scanning along the course of the serratus muscle posteriorly at the level of the fifth rib identifies the muscle, starting in the midaxillary line. Scanning can also start at a higher level, and ribs can be counted from the clavicle down to reach the fifth rib, where the block is performed. The size of the muscle varies according to its position along the chest wall, being larger posteriorly. Tilting the probe from side to side can also change the viewable section of the muscle according to the trajectory of the beam. The muscle is identified by its position just on top of the ribs, distinguished from the intercostal muscles located between the costal hyperechoic lines. As the probe moves posteriorly, the beam will encounter the large latissimus dorsi muscle, superficial to the serratus anterior. The needle is inserted in-plane from anterior to posterior (however, it can be introduced from the dorsal side of the probe if needed). The LA is injected

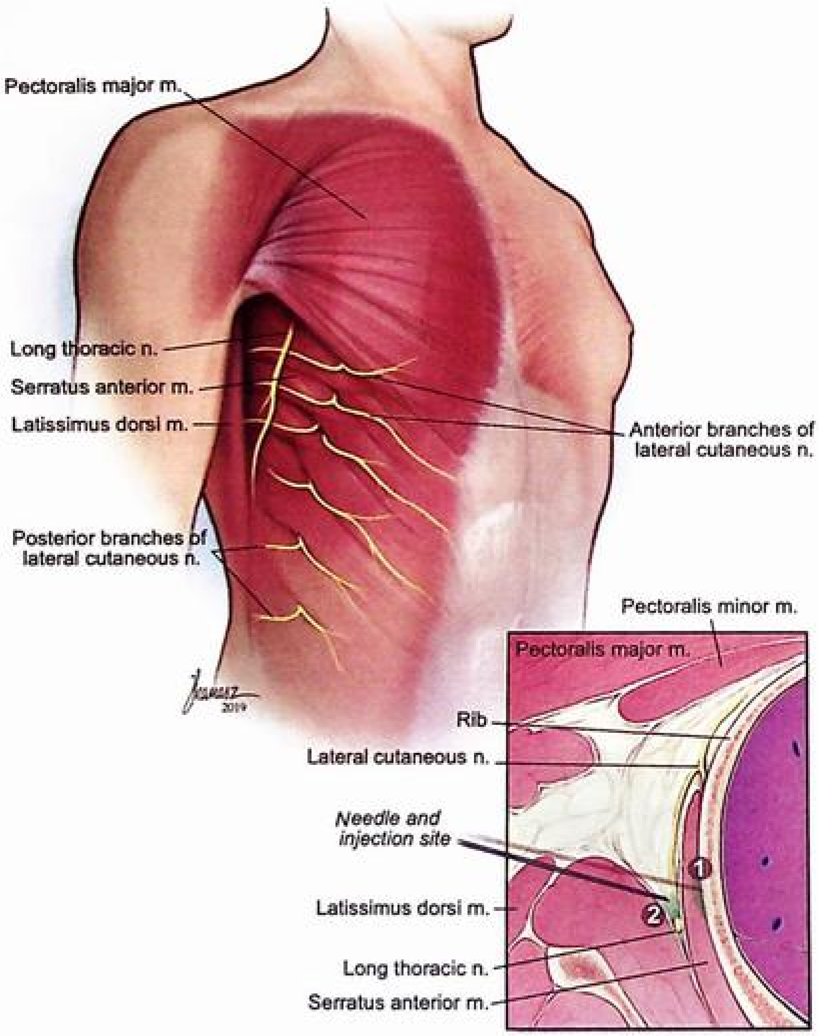


Fig. 39.1 Anatomy of the anterior chest wall, showing the sensory distribution of the serratus anterior block.

in one of two fascial planes: superficial to the serratus anterior (deep to the latissimus dorsi) or deep to the serratus anterior, lifting the muscle of the ribs and intercostal muscles. As mentioned previously, clinical results have been reported to be similar, because the long thoracic nerve and the branches of the intercostal nerves run across both planes. It is the author's practice to instill half of the volume in each plane, starting with the deeper one first, for a wider spread.

The optimal level of injection is at the posterior axillary line at the level of the fifth or sixth rib to allow more coverage of the lateral and posterior cutaneous branches.

The single-shot technique, as well as a continuous indwelling catheter, has been described for this block (Figs. 39.2–39.4, Video 39.1).

POTENTIAL COMPLICATIONS

Intramuscular hematoma and pleural puncture can be possible complications of this block but are rare. Care should be taken to visualize the needle the entire time it is advanced below the ultrasound beam to avoid vascular or pleural puncture.

Multiple encounters of the surface of the ribs are unnecessary, can be painful to patients, and should be minimized.

Nerve injury is unlikely, given that the needle is not steered directly at nerves but instead, toward the plane through which the nerves run.

PEARLS

- The serratus anterior block is usually a superficial block going 2 to 3 inches deep in most patients.

Accordingly, there is no need to use a needle longer than 3 to 4 inches in length.

- Like most fascial plane blocks, the target is not a specific nerve as much as it is a plexus of nerves formed by the communication of multiple branches. The injection of a large volume (20–30 mL) is necessary to have a wider spread and block most of those branches. Care should be taken to calculate

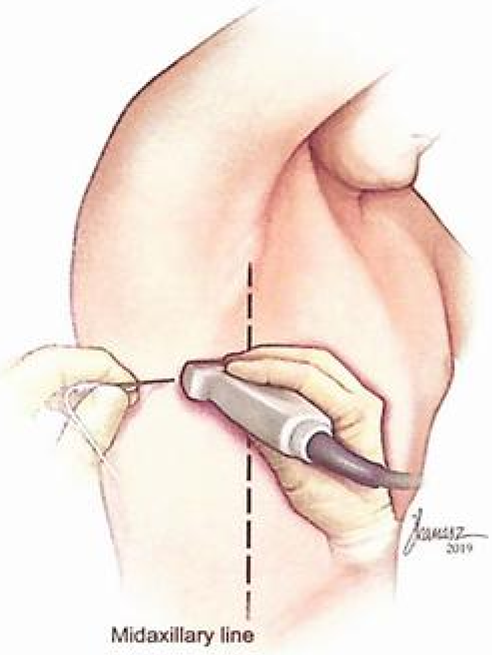


Fig. 39.2 Ultrasound probe position. Note the in-plane technique of the block.

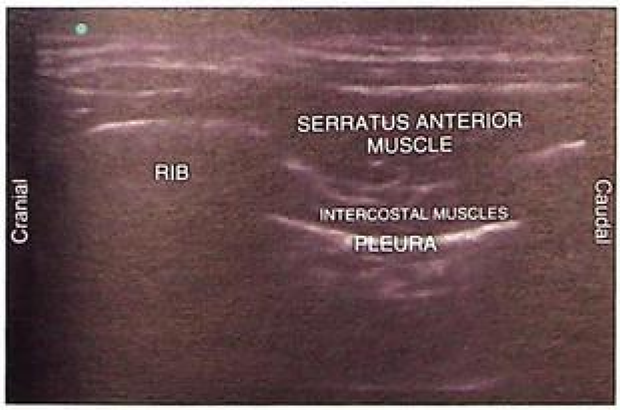


Fig. 39.3 Ultrasound image of the serratus anterior block, showing the serratus anterior and intercostal muscles. It is very important to visualize the pleura when performing the block, as shown in the figure.

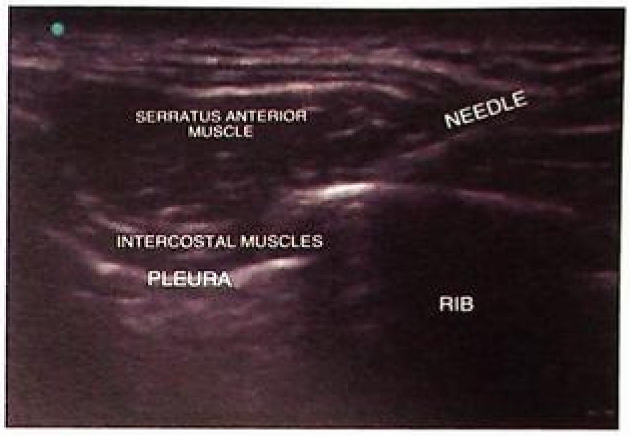


Fig. 39.4 Ultrasound image of the serratus anterior block with the needle deep to the serratus anterior muscle but superficial to the intercostal muscles. The injection of LA is between the serratus anterior and intercostal muscles. Note that the pleura is always visualized when performing the block to avoid pneumothorax or injury to the lung.

the maximum dose of LA injected to avoid systemic toxicity.

- The thoracodorsal artery lies in the plane between the latissimus dorsi and serratus anterior muscles and should be identified using color Doppler before performing the block.
- Combining pectoral nerve blocks with the serratus anterior block may be necessary to cover anterior and anterolateral chest wall incisions.
- For continuous infusion techniques, intermittent bolus programming may provide better spread and more effective block.

Ultrasound for Intercostal Block 40

Ehab Farag

Key Points

- The intercostal nerves supply the major parts of the skin and the musculature of the chest and abdominal wall.
- The intercostal nerve block is now commonly performed for treatment of acute and chronic pain conditions affecting the thorax and upper abdomen.
- The intercostal nerve block provides excellent analgesia for chest trauma such as rib fractures and after chest and upper abdominal surgeries.
- Ultrasound provides the safest and most successful way to perform intercostal nerve blocks.
- The online technique is the preferred way for performing the block.

SONOANATOMY

There are three layers of intercostal muscles: the external, internal, and innermost intercostal muscles, which are all thin, incomplete layers of muscle and tendinous fibers. The neurovascular bundle lies between the internal and innermost intercostal muscles in the costal groove. Of note, the neurovascular bundle lies midway between the ribs in the majority of cases. The use of ultrasound allows the visualization of the pleura and the different layers of the intercostals. The pleura will be identified easily as a hyperechoic line that glides with respiration (the sliding sign).

TECHNIQUE

A linear probe with high resolution (6–13 Hz) is used for the technique. The patient can be placed in the prone position, sitting position, or lateral position, with the side to be blocked facing upward. The angle of the rib, which is 6 to 7.5 cm from the spinous process or on the lateral edge of the paraspinal muscle, is the common site of injection, as the rib is the thickest at this site and the intercostal nerve has not yet branched. The probe is usually placed in the short axis to the ribs, so the two consecutive ribs are in view. The probe can also be placed in the long axis of the consecutive ribs, the author's preferred technique. Both in-plane and out-of-plane techniques could be used for intercostal nerve block. The author prefers the in-plane technique, as the complete needle path can be visualized. The needle is advanced under real-time ultrasound guidance until the tip is positioned between intercostal and innermost intercostal muscles. After proper positioning of the needle, 4 to 5 mL of local anesthetic is usually injected for each intercostal space (Figs. 40.1A,B–40.3, Video 40.1).

PEARLS

- The preferred local anesthetic for this block is either 0.2% ropivacaine for sensory block or 0.5% for surgical block.
- The pleura should be observed at all times when performing the technique.
- After performing the block, ultrasound can be used to scan for the possible complication of pneumothorax.
- Pneumothorax can be diagnosed by absence of the sliding sign and/or comet-tail artifacts that appear as vertical lines to the pleura.

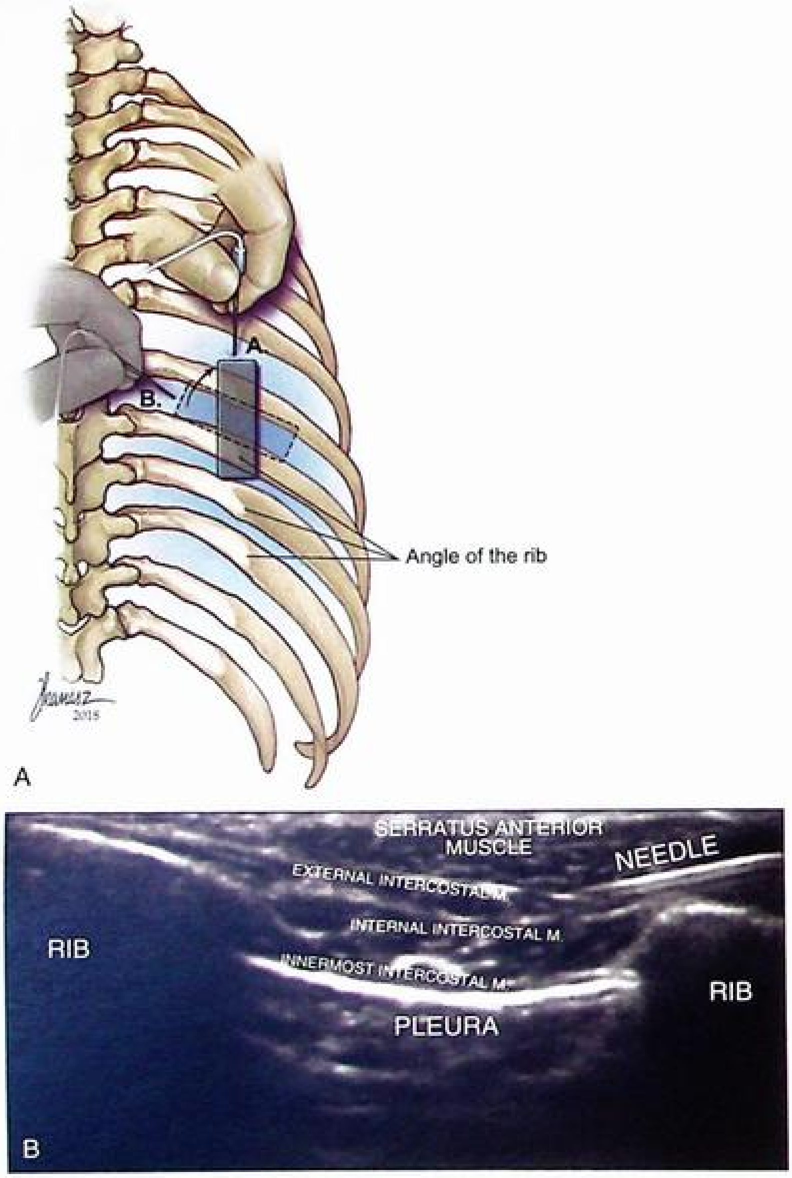


Fig. 40.1 (A) The position of the ultrasound probe at the angle of the ribs is either at the short axis (*A., across the ribs*) or at the long axis (*B., parallel to the ribs*). Note that the in-plane technique is preferred. (B) Ultrasound image of the intercostal block shows the three intercostal muscles and the pleura.

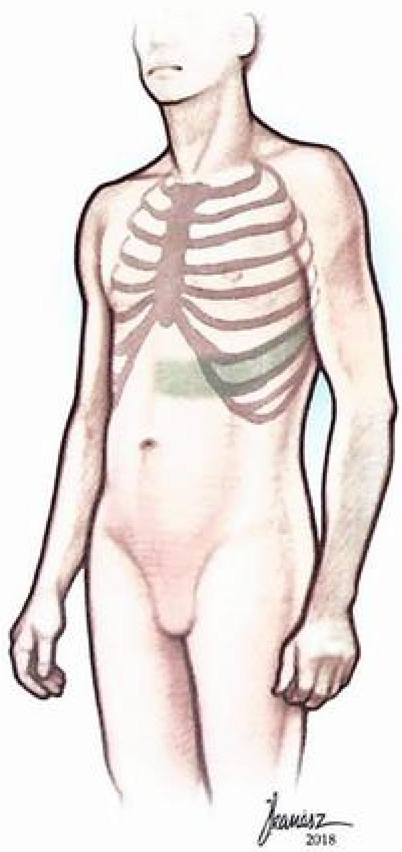


Fig. 40.3 The distribution of analgesia after the intercostal block.

Paravertebral Block 41

Ehab Farag

Key Points

- The thoracic paravertebral block, with or without catheter, can be used in lieu of thoracic epidural catheter for unilateral procedures and for breast surgeries.
- Pneumothorax is the major complication of this block.
- When performing the block and the injection, make sure the needle tip always remains visible in the plane.

INDICATIONS

- Thoracic paravertebral catheter can be used in lieu of thoracic epidural analgesia for unilateral procedures like thoracotomies, nephrectomies (either partial or radical), rib fractures, and breast surgeries.
- This block is used in cases where epidural catheter is difficult or epidural analgesia failed for unilateral procedures.
- Bilateral paravertebral blocks, with or without catheter insertion, can be used for bilateral procedures, taking care to avoid the development of bilateral pneumothoraces and local anesthetic overdose toxicity.

CONTRAINDICATIONS

- The same contraindications exist as with epidural catheter insertions regarding the use of anticoagulants and antiplatelet drugs.
- Pneumothorax is the main complication of thoracic paravertebral block, with or without catheter insertion. Therefore inexperience performing regional anesthesia using ultrasound is considered a relative contraindication for thoracic paravertebral block.

SONOANATOMY

The thoracic paravertebral space lies adjacent to the thoracic spine bodies and contains the spinal nerves as they emerge from the intervertebral foramina, the anterior divisions (intercostal nerves), the posterior divisions, and the rami communicantes. The thoracic paravertebral space is sandwiched between the parietal pleura anteriorly and the superior costotransverse ligament posteriorly. The vertebral body, intervertebral disc, and intervertebral foramen form the medial boundary. The thoracic paravertebral space is connected to the level above and below, with the caudad limit being the origin of the psoas major at T12.

The thoracic paravertebral space can be scanned in both the transverse (intercostal) and paramedian approaches. In the transverse approach, the probe is aligned in the space between two adjacent ribs overlying the transverse process. In this approach, the external intercostal muscle, the internal intercostal membrane that binds medially with the costotransverse ligament, and the parietal pleura can be viewed. The landmarks in this scan are the bony reflections from the transverse process with its dropout shadow, and the pleural reflection, which moves with respiration.

In the paramedian (longitudinal) approach, the probe lies in the paramedian plane of the transverse processes. The main landmarks in this approach are reflections and dropout from the tips of the transverse processes. The external intercostal muscle and costotransverse ligament lie between the transverse processes. The parietal pleura lie deep to these layers and can be recognized by their movement with respiration as evidenced in ultrasound by characteristic sliding and comet-tails signs (Fig. 41.1).

TECHNIQUE

The linear ultrasound probe (50-mm footprint) is usually used for this block. In the transverse approach, the probe is aligned over the long axis of the rib; then it is moved medially to visualize the transverse process. By toggling (tilting) the probe, the external intercostal muscle, the internal intercostal membrane that binds medially with the costotransverse ligament, and the parietal pleura can be identified. The needle is introduced in-plane at the lateral end of the probe, from the lateral to medial direction. The needle tip should be positioned just deep to the costotransverse ligament in the paravertebral space. Local anesthetic spread should cause displacement of the pleura anteriorly.

In the paramedian (longitudinal) approach, the linear ultrasound probe (50-mm footprint) or curvilinear probe can be used for this approach. However, the author prefers to use the linear probe for this block. First, the technician

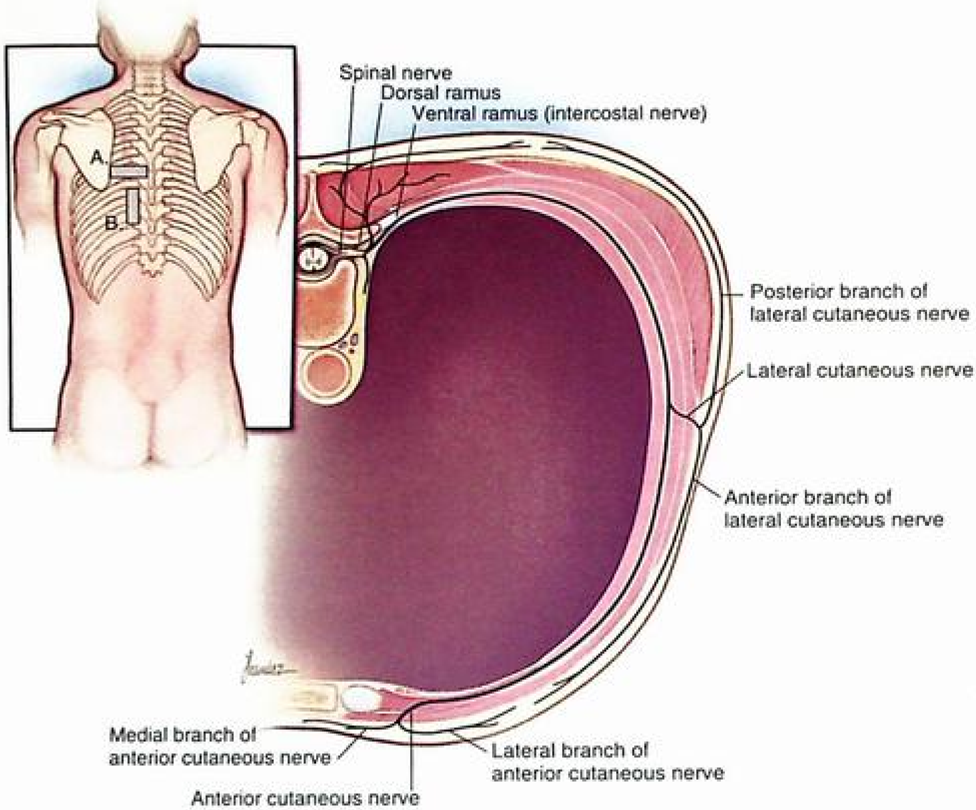


Fig. 41.1 Anatomy of the paravertebral space.

scans the spinous process and then moves the probe laterally to visualize the transverse process. The probe then will be rotated through 90 degrees to lie 2.5 cm lateral to the spine over the desired thoracic levels. The needle is introduced in-plane at the lower end of the probe. For better needle visualization, the probe can be rotated to lie oblique to the spine, rather than parallel to it. As in the transverse approach, the needle tip should be positioned just deep to the costotransverse ligament in the paravertebral space. Injecting local anesthetic will displace the pleural anteriorly. In both techniques, the catheter can be inserted via a Tuohy needle (Figs. 41.2–41.5, Video 41.1).

PEARLS

- Patients may be positioned in the sitting, lateral decubitus (surgical side up), or prone position during the block.
- The parietal pleura appear as a glittering hyperechoic structure between the transverse processes.
- The presence of lung sliding, which is the to-and-fro movement of the lung caused by respiration, and comet-tail signs rule out pneumothorax after a thoracic paravertebral block.
- Patients with lung hyperventilation, as in chronic obstructive lung disease, are at higher risk of developing pneumothorax.
- The costotransverse ligament can be mistaken for parietal pleura, and the injection of local anesthetic superficial to the ligament will result in block failure. Optimizing the image depth and gain will help with proper identification of the pleura and the costotransverse ligament. Furthermore, asking the patient to take a deep breath will identify the visceral and parietal pleura. The latter maneuver will cause a visible movement of the visceral and parietal pleura over each other (the sliding sign).
- The paramedian approach is the preferred one for catheter insertion, as theoretically it decreases the incidence of placing the catheter in the epidural space.
- The continuous thoracic paravertebral catheter infusion rate is 5 to 10 mL per hour of 0.2% ropivacaine. However, for a paravertebral block without catheter insertion, 5 mL of 0.2% or 0.5% ropivacaine is injected at each level.
- Pneumothorax is the major complication of this block. Injections into the root canal and epidural or spinal blockade are other possible complications.

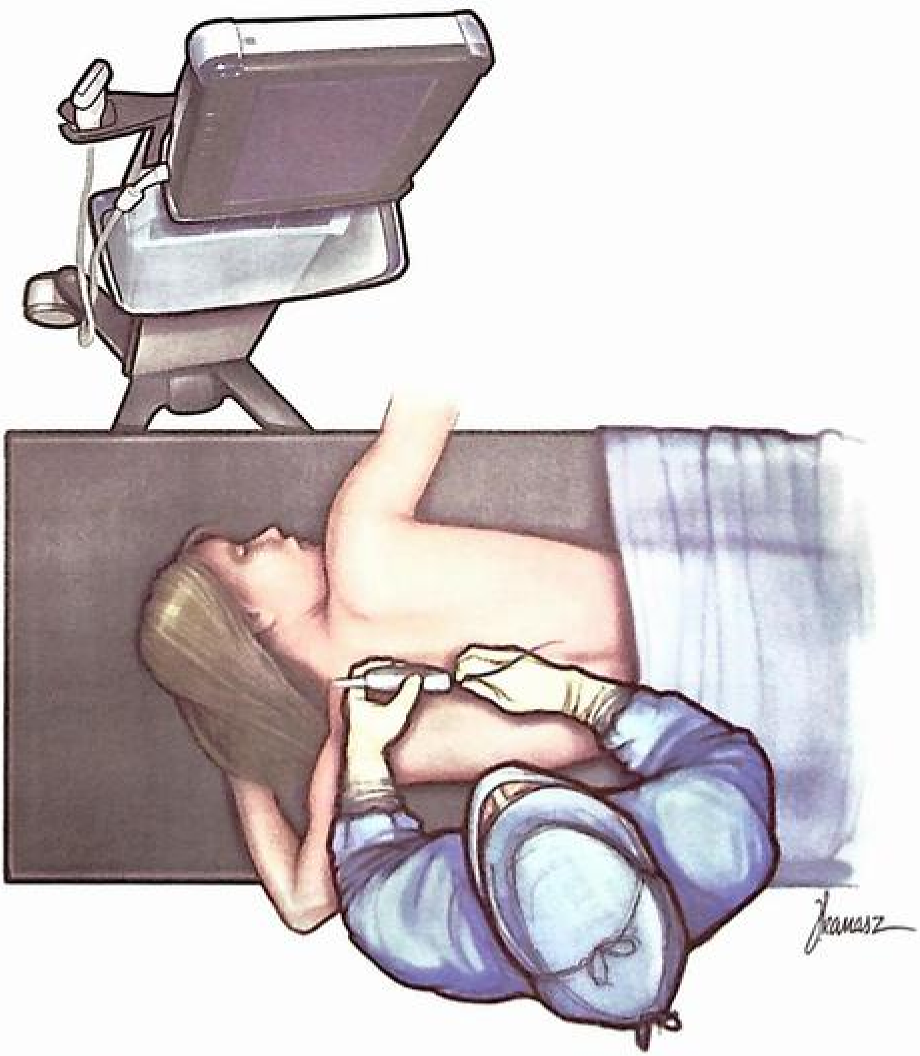


Fig. 41.2 The patient positioned with ultrasound machine for the paravertebral block.

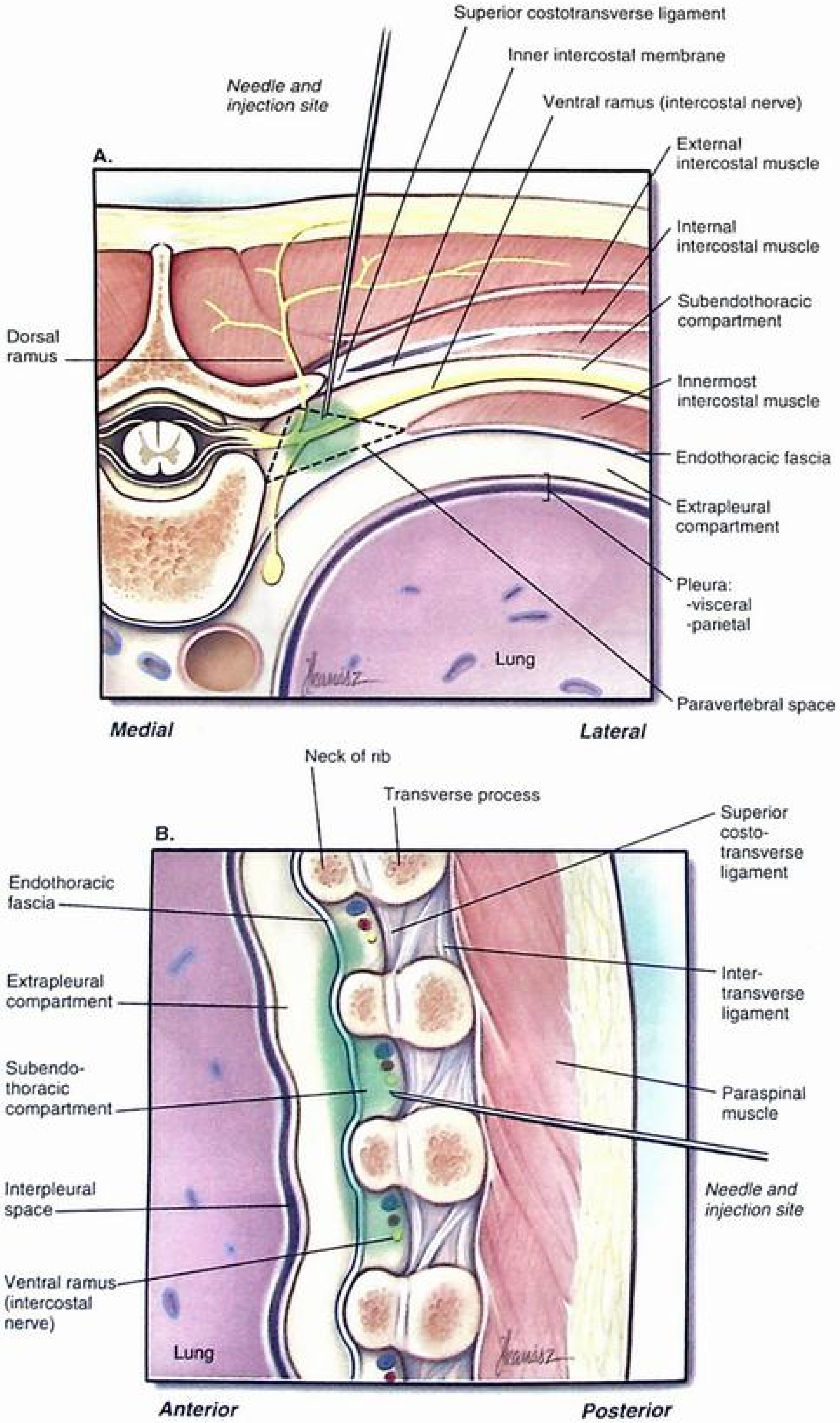


Fig. 41.3 (A) The transverse intercostal technique for the paravertebral block. Note that the internal intercostal membrane binds medially with the costotransverse ligament. (B) The paramedian (longitudinal) approach for the paravertebral block.

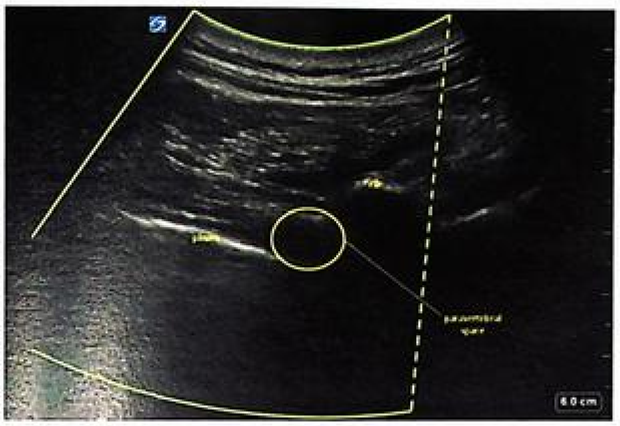


Fig. 41.4 The transverse approach for the paravertebral block.

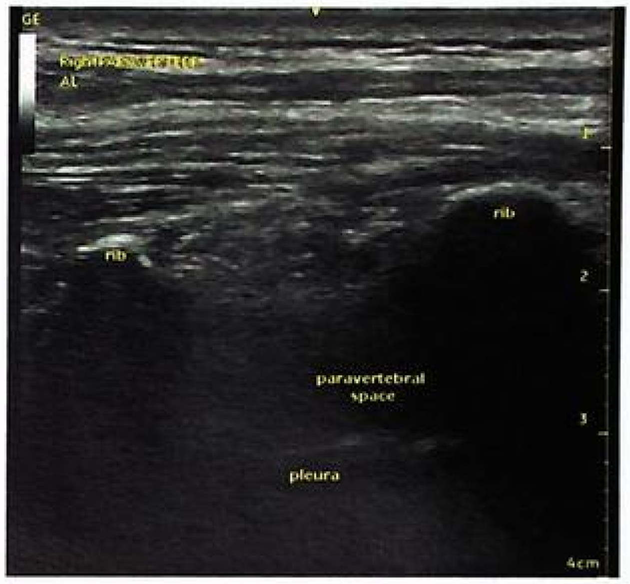


Fig. 41.5 The paramedian (longitudinal) approach for the paravertebral block.

42 Erector Spinae Plane Block and Catheters

Vicente Roqués-Escolar and Mauricio Forero

Key Points

- Erector spinae plane block (ESPB) actually is used for acute and chronic thoracoabdominal pain syndromes, although its indication has been described for the treatment of pain in other locations.
- It is advisable to use a high-frequency transducer in high thoracic regions (7–12 MHz) and a low-frequency curvilinear transducer (2–5 MHZ) for low thoracic and lumbar regions.
- Clear identification of the transverse process is mandatory prior to infiltration or catheter insertion.
- Injection volumes ranging from 20 to 40 mL of long-lasting local anesthetic are commonly used.
- Local anesthetic injected over the transverse process and beneath the erector spinae muscle spreads cranial and caudal to achieve multiple vertebral levels and reaches the dorsal ramus and paravertebral space.

PERSPECTIVE

The ESPB was first described by Forero et al. in 2017 and initially was applied in the management of thoracic neuropathic pain. Actually, there are more than 1000 reports published, most of which demonstrated efficacy for acute and chronic thoracoabdominal pain syndromes.

The ESPB is an interfascial plane block whereby local anesthetic is injected within a plane beneath the erector spinae muscle to achieve multimodal analgesia for thoracic or abdominal surgery. Its analgesic effect appears due to local anesthetic diffusion into the paravertebral space, affecting both the dorsal and ventral ramus of the thoracic spinal nerves. By blocking the posterior rami of the spinal nerves, many structures traumatized during posterior approach spinal surgery could be targeted for alleviation by an ESPB.

Clinical results indicate that local anesthetic injected over the transverse process and beneath the erector spinae muscle spreads cranial and caudal to achieve multiple vertebral levels and reaches the paravertebral space to anesthetize dorsal and ventral ramus as well as the rami communicantes, which supply the sympathetic chain. The exact pathway by which the local anesthetic reaches the spinal nerves is still undefined. Some three-dimensional (3D) topography studies of the posterior boundary and connectivity of the thoracic paravertebral space provide an anatomical rationale supporting the notion that paravertebral spread may be achieved with an injection outside the paravertebral space.

INDICATIONS

Spine region	Indications
High thoracic T2 or T3	Chronic shoulder pain syndrome
	Postsurgical shoulder pain
Midthoracic T4 to T6	Rib fracture (midpoint of level of rib fracture)
	Open thoracotomy and VATS lobectomy (T5)
	Rescue after TE failure for thoracic surgery (T5)
	Cardiac surgery—sternotomy (T5)
	Breast surgery with axillary lymph node dissections (T3)
	Chronic postherpetic neuralgia (level of segment involved)
	Chronic postthoracotomy pain (level of segments involved)
	Metastatic rib cancer (level of segments involved)
Low thoracic T7 to T12	Nephrectomies (T8)
	Hysterectomies (T10)
	Laparoscopic ventral hernia repair with mesh (T7)
	Laparotomies (T7)
	Chronic postherpetic neuralgia (level of segment involved)
	Chronic abdominal pain syndrome (T7–T10)
	Chronic pelvic pain syndrome (T10)
Lumbar (L4)	Spine surgery (midpoint of levels involved)
	Postsurgical hip replacement pain management (L4)

TE, *Thoracic epidural anesthesia;* VATS, *video-assisted thoracoscopic surgery.*

Pharmacologic Choice. Long-acting local anesthetics (bupivacaine, levobupivacaine, or ropivacaine) are used at concentrations of 0.5% (unilateral) or 0.25% (bilateral), with 2.5 μg/mL of epinephrine. Further studies are necessary to determine the optimal dosing of both single-shot and continuous techniques.

The exact volume and concentration of local anesthetic to be used in ESPB is not well established. Injection volumes ranging from 20 to 40 mL are commonly used.

Following the administration of a 20-mL initial bolus, a catheter can be inserted for long-lasting analgesia. For unilateral infusions, the local anesthetic recommended is bupivacaine 0.2%, and for bilateral infusions, it is 0.125%, at a rate between 8 and 12 mL per catheter per hour. Usually, 12 mL per hour provides sensory block to around six spinal levels. As pressure during injections may be an important factor for its effectiveness, PCA- (patient-controlled analgesia) programmed intermittent boluses have been suggested as a better option than continuous infusions.

Anatomy. The back plays a major role in how the entire body functions. By virtue of its attachments to the vertebral column, the back integrates the activity of the lower limbs, upper limbs, spine, and pelvis.

The muscles of this region can be divided easily into two major groups:

- *The extrinsic back muscles* functionally belong to the upper limbs but are situated on the posterior aspect of the trunk, also known as "immigrant" muscles (trapezius, rhomboid, latissimus dorsi, and serratus posterior inferior muscles) (Fig. 42.1A).
- *The intrinsic back muscles* act specifically on the vertebral column. The erector spinae muscle is included in this group (Fig. 42.1B).

The ESPB targets the erector spinae plane, which lies in the chest wall between the anterior surface of the erector spinae muscles and the posterior surface of the spinal transverse processes.

The erector spinae are not just one muscle, but a bundle of muscles and tendons. Actually, the erector spinae muscle consists of three columns of muscles (the iliocostalis, longissimus, and spinalis muscles), each running parallel on either outer side of the vertebral column. This muscular column is encased in a retinaculum (a complex sheet of blended aponeurosis and fascia) that extends from the sacrum to the skull base (Fig. 42.2A,B).

Each spinal nerve splits into a dorsal and ventral ramus as it exits from the intervertebral foramen. The dorsal ramus travels posteriorly through the costotransverse process and gets into the erector spinae muscle. The ventral ramus travels laterally as the intercostal nerve, running deep to the internal intercostal membrane.

Position. Depending on the operator's and patient's comfort, a sitting, lateral decubitus, or prone position is chosen.

Ultrasound-Guided Injection Technique. A high-frequency linear transducer (7–12 MHz) is used. For a high BMI (body mass index; person's weight in kilograms divided by their height in meters squared) or low thoracic and lumbar region, a curvilinear transducer (2–6 MHz) is advised.

Initially, place the probe in transverse orientation over the spinous process in the midline and transverse process laterally (axial view). The tip of the transverse process, costotransverse joint, and rib are well defined as a hyperechoic structure superficial and lateral to the lamina. This axial view allows marking our target (transverse process tip) over the skin of the patient to rotate the transducer posteriorly in a cranial-caudal orientation (sagittal-paramedian view). It is important to keep the tip of the target transverse process in the middle of the ultrasound screen.

As the transducer moves lateral or medial, the acoustic shadows generated by the costotransverse joint, rib, or lamina, respectively, can be observed. Clear identification of the transverse process is mandatory prior to infiltration or catheter insertion. The transverse process will be more superficial, blunter, and wider, while the rib will be deeper, rounder, and thinner (Fig. 42.3).

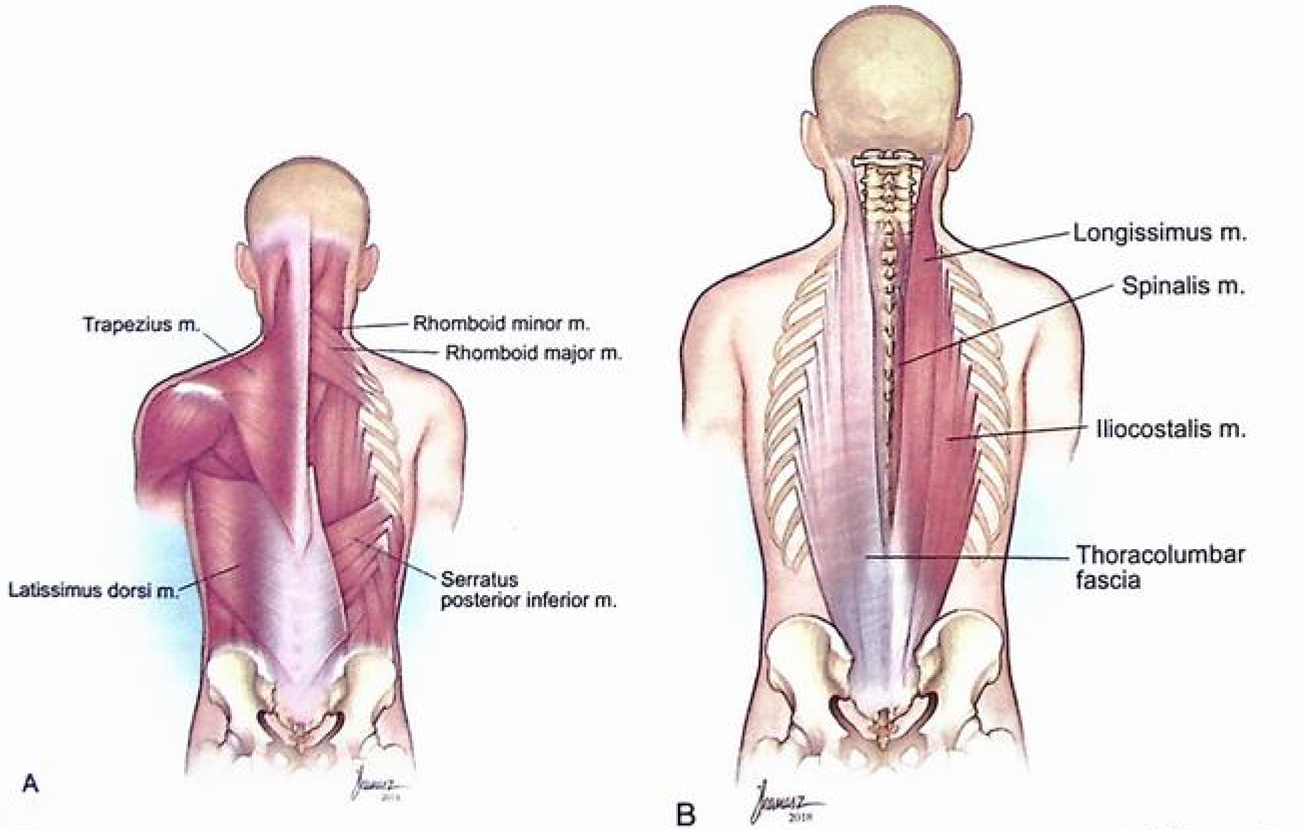
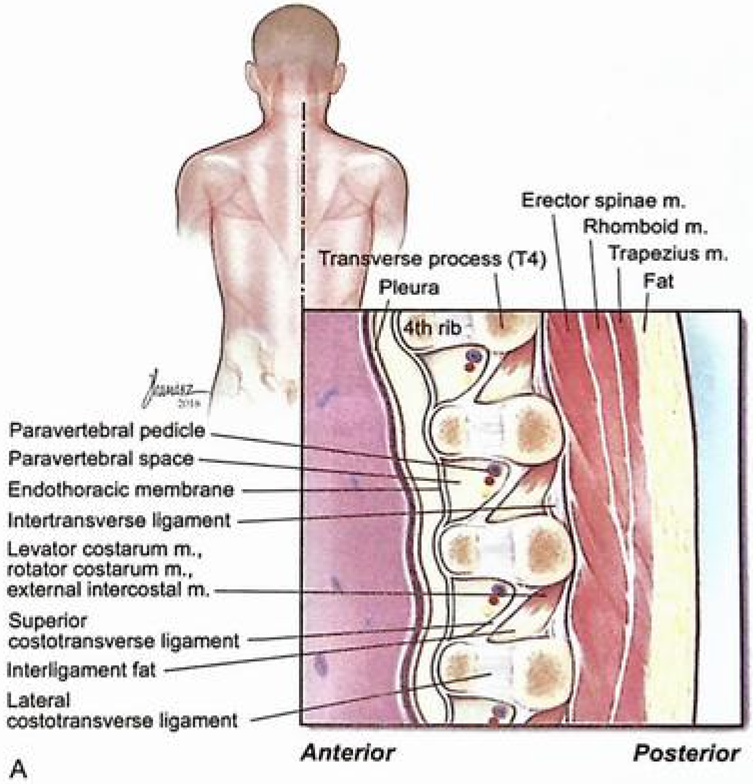


Fig. 42.1 (A) The extrinsic back muscles: trapezius, rhomboid major and minor, latissimus dorsi, and serratus posterior inferior muscles. (B) The intrinsic back muscles: longissimus, spinalis, and iliocostalis muscles and thoracolumbar fascia.



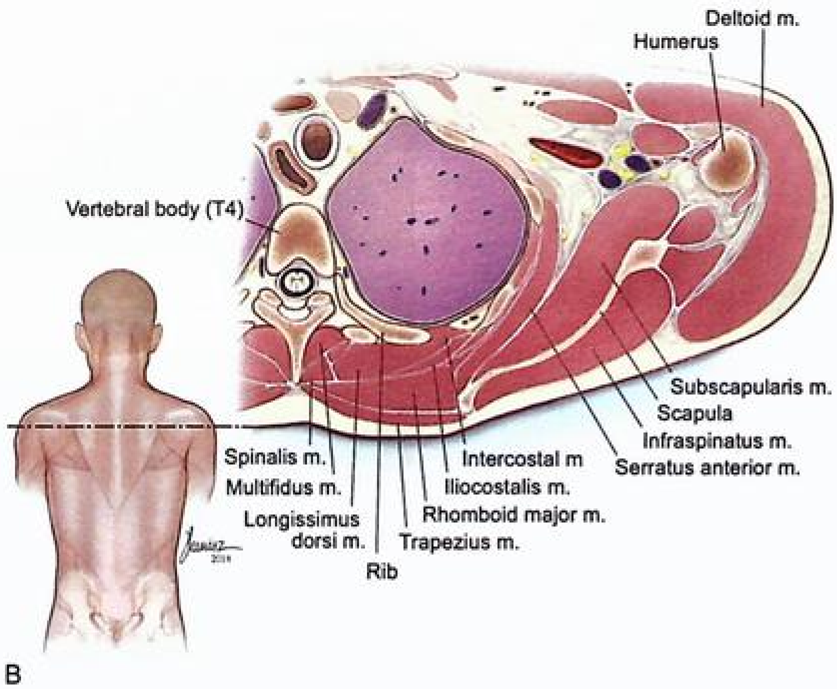


Fig. 42.2 (A) Sagittal-paramedian cross section of posterior wall of thorax. (B) Axial cross-section at T4 level.

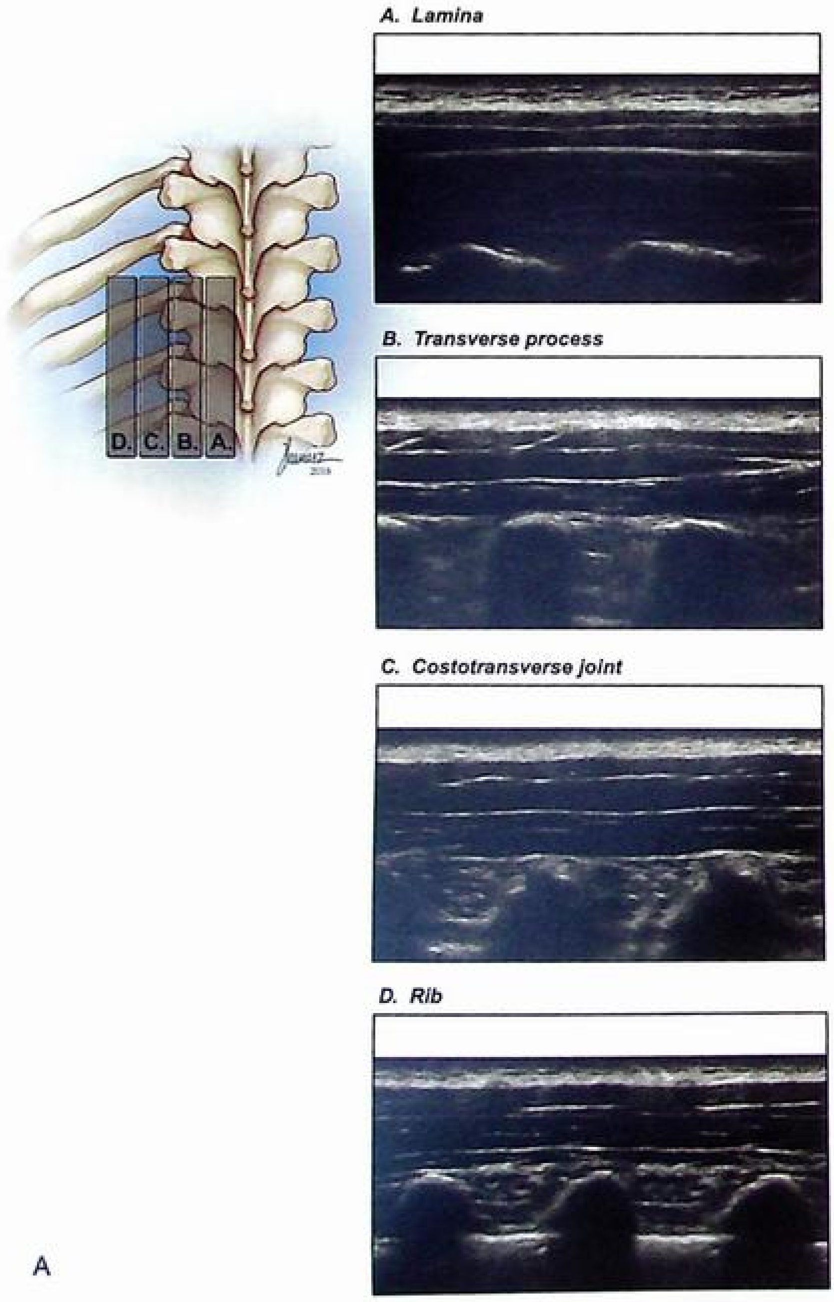
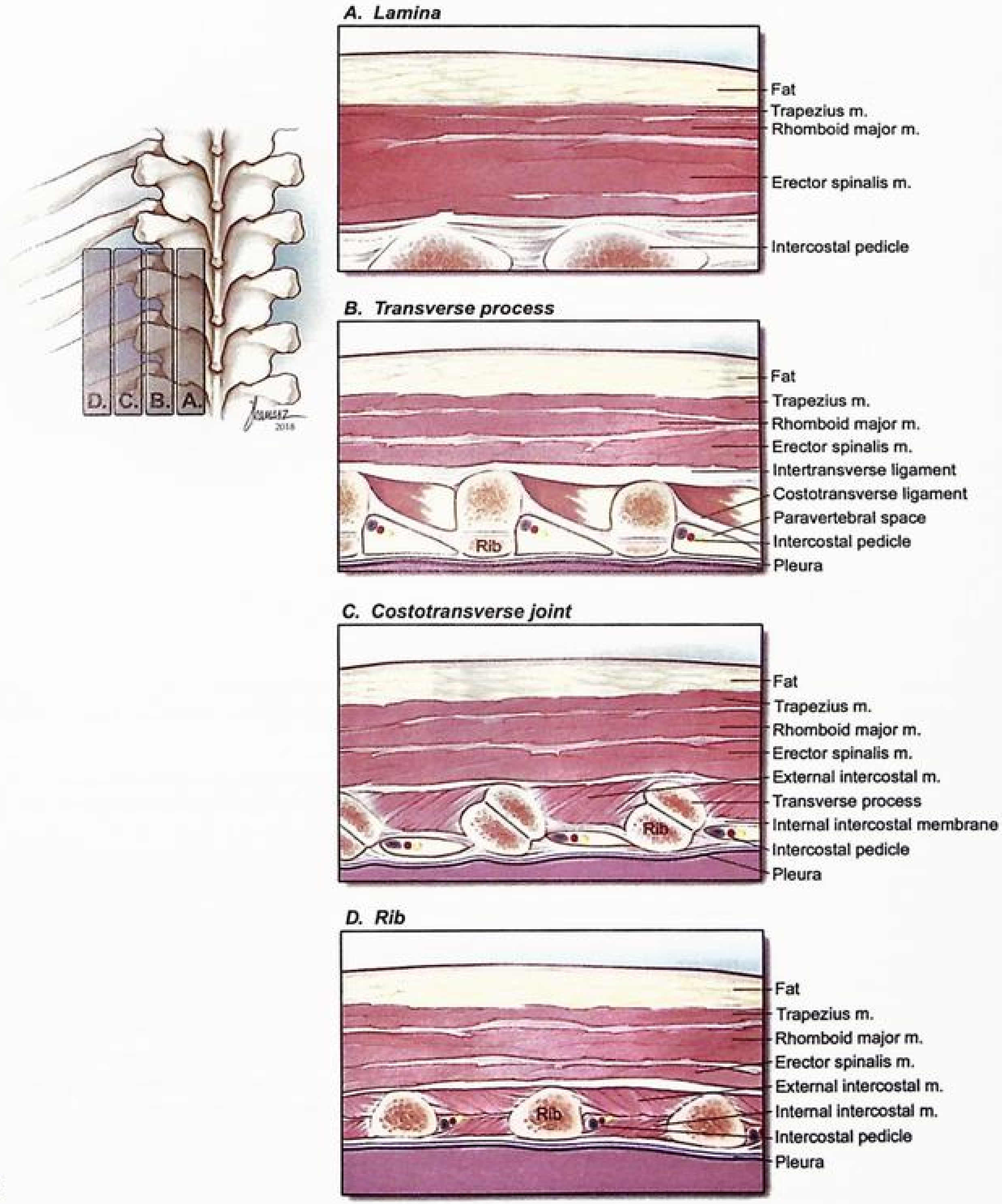


Fig. 42.3 Sonoanatomy of anatomical structures in sagittal-paramedian scanning for erector spinae plane block.



B

Fig. 42.3—cont'd

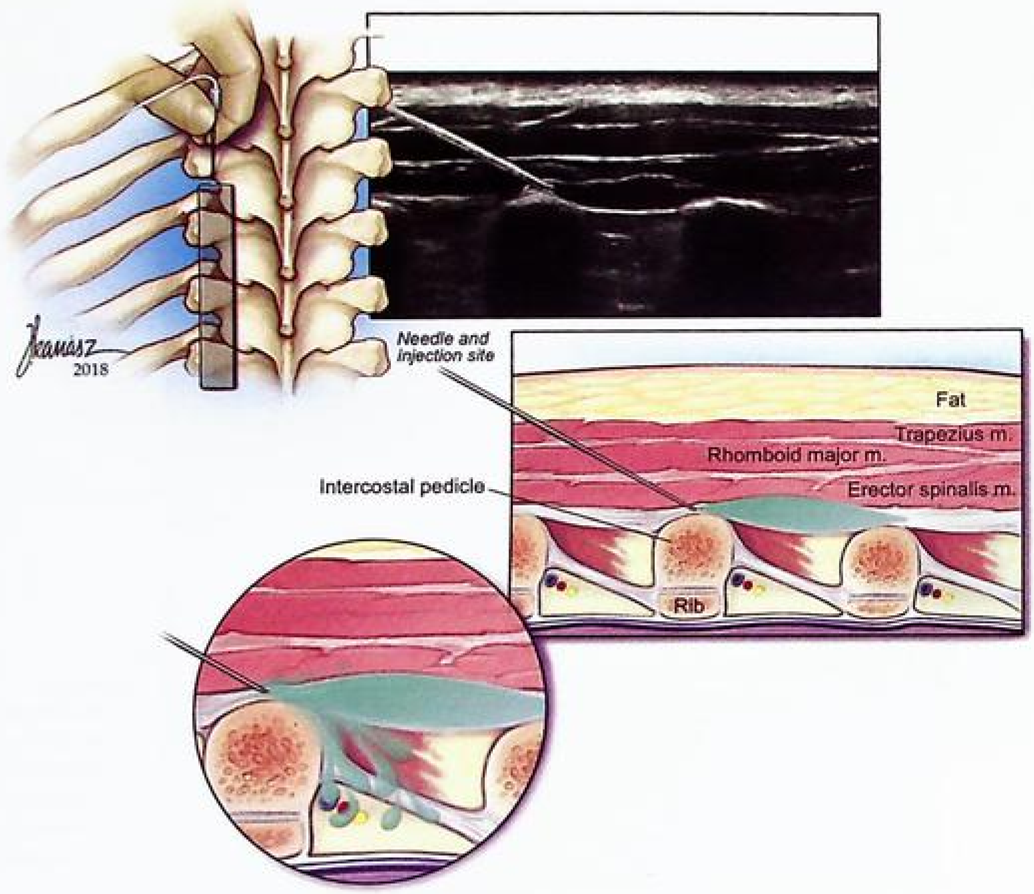


Fig. 42.4 In-plane approach, from cranial-caudal in sagittal-paramedian view.

A cranial-caudal in-plane approach is preferred to facilitate diffusion of local anesthetic. The needle insertion point is 1 to 1.5 cm away from the ultrasound probe. Once the tip of the needle approaches the transverse process in its distal end, hydrodissection with normal saline is used to ensure spread anterior to the anterior fascia of the erector muscle and posterior to the transverse process. Following confirmation of appropriate cranial-caudal spread, the total volume of local anesthetic is deposited (Fig. 42.4, Video 42.1).

The use of catheters for continuous infusion has also been described. After injecting 10 mL of the local anesthetic solution, the catheter can thread easily into the erector spinae plane. It is prudent to thread 5 to 7 cm of the catheter into the space to avoid inadvertent dislodgement of the catheter. The last 10 to 20 mL can then be injected through the catheter after confirming that the catheter is not intravascular (Fig. 42.5, Video 42.1).

POSITION

Depending on the operator's and patient's comfort, a sitting, lateral decubitus, or prone position is chosen.

POTENTIAL COMPLICATIONS

No complications have been reported, although the high volumes and doses of local anesthetic used are associated with high plasma levels that could facilitate local anesthetic toxicity.

PEARLS

- When scanning, you can find the transverse process tip moving either from medial to lateral (from lamina to transverse process) or from lateral to medial (from rib to transverse process). It is probably easier moving from lamina, which is a flat and deeper bony structure, to lateral, where the transverse process will be identified clearly as a more superficial, bony, flat structure.
- The needle must be aligned with the axis of the ultrasound probe. Place the target transverse process in the middle of the ultrasound screen, then make sure that your needle entry point is 1 to 1.5 cm away

Cervical Paraspinal Interfascial Plane Block 43

Michael Rahimi and Jeff L. Xu

Key Points

- The cervical paraspinal interfascial plane (CPIP) block is a group of blocks involving injection of local anesthetic (LA) between the posterior cervical paraspinal muscles.
- CPIP may include cervical multifidus plane (CMP), cervical cervicis plane (CCeP), and cervical capitis plane (CCaP) blocks, depending on the location of the LA injection.
- CPIP targets the cervical dorsal rami from C1 to C7.
- CPIP can be used for postoperative analgesia for posterior cervical laminectomy/fusion.
- Intraoperative neuromonitoring signals, such as somatosensory-evoked potentials (SSEPs)/motor-evoked potentials (MEPs), have been shown not to be affected by the block.

PERSPECTIVE

Interfascial plane blocks of the paraspinal region were first described by Hand et al. in 2015 for the lumbar region and called the thoracolumbar interfascial plane (TLIP) block. As the technique continued to develop, subsequent studies described a multitude of blocks at the thoracolumbar region with differing nomenclature to target the dorsal rami of thoracic and lumbar spinal nerves. Similarly, LA can be deposited between the paraspinal muscles of the cervical region by targeting the cervical dorsal rami to provide innervation to the skin and muscles of the posterior neck and occiput.

ANATOMY

The posterior group of cervical muscles includes but is not limited to the multifidus, semispinalis cervicis, semispinalis capitis, splenius capitis, trapezius, and levator scapulae muscles (Fig. 43.1). The multifidus muscles run along the laminae and span from the articular processes of the cervical vertebra to the spinous processes above their origin points. The semispinalis capitis muscles originate from the cervical and high thoracic transverse processes and insert at the occipital bone and the spinous processes of the vertebral bodies above their point of origin. The semispinalis capitis muscles lie superior to the semispinalis cervicis muscles.

For nomenclatural purposes, the interfascial planes between these paraspinal muscles can be referred to as the CMP between the muscle of multifidus and semispinalis cervicis, the CCeP between the muscle of semispinalis cervicis and semispinalis capitis, and the CCaP between the muscle of semispinalis capitis and splenius capitis.

The dorsal rami of the cervical spinal nerves run through a continuous plane posteriorly through these muscles and their interfascial planes from the occiput to the C7 level to provide branches that innervate the posterior cervical muscles and skin (Fig. 43.2).

SONOANATOMY

- The CCeP is a unique interfascial plane. This nerve-containing layer can be identified as a hyperechoic plane between the semispinalis cervicis muscle and semispinalis capitis muscle (Figs. 43.2–43.4). The CCeP is a continuous plane that extends from the occiput to the C7 level.
- The deep cervical artery, a branch of the costocervical trunk, runs up in the CCeP and can be visualized continuously along the posterior cervical spine at the level of the articular process between the semispinalis cervicis muscle and semispinalis capitis muscle (Figs. 43.3 and 43.4).
- In the upper cervical levels, the CCeP can be identified between the obliquus capitis inferior muscle and semispinalis capitis muscle at the C2 level (Fig. 43.5). The greater occipital nerve, the medial branch of the dorsal ramus of the C2 spinal nerve, can be visualized in the CCeP in the upper cervical levels (Figs. 43.6 and 43.7).

TECHNIQUE

- Because of the superficial nature of the muscle layers involved, a high-frequency linear probe can provide optimal imaging in most situations.
- An ultrasound probe is placed in a transverse orientation and located 1 to 2 cm lateral to the spinous process while the patient is in the prone position.
- To perform a CCeP block with the in-plane technique, an echogenic nerve block needle is advanced from the lateral to medial direction to lie

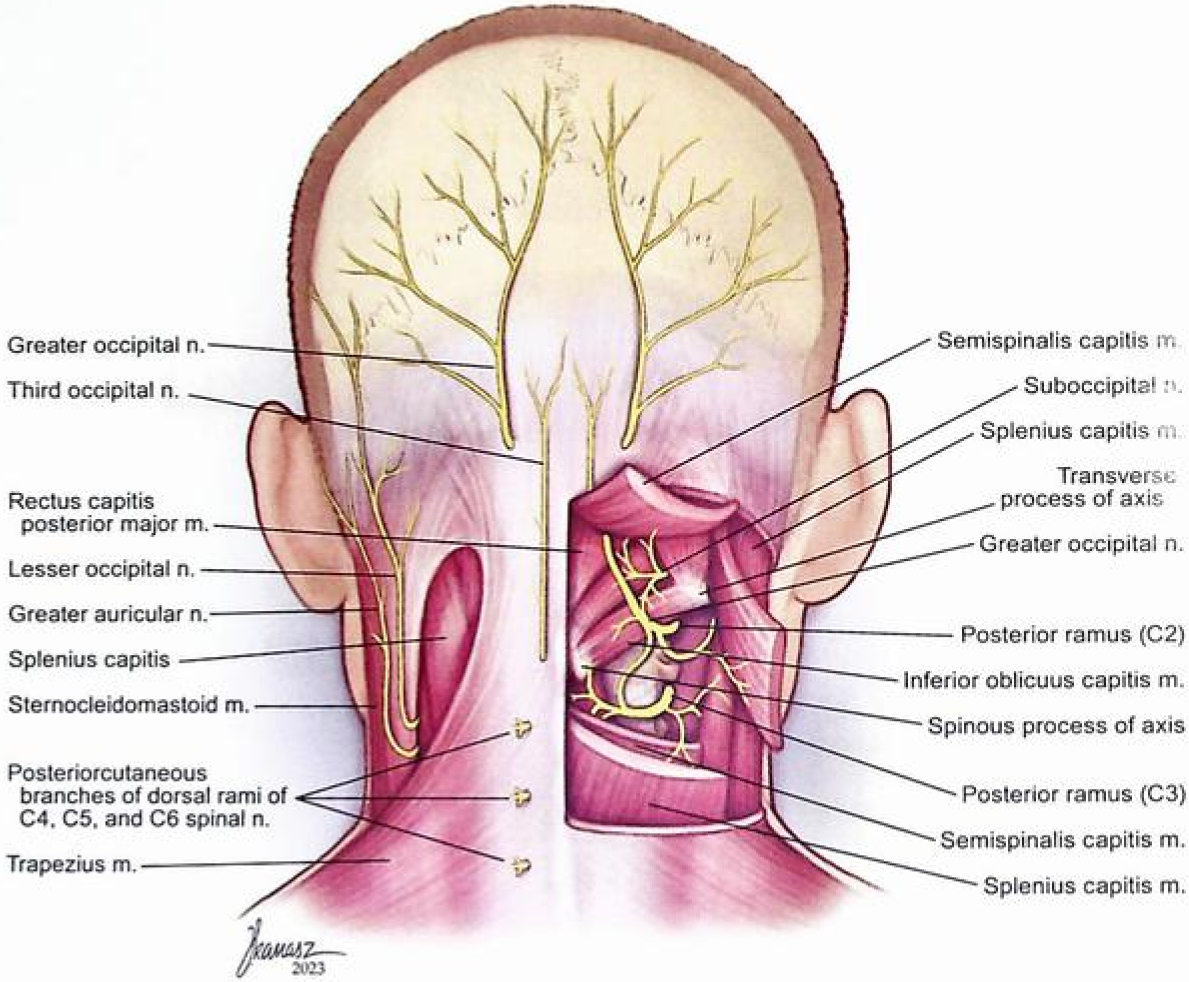


Fig. 43.1 Surface and muscular anatomy and innervation of the posterior scalp and cervical region.

between the semispinalis cervicis and semispinalis capitis muscles. A distinct "pop" is usually felt if the needle is in the right location.

- To perform a CCaP block, an echogenic nerve block needle is advanced from the lateral to medial direction to lie between the semispinalis cervicis and the splenius capitis muscles.
- To perform a CMP block, the needle is advanced to lie between the semispinalis capitis and the cervical multifidus muscles.
- For adult patients, an injection of 10 mL of LA (e.g., 0.25% or 0.5% of bupivacaine) with 10 µg of dexmedetomidine and 5 µg/mL epinephrine bilaterally will provide sufficient spread of analgesia to the posterior neck and occiput.

PEARLS

- The CCeP is a hyperechoic plane (Figs. 43.4 and 43.7).
- The deep cervical artery can be visualized continuously along the posterior cervical spine at the level of the articular process in the CCeP.
- The deep cervical vein is usually accompanied by the deep cervical artery, which may be compressed by the ultrasound probe and can be harder to visualize. Therefore negative blood aspiration must be confirmed before depositing the LA to avoid intravascular injection.
- The greater occipital nerve can be visualized in the CCeP at the upper cervical levels.
- The block can be used to cover surgical pain from upper and/or lower cervical surgery with a posterior approach.
- The block can be performed either before the incision is made or the surgical wound is closed at the end of the surgery.
- Caution should be taken if the dural sac has been compromised by the surgical team as this may increase the risk of intrathecal spread of LA.

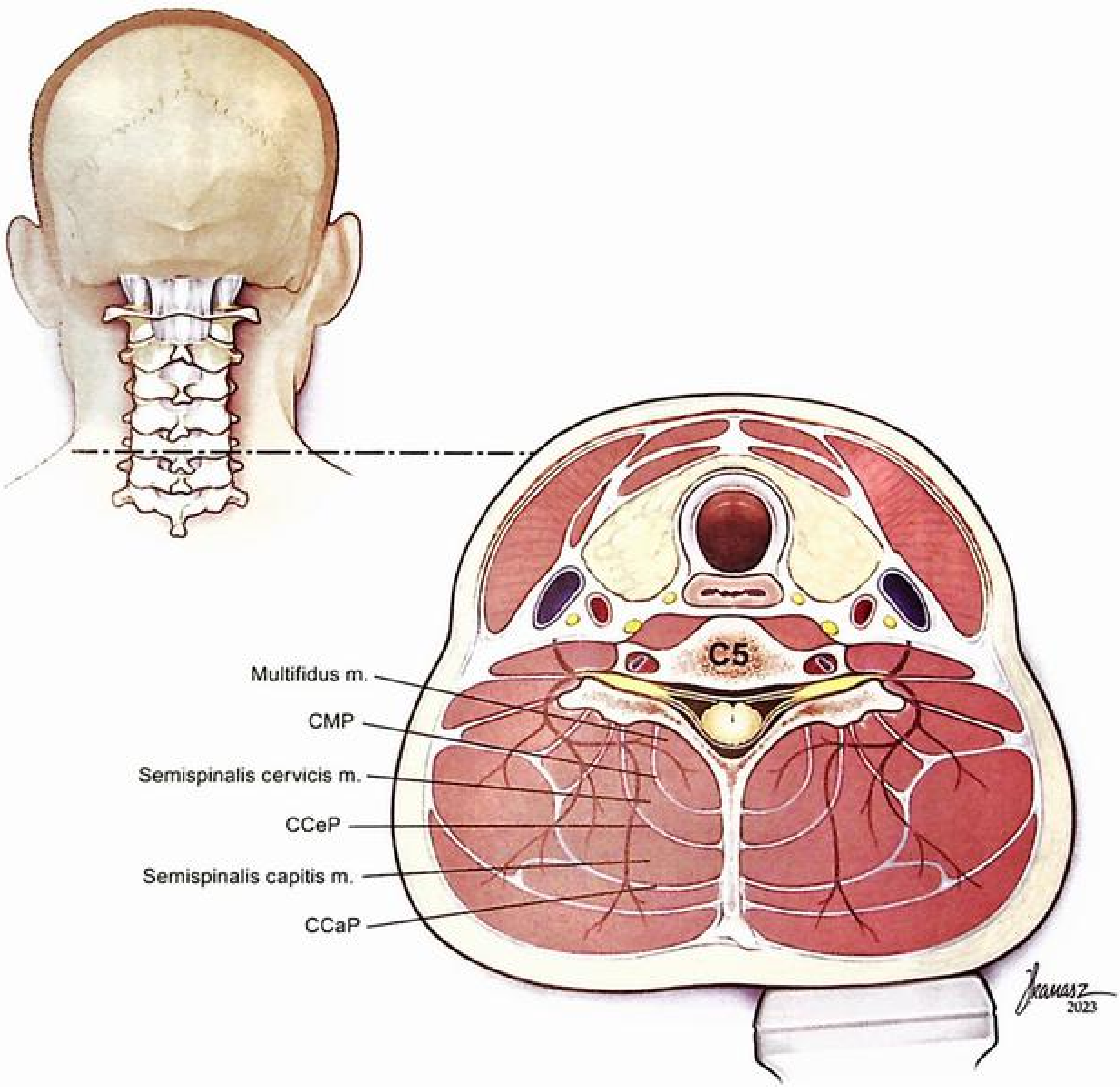


Fig. 43.2 Cross-sectional anatomy of the cervical region at the level of the fifth cervical vertebra. The ultrasound probe is placed in a transverse orientation to visualize the cervical multifidus plane *(CMP)*, cervical cervicis plane *(CCeP)*, and cervical capitis plane *(CCaP)*.

COMPLICATIONS

Similar to other interfascial plane blocks, local anesthetic systemic toxicity (LAST) is a potential complication. In addition, infection is another possible complication; thus a strict aseptic technique must be applied. Although it has not yet been reported that a cervical paraspinal interfascial block abolishes SSEPs and/or MEPs, caution must be used with a high-volume LA injection.

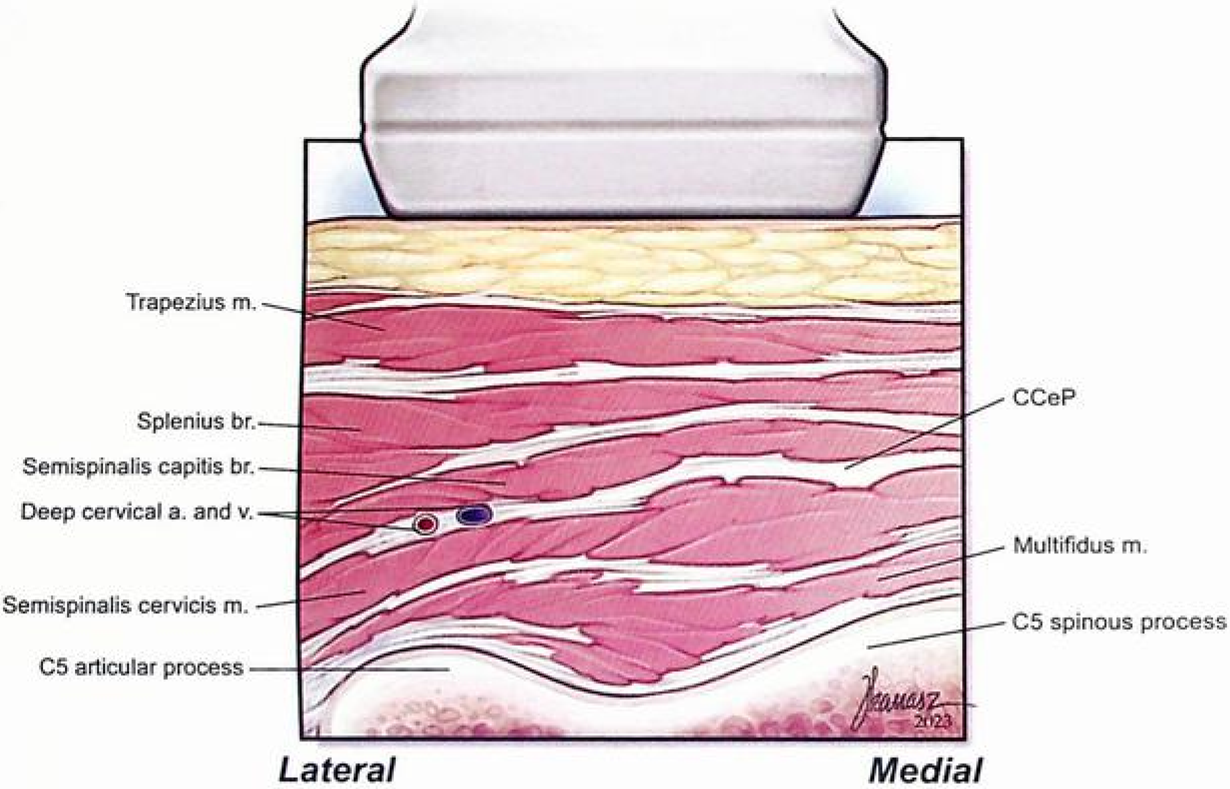


Fig. 43.3 Detail of anatomy at the level of the fifth cervical vertebra. The deep cervical artery is situated at the level of the articular process in the cervical cervicis plane *(CCeP)*.

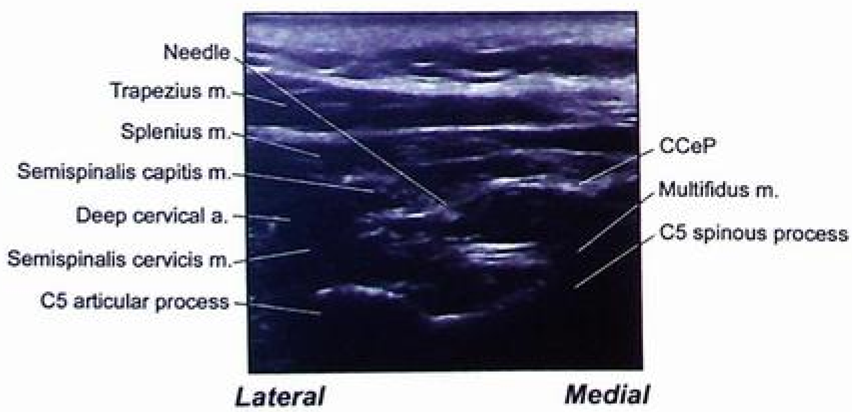


Fig. 43.4 Ultrasound image of cervical cervicis plane *(CCeP)* block with needle at the level of the fifth cervical vertebra. Pulsatile motion of deep cervical artery can be observed in real-time ultrasonography.

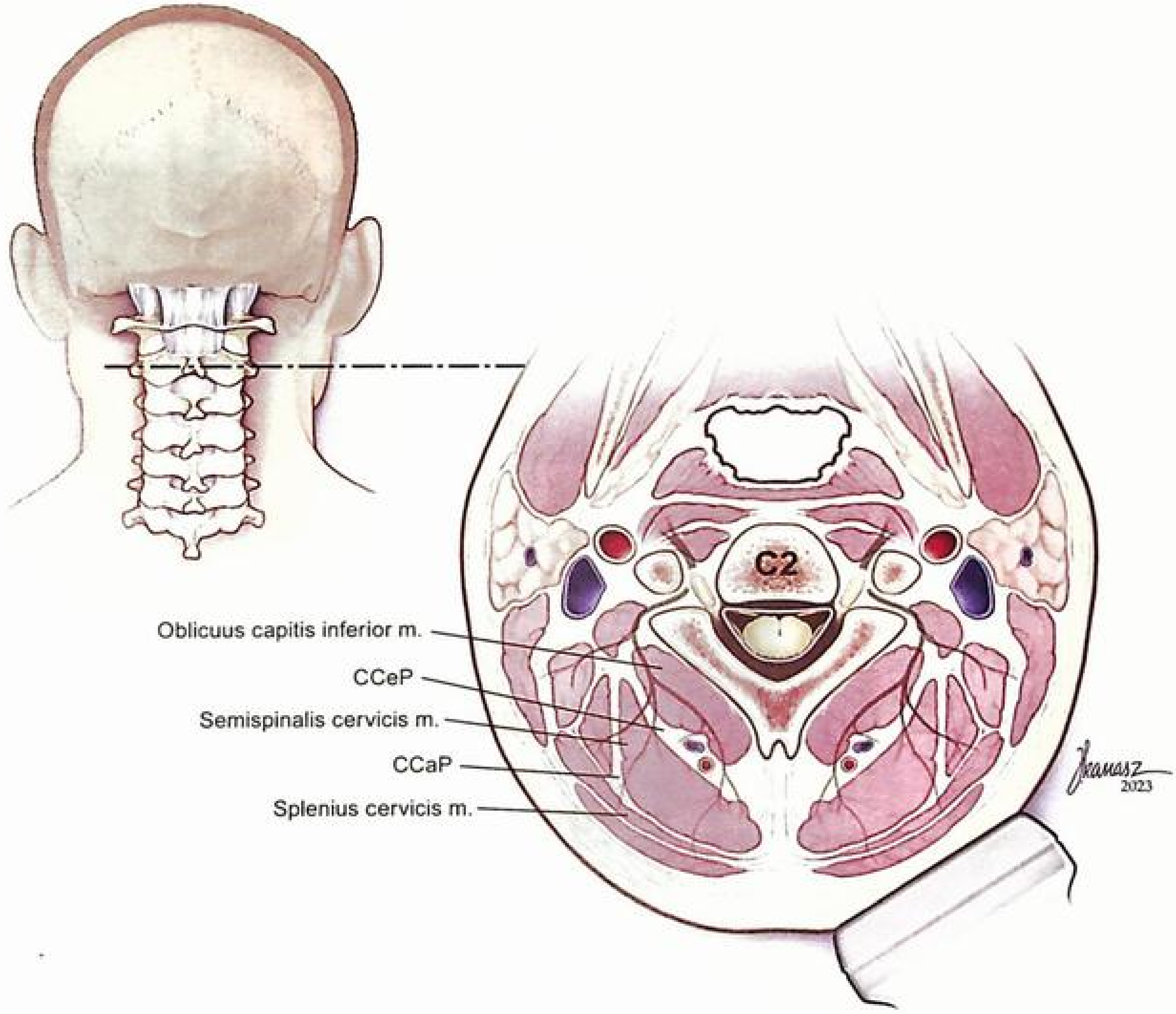


Fig. 43.5 Cross-sectional anatomy of the cervical region at the level of the second cervical vertebra. *CCaP*, Cervical capitis plane; *CCeP*, cervical cervicis plane.

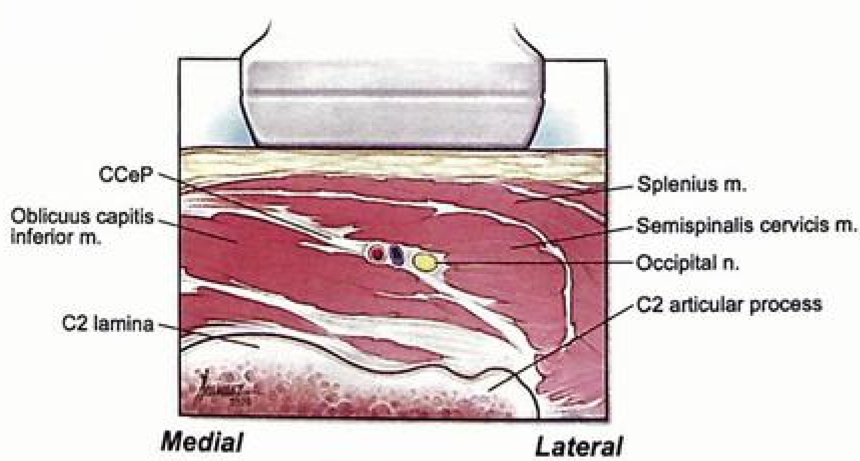


Fig. 43.6 Detail of anatomy at the level of the second cervical vertebra. The greater occipital nerve can be visualized in the cervical cervicis plane *(CCeP)*.

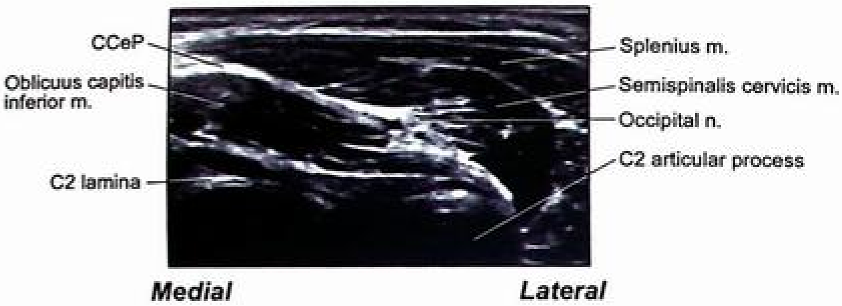


Fig. 43.7 Sonoanatomy of cervical cervicis plane *(CCeP)* at the level of the second cervical vertebra.

Thoracolumbar Paraspinal Interfascial Plane Block 44

Iyabo Muse and Jeff L. Xu

Key Points

- A thoracolumbar paraspinal interfascial plane (TPIP) block primarily anesthetizes the dorsal rami of the spinal nerves.
- A low-frequency curvilinear transducer is preferred for TPIP.
- A TPIP may have a lower risk of compromising the conduction of ventral rami neurons and lumbar plexus.
- A TPIP block consists of a group of blocks at both the thoraco- and lumbar regions.
- Lumbar multifidus plane (LMP) and lumbar longissimus plane (LLP) blocks are TPIP blocks at the lumbar region.
- A LMP block is performed by depositing local anesthetic (LA) between the fascial plane of the multifidus and longissimus muscles, whereas a LLP block deposits LA between the fascial plane of the longissimus and iliocostalis muscles.
- Caution should be taken if the dural sac has been compromised by the surgical team because this may increase the risk of intrathecal spread of LA.

PERSPECTIVE

A thoracolumbar interfascial plane (TLIP) block is a novel regional anesthesia technique that was first described by William Hand and his colleagues in 2015. The TLIP block is placed between the paraspinal muscles of the lumbar multifidus and lumbar longissimus to target the dorsal rami of the spinal nerves at the lumbar region.

For nomenclatural purposes, paraspinal interfascial plane blocks at the thoraco- and lumbar regions can be referred to as TPIP blocks. The two TPIP blocks commonly performed at the lumbar region are the LMP and LLP blocks. Several studies have shown these blocks to be effective in providing adequate analgesia for lumbar spine surgeries and reducing in opioid consumption.

ANATOMY

Lumbar paraspinal muscles consist of three muscle groups: the multifidus (MF), longissimus (LS), and iliocostalis (IC). The lumbar spinal nerves emerge from the intervertebral foramen and split into the dorsal rami and ventral rami. The dorsal ramus nerve ascends to emerge onto the posterior surface of the vertebrae at the junction between the superior articular process (SAP) and transverse process, where it splits into three branches (medial, intermediate, and lateral) that then ascend to a superficial location, usually following the intermuscular plane (Fig. 44.1). The MF muscle is immediately adjacent to the spinous process (SP) in the midline. Last are the LS muscle and the IC muscle (the most lateral muscle).

SONOANATOMY

A TPIP block at the lumbar region consists of LMP and LLP blocks. Each block can be performed in the prone or lateral position. The prone position is more accessible and easier to complete because the patient will be in the same prone position for the surgery. A low-frequency curvilinear probe is placed in a transverse orientation in a paramidline position at the level of the surgical lumbar vertebra.

First, identify the corresponding SP, SAP, and tranverse process acoustic shadows. Using these as landmarks, move laterally to identify the MF muscle, which is the muscle adjacent to the SP. The LS muscles are lateral to the MF, and the IC muscle is lateral to the LS (Fig. 44.2). The echotexture is different among the three muscles (Fig. 44.3).

TECHNIQUE

The LMP block is performed by depositing LA in the fascial plane between the MF and LS muscles (MF-LS). Using a 10-cm, 21-gauge EchoBlock needle with the bevel up, start from a lateral-to-medial orientation at an approximate angle of 30 degrees to the skin. With the in-plane technique, advance the needle through the belly of the LS toward the MF and deposit the LA in the plane close to the SAP. An distinct "pop" is usually felt if the needle is in the right location. An LLP block is performed by depositing LA between the LS and IC muscles (LS-IC).

Typical injection of LA consists of bilateral injections of 20 mL of 0.25% bupivacaine or 0.2% ropivacaine with 10 μg of dexmedetomidine and 5 μg/mL epinephrine given bilaterally. Dexmedetomidine helps to prolong the block, while epinephrine reduces systemic absorption

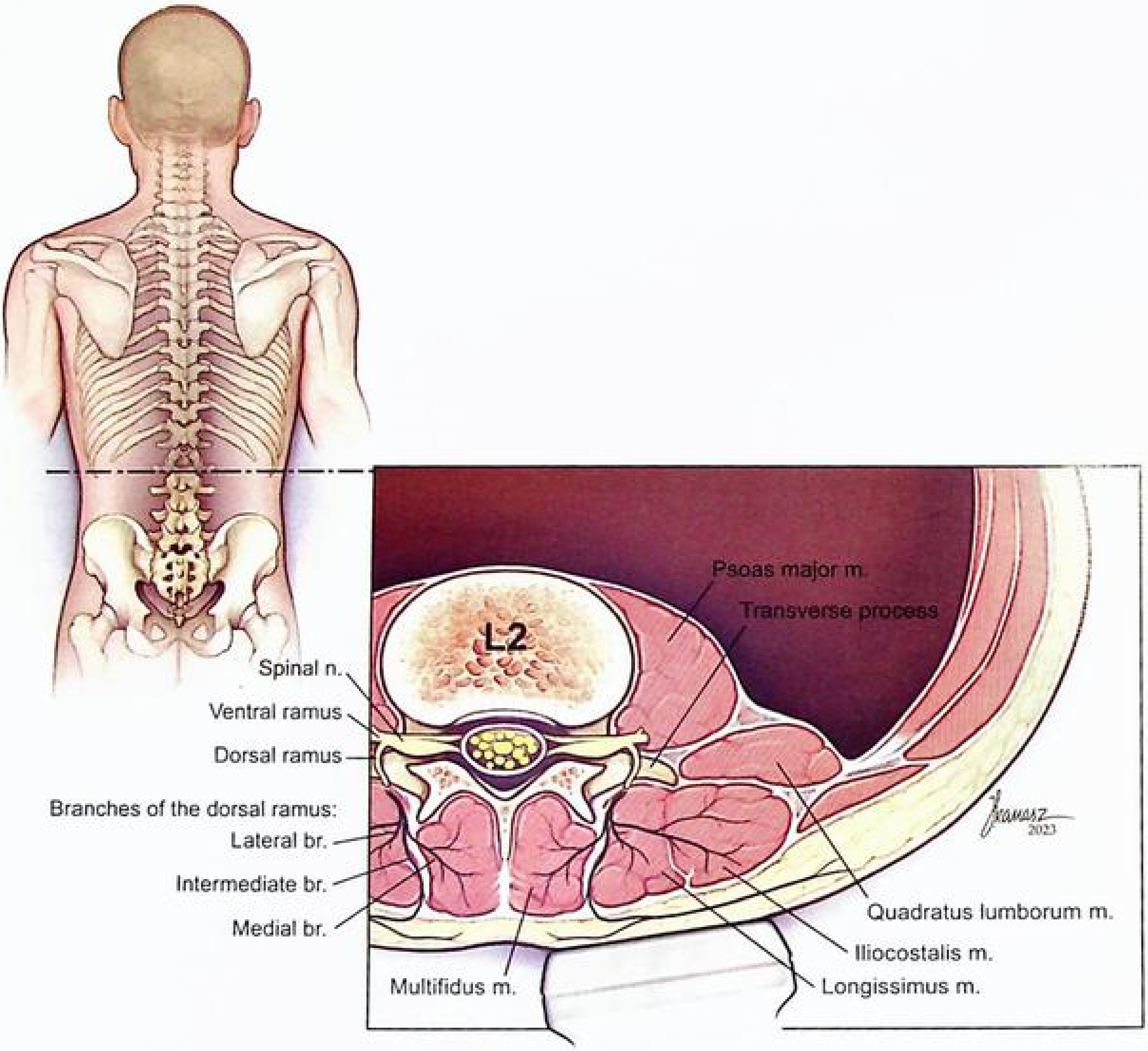


Fig. 44.1 Cross-sectional anatomy of the thoracolumbar paraspinal region at the level of the L2 vertebrae.

and risk of LA system toxicity. To avoid wasting LA, hydrodissection with an inactive fluid, such as normal saline or 5% dextrose with a three-way stopcock, is used. Correct placement of LA is noted when there is proximal spread toward the main branch of the dorsal ramus, thus anesthetizing all the nerves supplying the skin and muscle of the lumbar area.

INDICATIONS

- Spinal cord stimulator implantation placed with a posterior lumbar midline incision.
- Lumbar spine surgeries, such as lumbar laminectomy, lumbar fusions, or minimally invasive surgery (i.e., lumbar microdiscectomy).
- Vertebral fracture surgery.

PEARLS

Identification of each muscle may be difficult to ascertain, as these structures may appear as a single larger muscle. Visualization can be enhanced with lumbar extension (reverse Trendelenburg of the bed) and slight rotation (right or left tilt of the bed) of the patient. This maneuver results in displacing the LS muscle over the lateral border of the MF muscle and better delineates the border of each muscle.

The plane between the MF and LS can be distinguished using several techniques. First, the two muscles have different echotextures, and the MF muscle has a rounded shape at L2 level. However, at the lower lumbar area, it is much smaller and triangular in shape. In addition, the dividing plane usually runs between the tip of the SAP and the tip of the SP.

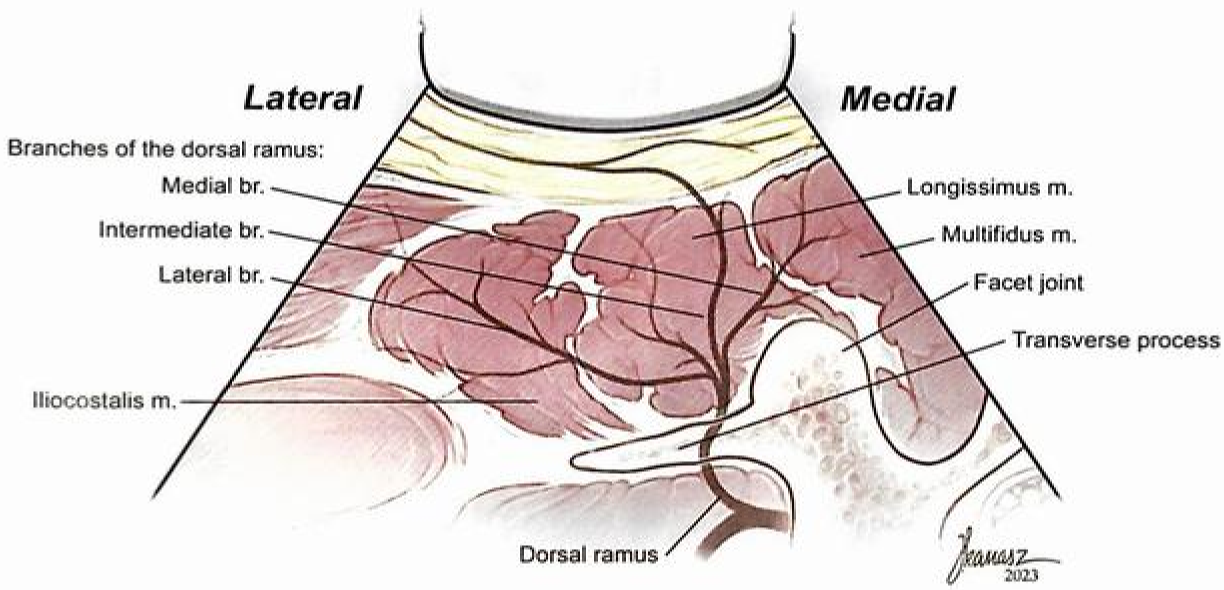


Fig. 44.2 Detail of the anatomy of the thoracolumbar paraspinal interfascial plane at the lumbar region and the corresponding structures.

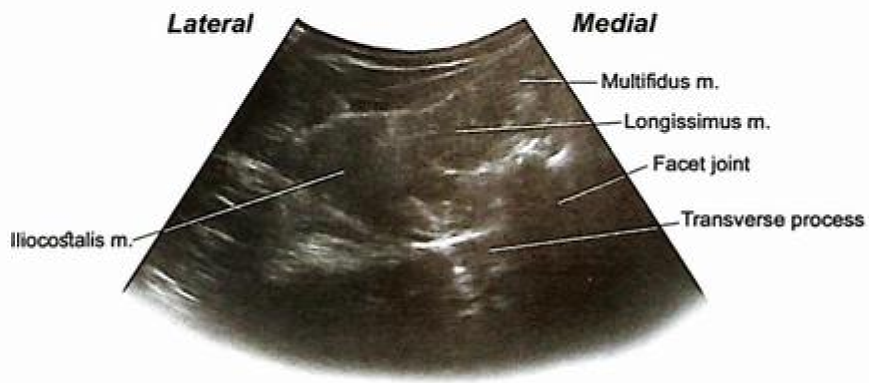


Fig. 44.3 Ultrasound image of the multifidus, longissimus, and iliocostalis muscles and their corresponding structures.

COMPLICATIONS

Some complications may arise from a TPIP block. Although it is unlikely that the TPIP block will abolish somatosensory-evoked potentials/motor-evoked potentials, it potentially could cause a reduction in baseline signal amplitude +/− latency, especially when using a high volume of LA injection and performing the block at the end of the surgery, after the surgical wound was closed. LA systemic toxicity is also a potential complication, although it has not been reported yet in the literature. Another possible complication is infection; thus strict aseptic technique always should be used prior to performing the block.

External Oblique Intercostal Fascial Plane Block

45

Adeeb Oweidat and Sree Kolli

Key Points

- The lateral cutaneous branches of T7 to T11 can be blocked by deposition of a large volume of local anesthetic (LA) deep to the external oblique muscle at the level of the sixth rib medial to the anterior axillary line.
- Subcostal transversus abdominal plane (TAP) block does not cover the upper lateral cutaneous branches of the abdomen.
- External oblique intercostal (EOI/EOIFP) fascial plane block is indicated for analgesia of subcostal incisions used in open procedures like hepatobiliary surgery, nephrectomy, splenectomy, and cholecystectomy.
- EOI block does not provide visceral analgesia.
- Pneumothorax can be avoided by aiming the tip of the needle at the rib as an end point.
- EOI catheters can be placed easily for longer duration of use.

PERSPECTIVE

Open abdominal surgeries cause a significant degree of acute pain and require multimodal analgesia, including opioids. Fascial plane blocks are known to reduce opioid requirements without the adverse effects associated with neuraxial analgesia, which include hypotension, urinary retention, and epidural hematoma.

In recent years, fascial plane block techniques have been incorporated as a part of multimodal analgesia for abdominal surgeries. Optimal analgesia is an integral part of enhanced recovery after surgery programs designed to improve the patient's perioperative experience and outcomes. The role of abdominal plane blocks has gained significant stride in that regard. Since then, the oblique subcostal TAP block has been used for major upper abdominal surgery and in conjunction with the bilateral TAP block for laparoscopic surgery covering the entire abdominal wall. In the early description of the oblique subcostal TAP block, it was proposed that it would provide effective analgesia of the abdominal wall above the umbilicus.

However, studies failed to demonstrate any cutaneous sensory blockade of the upper lateral abdomen with the oblique subcostal. A recent study mapped the analgesic efficacy of subcostal TAP block, observing that the technique produces effective analgesia in the anterior abdominal wall except for the upper lateral abdomen. The EOIFP block has become the new modified block that can provide optimal coverage for the anterior and lateral upper abdominal region.

RELEVANT ANATOMY AND SONOANATOMY

The external oblique muscle is an abdominal muscle, but there is an important part of it that lies over the thoracic cage. It originates from the external surfaces of ribs 5 to 12, running down and medial to insert to the linea semilunaris. The attaching fibers interdigitate with those of the serratus anterior and latissimus dorsi on the lateral side of thorax. At the midclavicular line medially and inferiorly, the external oblique muscle continues as an aponeurosis, via which it inserts to the linea alba, pubic tubercle, and anterior half of the iliac crest.

As shown in Fig. 45.1, the thoracoabdominal nerves originate from the anterior rami of spinal nerves T7 to T11. About the middle of their course through the intercostal space anterior to the midclavicular line, they give off a lateral cutaneous branch, which pierces the external intercostal and external oblique muscle to divide subsequently into anterior and posterior branches that innervate the skin of the lateral thorax and abdominal wall as far as the margin of the rectus abdominis muscle anteriorly. The terminal part of the thoracoabdominal nerves pass behind the costal cartilage and continue anteriorly in the plane between the internal oblique and TAP muscle before piercing the rectus abdominis sheath as anterior cutaneous branches supplying the skin of the midabdomen. It is the terminal branches of the thoracoabdominal nerves that are blocked by both the oblique subcostal TAP block and the rectus sheath block, which explains the similarity in cutaneous sensory block distribution. Thus effective analgesia for incisions involving the upper lateral abdomen requires blockade of the lateral cutaneous branches of T7 to T11 that could potentially be achieved by instilling LA solution above the costal margin in the thoracic fascial plane, either deep or superficial to the external oblique muscle.

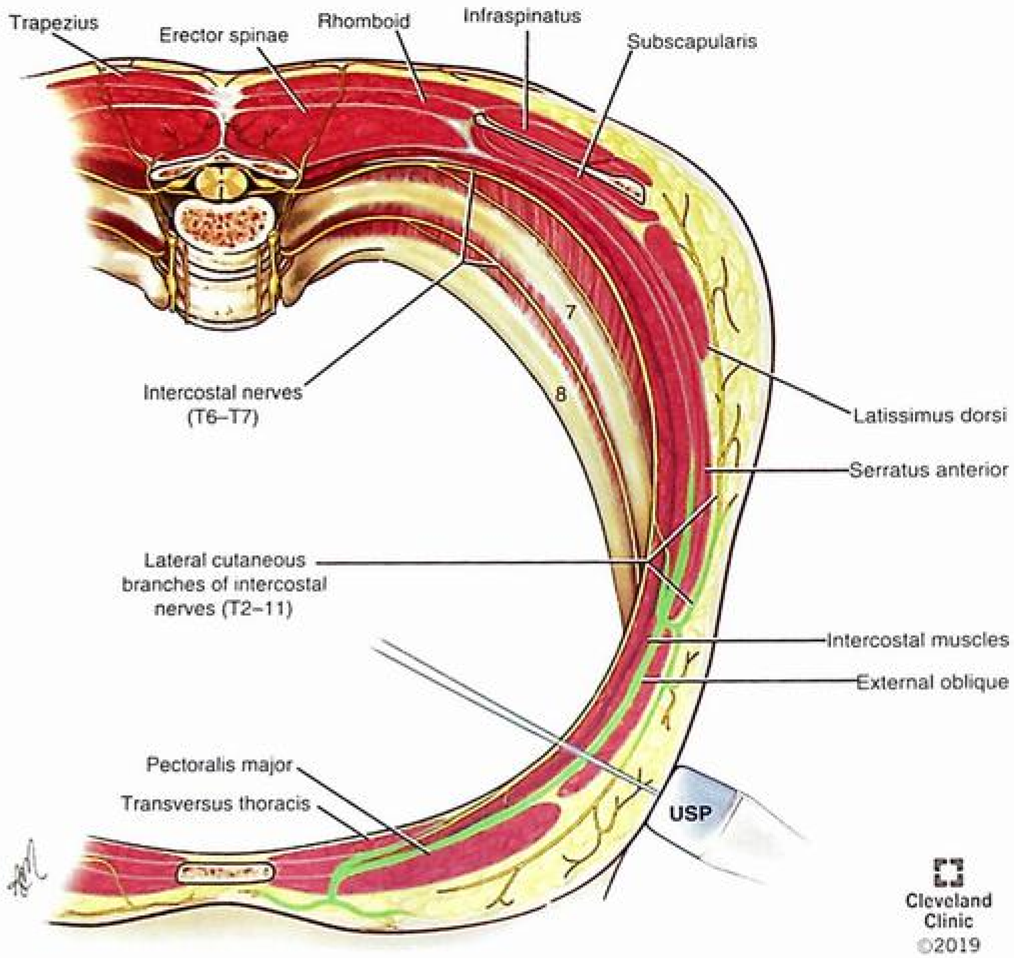


Fig. 45.1 Chest wall anatomy: cross-sectional view. Course of the thoracoabdominal nerves T7 to T11.

TECHNICAL DESCRIPTION OF THE BLOCK

The block is performed with the patient in the supine position with their ipsilateral arm abducted. The ideal position for the linear ultrasound probe is to be placed on the chest wall in the sagittal orientation between the midclavicular and anterior axillary lines at the level of the sixth rib. This is achieved by identifying the sixth rib, either by placing the ultrasound transducer at the level of the lower costal margin (tenth rib) and counting cranially, or by identifying the seventh rib at the level of the xiphoid process and then moving the transducer one rib cranially. The transducer is then rotated so the cranial end is directed slightly medially and the caudal end laterally to produce a paramedian sagittal oblique view with a short-axis view of the ribs, approximately 1 to 2 cm medial to the anterior axillary line. The external oblique muscle is identified at the level of ribs 6 and 7, in line with the xiphoid process. The layers that can be identified from superficial to deep include subcutaneous tissue, the external oblique muscle, and the intercostal muscles between ribs, pleura, and lung. The skin entry point for the injection is cranial to the sixth rib level just medial to the anterior axillary line, with the needle advanced in-plane from a superomedial to inferolateral direction through the external oblique muscle. The needle tip end point is the tissue plane between the external oblique and intercostal muscles at the caudal end of the sixth rib and between the sixth and seventh ribs (Fig. 45.2). In our practice, we usually inject 20 mL of either bupivacaine 0.25% or ropivacaine 0.2% in each side of the bilateral block. The LA is injected between the external oblique and the intercostal muscles, dissecting the tissue plane between the sixth and seventh ribs, and then the needle is directed caudally toward the eighth rib. A catheter can be threaded 5 cm beyond the tip of the Tuohy needle and tunneled away from the surgical incision (Fig. 45.3, Video 45.1).

LITERATURE REVIEW AND EVIDENCE

Cadaver studies have consistently shown spread of dye staining of both lateral and anterior branches of intercostal nerves from T7 to T10. Studies have shown dermatomal sensory blockade of T6 to T10 at the anterior axillary line and T6 to T9 at the midclavicular reduction in opioid consumption postoperatively.

INDICATIONS

All supraumbilical procedures are as follows: chevron incisions for hepatobiliary surgery, open nephrectomy, splenectomy, and open cholecystectomy.

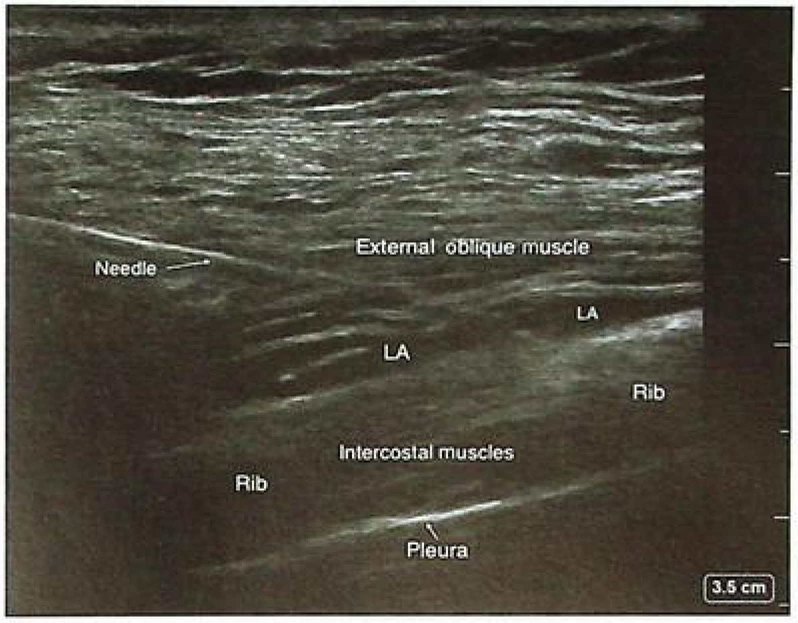


Fig. 45.2 Sagittal ultrasound image of the external oblique intercostal block showing the needle tip on rib 6 elevating the external oblique muscle off the rib and intercostal muscles with local anesthetic *(LA)* injection.

Fig. 45.3 External oblique intercostal catheter placed postoperatively for left subcostal incision in a patient for nephrectomy.

CLINICAL DISCUSSION INCLUDING PROS AND CONS OF THE BLOCK

Neuraxial block is the gold standard for abdominal surgeries, but there are concerns about hemodynamic instability, anticoagulation, urinary retention, and restriction of ambulation. The EOIFP block may be a valuable therapeutic option in the management of patients with upper abdominal surgeries, especially in obese patients, where neuraxial, TAP, and erector spinae plane block techniques can be more challenging.

The potential advantages of the EOIFP block are that it is a superficial block; it provides coverage to the lateral upper abdominal area; and the needle/catheter insertion sites are distant from the site of surgery compared with the other abdominal fascial plane blocks. Thus this block has a huge advantage for liver transplant patients who are coagulopathic and in need of high-quality analgesia.

Like other fascial plane blocks, the limitation of the EOI block is that it lacks visceral analgesic coverage. The EOIFP block also does not extend below the umbilicus reliably. There is a potential risk of pneumothorax and LA systemic toxicity.

PEARLS

- Pneumothorax is the major complication of this block.
- Proper counting of the ribs is essential for block success.
- When performing the block, aim the tip of the needle at the corresponding rib as protection from further advancement.

Suggested Reading

Coşarcan SK, Erçelen Ö. The analgesic contribution of external oblique intercostal block: case reports of 3 different surgeries and 3 spectacular effects. *Medicine (Baltimore).* 2022;101(36):e30435.

Elsharkawy H, Kolli S, Soliman LM, et al. The external oblique intercostal block: anatomic evaluation and case series. *Pain Med.* 2021;22(11):2436–2442. https://doi.org/10.1093/pm/pnab296.

Hamilton DL, Manickam BP. Is a thoracic fascial plane block the answer to upper abdominal wall analgesia? *Reg Anesth Pain Med.* 2018;43(8):891–892.

Hebbard P. Subcostal transversus abdominis plane block under ultrasound guidance. *Anesth Analg.* 2008;106:674–675.

Rectus Sheath Block and Catheter in Adults 46

Samantha Stamper and John Seif

Key Points

- A high-frequency transducer is preferred for this block.
- The rectus sheath block provides periumbilical somatic analgesia from levels T9 to T11 and is used for surgeries involving a periumbilical incision.
- The block is performed at or slightly above the level of the umbilicus to avoid injury to the deep epigastric artery.
- Direct visualization of the nerves is not required to perform a successful rectus sheath nerve block; instead, identification of the fascial plane is paramount.
- The branches of the thoracolumbar nerves do not cross midline; therefore in order to provide a bilateral block, a right and left rectus abdominis block is performed.

SONOANATOMY

The rectus abdominis muscle receives sensorimotor innervation through thoracolumbar spinal segmental nerves from spinal levels T7 to L1. These nerves travel in the fascial plane between the internal oblique and the transversus abdominis muscles to the anterior abdominal wall.

At the lateral border of the rectus abdominis, the aponeuroses of the external oblique, internal oblique, and transversus abdominis muscle combine to form the linea semilunaris. At this lateral aspect, the thoracolumbar spinal segmental nerves pierce through the rectus abdominis muscle and create a nerve plexus to provide motor and sensation to the rectus abdominis muscles (Fig. 46.1). The common aponeurosis splits into anterior and posterior aponeuroses that encase the rectus abdominis muscle and nerve plexus in a sheath.

The rectus sheath is composed of anterior and posterior aponeuroses that bind the rectus abdominis muscle and form the rectus sheath. At midline, the anterior and posterior aponeuroses of the right and left rectus abdominis muscles combine to form the linea alba, a thick fibrous band of fascia. The thoracolumbar spinal nerves do not cross the linea alba; therefore a rectus sheath block requires a bilateral block or two separate catheters to be performed.

It is important to note that the deep epigastric artery provides blood supply to the rectus abdominis muscle and enters the muscle body at the level of the arcuate ligament. To avoid this, the block should always be performed at or above the level of the umbilicus. Beneath the rectus sheath, the peritoneal cavity can be appreciated with the presence of abdominal contents, which can usually be observed during the block.

TECHNIQUE

With the patient in a supine position, a high-frequency linear ultrasound probe is placed in a transverse position just lateral to the umbilicus (Fig. 46.2). The lens-shaped rectus abdominis muscle is identified below the ultrasound transducer, with attention to identifying and avoiding the deep epigastric artery during the procedure (Fig. 46.3). The authors recommend sliding the probe lateral from this position to identify the linea semilunaris. This location allows for a more direct visualization of the posterior rectus sheath and a more superficial access to the posterior fascial plane (Fig. 46.4). Direct identification of the intercostal nerves is not required in order to complete a successful rectus sheath block.

In this position, the block needle is inserted in-plane from the lateral side of the transducer at a 45-degree angle through the anterior abdominal fascia and rectus abdominis muscle body. When the needle tip is near the posterior rectus sheath, an aspiration test followed, by injection of a small amount of local anesthetic (LA) or saline, can elucidate the exact location of the needle tip. For placement of catheters, the authors recommend using normal saline for this step in order to conserve LA for ultrasound visualization of LA spread through the nerve catheter after placement. If intramuscular, the needle is carefully advanced 1 to 2 mm, followed by an aspiration test and injection until a satisfactory position is obtained.

Once confirmed, 10 to 20 mL of LA is injected after aspiration. During injection, advancement of the needle under direct ultrasound visualization separates the rectus abdominis from the posterior fascial sheath to create a lens-shaped space and ensure coverage of intercostal nerves while avoiding displacement of the needle as the rectus abdominis muscle is separated from the posterior fascial sheath. The authors recommend optimizing this space prior to attempting catheter insertion (Video 46.1).

Upon placement of a catheter, a negative aspiration, injection of LA through the catheter, and visualization of an expanding cavity confirm correct placement.

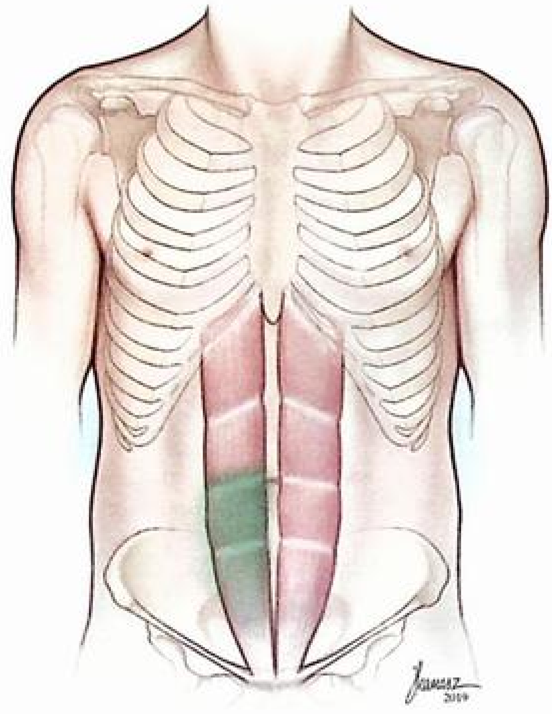


Fig. 46.1 A representation of the sensory distribution of the T9 to T11 thoracolumbar spinal nerves in the rectus abdominis muscle.

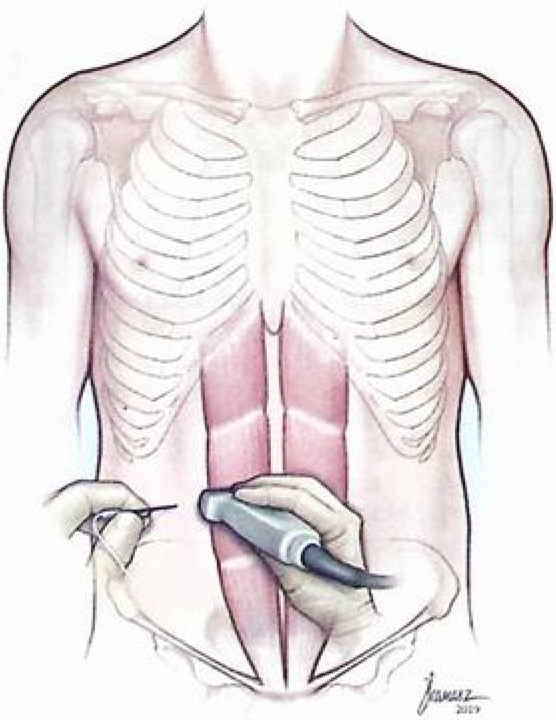


Fig. 46.2 A depiction of the preferred orientation to perform a rectus sheath block.

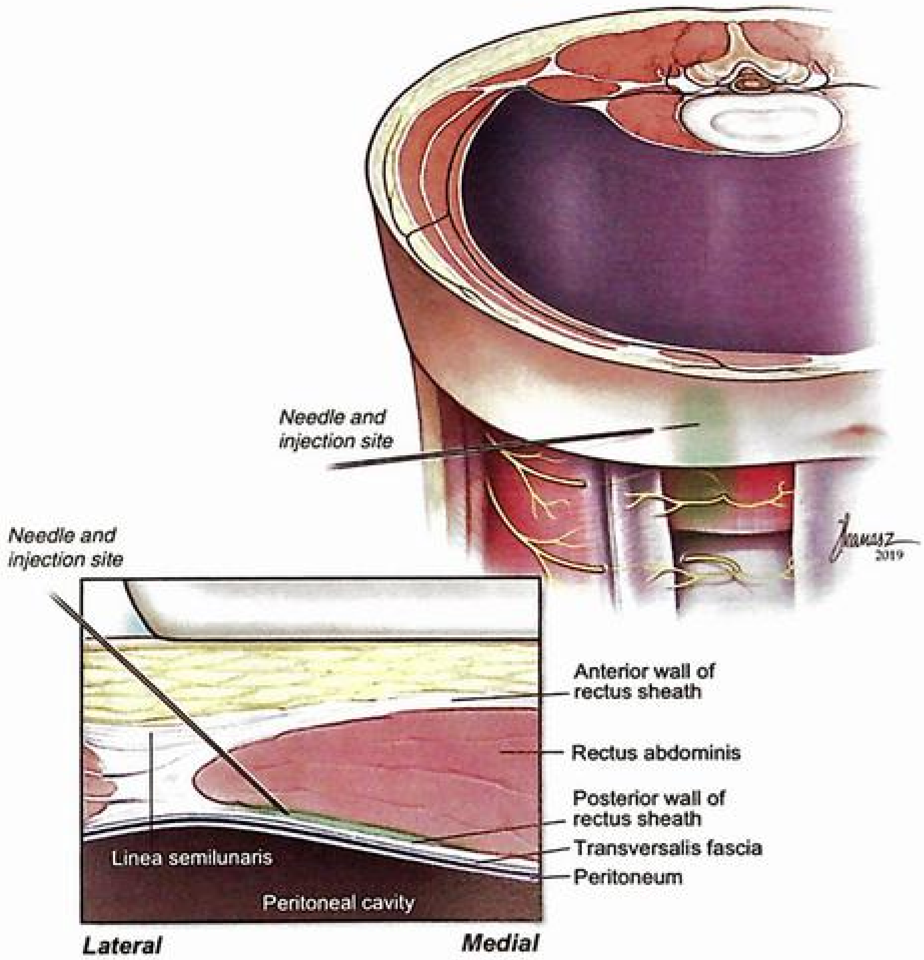


Fig. 46.3 A coronal section showing the path the thoracoabdominal nerves travel to the rectus abdominis muscle. Next to it is an illustration of an ultrasound image at the level of the umbilicus and the anterior and posterior rectus sheath components encasing the muscle.

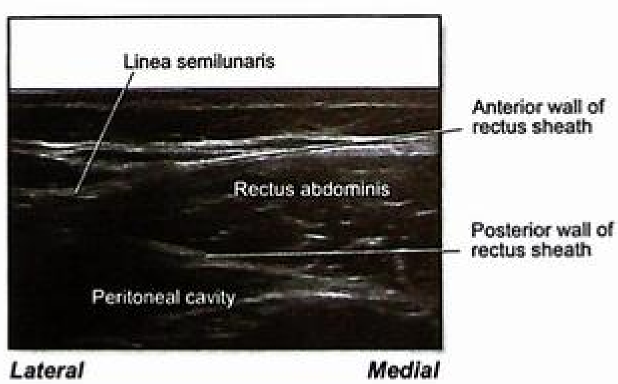


Fig. 46.4 An ultrasound image showing an ideal view to perform a successful block.

PEARLS

- The block needle should be inserted from the lateral side of the transducer at a 45-degree angle or shallower in order to avoid penetration through the peritoneum.
- Normal saline should be used for placement of rectus sheath catheters in order to conserve LA for direct ultrasound visualization through the catheter when placed.
- Once proper needle insertion is observed under ultrasound (rectus abdominis separating from posterior rectus sheath), 10 to 20 mL of LA can be injected after a negative aspiration.
- During injection, advancement of the needle into the newly formed lens-shaped space using direct ultrasound visualization separates the rectus abdominis from the posterior fascial sheath to ensure coverage of the intercostal nerves.

47 Transversus Abdominis Plane Block (Classic Approach)

Loran Mounir-Soliman

Key Points

- The transversus abdominis plane (TAP) block is a tissue plane block dependent on the adequate spread of local anesthetics through the plane—accordingly, a minimum volume of 20 mL usually is needed for an effective block.
- Frequently injecting small, incremental amounts of saline while advancing the needle can identify the progress of the needle tip through the various tissue planes.
- When performed appropriately, the TAP block is very safe and devoid of major complications and can be placed safely in anesthetized patients.
- For midline incisions, bilateral blocks are needed; the rectus sheath block may be considered as an alternative.

RELEVANT ANATOMY

The ventral rami of the lower six thoracic nerves (T7–L1) emerge through the intervertebral foraminae to pass through the corresponding intercostal spaces and enter a fascial plane between the transversus abdominis and the internal oblique muscles of the abdominal muscular wall (known as the TAP), accompanied by blood vessels. They follow the curvilinear course of this neurovascular plane to reach the anterior abdominal wall as far as the semilunar line at the lateral border of the rectus abdominis muscle (Fig. 47.1).

The abdominal wall consists of three muscle layers: the external oblique, the internal oblique, and the transversus abdominis muscles and their associated fascial sheaths. The three muscles, as well as the parietal peritoneum, are innervated by the ipsilateral ventral rami of T7 to L1. The external oblique and the anterior lamella of the internal oblique aponeurosis pass anteriorly to the rectus muscle, forming the anterior rectus sheath. The aponeuroses from the posterior lamella of the internal oblique muscle and the transversus abdominis muscle pass posteriorly to the rectus muscle, forming the posterior layer of the sheath. At this point, the ventral rami of the lower thoracic nerves are located between the posterior rectus sheath and the rectus muscle. They run medially within the sheath before perforating the muscle anteriorly, forming the anterior cutaneous branches. Along their course through the TAP, the lower thoracic spinal nerves give origin to the lateral cutaneous branches posterior to the midaxillary line. Within the TAP, the nerves communicate with each other, forming neural plexuses in close proximity to the vessels in this neurovascular plane.

TECHNIQUE

A linear high-frequency probe (8–12 MHz) usually is used for optimal identification of the different muscle layers and their corresponding fascial sheaths. However, a curvilinear lower-frequency probe (2–5 MHz) may be used in obese patients. The block can be performed in the supine or lateral position, with the side to be blocked upward and a wedge beneath the lower side in order to stretch the flank on the upper side. The lower costal margin and the iliac crest are identified, and the probe is placed in a transverse orientation between the two bony landmarks at the midaxillary line. The probe is moved both cephalad and caudad to get the best view of the three muscles. Scanning too medially may show only two muscle layers, because the external oblique muscle forms an aponeurosis; also, scanning more posteriorly may encounter the large latissimus dorsi muscle, which may confuse the view of the muscles.

The fascial layers appear as hyperechoic structures under ultrasound, giving the muscles their characteristic multiple striations.

A blunt needle is introduced from the posterior edge of the probe with the in-plane technique (parallel to the ultrasound beam) and advanced in a medial anterior direction through the skin, subcutaneous fat, and external and internal oblique muscles to reach the interfascial layer between the internal oblique and transversus abdominis muscles (TAP). The endpoint of the needle should be superficial to the transversus abdominis muscle. Deeper to this muscle, there is a layer of preperitoneal fat separating it from the peritoneum and the bowels, which are often identified by their peristaltic movements. A blunt needle is preferred to appreciate the tactile "pop" when crossing each fascial layer. The intramuscular location of the needle within the internal oblique muscle is identified by retraction of the needle when it is released, as well as swelling of the muscle with injection instead of separation from the transversus abdominis (Video 47.1).

INDICATIONS

- The TAP block potentially can provide unilateral analgesia to the skin, muscles, and parietal peritoneum

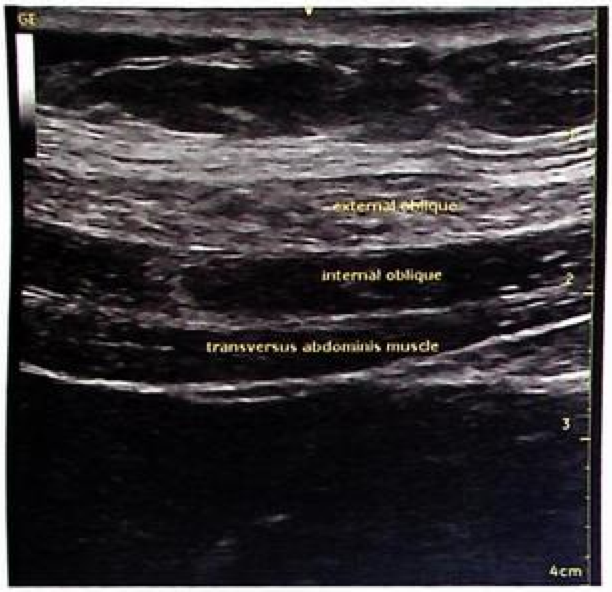


Fig. 47.1 Ultrasound still of the anatomy of the transversus abdominis plane block.

of the anterior abdominal wall, although the extent of the block has been reported to be variable in different studies.

- Bilateral blocks have been used for midline and transverse incisions.
- Classical TAP has been reported to provide adequate analgesia following cesarean section, hysterectomy, hernia repair, kidney transplant, colostomy closure, and multiple other lower abdominal surgeries.
- Both single-shot and continuous catheters have been used successfully.
- The TAP block has been used for patients with chronic abdominal pain to identify somatic pain originating from the abdominal muscular wall and the parietal peritoneum versus visceral pain, which is transmitted via sympathetic innervation instead.

PEARLS

- Placement of the needle as far posteriorly as possible (by the midaxillary line or behind) has the theoretical advantage of blocking the lateral cutaneous branches before they exit the TAP.
- The internal oblique muscle is usually identified as the largest muscle among the three abdominal muscles.
- The transversus abdominis muscle sometimes shows as a hypoechoic band that can be confused with the underlying preperitoneal fatty layer. The peristaltic movements of the bowels within the preperitoneal fatty layer can identify it from the muscular layer.
- An out-of-plane technique can be more suitable for obese patients when the needle path is not seen easily.

Subcostal Transversus Abdominal Plane Block 48

Ehab Farag

Key Points

- The subcostal transversus abdominal plane (TAP) approach is very useful for supraumbilical procedures.
- The most cephalad sensory dermatomal spread is T8.
- The bilateral continuous catheter infusion can be used in upper abdominal surgeries where epidural analgesia is contraindicated or has failed.
- The key to success of this technique is the proper identification of the fascial plane between the transversus abdominis and rectus abdominis muscles.

SONOANATOMY

There are four paired muscles of the anterolateral abdominal wall: the anterior rectus abdominis muscles and, from deep to superficial, the three lateral muscles: transversus abdominis, internal oblique, and external oblique muscles. It is only in the lateral abdomen that the three fleshy muscle bellies overlie one another, because medially they become an aponeurosis. Under ultrasound, the rectus abdominis can be easily identified and, by moving laterally, the transversus abdominis muscle will appear beneath the rectus abdominis muscle. The transversus abdominis has two key features on ultrasound imaging. It is usually darker (more hypoechoic) than other muscles, and it passes beneath the rectus abdominis muscle (Fig. 48.1).

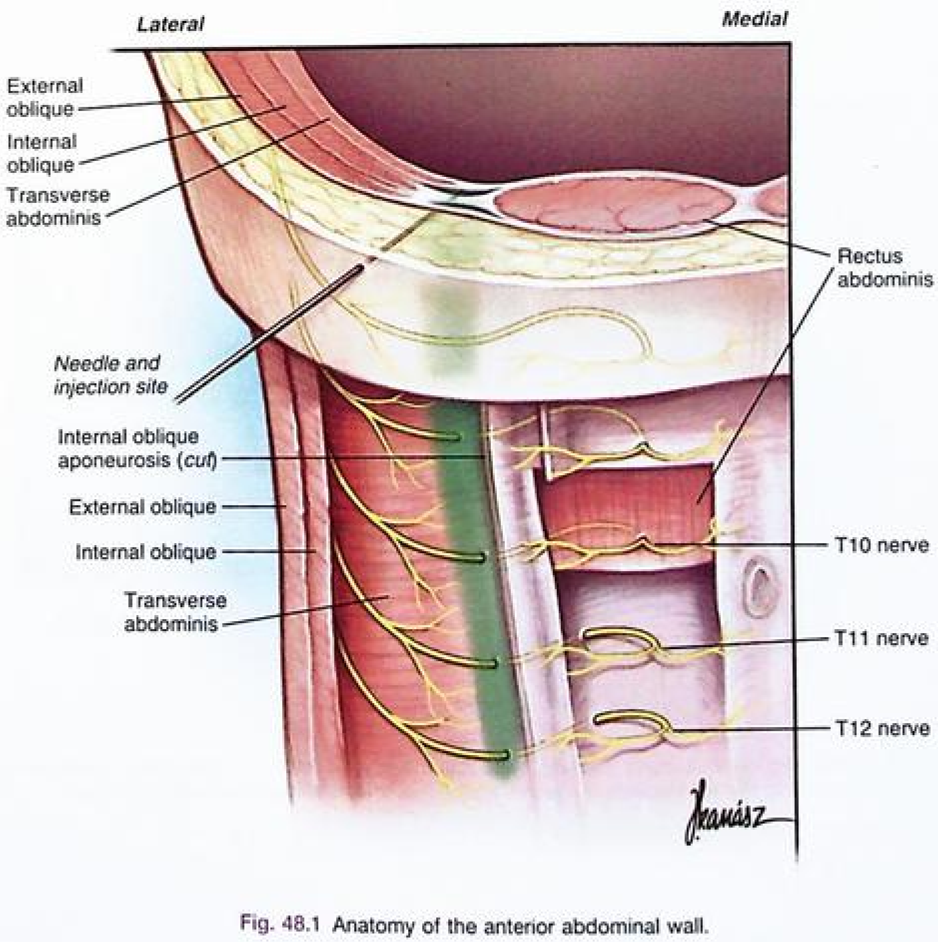


Fig. 48.1 Anatomy of the anterior abdominal wall.

TECHNIQUE

The linear ultrasound probe will be placed over the anterior abdominal wall immediately inferior and parallel to the costal margin. The rectus abdominis muscle will be identified medially, and then the probe will be moved laterally until the transversus abdominis muscles are also identified. Further lateral movement of the ultrasound probe will demonstrate the lateral abdominal wall muscles (external and internal obliques and transverse abdominis muscles) to provide further confirmation of sonographic anatomy. Using the in-plane approach, the needle will be inserted from the posterolateral position and advanced anteromedially until its tip is in the fascial plane between the rectus abdominis and transverse abdominis muscles. The author usually injects 20 mL of ropivacaine 0.5% in each side of the bilateral block (Figs. 48.2–48.4).

INDICATION

- Used in supraumbilical procedures.
- Bilateral continuous subcostal TAP can be used in lieu of epidural analgesia for midline supraumbilical procedures.

PEARLS

- When performing the procedure on the right side, care should be taken not to injure the liver, especially in patients with hepatomegaly or a thin patient.
- For the single-shot technique, the author prefers to use 22-gauge needles; however, in the continuous catheter technique, the author inserts the catheter via a 17- to 18-gauge Tuohy needle.

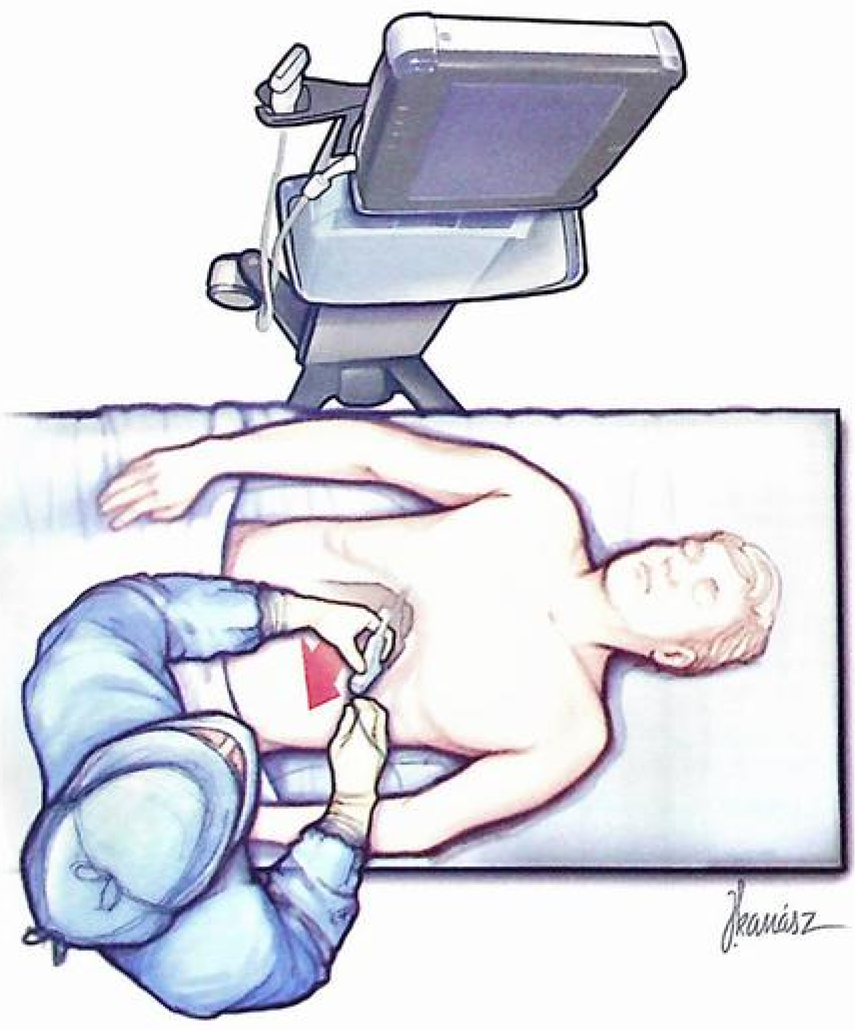


Fig. 48.2 Position of the patient and the ultrasound machine. Note that the probe position is immediately inferior and parallel to the costal margin. Moving the probe laterally will visualize the rectus abdominis and transverse abdominis muscles.

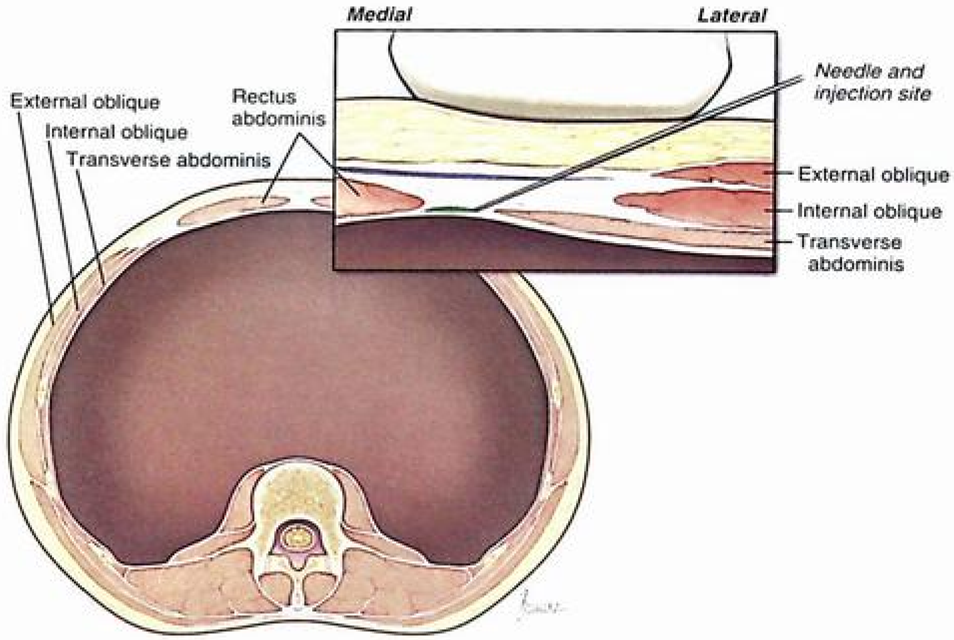


Fig. 48.3 The in-plane technique for the subcostal transversus abdominal plane block. The needle direction is from lateral to medial.

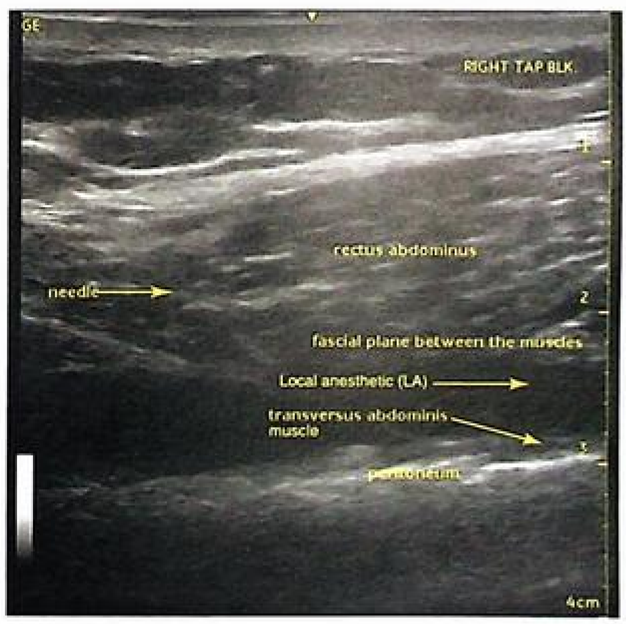


Fig. 48.4 Ultrasound image of the subcostal transversus abdominal plane *(TAP)* block with needle.

49 Quadratus Lumborum Block

Hesham Elsharkawy and Ehab Farag

Key Points

- The quadratus lumborum (QL) block is a novel approach for managing postoperative pain in patients undergoing abdominal and hip surgeries.
- The sensory dermatomal coverage of only the anterior approach technique of the QL block can spread toward the thoracic paravertebral space.
- There is currently no general consensus on the mechanism of action of the QL blockade.
- This is a "tissue plane" block and thus requires a large volume of local anesthetic to obtain a reliable block.

PERSPECTIVE

The QL block was developed from the transversus abdominis plane (TAP) block to accomplish more extensive post-surgical analgesia. In 2015, Blanco et al. introduced a modified QL block technique with an injection site at the posterior border of the QL muscle. Theoretically, QL blocks might give better and longer-lasting analgesia compared with TAP blocks due to the proposed spread to the thoracic paravertebral space and the sympathetic nerves in the thoracolumbar fascia (TLF).

There are three techniques for the QL block. In the QL 1 technique, the injection is at the lateral edge of the QL muscle, superficial to the transversalis fascia (TF). In QL 2, the injection is made at the posterior edge of the QL muscle, behind the middle layer of the TLF. Finally, in the anterior transmuscular QL block (the QL 3 technique), the injection will be made into the anterior TLF plane between the QL and psoas muscles at the L4 vertebral level.

SONOANATOMY

The ultrasound probe is placed in the posterior axillary line between the iliac crest and the costal margin (Fig. 49.1). The TF covers the peritoneal surface of the transversus abdominis muscle and continues posteromedially, covering the anterior side of the investing fascia of both the QL and psoas major (PM) muscles. The QL muscle is generally visualized as hypoechoic relative to the hyperechoic PM muscle, located anteromedial to the QL muscle.

The QL muscle, surrounded by the TLF, is the target of the injection, not the muscle itself. The three-layered model of TLF comprises the anterior, middle, and posterior layers. The posterior layer surrounds the erector spinae muscles; the middle layer of the TLF passes between the erector spinae muscles and the QL muscle; and the anterior layer is thin and lies anterior to both the QL and PM muscles. The anterior layer of the TLF turns posterior between the QL and the psoas and attaches to the anterior aspect of each transverse process (Fig. 49.2).

At the L3 to L4 levels, the transverse process of the third or fourth lumbar vertebrae, erector spinae muscle, PM muscle, and the QL muscle can be identified as the so-called "shamrock sign" as the QL muscle attaches to the tip of the transverse process.

The external oblique muscle abuts the latissimus dorsi muscle. With the transversus abdominis muscles, the internal oblique forms the aponeurosis of the middle TLF (lateral raphe) posterior to the QL muscle (Fig. 49.2).

TECHNIQUES

- ***Lateral QL*** (previously referred to as the QL 1 block). The needle can be directed from anterior to posterior toward the junction of the tapered transversus abdominis muscle and QL muscle; local anesthetic (LA) will then be deposited in the lateral border of QL muscle at the junction of the TF and penetrate the aponeurotic attachment of the transversus abdominis muscle (lateral raphe) (Figs. 49.3 and 49.4, Video 49.1).
- ***Posterior*** (previously referred to as the QL 2 block). By advancing the needle more posteriorly, LA can be deposited posterior to the lateral edge of the QL muscle, between the QL muscle and the erector spinae and latissimus dorsi muscles (Figs. 49.3 and 49.4).
- ***Anterior*** (previously referred to as the transmuscular or QL 3 block). The needle can be advanced either posteriorly through the erector spinae muscle or anteriorly through the latissimus dorsi muscle, and then through the muscle (transmuscular approach) to deposit the LA in the fascial plane between the QL and PM muscles (Figs. 49.3 and 49.4).
- ***Subcostal*** (paramedian oblique sagittal). The ultrasound transducer is positioned lateral to the lumbar spinous process at the L1 to L2 levels. Using a curvilinear transducer with the orientation marker of the ultrasound directed cranially, the probe is

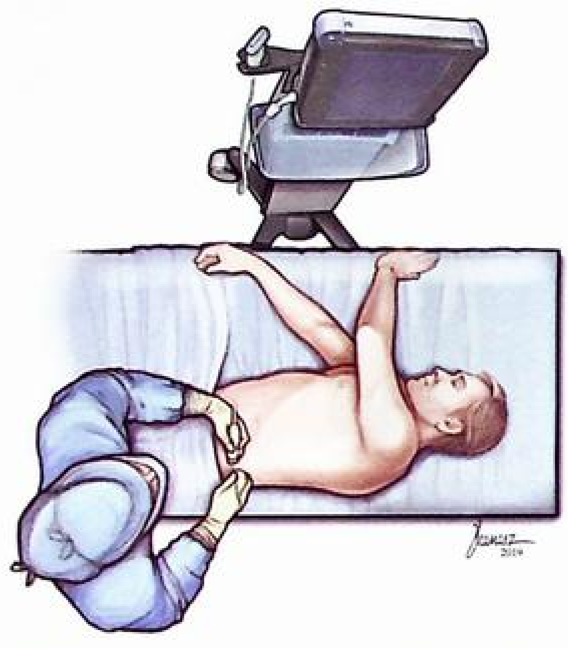


Fig. 49.1 Patient in the lateral decubitus position for quadratus lumborum blocks.

tilted slightly medially. The needle is advanced in the plane with ultrasound in a caudal to cephalad direction, through the latissimus dorsi and QL muscles. Then LA is deposited anterior to the QL muscle, between the QL muscle and the anterior layer of the thoracolumbar fascia (ATLF)/TF, observing spread in a cephalad direction close to the last rib, a lunar-shaped distribution of LA with anterior displacement of the ATLF (Figs. 49.5 and 49.6).

- ***Suprailiac anterior.*** Above the iliac crest, a curvilinear transducer is placed in a transverse orientation with slight medial and caudal angulation to obtain a transverse oblique view at the L5 transverse process. The ultrasound probe is further tilted so the lateral end of the ultrasound probe is more cranial than the medial side of the probe to avoid the acoustic shadow of the iliac crest. The needle is advanced in-plane in a lateral-to-medial direction through the latissimus dorsi and QL muscle to position the tip between the QL and PM muscles, close to the transverse process. Spread is deemed appropriate when the injectant is seen

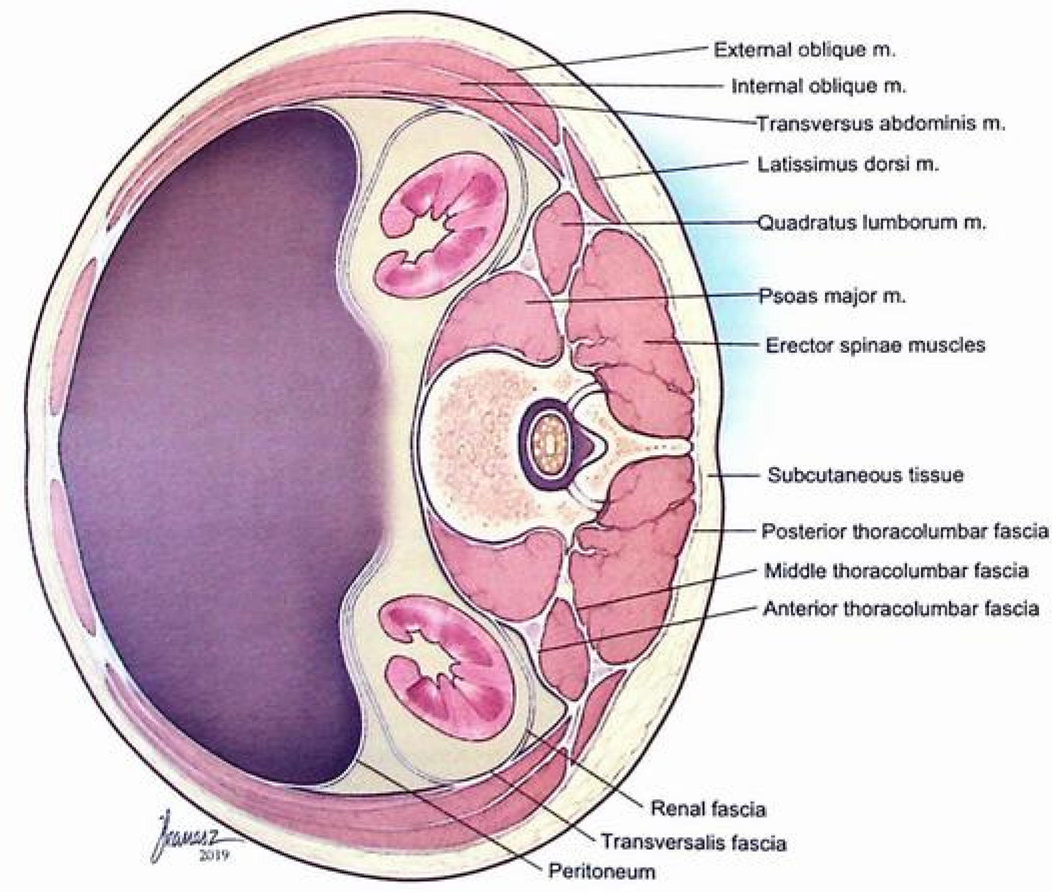


Fig. 49.2 A schematic illustration of cross section showing the quadratus lumborum muscle with the different layers of the thoracolumbar fascia (three-layered model).

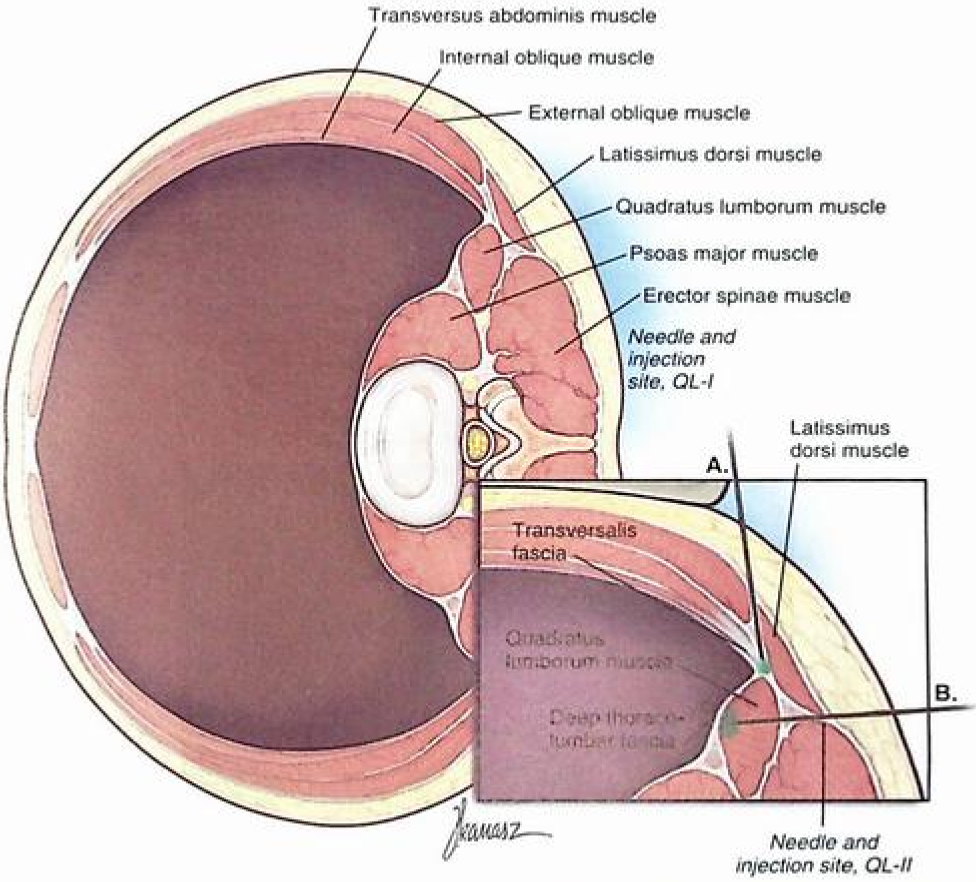


Fig. 49.3 A schematic illustration showing the different sites of injection of local anesthetics in relation to the quadratus lumborum muscle.

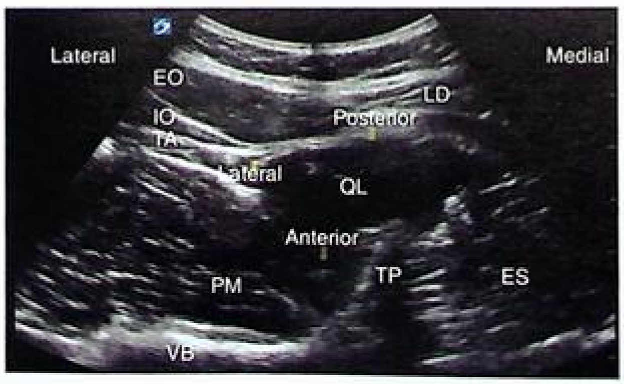


Fig. 49.4 Ultrasound still showing the different sites of injection in relation to the quadratus lumborum muscle. *EO*, External oblique; *ES*, erector spinae; *IO*, internal oblique; *LD*, latissimus dorsi; *PM*, psoas major; *QL*, quadratus lumborum; *TA*, transversus abdominis; *TP*, transverse process; *VB*, vertebral body.

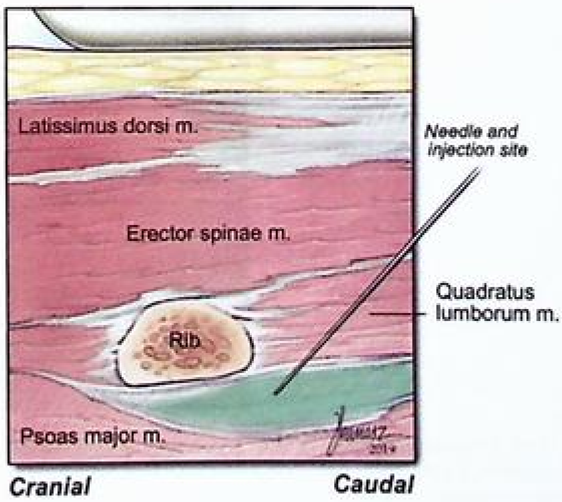


Fig. 49.5 Schematic representation of the subcostal approach

between QL and PM muscles and tracked medially toward the L5 transverse process (Figs. 49.7 and 49.8). This approach blocks T10 to L3 nerve territories and has clinical utility for analgesia in hip surgery (Figs. 49.7 and 49.8).

PEARLS

- The QL muscle is attached to the transverse process which once identified, provides orientation for the operator.
- If the QL muscle is small and difficult to delineate, the ipsilateral hip joint is abducted and laterally flexed toward the same side of the block to contract the QL muscle; this temporarily thickens the QL muscle.
- While performing the block, especially with the subcostal approach, it is common to visualize the lower pole of the kidney and lower lobe of the liver and spleen; great caution should be taken to avoid any visceral injury.
- The QL muscle acts like a bed for the kidney, which helps to identify the QL muscle.
- Apply color Doppler before inserting the needle to detect the abdominal branches of the lumbar arteries on the posterior aspect of the QL muscle or any other vessels close to the transverse process, and on the intended track of the needle.
- The tactile feedback (as pops) when encountering different fascial planes is not accurate in QL blocks due to the complexity of the anatomical planes, multilayered components of the TLF muscle, and the approach angle. Therefore visual confirmation

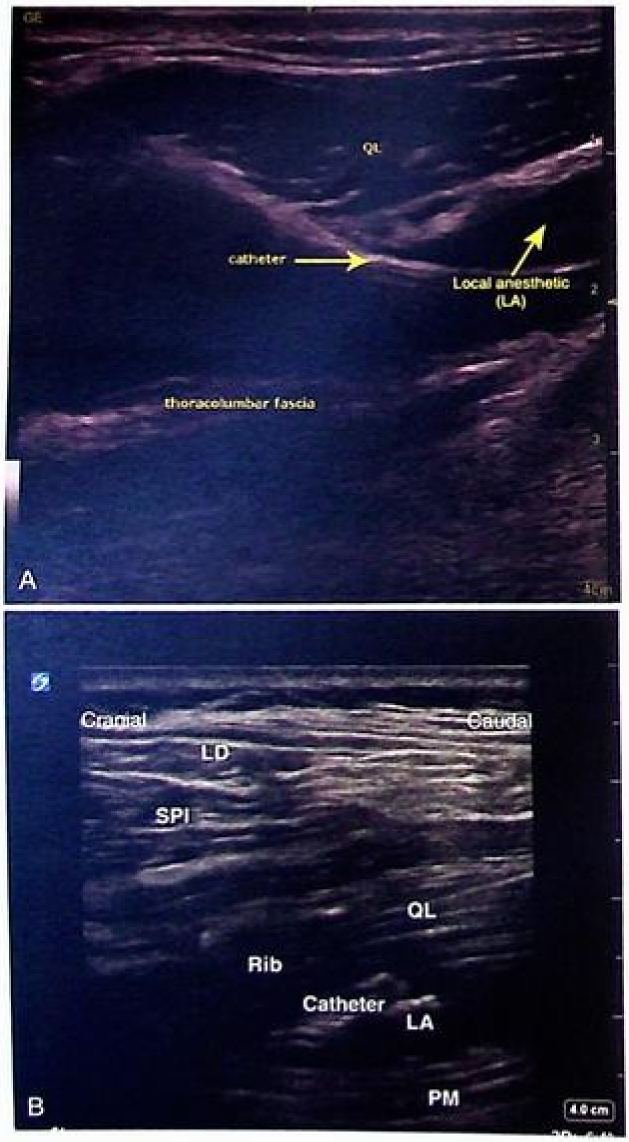


Fig. 49.6 Ultrasound picture of the local anesthetics *(LA)* spread and catheter placement through the subcostal approach. (A) Between the quadratus lumborum *(QL)* and thoracolumbar fascia. (B) Between the QL and psoas major *(PM)*. *LD*, Latissimus dorsi; *SPI*, serratus posterior inferior.

SECTION 7
Neuraxial Blocks

Ultrasound-Assisted Neuraxial Blocks

50

Nour El Hage Chehade, Adeeb Oweidat, and
Loran Mounir-Soliman

Key Points

- Prepuncture ultrasound scanning is helpful to determine the midline, the depth from the skin, the desired level, and rotation of the spine.
- There are limited outcome data on the real-time guidance with ultrasound for neuraxial blocks.
- The available evidence suggests that the use of ultrasound may improve the success rate from the first attempt, reduce the number of attempts, and improve patient comfort.
- The use of ultrasound for epidural access is a technically advanced procedure. It requires adequate experience with ultrasound scanning and ultrasound guidance of the needle at deep levels with a less-than-optimal angle of incidence.
- Thorough understanding of the neuraxial anatomy and conceptual visualization of the different echogenic structures are necessary for ultrasound scanning of the epidural space.

RELEVANT SONOANATOMY OF THE SPINE

There are a couple of challenges for ultrasound imaging of the spine and the neuraxial structures. The depth of the spine makes it less than optimal for the ultrasound beams to produce higher-resolution images. Also, the osseous structure of the laminae and articular processes conceal the underlying neuraxial structures of interest to perform the blocks. Accordingly, it is important to have a visual appreciation of the spine outline when scanning for neuraxial blocks. In general, scanning the vertebrae demonstrates three hyperechoic levels: the spinous process, the lamina, and the articular facet joint with the transverse process.

The spinous processes reflect the most superficial hyperechoic shadow closest to the skin. Careful scanning cephalad and caudad to the spinous process reveals an acoustic window representing the interspinous space occupied with the less echogenic interspinous ligaments. Careful examination of the deeper layer of the ligamentous structure shows the ligamentum flavum as a slightly more hyperechoic layer separated from another hyperechoic layer—the posterior dura—by the epidural space. The spinal canal underneath represents the next anechoic layer deeper to the posterior dura. On the deeper side of the spinal canal (anterior), the anterior dura with the postlongitudinal ligament form a hyperechoic structure called the *anterior complex*.

With the aforementioned echogenic characteristics of the neuraxial structures in mind, scanning the different levels of the spine leads to different views. These views also depend on the scanning plane and orientation of the ultrasound beam. There are four main planes for scanning the spine:

1. **Median sagittal plane:** A longitudinal scan along *the midline*, where the beam of the ultrasound is parallel to the long axis of the spine on top of the spinous processes (unless the spine is scoliotic).
2. **Paramedian sagittal plane:** A longitudinal scan parallel to the long axis of the spine but off the midline. The beams are usually on top of the transverse processes or the laminae, with the articular joints (facets) between the adjacent spines.
3. **Paramedian sagittal oblique plane:** Another longitudinal plane that is similar to the paramedian sagittal plane, with the probe tilted medially to direct the beams toward midline. The ultrasound beams usually travel across the laminae, with the intervertebral foraminae in between. *Access to the ligaments, dura, and spinal canal are usually accessed with the beam within the interlaminar windows.*
4. **Transverse axial view:** A transverse view where the beam of the ultrasound is perpendicular to the long axis of the spine. With this orientation, the ultrasound probe can be on top of the vertebra where the beams cross the spinous process, lamina, and transverse process. If the beam is steered cephalad or caudad by sliding or tilting the probe, an interspinous (acoustic) window is obtained. The ligaments, epidural space, and spinal canal can be visualized through this window.

TECHNIQUE

Except for the caudal block, the neuraxial scanning requires a low-frequency (2–5 MHz) curvilinear probe to see the depth of the target structures. In addition to the ability to scan deeper structures, the curved probe provides a divergent beam, giving a wider field of vision and helping to scan the different anatomic structures in a single view compared with the limited field of vision produced by the linear probe. The disadvantage of the curved probe is a lack of spatial resolution at deeper levels, making viewing the needle a challenge when performing the block. Scanning the spine for procedures can be performed in the sitting, lateral, and prone positions, depending on the level of the procedure to be performed.

CAUDAL EPIDURAL BLOCK

Because the sacral hiatus is a relatively superficial structure, a high-frequency linear probe (6–13 MHz) usually is used for caudal scanning. The block is performed in the prone position with a pillow under the pelvis. The ultrasound probe is placed in a transverse orientation (axial scan) to scan the sacral cornua as two hyperechoic, reversed U-shaped structures. The sacrococcygeal ligament connecting both cornua, forming the superficial boundary of the sacral hiatus, appears as a hyperechoic band. The anterior boundary of the sacral canal is formed by the posterior surface of the sacrum, which appears as another hyperechoic linear structure anterior (deep) to the sacrococcygeal ligament. The sacral hiatus appears as a hypoechoic space between these two described hyperechoic lines. With this view, the needle can be introduced in the middle of the probe, perpendicular to the ultrasound beams, out-of-plane approach, and targeting the sacral hiatus (Fig. 50.1). With the sacral hiatus and the sacrococcygeal ligament identified, the ultrasound probe can be rotated 90 degrees to the median sagittal plane scan. A long-axis view of the sacrococcygeal ligament and the sacral bony surface is reidentified, with the sacral hiatus between them. The needle is introduced with an in-plane approach from the caudal end of the probe to be able to

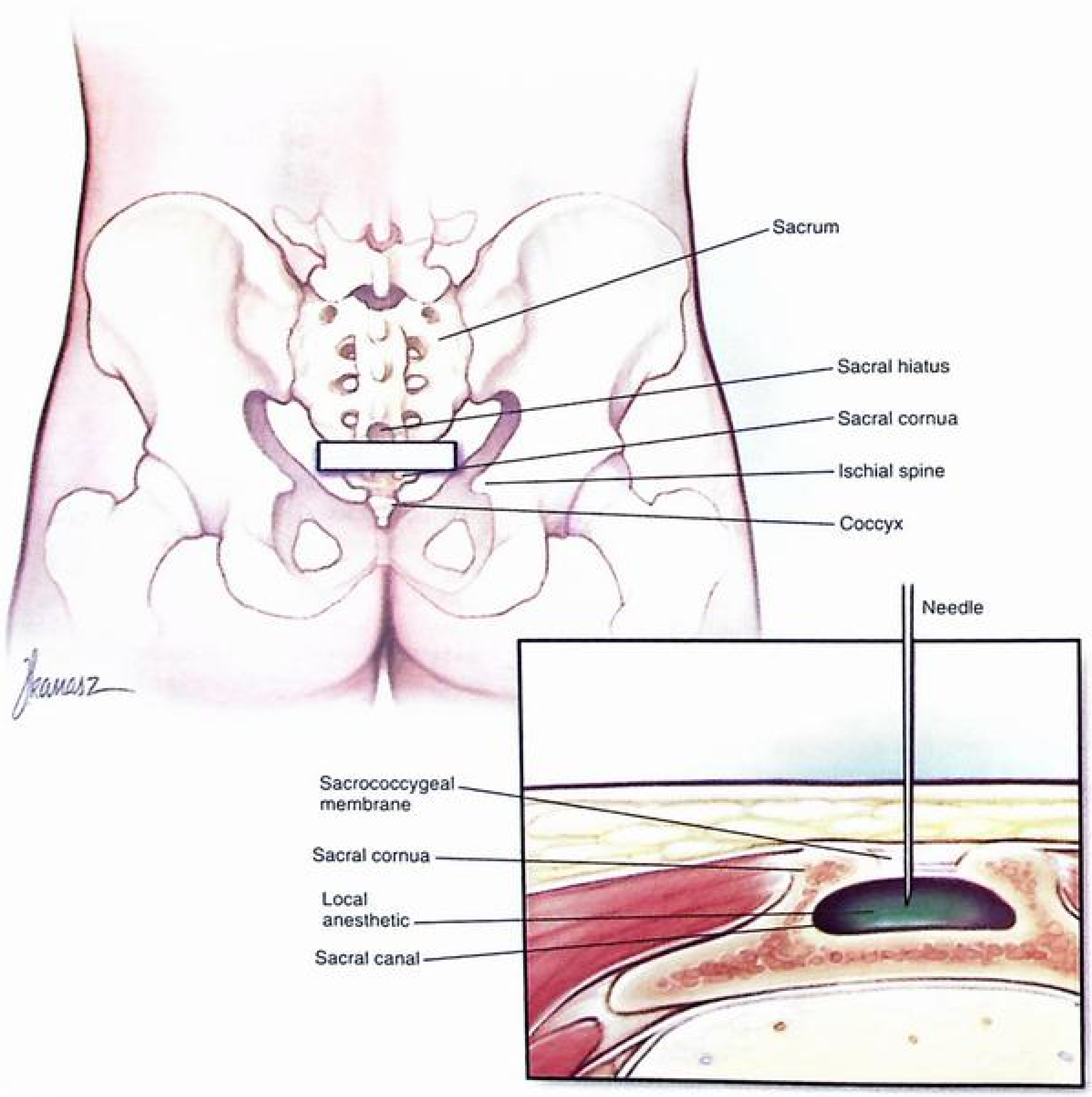


Fig. 50.1 The transverse approach to the caudal block. The needle is introduced in the out-of-plane direction in the middle of the probe targeting the sacral hiatus.

visualize the whole length of the needle. Crossing the tip of the needle through the sacrococcygeal membrane into the sacral canal is associated with a "pop" feeling, especially when using a blunt needle. The sacral bony structure impedes the ultrasound beams, making it hard to see the tip of the needle or the spread of the injection in the sacral canal (Figs. 50.2–50.4, Video 50.1).

LUMBAR NEURAXIAL BLOCKS

The lumbar epidural space can be scanned in the sitting, lateral, or prone position. The author's preference is to perform the scan in the sitting position to allow for maximum flexion of the spine (similar to the familiar landmark technique). A curved array probe is used for the ultrasonic views. Identification of the desired level for the procedure starts by placing the ultrasound probe parallel to the long axis of the sacrum in the midline to identify its flat surface. The probe is moved cephalad slowly to identify the intervertebral space between L5 and S1 as an interruption of the continuity of the sacral line. The ultrasound probe can be advanced longitudinally cephalad along this midline plane or turned 90 degrees to obtain a transverse view of the L5 to S1 interspinous space and then advanced cephalad, keeping the transverse orientation of the probe. Counting the spinous processes (hyperechoic shadows) and the interspinous spaces (hypoechoic windows) will help identify the desired level for the block.

Ultrasound can be used for all neuraxial procedures including epidural insertion and spinal anesthesia, as well as epidural blood patch. Literature has proven the benefit of ultrasound use in neuraxial procedures, especially for difficult placement, in elderly, obese, and scoliotic patients, and patients with anatomical abnormalities.

Ultrasonography can be used in two basic ways for the lumbar neuraxial block: preprocedural ultrasound scanning or real-time ultrasound guidance.

The key ultrasonographic views for the lumbar neuraxial block include the transverse midline interlaminar and parasagittal oblique views.

Transverse Axial View

This view is used mainly to identify the midline when the spinous process is not easily palpable. There are two basic transverse views for lumbar neuraxial block: the transverse spinous process view and the transverse interlaminar view.

The spinous process and the lamina on either side are seen as a hyperechoic reflection anterior to which there is a dark acoustic shadow that completely obscures the underlying spinal canal and thus the neuraxial structures. It looks like a bat shape. The probe can also be moved slowly caudad or cephalad to identify interspinous spaces. The ligamentous structure on the interspinous space is identified at the desired level by its characteristic echogenic appearance (as discussed previously), as well as the ability to see the deeper spinal canal. The needle is usually advanced from lateral to medial, parallel to the ultrasound beam (in-plane approach) until the tip of the needle is engaged in the ligamentum flavum. This approach is considered mainly in pediatrics. The epidural space is usually identified by the traditional loss of resistance technique by putting the ultrasound probe down (single operator) or through a second operator.

Tip: The lateral edge of the ultrasound probe can be lifted off the skin to obtain a needle insertion point closer to the midline (Figs. 50.5 and 50.6).

Parasagittal Views

There are five basic sagittal plane views of the lumbar spine, according to the probe location and direction. By moving the probe from a lateral position to the midline of the neuraxis, sagittal transverse process, sagittal articular process, sagittal lamina, and sagittal spinous process views can be obtained. From the probe position having the sagittal articular process view or sagittal lamina view, the parasagittal oblique view can be obtained by tilting the probe medially toward the midline. The parasagittal oblique view can be used for the determination of the optimal intervertebral level for puncture by identifying the intervertebral level at which the posterior complex (ligamentum flavum–dura complex) and the anterior complex (the posterior longitudinal ligament, posterior surface of the vertebral body, and intervertebral disc) are visualized most clearly. It is also useful to select the intervertebral level at which the interlaminar height is the largest. The position and orientation of the ultrasound probe used is illustrated in Fig. 50.7A,B.

The parasagittal view of the sacrum and lower lumbar spine helps to identify the level of the vertebrae and the level of the block. Place the ultrasound transducer over the sacrum to identify the flat sacral bone, L5 transverse process, and L5 to S1 intervertebral space. Mark the levels and the intended level of insertion.

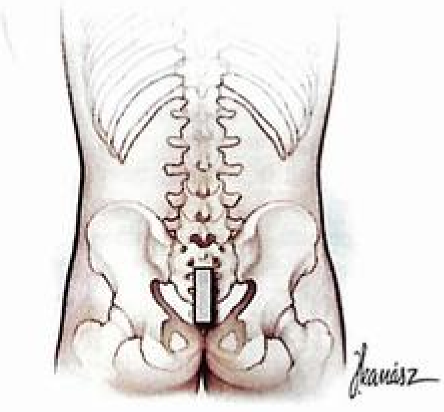


Fig. 50.2 The median approach to the caudal block. Note that the probe is in the long-axis view of the sacrococcygeal ligament.

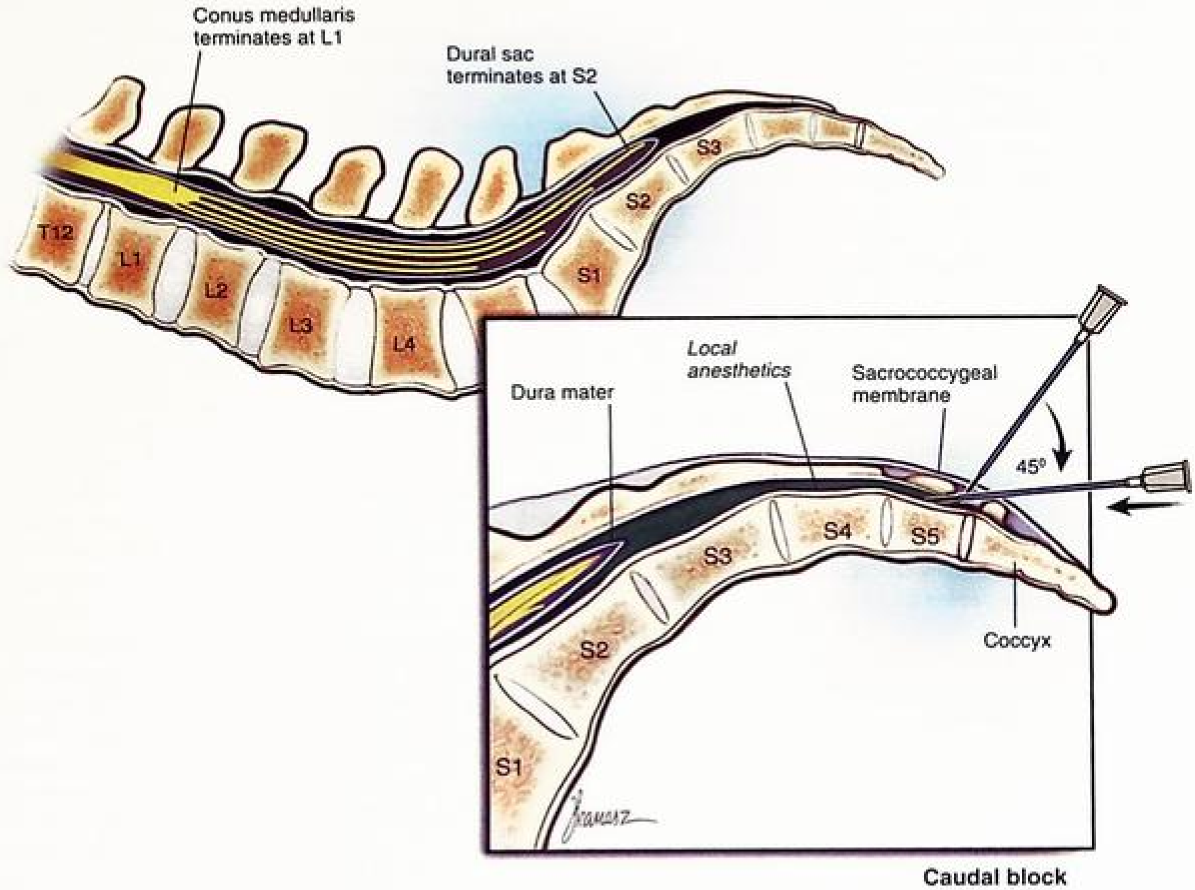


Fig. 50.3 Anatomy of the caudal block with the median approach. Note the in-plane position of the needle and its direction from caudal to cephalad position.

These views can be used to estimate the accurate vertebral level before the neuraxial procedure. Place the transducer in a parasagittal plane, a few centimeters lateral to the midline and cephalad to the sacrum. Move slowly toward the midline to identify the three different views mentioned earlier.

Parasagittal Transverse Process View. The first view scanned is the parasagittal transverse process view. The transverse processes of successive vertebrae appear as hyperechoic curvilinear structures with deeper hypoechoic shadows as dark fingerlike projections, often described as a "trident sign." The view is illustrated in Fig. 50.8.

Parasagittal Articular Process View. From the parasagittal transverse process view, slide the transducer medially until a continuous white hyperechoic line of humps is evident, known as the "camel hump sign."

Paramedian Sagittal Oblique View. After identifying the appropriate level (as described earlier), the probe is oriented in a paramedian sagittal oblique view (as discussed earlier) to allow identification of the epidural space through the interlaminar acoustic window. This is the most important view in sagittal scanning to identify interspaces and mark the skin appropriately. This view is also helpful in identifying the most patent spaces for a paramedian approach to a neuraxial procedure.

The epidural space shows as a hypoechoic space between two hyperechoic lines: the ligamentum flavum (posteriorly) and posterior dura (anteriorly). The spinal canal (intrathecal space) can be seen as an anechoic space anterior to the posterior dura, separating it from the anterior complex that appears as a hyperechoic structure.

The needle can be approached through either an in-plane technique from the caudad side of the probe or an out-of-plane technique from the medial side (midline) of the middle of the probe (Fig. 50.7).

THORACIC NEURAXIAL BLOCKS

The same concepts and ultrasound techniques are used for scanning the thoracic spine. However, due to the acute angulation and narrower interspinous and interlaminar spaces, the echogenic windows are more challenging to identify and the neuraxial structures are less visible. Paramedian scanning is the only relevant technique for approaching the thoracic epidural space (especially the midthoracic segments with the maximum angulation). Usually, ultrasound is used to guide the needle to the upper edge of the corresponding lamina, and loss of resistance is used to guide the needle through the ligamentum flavum and epidural space. Parasagittal windows can be obtained by beginning laterally with identification of ribs and pleura, then sliding medially, identifying the transverse process, articular process, and lamina.

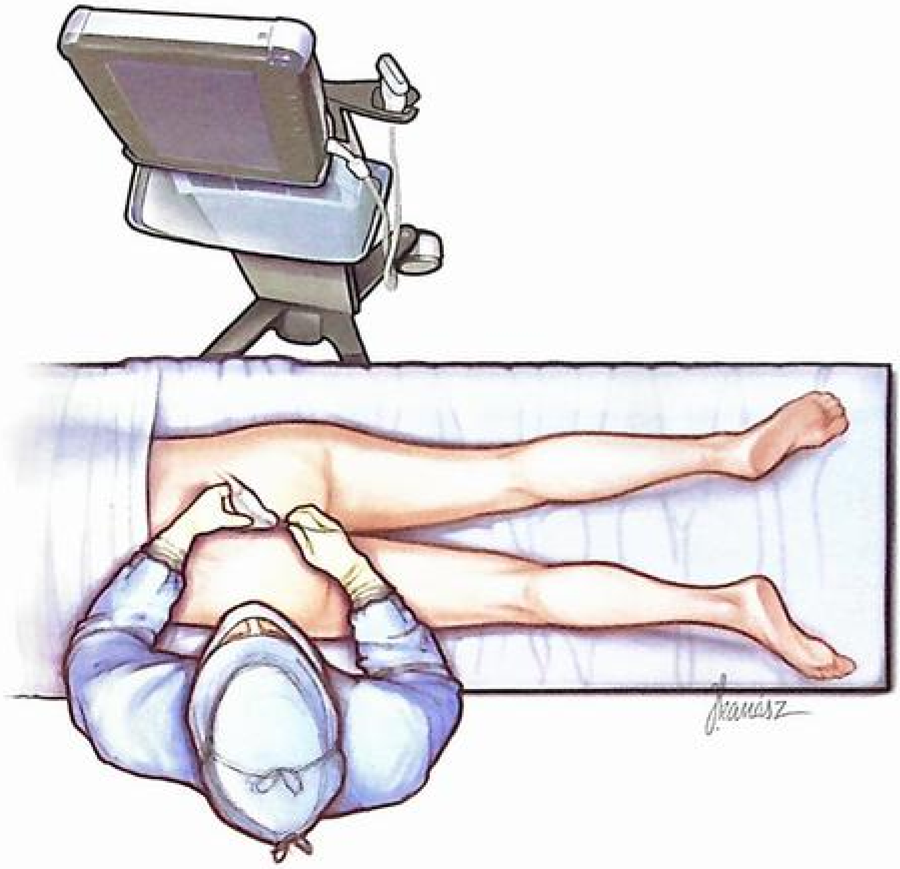


Fig. 50.4 Ultrasound machine position during caudal block performance. Note that the probe is in the long-axis view of the spine.

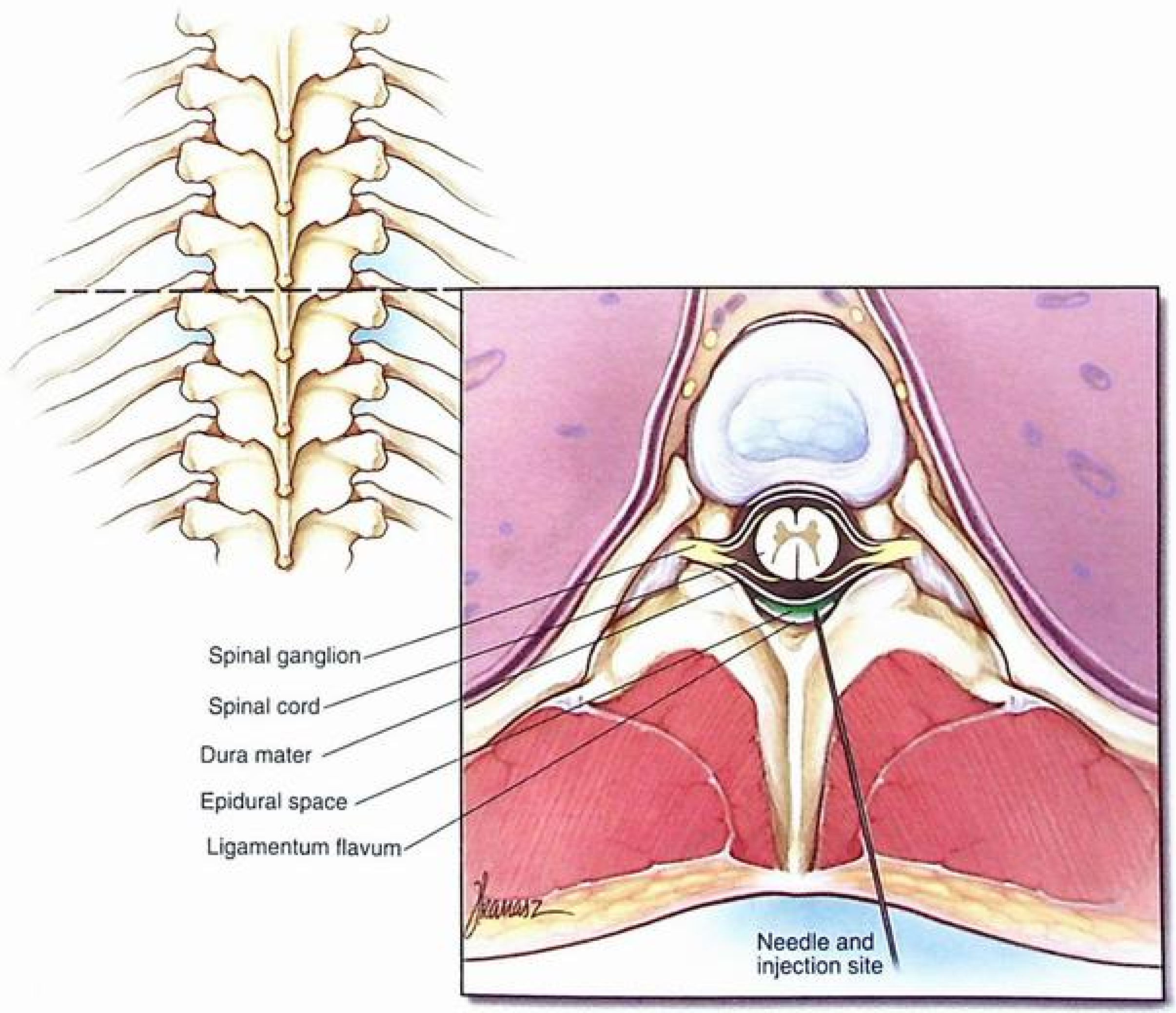


Fig. 50.5 The transverse axial view for the lumbar neuraxial block.

PEARLS

- Echogenic Tuohy needles can be helpful to identify the tip of the needle.
- Usually, loss of resistance is needed to confirm the position of the needle tip within the epidural space.
- In pediatric patients and thin patients, some changes can be identified with loss of resistance to saline, a characteristic of correct needle placement, mainly:
  - Widening of the epidural space with anterior displacement of the posterior dura.
  - Compression of the thecal sac can be seen occasionally.
  - Doppler flow of the injected fluid (mainly in small children).
- Spring-loaded syringes have been introduced to the market recently. They make it possible to perform real-time ultrasound-guided access to the epidural space, with loss of resistance confirmed by a single operator.

Fig. 50.6 Patient and ultrasound machine positions for the lumbar neuraxial block using the transverse axial view.

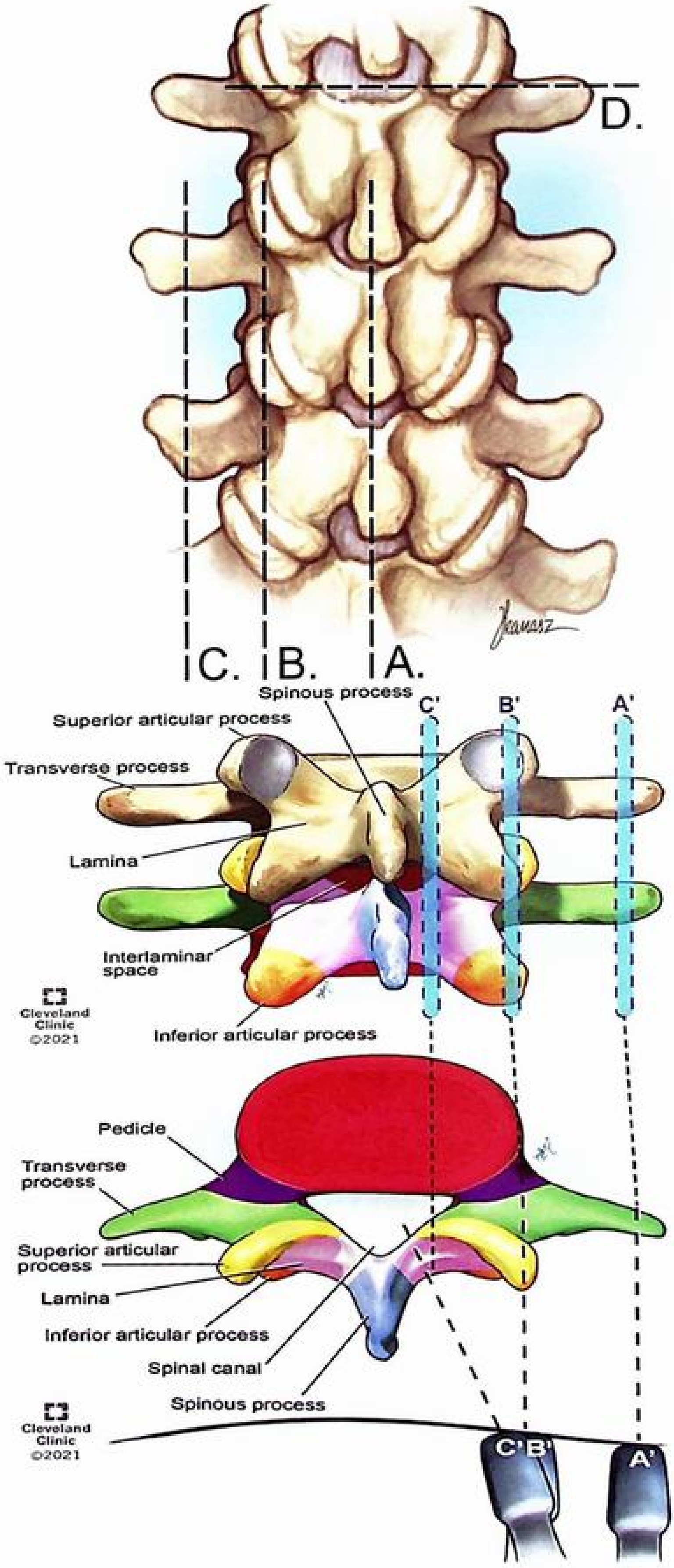


Fig. 50.7 (A) The paramedian sagittal oblique view for lumbar neuraxial block. *(A)* Midline longitudinal view: spinous process level. *(B)* Paramedian longitudinal view: lamina and articular process level. *(C)* Paramedian longitudinal view: transverse process level. *(D)* Transverse axial view: transverse process level. (B) Another picture illustrating parasagittal views. *(A')* Parasagittal transverse process view of the spine showing transverse processes. *(B')* Parasagittal articular process view showing the articular processes. *(C')* Parasagittal oblique interlaminar view showing the interlaminar acoustic windows

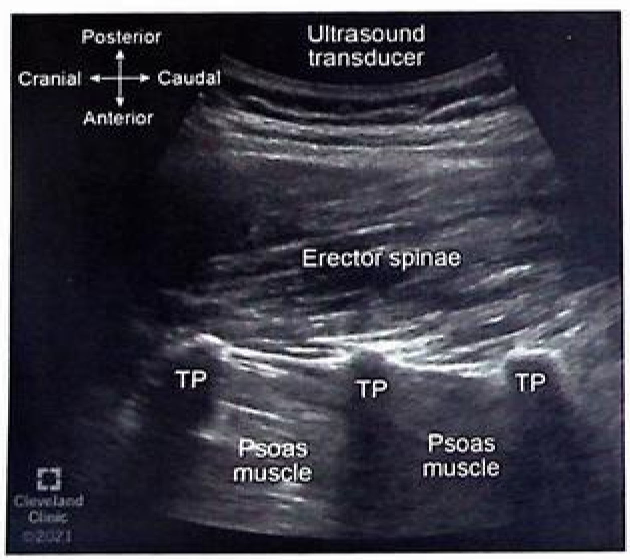


Fig. 50.8 Image illustrating an ultrasound view of the parasagittal transverse process *(TP)* view.

51 Spinal Block

David L. Brown and Ehab Farag

Key Points

- Spinal anesthesia is unparalleled in that a small mass of local anesthetic can produce dense surgical anesthesia.
- Bupivacaine is the ideal drug for spinal anesthesia.
- Identification of the lamina at 1 cm lateral to the spinous process is very crucial for a successful paramedian approach.
- The use of a 25-gauge spinal needle is very helpful to avoid postdural puncture spinal headache.
- The Taylor technique is a paramedian approach that is performed at the L5 to S1 interspace, the largest interlaminar interspace of the vertebral column.

PERSPECTIVE

Spinal anesthesia is unparalleled in that a small mass of drug, virtually devoid of systemic pharmacologic effect, can produce profound, reproducible surgical anesthesia. Further, by altering the small mass of drug, very different types of spinal anesthesia can be produced. Low spinal anesthesia, a block below T10, has a different physiologic impact than does a block performed to produce higher spinal anesthesia (above T5). The block is unexcelled for lower abdominal or lower extremity surgical procedures. However, for operations in the midabdomen to upper abdomen, light general anesthesia may have to supplement the spinal block because stimulation of the diaphragm during upper abdominal procedures often causes some discomfort. This area is difficult to block completely through high spinal anesthesia because to do so requires blockade of the phrenic nerve.

Patient Selection. Patient selection for spinal anesthesia often places too much emphasis on a side effect of the technique—namely, spinal headache—than on the applicability of the technique in a given patient. It is clear that the incidence of spinal headache increases with decreasing age and female sex; however, with proper technique and selection of needle size and tip configuration, the incidence of headache should not preclude the use of spinal anesthesia in young, healthy patients if the block has advantages over epidural anesthesia. Almost any patient who must have a lower extremity operation is a candidate for spinal anesthesia, as are most patients scheduled for lower abdominal surgery such as inguinal herniorrhaphy and gynecologic, urologic, and obstetric procedures.

Pharmacologic Choice. In the United States, three local anesthetics are commonly used to produce spinal anesthesia: lidocaine, tetracaine, and bupivacaine. Lidocaine is a short- to intermediate-acting spinal drug; tetracaine and bupivacaine provide intermediate- to long-acting blocks. Lidocaine, without epinephrine, is often chosen for procedures that can be completed in 1 hour or less. It is likely that the lidocaine mixture most commonly used is still a 5% solution in 7.5% dextrose, although increasingly, anesthesiologists are using 1.5% to 2% concentrations of lidocaine without dextrose as alternatives. When epinephrine (0.2 mg) is added to lidocaine, the useful length of clinical anesthesia in the lower abdomen and lower extremities is approximately 90 minutes. Tetracaine is packaged both as Niphanoid crystals (20 mg) and as a 1% solution (2 mL total). When dextrose is added to make tetracaine hyperbaric, the drug generally produces effective clinical anesthesia for procedures of up to 1.5 to 2 hours in the plain form, for up to 2 to 3 hours when epinephrine (0.2 mg) is added, and for up to 5 hours for lower extremity procedures when phenylephrine (5 mg) is added as a vasoconstrictor. Bupivacaine spinal anesthesia is commonly carried out with 0.5% or 0.75% solution, either plain or in 8.25% dextrose. My impression is that the clinical difference between 0.5% tetracaine and 0.75% bupivacaine as a hyperbaric solution is minimal. Bupivacaine is appropriate for procedures lasting up to 2 or 3 hours.

In addition, local anesthetics can be mixed to produce hypobaric spinal anesthesia. A common method of formulating a hypobaric solution is to mix tetracaine in a 0.1% to 0.33% solution with sterile water. Also, lidocaine can be mixed to provide useful hypobaric spinal anesthesia. This drug is diluted from a 2% solution with sterile water to make a 0.5% solution using a total of 30 to 40 mg.

Many anesthesiologists avoid vasoconstrictors for fear of somehow increasing the risk with spinal anesthesia. These anesthesiologists believe that phenylephrine or epinephrine has such potent vasoconstrictive action that it puts the blood supply of the spinal cord at risk. There are no human data supporting this theory. In fact, because most local anesthetics are vasodilators, the addition of these vasoconstrictors does little more than maintain spinal cord blood flow at a basal level. Commonly used doses of vasoconstrictors are 0.2 to 0.3 mg of epinephrine and 5 mg of phenylephrine added to the spinal anesthetic.

PLACEMENT

Anatomy. As outlined in Chapter 50, Ultrasound-Assisted Neuraxial Block, the spinous processes of the lumbar vertebrae have an almost horizontal orientation in relation to the long axis of their respective vertebral bodies (Fig. 51.1). When a midline needle is inserted between the lumbar vertebral spinous processes, it is most effective if it is placed almost perpendicularly in relation to the long axis of the back. To facilitate spinal anesthesia, the anesthesiologist constantly must keep in mind the midline of the patient's body and the neuraxis in relation to the needle. As illustrated in Fig. 51.1, as a midline needle is inserted into the cerebrospinal fluid (CSF), it logically must puncture the skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space, and finally, the dura mater and arachnoid mater to reach the CSF.

Position. Spinal anesthesia is carried out in three principal positions: lateral decubitus (Fig. 51.2), sitting (Fig. 51.3), and prone jackknife (Fig. 51.4). In both the lateral decubitus

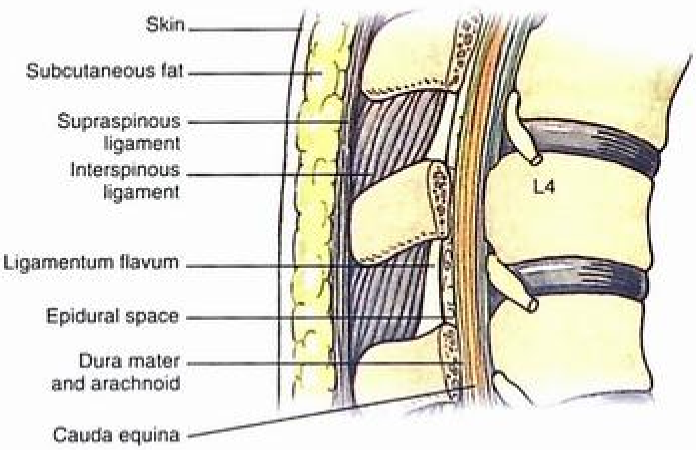


Fig. 51.1 Spinal block: functional lumbar anatomy.

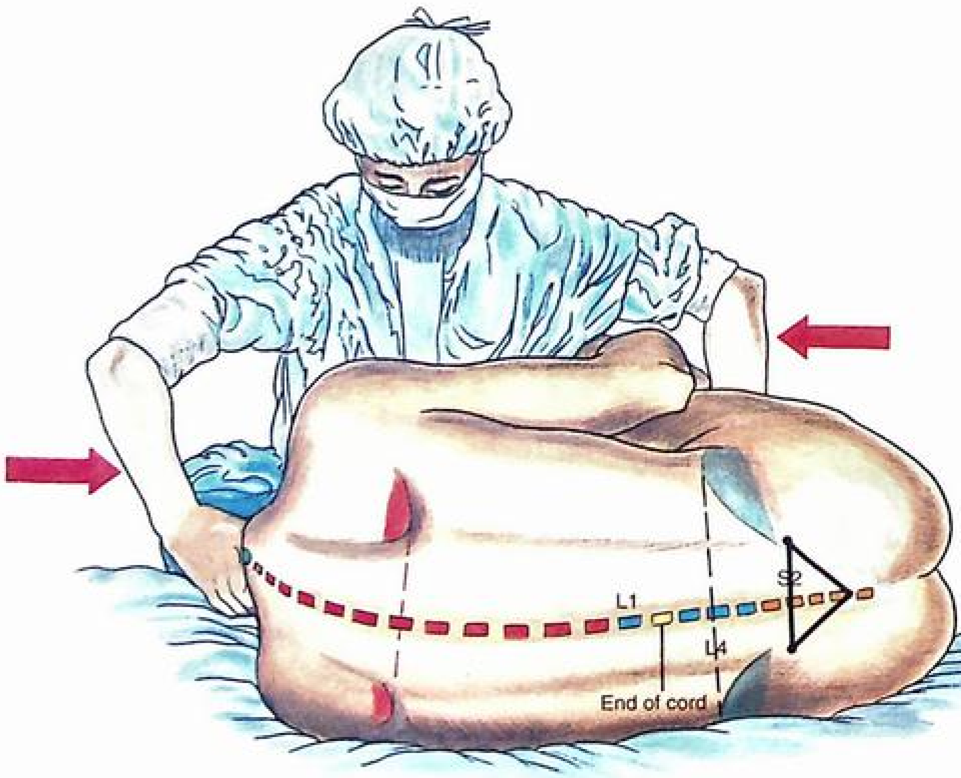


Fig. 51.2 Spinal block: lateral decubitus position.

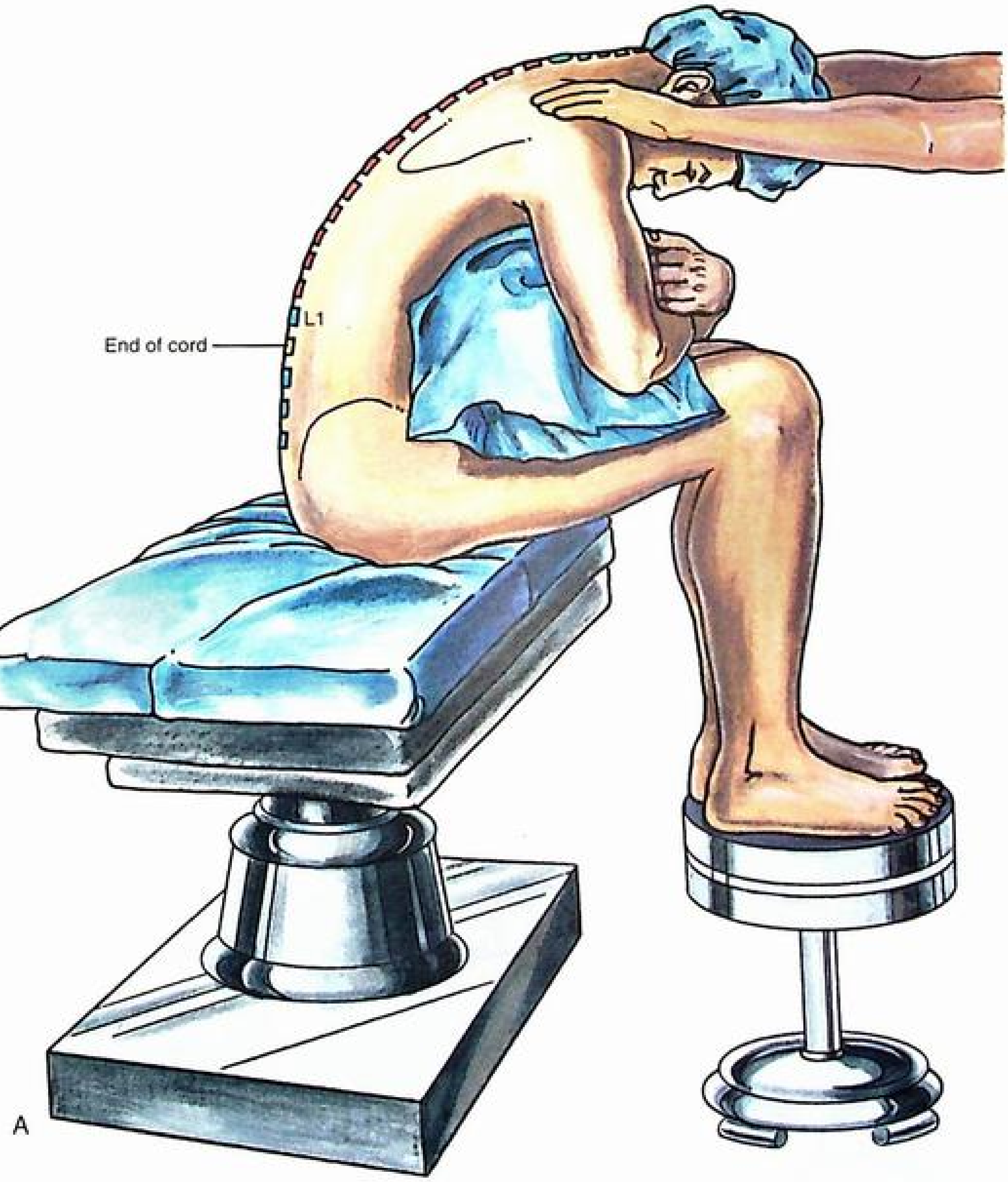


Fig. 51.3 Spinal block: sitting position. (A) Lateral view.

and sitting positions, a well-trained assistant is essential if the block is to be easily and efficiently administered by the anesthesiologist. As illustrated in Fig. 51.2, the assistant can help the patient assume the position of legs flexed on the abdomen and chin flexed on the chest. This is most easily accomplished by having the assistant pull the head toward the chest, place an arm behind the patient's scan also be facilitated by using an appropriate amount of sedation that allows the patient to be relaxed yet cooperative.

In some patients, the sitting position can facilitate location of the midline, especially in obese patients or in those with some scoliosis that makes midline identification more difficult. As illustrated in Fig. 51.3A, the patient should assume a comfortable sitting position, with the legs placed over the edge of the operating table and the feet supported by a stool. A pillow should be placed in the patient's lap and the patient's arms allowed to drape over the pillow, resting on the flexed lower extremities. The assistant should be positioned immediately in front of the patient, supporting the shoulders and allowing the patient to minimize lumbar lordosis, while ensuring that the vertebral midline remains in a vertical position (see Fig. 51.3B).

Sometimes, it is more efficient to place the patient in a prone jackknife position before administering the spinal anesthetic (see Fig. 51.4). An assistant is not as essential for this technique as for the lateral decubitus and sitting positions, although to make the most efficient use of operating room block time, it is often helpful for the assistant to position the patient in the prone jackknife position while the anesthesiologist readies the spinal anesthesia tray and drugs.

In all three positions, the goal is to place the patient so that the midline is readily identifiable and lumbar lordosis is reduced. Fig. 51.5 shows what the lumbar anatomy looks like when the patient's lumbar lordosis has been ineffectively reduced by poor positioning. As illustrated, the intralaminar space is small and difficult to enter with a needle in the midline. In contrast, Fig. 51.6 illustrates how effective positioning can open the intralaminar space to allow easy access for subarachnoid puncture.

Needle Puncture. One of the first decisions to be made in considering spinal anesthesia is what kind of needle to use. Although there are many eponyms for spinal needles, they fall into two main categories: those that cut the dura sharply and those that disrupt the dural fibers by spreading them with a cone-shaped tip. The former category includes the traditional disposable spinal needle, the Quincke-Babcock needle; the latter category comprises the Greene, Whitacre, and Sprotte needles. If a continuous spinal technique is chosen, the use of a Tuohy or other thin-walled,

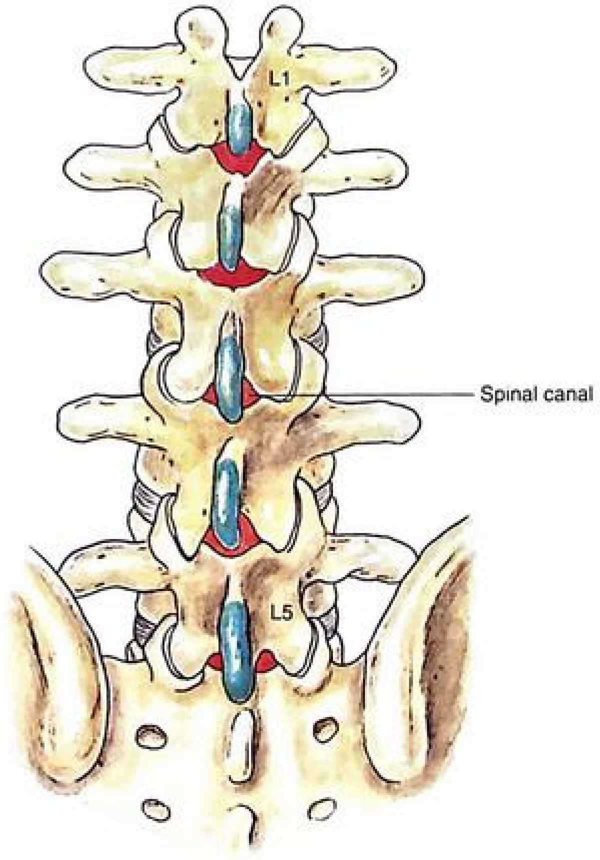


Fig. 51.5 Spinal block: lumbar vertebra. Lumbar lordosis is present because the positioning is inadequate.

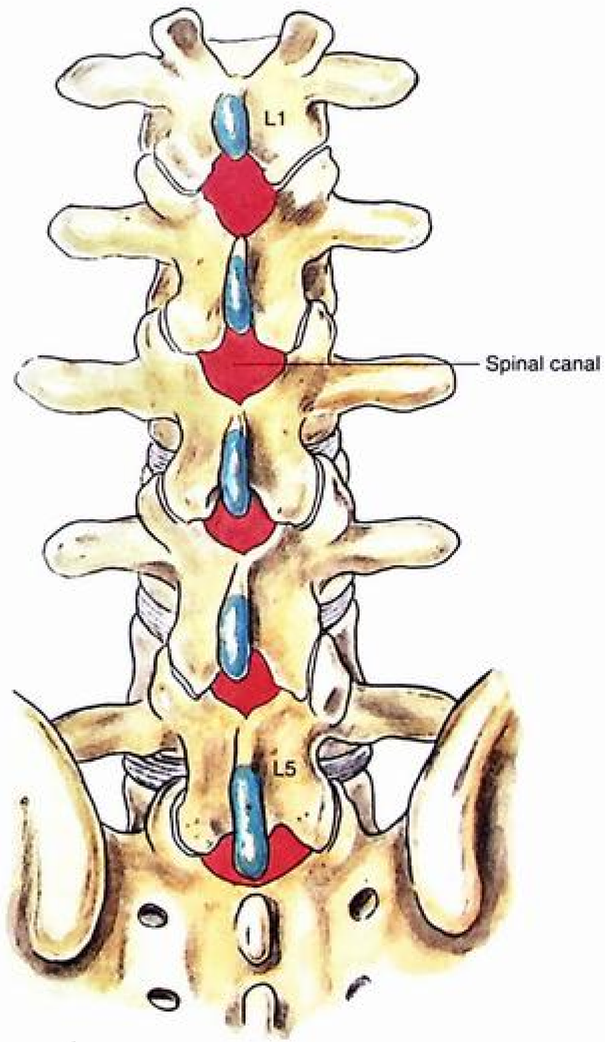


Fig. 51.6 Spinal block: lumbar vertebra. Lumbar lordosis is reversed with ideal spinal positioning.

curve-tipped needle will facilitate passage of the catheter. To make a logical choice of a spinal needle, the risks and benefits of each must be understood. The use of small needles reduces the incidence of postdural puncture headache; the use of larger needles improves the tactile sense of needle placement, thus increasing operator confidence.

Probably, the risk-benefit calculation is not as simple as this. For example, the use of a small needle, such as a 27-gauge needle, will not decrease the incidence of headache in younger patients if a number of "passes" through the dura are required before CSF flow is recognized. Likewise, a larger needle, such as a 22-gauge Whitacre needle, may result in a lower incidence of postdural puncture headache if the subarachnoid needle location is recognized on the first pass. Different needle tip designs result in differences in the incidence of postdural puncture headache, even when needle sizes are comparable.

With the patient in the proper position, the anesthesiologist uses the palpating hand to clearly identify the patient's intervertebral space and midline. As illustrated in Fig. 51.7 (*Step 1*), the anesthesiologist can effectively carry out this important maneuver by moving the fingers of the palpating hand alternately cephalocaudad and rolling them from side to side. When the appropriate intervertebral space has been clearly identified, a skin wheal is raised over the space. Next, an introducer is inserted into the substance of the interspinous ligament, taking care to firmly seat it in the midline (Fig. 51.7, *Step 2*). The introducer is grasped with the palpating fingers and steadied while the other hand holds the spinal needle, somewhat like a dart, as illustrated in Fig. 51.7 (*Step 3*). With the fifth finger of the needle hand used as a tripod against the patient's back, the needle, with bevel (if present) parallel to the long axis of the spine, is advanced slowly to heighten the sense of tissue planes traversed, as well as to avoid skewing the nerve roots, until a characteristic change in resistance is noted as the needle passes through the ligamentum flavum and dura. The stylet is then removed, and CSF should appear at the needle hub. If it does not, the needle is rotated in 90-degree increments until CSF appears. If CSF does not appear in any quadrant, the needle should be advanced a few millimeters and rechecked in all four quadrants. If CSF still has not appeared and the needle is at a depth appropriate for the patient, the needle and introducer should be withdrawn and the insertion steps repeated, because the most common reason for lack of CSF return is that the needle was inserted off the midline. Another common error preventing subarachnoid placement is insertion of the needle with too great a cephalad angle on the initial insertion (Fig. 51.8).

Once CSF is freely obtained, the dorsum of the anesthesiologist's nondominant hand steadies the spinal needle against the patient's back while the syringe containing the therapeutic dose is attached to the needle. CSF is again freely aspirated into the syringe and the dose is injected. Sometimes, when the syringe has been attached to a needle from which CSF was clearly previously dripping, aspiration of additional CSF becomes impossible. As illustrated in Fig. 51.9, one technique that can be used to facilitate CSF aspiration is to "unscrew" the syringe plunger (see Fig. 51.9A), rather than providing constant steady pressure (see Fig. 51.9B).

After the local anesthetic has been injected, the patient and the operating table should be placed in the position appropriate for the surgical procedure and the drugs being used. The midline approach to subarachnoid block is the technique of first choice because it requires anatomic projection in only two planes, and the needle insertion plane is a relatively avascular one. When difficulties with needle insertion are encountered with the midline approach, an option is to use the paramedian route, which does not require the same level of patient cooperation or reversal of lumbar lordosis to be successful. As illustrated in Fig. 51.10, the paramedian approach exploits the larger "subarachnoid target" that exists if a needle is inserted slightly lateral to the midline. In the paramedian approach, the palpating fingers should identify the caudal edge of the cephalad spinous process of the intervertebral space chosen, and a skin wheal should be raised 1 cm lateral and 1 cm caudal to this point. A longer needle, such as a 4-cm, 22-gauge short-beveled needle, is then used to infiltrate the deeper tissues in a cephalomedial plane. The spinal introducer and needle are then inserted 10 to 15 degrees off the sagittal plane in a cephalomedial plane, as noted in Fig. 51.10. As with the midline approach, the most common error made with this technique is to angle the needle too far cephalad in its initial insertion. Once the needle contacts bone with this approach, it is redirected in, slightly cephalad. If bone is again contacted after the needle has been redirected but at a deeper level, this needle redirection is continued because it is likely that the needle is being "walked up" the lamina toward the intervertebral space. After CSF is obtained, the block continues in the same way as that described for the midline approach.

A variation of the paramedian approach is the lumbosacral approach of Taylor. The technique is carried out at the L5 to S1 interspace, the largest interlaminar interspace of the vertebral column. As illustrated in Fig. 51.11, the skin insertion site is 1 cm medial and 1 cm caudal to the ipsilateral posterosuperior iliac spine. Through this point, a 12- to 15-cm spinal needle is inserted in a cephalomedial direction toward the midline. If bone is encountered on the first needle insertion, the needle is "walked off" the sacrum into the subarachnoid space, as in the method used for a lumbar paramedian approach. Once CSF is obtained, the steps are similar to those previously outlined.

POTENTIAL PROBLEMS

The complication most feared by patients and many anesthesiologists after spinal anesthesia is neurologic injury. However, the risk-benefit calculation of neurologic injury after anesthesia must include those cases that are possible after general anesthesia. These comparisons may show that the incidence of neurologic injury after spinal anesthesia is in fact lower than that after general anesthesia. However, this statement must remain speculative.

In patients in whom the spinal block level has to be precisely controlled or whose operation is expected to outlast the usual duration of the anesthetic drugs, a continuous spinal catheter may be used. However, when using a continuous spinal technique, one should be cautious about repeating local anesthetic injections if the block height does not reach the predicted levels. Neurotoxicity (cauda equina syndrome) is hypothetically possible when the spinal

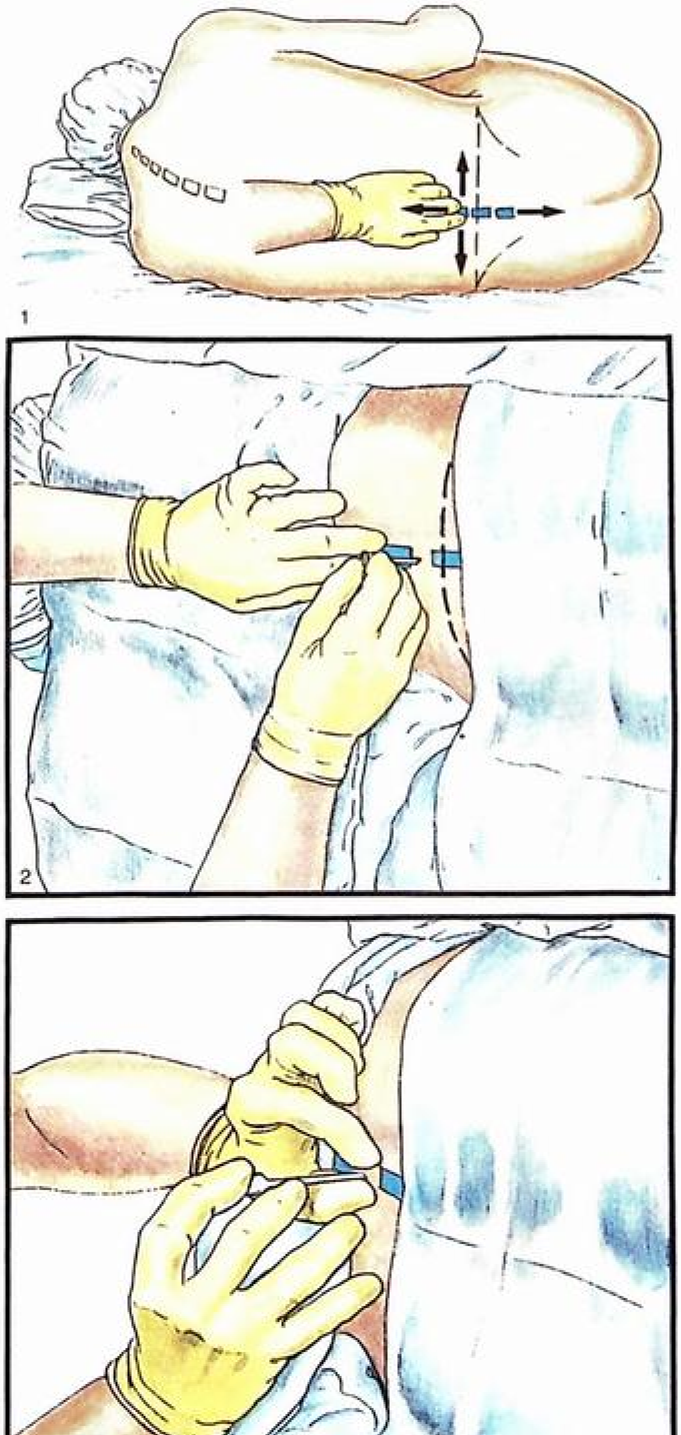


Fig. 51.7 Spinal block: technique.

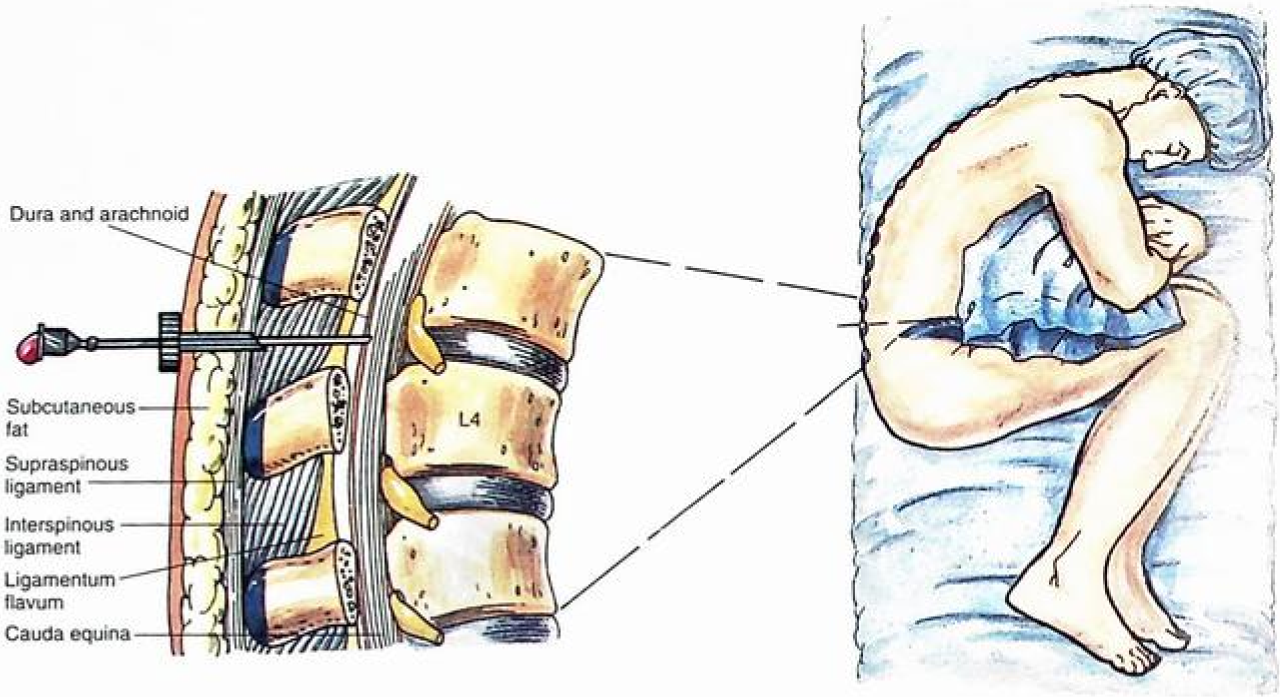


Fig. 51.8 Spinal block: avoiding too large a cephalad angle on insertion.

catheter position allows local anesthetic concentrations to reach higher than expected levels.

A more common complication of spinal anesthesia is postoperative headache. Factors that influence the incidence of postdural puncture headache are age (more frequent in younger patients), sex (more likely in female patients), needle size (more frequent with larger needles), needle bevel orientation (increased incidence when dural fibers are cut transversely), pregnancy (incidence increased), and number of dural punctures necessary to obtain CSF (more likely with multiple punctures). Perhaps more important to physicians than knowing the factors resulting in an increased incidence of postdural puncture headache is the knowledge of how and when to carry out definitive therapy—that is, an epidural blood patch. To use spinal anesthesia effectively, epidural blood patching, when indicated, must be used early. The success rate from a single epidural blood patch should be in the 90% to 95% range and if a second patch is required, a similar percentage should be obtainable.

One other common side effect of spinal anesthesia is the appearance of a backache in approximately 25% of patients. Patients often blame "the spinal" for the backache, but when looked at systematically, it appears that just as many patients have backaches after general anesthesia as after spinal anesthesia. Thus backache after neuraxial block should not be attributed immediately to "needling" of the back.

PEARLS

Probably the most important factor contributing to success with spinal anesthesia in the day-to-day life of an anesthesiologist is the efficiency of the technique. If nurses and surgeons are to be advocates of spinal anesthesia, its use cannot measurably add time to the surgical day. Thus one should plan ahead to maximize efficiency. Often overlooked in this maxim is the fact that if properly sedated, patient preparation for the operation can begin almost as soon as the block is administered.

Intraoperatively during high spinal anesthesia (often during cesarean section), patients occasionally complain of dyspnea. This often appears to be a result of loss of chest wall sensation rather than of significantly decreased inspiratory capacity. The loss of chest wall sensation does not allow the patient to experience the reassurance of a deep breath. This impediment to patient acceptance often can be overcome simply by asking the patient to raise a hand in front of their mouth and exhale forcefully. The tactile appreciation of a deep exhalation often seems to provide the needed reassurance.

If spinal anesthesia has been used and a neurologic complication is noted after surgery, it is essential to obtain an early neurologic consultation. In this way, an unbiased consultant can examine the patient and determine whether the "new" neurologic finding preexisted, is related to a peripheral neuropathy, or, more rarely, is potentially related to the spinal anesthetic. Latent electromyographic alterations associated with denervation due to neurologic injury take time to develop in the lower extremities (14–21 days). Therefore after a potentially spinal anesthesia–related lesion has been identified, electromyographic studies should be obtained early to establish a preblock baseline and allow serial comparison.

It is also useful to consider adding fentanyl (15–25 μg) rather than epinephrine to some shorter-acting spinal local anesthetic mixtures (e.g., lidocaine) because it prolongs the effective sensory block without measurably prolonging the

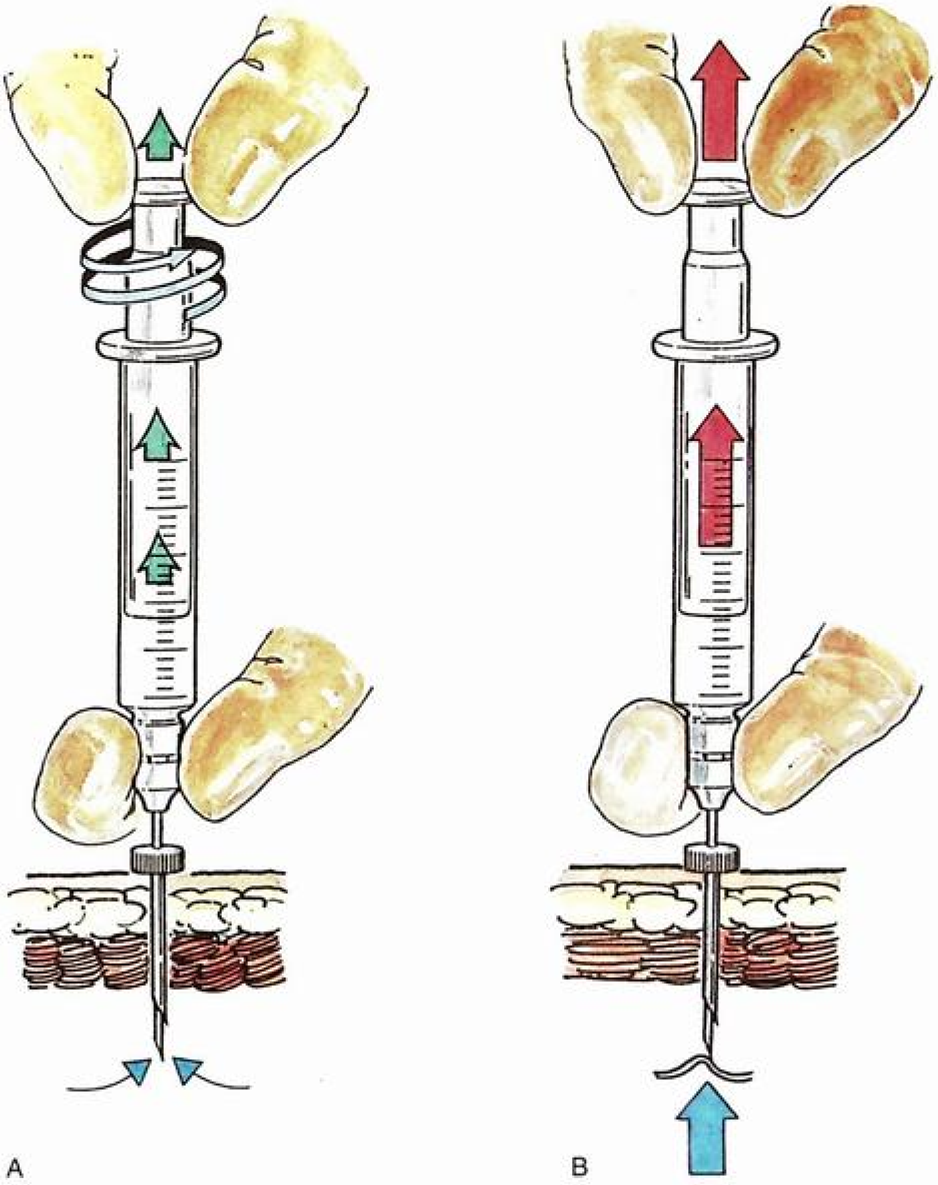


Fig. 51.9 Spinal block: syringe technique to facilitate aspiration of cerebrospinal fluid. (A) Unscrew the syringe plunger. (B) Avoid applying constant aspiration.

motor block or the time to voiding. This is especially useful in selected surgical outpatients.

Another way to titrate spinal anesthesia for outpatients, or any surgical procedure in which the length of surgery is difficult to predict, is to use a combined spinal-epidural technique. In this technique, an epidural needle is placed in the epidural space in a standard fashion, and then a small-gauge spinal needle is advanced through the epidural needle into the CSF. A spinal local anesthetic mixture is then injected and matched to the projected length of the shortest surgical procedure planned. After removal of the spinal needle, an epidural catheter is inserted into the epidural space. At this point, if the surgical procedure lasts longer than anticipated, the epidural catheter can be injected with a local anesthetic appropriate for the anticipated surgical needs. This combined spinal-epidural technique provides flexibility for both spinal and epidural anesthesia in selected patients.

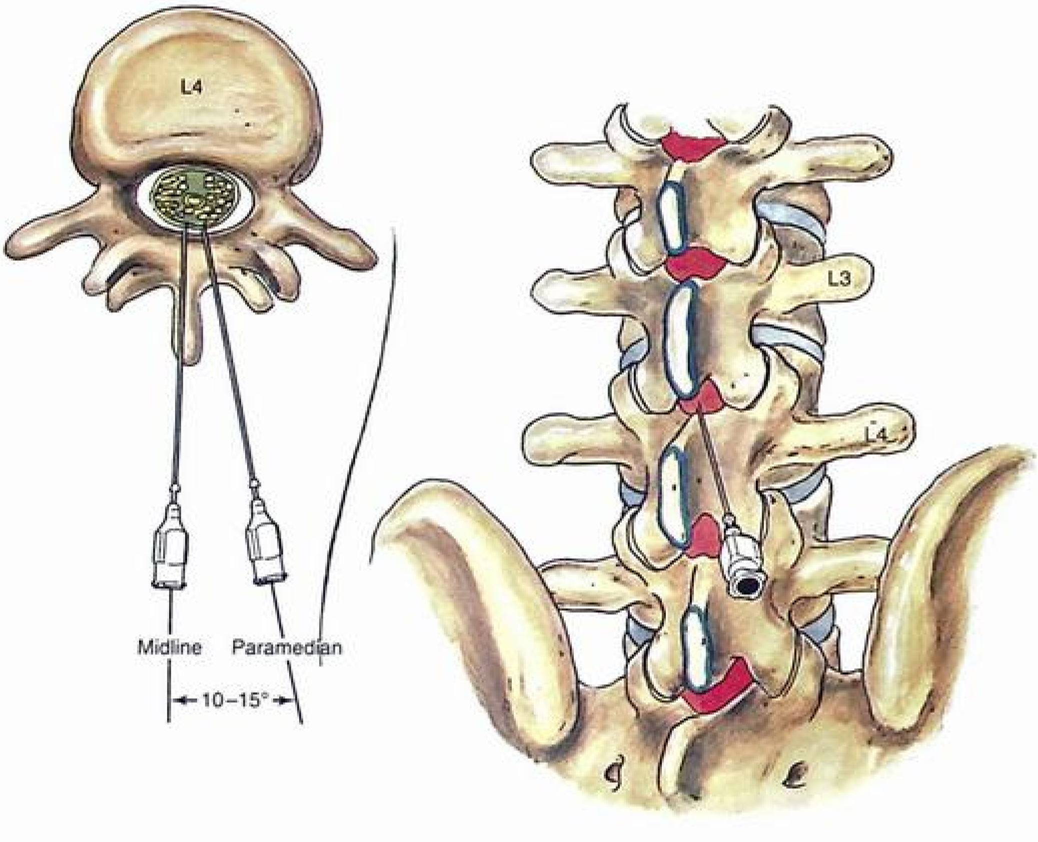


Fig. 51.10 Spinal block: paramedian technique.

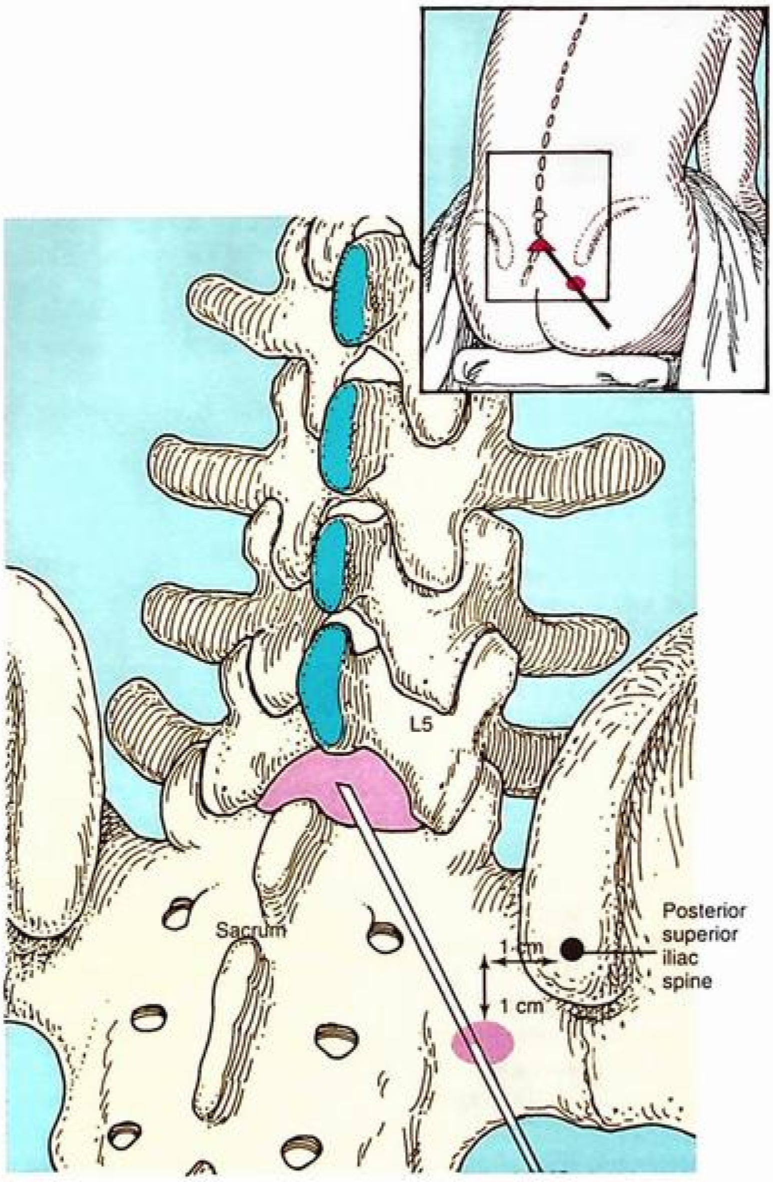


Fig. 51.11 Spinal block: L5 to S1 paramedian technique (Taylor approach).

52 Epidural Block

David L. Brown and Ehab Farag

Key Points

- An epidural block can be performed in the cervical, thoracic, and lumbar regions of the vertebral column.
- The paramedian approach is the preferred technique for thoracic epidural, while median and paramedian approaches are suitable for lumbar epidural.
- The T5 to T6 interspace is the preferred position for thoracic epidural catheter insertion.
- The ligamentum flavum is congenitally absent in the midline in some people, which makes them prone to the dural puncture during epidural block.
- Checking for the coagulation status of the patients is very crucial before attempting the epidural block.
- Early diagnosis and management of epidural hematoma are crucial to avoid permanent neural damage.

PERSPECTIVE

Epidural anesthesia is the second primary method of neuraxial block. In contrast to spinal anesthesia, epidural block requires pharmacologic doses of local anesthetics, making systemic toxicity a concern. In skilled hands, the incidence of postdural puncture headache should be lower with epidural anesthesia than with spinal anesthesia. Nevertheless, as outlined in Chapter 51, Spinal Block, I do not believe this should be the major differentiating point between the two techniques. Spinal anesthesia is typically a single-shot technique, whereas frequently intermittent injections are given through an epidural catheter, thus allowing reinjection and prolongation of epidural block. Another difference is that epidural block allows production of segmental anesthesia. Thus if a thoracic injection is made and an appropriate amount of local anesthetic is injected, a band of anesthesia that does not block the lower extremities can be produced.

Patient Selection. Epidural block is appropriate for virtually the same patients who are candidates for spinal anesthesia, except that epidural anesthesia can be used in the cervical and thoracic areas as well—levels at which spinal anesthesia is not advised. As with spinal anesthesia, if epidural block is to be used for intraabdominal procedures involving the upper abdomen, it is advisable to combine this technique with a light general anesthetic because diaphragmatic irritation can make the patient, surgeon, and anesthesiologist uncomfortable. Other candidates for epidural anesthesia are patients in whom a continuous technique has increasingly been found to be helpful in providing epidural local anesthesia or opioid analgesia after major surgical procedures. This clinical application likely explains the increased interest in epidural block over the last 20 years.

Pharmacologic Choice. To use epidural local anesthetics effectively, one must combine an understanding of the potency and duration of local anesthetics with estimates of the length of the operation and the postoperative analgesia requirements. Drugs available for epidural use can be categorized as short-acting, intermediate-acting, and long-acting agents; with the addition of epinephrine to these agents, surgical anesthesia ranging from 45 to 240 minutes after a single injection is possible.

Chloroprocaine, an amino ester local anesthetic, is a short-acting agent that allows efficient matching of the length of the surgical procedure and the duration of epidural analgesia, even in outpatients. 2-Chloroprocaine is available in 2% and 3% concentrations; the latter is preferable for surgical anesthesia and the former for techniques not requiring muscle relaxation.

Lidocaine is the prototypical amino amide local anesthetic and is used in 1.5% and 2% concentrations epidurally. Concentrations of mepivacaine necessary for epidural anesthesia are similar to those of lidocaine; however, mepivacaine lasts from 15 to 30 minutes longer at equivalent dosages. Epinephrine significantly prolongs (i.e., by approximately 50%) the duration of surgical anesthesia with 2-chloroprocaine and either lidocaine or mepivacaine. Plain lidocaine produces surgical anesthesia that lasts from 60 to 100 minutes.

Bupivacaine, an amino amide, is a widely used long-acting local anesthetic for epidural anesthesia. It is used in 0.5% and 0.75% concentrations, but analgesic techniques can be performed with concentrations ranging from 0.125% to 0.25%. Its duration of action is not prolonged as consistently by the addition of epinephrine, although up to 240 minutes of surgical anesthesia can be obtained when epinephrine is added.

Ropivacaine, another long-acting amino amide, is also used for regional and epidural anesthesia. For surgical anesthesia, it is used in 0.5%, 0.75%, and 1% concentrations. Analgesia can be obtained with concentrations of 0.2%. Its duration of action is slightly less than that of bupivacaine in the epidural technique, and it appears to produce slightly less motor blockade than a comparable concentration of bupivacaine.

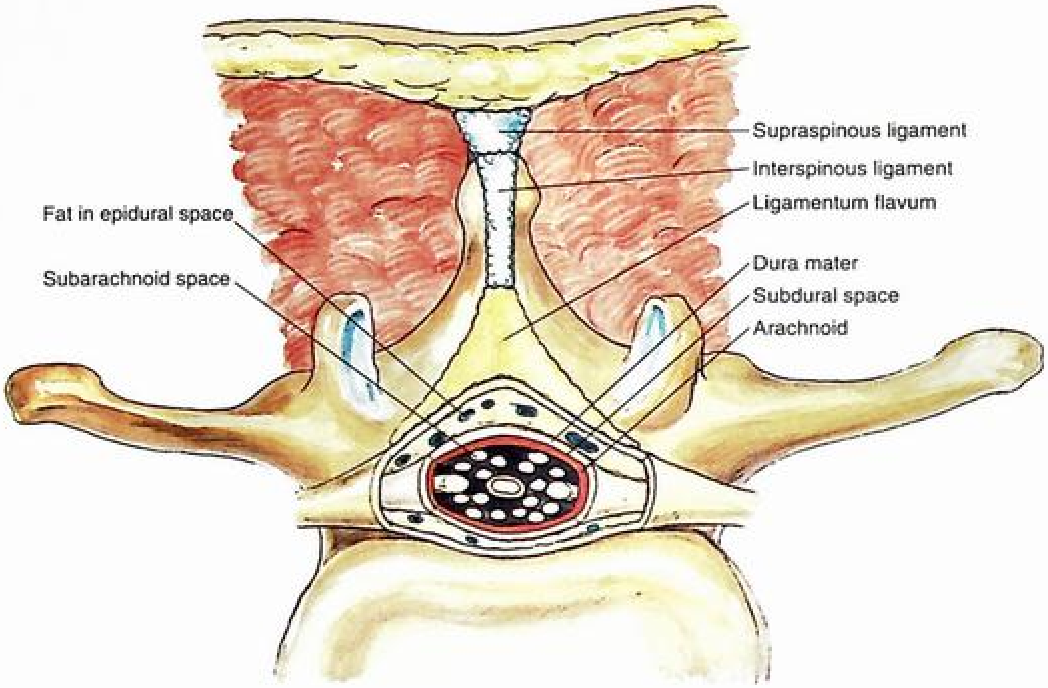


Fig. 52.1 Epidural block: cross-sectional anatomy.

In addition to the use of epinephrine as an epidural additive, some anesthesiologists recommend modifying epidural local anesthetic solutions to increase both the speed of onset and the quality of the block produced. One recommendation is to alkalinize the local anesthetic solution by adding bicarbonate to achieve both these purposes. Nevertheless, the clinical advisability of routinely adding bicarbonate to local anesthetic solutions should be determined by local practice protocols.

PLACEMENT

Anatomy. As with spinal anesthesia, the key to carrying out successful epidural anesthesia is understanding the three-dimensional midline neuraxial anatomy that underlies the palpating fingers (Fig. 52.1). When a lumbar approach to the epidural space is used in adults, the depth from the skin to the ligamentum flavum is commonly near 4 cm; in 80% of patients, the epidural space is cannulated at a distance of 3.5 to 6 cm from the skin. In a small number of patients, the lumbar epidural space is as near as 2 cm from the skin. In the lumbar region, the ligamentum flavum is 5 to 6 mm thick in the midline, whereas in the thoracic region, it is 3 to 5 mm thick. In the thoracic region, the depth from the skin to the epidural space depends on the degree of cephalad angulation used for the paramedian approach, as well as the body habitus of the patient (Fig. 52.2). In the cervical region, the depth to the ligamentum flavum is approximately the same as that in the lumbar region, 4 to 6 cm.

The ligamentum flavum will be perceived as a thicker ligament if the needle is kept in the midline than if the needle is inserted off the midline and enters the lateral extension of the ligamentum flavum. Fig. 52.3 illustrates how important it is to maintain the midline position of the epidural needle (*needle A*) during lumbar epidural techniques. If an oblique approach is taken, a "false release" can be produced (*needle C*), or the perception of a thin ligament can be reinforced (*needle B*).

Position. Patient positioning for epidural anesthesia is similar to that for spinal anesthesia, with lateral decubitus, sitting, and prone jackknife positions all applicable. The lateral decubitus position is applicable for both lumbar and thoracic epidural techniques, and the sitting position allows the administration of lumbar, thoracic, and cervical epidural anesthetics. The prone jackknife position allows access to the caudal epidural space.

Needle Puncture: Lumbar Epidural. A technique similar to that used for spinal anesthesia should be carried out to identify the midline structures, and the bony landmarks should be used to determine the vertebral level appropriate for needle insertion (Fig. 52.4). When choosing a needle for epidural anesthesia, one must decide whether a continuous or single-shot technique is desired. This is the principal determinant of needle selection. If a single-shot epidural technique is chosen, a Crawford needle is appropriate; if a continuous catheter technique is indicated, a Tuohy or other needle with a lateral-facing opening is chosen.

The midline approach is most often indicated for a lumbar epidural procedure. The needle is inserted into the midline in the same way as for spinal anesthesia. In the epidural technique, the needle is slowly advanced until the change in tissue resistance is noted as the needle abuts the ligamentum flavum. At this point, a 3- to 5-mL glass syringe is filled with 2 mL of saline solution, and a small (0.25 mL) air bubble is added. The syringe is attached to the needle, and if the needle tip is in the substance of the ligamentum flavum, the air bubble will be compressible (Fig. 52.5A). If the ligamentum flavum has not yet been reached, pressure on the syringe plunger will not compress

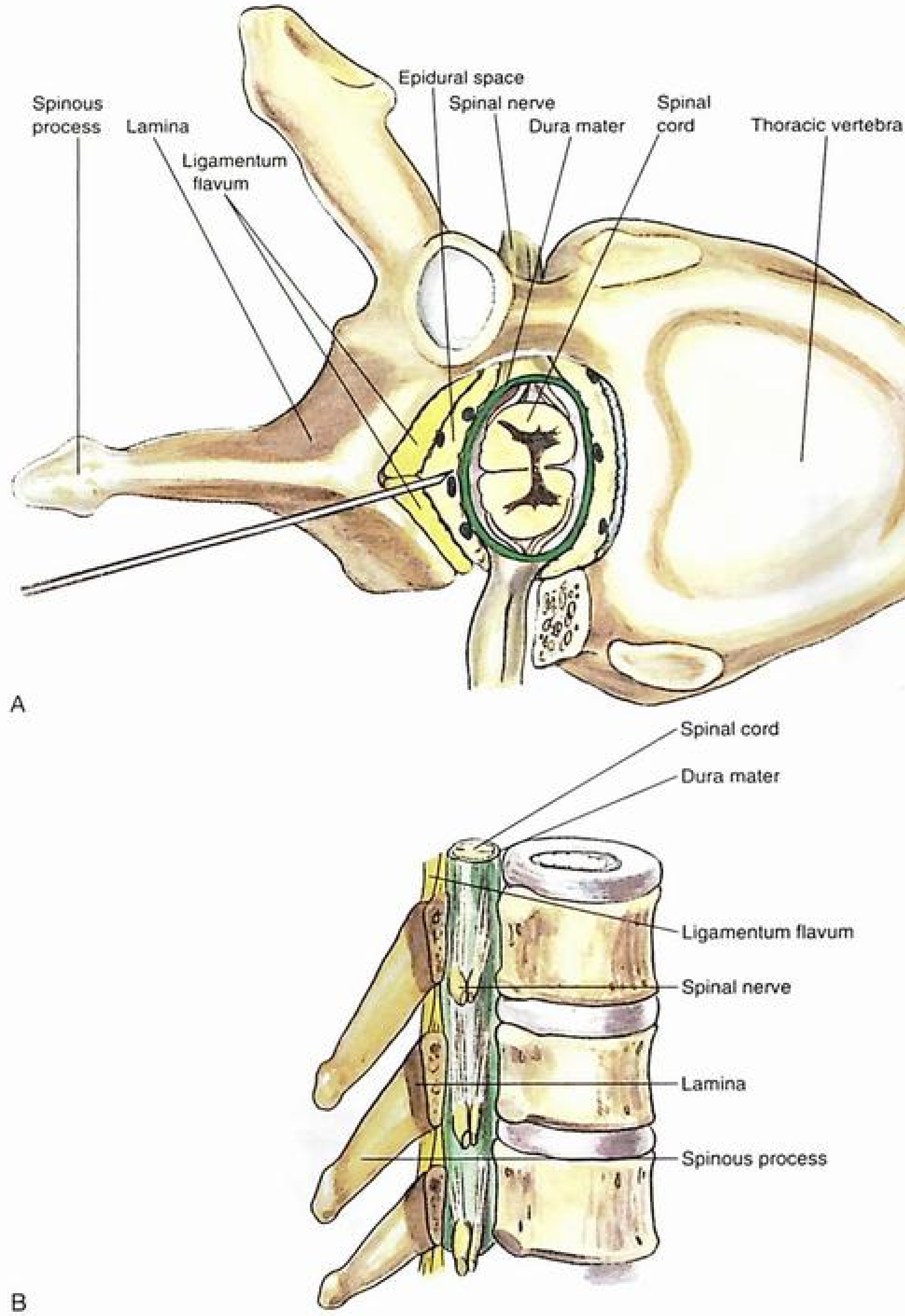


Fig. 52.2 Thoracic epidural block anatomy: overlapping of midthoracic spinous processes requires a paramedian technique. (A) Cross section, superior view. (B) Lateral view, paramedian section.

the air bubble (Fig. 52.5B). Once compression of the air bubble has been achieved, the needle is grasped with the nondominant hand and pulled toward the epidural space, while the dominant hand (thumb) applies constant steady pressure on the syringe plunger, thus compressing the air bubble. When the epidural space is entered, the pressure applied to the syringe plunger will allow the solution to flow without resistance into the epidural space. An alternative technique, although one that the author believes has a less precise endpoint, is the hanging-drop technique for identifying entry into the epidural space. In this technique, when the needle is placed in the ligamentum flavum, a drop of solution is introduced into the hub of the needle (Fig. 52.6A). No syringe is attached and, when the needle is advanced into the epidural space, the solution should be "sucked into" the space (Fig. 52.6B).

No matter what method is chosen for needle insertion, when the epidural space is cannulated with a catheter, success may be increased by advancing the needle 1 to 2 mm farther once the space has been identified. In addition, the incidence of unintentional intravenous cannulation with an epidural catheter may be decreased by injecting 5

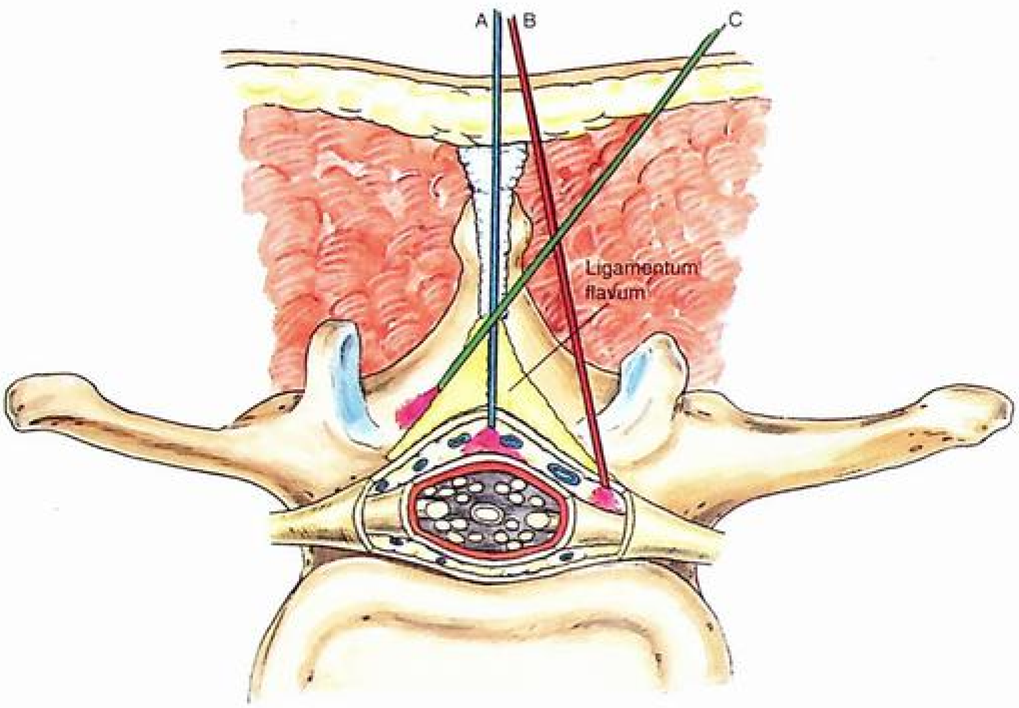


Fig. 52.3 Epidural block: functional anatomy of ligamentum flavum. This figure shows how important it is to maintain the midline position of the epidural needle (*needle A*) during lumbar epidural techniques. If an oblique approach is taken, a "false release" can be produced (*needle C*), or the perception of a thin ligament can be reinforced (*needle B*).

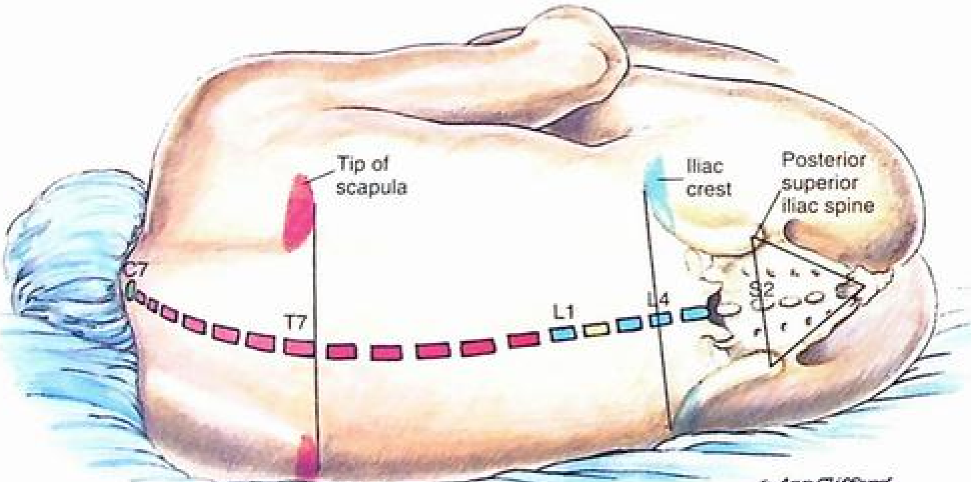


Fig. 52.4 Neuraxial anatomy: surface relationships.

to 10 mL of solution before threading the catheter. If a catheter is inserted, it should be inserted only 2 to 3 cm into the epidural space because threading it farther may increase the likelihood of catheter malposition. Obstetric patients require catheters to be inserted 3 to 5 cm into the epidural space to minimize dislodgement during labor analgesia.

Needle Puncture: Thoracic Epidural. As with lumbar epidural anesthesia, patients are usually placed into a lateral decubitus position for needle insertion into the thoracic epidural space (Fig. 52.7). In this technique, the paramedian approach is preferred because it allows easier access to the epidural space. This is because the spinous processes in the midthoracic region overlap each other from cephalad to caudad (Fig. 52.8). The paramedian approach is carried out in a manner similar to that used for the lumbar epidural space, although in almost every instance, the initial needle insertion will result in contact with the thoracic vertebral lamina by the epidural needle (Fig. 52.9). When this occurs, the needle is withdrawn slightly and the tip redirected cephalad in small, incremental steps until the needle is firmly seated in the ligamentum flavum. At this point, the loss-of-resistance technique and insertion of the catheter are carried out in a manner identical to that used for lumbar

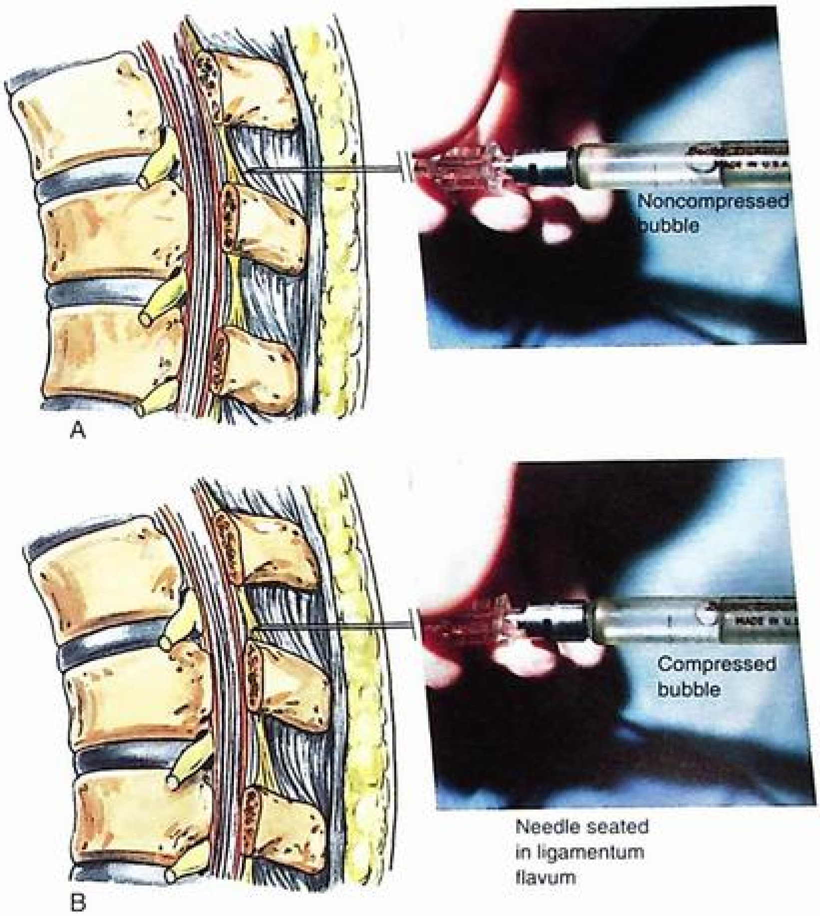


Fig. 52.5 Epidural block: loss-of-resistance technique showing (A) noncompression and (B) bubble compression.

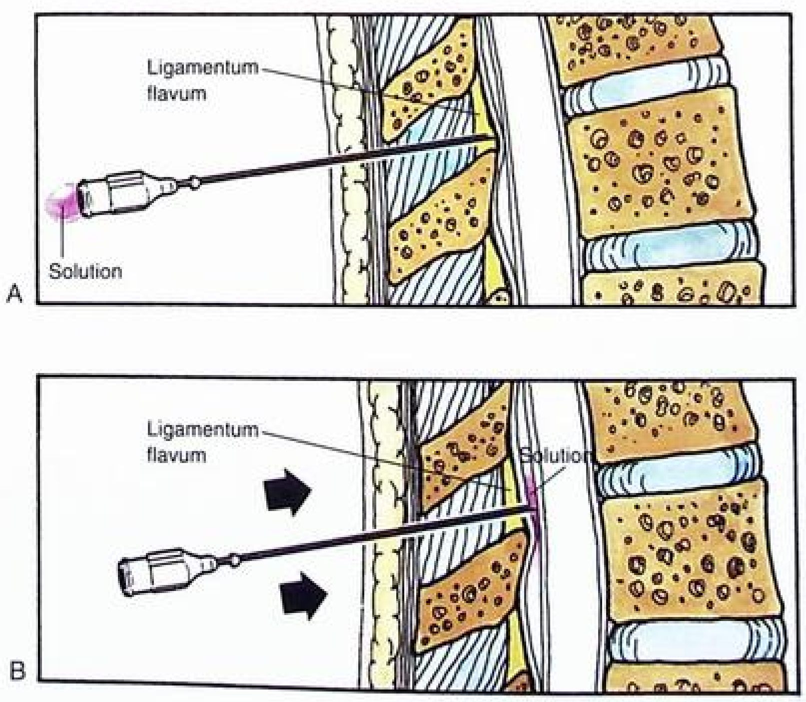


Fig. 52.6 Epidural block: hanging-drop technique. (A) A drop of solution is introduced into the hub of the needle and, when advanced into the epidural space, (B) the solution should be "sucked into" the space.

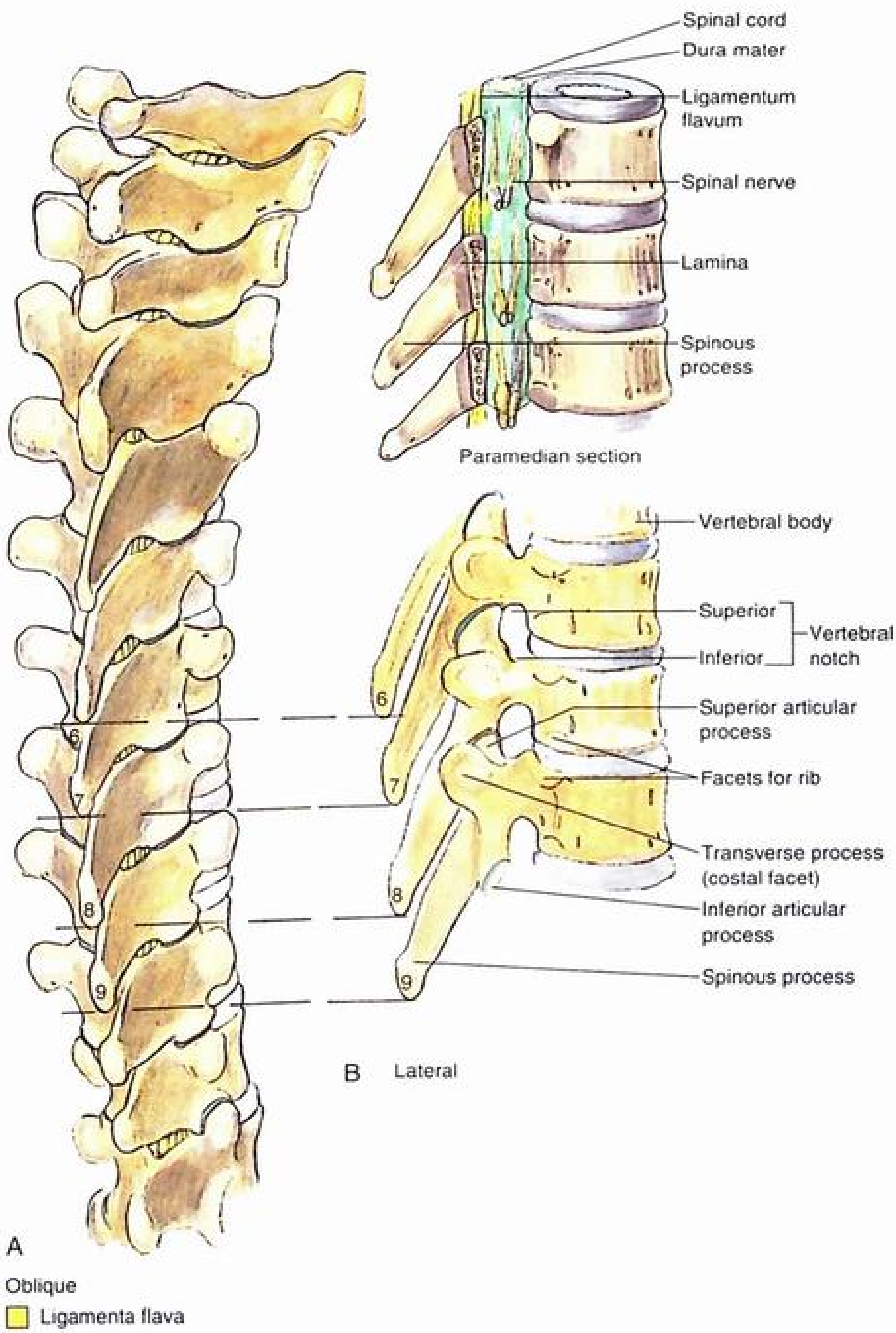


Fig. 52.8 Thoracic vertebral anatomy: the degree of spinous process overlap changes from high thoracic to midthoracic to low thoracic. (A) Oblique view. (B) Lateral view and paramedian section.

onto the ligamentum flavum will be appreciated at a depth similar to that seen in the lumbar epidural block (i.e., 3.5–5.5 cm), and needle placement is then performed using the loss-of-resistance technique, as in the other epidural methods. The hanging-drop method is also an option for the identification of the cervical epidural space.

POTENTIAL PROBLEMS

One of the most feared complications of epidural anesthesia is systemic toxicity resulting from intravenous injection of the intended epidural anesthetic (Fig. 52.13). This can occur with either catheter or needle injection. One way to minimize intravenous injection of the pharmacologic doses of local anesthetic needed for epidural anesthesia is to verify needle or catheter placement by administering a test dose before the definitive epidural anesthetic injection. The current recommendation for the test dose is 3 mL of local anesthetic solution containing 1:200,000 epinephrine (15 μg of epinephrine). Even if the test dose is negative, the anesthesiologist should inject the epidural solution incrementally, be vigilant for unintentional intravascular injection, and have all necessary equipment and drugs available to treat local anesthetic–induced systemic toxicity.

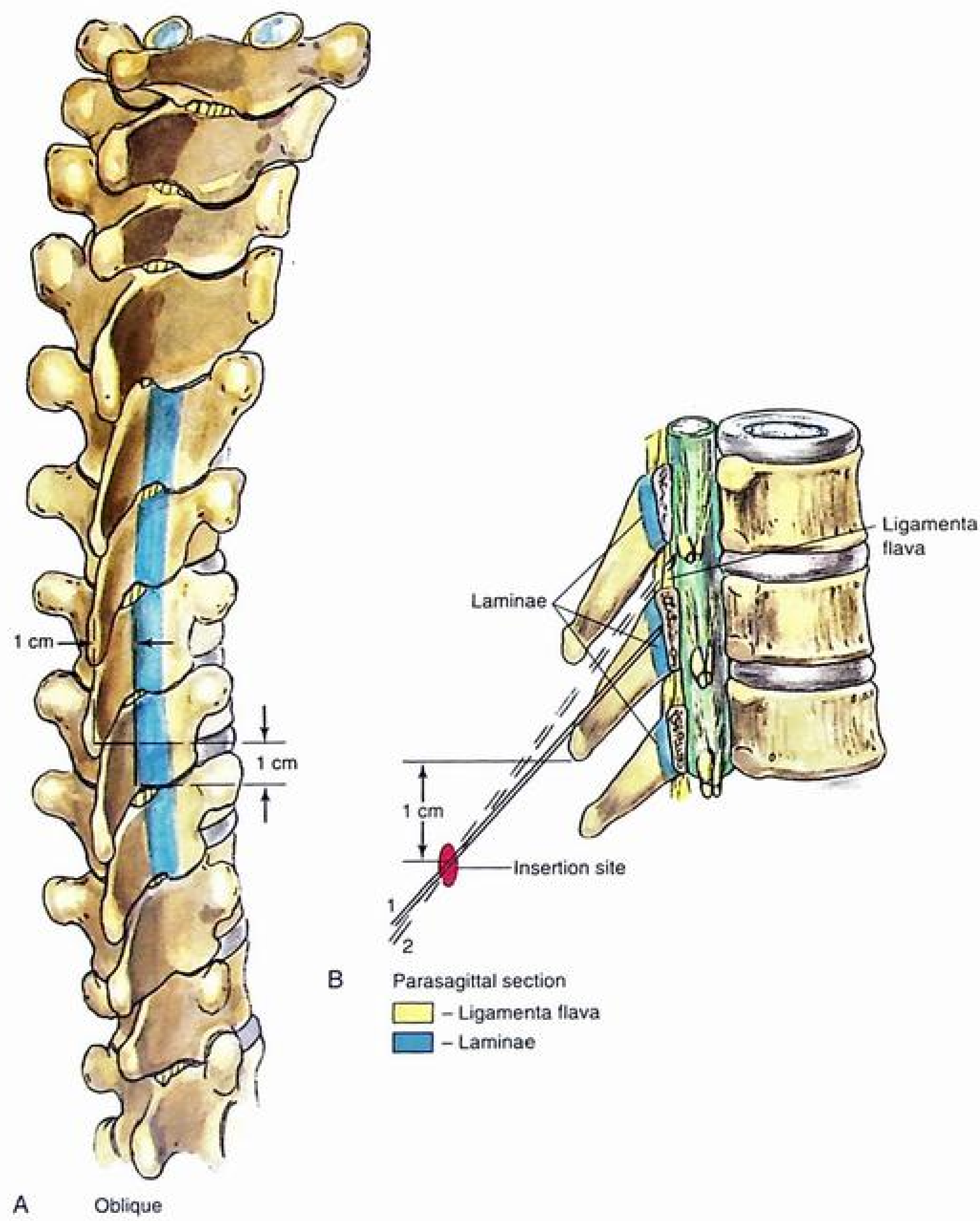


Fig. 52.9 Thoracic epidural block technique. (A) Using the paramedian approach, the needle insertion site is 1 cm caudad and 1 cm lateral to the tip of the more cephalad spinous process, similar to the needle insertion used in the lumbar paramedian technique. (B) Parasagittal view of needle insertion and initial contact with lamina (*blue shading*).

Another problem that can occur with epidural anesthesia is the unintentional administration of an epidural dose into the spinal fluid. In this event, as when any neuraxial block reaches high sensory levels, blood pressure and heart rate should be supported pharmacologically and ventilation should be assisted as indicated. Usually, atropine and ephedrine will suffice to manage this situation or, at least, will provide time to administer more potent catecholamines. If the entire dose (20–25 mL) of local anesthetic is administered into the cerebrospinal fluid, tracheal intubation and mechanical ventilation are indicated because it will be approximately 1 to 2 hours before the patient can maintain adequate spontaneous ventilation consistently. When epidural anesthesia is performed and a higher than expected block develops after a delay of only 15 to 30 minutes, subdural placement of the local anesthetic must be considered. Treatment is symptomatic, with the most difficult part involving recognition that a subdural injection is possible.

As with spinal anesthesia, if neurologic injury occurs after epidural anesthesia, a systematic approach to the problem is necessary. No particular local anesthetic, use of needle versus catheter technique, addition or omission of epinephrine, or location of epidural puncture seems to be associated with an increased incidence of neurologic injury. Despite this observation, the performance of cervical or thoracic epidural techniques demands special care with hand and needle control because the spinal cord is immediately deep to the site of both these epidural blocks.

Fig. 52.10 Thoracic epidural block technique: Bromage grip for loss-of-resistance technique in thoracic block.

An additional problem with epidural anesthesia is the fear of creating an epidural hematoma with the needles or catheters. This probably happens less frequently than severe neurologic injury after general anesthesia. Concern about epidural hematoma formation is greater in patients who have been taking antiplatelet drugs such as aspirin or who have been receiving preoperative anticoagulants. The magnitude of an acceptable level of preoperative anticoagulation and the risk-benefit calculation of performing epidural anesthesia in the anticoagulated patient remain indeterminate at this time. The use of epidural techniques in patients receiving subcutaneous heparin therapy is probably acceptable if the block can be performed atraumatically, although the risk-benefit ratio of the technique must be weighed for each patient. Perioperative anticoagulant regimens that demand special consideration are the use of low-molecular-weight heparin (LMWH) or potent antiplatelet drugs concurrently with epidural block. LMWH is used for prophylaxis of deep venous thrombosis and produces more profound effects than other intermittently dosed heparin products. It is currently recommended that no procedure, including withdrawal or manipulation of an epidural catheter, should occur within 12 hours after a dose of LMWH, and the next dose of LMWH should be delayed for at least 2 hours after atraumatic epidural needle or catheter insertion or manipulation. The antiplatelet drugs (e.g., ticlopidine, clopidogrel, and platelet glycoprotein IIb/IIIa receptor antagonists) are sometimes combined with aspirin and other anticoagulants. Expert guidelines need to be consulted when using regional blocks in the increasing number of patients on antiplatelet compounds.

As in spinal anesthesia, postdural puncture headache can result from epidural anesthesia when unintentional subarachnoid puncture accompanies the technique. When using the larger-diameter epidural needles (18 and 19 gauge), it can be expected that at least 50% of patients experiencing unintentional dural puncture will have a postoperative headache.

PEARLS

Avoiding catheters during epidural anesthesia—that is, by selecting an appropriate local anesthetic—can avoid a potential source of difficulty with the technique. Epidural catheters can be malpositioned in a number of ways. If a catheter is inserted too far into the epidural space, it can be routed out of the foramina, resulting in patchy epidural block. The catheter can also be inserted into the subdural or subarachnoid space or into an epidural vein. Similarly, the use of epidural catheters may be complicated by a prominent dorsomedian connective tissue band (epidural septum or fat pad), which is found in some patients.

Another means of facilitating the success of epidural anesthesia is to allow the block enough "soak time" before beginning the surgical procedure. This is accomplished most effectively if the block is carried out in an induction room, separate from the operating room. There appears to be a plateau effect in the doses of epidural local anesthetics; that is, once a certain quantity of local anesthetic has been injected, more of the same agent does not significantly increase the block height but rather, may make the block denser, perhaps improving quality.

One observation that needs to be emphasized about epidural anesthesia through a catheter is the often faulty clinical logic that by giving incremental doses through a catheter, the level of sensory anesthesia can be slowly developed, thereby allowing frail and physiologically compromised patients to undergo epidural anesthesia. However, when this approach is taken, anesthesiologists usually do not allow enough time between injections because of the reality of time pressures in the normal operating room. They inject

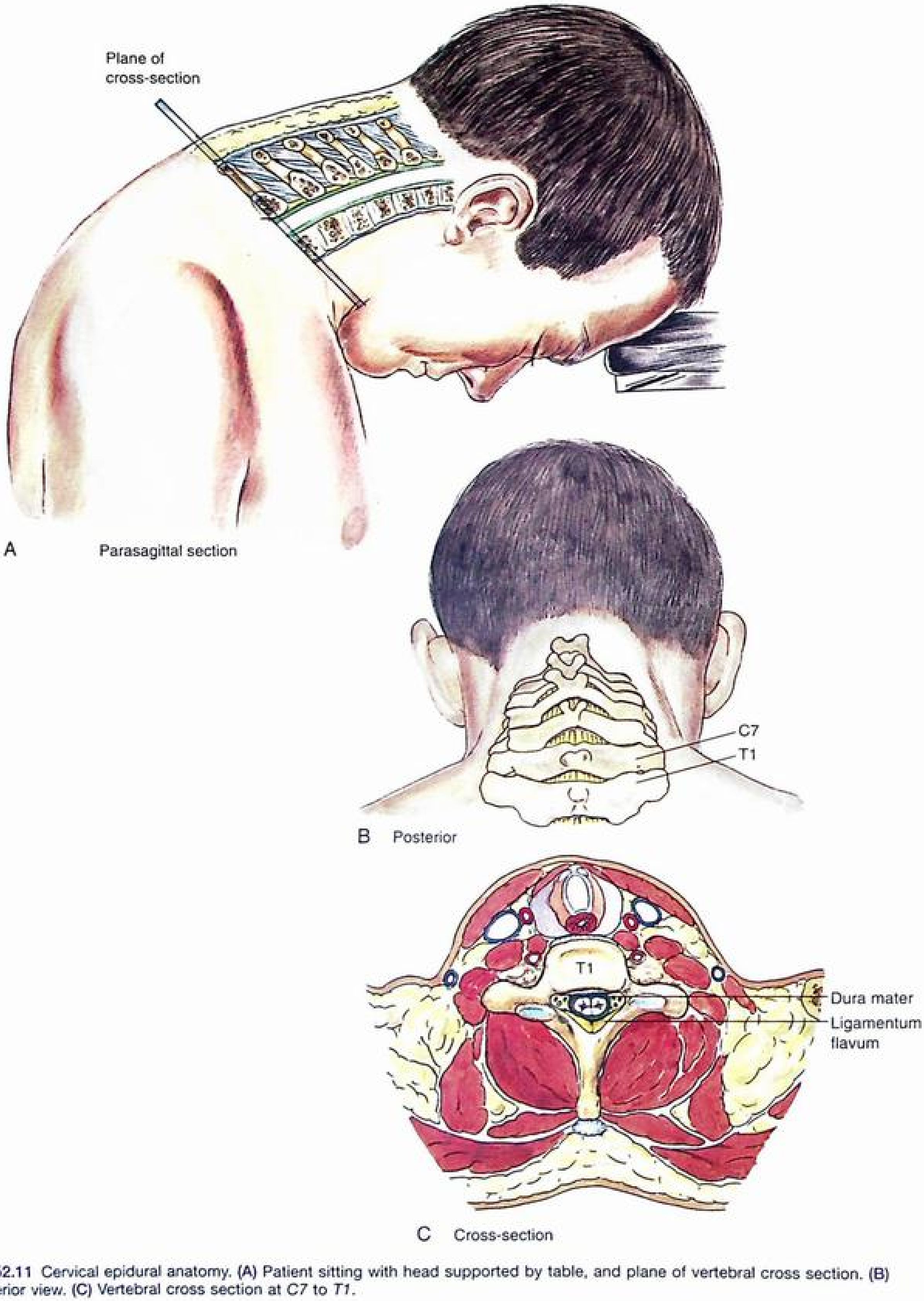


Fig. 52.11 Cervical epidural anatomy. (A) Patient sitting with head supported by table, and plane of vertebral cross section. (B) Posterior view. (C) Vertebral cross section at *C7* to *T1*.

small doses through the catheter but then do not allow sufficient time to pass before performing the next incremental injection. Often, the clinical result is high block levels in just those patients in whom lower levels were the goal. Furthermore, this approach to epidural anesthesia unnecessarily delays preparing the patient for the operation and makes surgical and nursing colleagues less accepting of the technique.

Epidural catheters are indicated in many situations, especially when the technique is used for postoperative analgesia. To place a known length of catheter into the epidural space, either the catheter and needle both must

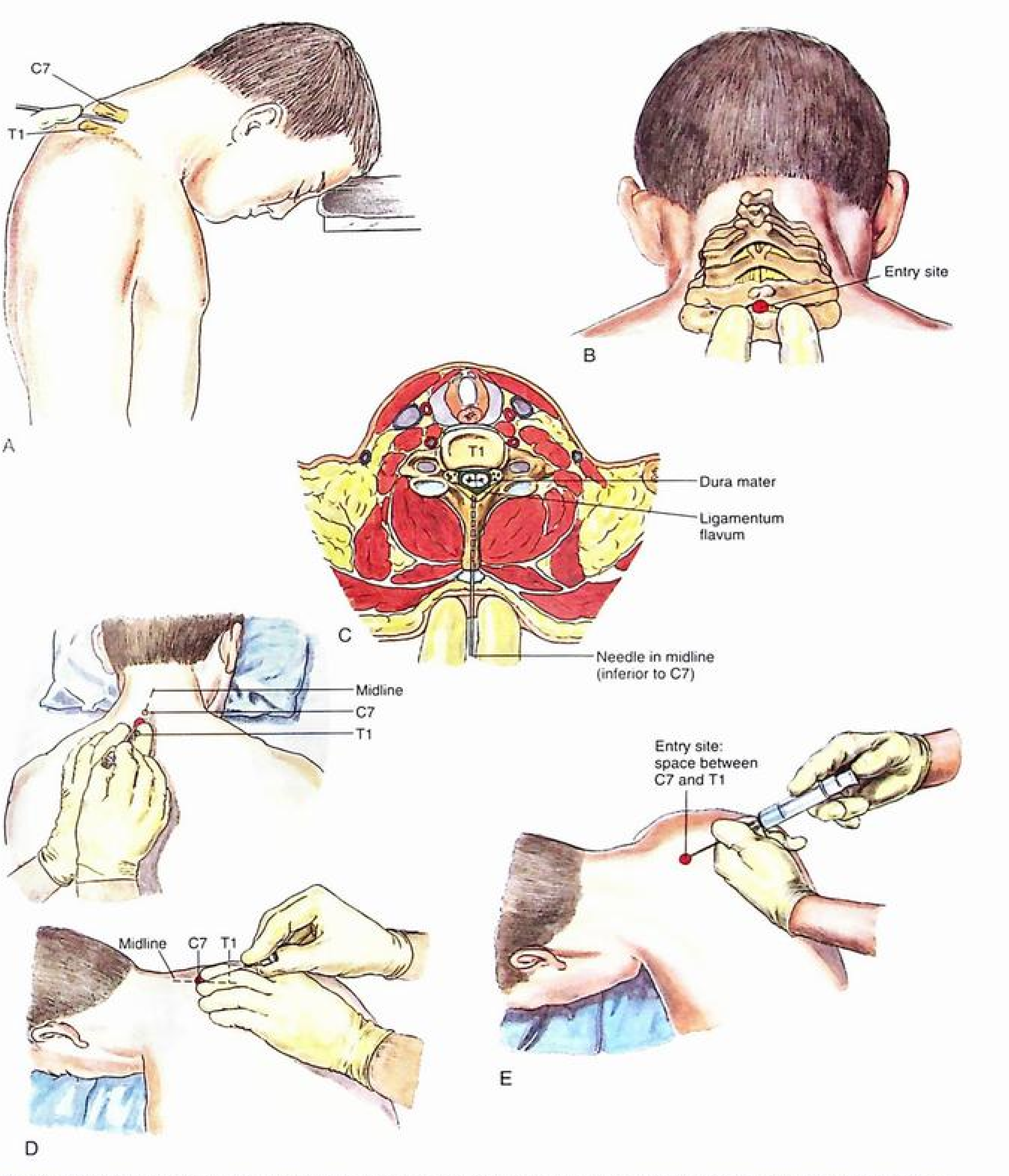


Fig. 52.12 Cervical epidural technique. (A) Patient sitting with head supported by a table, with the needle oriented parallel to the floor. (B) Application of the fingers to the posterior neck to facilitate cervical epidural block. (C) Insertion of the needle into ligamentum flavum. (D) Insertion of the needle during palpation. (E) Bromage grip during needle advancement.

have distance markers, or a way must be found to maintain the catheter position once the needle has been withdrawn over the catheter. Because some epidural needles do not have distance markers, a method of maintaining catheter position while the needle is withdrawn over the catheter is required. One technique of positioning the catheter is illustrated in Fig. 52.14. An object of known length, such as a syringe or the anesthesiologist's finger, is selected, and that object is placed next to the needle-catheter assembly after the catheter has been inserted 3 cm (or other known distance) into the epidural space. Because the catheter is marked, a known point on the catheter can be related to a known point on either the finger or the syringe. As shown in Fig. 52.14A, the 15-cm mark is opposite the

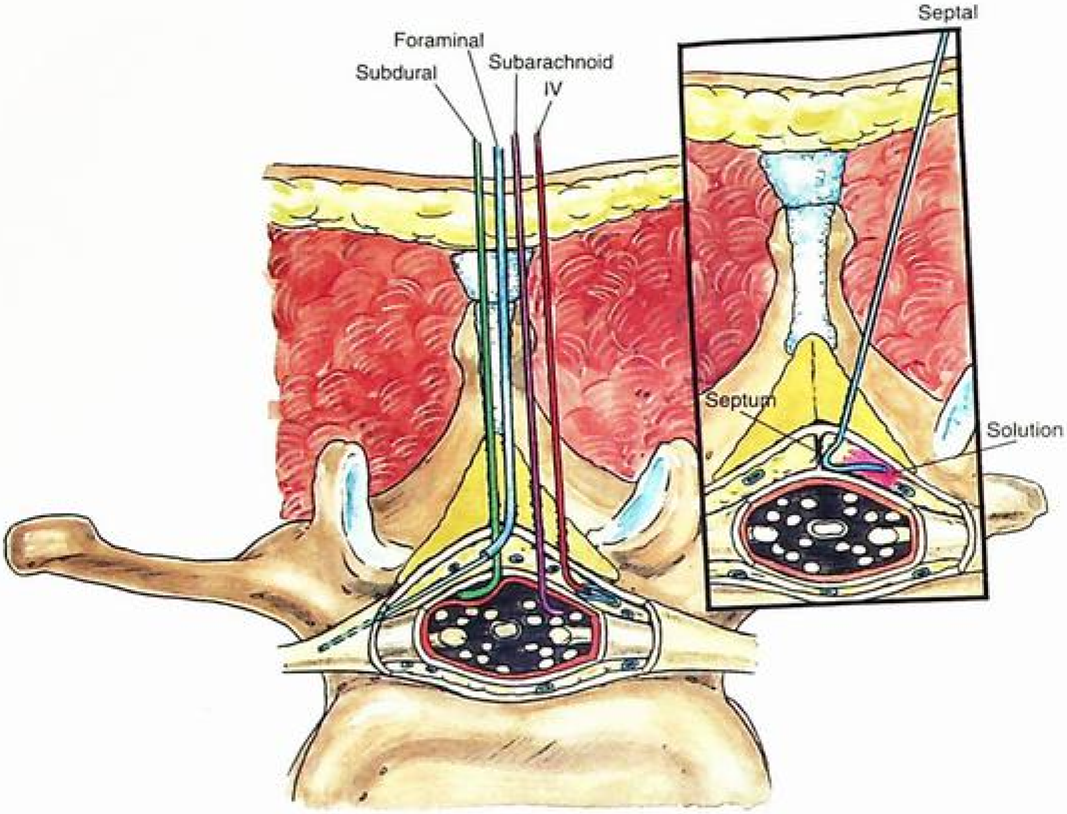


Fig. 52.13 Epidural block: cross-sectional anatomy showing potential incorrect injection sites. *IV*, Intravenous.

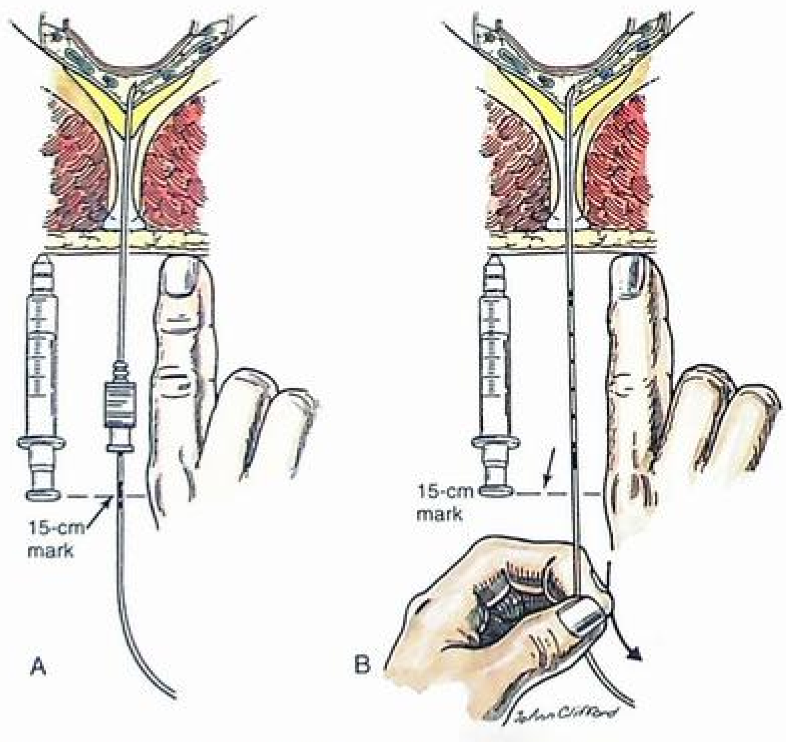


Fig. 52.14 Epidural block: catheter measurement technique. (A) The 15-cm mark is opposite the plunger on the syringe or the anesthesiologist's knuckle. (B) The measurement object is then placed next to the catheter.

plunger on the syringe or the anesthesiologist's knuckle. Once this relationship has been noted, the needle is removed while the catheter position is maintained. The measurement object is then placed next to the catheter, as illustrated in Fig. 52.14B, and the catheter is withdrawn to the point at which the distance marker on the catheter relates to the previously identified point. In this example, the 15-cm mark on the catheter is placed opposite the plunger of the syringe or the anesthesiologist's knuckle. By using this technique, the epidural catheter can be accurately placed without the need for either a marked needle or a ruler.

53 Caudal Block

David L. Brown and Ehab Farag

Key Points

- In approximately 5% of adult patients, the sacral hiatus is nearly impossible to cannulate with either needle or catheter.
- In some patients, the tissue mass overlying the sacrum makes the technique difficult.
- The sacral hiatus lies at the tip of the equilateral triangle that joins the posterior superior iliac spines bilaterally.
- A caudal block can be performed in a lateral decubitus or a prone position.
- Volumes of local anesthetic in the 25- to 35-mL range can be injected in adult patients to reach a sensory level of T12 to T10 with a caudal block.

PERSPECTIVE

With advances in lumbar epidural anesthesia, caudal anesthesia has become an infrequently used and taught technique. Nevertheless, caudal anesthesia can be used effectively for anorectal and perineal procedures, as well as some lower extremity operations.

Patient Selection. Patient selection for caudal anesthesia should be determined by examining the anatomy of the sacral hiatus. In approximately 5% of adult patients, the sacral hiatus is nearly impossible to cannulate with either needle or catheter; thus in 1 of 20 patients, the technique is clinically unusable. Likewise, there are patients in whom the tissue mass overlying the sacrum makes the technique difficult, so if another technique is applicable, caudal anesthesia should be avoided. Probably more so than for any other block, experience and confidence on the anesthesiologist's part are necessary to carry out the technique effectively.

Pharmacologic Choice. When choosing local anesthetics for caudal anesthesia, the same considerations as those applied to epidural anesthesia are needed. Volumes of local anesthetic in the 25- to 35-mL range are necessary to provide predictably a sensory level of T12 to T10 with caudal injection for adults.

PLACEMENT

Anatomy. Anatomy pertinent to caudal anesthesia centers on the sacral hiatus (Fig. 53.1). This can be most effectively localized by finding the posterosuperior iliac spines bilaterally, drawing a line to join them, and then completing an equilateral triangle caudad. The tip of the equilateral triangle will overlie the sacral hiatus (Fig. 53.2). The caudal tip of the triangle will rest near the sacral cornua, which are unfused remnants of the spinous processes of the fifth sacral vertebra. Overlying the sacral hiatus is a fibroelastic membrane, which is the functional counterpart of the ligamentum flavum. Perhaps more than with any other sex difference found in regional anesthesia, the sacrum is distinctly different in men and women. In men, the cavity of the sacrum has a smooth curve from S1 to S5. Conversely, in women, the sacrum is quite flat from S1 to S3, with a more pronounced curve in the S4 to S5 region (Fig. 53.3).

Position. Caudal block can be carried out in a lateral decubitus position or a prone position. In adults, the author finds the prone position with a pillow placed beneath the lower abdomen most effective. In this position, patients can be sedated sufficiently to make the block comfortable, and it makes the midline more easily identifiable than in the lateral position. As illustrated in Fig. 53.4, pediatric caudal anesthesia is commonly carried out with the child in the lateral decubitus position. Because most pediatric caudal blocks are performed after induction with general anesthesia, the lateral position is almost mandatory. Identification of the midline and performance of the block are less complicated in the pediatric patient, thus making the lateral position clinically practical. To optimize identification of the sacral hiatus, the prone patient should have the legs abducted to a 20-degree angle, with the toes rotated inward and the heels outward. This helps relax the gluteal muscles, making it easier to identify the sacral hiatus (Fig. 53.5).

Needle Puncture. As with lumbar epidural anesthesia, caudal anesthesia requires a decision about the use of a single-injection or a catheter technique. If a single-shot caudal block is to be performed, almost any needle of sufficient length to reach the caudal canal is acceptable. In adults, a needle of at least 22 gauge is recommended because it is large enough to allow sufficiently rapid injection of solution to help detect misplaced local anesthetic injections. If a catheter is to be used, a needle that is large enough to allow passage of the catheter is required. As illustrated in Fig. 53.6, after the sacral hiatus is identified, the index and middle fingers of the palpating hand are each placed on the sacral cornua, and the caudal needle is inserted at an angle of approximately 45 degrees to the sacrum. As the anesthesiologist advances the needle, they will become aware of a decrease in resistance as the needle enters the caudal canal (*needle position 1*). The needle is then advanced until it contacts bone; this should be the dorsal aspect of the ventral

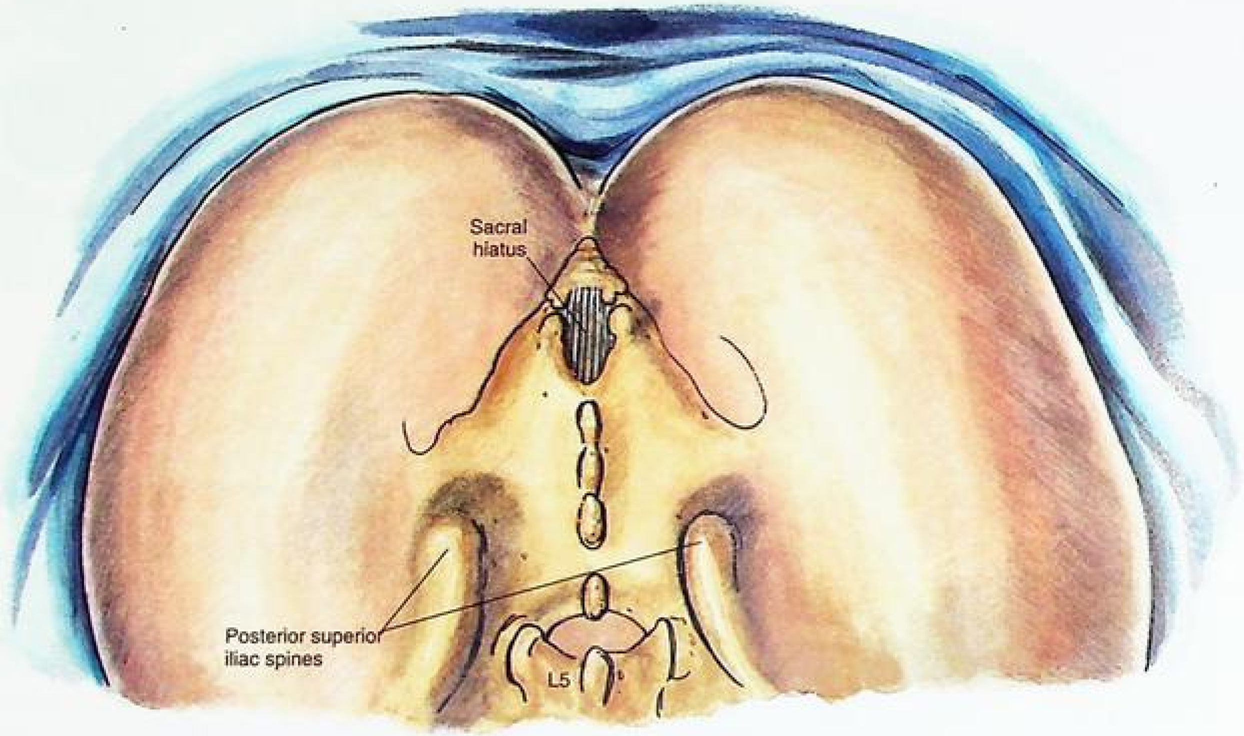


Fig. 53.1 Caudal block: surface anatomy.

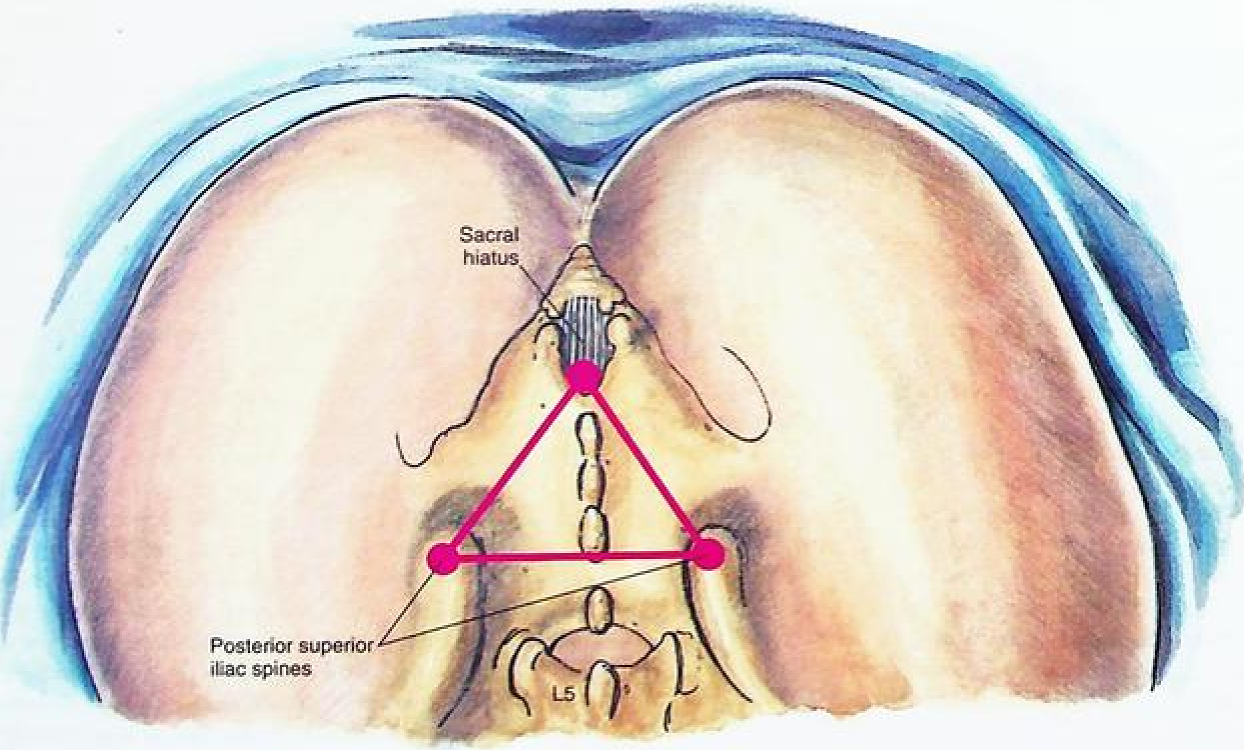


Fig. 53.2 Caudal block: surface anatomy showing sacral hiatus localization.

plate of the sacrum. The needle is then withdrawn slightly and redirected so that the angle of insertion relative to the skin surface is decreased. In male patients, this angle will be almost parallel with the tabletop, whereas in female patients, a slightly steeper angle will be necessary (*needle position 2*).

During the redirection of the needle and after noting loss of resistance, the needle should be advanced approximately

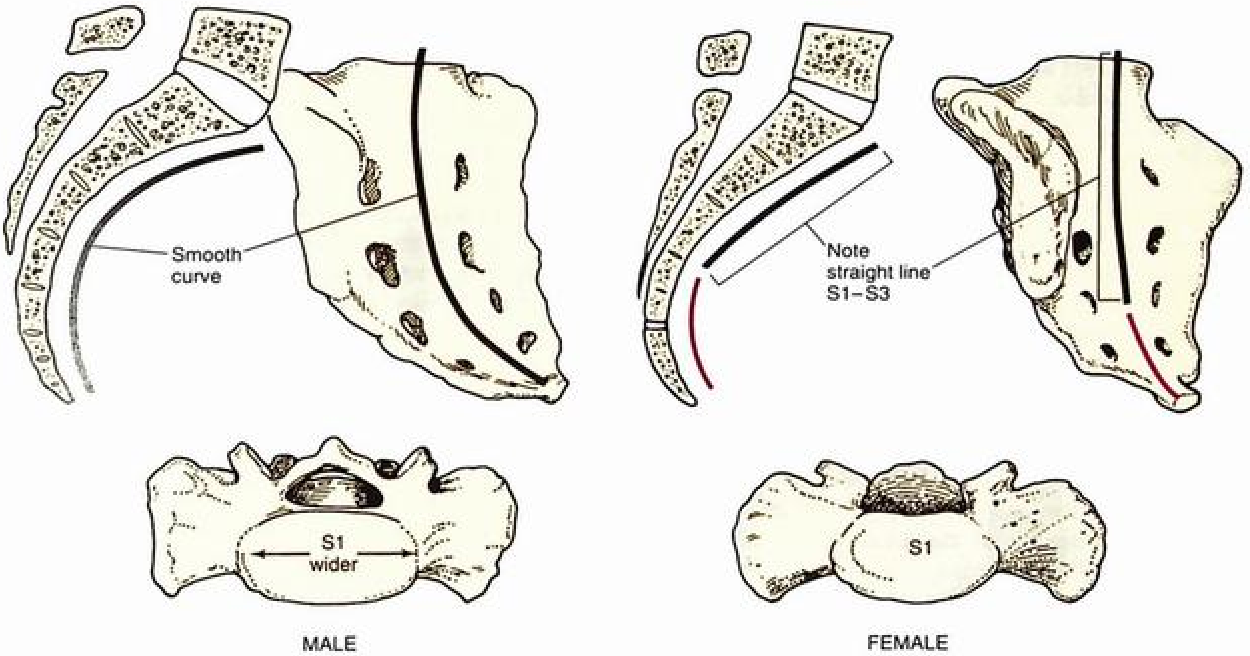


Fig. 53.3 Caudal block: relationship of sacral anatomy to sex.

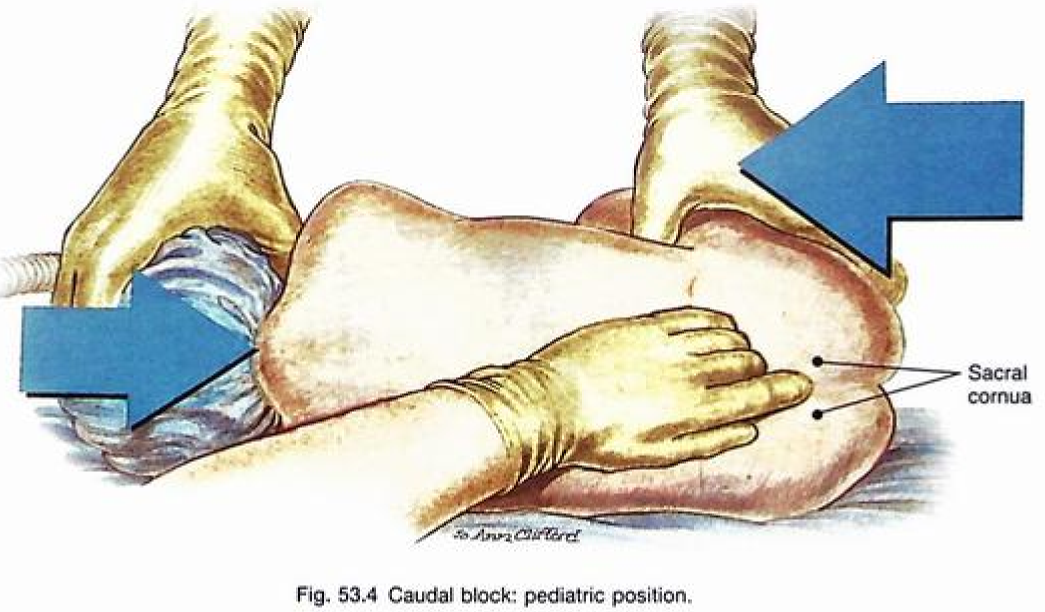


Fig. 53.4 Caudal block: pediatric position.

1 to 1.5 cm into the caudal canal. Further advance is not advised because dural puncture and unintentional intravascular cannulation become more likely. Before the injection of the therapeutic dose of local anesthetic, aspiration should be performed and a test dose administered because a vein or the subarachnoid space can be entered unintentionally, as is the case in lumbar epidural anesthesia.

POTENTIAL PROBLEMS

Caudal anesthesia entails most of the same complications that can accompany lumbar epidural anesthesia, although there are some differences. The frequency of local anesthetic toxicity after caudal anesthesia appears to be higher than it is with lumbar epidural block. Another distinct difference is that the incidence of subarachnoid puncture is exceedingly low with the caudal technique. The dural sac ends at approximately the level of S2; thus unless a needle is inserted deeply within the caudal canal, subarachnoid puncture is unlikely. In children, the dural sac is placed more distally in the caudal canal, and this should be considered when carrying out pediatric caudal anesthesia.

Perhaps the most frequent problem with caudal anesthesia is ineffective blockade, which results from the considerable variation in the anatomy of the sacral hiatus. If anesthesiologists are unfamiliar with the caudal technique and the needle passes anterior to the ventral plate of the sacrum, puncture of the rectum or, in obstetric anesthesia, of fetal parts is possible. As illustrated in Fig. 53.7, the area surrounding the sacral hiatus can be imagined as a potential "circle of errors." The practitioner may be faced with a slitlike hiatus that does not allow easy needle insertion; the hiatus may be located more cephalad than anticipated, or, in fact, may be closed. Likewise, loss of resistance may be encountered if the needle is inserted into one of the sacral foramina rather than the hiatus. In the lateral view, it is obvious that needles may be misdirected into subcutaneous or periosteal locations as well as into the marrow of sacral bones (Video 53.1).

PEARLS

To produce effective caudal anesthesia, anesthesiologists should be selective about the patients in whom it is attempted. It makes no sense to use the technique in a patient whose anatomy is unfavorable. Because of the anatomic variations in the area around the sacral hiatus, this block seems to require more operator experience and a longer time to attain proficiency than many other regional blocks. As a result, anesthesiologists should develop their technique in patients whose anatomy is favorable.

One helpful hint that will confirm needle location when carrying out caudal anesthesia is illustrated in Fig. 53.8. Once the needle has entered what is thought to be the caudal canal, the anesthesiologist should place a palpating hand across the sacral region dorsally. Then 5 mL of saline solution should be rapidly injected through the caudal needle. By placing the hand as shown, the anesthesiologist should be immediately aware of the subcutaneous needle position overlying the sacrum. If the needle is mispositioned subcutaneously, a bulge during injection will develop in the midline. If the needle is correctly positioned in the caudal canal, no midline bulge should be palpable. In thin individuals, accurate needle placement in the caudal canal and rapid injection of solution may allow the anesthesiologist to feel small pressure waves more laterally overlying the sacral foramina. These smaller pressure waves should not be confused with those associated with a misplaced subcutaneous needle.

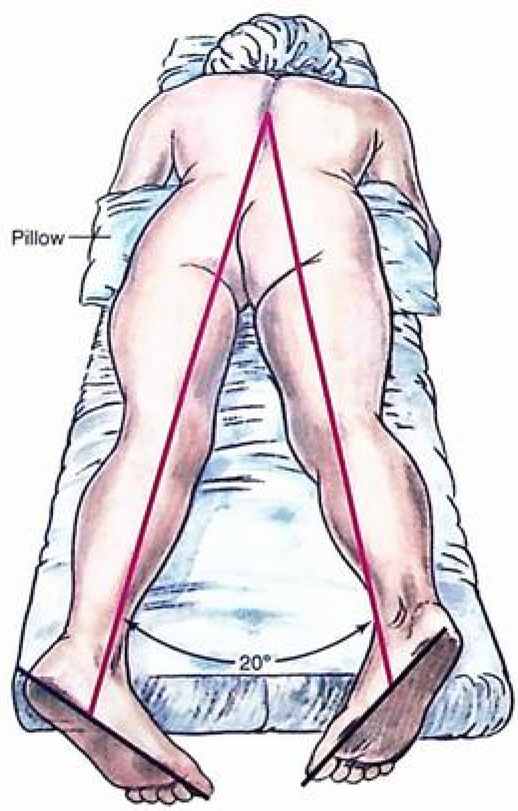


Fig. 53.5 Caudal block: prone position.

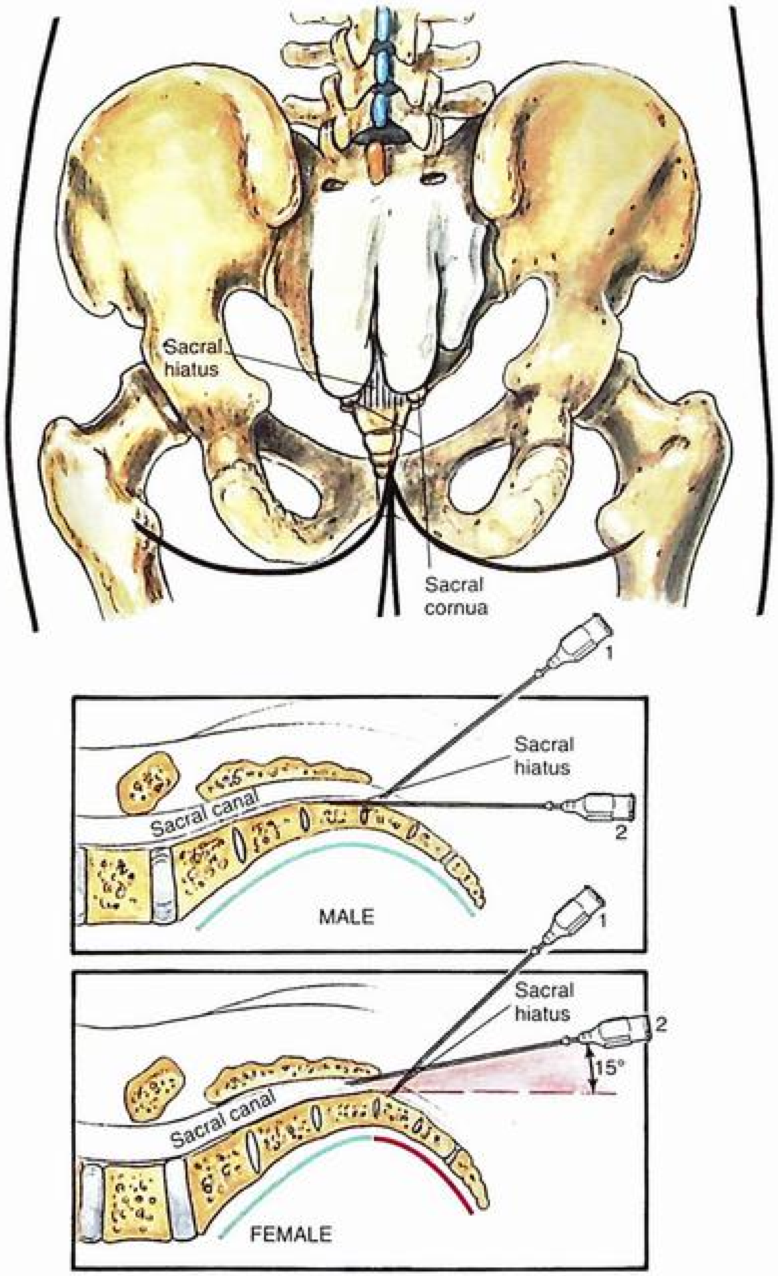


Fig. 53.6 Caudal block: technique.

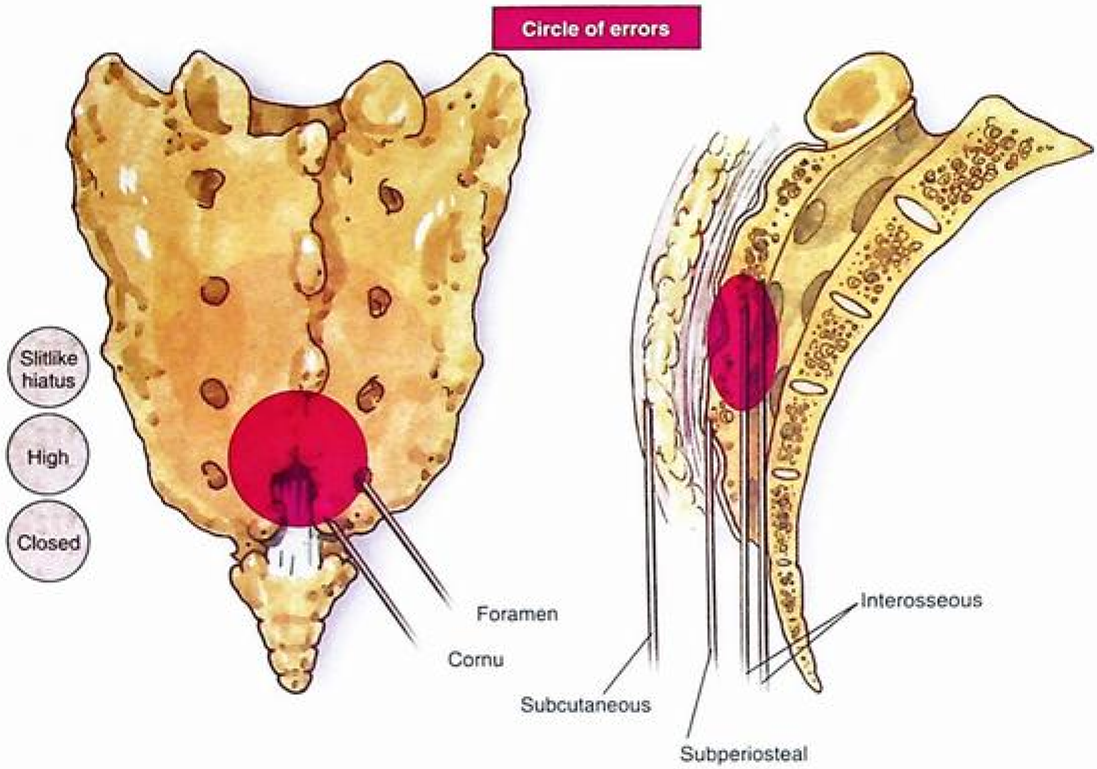


Fig. 53.7 Caudal block: circle of errors.

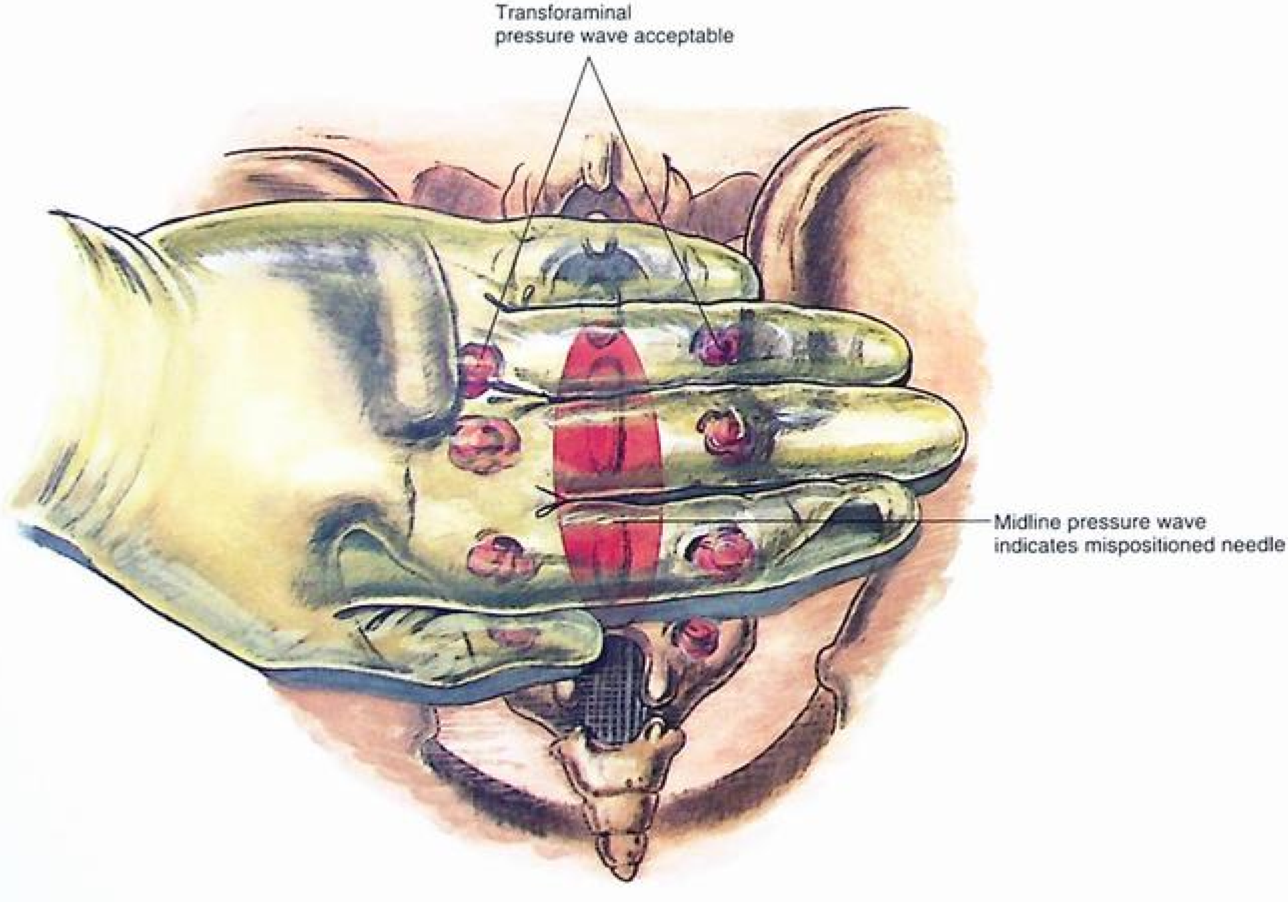


Fig. 53.8 Caudal block: palpation technique.

levels). Two randomized controlled trials comparing US-guided and fluoroscopy-guided SIJ injections showed no significant difference in pain outcomes following injection. However, Jee et al. found that US-guided SIJ injection was less accurate (87.3%) than fluoroscopy-guided SIJ injection (98.2%). A significant advantage to using US comes from the ability to identify and avoid peri- or intraarticular vasculature. This same study found that 12.7% of participants had intraarticular vessels, 41.8% of participants had periarticular vessels, and 7.2% of participants had both.

TECHNIQUE OF ULTRASOUND-GUIDED SIJ INJECTION

The patient is placed in the prone position, with a pillow underneath the abdomen to minimize lumbar lordosis. Usually, a low-frequency curvilinear transducer is used, especially in obese patients, to increase penetration. The transducer is placed transversely over the lower part of the sacrum (at the level of the sacral hiatus) and the lateral edge of the sacrum is identified. Then the transducer is

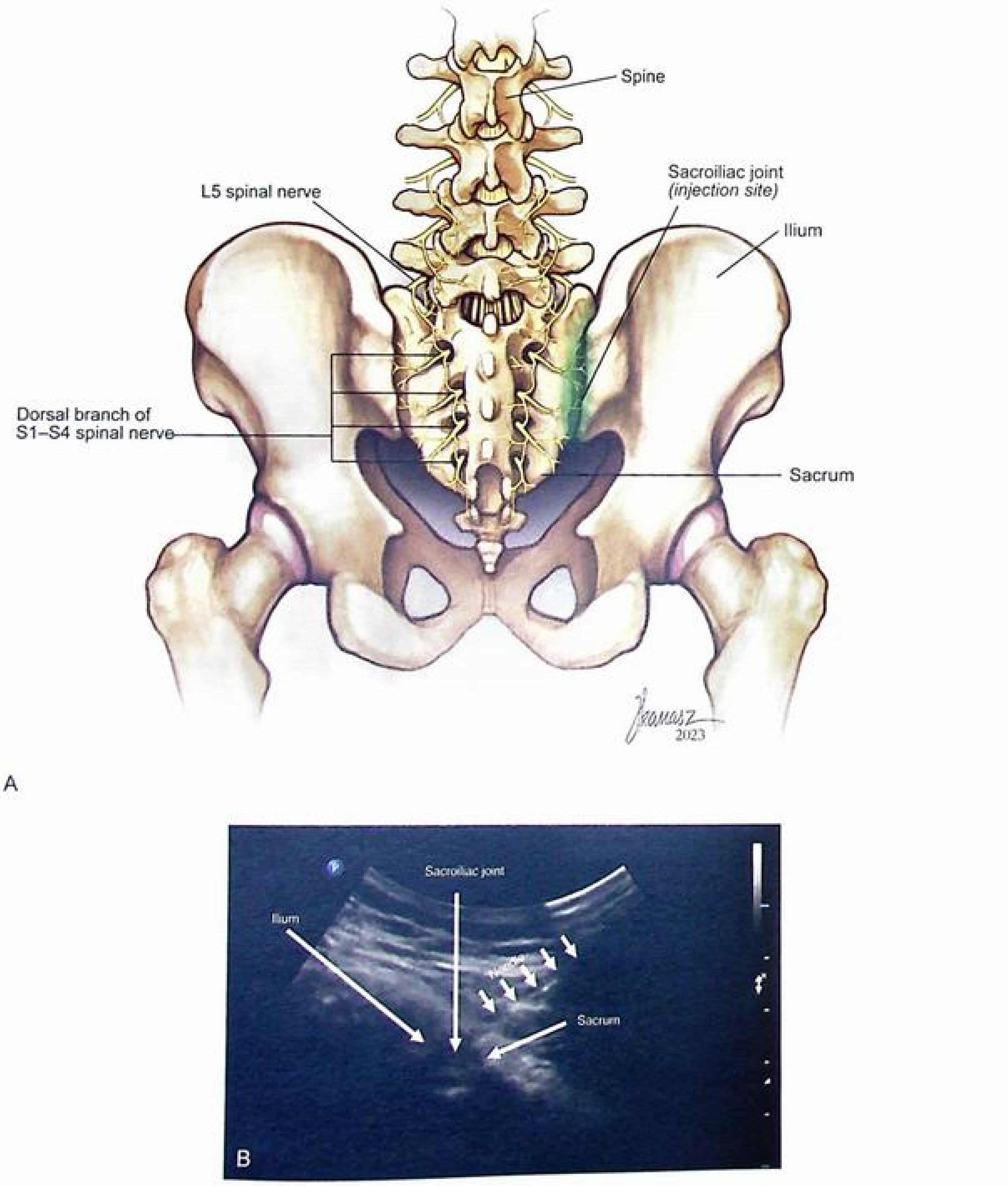


Fig. 54.1 (A) Coronal image of the right sacroiliac joint. Ideal joint access in the lower one-third of the joint is shown. (B) Ultrasound short-axis view of the sacroiliac joint with the in-plane needle approach to the sacroiliac joint is shown.

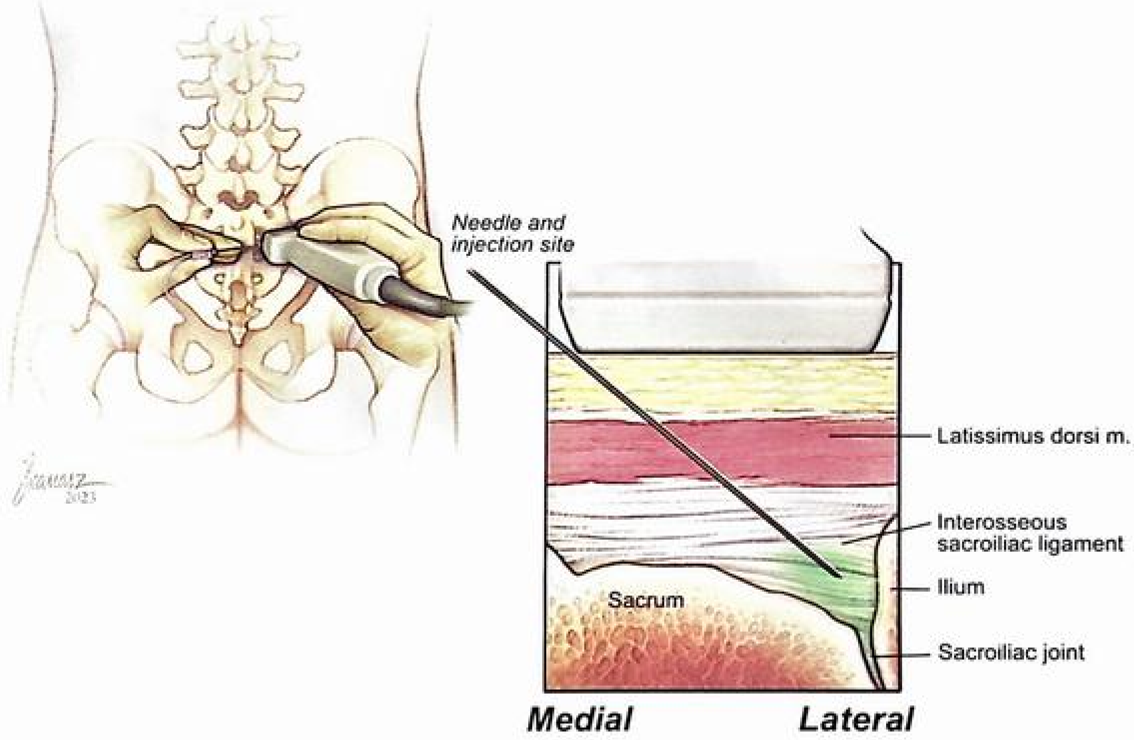


Fig. 54.2 A zoomed-in view of the right sacroiliac joint (SIJ) showing a linear array ultrasound probe overlying the SIJ, with the point of entry into the SIJ shown utilizing an in-plane needle approach.

moved laterally and cephalad till the bony contour of the ileum is clearly identified. The cleft seen between the medial border of the ileum and the lateral sacral edge represents the SIJ, and the most inferior point is targeted (Fig. 54.1A,B).

A 22-gauge needle is then inserted at the medial end of the transducer and advanced deeper and laterally in-plane with the US beam until it is seen entering the joint. The course of the needle will traverse the skin and subcutaneous fat, thoracolumbar fascia, and posterior sacroiliac ligament prior to reaching the posterior portion of the synovial capsule (Fig. 54.2).

PEARLS

- The in-plane technique is the preferred technique.
- Scanning before approaching the joint is desirable to familiarize the operator with the sonoanatomy of the SIJ as well as the surrounding structures.
- For beginners, it is recommended to combine US with fluoroscopy, as fluoroscopy is considered the gold standard modality to visualize the arthrogram and confirm intraarticular injection.

Suggested Reading

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SECTION 8
Pediatric Regional Using Ultrasound

55 Caudal Block in Pediatrics

John Seif and Nour Hochaimi

Key Points

- Checking the anatomy with ultrasound before and during the procedure ensures success. Because the sacrum is not fully ossified, it still can be penetrated by the ultrasound beams.
- Loss of resistance is not significant when placing an epidural, because the sacrococcygeal ligament is softer in the pediatric population.
- The needle may be misplaced in the subcutaneous periosteal location or in the dural sac.

POSITION

After induction with general anesthesia, the lateral decubitus position is the most optimum position for full exposure of the sacral hiatus. Flex both knees to the abdomen and identify the midline above the gluteal crease, where the sacral hiatus can be palpated.

ANATOMY

It is important to know the differences between pediatric and adult anatomy when performing a neuraxial block in the pediatric population. The conus medullaris ends between L2 and L3 in infancy and reaches adult levels L1 to L2 by the end of the first year of life. The dural sac is at the S4 level at birth and reaches S2 by the end of the first year. The line joining the two superior iliac crests (intercristal line) crosses at L5 to S1 interspace at birth, L5 vertebra in young children, and L3 to L4 interspace in adults (Fig. 55.1).

Draw a triangle with the baseline between the two posterosuperior iliac spines (PSIS) and the apex at the sacral hiatus. The caudal tip will lie between the two sacral cornua of the fifth sacral vertebrae. The sacrococcygeal ligament, which resembles the ligamentum flavum, lies between the two sacral cornua.

SONOANATOMY

This technique becomes even more complex when considering variation in patient age, weight, and varying levels of bone ossification. Ultrasound guidance for this procedure is helpful in identifying the underlying anatomic structures. The ones most commonly of interest include the sacral hiatus, sacral cornua, coccyx, and sacrococcygeal ligament. Although probe orientation can be done using either a transverse or longitudinal view of the midline, it is typically best to orient and assess landmarks before performing the procedure. When placing the probe's transverse plane at the coccyx, the sacral cornua are viewed laterally as humps. The sacral hiatus is located between an upper hyperechoic line, representing the sacrococcygeal membrane or ligament, and an inferior hyperechoic line, representing the dorsum of the pelvic surface of the sacrum (Figs. 55.2 and 55.3).

TECHNIQUE

If single-shot analgesia is required, a 22-gauge Angiocath is used, and if an epidural catheter is required, then a larger Angiocath—for example, 20- or 18-gauge—is the appropriate choice. After identifying the anatomy, palpate the sacral cornua with the index finger. Advance the needle at a 45-degree angle to the skin, distal to the index finger. A doughy sensation is felt as the needle is advanced. Then the angle of the Angiocath is dropped to 15 degrees and advanced until a loss of resistance is felt (a light "pop" in the pediatric population). Before injecting the local anesthetic, aspiration and a test dose should be performed.

For a caudal catheter, attaining access to the caudal space follows the same technique as that of the single-shot caudal block discussed earlier. Either a pediatric epidural kit needle or an 18-gauge Angiocath can be used. First, it is important to determine and mark the level where the catheter tip is to be positioned; it usually is in the thoracic upper lumbar, depending on the surgical incision site. This can be achieved by external measurement, measuring the distance from the skin covering the sacral hiatus to the skin covering the desired marked level. It is advisable to confirm that the catheter passes through the Angiocath before starting the procedure.

CATHETER TIP LOCATION CONFIRMATION

There are several ways to identify the caudal epidural space. The most common one is the detection of the characteristic "give" or "pop" on penetration of the sacrococcygeal ligament. Since pain assessment in infants is very difficult, any additional information that would allow confirmation of correct catheter position can be of clinical benefits.

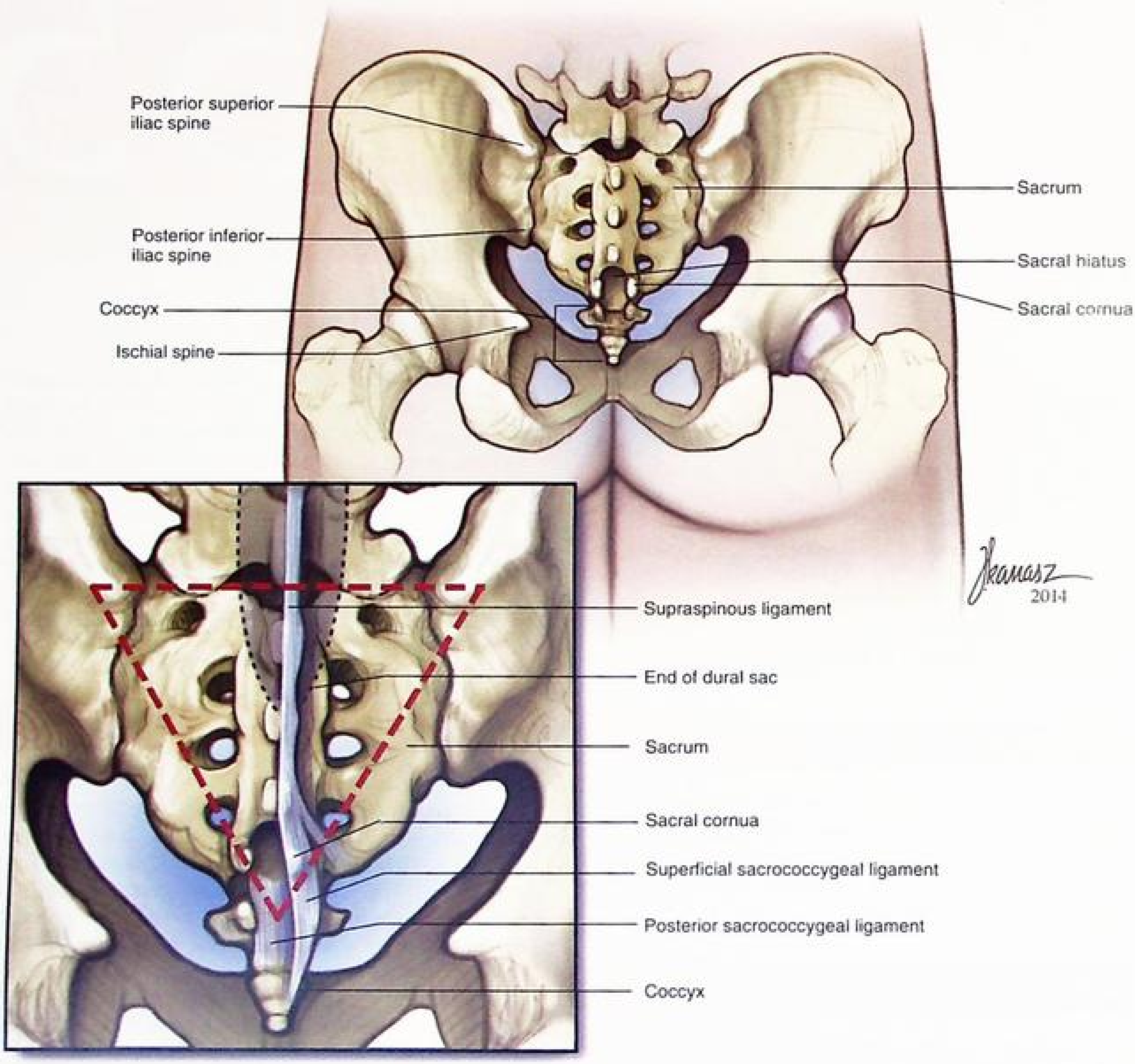

Fig. 55.1 Surface anatomy of caudal space; posterosuperior iliac spine and sacral hiatus.

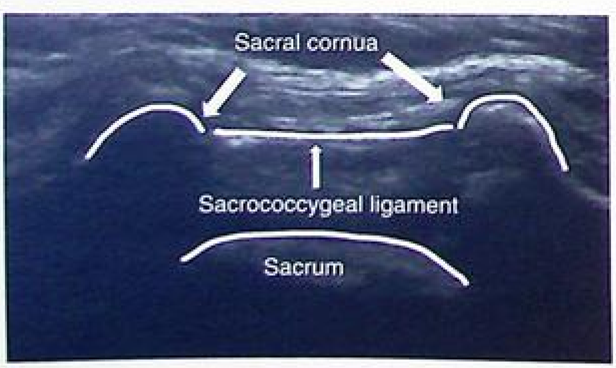

Fig. 55.2 Ultrasound still of anatomy of caudal block in pediatrics.

Ultrasound. This method offers a radiation-free method for placement. The metal stylet can be visualized rapidly and easily, and traced caudal-to-cephalad under real-time ultrasound guidance.

Epidurogram or Fluoroscopy. After advancing the catheter to the predetermined marked vertebral level, an epidurogram or fluoroscopy can be used to confirm the site of the catheter's tip. For a stylet catheter, fluoroscopy is used to confirm that the tip of the catheter has reached the desired vertebral space level, but it does not rule out intravascular or intrathecal catheter. Iopamidol is injected and imaged using fluoroscopy. A characteristic "bubbly" pattern in the midline is diagnostic of proper placement. This technique confirms epidural space placement, and it also rules out incorrect anatomic space and predicts analgesic coverage by showing the extent of the contrast spread.

TUNNELING

Because caudal catheters are at risk of contamination from fecal material, it is advisable to tunnel the catheter subcutaneously. This can be achieved using an 18-gauge long

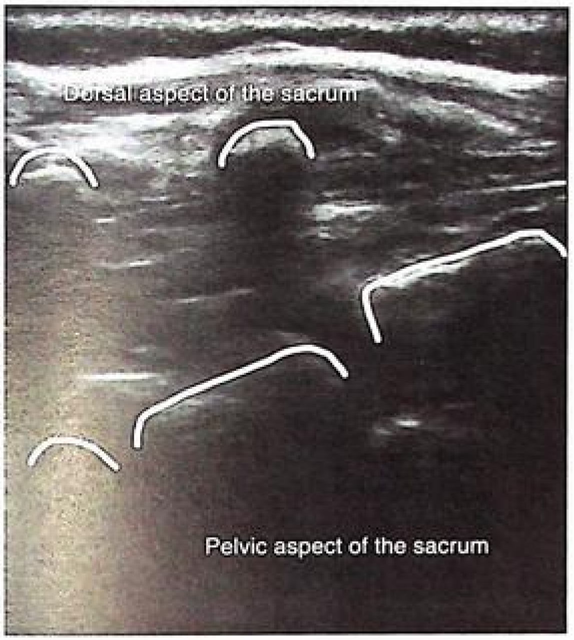

Fig. 55.3 Ultrasound still of anatomy of caudal block in pediatrics.

intravenous Angiocath that would create a tunnel from the site of the caudal catheter entry to a more cephalad skin site out of the diaper area. This is followed by removing the needle, keeping the Angiocath in site and threading the caudal catheter through the Angiocath, which will be removed thereafter. This will result in modifying the port of entry of the caudal catheter from a caudad site to a more cephalad site, reducing the incidence of infection in addition to providing more catheter stabilization. It is important to apply a transparent dressing over the site of entry to assess for redness or any sign of infection.

PEARLS

- Check the block with normal saline first before injecting the local anesthetic and palpate the sacrum for any subcutaneous injection.
- Patient selection and experience play a big role in the success of the block.

Suggested Reading

Bubeck J, Boos K, Krause H, Thies KC. Subcutaneous tunneling of caudal catheters reduces the rate of bacterial colonization to that of lumbar epidural catheters. *Anesth Analg.* 2004;99(3):689–693.

Goyal R, Jindal K, Baj B, Singh S, Kumar S. Paediatric spinal anesthesia. *Indian J Anaesth.* 2008;52(3):264–270.

Taenzer AH, Clark C 5th, Kovarik WD. Experience with 724 epidurograms for epidural catheter placement in pediatric anesthesia. *Reg Anesth Pain Med.* 2010;35(5):432–435. https://doi.org/10.1097/AAP.0b013e3181ef4b76.

Tsui BC, Tarkkila P, Gupta S, Kearney R. Confirmation of caudal needle placement using nerve stimulation. *Anesthesiology.* 1999;91:374–378.

Van Schoor AN, Bosman MC, Bosenberg AT. Descriptive study of the differences in the level of the conus medullaris in four different age groups. *Clin Anat.* 2015;28:638–644.

Ilioinguinal and Iliohypogastric Block 56

John Seif

Key Points

- Identifying the different layers of the muscles is crucial, because the peritoneum is the shiniest layer under the transversus abdominis muscle. When the bowels are seen under the peritoneum under ultrasound, the sliding sign appears in response to breathing.
- Loss of resistance when penetrating the different muscle layers can be felt as a pop. Extra caution is needed, because the needle could advance accidentally into the peritoneum and perforate the bowel.
- Avoid puncturing the blood vessels, especially the inferior epigastric vessels, because they sometimes accompany the ilioinguinal and iliohypogastric nerves along their path. Ultrasound aids in visualizing these small vessels, especially if using Doppler mode.

POSITION

The patient is placed in the supine position, with exposure of the abdominal and pelvic areas (Fig. 56.1).

ANATOMY

Identify the anterosuperior iliac spine (ASIS) and the umbilicus and draw a line between these two points. Divide this line into three equal distances at the point where the outer one-third meets the inner two-thirds. This is the point of the needle entry. This point is about 2 cm medial and cephalad to the ASIS (Fig. 56.2).

The ilioinguinal and iliohypogastric nerves are formed by branches from T12 to L1, which pass between the internal oblique and transversalis muscles. Performing this block provides good analgesia for most operations of the inguinal regions.

SONOANATOMY AND TECHNIQUE

Place the ultrasound probe on the line connecting the umbilicus to the ASIS. A transverse longitudinal view will reveal the underlying muscles: the external oblique, internal oblique, and transversus abdominis muscle (Fig. 56.3). Advance the blunt injecting needle in-plane with the ultrasound probe until two "pops" are felt. The first pop occurs between the external oblique and the internal oblique muscles. The second pop occurs between the internal oblique and the transversus abdominis muscle (Fig. 56.4A); this is where the local anesthetic (LA) is injected (Fig. 56.4B, Video 56.1).

PEARLS

- Visualizing the spread of LA in the plane between the internal oblique and the transversus abdominis muscles can help ensure excellent results.
- Tenting the muscles is common when using the blunt needle, so a more perpendicular angle needle entrance technique is used.

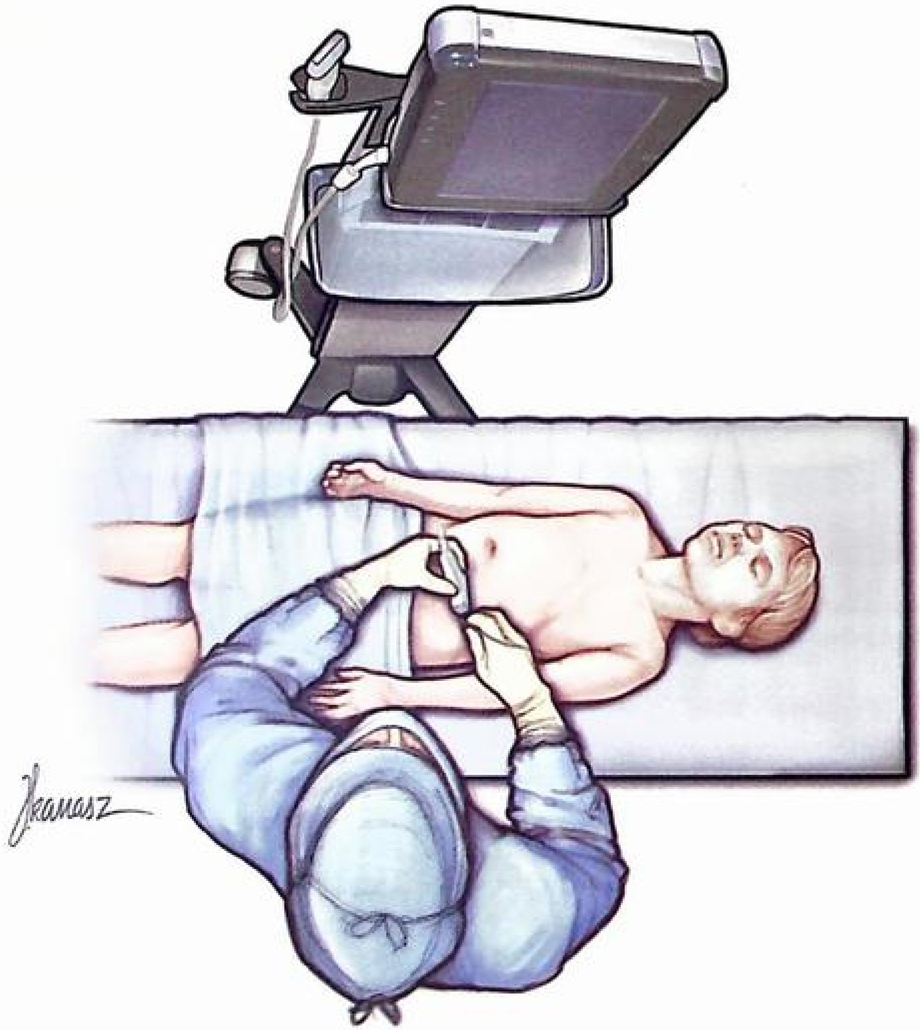

Fig. 56.1 The inguinal and the abdominal areas are exposed, and the ultrasound is on the opposite side of the block.

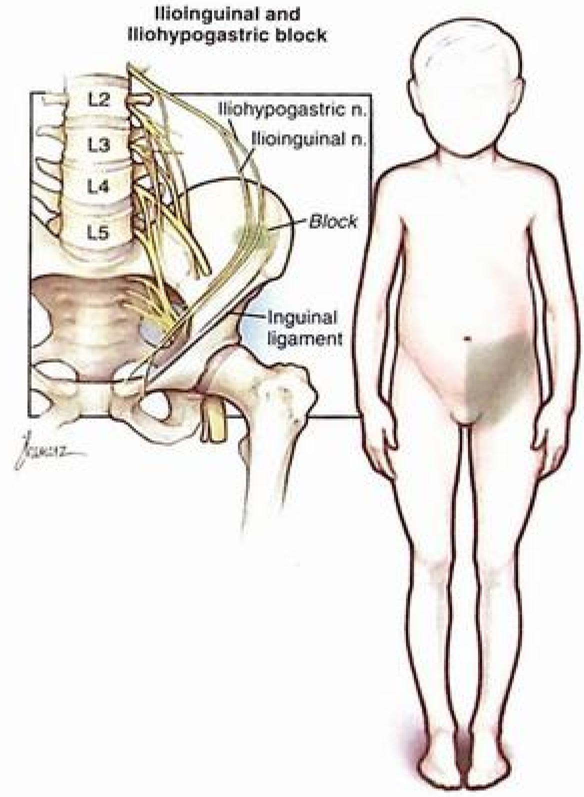

Fig. 56.2 Identify the anterosuperior iliac spine and the umbilicus and draw a line connecting these two points. Apply the ultrasound probe on this line, and the needle entrance point will be at the outer third junction of the line.

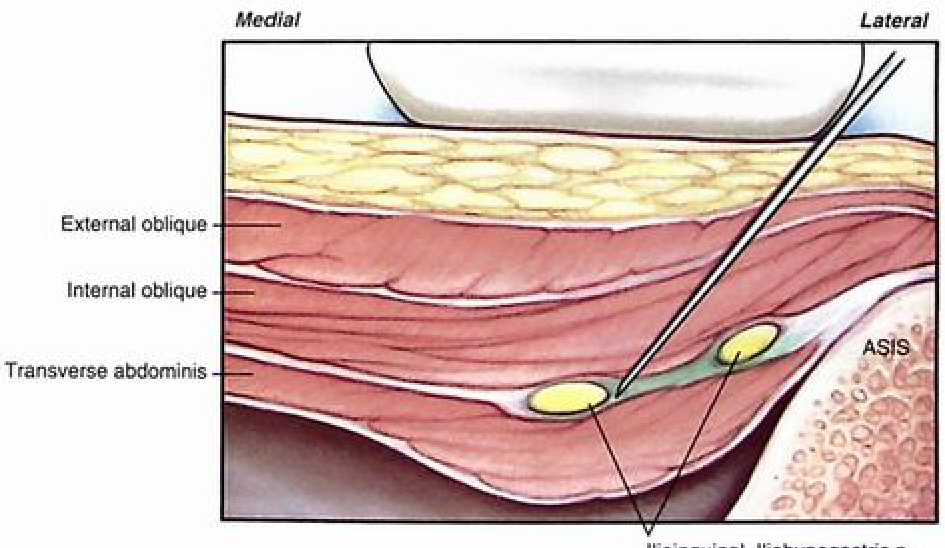

Fig. 56.3 The needle is advanced under ultrasound using an in-plane approach, penetrating the external and internal oblique muscles, targeting the ilioinguinal and iliohypogastric nerves lying in the plane between the internal oblique and the transverse abdominus muscles. *ASIS*, Anterosuperior iliac spine.

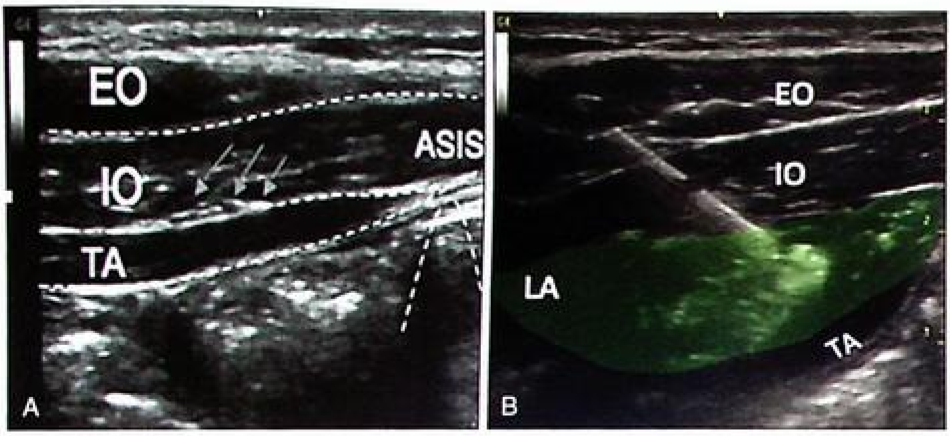

Fig. 56.4 (A) The three muscles under ultrasound, visualizing the ilioinguinal and iliohypogastric nerves *(arrows)*. (B) Local anesthetic *(LA)* spread between the internal oblique *(IO)* and transverse abdominus *(TA)* muscles, as shown in the image. *ASIS*, Anterosuperior iliac spine; *EO*, external oblique.

Superficial Cervical Plexus and Suprazygomatic Maxillary Nerve Blocks

57

John Seif and Nour Hochaimi

Key Points for Superficial Cervical Plexus Block

- Stabilize the neck position and identify the sternocleidomastoid muscle.
- If not using ultrasound, always feel for the infiltration with the other hand to avoid injecting the local anesthetic into any vascular structure.
- Infiltrate along the posterior border of the sternocleidomastoid muscle superior and inferior to the point of needle entry.
- Superficial injection of local anesthetic with a 22-gauge needle is recommended.
- This block covers only cutaneous sensation and could be used in mastoidectomy and in clavicular bone fracture, especially in the lateral one-third of the clavicle, for postoperative pain control (see Fig. 57.4).

Key Points for Suprazygomatic Maxillary Nerve Block

- The suprazygomatic maxillary block is used for cleft palate repair surgery in infants.
- It is a deep block; however, it holds a lower risk of vascular injury.

POSITION

Place the patient in the supine position without a pillow. The head is turned to the opposite side of the one being blocked (Fig. 57.1).

ANATOMY AND TECHNIQUE

The superficial cervical plexus provides cutaneous innervation to the ventral rami of C1 to C4 (Fig. 57.2). It includes the lesser occipital, greater auricular, transverse cervical, and supraclavicular nerves (Fig. 57.3). At the midpoint on the posterior border of the sternocleidomastoid muscle is the point of needle entry. The needle is inserted, and local anesthetic is injected behind and along the posterior border of the clavicular head of the sternocleidomastoid muscle.

Under ultrasound, use the linear probe and place it in a transverse position at the needle entry point over the sternocleidomastoid muscle. The needle is aligned with the ultrasound probe in the in-plane position. Visualizing the local anesthetic spread on the posterior border of the sternocleidomastoid muscle is the key to a successful block (Fig. 57.4).

PEARLS

- If deep injection occurs, it could lead to a deep cervical plexus block and a partial phrenic nerve block. Hoarseness and an inability to clear secretions may occur.

ANATOMY

The maxillary nerve, the second division of the trigeminal nerve, leaves the cranial part of the face through the foramen rotundum and then passes forward and laterally through the pterygopalatine fossa. It reaches the floor of the orbit by the infraorbital foramen. It supplies sensory innervation of the lower eyelid, the upper lip, the skin between them, and the palate.

Compared with the infraorbital route, the suprazygomatic maxillary block is a deep approach to the trigeminal nerve in the pterygopalatine fossa, minimizing risks of vascular and nerve puncture.

TECHNIQUE

The puncture site is at the frontozygomatic angle, at the junction of the upper edge of the zygomatic arch and the frontal process (Fig. 57.5). The needle is inserted perpendicular to the skin. It is advanced to reach the greater wing of sphenoid, then withdrawn a few millimeters and redirected toward the nasolabial fold in a 20-degree forward and 10-degree downward direction. Loss of resistance after passing through the temporalis muscle assists in determining the puncture depth.

In real-time ultrasound guidance, the ultrasound transducer is located in the infrazygomatic area. The probe location allows visualization of pterygopalatine fossa, limited anteriorly by the maxilla and posteriorly by the greater wing of the sphenoid (Fig. 57.6).

Fig. 57.1 Supine position, turning the head to the opposite side of the block, and ultrasound position on the opposite side of the block, facing the physician.

The anatomic location of the internal maxillary artery in the anterior part of the pterygopalatine fossa makes its accidental puncture unlikely because of the caudal inclination of the needle during the puncture.

PEARLS

Cleft palate repair surgery is associated with postoperative airway obstruction, which can be aggravated with narcotic administration for pain relief and consequently lead to a higher incidence of perioperative respiratory adverse events. Thus performing a regional block for infants undergoing this procedure is of clinical importance to decrease postoperative pain, narcotic requirements, and respiratory complications, in addition to resuming feeding earlier.

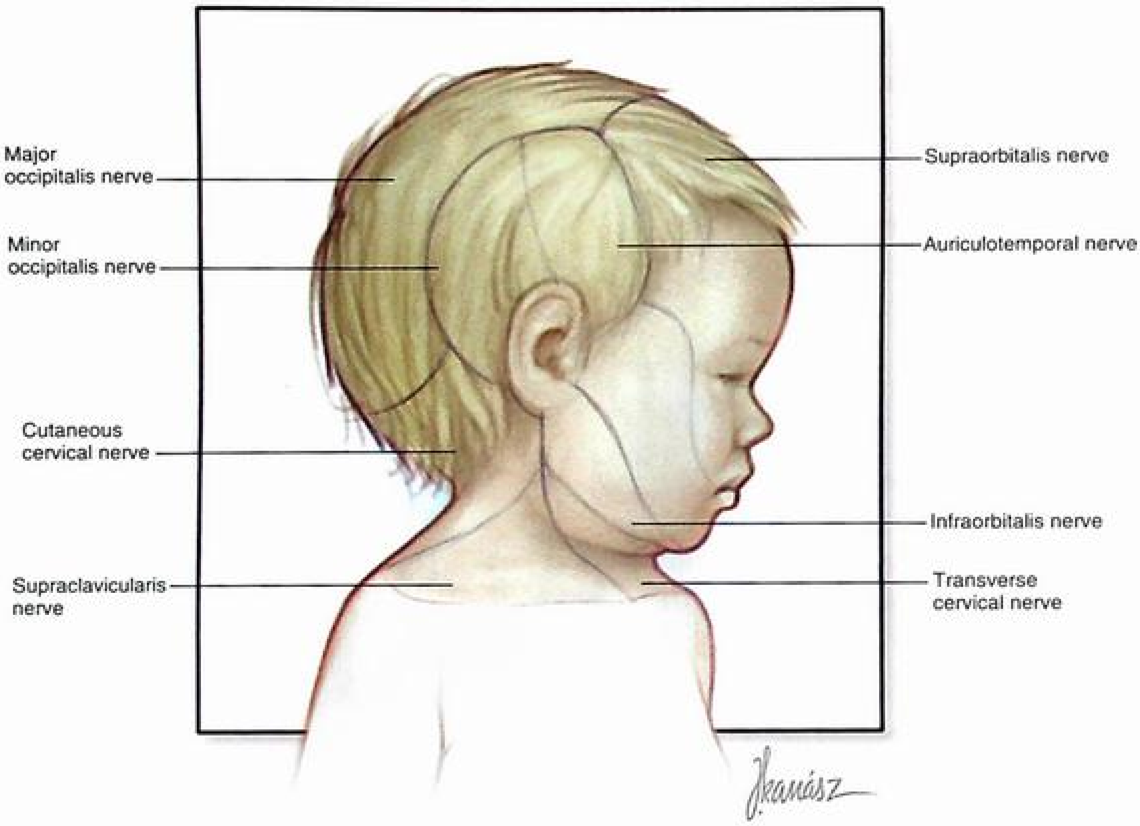

Fig. 57.3 The superficial plexus block will cover the following: lesser occipital, greater auricular, transverse cervical, medial and lateral supraclavicular nerves, and accessory nerve.

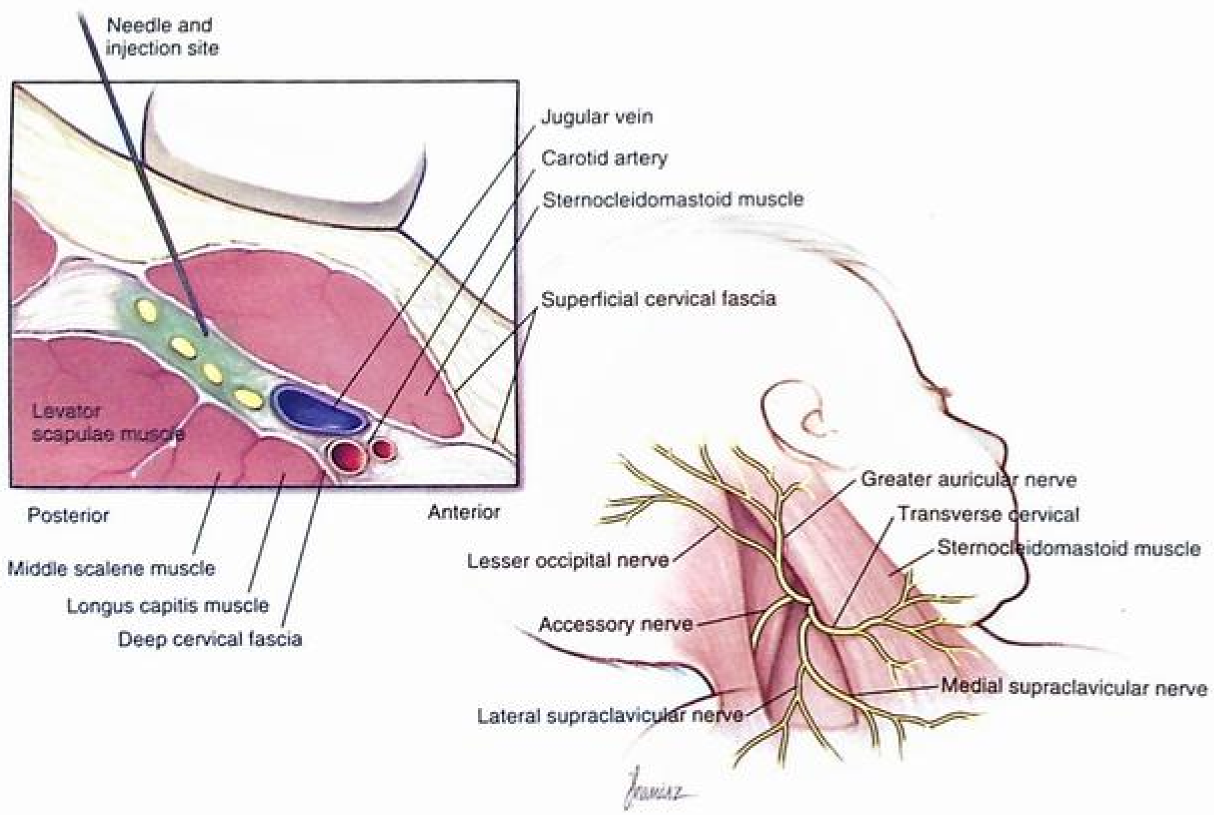

Fig. 57.4 Visualizing the needle advancement in linear approach, targeting the posterior border of the sternocleidomastoid muscle, and infiltrating the area with local anesthetic.

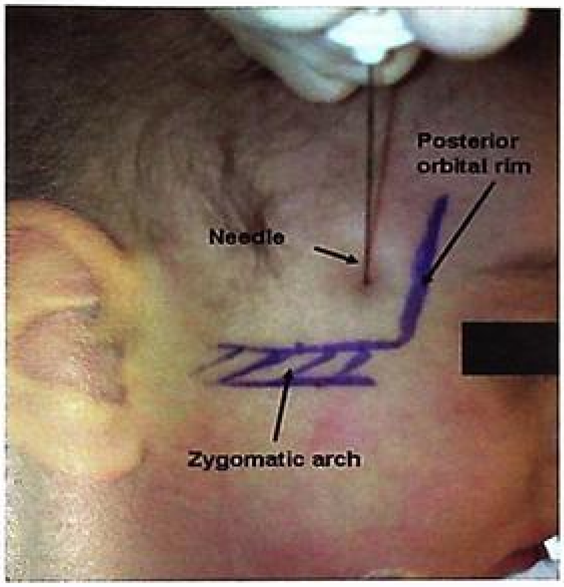

Fig. 57.5 **Suprazygomatic maxillary nerve block landmarks.** (Chiono J, Raux O, Bringuier S, et al. Bilateral suprazygomatic maxillary nerve block for cleft palate repair in children: a prospective, randomized, double-blind study versus placebo. *Anesthesiology*. 2014;120(6):1362-1369. © 2014, the American Society of Anesthesiologists, Inc. Lippincott Williams & Wilkins. Reprinted with permission.)

Fig. 57.6 **Ultrasound image of pterygopalatine fossa.** (Sola C, Raux O, Savath L, Macq C, Capdevila X, Dadure C. Ultrasound guidance characteristics and efficiency of suprazygomatic maxillary nerve blocks in infants: a descriptive prospective study. *Paediatr Anaesth*. 2012;22(9):841-846. © 2012 Blackwell Publishing Ltd. Reprinted with permission.)

58 Pudendal Nerve Block

John Seif

Key Points

- Patient selection plays a major role in performing the block; it is challenging with obese patients.
- Ultrasound experience is required to maximize the success rate of the block.
- Vascular injection is a risk if no spread is visualized with deposition of local anesthetics (LAs) under ultrasound.
- Avoid contamination, because the area of injection is close to the perianal area.

INDICATIONS

- Perineal operations in both sexes.
- Hypospadias and circumcision are the most common surgeries.
- Scrotal and testicular surgeries with a supplementation of ilioinguinal blockade.

CONTRAINDICATIONS

- Infection or presence of perianal inflammation.

SONOANATOMY

- The pudendal nerve derives its fibers from the ventral branches of the second, third, and fourth sacral nerves. It leaves the pelvis through the lower part of the greater sciatic foramen, passes behind the spine of the ischium, and reenters the pelvis through the lesser sciatic foramen. It accompanies the internal pudendal vessels along the medial border of the ischial tuberosity (Fig. 58.1).
- Placing the patient in a frog-like or lithotomy position helps to expose the area and identify the underlying structures. The linear ultrasound transducer probe is placed on the perineum lateral to the anus at 3 o'clock to 9 o'clock and overlies the ischial tuberosity (Fig. 58.2).
- The pudendal artery can be visualized medial to the ischial tuberosity.

TECHNIQUE

- The ischial tuberosity is visualized, and the needle is introduced out-of-plane at a 45-degree angle to the skin. The needle is advanced in an anterior to posterior direction in the middle of the ultrasound probe just medial to the ischial tuberosity, where the LA solution is deposited (Fig. 58.3).
- Little resistance will be experienced by passing through the sacrotuberous ligament.
- A nerve stimulator is used at 0.3 to 1.0 mA beside the ultrasound where penile and anal contractions are observed, which also confirms the pudendal nerve. Sometimes, it is challenging to find the nerve under ultrasound.
- Bupivacaine 0.25% up to 1 mL/kg in pediatric populations.
- This block is performed bilaterally to reach maximum pain relief.

PEARLS

- Positioning in lithotomy/frog-like position facilitates the block performance.
- Use color Doppler ultrasound to visualize the pudendal artery medial to the ischial tuberosity, where the pudendal nerve is located.
- Visualizing the LA spread medial to the ischial tuberosity increases the success rate of the block.

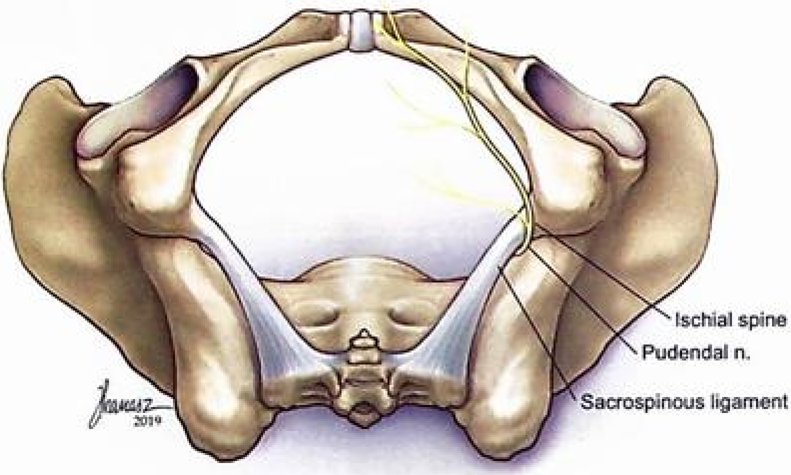

Fig. 58.1 The pudendal nerve is located medial to the ischial tuberosity, under the ischial spine ligament.

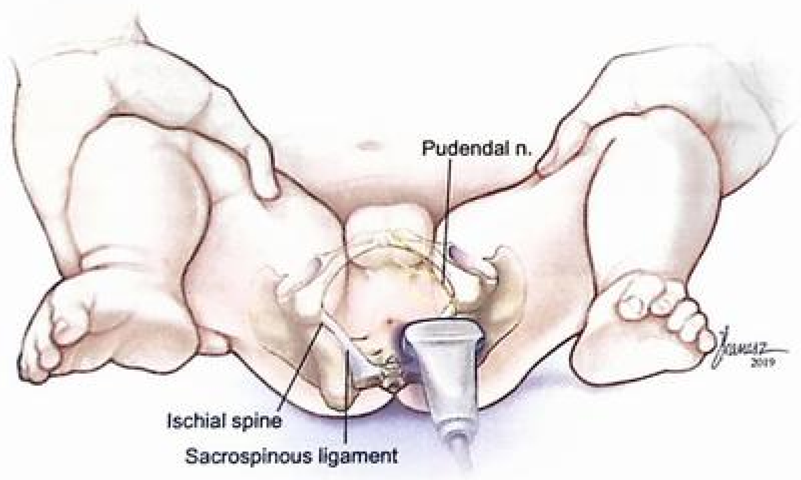

Fig. 58.2 In the lithotomy/frog-like position, the ischial tuberosity is the most medial bony prominence. The linear ultrasound probe overlies the ischial tuberosity.

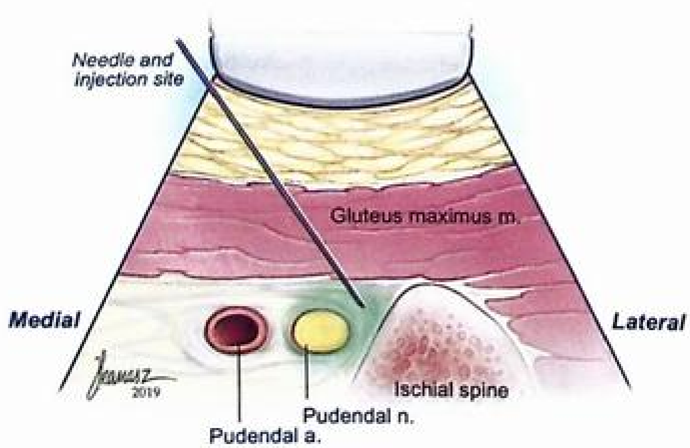

Fig. 58.3 Needle-tip target is medial to the ischial tuberosity, where the LA is deposited.

59 Paravertebral Catheters in Pediatrics

John Seif

Key Points

- Performing this block requires ultrasound experience.
- Needle visualization plays a major role in achieving a successful block.
- Epidural spread can occur from a unilateral injection.

INDICATIONS

- Patients who undergo operative procedures of the chest and upper abdomen.
- Unilateral coverage as thoracotomies, cholecystectomy, mastectomies, and other urological procedures with preservation of the pulmonary functions.
- Inadequate or unsuccessful epidural placement where bilateral catheters are placed.

CONTRAINDICATIONS

- Caution with populations using anticoagulation and antiplatelet therapy.

SONOANATOMY

- The thoracic paravertebral space is a small triangular space lateral to the vertebral column.
- Bounded posteriorly by the superior costotransverse ligament, anteriorly by the parietal pleura, and superiorly and inferiorly by the adjacent head and neck of the adjacent rib.
- The paravertebral space can be scanned in both the transverse and paramedian approaches.
- In the transverse approach (short access), the ultrasound probe is aligned in the space between the two adjacent ribs overlying the transverse process. In this approach, the space can be identified between the external intercostal muscle and intercostal membrane superiorly and parietal pleura inferiorly.
- In the paramedian approach (long access), the probe lies in the paramedian plane of the transverse process. The external intercostal muscle and costotransverse ligament lie between the transverse process, and deeper to it is the parietal pleura. The area between is the paravertebral space.

TECHNIQUE

- In the transverse approach, the linear ultrasound probe is aligned over the long axis of the rib. Identifying the transverse process medially and the intercostal muscles and deep to it is the parietal pleura (sliding sign) (Fig. 59.1).
  - An 18-gauge Tuohy needle is introduced in line with the linear ultrasound probe from lateral to medial under direct visualization. The needle tip ends in the paravertebral space deep to the costotransverse ligament and just above the parietal pleura, where the local anesthetic (LA) is deposited. Then a 19-gauge paravertebral catheter is inserted through the Tuohy needle up to 5 cm beyond the length of the needle.
  - LA used is a ropivacaine 0.2% (1 mL/kg) bolus up to 10 mL, followed by a continuous infusion (maximum 0.4 mg/kg/h).
- In the paramedian approach, a linear ultrasound probe is used (short access), visualizing the transverse process and the intercostal muscles and identifying the lung pleura deeper. The LA is deposited above the pleura and underneath the internal intercostal membrane.

PEARLS

- Placing the patient in a lateral position is the best option in the pediatric population.
- Identify the parietal pleura from the costotransverse ligament by visualizing the sliding sign, where the parietal and visceral layers of the lung rub against each other.
- The presence of the lung sliding sign before and after the procedure is important, because it rules out pneumothorax.
- Pneumothorax, complete spinal blockade, and LA toxicity are common complications for this block, which can be avoided when performed by experienced practitioners.

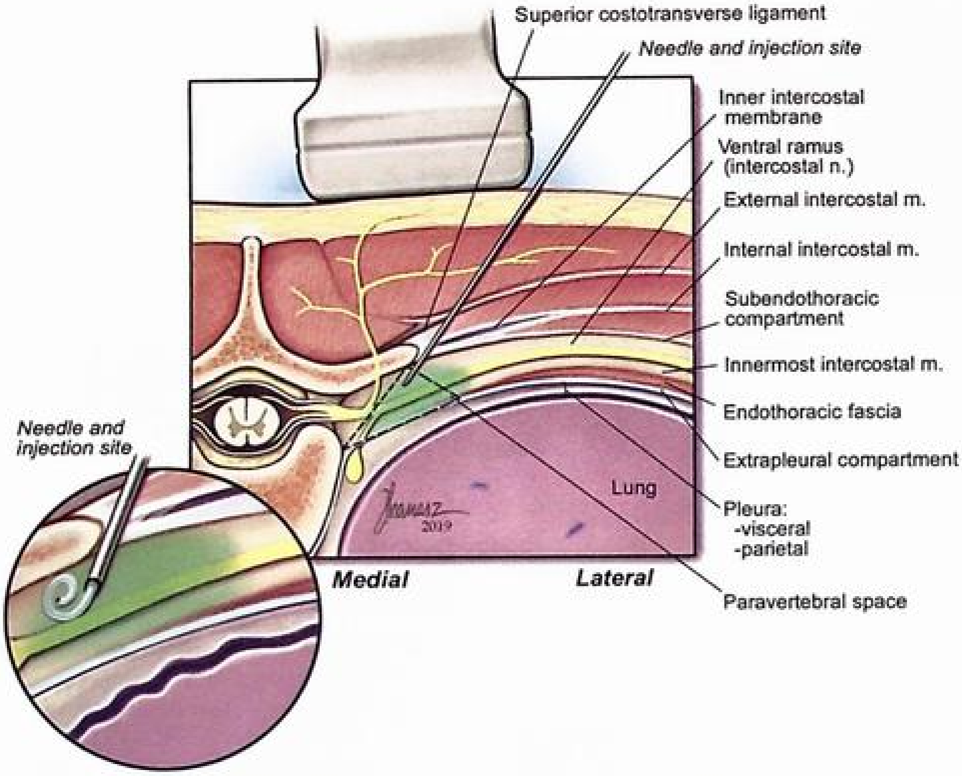

Fig. 59.1 The ultrasound probe in a transverse approach with needle advancement from lateral to medial approaching the paravertebral space.

Section 9
Obstetrics Regional Anesthesia

Regional Techniques During Pregnancy and Delivery

60

Cynthia A. Wong

Key Points

- Neuraxial analgesia/anesthesia techniques (spinal, epidural, and combined spinal-epidural) are the mainstays of safe anesthesia care of the obstetric patient. The anesthesia provider is caring for the mother and, by extension, the fetus.
- Hormonal and anatomic changes during pregnancy influence neuraxial technique and drug administration.
- Neuraxial analgesia (usually epidural or combined spinal-epidural) is the only analgesic technique that provides complete analgesia for labor and vaginal delivery.
- Neuraxial labor analgesia is usually initiated in a mid-lumbar interspace; a sensory block from T10 to S4 is necessary for complete labor analgesia.
- During cesarean delivery, a dense block to T6 is necessary to block afferent nerves innervating pelvic and abdominal organs. The addition of lipid-soluble opioids to neuraxial local anesthetics potentiates the density of the block.

PERSPECTIVES

The anesthesia care of obstetric patients is dominated by regional anesthesia and analgesia, primarily neuraxial techniques (spinal, epidural, and combined spinal-epidural). The anesthetic care of the obstetric patient must also consider the effects on the fetus/neonate. In general, neuraxial compared to systemic analgesia/anesthesia results in less drug transfer across the placenta to the fetus.

Neuraxial analgesia is the only analgesic technique that can provide complete analgesia for labor and vaginal delivery. Given that labor lasts a variable duration (from less than an hour to several days), a continuous technique is optimal. Neuraxial labor analgesia is typically initiated with a bolus injection of local anesthetic combined with a lipid-soluble opioid into the subarachnoid or epidural space. An epidural catheter (rarely, a spinal catheter) is sited and used to maintain analgesia throughout labor and delivery. Other regional techniques and nerve blocks may be performed, often by the obstetrician (bilateral paracervical blocks and bilateral pudendal nerve blocks), but these techniques are not continuous and do not provide complete analgesia. Paracervical blocks provide analgesia for the first stage of labor, when pain impulses originate from the cervix and lower uterine segment. Pudendal nerve blocks are useful for the second stage of labor as the fetus descends in the birth canal when, pain originates from the vagina and perineum. Only neuraxial analgesia can block these pain impulses simultaneously.

Neuraxial anesthesia is considered the optimal technique for cesarean delivery, both scheduled and intrapartum deliveries. Advantages compared with general anesthesia include the following: (1) it is safer for the mother (no need to manipulate the airway), (2) less drug(s) crosses the placenta and depresses the fetus/neonate, and (3) it allows the mother to be awake and partner to be present for the delivery of their child. Single-shot spinal anesthesia is frequently used for elective procedures. Combined spinal-epidural anesthesia is used when long case duration is anticipated (e.g., repeat procedure and obese body habitus). Epidural anesthesia is a common technique for intrapartum cesarean delivery in women who have an indwelling epidural catheter sited for labor analgesia; epidural analgesia is transitioned to epidural anesthesia.

Postcesarean delivery analgesia is most often provided using multimodal analgesia—a common component of multimodal analgesia is single-shot neuraxial morphine analgesia. In women who are not able to receive neuraxial morphine (e.g., general anesthesia is used), the transversus abdominal plane block (see Chapter 47) and the quadratus lumborum block (see Chapter 49) have been shown to supplement systemic analgesia. However, these blocks do not improve the analgesia provided by neuraxial morphine and are therefore not indicated in women who receive spinal or epidural morphine.

PATIENT SELECTION

Most obstetric patients are candidates for neuraxial analgesia/anesthesia. Contraindications mimic those for nonpregnant patients. Absolute contraindications include patient refusal, coagulopathy, infection at the site of needle placement, and uncorrected maternal hypotension (e.g., in the setting of hemorrhage). Systemic infection is a relative contraindication, although most clinicians will proceed with a neuraxial technique once antibiotics have been administered and the patient is not exhibiting signs of frank septicemia. Thromboembolic disease is a major cause of maternal morbidity and mortality; thus many pregnant women receive pharmacologic anticoagulation. Guidelines for the initiation of neuraxial procedures in women who have received pharmacologic anticoagulation generally mimic those for the nonobstetric population, although a thorough risk-benefit analysis should be individualized to each patient. Several obstetric conditions are associated with a frank consumptive coagulopathy, including placental abruption and amniotic fluid embolism. Coagulopathy should be ruled out in these women before proceeding with a neuraxial procedure.

PHARMACOLOGIC CHOICE

In the United States, four local anesthetics are commonly used for obstetric neuraxial analgesia/anesthesia. Bupivacaine (0.0625%–0.125%) and ropivacaine (0.1%–0.2%) are commonly used for epidural labor analgesia. Spinal anesthesia for cesarean delivery is usually initiated with 0.75% bupivacaine with dextrose (hyperbaric bupivacaine), although some clinicians use plain bupivacaine. In most patients, plain bupivacaine is slightly hypobaric. Epidural anesthesia is commonly initiated with 2% lidocaine plus epinephrine 1:200,000, or 3% 2-chloroprocaine (useful for emergency procedures when short latency to onset of anesthesia is critical). Typically, 18 to 25 mL of a local anesthetic solution is required for epidural anesthesia for cesarean delivery. Neuraxial anesthesia is also indicated for cervical cerclage placement (both elective and rescue procedures) and postpartum tubal ligation surgery, although these procedures are usually of short duration and use of short-acting local anesthetic agents may be appropriate.

In almost all cases, a lipid-soluble opioid (fentanyl or sufentanil) is added to the local anesthetic. The opioid and local anesthetic work synergistically, thus lower doses of both drugs are needed, contributing to decreased side effects from both the local anesthetic and opioid. Fentanyl 10 to 25 µg and sufentanil 1.5 to 5 µg are common spinal adjuvants for initiation of combined spinal-epidural labor analgesia and spinal anesthesia for cesarean delivery. Fentanyl 1.5 to 3 µg/mL or sufentanil 0.2 to 0.4 µg/mL is often combined with a low-concentration local anesthetic solution to maintain epidural labor analgesia. Neuraxial morphine is commonly used as part of a multimodal technique for postcesarean delivery analgesia (spinal dose 0.050–0.150 mg, epidural dose 2–4 mg).

Epinephrine (0.2 mg) may be added to spinal bupivacaine to prolong the duration of anesthesia. Spinal and epidural clonidine may enhance analgesia and anesthesia, although the use is off label in the United States for obstetric patients because it may cause hypotension and sedation.

PLACEMENT

ANATOMY

During labor, painful impulses from the uterus and cervix are transmitted by visceral afferent nerve fibers that travel with sympathetic nerve fibers and enter the spinal cord at the low thoracic and high lumbar (T10 through L1) spinal segments. As labor progresses and the fetus descends in the birth canal, distention of the vagina and stretching of the perineum results in pain impulses that are transmitted via the pudendal nerves to the S2 to S4 spinal segments. Epidural catheters are commonly sited in the midlumbar epidural space. Early in labor, the sensory block must extend cephalad to T10 to block labor pain. Later in labor, sensory blockade must also extend caudad to the sacral dermatomes to provide complete analgesia as the fetus descents in the birth canal.

During cesarean delivery, afferent nerves innervating the abdominal and pelvic organs must be blocked. These nerves travel with sympathetic nerve fibers from the T5 through L1 spinal segments. Therefore dense motor and sensory block, which extends from the sacral dermatomes to T6, is necessary to provide satisfactory cesarean delivery anesthesia. Because of differential sensory blockade (i.e., block to touch occurs at a lower dermatome than block to temperature), most clinicians aim for a sensory block to a cold stimulus at the T4 dermatome. Inadequate extent and density of anesthesia during cesarean delivery—which is more common with epidural than spinal anesthesia—will contribute to intraoperative nausea, vomiting, and pain.

Anatomic and hormonal changes during pregnancy contribute to progressively lower anesthetic requirements as gestation advances. Elevated progesterone levels, among other hormonal changes, contribute to altered pharmacodynamics during pregnancy. Progressive lumbar lordosis during pregnancy alters the relationship of the vertebral column to surface anatomy. The imaginary line joining the posterior superior iliac crests (Tuffier line) crosses the vertebral column at a higher (more cephalad) position in pregnancy. This may increase the risk of misidentifying the actual lumbar interspace (i.e., anesthesia providers using landmark techniques may identify an interspace that is one or two levels higher than the intended interspace). The space between adjacent spinous processes is narrower and it may be harder for pregnant women to assume the flexed position that facilitates needle access to the neuraxial canal. Ligaments become more "lax," causing the ligamentum flavum to feel less "dense" during advancement of the spinal or epidural needle. Blood volume increases and by midgestation, the enlarging uterus compresses the inferior vena cava and impedes venous return from the lower extremities. Along with an increase in intraabdominal pressure, this results in the shunting of blood from the inferior vena cava to the azygous system. The expanded blood volume in the lumbar neuraxial canal, along with the increasing fat volume that accompanies pregnancy, causes a decrease in lumbar cerebrospinal fluid (CSF) volume as the dural sac is compressed and lumbar CSF is translocated cephalad. Additionally, the apex of the normal lumbar lordosis shifts caudad and the normal thoracic kyphosis is reduced and shifts cephalad. Finally, CSF-specific gravity decreases during pregnancy. These changes contribute to the altered distribution of subarachnoid hyperbaric (or hypobaric) anesthetic solutions. At term, the local anesthetic dose required for neuraxial anesthesia is reduced by 25% to 30% compared with nonpregnant patients.

The enlarged epidural veins may increase the risk of unintentional cannulation of epidural veins by a needle or catheter. Additionally, engorgement of the foraminal veins may block egress of anesthetic solution injected into the epidural space and contribute to the lower epidural anesthetic requirement observed during pregnancy.

POSITION

Patient positioning for the initiation of neuraxial analgesia does not differ in the pregnant patient (see Chapters 51 and 52). Laboring patients may prefer the lateral or sitting position, and clinicians may have a preference for one position. Occasionally, patient comorbidities may dictate patient position (e.g., a patient with a dilated cervix and fetus with a footling breech presentation should be placed in the lateral position to decrease the risk of umbilical cord prolapse). Patient position should be considered when initiating spinal anesthesia with a hyperbaric (or, less commonly, hypobaric) anesthetic solution. Monitoring during the initiation of anesthesia mimics that for nonpregnant patients, with the addition of fetal heart rate monitoring. The anesthesia provider may need to collaborate with the nurse or midwife to position the patient for optimal neuraxial anesthesia and fetal monitoring.

Increasingly more common, preprocedural ultrasonography is used to facilitate identification of lumbar vertebral anatomy (see Chapter 50). It is particularly useful for obese parturients in identifying the midline, the interspinous space, and the estimated depth to the epidural space. Two views are typically obtained with a low-frequency (2–5 MHz) curved array probe, the parasagittal oblique (PSO) view, and the transverse median (TM) view. The acoustic window may be larger using the PSO view, especially in patients with narrow interspaces. The depth to the epidural space is estimated by obtaining an image of the posterior complex (the ligamentum flavum, the epidural space, and the posterior dura-arachnoid) using the PSO or TM view. The estimation of the depth to the epidural space may underestimate the actual depth measured by the neuraxial needle by as much as 1 cm, especially in obese patients. This underestimation is attributable to soft tissue compression by the ultrasound probe, which is often necessary to obtain a satisfactory view.

Spinal anesthesia is initiated in a midlumbar interspace (L2–L3 or lower). Epidural analgesia/anesthesia is also usually initiated in a midlumbar interspace because of the need for both thoracic and sacral anesthesia. Like spinal anesthesia, combined spinal-epidural analgesia/anesthesia is initiated at the L2 to L3 interspace or lower because of the need to avoid trauma to the conus medullaris.

Use of sterile technique during the initiation of neuraxial anesthesia is critical to the safety of the parturient. When in the sitting position, the parturient should don a surgical hat to keep hair and scalp skin flakes from falling onto the sterile field. Each individual in the labor room should don a face mask and, commonly, only one support person is allowed to stay in the labor room during the procedure. The skin over the needle puncture site is usually decontaminated with chlorhexidine or povidone-iodine in alcohol. The proceduralist should wash their hands with an alcohol-based antiseptic solution, and all hand and wrist jewelry and watches should be removed before donning sterile gloves.

NEEDLE PUNCTURE

Young females of childbearing age are at increased risk for postdural puncture headache; therefore subarachnoid puncture should be performed with a small-gauge (usually 25- to 27-gauge) pencil-point needle.

Epidural analgesia/anesthesia is usually initiated with a 17-gauge Tuohy or other epidural needle appropriate for catheter insertion. In virtually all cases, a single or multiorifice epidural catheter (19- or 20-gauge) is passed through the epidural needle and secured for the duration of labor and delivery. A midline approach is common—obstetric patients are young and the interspinous ligament is rarely calcified. The depth to the epidural space is increased in pregnancy because of an increase in subcutaneous fat. Loss of residence to saline is a common technique to identify the epidural space; the hanging-drop method is less reliable during pregnancy because of increased intraabdominal and therefore epidural space pressure. A small bolus dose of anesthetic solution may be injected through the epidural needle before the epidural catheter is passed through the needle. More commonly, the epidural catheter is threaded into the epidural space, and the anesthetic solution necessary to establish analgesia/anesthesia is injected incrementally through the catheter.

Combined spinal-epidural analgesia/anesthesia combines the advantages of both spinal and epidural anesthesia: rapid onset of analgesia with a low dose of drug(s), followed by the ability to provide continuous analgesia/anesthesia. It may be used for both labor analgesia and cesarean delivery anesthesia. It is most common to use a needle-through-needle technique in which the epidural needle is advanced into the epidural space (Fig. 60.1A,B). The epidural needle then acts as an "introducer" for a long spinal needle (25- to 27-gauge). The spinal needle is advanced through the epidural needle using the anesthesia provider's dominant hand, while the nondominant hand anchors the epidural needle by grasping the epidural needle hub between the thumb and first finger and placing the back of the hand against the patient's back. This technique is similar to spinal anesthesia, during which the nondominant hand steadies the introducer needle as the spinal needle is advanced with the dominant hand. As the spinal needle tip passes the tip of the epidural needle, a small increase in resistance to advancement is usually noted. As soon as the anesthesia provider perceives the "pop," indicating puncture of the dura-arachnoid with the tip of the spinal needle, spinal needle advancement should stop. The hubs of the spinal needle and epidural needle are then firmly grasped together between the thumb and first finger of the nondominant hand and the spinal needle stylet is removed. After verifying the backflow of CSF through the spinal needle, the syringe with the prepared spinal anesthetic solution is attached to the spinal needle hub and injected, and the empty syringe and spinal needle are removed together. The epidural catheter is then sited in the epidural space, exactly as if initiating continuous epidural anesthesia. In dural puncture epidural (DPE) analgesia, the procedure mimics that of combined spinal-epidural anesthesia, except no spinal dose is injected through the spinal needle. Data are inconsistent as to whether the presence of a dural puncture with a small-gauge

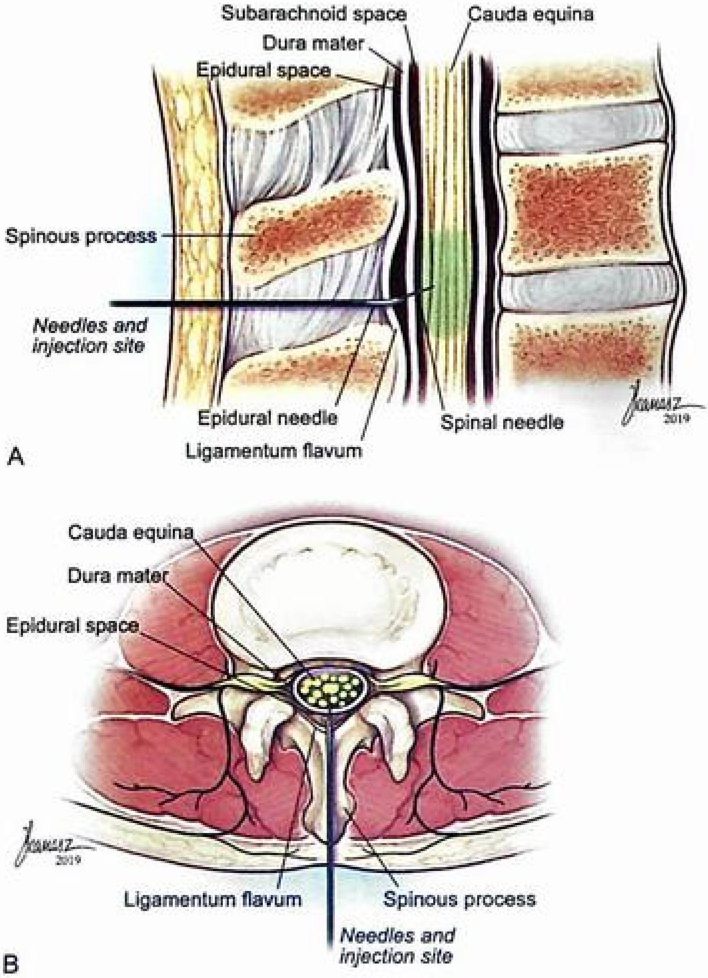

Fig. 60.1 Combined spinal-epidural block. The epidural needle is sited in the normal fashion and a long spinal needle is passed through the epidural needle to puncture the dura. (A) Sagittal view. (B) Transverse view.

(25- to 27-gauge) needle improves labor analgesia compared with epidural analgesia without a dural puncture.

POTENTIAL PROBLEMS

Adverse effects and complications of neuraxial anesthesia in obstetric patients mimic those observed in nonpregnant patients. The neuraxial injection of local anesthetic agents results in sympathetic blockade. This blockade is extensive when anesthesia for cesarean delivery is initiated; neuraxial anesthesia to the midthoracic dermatomes results in a significant decrease in systemic vascular resistance as a result of arterial vasodilation. Cardiac output increases and blood pressure decreases, sometimes profoundly. Uteroplacental perfusion is not autoregulated; therefore perfusion is directly related to maternal blood pressure. A decrease in uteroplacental perfusion results in a decrease in oxygen delivery to the fetus. Although the margin of safety in oxygen delivery to the healthy placenta and fetus is significant, this margin is reduced in some patients (e.g., those with preeclampsia). Maternal hypotension is associated with low neonatal Apgar scores and acidemia. Thus it is critical that the anesthesia provider maintain maternal blood pressure close to baseline during neuraxial analgesia/anesthesia. Blood pressure should be carefully monitored after the initiation of anesthesia. A patient complaint of shortness of breath, nausea, or just "not feeling well" within 15 minutes of initiating neuraxial anesthesia is caused by hypotension until proven otherwise. Often, the hypotension is preceded by an increase in heart rate. A combination of a rapidly administered intravenous fluid bolus beginning at the time of initiation of anesthesia (so-called coload) and administration of a prophylactic vasopressor (e.g., phenylephrine), is the best method for maintaining blood pressure; hypotension should be treated with additional bolus doses of a vasopressor.

Other adverse effects of neuraxial analgesia/anesthesia include pruritus (from neuraxial opioid administration), urinary retention, and shivering. Low-grade fever occurs in approximately 15% of parturients with neuraxial analgesia—the mechanism is currently not known but is likely related to noninfectious inflammation.

Neuraxial analgesia/anesthesia may fail for a number of reasons. The most obvious cause is failure to inject the drugs into the intended space. Patients in advanced labor may complain of pain because of "sacral sparing." Anesthesia solution injected into the lumbar epidural space preferentially distributes cephalad rather than caudad. Therefore the low thoracic sensory block established early in labor may provide satisfactory analgesia early in labor, but as labor progresses and sacral dermatome blockade is necessary, breakthrough pain may result. The injection of a large volume of dilute local anesthetic solution (10–15 mL) may facilitate local anesthetic distribution to the sacral canal.

Complications of neuraxial anesthesia in obstetric patients mirror those in nonobstetric patients and are discussed in Chapters 51 and 52. These include the unintended injection of the local anesthetic solution into an epidural vein, resulting in local anesthetic systemic toxicity, or into the subarachnoid space, resulting in high or total spinal anesthesia. Occasionally, the epidural needle tip or catheter is sited unintentionally in the subdural "space" (a potential space between the dura and arachnoid membranes). The injection of local anesthetic solution into this space results in a characteristically patchy block; onset time is similar to epidural anesthesia, but the cephalad extension of the block may be higher than expected.

Multiple drug errors have been reported—care must be taken to correctly identify all drugs prepared for neuraxial injection, particularly those injected into the subarachnoid space. Permanent cauda equina syndrome may result from the unintentional injection of neurotoxic substances.

Neuraxial damage may result from direct trauma to the spinal cord, conus medullaris, cauda equina, or spinal nerves. Indirect nerve tissue damage may result from ischemia or compression injury from a neuraxial hematoma or abscess. Obstetric patients are at increased risk for thromboembolic disease and death from pulmonary embolism; thus many patients receive prophylactic pharmacologic anticoagulation therapy. A thorough drug history is necessary before planning a neuraxial technique.

Neuraxial infection is a rare but feared iatrogenic complication of neuraxial analgesia/anesthesia. Epidural abscesses are usually caused by skin contaminants—thorough skin decontamination is indicated before initiating neuraxial techniques, particularly in the labor and delivery room, which is not a clean/sterile environment compared with an operating room. Meningitis after neuraxial procedures is almost always associated with a break in sterile technique. Streptococcus viridans species, which thrive in a watery medium (e.g., CSF) may be transmitted from the oropharynx of the proceduralist to the needles, catheters, and drugs used for neuraxial anesthesia.

Postdural puncture headache is a complication of neuraxial procedures. Young patients are at higher risk than other patient populations. The unintentional puncture of the dura-arachnoid with a large-bore epidural needle can cause a debilitating headache in the postpartum period, interfering with maternal-neonatal bonding.

Short-term backache after an obstetric neuraxial procedure may be due to local tissue trauma. There is no evidence that obstetric neuraxial procedures are associated with long-term backache, although many patients suffer musculoskeletal back pain in the postpartum period.

PEARLS

- Preprocedural ultrasound facilitating identification of neuraxial anatomy is particularly helpful for obese parturients; however, the posterior complex may be difficult to visualize. In the TM view, the depth from the skin to a line drawn between the transverse processes approximates the depth to the epidural space. It may not be possible to accurately identify the interspace in morbidly obese patients, but it is almost always possible to identify the tip of the spinous process. It is useful to remember that the length (posterior to anterior) of the typical adult lumbar spinous process is 3 to 3.5 cm. An estimate of the depth to the epidural space can be obtained by adding this value to an ultrasound-measured distance from the skin to the tip of the spinous process. Finally, an ultrasound-assisted paraspinous approach has been described in which the hyperechoic tips of adjacent spinous processes are identified and marked on the skin in the TM view. The needle is introduced 1 cm lateral and 1 cm superior to the tip of the spinous process and advanced using a classical paraspinous approach to the interlaminar space (the needle is angled slightly cephalad [5–10 degrees] and slightly toward the midline [5–10 degrees], and walked off the lamina if bone is encountered).
- When caring for obese patients, longer needles (e.g., 10–13 cm) may be necessary to reach the neuraxial canal, and use of a larger-gauge needle (e.g., 24-gauge spinal needle) mitigates the tendency of small-gauge needles to veer off to the side as they are advanced. Alternatively, a combined spinal-epidural technique can be considered because it is easier to advance the larger-gauge epidural needle through the spinal ligaments into the epidural space.
- Laboring patients may have difficulty maintaining a still position. Patients may reflexively move and rotate their spine during painful contractions. If difficulty advancing the neuraxial needle is encountered (e.g., repeatedly contacting the vertebra), reassessment of body position may be helpful. Additionally, most patients are readily able to differentiate needle movement to the left or right side of the sagittal midline plane. When difficulty is encountered, it may be helpful to ask the patient, "Do you feel this on the left or right side, or in the middle?" Assessment of shoulder height may help identify axial rotation (the shoulders should be level if the spine is not rotated). Continuous, reassuring verbal communication with the patient is critical to success.
- When using the combined spinal-epidural technique, the spinal needle tip must extend 12 to 17 mm beyond the epidural needle tip when the spinal needle is fully advanced through the epidural needle (Fig. 60.2), or the spinal needle tip may not reliably reach the subarachnoid space when the epidural needle tip is sited in the epidural space. A 127-mm spinal needle is commonly used with a standard 9-mm epidural needle. However, because of differences in hub configurations among needle manufacturers, some spinal and epidural needles may not be compatible for combined spinal-epidural anesthesia; the spinal needle tip may not extend far enough beyond the epidural needle tip. Some manufacturers provide combined spinal-epidural

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