Neuraxial Blocks: Spinal and Epidural Anesthesia

41

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Contents

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Introduction

Central neuraxial techniques are among the most reliable regional anesthesia techniques at the disposal of the anesthesiologist. Although relatively simple to perform, a thorough knowledge of neuraxial anatomy and the factors determining the spread and duration of anesthesia is important to their success. Similarly, an understanding of the physiological effects and potential complications of these neuraxial techniques is paramount for patient safety.

Spinal anesthesia is the administration of local anesthetic (and optional adjuncts) into the cerebrospinal fluid within the subarachnoid space. This results in the rapid onset of a dense sensory and motor block of the lower torso and legs that is suitable for surgical anesthesia.

Epidural anesthesia involves the instillation of local anesthetic into the fat-filled epidural space, usually through an indwelling catheter. This results in a slower-onset block and one which is generally less dense. This is most often used to provide analgesia rather than surgical anesthesia.

Spinal anesthesia is usually only performed at the lower lumbar intervertebral levels in order to avoid spinal cord injury. Epidural anesthesia may, however, be performed at the lumbar, thoracic, or even cervical levels depending on the desired area of sensory blockade.

Combined spinal-epidural anesthesia is a technique that takes advantage of the rapid onset of spinal anesthesia as well as the ability to extend the duration of the block with further local anesthetic administration through an epidural catheter.

Applied Functional Anatomy

A three-dimensional understanding of spinal anatomy serves to improve success of neuraxial blockade, particularly when difficulty is encountered. This most commonly occurs in patients with pathology of the spine (e.g. scoliosis, vertebral collapse, calcified spinal ligaments) or in those with a high body mass index, which can make patient positioning and palpation of bony landmarks more challenging. The previous chapter presents a detailed discussion of spinal anatomy. Here, we will briefly review only the most important aspects relevant to neuraxial blockade.

Surface Anatomy

Surface landmarks can be used to locate a particular vertebral level. Figure 41.1 illustrates these landmarks and the vertebral levels to which they correspond. It should be noted that these landmarks only provide an approximate estimation of vertebral level. Many factors, including normal anatomical variation, subcutaneous fat and patient positioning can render the identification of vertebral levels by surface landmarks somewhat inaccurate. It is recommended that radiological

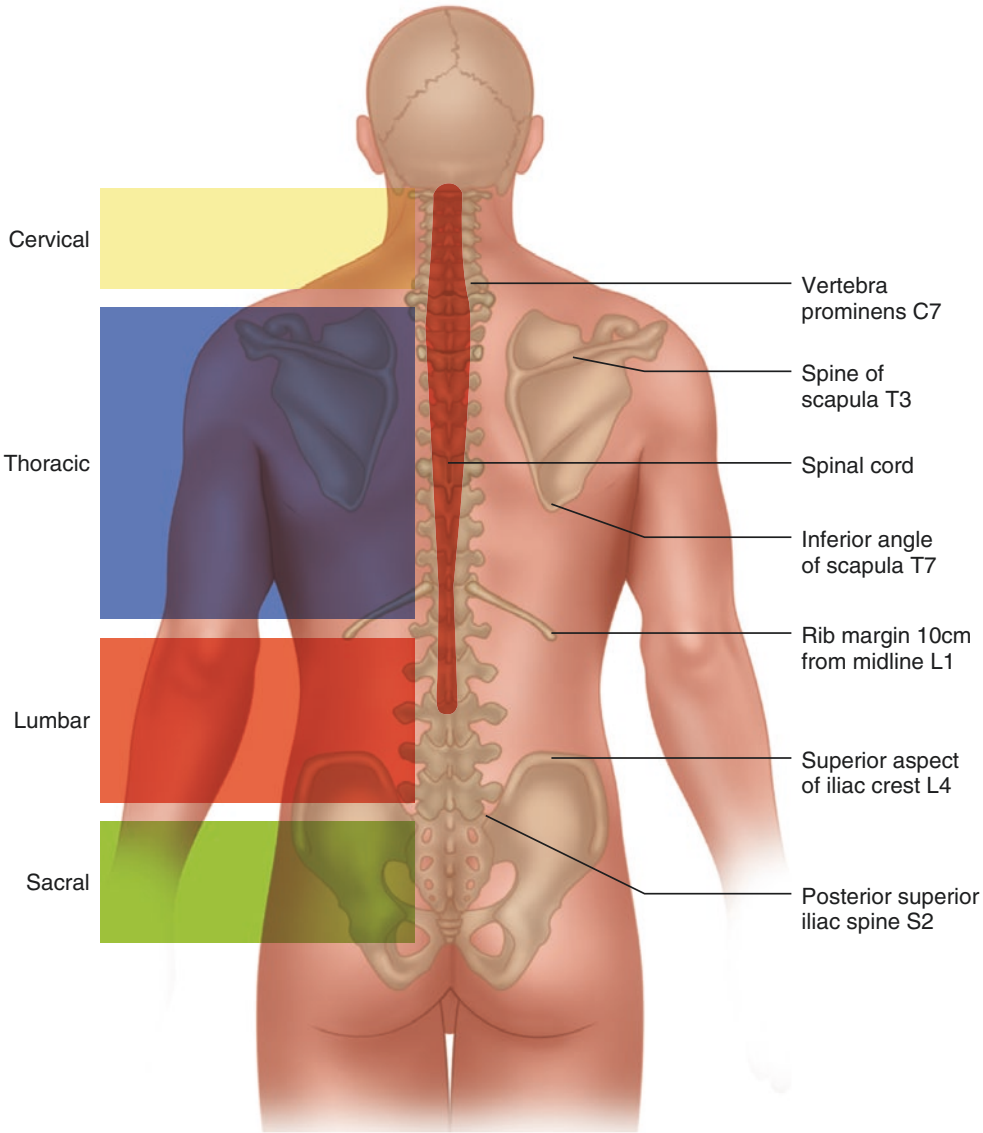

Fig. 41.1 Illustration showing the surface landmarks used to locate a particular vertebral level

imaging, e.g. using ultrasound or fluoroscopy, be used to confirm the surface location of specific intervertebral spaces in scenarios where precision and accuracy are essential.

Spinous Processes

The lumbar vertebrae have spinous processes that are nearly horizontal, whereas thoracic vertebrae have spinous processes that are angled caudally (Fig. 41.2b, c). As a result, needle insertion should always start perpendicular to the skin when performing spinal anesthesia or a lumbar epidural via a midline approach through the interspinous space; little to no cranial angulation is usually needed to enter the interlaminar space. In contrast, greater cranial angulation of the needle will be required when performing an epidural in the thoracic region (Fig. 41.3a).

Spinal Curves

The kyphotic thoracic curve and the lordotic lumbar curve can influence the spread of local anesthetic injected into the subarachnoid space. Hyperbaric local anesthetic injected at the midpoint of the lumbar lordosis will spread both caudad and cranial when the patient is supine (Fig. 41.3b). The cranial extent of this spread is limited by the upward slope of the mid-thoracic concavity. (A useful illustration of this concept can be found at https://www.youtube.com/watch?v=XQ7zh5rdu6o).

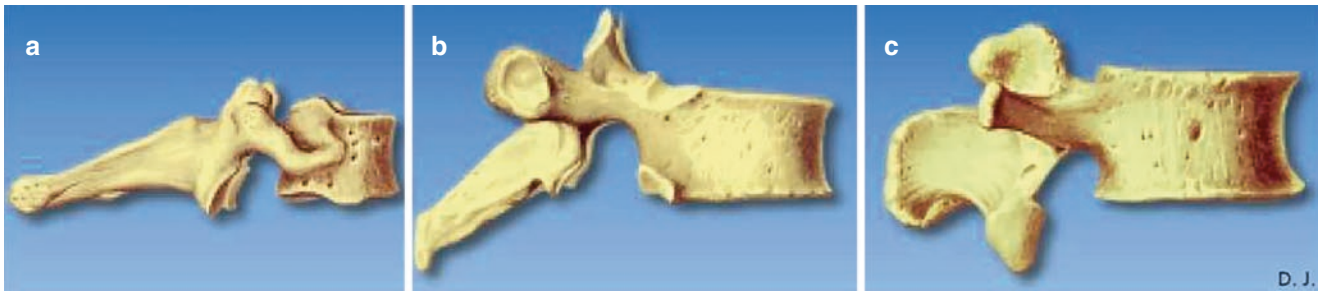

Fig. 41.2 (**a**) Cervical (**b**) Thoracic and (**c**) Lumbar spinous processes. (Reproduced with permission from Dr. Danilo Jankovic)

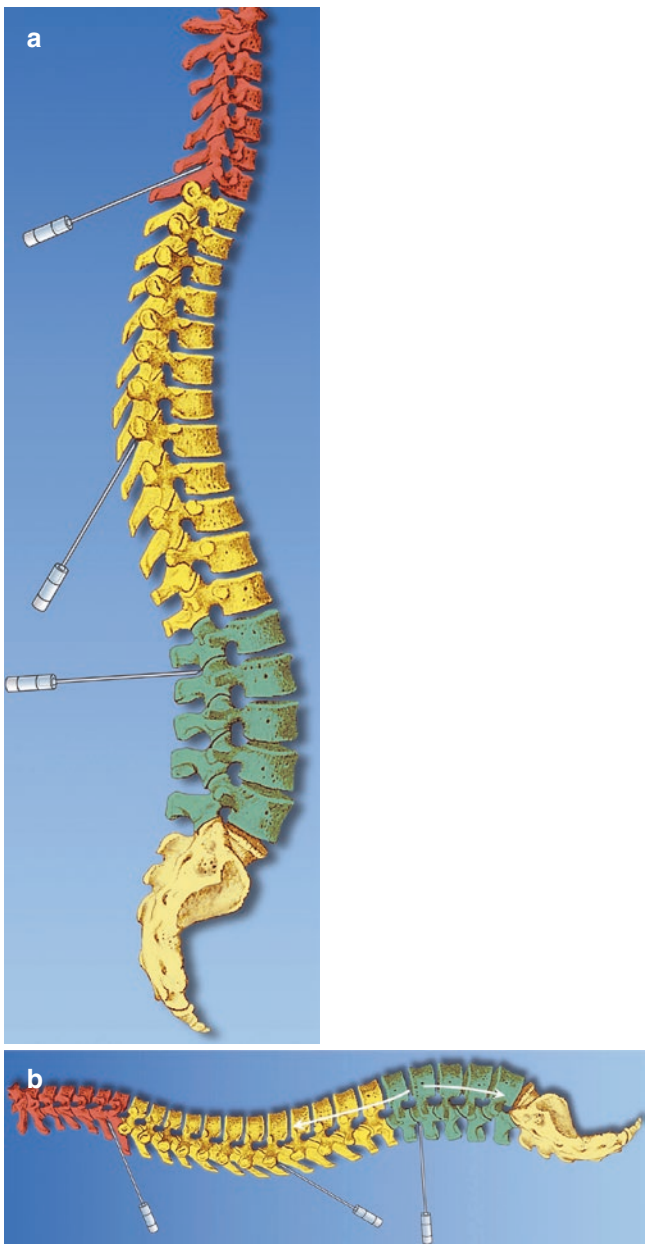

Fig. 41.3 (**a**) Degree of needle angulation required at the lumbar, thoracic, and cervical intervertebral spaces. (**b**) White arrows show spread of hyperbaric local anesthetic within intrathecal space following lumbar intrathecal injection when the patient is supine. (Reproduced with permission from Dr. Danilo Jankovic)

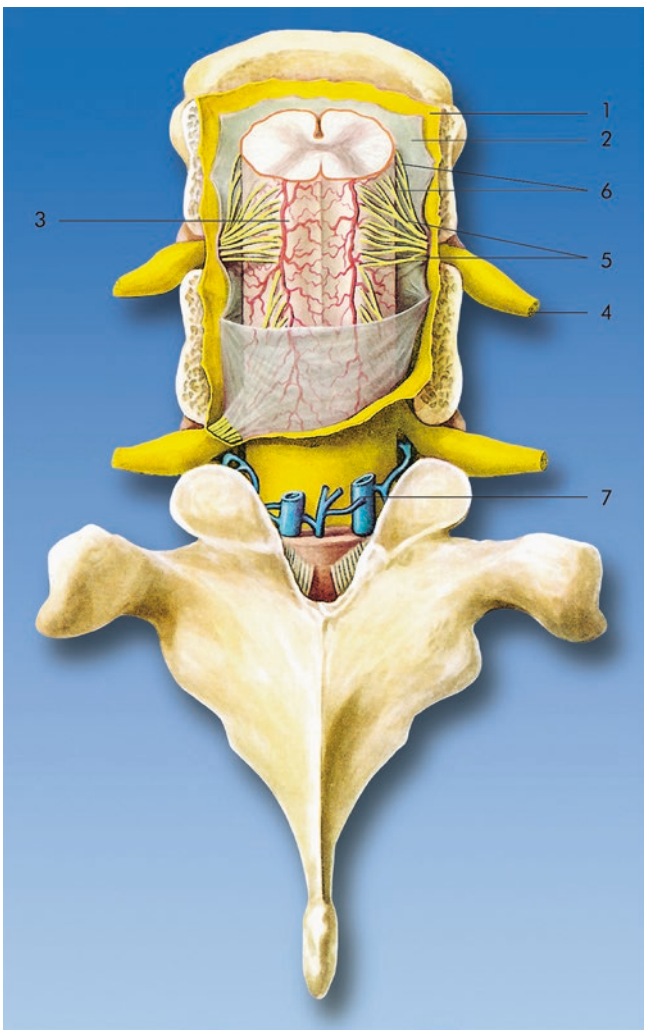

Fig. 41.4 (1) Dura mater, (2) arachnoid mater, (3) pia mater, (4) spinal nerve, (5) dorsal (posterior) nerve root, (6) ventral (anterior) nerve root, and (7) internal vertebral venous plexus. (Reproduced with permission from Dr. Danilo Jankovic)

Meninges

The three meningeal layers—the dura, arachnoid, and pia mater—envelop and protect the spinal cord (Fig. 41.4). The dura mater is the tough, outermost meningeal layer. The epidural space is superficial to this layer and is the target for epi-

dural anesthesia. The subdural space lies between the dura and the arachnoid mater. Unintentional deposition of local anesthetic into the subdural space produces an unpredictable and patchy block. The arachnoid mater encloses the subarachnoid space which contains the cerebrospinal fluid (CSF). Both the spinal cord and the spinal nerve roots are exposed to cerebrospinal fluid. These are the sites of action of local anesthetic deposited within the subarachnoid space during a spinal anesthetic.

Spinal Ligaments

A needle inserted in the midline will traverse the following structures to access the subarachnoid space (Fig. 41.5a, b):

- Skin.
- Subcutaneous tissue.
- Supraspinous ligament.
- Interspinous ligament.
- Ligamentum flavum.
- Epidural space.
- Dura mater.
- Subdural space.
- Arachnoid mater.

There is a characteristic "feel" to the different tissue structures as the needle tip is advanced through skin, subcutaneous tissue (a loose sensation), supraspinous and interspinous ligament (a gritty, tearing sensation with firmer resistance to advancement), and ligamentum flavum (a firm, rubbery resistance). A paramedian needle insertion (discussed later in the chapter) bypasses the supraspinous and interspinous ligaments, passing instead through the paraspinal muscles to enter the ligamentum flavum. This approach can be useful in older patients who may have calcified ligaments, or patients in whom the interspinous space is narrowed because of suboptimal positioning (e.g. in hip fracture) or degenerative disease.

The Location of the Conus Medullaris

This varies with age. In the fetus, the spinal cord extends to the end of the vertebral column. The vertebrae grow more quickly than the spinal cord such that by birth, the terminal end of the cord, the conus medullaris, extends only to L3. In the majority of adults, the conus ends at L1. To avoid the risk of spinal cord injury, spinal anesthetics should be performed at the L2–3 intervertebral space or lower.

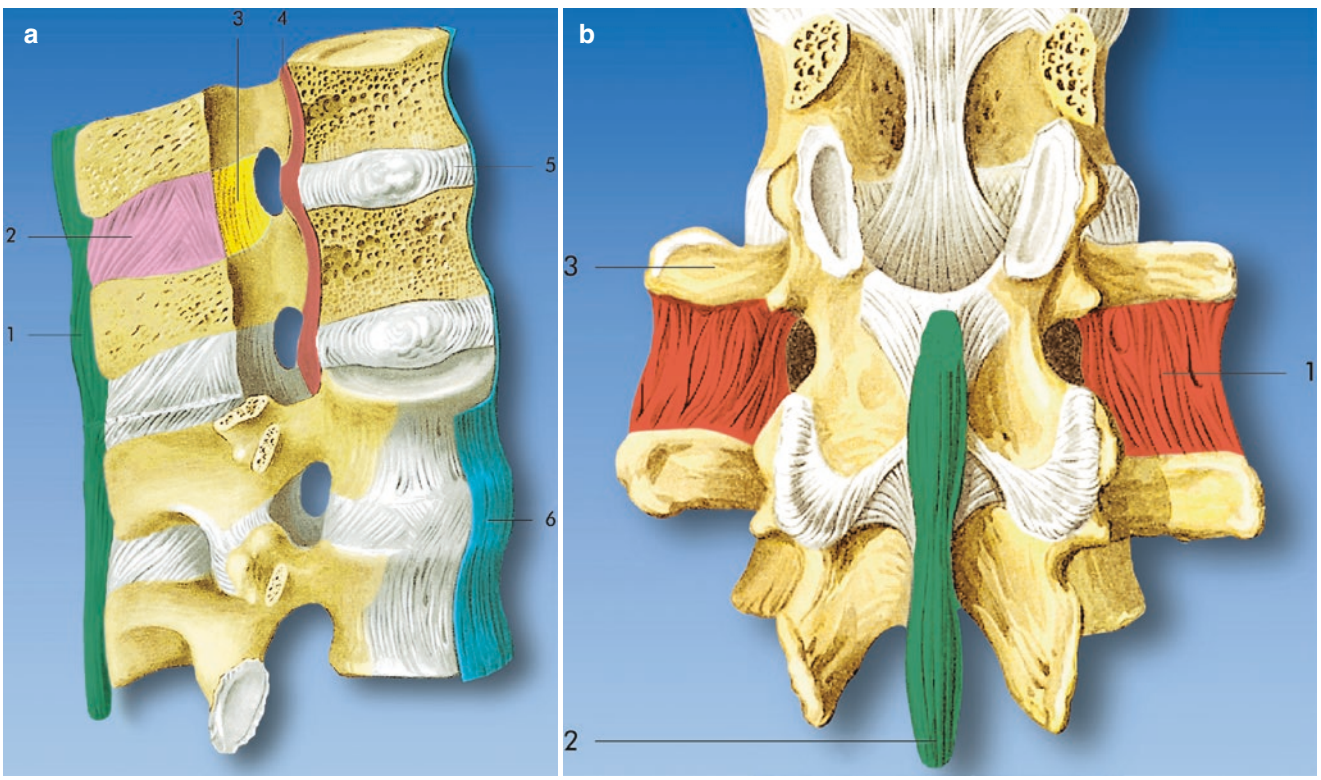

Fig. 41.5 (**a**) Sagittal section of the vertebral column illustrating the ligaments of the spinal cord. (1) Supraspinous ligament, (2) interspinous ligament, (3) ligamentum flavum, (4) posterior longitudinal ligament, (5) intervertebral disk, and (6) anterior longitudinal ligament. (**b**) Ligaments of the spinal cord. (1) Intertransverse ligament, (2) supraspinous ligament, (3) transverse process. (Reprinted with permission from Danilo Jankovic)

Epidural Space

The depth of the epidural space from the skin varies with body habitus, being deeper in obese and pregnant individuals. Ultrasound is a useful tool for measuring this and predicting actual needle insertion depth.

The epidural space is not a continuous space but is segmented along its length. Cryomicrotome sectioning and imaging has shown that the various compartments of the epidural space are segmented by areas where the dura is directly fused with the bone. The lateral epidural compartment is divided by intervening pedicles which are in contact with dura. The posterior epidural compartment is divided by dural contact with bone beneath the cranial half of each lamina. The anterior epidural compartment is divided by the attachment of the posterior longitudinal ligament to the intervertebral disc at each level. These posterior, lateral, and anterior compartments of the epidural space may impede the movement of injectate and may explain the unpredictable spread (or lack thereof) of epidural blockade that is occasionally seen.

Epidural fat in the epidural space (Fig. 41.6) may play an important role in the pharmacokinetics of lipophilic drugs administered here by acting as a reservoir. This may result in a delayed onset and a longer duration of action. A reduction in the epidural fat with age may partly explain the age-related changes in epidural dose requirements.

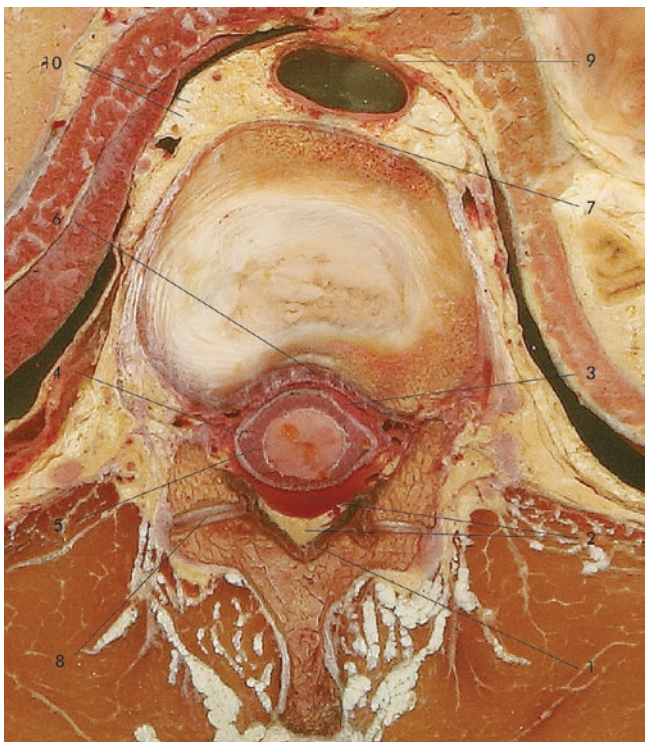

Fig. 41.6 Transverse dissection at the level of the T9 vertebra. (1) Ligamentum flavum, (2) posterior epidural space with fat, (3) anterior epidural space with veins, (4) spinal dura mater, (5) subarachnoid space with spinal cord, (6) posterior longitudinal ligament, (7) anterior longitudinal ligament, (8) zygapophysial joint, (9) aorta, and (10) sympathetic ganglion. (Reprinted with permission from Danilo Jankovic)

Physiology of Neuraxial Blockade

The physiological effects of both subarachnoid and an epidural block are similar. However, the effects of an epidural block have a slower onset and are usually confined to a segmental range of spinal nerves with an upper and lower limit, whereas spinal anesthesia blocks all of the nerve roots below a particular level. These effects are summarizes below.

Neurological Blockade

The injection of local anesthetic within the intrathecal or epidural space produces nerve blockade. Generally, the speed of onset of nerve blockade is inversely related to the nerve's diameter and degree of myelination. Thus, **sympathetic** blockade manifests before **sensory** block, which in turn precedes the **motor** block. Among the sensory modalities, the sequence of blockade is initially temperature, followed by pain, light touch, pressure and finally proprioception. Sensory block usually extends for two to four segments higher than the motor block, while sympathetic block extends two to four segments higher still. Block offset occurs in the reverse manner with autonomic sympathetic fibers being the last to recover.

Cardiovascular Effects

Blockade of the thoracolumbar sympathetic nerves manifests as the cardiovascular effects that follow a neuraxial block, including **hypotension** and **bradycardia**. These effects are in proportion to the extent of the block produced. They may be exaggerated in patients who are hypovolemic or those that are taking medications that affect the cardiovascular system such as antihypertensives and beta-blockers. Hypotension is the result of arteriolar vasodilatation and venous pooling which diminishes cardiac preload. Bradycardia is due in part to blockade of cardiac accelerator fibers (T1–T5). It may also result from decreased preload which activates cardiac reflexes involving intra-cardiac stretch receptors. The **Bezold–Jarisch reflex** is invoked as an explanation for the severe bradycardia and even asystole following spinal anesthesia that is occasionally observed in young healthy adults.

In general, the sympathetic block following a spinal anesthetic is more rapid in onset and greater in extent compared to an epidural. Thus, a gradually dosed epidural anesthetic

may be useful in providing hemodynamic stability in patients with risk factors for cardiovascular compromise following neuraxial blockade.

Respiratory Effects

In a patient with normal lung function, neuraxial blocks usually have a negligible impact on respiratory function. However, with a high thoracic blockade or in a patient with pre-existing respiratory compromise, this effect may be significant. The paralysis of abdominal and intercostal muscles can negatively impact **expiratory** function causing a reduction in peak expiratory flows, expiratory reserve volume, and maximal minute ventilation. This may manifest as dyspnea. Nevertheless, these effects are usually outweighed by the pain relief obtained following thoracic or abdominal surgery, and thus thoracic epidural analgesia is associated with an overall improvement in postoperative outcome and a reduction in postoperative pulmonary complications.

Spread of local anesthetic to cervical segments can affect **inspiratory** effort due to blockade of the phrenic nerve and subsequent loss of diaphragmatic function.

A **total spinal** is a rare complication of spinal anesthesia in which there is excessive cranial spread of local anesthetic within the intrathecal space. Apart from respiratory distress from thoracic wall and diaphragmatic paralysis, it can lead to respiratory arrest due to medullary hypoperfusion rather than an effect of local anesthetics per se.

Gastrointestinal Function

The splanchnic blockade (T6–L2) produced following a neuraxial block leads to unopposed parasympathetic activity. This results in increased gastrointestinal secretions, increased intestinal motility and relaxation of sphincters. This prevents bowel distension and allows better access during abdominal surgery. Vasodilation increases visceral perfusion, which may improve healing, and contribute to an earlier return of bowel function following surgery.

Nausea and vomiting, if observed, are usually secondary to unopposed vagal tone and hypotension, and resolve with vasopressor treatment and restoration of normal blood pressure.

Genitourinary Effects

Neuraxial anesthesia does not directly affect renal blood flow since it is autoregulated. Sacral blockade produces an atonic bladder and an increased bladder sphincter tone. This not infrequently results in urinary retention until the resolution of the block.

Thermoregulation

Redistribution of heat following sympathetic block and vasodilation of the lower body results in mild hypothermia. This induces thermoregulatory vasoconstriction and shivering above the level of the neuraxial block.

Neuroendocrine Effects

Neuraxial block effectively inhibits the afferent innervation from the surgical site and it is responsible for the inhibition of the surgical stress response that involves release of a variety of mediators (including catecholamines, vasopressin, growth hormone, renin, angiotensin, glucose, antidiuretic hormone, and thyroid stimulating hormone). The magnitude of the stress response correlates with postoperative morbidity and thus its attenuation may be of benefit in enhancing post-surgical recovery.

Spinal Versus Epidural Anesthetic

Both spinal and epidural anesthesia provide a temporary blockade of nerve conduction in the autonomic (sympathetic), sensory, and motor fibers. There are, however, some important differences between the two. These are summarizes in Table 41.1.

Table 41.1 Important differences between a spinal and an epidural anesthetic

Variable	Spinal anesthetic	Epidural anesthetic
Space accessed	Subarachnoid space	Epidural space
Time needed to perform	Takes less time (since it is usually a single-injection) technique)	Takes more time (since it is usually a catheter technique)
Onset of conduction block	Faster	Slower
Nature of conduction blockade	Denser, therefore, mainly employed as an anesthetic technique	Less dense, therefore, mainly employed as an analgesic technique. Sufficient volume and concentration of local anesthetic will produce an anesthetic block
Duration of conduction blockade	Fixed duration unless a catheter is inserted; the length of this is dependent on dose administered and the local anesthetic drug used	Duration is flexible as a catheter is usually inserted and local anesthetic can be infused as required
Cardiovascular effect	Rapid drop in blood pressure	A more gradual and limited drop in blood pressure

Comparison to General Anesthesia

Compared to an opioid-based general anesthetic, the central neuraxial anesthesia techniques offer the following advantages:

- Avoidance of airway manipulation.
- Avoidance of side effects of a general anesthetic (sore throat, nausea and vomiting, dental damage, aspiration of gastric contents, malignant hyperthermia, etc.).
- Predictable physiological changes.
- Minimal metabolic disturbances (in hepatic or renal disease).
- Preservation of consciousness.
- Extension into postoperative analgesia (with insertion of an epidural catheter).
- Enhanced gastrointestinal perfusion and motility.
- Reduced postoperative nausea and vomiting.
- Reduced adverse cardiovascular events, perioperative pulmonary complications, thromboembolic events, development of chronic pain, surgical stress response, immune dysfunction, and morbidity and mortality.

However, general anesthesia is advantageous over neuraxial block when better control over hemodynamics is desired (such as in severe or critical aortic stenosis). It also offers definitive control of the airway and it allows for immediate assessment of the adequacy of postoperative analgesia.

Indications

The indications for spinal and epidural anesthetic are considered in Table 41.2. Figure 41.7a, b illustrate the required sensory levels for different procedures, and how to test for them.

Table 41.2 Indications for spinal and epidural anesthesia

Spinal anesthetic	Epidural anesthetic
Surgical indications Most surgical procedures below the level of the umbilicus are amenable to spinal anesthesia • Surgical procedures in the area of the lower extremities, hip joint, and inguinal region • Urological procedures (prostate, bladder) • Gynecological and obstetric procedures • Surgery in the perineal and perianal region • Lumbar spinal surgery	*Surgical indications* • Surgical procedures in the area of the lower extremities, hip joint, and inguinal region • Upper abdominal and thoracic procedures, in combination with general anesthesia • Urological procedures (prostate, bladder) • Gynecological and obstetric procedures • Procedures in the perineal and perianal region *Postoperative and post-traumatic pain therapy* Usually in combination with local anesthetics and opioids

Combined Spinal Epidural (CSE)

These have the advantage of providing a rapid anesthetic block which can subsequently be prolonged either as an anesthetic or analgesic block. This is particularly advantageous when the duration of a surgical procedure is likely to be longer than the expected duration of spinal anesthesia. For example, CSEs may be used for bilateral total hip or knee arthroplasty or complex revisions where the operative time is expected to be prolonged.

Continuous Spinal Anesthesia (CSA)

This is another technique that can be used to provide extended neuraxial anesthesia. It is, however, less-commonly used than CSE as it requires a specialized needle and catheter kit, and it carries a higher risk of post-dural puncture headache compared to a single-injection spinal anesthetic with a small-gauge needle. It may occasionally be employed in obstetric practice when there is an inadvertent dural puncture during attempted labor epidural analgesia; the catheter can be inserted into the subarachnoid space and with appropriate dosing, used to provide analgesia for labor and delivery.

Contraindications

The absolute and relative contraindications to spinal and epidural anesthesia are summarizes in Table 41.3.

Coagulopathy

Whether secondary to anticoagulants or a disease process, impaired coagulation is an important contraindication to neuraxial blockade. The primary concern is that patients may develop a spinal hematoma which can lead to compressive ischemia of the spinal cord and, consequently, permanent neurological disability. In Table 41.3, it has been classified as a relative contraindication, only because there is a spectrum of severity. There are certain thresholds for coagulation parameters and anticoagulation therapy, beyond which the majority of practitioners would consider it to be an absolute contraindication. Decision-making in individual patients should be based upon balancing the small but very real risk of a spinal hematoma against the potential benefits of neuraxial blockade. The American Society of Regional Anesthesia and Pain Medicine has published expert consensus guidelines to help guide treatment decisions; the key messages are summarizes below (see Chap.1).

- Neuraxial blockade may be undertaken 4–6 h after the last dose of **IV unfractionated heparin** provided that a normal coagulation result is obtained.
- 12 h should pass from the last dose of **prophylactic SC low molecular weight heparin** (LMWH) and 24 h if a **treatment dose** is used.
- Isolated **non-steroidal anti-inflammatory drug** (NSAID) therapy, including low dose aspirin (81 mg), is not a contraindication to neuraxial blockade. However, needle insertion should be limited to one or two attempts, as the risk of a spinal hematoma increases with the degree of trauma.
- Neuraxial blockade should be avoided for 7 days after **clopidogrel** and 14 days after **ticlopidine**.
- Neuraxial blockade is considered safe with an **international ratio (INR) < 1.5**.
- Administration of anticoagulants should be timed not only to provide a suitable window for inserting an epidural catheter but also to ensure the safe timing of epidural catheter removal.
- If an epidural vein is punctured, subcutaneous heparin administration should be held for at least 2 h, and LMWH held for at least 24 h.
- **GIIa/IIIb inhibitors** should be withheld for at least 4 weeks prior to epidural placement.

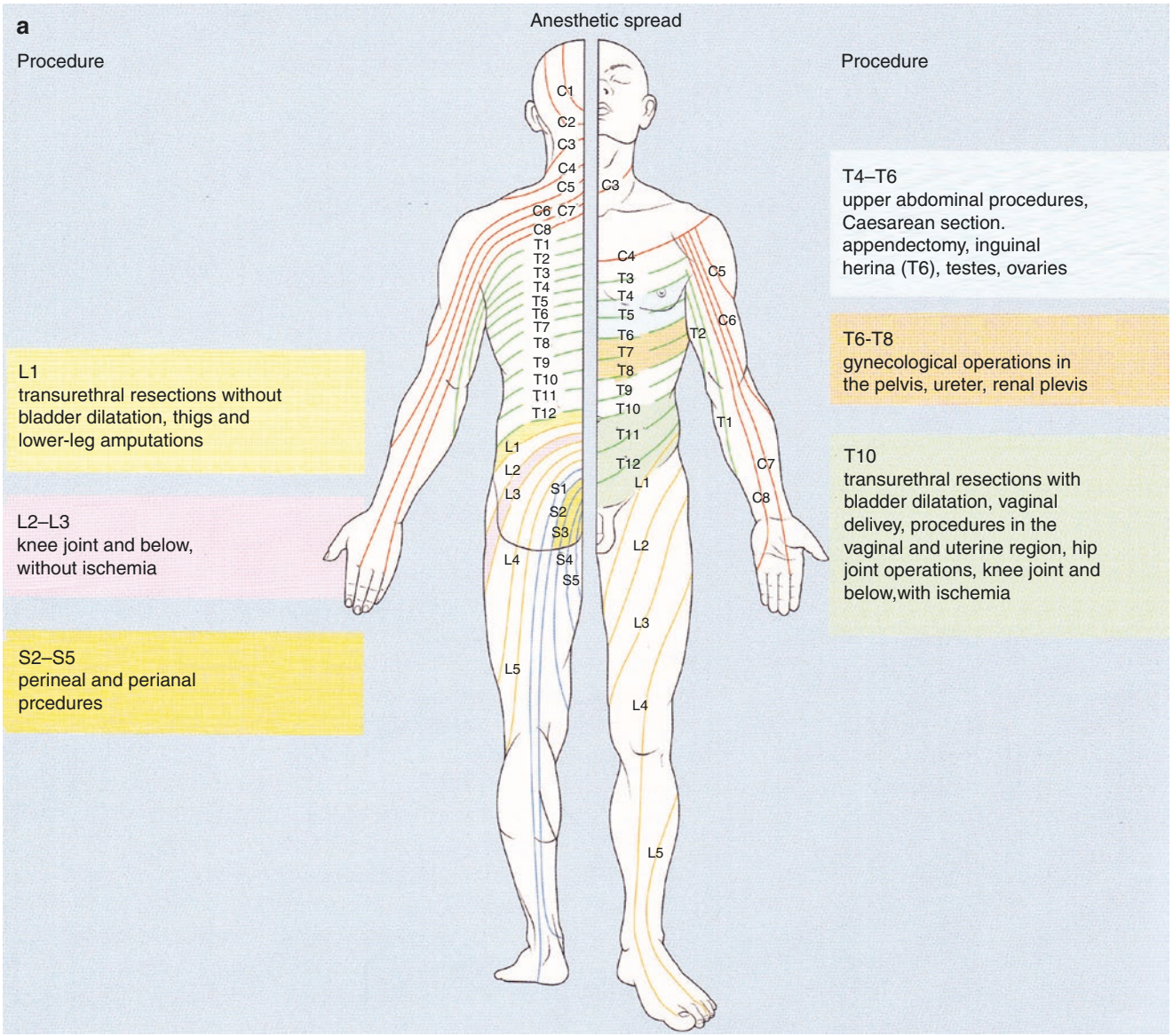

Fig. 41.7 (**a**) Location of the procedure and required sensory spread of local anesthetic. (Reprinted with permission from Danilo Jankovic). (**b**) Landmarks for testing the spread of local anesthetic after neuraxial anesthesia. (Reprinted with permission from Danilo Jankovic)

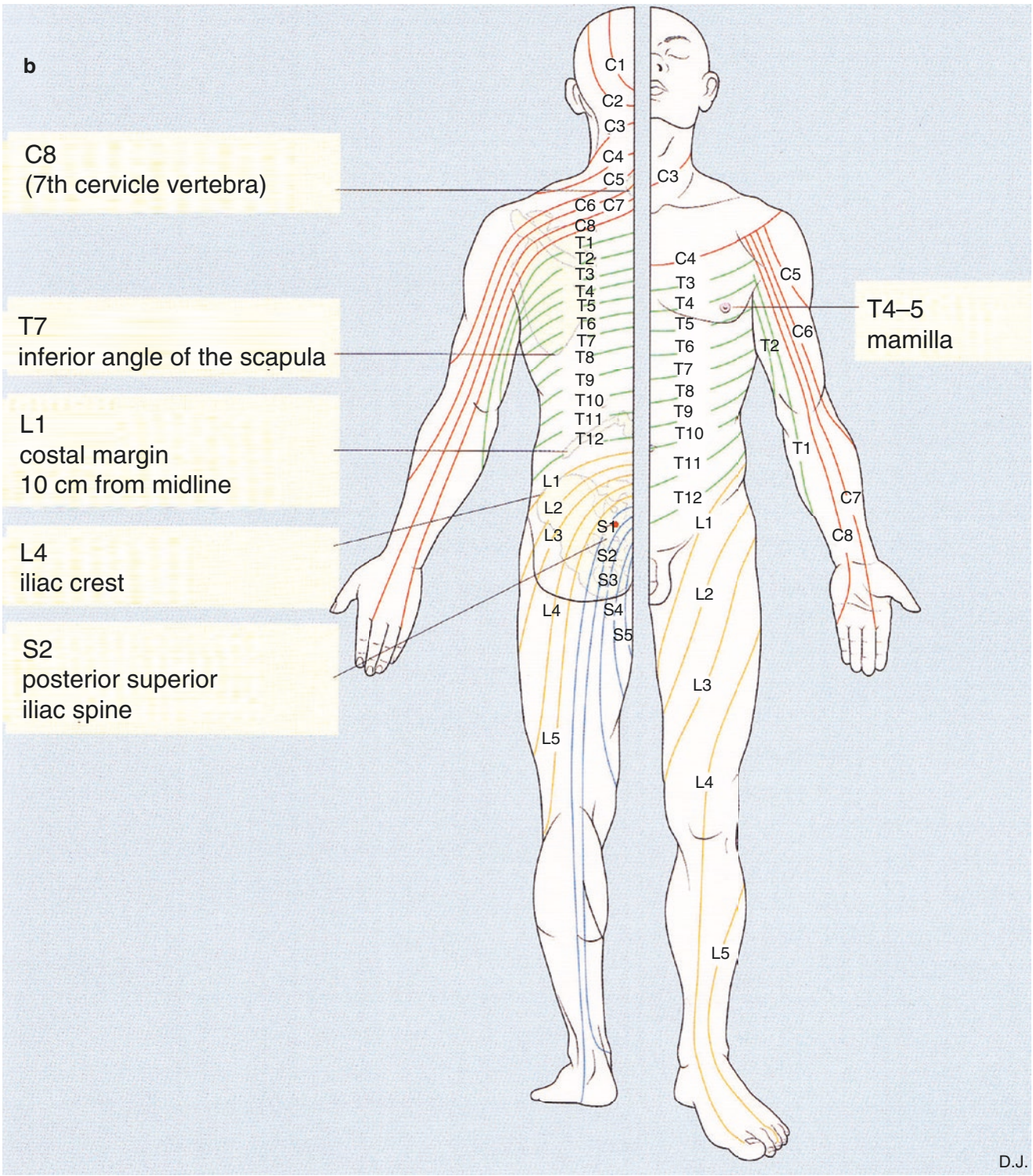

Fig. 41.7 (continued)

Table 41.3 Contraindications to neuraxial blockade

Absolute	Relative
• Patient refusal • Sepsis or local infection at the injection site • Severe decompensated hypovolemia • Acute cerebral or spinal cord diseases • Increased intracranial pressure • Uncooperative patient	• Coagulopathy: Coagulation disorders or anticoagulant therapy • Spinal pathology including severe spinal deformities, arthritis, osteoporosis, intervertebral disk prolapse, spinal canal stenosis, post spinal surgery, and spinal metastases • Unknown duration of surgery • Severe cardiovascular diseases of myocardial, ischemic, or valvular origin • Pre-existing neurological deficits (radiculopathies, peripheral neuropathies, multiple sclerosis)

Cardiovascular Disease

Patients with aortic stenosis deserve special mention. The concern in these patients is that they have a fixed cardiac output which cannot be increased in response to a reduction in intravascular resistance. They are therefore at risk of hypotension, myocardial ischemia, and cardiovascular collapse following the disruption to sympathetic outflow seen following neuraxial blockade. However, decades of clinical experience indicate that this is only of concern in patients with severe or critical aortic stenosis; hence it is a relative contraindication. Neuraxial techniques can be used safely, especially in mild-moderate degrees of aortic stenosis, with appropriate monitoring and preparation to promptly treat or pre-empt any hypotension. Intra-arterial blood pressure monitoring should be instituted before the neuraxial block is performed. Ensuring availability of vasopressor drugs (as boluses or continuous infusion), maintaining normovolemia, and appropriate dosing of local anesthetic, are also essential.

Consent for Neuraxial Blockade

In addition to a description of the procedure itself, the following risks and complications should be discussed with patients as part of the consent process.

Benefits

- Avoidance of airway manipulation and invasive ventilation.
- Reduced post-operative nausea and vomiting.
- Reduced risk of DVT and PE.
- Reduced postoperative drowsiness, especially if judicious sedation is used.
- Improved post-operative analgesia (particularly if opiate adjuncts are used).

Risks and Complications

- Pain and bruising at site of injection.
- Hypotension.
- Nausea and vomiting.
- Urinary retention.
- Inadvertent dural puncture (epidural anesthesia only).
- Post-dural puncture headache.
- Failure or insufficient efficacy with need to repeat the procedure or revert to a general anesthetic.
- High or complete spinal.
- Temporary nerve injury.
- Permanent nerve injury (1 in 24,000 to 1 in 51,000).

Performing Neuraxial Blockade

Preparation and Equipment

- Check that the emergency equipment is complete and in working order (intubation kit, emergency drugs, anesthetic machine).
- Obtain intravenous access and start an IV infusion. Consider volume loading (250–500 mL of a balanced electrolyte solution).
- Vasopressors such as ephedrine, phenylephrine, or metaraminol should be readily available.
- ECG, non-invasive blood pressure and pulse oximetry monitoring are essential.
- Skin preparation using an alcohol, iodine or chlorhexidine. If chlorhexidine is used, extreme care must be taken to prevent its inadvertent introduction into the neuraxis, as it has been implicated in chemical arachnoiditis. Chlorhexidine concentration should not exceed 0.5%. Sterile precautions including drape with fenestration and full sterile gown, gloves, facemask.
- Local anesthetic for skin infiltration.
- Appropriate medication for injecting into the intrathecal or epidural space—usually a combination of local anesthetic and opiate. These must be preservative free.
- Local anesthetic systemic toxicity management kit including 20% lipid emulsion and instructions for use.

Spinal Needles

These are usually of the following two types (Fig. 41.8a–c):

25–27 G spinal needles with a conical tip (pencil-point)—e.g. Sprotte, Pencan, and Whitacre. When the dura is penetrated with these needles, the dural fibers are separated (rather than cut) and then close together again. This reduces the risk of postdural puncture headache.

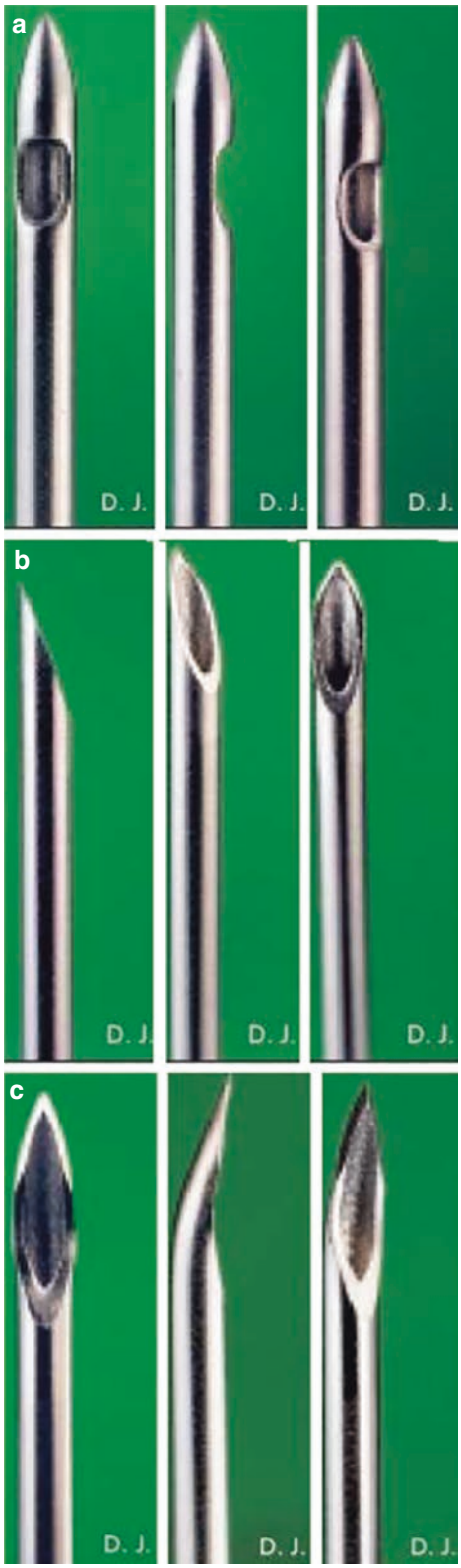

Fig. 41.8 (**a**–**c**) Spinal needles. (**a**) Pencil-point, 25G; (**b**) Quincke tip, 27G; (**c**)Atraucan Special Cut, 26G. (Reprinted with permission from Danilo Jankovic)

25–27 G spinal needles with Quincke tip. The advantage of the Quincke tip is that it will pierce skin, and dense or calcified tissues with less effort, and with less risk of the needle bending and deviating from the intended trajectory.

A thicker 22-G Quincke tip needle is advantageous for similar reasons—the increased stiffness of the shaft makes it easier to handle and to redirect in small increments and may be used in patients with more challenging anatomy—e.g. narrowed interlaminar spaces, or suboptimal positioning, as well as obese patients with a large amount of overlying soft tissue.

The types of epidural needles are discussed later in the chapter.

Patient Positioning

Optimal patient positioning both prior to and immediately after performing neuraxial anesthesia is essential for ensuring block success. The most common positions used are the sitting or the lateral decubitus position. The prone or jack knife position is another alternative but one that is rarely utilized in modern anesthetic practice.

Lateral Decubitus Position

The assistant stands in front of the patient to help with stabilization and to prevent any falls. The patient's legs are flexed at the hips and knees as far as possible without causing discomfort, and the chin is flexed down onto the chest (Fig. 41.9). This reverses the lumbar lordosis and widens the lumbar interspinous and intervertebral spaces.

It may be easier for novices to maintain an appropriate needle trajectory if the patient is kept in a strict lateral position. However, with larger patients, allowing them to tilt anteriorly towards the assistant may improve the stability of their position. In this case, the operator must compensate by angling the needle towards the surface of the bed when advancing in a midline approach, to maintain the needle in the sagittal plane of the patient (Fig. 41.10a, b). This slightly tilted position is also advantageous when employing a paramedian approach from the dependent side of the spine as it creates more room between the needle hub and the surface of the bed.

A key point to note is that gravity will cause the soft tissues to sag downwards and thus the surface midline groove of the back will be slightly lateral to the bony midline and spinous processes. This must be taken into account when palpating the spinous processes and choosing a skin insertion site. The position of the overlying skin and subcutaneous tissues must be controlled with the fingers of the non-dominant hand during needle insertion (Fig. 41.11).

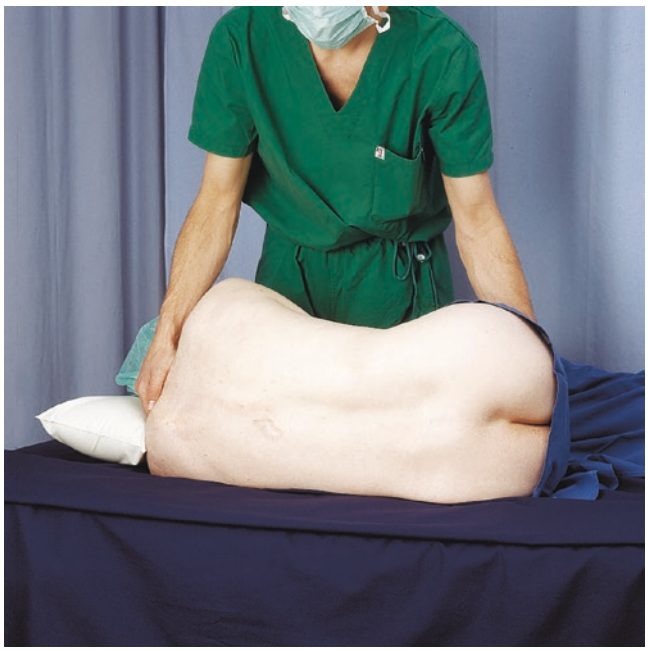

Fig. 41.9 Lateral decubitus position. (Reprinted with permission from Danilo Jankovic)

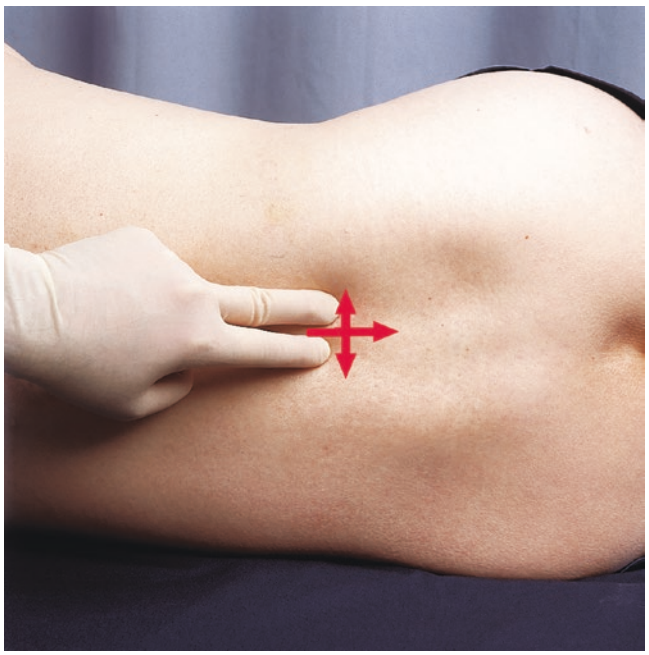

Fig. 41.11 Palpation of the intervertebral space. (Reprinted with permission from Danilo Jankovic)

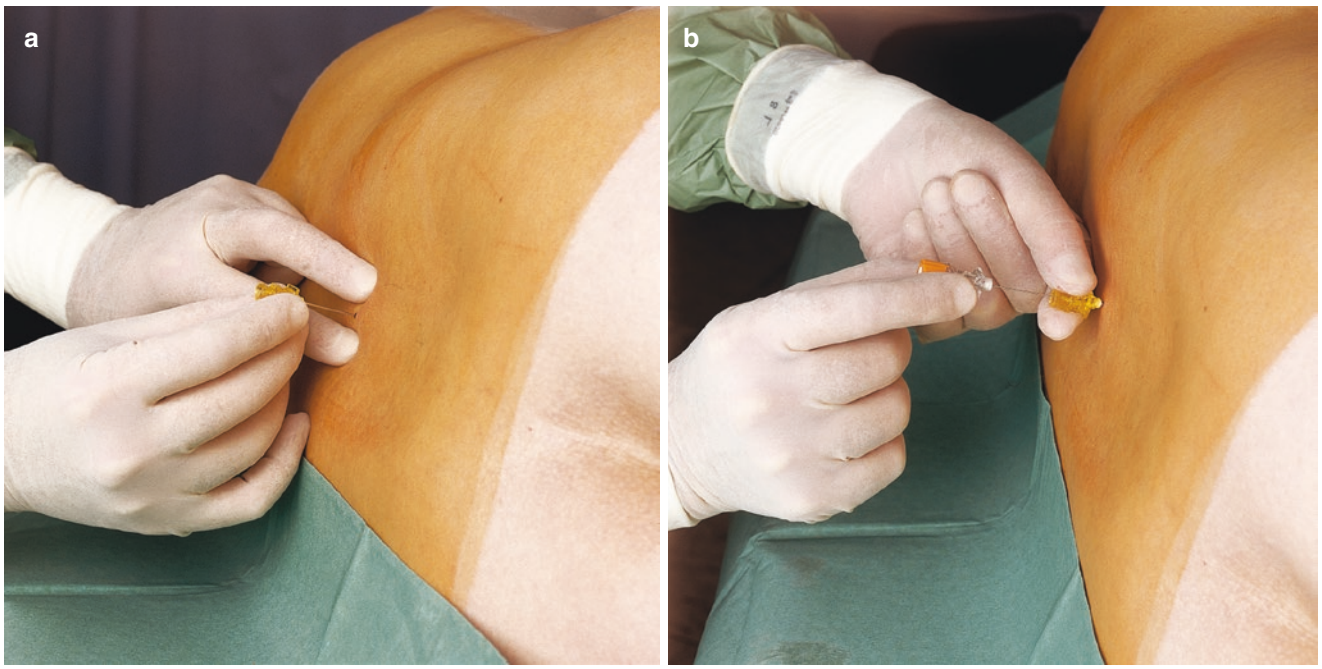

Fig. 41.10 (**a** and **b**) Tilting the patient away from the operator can provide a more stable position, but the trajectory must be adjusted downwards relative to the bed surface as needed to keep the needle advancing in the midline. (Reprinted with permission from Danilo Jankovic)

Advantages

- Increased patient comfort.
- Reduced risk of venous pooling, orthostatic hypotension, and cardiovascular instability.
- Unilateral anesthesia is obtained more reliably when hyperbaric or hypobaric solutions are used.

Disadvantages

- Difficulty may arise in correct identification of the midline, especially if the pelvis is tilted too anteriorly or there is extensive subcutaneous tissue.

Sitting Position

The patient is seated on the edge of the operating table, supported by an assistant standing in front of them (Fig. 41.12). The patient's feet rest flat on a stool placed on the floor in front of them. It may also be helpful to provide a padded Mayo stand, adjustable table or similar device for the patient to lean on for additional support. Various audio cues are commonly used to encourage patients to flex their lumbar spine and correct the lordosis, such as "arch your back like an angry cat/prawn/shrimp" or "slouch like a sulky teenager." A visual demonstration sometimes improves patient positioning.

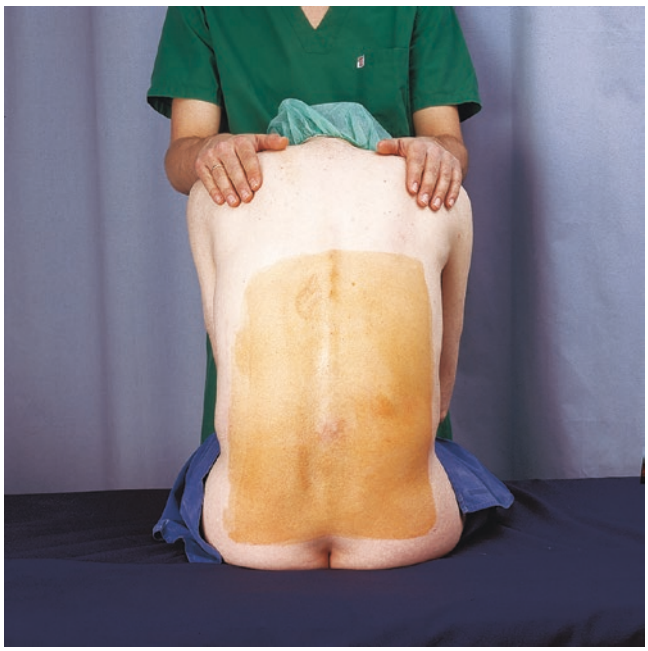

Fig. 41.12 Sitting position. (Reprinted with permission from Danilo Jankovic)

Advantages

- Easier to locate the midline, particularly in obese patients, as the tissue falls away to the sides rather than over the midline as in the lateral position.
- Optimal position for performing a saddle block whereby only the S2 to S5 dermatomes are anesthetized. This facilitates surgery in the perineal region while preserving power and sensation in the legs.

Disadvantages

- Risk of orthostatic hypotension. It should be avoided in frail and heavily sedated patients.

Spinal Anesthesia

Injection Technique

The subarachnoid space may be accessed using a midline, paramedian or Taylor's approach.

Midline Approach

Landmarks

The injection is carried out in the midline below the level of the conus medullaris, usually between the spinous processes of the L2–3, L3–4, or L4–5 vertebrae. L5-S1 may also be an option, especially in the older patient with degenerative narrowing of intervertebral spaces. Tuffier's line (or intercristal line) is determined by palpating the superior aspect of the iliac crests on each side. This line bisects the L4 vertebral body in roughly half of adults. Ultrasound imaging can be used to more precisely identify the desired intervertebral level.

The midline is identified by palpating the spinous processes above and below the intervertebral space. It is recommended that **the index and middle fingers of the non-dominant hand be used to palpate and identify the chosen interspace**, as they can subsequently be parted and used to **fix** the overlying skin (Fig. 41.11). This improves precision and accuracy in needle insertion.

Local Anesthesia Infiltration to Skin and Soft Tissues

The skin and the supraspinous and interspinous ligaments are anesthetized with 1–2 mL of a local anesthetic (e.g. 1% lidocaine). The injection is carried out between the spread index and middle fingers of the left hand (Fig. 41.13). The local anesthetic needle may be used to explore the under-

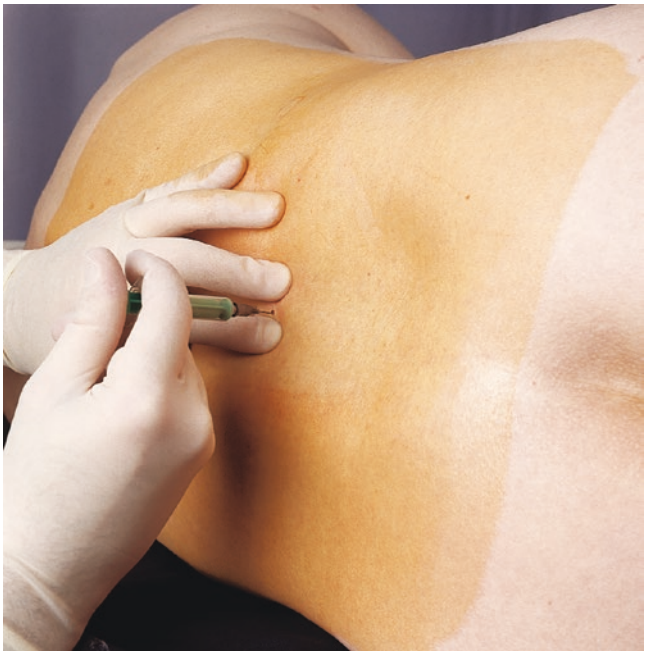

Fig. 41.13 Infiltration of the subcutaneous tissue with local anesthesia. (Reprinted with permission from Danilo Jankovic)

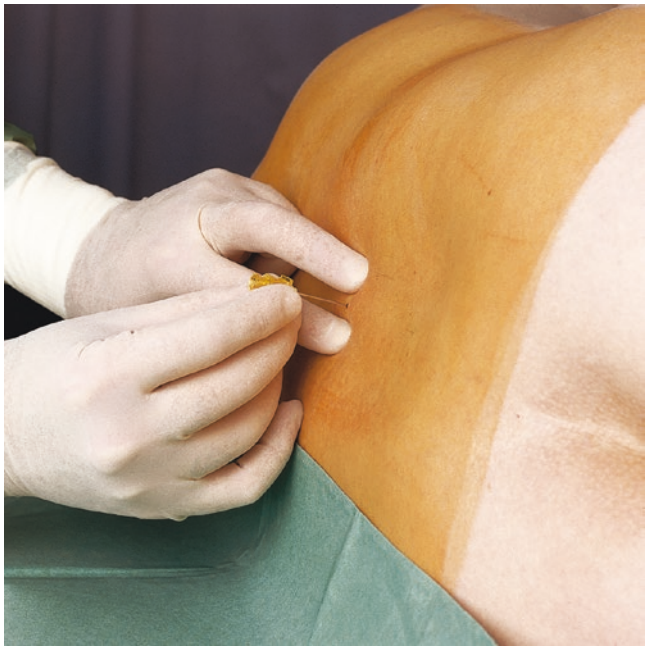

Fig. 41.14 Advancing the introducer needle in a midline approach. Note that the patient is tilted slightly anteriorly such that the surface of the back is not perpendicular to the surface of the bed. Keeping the needle in the sagittal plane during advancement therefore requires that the needle is angled slightly downwards towards the bed surface (see also Fig. 41.15). (Reprinted with permission from Danilo Jankovic)

lying anatomy. Bony contact at a relatively shallow depth indicates contact with the tip of the spinous process and the location of the midline. Firm resistance to further injection of local anesthetic indicates that the needle tip lies in the midline within the interspinous ligament, and not in the paraspinous muscles on either side.

Advancing the Introducer Needle

An introducer needle is used with 25–27G pencil-point needles to facilitate skin puncture and avoid bending or deviation during insertion. Without moving the spread index and middle finger of the left hand away from the intervertebral space (which prevents inadvertent movement of the skin overlying the chosen interspace), the introducer is grasped between the thumb and index finger of the right hand and advanced in the sagittal plane until it is felt to be sitting firmly in the interspinous ligament (Fig. 41.14). In very obese patients, however, the length of the introducer needle may be insufficient to reach the ligament. Insertion of a 22G needle does not require an introducer, but the same principle of skin fixation with the index and middle fingers of the non-dominant hand should be adhered to, to ensure the needle is travelling in the sagittal plane towards the bony midline rather than off to one side.

It is recommended keep cranial angulation to a minimum to start with, since the lumbar spinous processes are largely horizontal, especially if there is good flexion of the lumbar spine. Incremental cranial angulation is undertaken as needed if there is bony contact with the spinous process (Fig. 41.14). Once in place, the introducer is controlled with the thumb and index finger of the left hand, with the dorsum of the hand lying firmly on the patient's back.

Introducing the Spinal Needle and Dural Puncture

The spinal needle, held between the thumb and index finger (or middle finger) of the right hand, is inserted via the introducer needle (if used), through the interspinous ligament, ligamentum flavum, epidural space, dura, and arachnoid mater and into the subarachnoid space (Figs. 41.15 and 41.16). Each of these tissues has a characteristic "feel" as described above. Penetration of the interlaminar space and ligamentum flavum is usually evident by the "rubbery" resistance to needle advancement. A characteristic "dural click" may be felt when the subarachnoid space is reached; however, this does not always occur. It is therefore recommended that the stylet be intermittently withdrawn between incremental advancements to check for CSF backflow (see below) once the ligamentum flavum has been engaged by the needle tip.

Experience shows that failure to locate and enter the interlaminar space is usually due to deviation of the needle from the midline or excessive cranial angulation of the needle.

Removing the Stylet

The following may occur here:

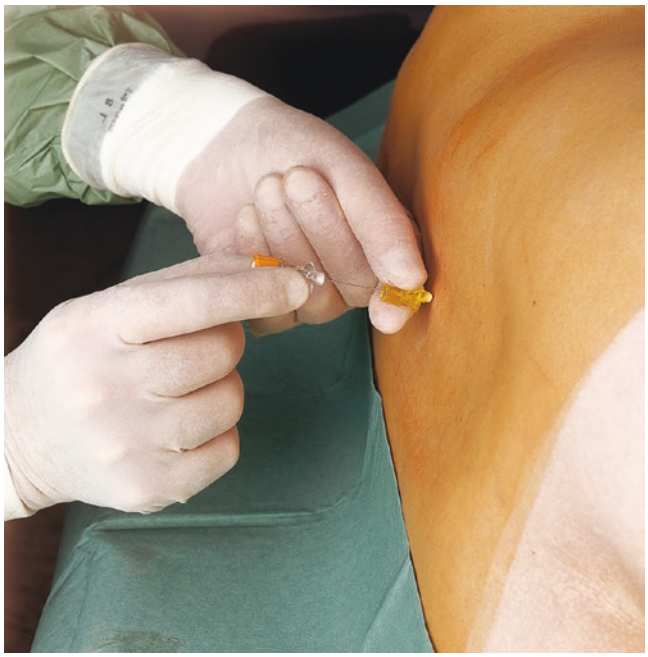

Fig. 41.15 Introducing the spinal needle and puncturing the subarachnoid space in a midline approach. Note the slight downward angle of the needle which is required due to the slight anterior tilt of the patient (see Fig. 41.14). (Reprinted with permission from Danilo Jankovic)

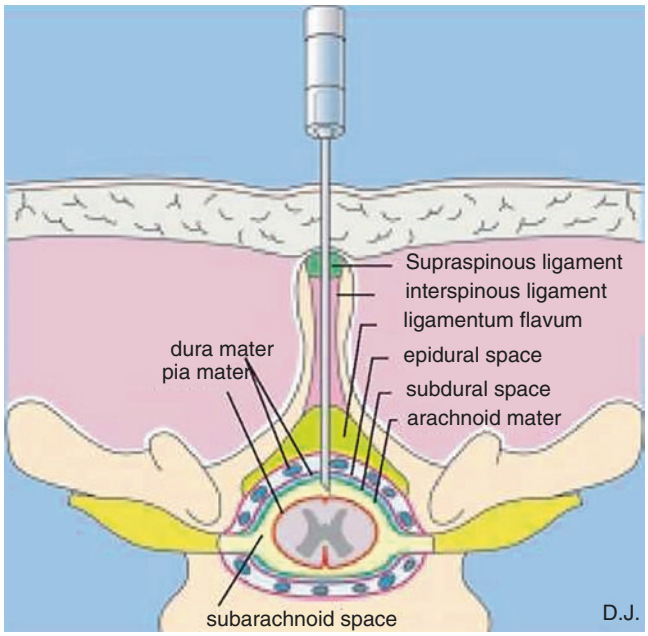

Fig. 41.16 Subarachnoid position of the needle. (Reprinted with permission from Danilo Jankovic)

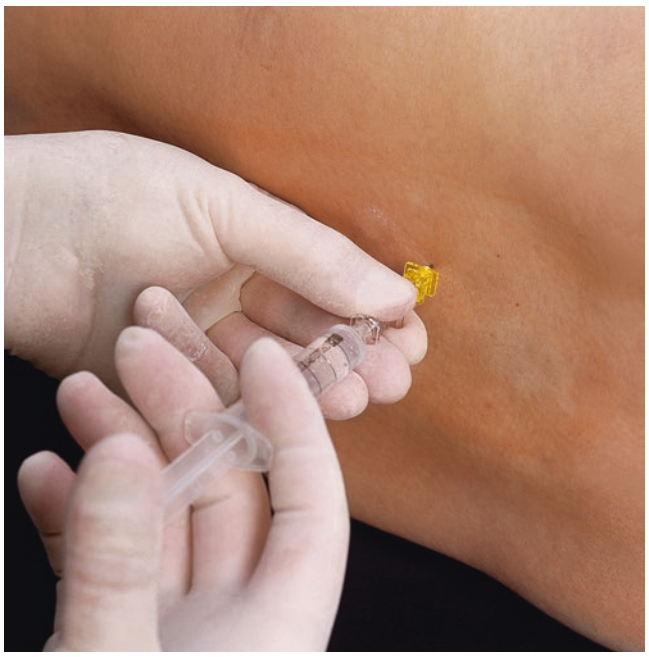

Fig. 41.17 Subarachnoid injection. (Reprinted with permission from Danilo Jankovic)

CSF Flows Freely

The injection needle is fixed between the thumb and index finger of the left hand, which is braced on the patient's back. The syringe containing the local anesthetic mixture is carefully and firmly attached to the needle (Fig. 41.17). Aspiration of CSF (0.1 mL) should be attempted immediately before and after injection of local anesthetic to confirm that the needle orifice is within the subarachnoid space. The rate of injection is not thought to play a significant part in determining the height of the block.

Blood in the CSF

Slightly bloodstained CSF which clears quickly (spontaneously, or after aspiration) usually occurs after penetration of an epidural vein on the way into the subarachnoid space. The local anesthetic can be injected if this is the case. However, backflow of frank blood indicates that the injection needle is likely positioned within a vein. A new attempt at puncture must be made, possibly in a different intervertebral space.

CSF Present in the Needle Hub But Does Not Flow Freely

This is more likely in elderly or dehydrated patients who may have low CSF pressure. It may also be caused by part of the cauda equina occluding the orifice of the needle, especially when negative pressure is applied to the syringe. Rotation of the needle to all four quadrants and careful gentle aspiration may improve flow. If aspiration continues to be impossible, it is recommended that the syringe be disconnected from the hub, and the fluid meniscus in the hub of the needle observed to see if the meniscus extrudes, signifying slow but positive CSF backflow. If this occurs, the syringe may be carefully reattached and injection performed without further reattempts at aspiration (which will only increase the risk of dislodgement of the orifice out of the subarachnoid space).

If no CSF flows in spite of all these measures, the needle should be removed and the procedure repeated with a different needle direction or at a different interspace.

Unexpectedly deep bony contact, or bony contact after the ligamentum flavum has been penetrated, suggests that the anterior wall of the vertebral canal or an intervertebral disk has been reached. The stylet should be removed, and the needle slowly and carefully withdrawn in small increments, pausing in between to observe for CSF backflow as the orifice re-enters the subarachnoid space. If CSF is not observed during this process, the bony contact may have been the base of the spinous process rather than the anterior wall of the vertebral canal, in which case further cranial redirection is required to enter the interlaminar space.

Pain or Paresthesia During Puncture

Pain or paresthesia prior to entry into the epidural or intrathecal space, especially if localized to one side, is most often due to needle contact with the facet joint, which forms the lateral border of the interlaminar space. The location of the midline should be reassessed, and the needle should be directed slightly more medially, away from the side on which the pain or paresthesia occurred.

It is not uncommon for a transient paresthesia radiating down one leg to occur upon needle entry into the intrathecal space; this signals contact with the cauda equina. The stylet should always be withdrawn at this point to check for CSF backflow. If the paresthesia or pain is persistent, the needle must be withdrawn slightly or repositioned, before any injection is performed. The local anesthetic must never be injected without evidence of CSF. The location and distribution of any paresthesia arising during the puncture procedure should be recorded.

Paramedian Approach (Lateral, Paraspinal)

In this technique (Figs. 41.18 and 41.19), the supraspinous and interspinous ligaments are avoided. The ligamentum flavum becomes the primary target on the way into the subarachnoid space.

Procedure

This technique can be used in all the patient positions mentioned above. Flexion of the spine to widen the interspinous spaces is not essential as the needle will bypass these—this is a major advantage of the technique. It may therefore be helpful in patients with degenerative changes of the spine, older patients with calcification of the supraspinous and interspinous ligaments and in patients who find it difficult to flex the lumbar spine.

The cranial edge of the lower spinous process of the desired interspace is marked (Fig. 41.20). The injection site is located in-line with this edge and not more than 1 cm lateral to the spinous process, which avoids the need for a large lateral-to-medial angle; this should be kept within 5–10°. The needle is inserted with a slight cranio-caudal angle of about 10–15°. It is not unusual to contact the lamina on the

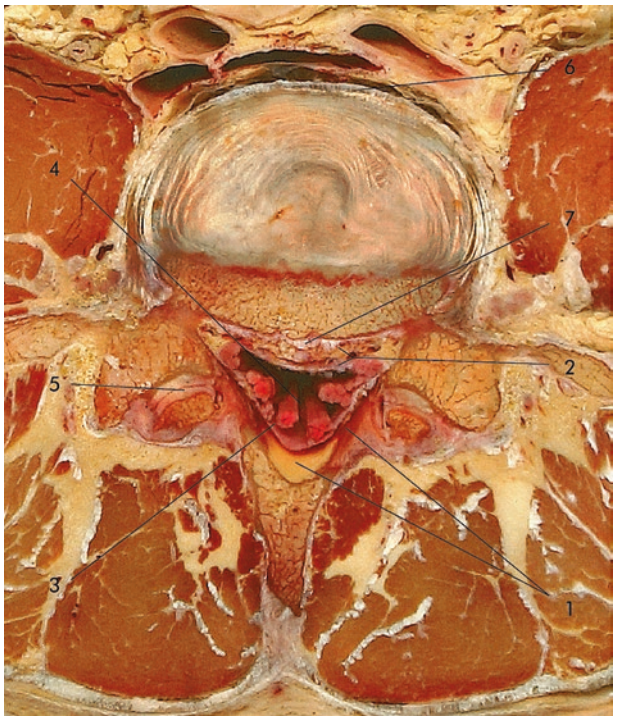

Fig. 41.18 Transverse dissection at the level of the L4/5. (1) Posterior epidural space with fat, (2) anterior epidural space with veins, (3) spinal dura mater, (4) subarachnoid space and cauda equine, (5) zygapophysial joint, (6) anterior longitudinal ligament, and (7) posterior longitudinal ligament. (Reprinted with permission from Danilo Jankovic)

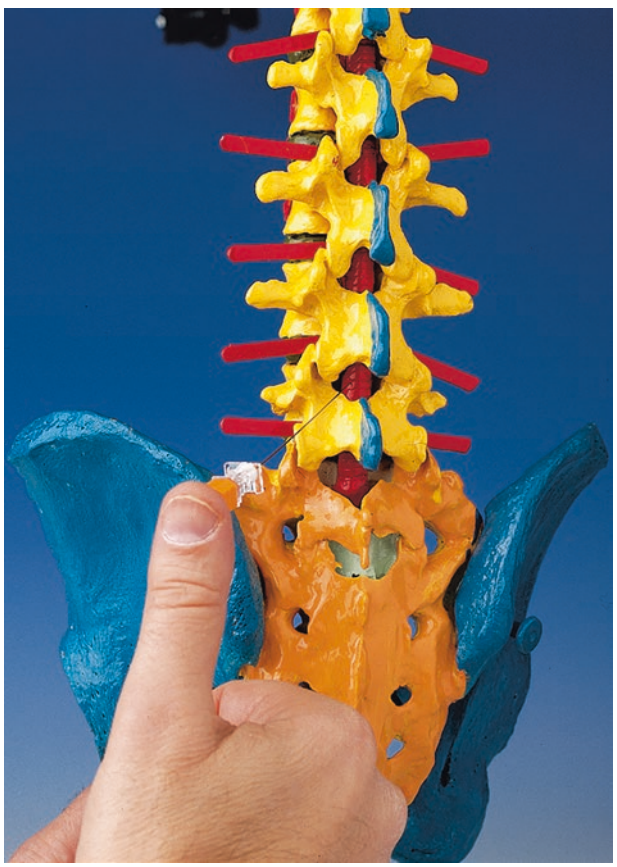

Fig. 41.19 Paramedian approach. (Reprinted with permission from Danilo Jankovic)

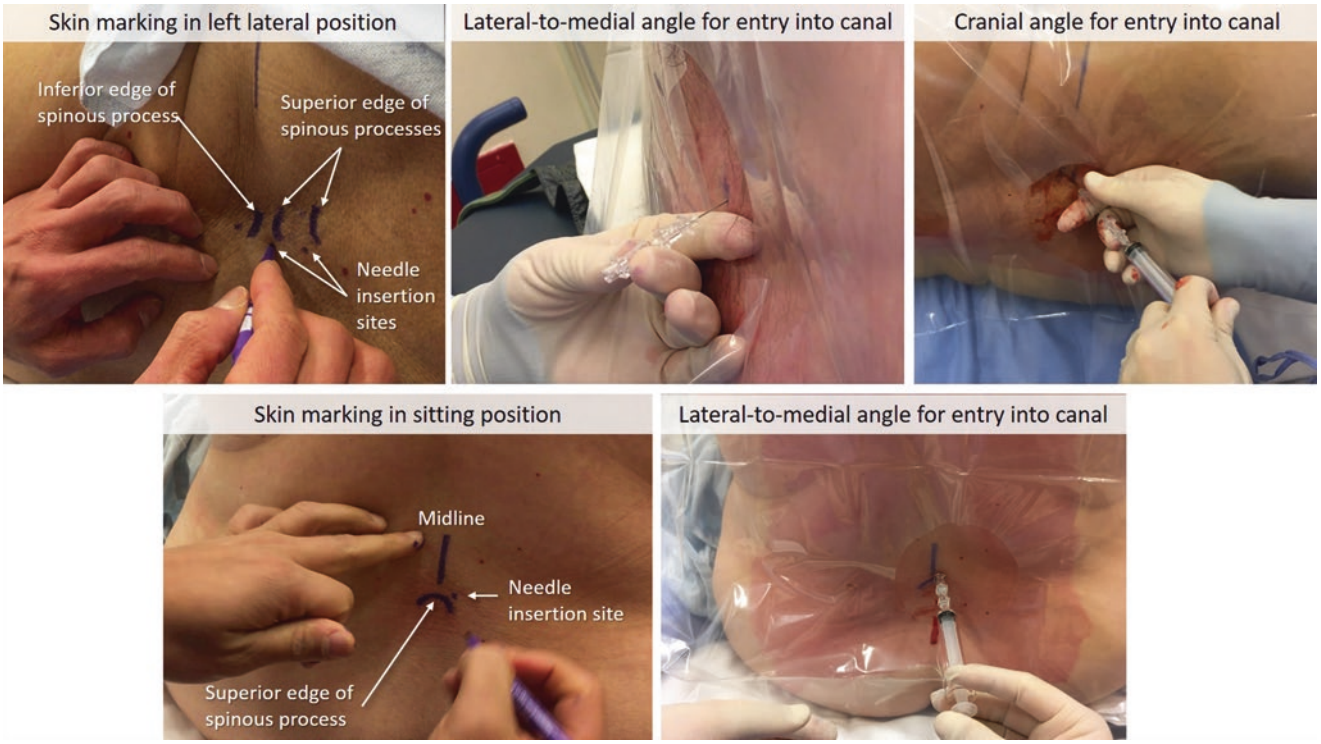

Fig. 41.20 Top row of images illustrates the paramedian (paraspinous) approach to spinal anesthesia in the lateral position; the bottom row illustrates the same approach in the sitting position. A suitable needle insertion site is approximately 1–1.5 cm lateral to the midline or just lateral to and superior to the superior edge of the spinous process. The lateral-to-medial angle should not exceed 10–15°, and maintained constant while the cranial angle of the needle trajectory is incrementally adjusted as needed, starting perpendicular to the skin, to walk off the lamina and into the vertebral canal. The exact angles required for success will vary depending on patient anatomy and the precision of the needle skin insertion site. (Reprinted with permission from Dr. Ki Jinn Chin)

first needle pass. The needle tip is then walked cranially in small increments until it slips off the lamina and deeper into the interlaminar space and ligamentum flavum; this will be signaled by the characteristic feel. Failure arises most commonly when the needle is angled too cranially or when the needle entry point is too lateral.

Taylor's Approach

This lumbosacral (L5–S1) approach (Figs. 41.21 and 41.22) is a paramedian injection via the intervertebral space of L5 and S1, the largest interlaminar space in the spinal region. As with the paramedian approach described above, this approach is somewhat more forgiving when patient positioning is suboptimal.

Procedure

The injection site is located 1 cm medial and inferiorly to the posterior superior iliac spine. The needle is directed 45°–55° cranially and medially. Initial resistance will be felt when the needle contacts the ligamentum flavum and subsequently the dura. If bony resistance is felt, this most likely reflects contact

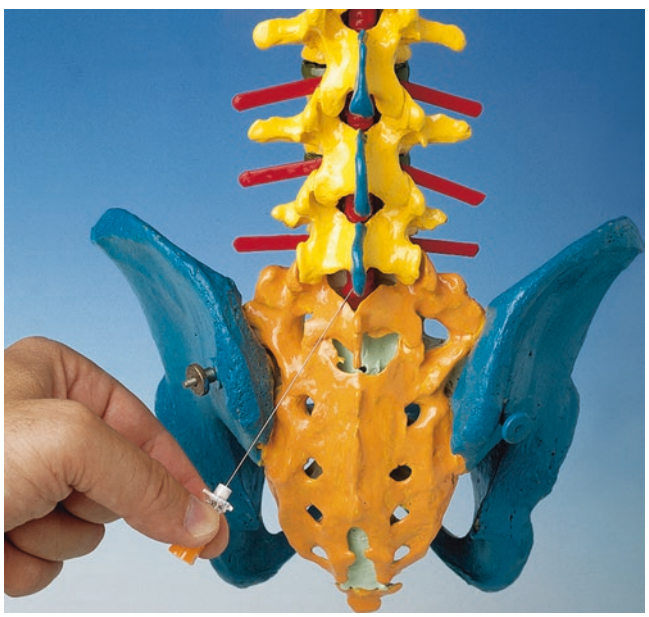

Fig. 41.21 Taylor's approach. (Reprinted with permission from Danilo Jankovic)

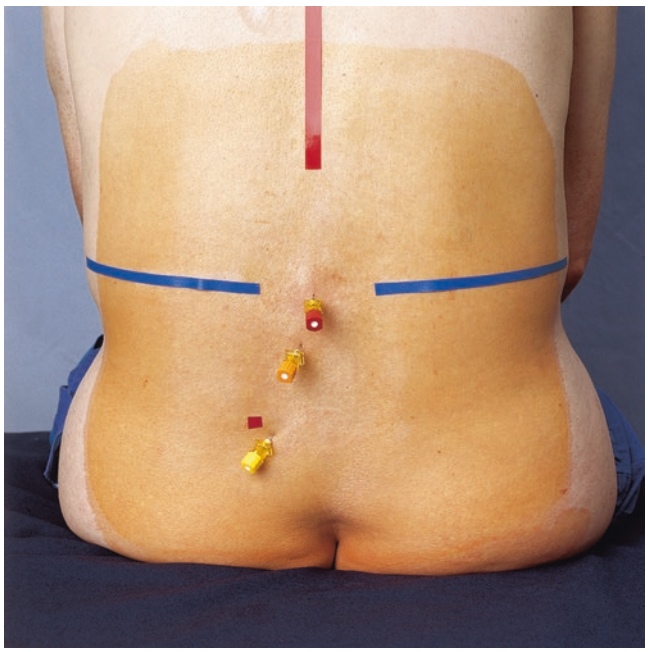

Fig. 41.22 Puncture of the subarachnoid space: (1) median, (2) paramedian, (3) Taylor. (Reprinted with permission from Danilo Jankovic)

with the sacrum. Withdraw the needle and redirect it medially and cranially. Spread of local anesthetic to higher spinal segments can be achieved more easily if hyper- or hypobaric solution is used and the patient is appropriately positioned.

Unilateral Spinal Anesthesia

Unilateral spinal anesthesia is intended to block only the anterior and posterior spinal nerve roots on the side being operated on, while the contralateral side—and particularly its sympathetic fibers—remains unblocked. This leads to a reduced incidence of hypotension.

Indications

Surgical procedures on the lower limbs.

Procedure

Patient positioning: lateral decubitus position, lying on the side that is to be operated on if a hyperbaric local anesthetic solution is used and on the opposite side if a hypobaric solution is used. Hyperbaric solutions usually have 8% glucose added to them and are commercially available, while hypobaric solutions can be concocted by 2:1 or 3:1 dilution with sterile water.

Injection technique: this is the same as for conventional spinal anesthesia. After piercing the dura, the opening of the pencil-point needle may be rotated to the operating side and the desired amount of local anesthetic is injected slowly. The patient remains in the same position for 15–20 min.

Advantages

- Reduced sympathetic block (by about 70%) as smaller volumes of local anesthetic can be used and fewer spinal segments are blocked.
- Improved hemodynamic stability.
- Faster recovery from anesthesia.
- Suitable for outpatient procedures.
- Greater acceptance by patients.

Disadvantages

True unilateral anesthesia is only achieved if adequate time (10–15 min) is allowed for the local anesthetic to settle on the operative side. However, a differential block of some degree can almost always be achieved.

Continuous Spinal Anesthesia

The insertion of a catheter into the subarachnoid space allows a continuous or repeated intermittent dosing of local anesthetic.

Indications

- Lower abdominal and lower limb surgery in elderly patients and high-risk patients.
- Postoperative pain relief.
- Chronic pain relief (in cancer patients).

Procedure

The procedure is similar to a standard spinal anesthetic. Usually, a 20–22 G spinal needle is used to gain access to the subarachnoid space, and a 25–27 G catheter is threaded (usually 2–3 cm) into the subarachnoid space (Fig. 41.23).

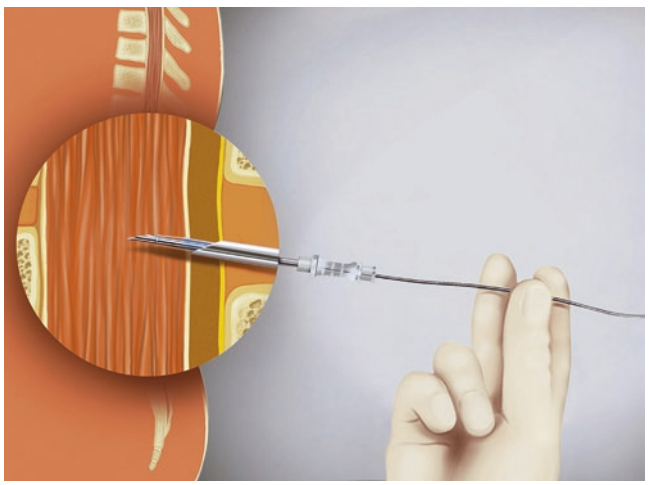

Fig. 41.23 Introducing the catheter in the subarachnoid space. (Reprinted with permission from Danilo Jankovic)

Advantages

- A smaller initial dose of local anesthetic can be injected without concern about inadequate block height or duration. This helps prevent hypotension due to excessive sympathetic block caused by large doses or greater spread of local anesthetic.
- Ability to prolong spinal anesthetic as needed.

Disadvantages

- Higher risk of post dural puncture headache as a higher gauge spinal needle is used.
- Use of small micro catheters (less than 24 G) may predispose to sacral pooling of local anesthetic leading to cauda equina syndrome.

Management of the Patient After Intrathecal Injection

Patient Positioning

The spread of local anesthetic to different vertebral levels is influenced by positioning the patient. It is checked with cold tests at intervals of 2–5 min.

Hyperbaric Spinal Anesthesia

Lateral decubitus position: the patient remains on the side of surgery for 10–15 min if unilateral anesthesia is desired. The patient is laid supine if bilateral anesthesia is required.

Sitting position: the patient is immediately laid supine to allow the anesthetic to spread cranial. The patient remains sitting if only sacral spread is desired (saddle block).

Hypobaric Spinal Anesthesia

The hypobaric technique has gained popularity in major hip surgery, which is often performed in the lateral position. Thus, repositioning of the patient will not be required when the spinal is performed in the lateral decubitus position, with the operative side uppermost. If the sitting position is used, it is recommended to sit them on the side of the operating table or bed that will allow them to lie down directly, once the spinal anesthesia is completed, with the operative side uppermost.

Isobaric Spinal Anesthesia

Horizontal positioning is adequate; other positions have no significant influence on the spread of the anesthesia.

Patient Monitoring

Sympathetic block following a spinal anesthetic usually results in a drop in blood pressure. This may be profound in patients who are elderly or fluid deplete. Bradycardia may occur after the peak of sympathetic block is achieved (30–60 min after spinal injection) due to the blockade of cardiac accelerator fibers. Unexpected bradycardia and cardiac arrest may occur in young healthy patients. Thus, continuous monitoring of the vitals (heart rate, blood pressure and oxygen saturation) is advocated both during the procedure and for the duration of the block. Supplemental oxygen administration is recommended after a spinal anesthetic, especially if sedation is used for patient comfort. Capnometry is also recommended if sedation is used.

Postoperatively, the patient should be monitored until the effects of spinal anesthetic have receded.

Block Assessment

The spread of anesthesia should be checked at short intervals. The first sign of an effect on the spinal nerve roots is a subjective sensation of warmth in the gluteal region and feet. The further development of the block encompasses touch, deep pressure, motor function, vibration sensitivity, and positional sense.

Motor function is completely blocked at the site of the greatest concentration of the local anesthetic. Sensory block extends two to four segments higher than motor block, and the sympathetic block extends for a further two to four segments higher than the sensory block.

Resolution of the block is marked by a return of motor function, followed by the sensory modalities. The autonomic function is the last to recover. This sometimes explains why patients continue to have a degree of hypotension in the post anesthetic care unit even after the sensory and motor block have resolved.

Pharmacology of Drugs Used for Spinal Anesthesia

There is a fairly limited range of local anesthetic agents and adjuvant medications commonly used for spinal anesthesia. The specific medication and dosage used will help to determine the spread, duration, and intensity of the block.

Pharmacokinetics of Intrathecal Local Anesthetics

Determinants of Intrathecal Distribution

Local anesthetic deposited within the subarachnoid space spreads to the nerves via bulk flow. Many factors have been proposed to influence the spread of local anesthetics within the subarachnoid space. These may be classified as follows:

Characteristics of the Injected Drug

Baricity: this is defined as the ratio of the density of the local anesthetic solution relative to the patient's CSF at 37 ° C. *Isobaric, hyperbaric,* and *hypobaric* solutions have the same, greater, and lesser density than the CSF, respectively.

While hyperbaric solutions will sink to the most dependent areas within the subarachnoid space, the hypobaric solutions rise upwards towards the nondependent areas. In general, hyperbaric solutions will produce a greater spread than isobaric or hypobaric solutions.

Mass: mass, volume, and concentration have been investigated for their effects on the spread of the local anesthetics in the intrathecal compartment. For plain solutions, the effect of drug mass injected is more important than the volume or the concentration. For hyperbaric solutions, this may not always be true, with some studies finding no effect.

Effect of additives: while the addition of vasoconstrictors prolong the block duration, the addition of opioids may increase spread and delay block recession. All additives must be labeled as preservatives carry a risk of causing adverse neurological outcomes.

Technical Considerations

Patient positioning immediately after a spinal anesthetic influences the extent of spread of local anesthetic. This is governed by gravity and is further influenced by the curvatures of the spine.

Level of injection: for an isobaric solution, a higher level of injection results in a greater cranial spread of the block. This is not consistently observed with hyperbaric solutions where the effect of gravity may be more profound.

Needle direction: turning the needle aperture cranial may result in a higher spread of the drug, with a shorter duration of action and faster resolution of the block. Cranial angulation of insertion has shown similar results.

Speed of injection: Has clinically minimal effects.

Barbotage: may shorten the time of onset with hyperbaric solutions.

Patient Factors

Individual patient factors such as age, height, body mass index, and sex do not help to predict the spread of intrathecal local anesthetics. However, excessive lordosis in pregnancy may promote cranial spread and lowering doses is recommended.

Uptake of Local Anesthetics

The local anesthetic deposited in the subarachnoid space spreads within the CSF. It is then taken up by the nerve roots in the cauda equina, resulting in neuronal block. This uptake is affected by the following factors:

- Concentration of the local anesthetic in the CSF.
- The surface area of the nerve root exposed to the CSF.
- The lipid content of the nerve root (since local anesthetics are lipid soluble).
- The blood flow within the nerve.

Elimination of Local Anesthetics

The elimination of local anesthetics from the subarachnoid space is determined by the following factors:

- Vascular absorption of the local anesthetic (this is the most important route).
- Escape of the drug to the epidural space, with subsequent vascular absorption.
- Lipophilicity of the local anesthetic (highly lipophilic drugs such as bupivacaine have a slower elimination due to greater binding with the neuronal tissue).

Determinants of Duration

Elimination of local anesthetics from the intrathecal space determines the duration of their neural block. The factors influencing this are as follows:

Physicochemical properties of the local anesthetic chosen: prilocaine is a short acting agent whereas lignocaine and mepivacaine are short to intermediate acting local anesthetics. Bupivacaine, levo-bupivacaine, and ropivacaine are longer acting agents.

Dose injected: in general, the duration of the block is increased with an increase in the dose (or mass) of the local anesthetic injected.

Block spread: for a given dose of the local anesthetic, a block with a greater spread (i.e. higher peak sensory block) will regress faster, thereby shortening the duration of action.

Addition of adjuvants: as mentioned above, the addition of vasoconstrictors and opioids may delay the regression of the block.

Intrathecal Local Anesthetics

The physicochemical properties of local anesthetics such as lipid solubility and protein binding impact the duration of block. They may be classified as follows:

Short Acting Agents

Procaine: It is an amino ester with a rapid onset (3–5 min) but short duration (50–60 min) of block. This is due to its poor lipid solubility and protein binding. Compared to lignocaine, it has a higher rate of block failure but a lower rate of transient neurologic syndrome (TNS).

2-Chloroprocaine: It is an amino ester with a rapid onset and short duration (60 min) of spinal block comparable to lignocaine. It has a lower incidence of TNS.

Prilocaine: It is a short acting amino amide with a short duration of action (60–120 min). It has been recently used for ambulatory surgery, with shorter recovery times when compared to lignocaine. It is not currently available in North America.

Short to Intermediate Acting Agents

Lignocaine: It is an amino amide with a rapid onset and short to intermediate duration of action (60 min, depending upon dose). Its use has dramatically declined due to higher frequency of TNS observed with its use (15–33%).

Mepivacaine: It is an amino amide with similar profile to lignocaine, but lower incidence of TNS (3–6%). It is seeing a resurgence in its use, particularly in the context of ambulatory surgery.

Long Acting Agents

Tetracaine: It is a long acting (3 h) amino ester with a high lipid solubility. It has been almost entirely replaced by bupivacaine due to poor reliability.

Bupivacaine: It is a prototypical amino amide with a long duration of action due to high lipid solubility. It is the most widely used intrathecal local anesthetic. It has an onset time of 10 min and a block duration of 3–4 h. Reducing the doses for unilateral spinal, or ambulatory surgery shortens the duration of action, but may also increase incidence of block failures.

Levo-bupivacaine: this less cardiotoxic stereoisomer of bupivacaine is almost identical to bupivacaine in its spinal anesthetic profile.

Ropivacaine: It is a long acting amino-amide which has gained popularity by virtue of its less cardiotoxic potential. When compared to bupivacaine, it is less potent and produces a block of shorter duration.

Doses

Dosages and duration of commonly used local anesthetics are summarizes in Tables 41.4 and 41.5.

Intrathecal Adjuvants

Additives are often used along with intrathecal local anesthetics to prolong or intensify their block. Although many drugs have been used and evaluated for this, the commonly used intrathecal additives include opioids, vasoconstrictors, and the α2-adrenergic agonists.

Opioids

These act synergistically with the local anesthetics by blocking the opioid receptors at the spinal level.

Morphine It is the most commonly used hydrophilic opioid. Because of its slow distribution within the CSF and a slow plasma clearance, it has a long duration of action when given intrathecally. Used in the doses of 100–400 μg, it provides good postoperative analgesia up to 24 h. However, the intrathecal use of morphine has been implicated in delayed respiratory depression due to rostral migration within the CSF. Higher doses of intrathecal morphine are associated with higher incidence of side effects such as nausea, vomiting, pruritus, urinary retention, and respiratory depression.

Fentanyl It is the most commonly used lipophilic opioid having a rapid onset (5–10 min) and an intermediate duration (1–2 h) of action. In the dose range of 10–25 μg, it increases the intensity of the block without prolonging it. This makes it a suitable option for ambulatory surgery. It should be noted, however, that there is a risk of nausea and vomiting, and pruritus, especially at higher doses.

Sufentanil It is a lipophilic opioid used in the dose range of 2.5–7.5 μg. It has been used in orthopedic surgery and labor analgesia.

Table 41.5 Dosages of isobaric local anesthetic

Local anesthetic	Dose	Duration of effect
Prilocaine 2%	3–4 mL (60–80 mg)	60–120 min
Mepivacaine 2%	3–5 mL (60–100 mg)	30–90 min
Lidocaine 2%	3–5 mL (60–100 mg)	30–90 min
Bupivacaine 0.5%	3–4 mL (15–20 mg)	160 min
Ropivacaine 0.5%	3–5 mL (15–25 mg)	60–120 min

Table 41.4 Dosages of hyperbaric local anesthetics

	0.5% Bupivacaine (5–8% glucose)		5% Lignocaine (7.5% glucose)		4% Mepivacaine (9.5% glucose)		1% Tetracaine (5% glucose)	
Local anesthetic	mL	mg	mL	mg	mL	mg	mL	mg
T6-high	2.5–4.0	12.0–20.0	1.5–2.0	75–100	1.5–2.0	60–80	1.5–2.0	7.5–10.0
T10-medium	2.0–2.5	10.0–12.5	1.0–1.5	50–75	1.0–1.5	40–60	1.0–1.5	5.0–7.5
L1-deep	1.5	7.5	1.0–1.2	50–60	1.0–1.2	40–48	1.0–1.2	5.0–6.0
S1–S5 saddle block	1.0	5.0	0.6–1.0	30–50	0.6–1.0	24–40	0.5–1.0	2.5–5.0
Onset of effect (min)	10–20		5–10		5–10		10–20	
Duration of effect (min)	Up to 160		Up to 60		Up to 60		Up to 150	
Prolongation with vasopressors	No clinically significant prolongation						Up to 180–240 min	

Vasoconstrictors

These drugs reduce the vascular uptake of intrathecal local anesthetics, thereby prolonging their duration. They include phenylephrine and epinephrine. The effect is seen primarily with tetracaine and is rarely utilized.

α2-Adrenergic Agonists

Clonidine and **dexmedetomidine** act on α2-adrenergic receptors in the **substantia gelatinosa** in the spinal cord, intensifying and prolonging both sensory and motor block produced by intrathecal local anesthetics. Clonidine also prolongs spinal block when given orally or intravenously. This, however, is accompanied by a higher incidence of undesirable side effects such as bradycardia, hypotension, and sedation, when compared with the intrathecal route. The recommended dose of clonidine is 15–150 μg (lower doses are advocated), while that of dexmedetomidine is 3 μg.

Ambulatory Surgery

Many surgical procedures are increasingly being performed as day cases. These include hip and knee arthroplasties, as well as minor general and urological procedures. Short acting spinal anesthesia is a useful tool to facilitate this, in conjunction with the principles of enhanced recovery; the prophylactic use of antiemetics, judicious use of opiate medications, etc.

Mepivacaine 2% and prilocaine 2% (the latter is not available in North America) at a dose of up to 3mls are particularly useful in this setting. The addition of sterile water (1-part water to 2-parts local anesthetic) enables a more unilateral block to be performed, thus reducing the total dose of local anesthetic and facilitating a faster recovery. A saddle block with as little as 0.4 mL of heavy bupivacaine 0.75% will reliably enable anal fistula and perineal surgery.

Epidural Anesthesia and Analgesia

Preparation and patient positioning for performing an epidural are the same as for spinal anesthesia.

Epidural Needles

The epidural needles required to perform an epidural block are generally large gauge (16–18G) needles with distinct tip design to facilitate entry into the epidural space and introduction of the catheter. Some of these are depicted below in Fig. 41.24. Of these, Tuohy tip epidural needles are most commonly used.

Needle Insertion: Midline Versus Paramedian (Paraspinous) Approach

The spinous processes of lumbar and lower thoracic vertebrae are directed horizontally. However, those of the upper to mid-thoracic vertebrae are angulated steeply downwards. Thus, while a midline approach is appropriate and commonly used at the lumbar and lower thoracic levels, a paramedian (or paraspinous) approach becomes increasingly useful at the upper to mid-thoracic levels. The midline approach has the advantage of a clear anatomical landmark, provided the relevant spinous processes are easily palpable. A paramedian approach may be preferable at the lumbar level in patients with significant narrowing of the space between adjacent spinous processes. The interlaminar space lateral to the spinous processes typically provides a larger window for needle entry compared to the interspinous space.

Occasionally, there is a failure of the left- and the right-sided ligamentum flavum to fuse in the midline. This anatomical anomaly has been implicated in inadvertent dural puncture and difficulty in localizing the epidural space with the "loss-of-resistance" technique when using a midline approach. The ligamentum flavum remains intact lateral to the midline even in cases where a midline gap is present. Thus, a paramedian approach which enters the epidural space lateral to the midline may offer higher sensitivity in determining loss of resistance compared to a midline approach.

Midline Approach Lumbar Epidural

As for spinal anesthesia, a lumbar epidural needle is inserted below the L2 vertebra, distal to the termination of the spinal cord.

Local Anesthesia

Infiltration of the skin and ligaments with lidocaine serves both to increase patient comfort and to allow exploration of the underlying anatomy as described earlier. Securing the skin with the index and middle finger of the non-dominant hand improves precision and accuracy in needle insertion (Fig. 41.25).

Epidural Needle Insertion

The following sequence of photos indicate midline lumbar epidural placement, with the patient in a left sided lateral decubitus position.

Without moving the index and middle fingers of the left hand from the intervertebral space, the local infiltration needle is removed and an epidural needle is held between

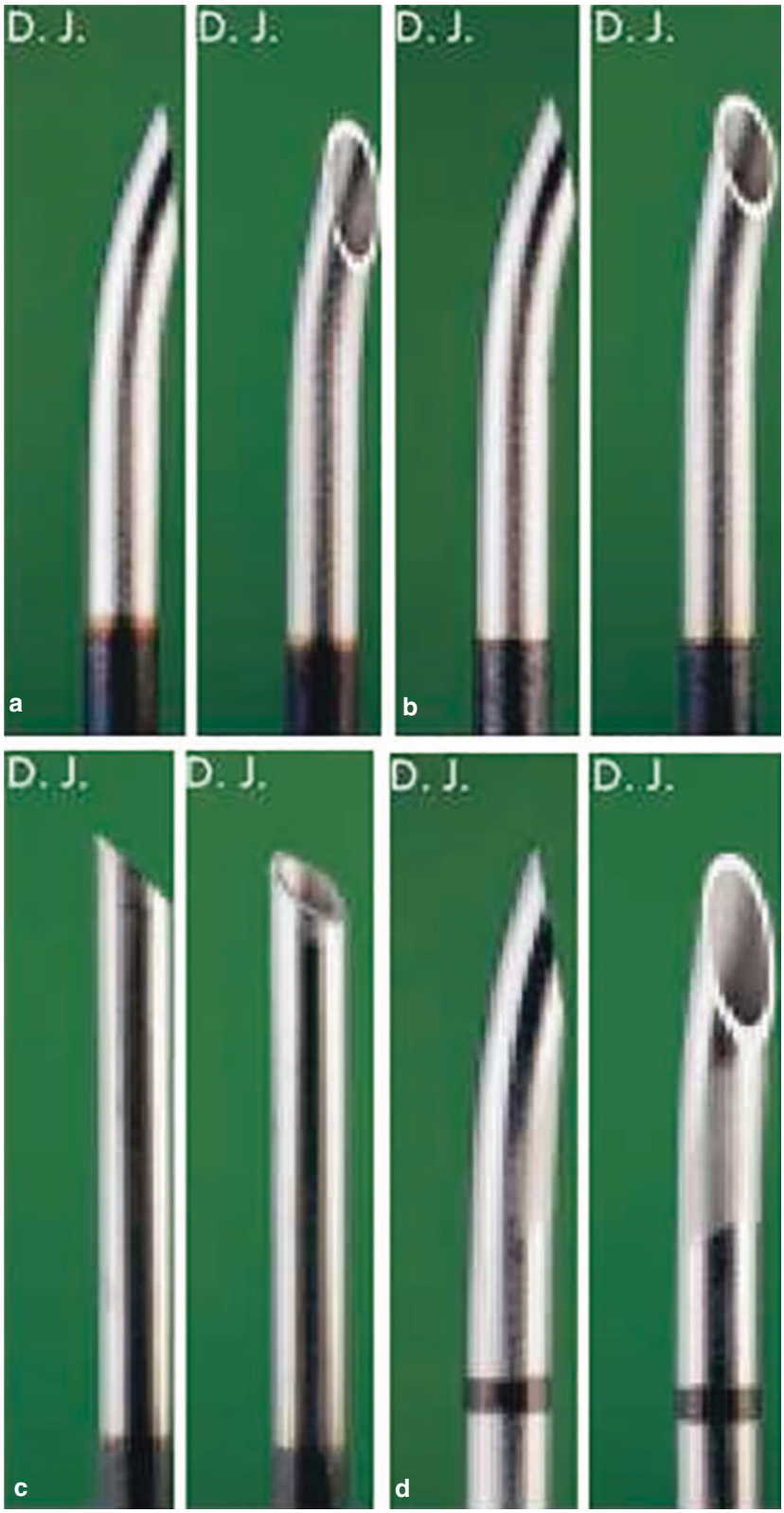

Fig. 41.24 Epidural needles. (**a**) Tuohy, (**b**) Hustead, (**c**) Crawford, (**d**) Weiss. Reprinted with permission from Danilo Jankovic)

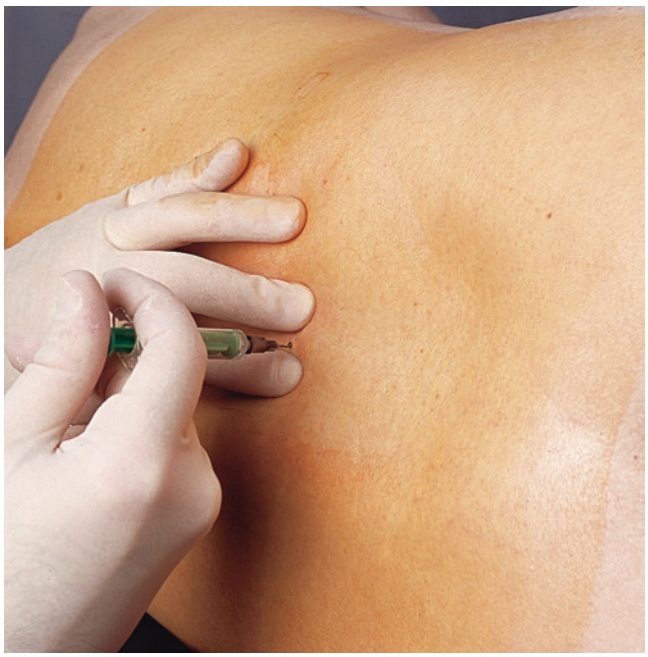

Fig. 41.25 Local anesthesia infiltration of soft tissues. (Reprinted with permission from Danilo Jankovic)

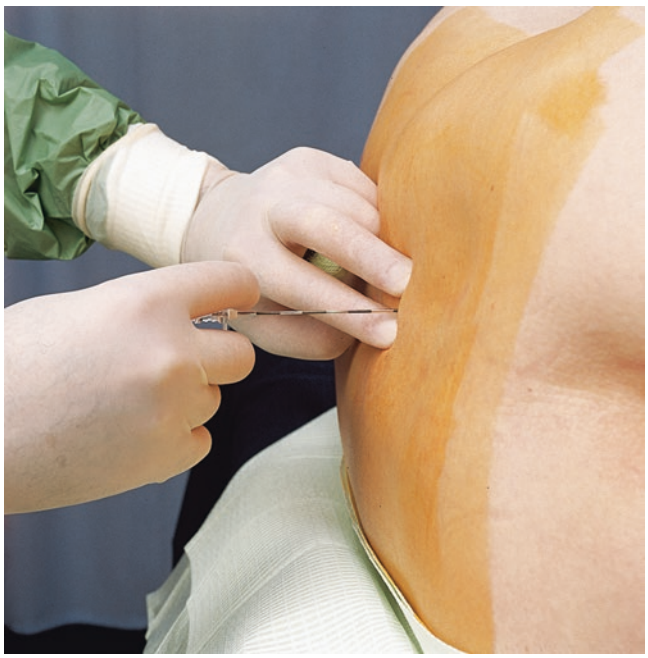

Fig. 41.26 Introducing the epidural needle while continuing to fix the skin with the left hand. (Reprinted with permission from Danilo Jankovic)

the thumb of the right hand (hub) and the index and middle finger (shaft) is advanced through the skin at the same site and trajectory with the bevel facing cephalad (Fig. 41.26). After traversing the supraspinous ligament, which is about 1 cm thick, the needle, the needle is slowly advanced a further 2–3 cm (depending on the anatomy), until it rests firmly in the interspinous ligament. Advancing through the interspinous ligament often produces a in a "gritty" sensation from the tip of the needle, especially in older patients. At this point the stylet is removed from the needle and a low friction (loss of resistance) syringe is attached (Fig. 41.27).

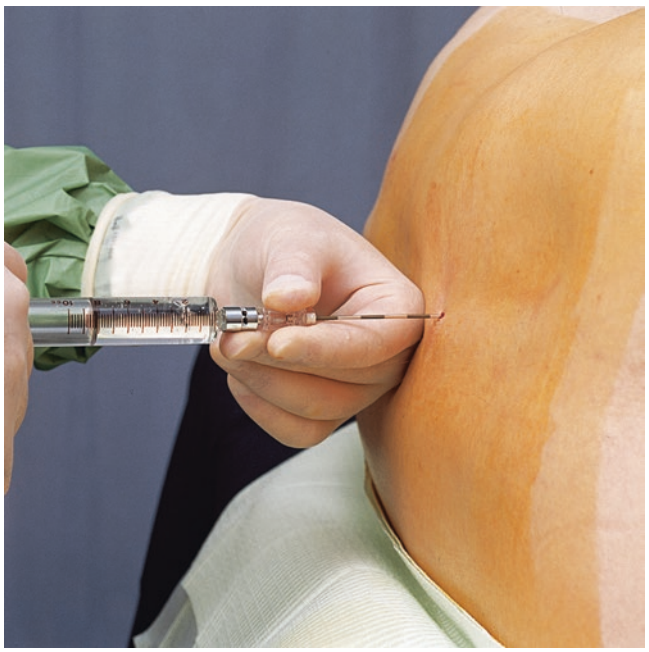

Fig. 41.27 Removing the stylet and attaching a low-friction syringe. (Reprinted with permission from Danilo Jankovic)

Locating the Epidural Space

With the dorsum of the left hand resting firmly on the patient's back, the left thumb and index finger (1) secure the needle, (2) advance it millimeter by millimeter, and (3) serve as a "brake" to prevent inadvertent forward movement. The thumb of the right hand applies pressure on the syringe plunger (Fig. 41.28). *Loss of resistance* indicates that the epidural space has been reached. The contents of the syringe are easily injected.

Care should be taken to ensure that the needle is kept in the midline. Inadvertent deviation from the midline leads to the needle passing the supraspinous ligament, with an angled entry into the interspinous ligament with only brief resistance and a subsequent false loss of resistance. This type of puncture ends in the paravertebral musculature and is accompanied by localized back pain.

Variations in the Loss of Resistance Technique

Saline only technique: The low-friction syringe is filled with a saline solution. Pressure is applied to the plunger as the needle is advanced and upon entry to the epidural space, a loss of resistance is detected with an ability to inject saline easily. Some operators advocate deliberately injecting

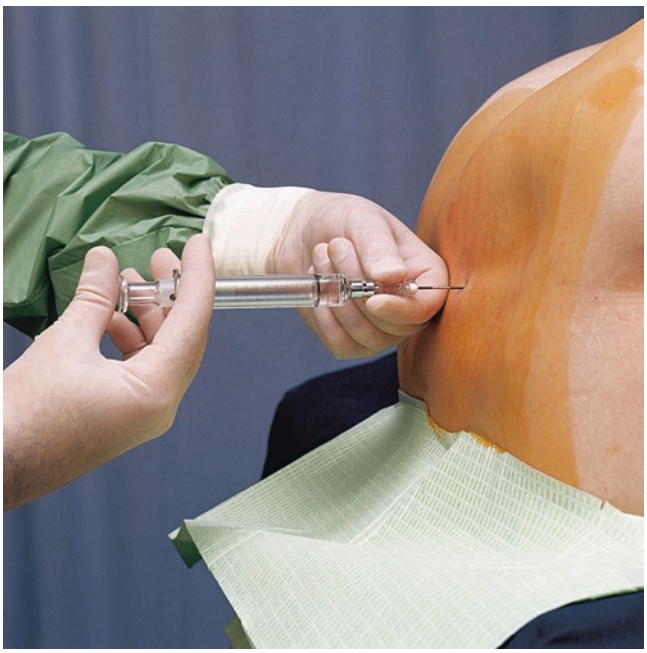

Fig. 41.28 Identifying the epidural space (loss of resistance). (Reprinted with permission from Danilo Jankovic)

approximately. 3 mL of saline to "open" the space and facilitate introduction of the catheter. However, excessive fluid injection may dilute subsequent injected agents (test dose and loading dose).

Loss of Resistance with Air

In this technique, the syringe is filled with air. Proponents of this technique argue that it allows clearer identification of an accidental dural puncture, as any fluid that emerges from the hub of the needle must be CSF. However, using air to locate epidural space has been associated with patchy blocks, venous air embolism, and pneumocephalus.

Saline with an Air Bubble

The low-friction syringe is filled with a saline solution, but a small air bubble is retained within the syringe as an additional visual indicator of the resistance to attempted injection. Visual compression of the bubble corresponds to tactile resistance to pressure on the syringe plunger (Fig. 41.29a). When the epidural space is reached, the bubble re-expands to its normal shape, the plunger is depressed with little resistance and the saline is injected (Fig. 41.29b).

Hanging Drop Technique

This technique is only advocated for use in thoracic epidural placement due to more consistent negative pressures in the epidural space in this region. After the interspinous ligament has been reached *(in midline approach)* or interlaminar space reached *(in paramedian approach)*, a drop of saline is placed within the hub of the needle (Fig. 41.30a). After the ligamentum flavum has been passed and the epidural space has been reached, the drop is "sucked in" due to the negative pressure in the epidural space caused by tenting of the epidural space by the needle (Fig. 41.30b). As both hands can grip the needle, needle advancement may be more controlled. By only advancing the needle during inspiration, negative pressure in the epidural space is maximized, to improve the sensitivity of this technique.

Paramedian Approach Epidural

This is performed using the same landmarks as for spinal anesthesia (Fig. 41.20), just with an epidural needle rather than a spinal needle. In the lumbar region where the spinous processes are close to horizontal in orientation, the skin puncture site is 0.5–1 cm lateral to the superior border of the lower spinous process of the intervertebral space being entered. The needle is advanced in a cranio-medial direction at a lateral to medial angulation of about 5–10° to the sagittal plane with a slight cranial angulation of 0–10° to the skin surface. If the lamina is encountered, the needle should be redirected with a slight increase in cranial angle, without altering the lateral to medial angulation to enter the interlaminar space. The only ligament that needs to be penetrated on the way to the epidural space is the ligamentum flavum.

Care should be taken to avoid excessive lateral to medial angulation to prevent crossing the midline to the ipsilateral side. The needle should essentially pass alongside the spinous process.

Catheter Placement into Epidural Space

Having reached the epidural space, the loss of resistance syringe is removed. The catheter is introduced, provided no CSF or blood is seen to drain from the needle. The thumb and index finger of the left hand secure the epidural needle, with the back of the hand lying firmly on the patient's back. The catheter is advanced cranially, using the thumb and index finger of the right hand, to a depth of 4–5 cm beyond the tip of the needle (Fig. 41.31). Advancing it further than this can lead to lateral deviation of the catheter and consequently a unilateral block. It is also associated with greater risk of intravascular placement. After placement of the catheter in the desired position, the needle is slowly withdrawn (Fig. 41.32), while the thumb and index finger of the left hand secures the catheter at the injection site (Fig. 41.33).

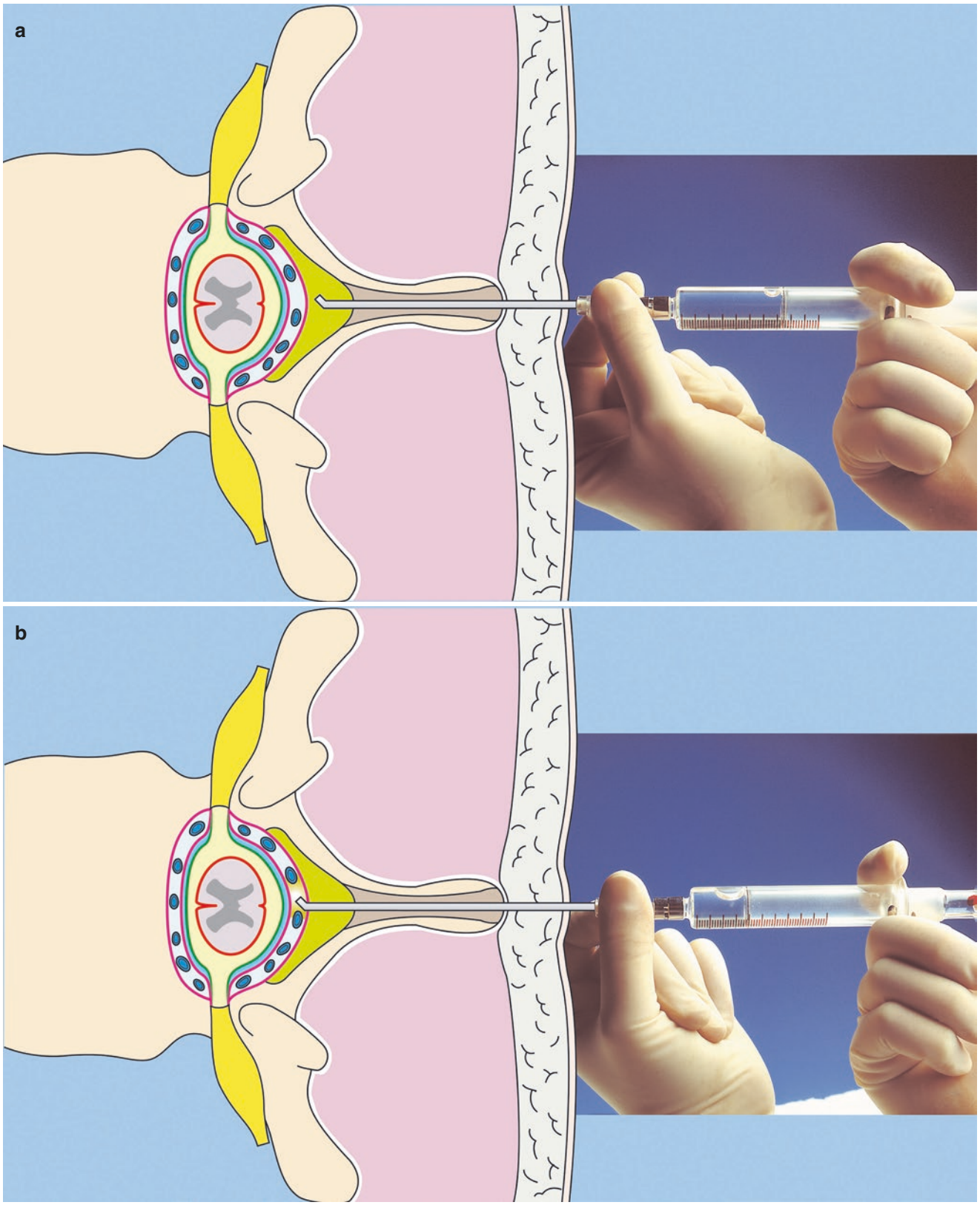

Fig. 41.29 (**a**) Loss-of-resistance technique with saline. The air bubble is compressed by pressure on the syringe plunger. (Reprinted with permission from Danilo Jankovic). (**b**) Loss-of-resistance technique with saline. The epidural space has been reached. The air bubble has returned to its normal shape and saline has been injected. (Reprinted with permission from Danilo Jankovic)

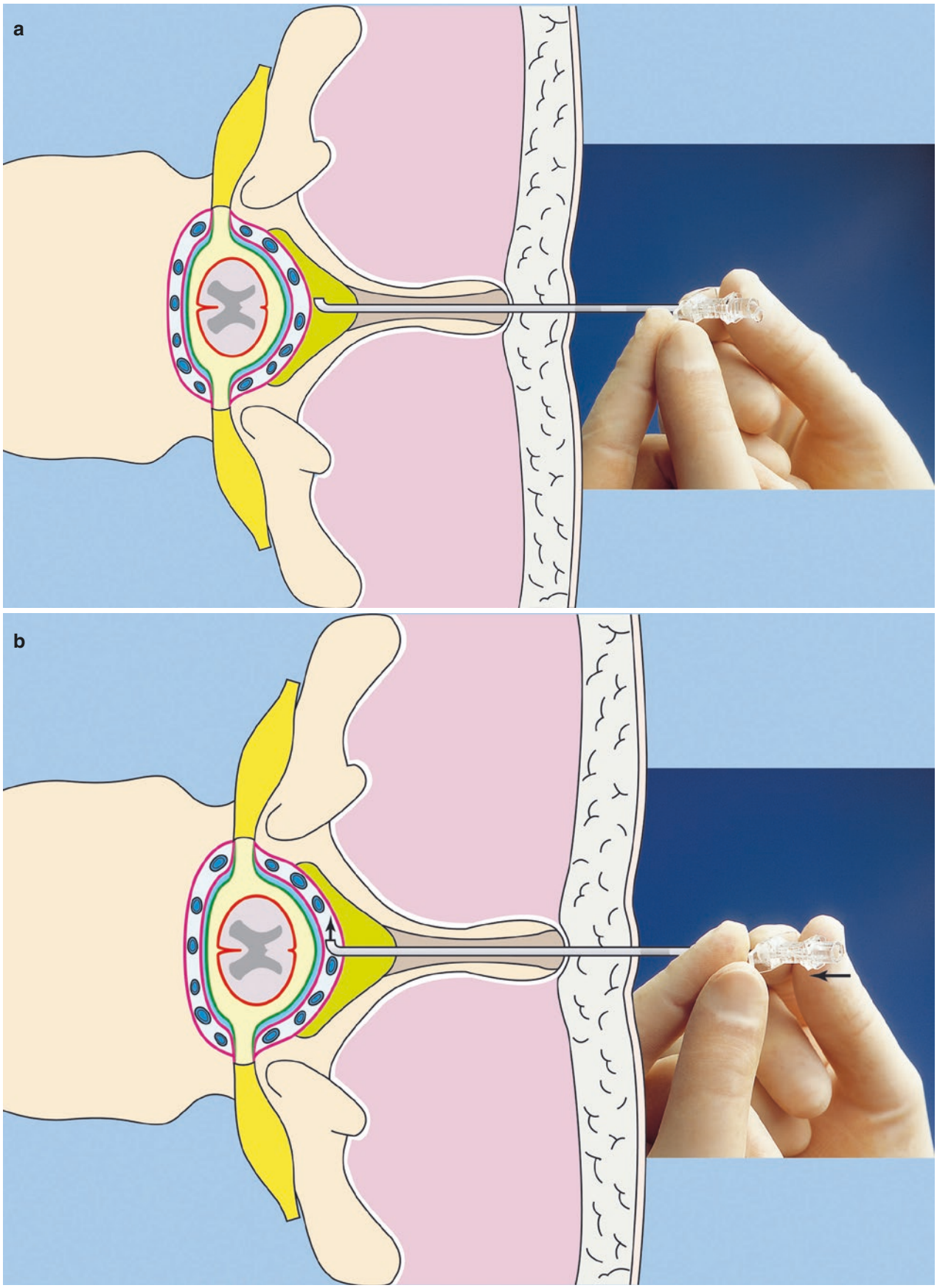

Fig. 41.30 (**a**) **"**Hanging drop" technique. The epidural needle is positioned in the ligamentum flavum. (Reprinted with permission from Danilo Jankovic). (**b**) "Hanging drop" technique. The epidural space has been reached. The drop is sucked back in. (Reprinted with permission from Danilo Jankovic)

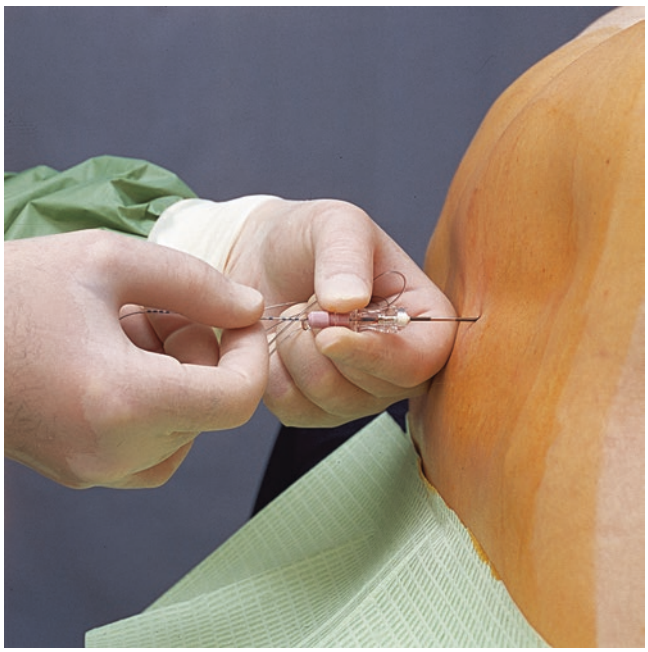

Fig. 41.31 Introducing the catheter. (Reprinted with permission from Danilo Jankovic)

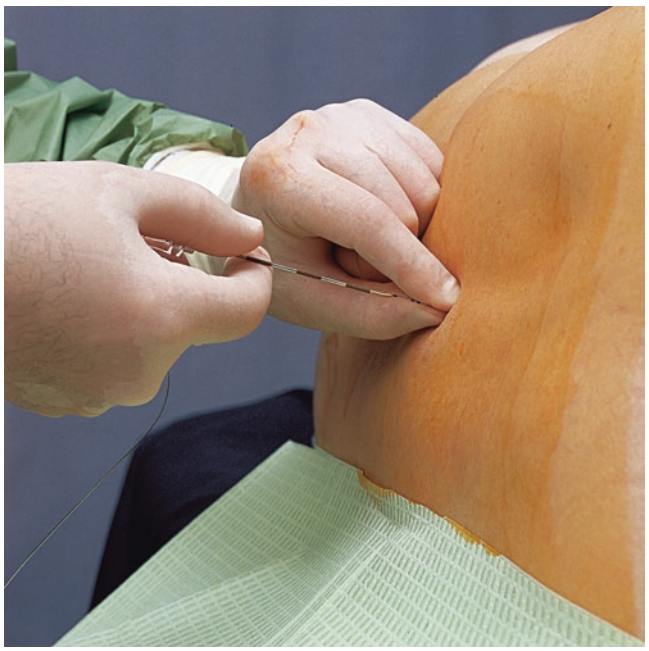

Fig. 41.33 The catheter is secured at the injection site with the thumb and index finger. (Reprinted with permission from Danilo Jankovic)

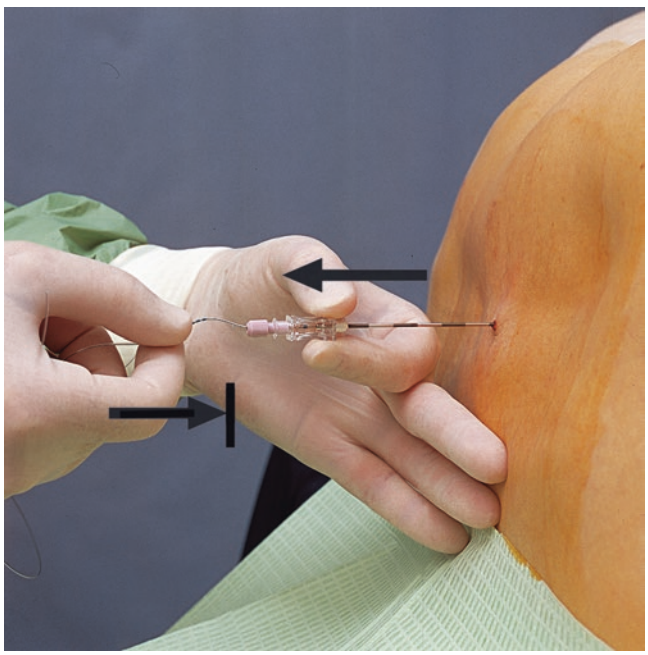

Fig. 41.32 Withdrawing the injection needle. (Reprinted with permission from Danilo Jankovic)

Length of Catheter Placement

The optimal length for catheter advancement is subject to conflicting views, with recommended distances for catheter insertion in the literature ranging from 2 to 6 cm. There is evidence that resistance is encountered at a mean distance of catheter insertion of only 2.5 cm. In theory, any further advancement has an increased risk of coiling, transforaminal exit or vascular puncture and some sources advocate a minimal insertion approach. However, studies have supported 5 cm insertion as non-inferior to 3 cm in terms of performance and complication rates.

The proximal orifice in multi-orifice catheters typically lies approximately 1.5 cm from the tip and this should also be taken into account as all orifices should remain in the epidural space. As catheter migration of up to 1–2 cm is common in the post-operative period, it is prudent to thread a small excess length of catheter to avoid migration out of the epidural space. This also provides a margin of safety for inadvertent dislodgement during epidural placement as the Tuohy needle is being removed and the catheter is being fixed to the skin. Based on this rationale, a 4–5 cm catheter insertion is advocated.

An adapter is attached to the proximal end of the catheter. Patency of the catheter is tested by injecting 1–2 mL of saline (Fig. 41.34). After aspiration, the syringe and adaptor are disconnected and the open end of the catheter is placed on a sterile drape below the puncture site. Attention must be given to any escaping fluid (CSF or blood) (Fig. 41.36). The catheter is then held vertically above the needle insertion point (Fig. 41.35). A rapid fall of the meniscus or fluid level within the catheter is a sensitive (though not specific) indicator of correct placement of the catheter within the epidural space.

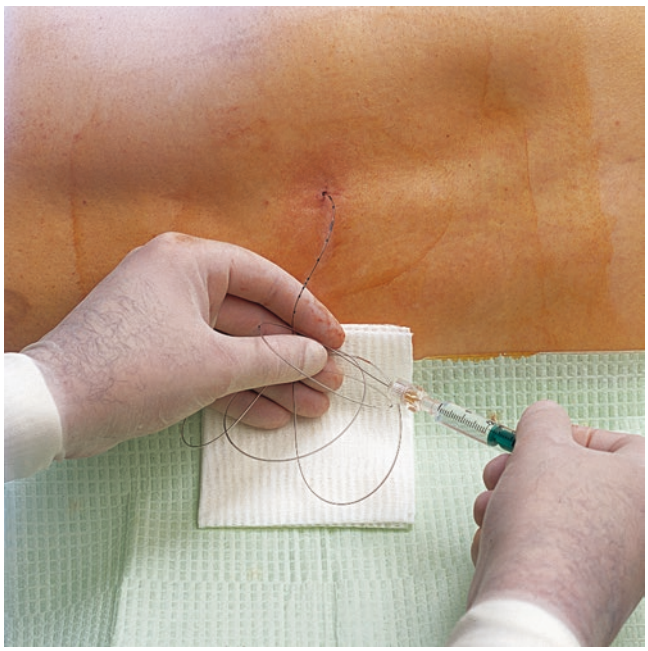

Fig. 41.34 Injection of 1 mL saline. (Reprinted with permission from Danilo Jankovic)

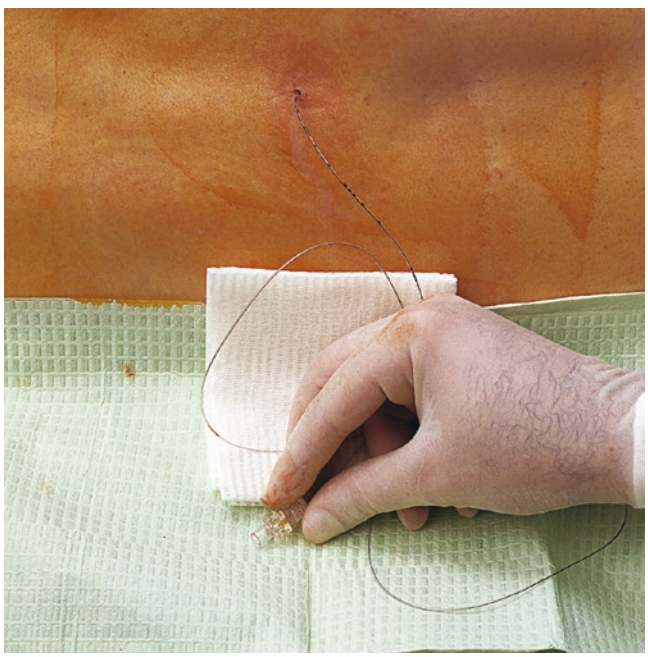

Fig. 41.35 The end of the catheter is placed below the injection site. (Reprinted with permission from Danilo Jankovic)

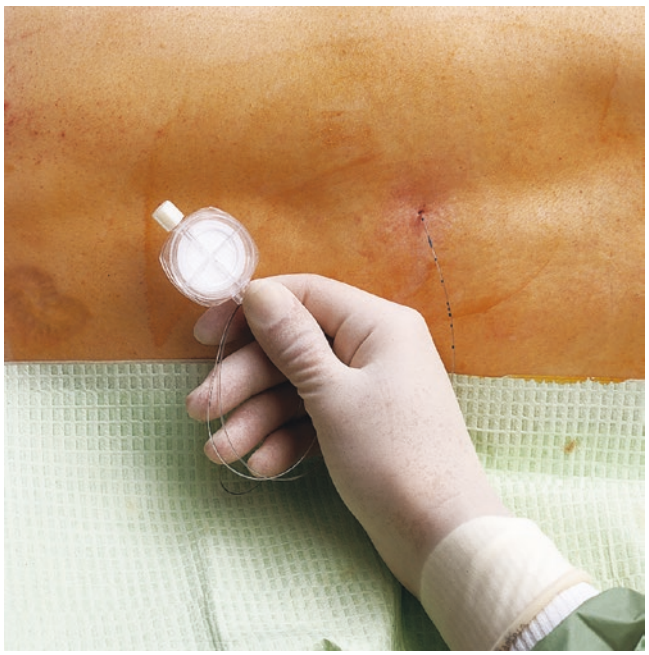

Fig. 41.36 Placing a bacterial filter

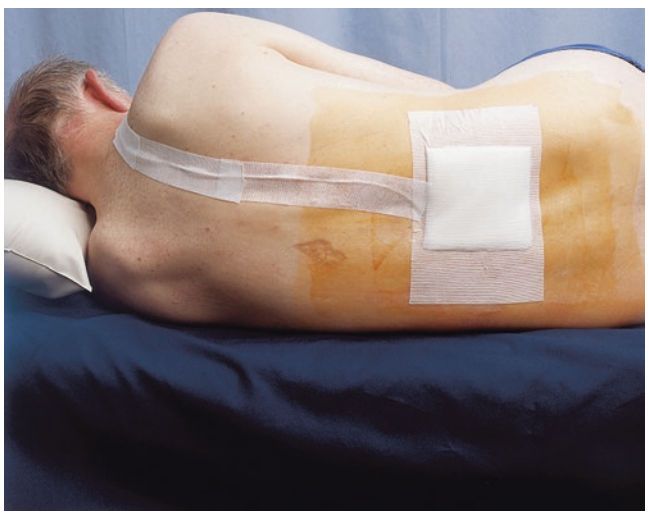

Fig. 41.37 Securing the catheter and dressing. (Reprinted with permission from Danilo Jankovic)

Test Dose and Fixation of Catheter

A bacterial filter is attached (Fig. 41.36) and a test dose (for example 45 mg lidocaine and an optional 15 μg epinephrine) is administered. The catheter is secured and dressed to prevent dislodgement and ensure sterility (Fig. 41.37). The patient is then placed in the desired position. Fixation of the catheter can be accomplished in a variety of ways (see section "Catheter Fixation").

The test dose allows detection of intrathecal injection (rapid development of spinal block) or intravascular injec-

tion (tachycardia, hypertension or T-wave changes on ECG). The addition of epinephrine can lead to unreliable results in patients taking beta-blockers, patients under general anesthesia, and pregnant patients. Due caution must be exercised while adding epinephrine in pregnant patients (as may cause transient fetal bradycardia due to reduced uterine blood flow), older patients with coronary artery disease and hypertensive patients. The use of epinephrine is best avoided in patients with closed angle glaucoma, and tachyarrhythmias.

Following test dose administration, it is important to maintain verbal contact with the patient, to conduct careful cardiovascular monitoring and to check the spread of the anesthesia in order to exclude the ever-present risk of inadvertent intrathecal injection. After 5 min, if no evidence of intrathecal or intravascular spread has occurred, the loading dose, adjusted for the individual patient, can be administered on an incremental basis until the desired level of anesthesia is reached. It may take 15—20 min for the test dose to produce a clinical block confirming correct epidural placement. In practice, this time may not be readily available, particularly if the epidural is being used in combination with general anesthesia and induction occurs soon after epidural placement.

Catheter Fixation

Epidural catheter migration and/or dislocation is a common phenomenon. Significant catheter migration (>20 mm inwards or outwards) is associated with diminished analgesia, early termination of epidural anesthesia and may contribute to more serious complications such as spinal hematoma or predispose to bacterial contamination (Ref: Sellman). Although evidence supports tunneling and suturing the catheter to minimize movement, this adds time and it has its own potential complications and it is not a widely practiced technique.

Methods for epidural fixation range from simple adhesive dressings to proprietary epidural fixation systems. There is insufficient evidence to support the use of a specific dressing. All may be compromised by perspiration or leakage of fluid or blood from the puncture site. Clean, dry skin is paramount for effective fixation regardless of the dressing used, as is attention to detail and examination of the site in the peri-operative period. Daily checks should be carried out post-operatively, and if any doubt on the integrity of the dressing, re-fixation in a sterile manner should take place.

Considerations regarding choice of fixation method include expense and ease of use in addition to efficacy of fixation. As an example, in a recent study, tissue glue (2-Ethyl cyanoacrylate adhesive) was associated with an absence of thoracic epidural catheter movement and also with decreased fluid leakage at the skin requiring refixation of dressings. These advantages have to be weighed against the cost of tissue glue.

Troubleshooting Needle/Catheter Entry

Fluid backflow from the needle hub: after the epidural space has been identified or after administration of the test dose, a few drops of fluid may still drip from the positioned needle. This may be saline from the syringe or CSF if intrathecal space has been punctured. A higher viscosity, higher temperature (Fig. 41.38), near neutral pH, higher glucose content and turbidity with thiopentone help identify the fluid as CSF. If the fluid is not CSF, one can proceed with the procedure.

Blood backflow from the needle hub or catheter: in this case (Figs. 41.39 and 41.40) it is best to withdraw the needle or the catheter. One may attempt another insertion at a segment higher or lower; or abandon the procedure and choose to administer general anesthesia and/or alternative regional anesthetic technique.

CSF backflow from the needle hub: The options in the event of accidental dural puncture include conversion to a spinal anesthetic by injecting an appropriately reduced dose of local anesthetic, or inserting a continuous spinal catheter (which must clearly be labeled as such, to avoid inadvertent overdosing with subsequent top-ups). Another attempt at insertion can also be made keeping in mind the possibility of another dural tap, and that an epidural dose of local anesthetic may unpredictably spread intrathecally through the first dural puncture site and lead to a total spinal anesthesia. Finally, one may choose to abandon the procedure and administer general anesthesia. In any case, the patients must be informed about the possibility of a postdural puncture headache. Insertion of a spinal catheter or further attempts at

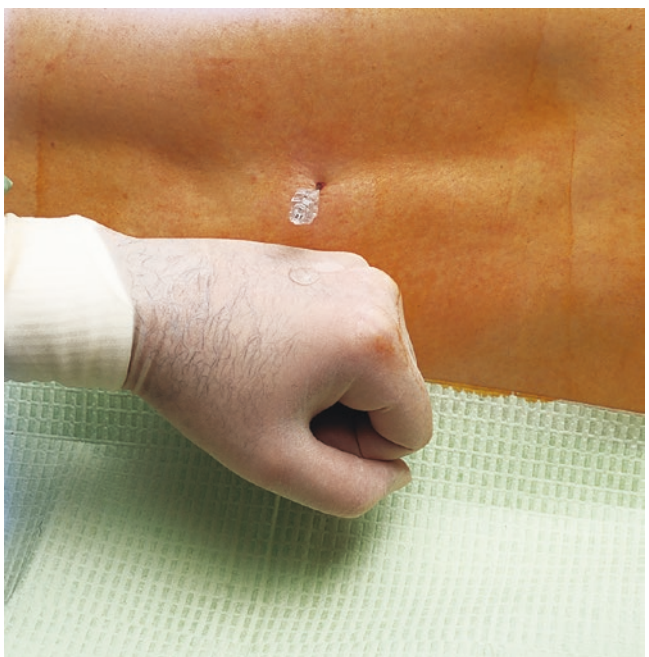

Fig. 41.38 Escaping fluid: is it cold or warm? (Reprinted with permission from Danilo Jankovic)

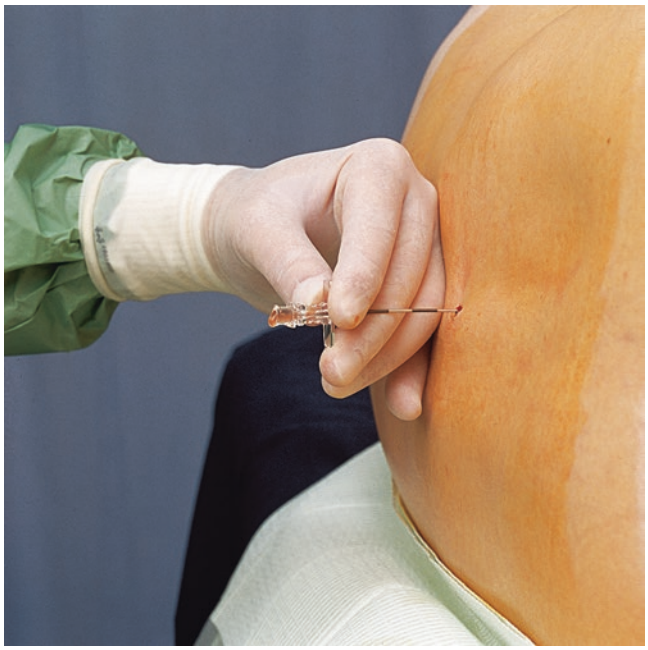

Fig. 41.39 Blood-tinged fluid. (Reprinted with permission from Danilo Jankovic)

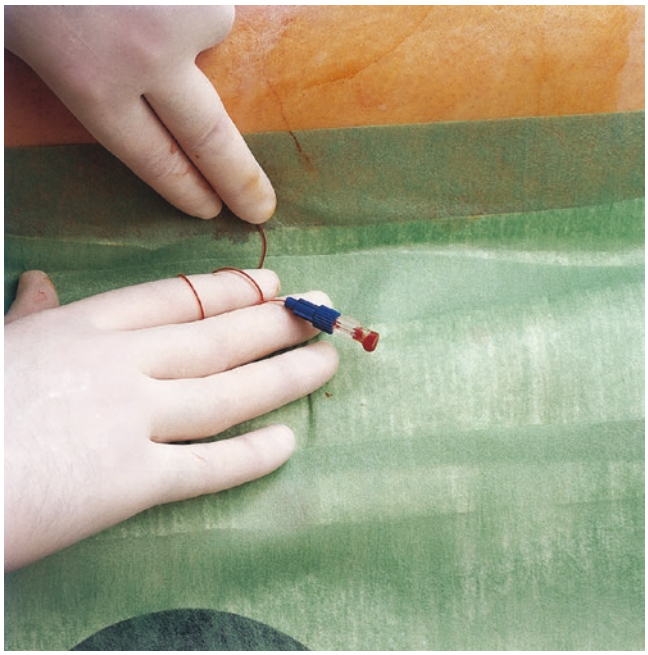

Fig. 41.40 Blood from the catheter hub. (Reprinted with permission from Danilo Jankovic)

insertion are not recommended in the thoracic region in the event of a dural puncture.

Inability to thread the catheter: this may happen when a false loss of resistance has been encountered in a superficial tissue plane. The catheter should be removed and the procedure reattempted, aiming to obtain a convincing loss of resistance. If the catheter is withdrawn through the needle, there is a potential risk of shearing of the catheter tip against the bevel of the needle. Gentle withdrawal of the needle through the catheter may be attempted; though if any resistance is encountered, we recommend that the needle and catheter are withdrawn en-bloc.

Thoracic Epidural Placement

While the general approach for thoracic epidural analgesia is as described in the preceding section in terms of preparation, equipment, catheter insertion, and fixation, there are notable differences between lumbar and thoracic epidural placement. Placement of thoracic epidurals is a fundamental anesthetic skill but is nonetheless considered a technically challenging procedure. This is reflected in the high primary failure rate of up to 22% (incorrect placement of the thoracic epidural catheter), as well as the potential for secondary failure (catheter migration or suboptimum dosing).

Thoracic epidurals are most often used to provide analgesia for thoracic or major abdominal surgery. The analgesic efficacy of thoracic epidural analgesia is well established as being superior to parenteral opioid administration. Additional benefits include improved perioperative outcomes relating to cardiac, respiratory, and gastrointestinal function. Adverse side effects of epidural analgesia include hypotension, urinary retention, pruritis, and motor block.

The level at which an epidural catheter is optimally sited is dependent on the desired area of sensory blockade. The catheter tip is typically located at a vertebral level corresponding to the midpoint of the surgical incision on a dermatomal map.

A needle inserted in the midline will traverse the skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, and ligamentum flavum to access the epidural space (Fig. 41.41). A paramedian insertion of the needle, on the other hand, bypasses the supraspinous and interspinous ligaments. Bony resistance is expected when the lamina is encountered and may be "walked off" in a cephalad direction to access the interlaminar space, ligamentum flavum, and epidural space.

Paramedian Approach for Upper to Mid-Thoracic Levels

Skin Puncture Site

At this level, the puncture site is located about 0.5–1 cm lateral from the caudal edge of the superior spinous process of space being entered (Fig. 41.42) and 1–2 cm caudal to the interlaminar space which is being targeted. This target may be identified by ultrasound (see previous chapter). These guidelines apply to the region of mid to upper thoracic spine

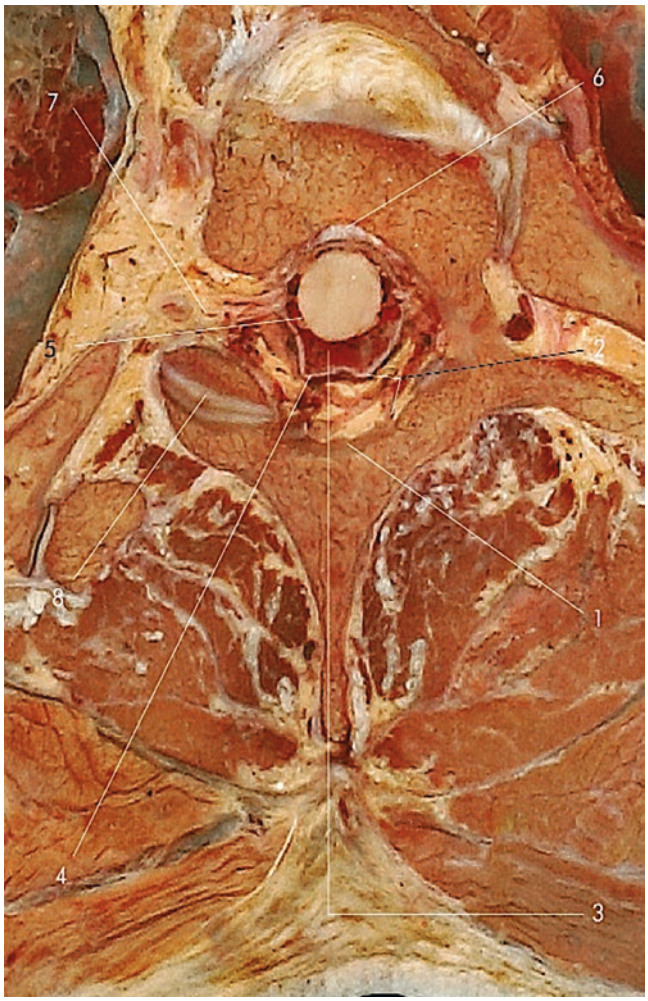

Fig. 41.41 Transverse dissection at the level of the T3. (1) Ligamentum flavum, (2) epidural space, (3) subarachnoid space with spinal cord, (4) spinal dura mater, (5) spinal pia mater, (6) posterior longitudinal ligament, (7) neural foramen with spinal nerves, and (8) zygapophysial joint. (Reprinted with permission from Danilo Jankovic)

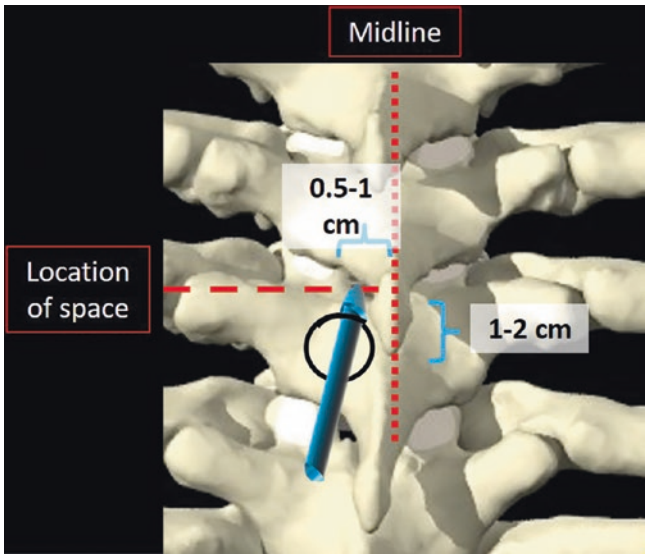

Fig. 41.42 The recommended insertion site for a paramedian approach to the thoracic epidural space in a typical adult patient is approximately 1–2 cm inferior to the tip of the spinous process, and not more than 1 cm lateral to the midline (just enough to avoid and pass alongside the spinous process). The needle should be angled not more than 5–10° towards the midline. It can be advanced initially at 90-degrees to the patient's back to contact the lamina, and then the tip walked cranially to enter into the space, maintaining the slight degree of lateral-medial angulation. (Reproduced with permission from Dr. Ki Jinn Chin)

where spinous processes are steeply angled and interlaminar spaces overlap.

A fan-shaped local anesthesia infiltration is used to anesthetize the skin. The local infiltration needle may also be used to explore the contours of the spinous processes/depth to lamina and to confirm the optimal trajectory. The epidural needle is introduced in a *cranio-medial direction* at a lateral to medial angulation of about 5–10° to the sagittal level and a cranial angulation of about 35–45° to the skin surface (Fig. 41.43) is required.

The only ligament that needs to be penetrated on the way to the epidural space is the ligamentum flavum. The initial needle advancement may be carried out with minimal cranial angulation with the intention of contacting the lamina. Upon bone contact, the needle is withdrawn by 0.5 cm, walked off the bone in a medial/cephalad direction to access the interlaminar space, while maintaining the same lateral-medial

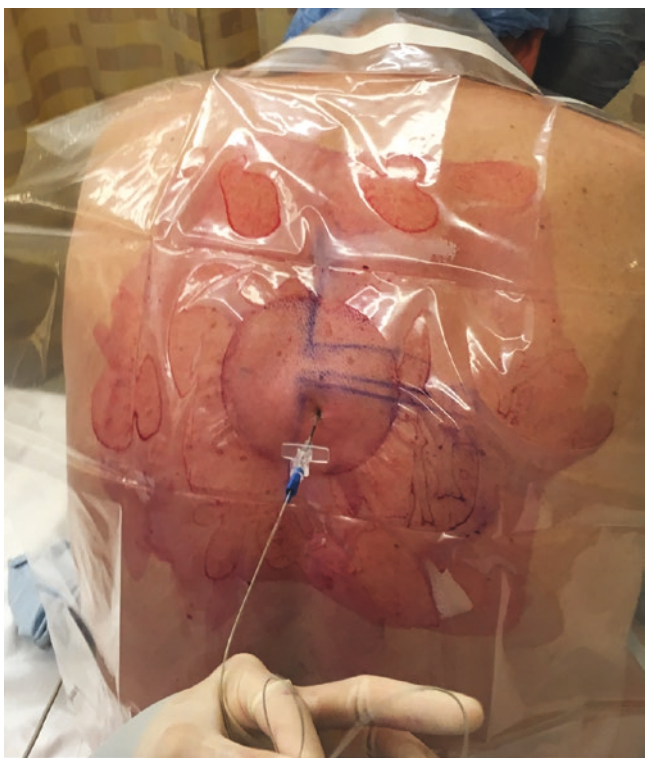

Fig. 41.43 Paramedian approach at T7/8 level. (Reprinted with permission from permission from Dr. Ki Jinn Chin)

angulation throughout. The stylet is then removed from the puncture needle and identification of the epidural space is carried out using a low friction/"loss of resistance" syringe.

It is recommended to avoid entering the skin at an excessively lateral point relative to the midline. The shallow lateral to medial approach advocated is useful for estimating the position of the needle tip when advancing the needle and it helps to prevent crossing the midline to the ipsilateral side.

Ultrasound Technique for the Identification of the Interlaminar Space

Preprocedural ultrasound of the thoracic spine with a paramedian approach has been associated with a decreased number of skin punctures and improved pain scores versus a palpation based paramedian approach. This technique allows the practitioner to determine an optimal skin entry point and to estimate the distance to the ligamentum flavum. The procedure for ultrasound scanning of the thoracic spine is described in Chap. 40.

The midline may be identified in the transverse view, and the interlaminar spaces are identified and marked using the parasagittal oblique view as indicated in Fig. 41.44. The depth from the skin to the interlaminar space or posterior complex is measured. This is the safe needle insertion depth. The actual depth to enter the epidural space will be greater due to needle angulation and the additional distance from lamina to the epidural space.

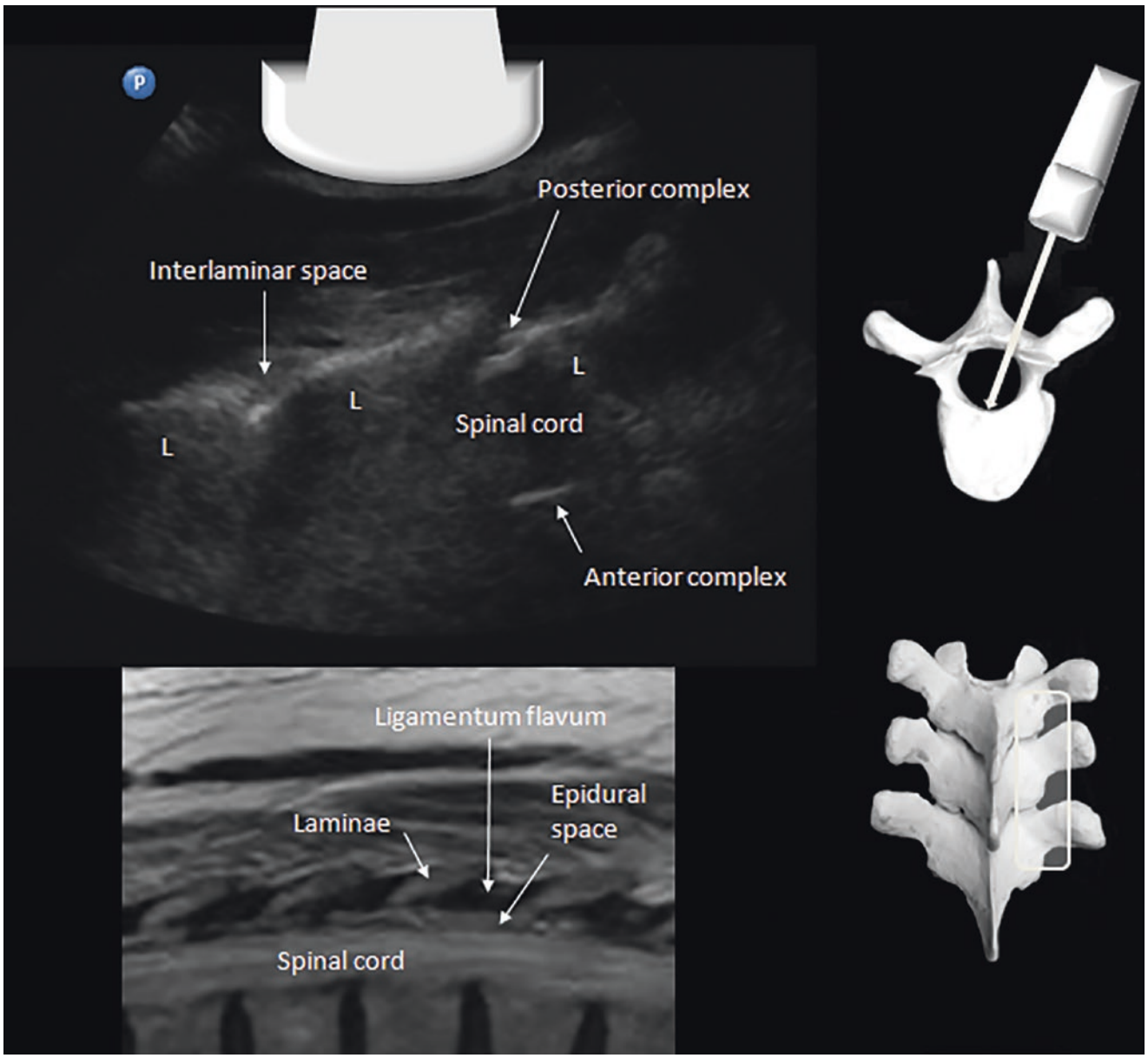

Fig. 41.44 Paramedian sagittal oblique view of the mid-thoracic spine and corresponding magnetic resonance image. Despite the narrow interlaminar space, it is possible to visualize the posterior and anterior complex at one or more levels. At a minimum, the location of the interlaminar space can be determined by the dip or gap between successive laminae (L). Note that the spinal cord is hypoechoic and cannot be distinguished from the surrounding cerebrospinal fluid

With this additional information, the needle approach to the thoracic epidural space can be triangulated more accurately. Marking a needle entry site approximately 0.5 cm lateral to the midline and 2 cm caudal to the identified interlaminar space will facilitate the required 55° cranial and 5–10° lateral to medial needle angulation. The shallow lateral to medial angle means that the needle is almost parallel to the spinous process and decreases the risk of the needle tip inadvertently crossing the midline to the contralateral paravertebral muscles or pleural space (Fig. 41.45).

Once the entry site has been identified, the preparation of the skin and the entry of the needle with the LOR technique is identical to that of the landmark technique. Real-time ultrasound-assisted thoracic epidural placement has also been described. However, this is not commonly practiced.

Test Dose for Thoracic Epidural

A test dose of 30 mg Lidocaine (3 mL 1.0% Lidocaine) and 15mcg epinephrine is advocated for thoracic epidurals. While the evidence base for an ideal test dose is lacking, the risk of high spinal with conventional lumbar test dose (45 mg lidocaine) warrants use of a lower test dose.

Drug Administration

Loading Dose

In adults, approximately 1–2 mL of local anesthetic is typically required per vertebral segment to be blocked. A maximum of 3–4 mL of loading dose should be injected at a time at thoracic levels. Use of a larger volume may lead to profound hypotension due to a widespread sympathetic block. It has been shown that with the same dose a greater number of segments are blocked in elderly patients compared to younger adults. As the autonomic effects of epidural analgesia are both more marked and often more poorly tolerated in older patients, they should be loaded more judiciously.

Clinical Testing of Loading Dose

A loading dose is typically given prior to induction of general anesthesia in epidurals placed for postoperative analgesia. The loading dose may be omitted at this timepoint in certain patients due to concerns that sympathectomy related hypotension would complicate induction. Clinical assessment of the efficacy of the epidural anesthesia via sensory testing requires approximately 15 min to demonstrate blockade in most patients (including 5 min for test dose assessment prior to loading dose). In the case of inadequate block following sufficient passage of time, the epidural should be reattempted, if time and circumstances allow. If this is not possible, alternative regional anesthetic options or increased parenteral opioid dosing should be considered.

Pharmacology of Drugs Used for Epidural Anesthesia and Analgesia

The local anesthetic injected spreads both cephalad and caudad in the epidural space. Since the band of anesthesia produced cannot be predicted accurately in a given patient, clinicians must be aware of major factors determining this spread. These are discussed below.

Drug mass, concentration, and volume: both total drug dose and volume are independent determinants of the spread of epidural block. However, they are not linearly related. A higher concentration produces a profound block of both motor and sensory nerves. Lower concentrations provide a more selective sensory block. In adults, approximately 1–2 mL of local anesthetic is usually required per vertebral segment to be blocked.

A higher dose (concentration and volume) also increases the degree of sympathetic block resulting in both reduced systematic vascular resistance and direct cardiac depressant effects (if sufficiently cephalad distribution). This results in hypotension.

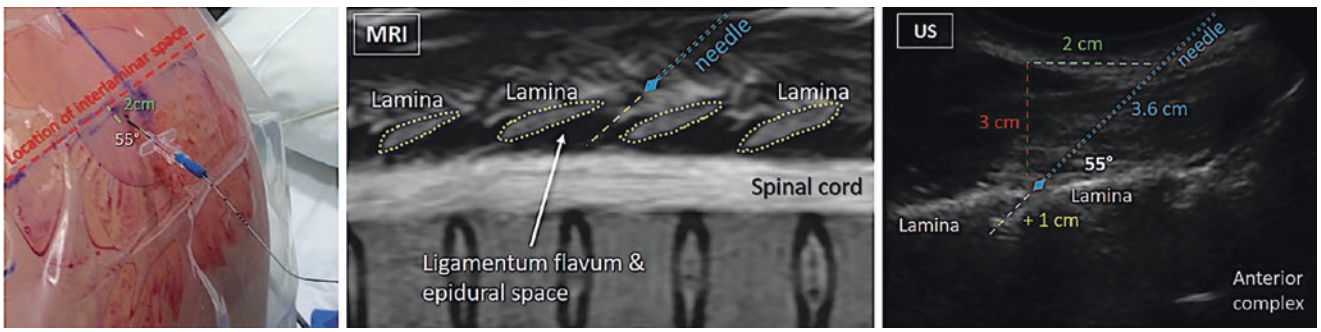

Fig. 41.45 Parasagittal ultrasound and MRI images of the thoracic spine illustrating the geometry of the thoracic epidural approach. Examples of measurements are provided. Ultrasound allows the laminae, the interlaminar space, and the vertical depth from skin to be identified. Needle insertion should be at a site approximately 2 cm inferior to the interlaminar space. A 55-degree angle to the patient's surface is recommended to pass through the interlaminar gap. The epidural space is usually reached within another 1 cm of needle insertion depth. This means that needle insertion depth to the epidural space usually exceeds the measured depth to the laminae by approximately 1.5–2 cm. (Reprinted with permission from Dr. Ki Jinn Chin)

Site of injection: this is a major determinant of the epidural spread. For example, the same volume of drug in the caudal space covers less dermatomes when compared to the thoracic level.

Other technical factors: patient position, needle angulation, direction of needle opening, and the speed of injection are not clinically significant.

Length of catheter in space: threading an epidural catheter more than 5 cm may lead to lateral placement of the catheter tip, resulting in missed segments or unilateral block.

Patient factors: increasing age, shorter height, and increased body mass index are associated with increased spread, but this is highly variable and it cannot be accurately predicted. The epidural spread is not affected by the sex of the patient.

Local Anesthetics Used for Epidurals

Local anesthetics used for epidural blocks are commonly classified by their duration of action. "*Time for two segment regression*" is the time taken for the block to recede by two dermatomes from its maximal extent, while the "*time for complete resolution*" is the time taken for the recovery from sensory block. While the former helps to time the repeating of an epidural dose intraoperatively, the latter is used to estimate the time for discharge of outpatients. Commonly used agents with doses are mentioned in Table 41.6.

In general, more dilute concentrations suffice for analgesia, while higher concentrations are used for a surgical block. The total dose and volume needed depend upon the surgery, patient factors, and the use of adjuvants medications.

Adjunct Medications Used in Epidural Anesthesia and Analgesia

Similarly to spinal anesthesia, adjuvant medications are used to improve the quality of an epidural block. These are summarizes below.

Alpha-1 Agonists

Epinephrine: in a concentration of 2.5–5 μg/mL (1:400,000–1:200,000), epinephrine prolongs both the sensory and motor block when added to short to intermediate acting local anesthetics. It reduces the vascular uptake of local anesthetics into the systemic circulation. It may also exert an analgesic effect through α2-adrenergic receptors, reducing pain transmission within spinal cord. The addition of epinephrine in an epidural block produces a vasodilatation secondary to β2-adrenergic effects in the periphery. This decreases the mean arterial pressure, but also increases the cardiac output.

Alpha-2 Agonists

Clonidine: It prolongs the sensory block only, when added to epidural local anesthetics. It is used in doses of 150–300 μg (2 μg/kg). Hypotension and sedation are common secondary to systemic uptake.

Dexmedetomidine: It possesses sedative and analgesic properties by activating α_2 receptors in the spinal cord. It produces a prolonged analgesic effect, with mostly sensory effects, although increased motor block has been noted at concentrations of 1 μg/mL. Hypotension, bradycardia, and sedation are associated side effects. Infusion dose: 0.5 μg/mL (range 0.25–1.0 μg/mL).

Opioids

While it has been established that epidural administration of opioid alone is of limited advantage over parenteral opioids, in combination with local anesthetics a synergistic effect exists. The use of opioids increases the speed of onset of block and the number of segments blocked. Opioid related side effects include nausea, pruritus, sedation, and respiratory depression.

Commonly used epidural opioids include fentanyl (0.5–0.15 μg/kg), sufentanil (0.3–0.7 μg/kg), hydromorphone (0.8–1.5 mg), and morphine (4–6 mg).

Alkalizing Agents

Bicarbonate: the addition of sodium bicarbonate (0.1 mEq/mL) to local anesthetics has been proposed as a means to hasten the onset of the blocks. While some studies have shown a faster onset, others have found no difference.

Table 41.6 Commonly used local anesthetic agents for a surgical epidural block

Drug and concentration	Dose (mL)	Onset time (min)	Time for two segment resolution (min)	Recommended "top-up" time (min)	Time for complete resolution (min)
Short acting agents					
Chloroprocaine 2–3%	15–25	6–12	45–60	45	100–160 min
Intermediate acting agents					
Lignocaine 1–2%	10–20	10–20	60–100	60	160–200
Mepivacaine 1.5–2.0%	15–30	10–30	60–100	60	160–200
Long acting agents					
Ropivacaine 0.2–1.0%	10–20		90–180	120	180–360
Bupivacaine 0.25–0.5%	10–20	5–20	120–240	120	300–480
Levobupivacaine 0.25–0.5%	10–20	5–20	120–240	120	300–480

Drug Regimens for Continuous Epidural Analgesia

Conclusions about the optimum anesthetic agents and combinations are difficult to make due to the wide ranges of drugs and concentrations used in various studies, however several typical and recommended regimens are listed below. The side effects of epidural local anesthetics and opioids differ from one another and are mostly dose dependent. By administering a combination of these agents in low concentrations, analgesia may be optimized while minimizing adverse effects. Opioids may be omitted if a history of allergy or sensitivity to opioids exists or if there is particular concern regarding respiratory depression.

Suggested Dosing Regimens for Continuous Thoracic Epidural Analgesia

Local Anesthetic

- Ropivacaine 0.15–0.2%.
- Bupivacaine 0.05–0.125%.

Opiates

- Fentanyl 2–5 μg/mL.
- Hydromorphone 5–10 μg/mL.

Rate

- 3–10 mL/h.

The evidence supporting either patient controlled epidural analgesia (PCEA) or continuous epidural infusions as being superior is conflicting for specific procedures. A meta-analysis indicates that continuous infusion produces superior analgesia but is associated with a higher incidence of nausea, vomiting, and motor block. Concurrent background infusion alongside PCEA is a further option.

Regardless of the regimen used, careful and methodical monitoring of the patient with assessment of analgesic efficacy and adverse effects must occur while the catheter remains in situ. Particular vigilance should be exercised following bolus dose administration or a change in the infusion rate.

Management of the Patient After an Epidural Block

Patient Positioning

Gravity does not play a clinically significant role in determining the spread of local anesthetic in the epidural space. Thus, the patient is generally placed supine after the block.

Patient Monitoring

- The patient should be monitored during and after the placement of an epidural block, just like a spinal block. However, the cardiovascular changes seen with an epidural block are generally slower and less profound when compared to a spinal anesthetic. Fluids and vasopressors are used to treat hypotension.
- Supplemental oxygen administration is recommended, especially if sedation is used for patient comfort.
- End-tidal carbon dioxide monitoring may be used to monitor the respiratory rate.
- Postoperatively, the patient should be monitored until the effects of epidural anesthetic have receded and the epidural catheter is removed.

Assessment of the Block

Epidural block leads to sensory, autonomic, and motor blockade which are assessed as follows:

Sensory Block

This can be assessed by testing for loss of touch, temperature, or pin-prick sensation. A differential block is noted between the complete loss of cold sensation which is one to two dermatomes more cephalad than the loss of both pin-prick and light touch sensation.

Autonomic Block

This can be subjectively assessed by sensing the skin temperature in the area of the block and the extent of the drop in blood pressure (sympathetic block). Digital plethysmogram and skin conductance are used in research settings to test this objectively.

Motor Block

Lumbar Epidural

This can be assessed by using the **Bromage scale**, as summarizes in Table 41.7.

Thoracic Epidural

This can be assessed using the Rectus Abdominus Muscle (RAM) scale, as summarizes in Table 41.8.

Alternative Techniques for Confirmation of Needle Entry to Epidural Space

The most frequently used method to identify the needle entry into the epidural is the loss of resistance technique which is described earlier. A major shortcoming of this method is the non-specificity of the loss of resistance endpoint. A false positive loss of resistance may occur due to age related cysts in the interspinous ligaments, the needle tip entering paraspinous muscles or other intermuscular planes if needle misdirection occurs. Several methods have been developed to confirm correct catheter placement to overcome this problem.

Table 41.7 Bromage scale for assessment of motor block

Grade	Criteria	Degree of block
I	Free movement of legs and feet	Nil (0%)
II	Just able to flex knees with free movement of feet	Partial (33%)
III	Unable to flex knees, but with free movement of feet	Almost complete (66%)
IV	Unable to move legs or feet	Complete (100%)

Table 41.8 RAM test of abdominal muscles

Power	Criteria
100%	Able to rise from supine to sitting position with hands behind the head
80%	Can sit only with arms extended
60%	Can lift only head and scapulae off the bed
0%	Can lift only shoulders off the bed
20%	An increase in abdominal muscle tension can be felt during effort; no other response seen

Epidural Pressure Waveform Analysis

Epidural Pressure Waveform analysis is based upon the distinctive pulsatile pressure waveform obtained when a needle or catheter located in the epidural space is transduced. The epidural space has a low or negative pressure which pulsates in synchrony with the arterial pressure. Application of this characteristic may be used to determine needle entry into the epidural space in place of loss of resistance or else as a confirmatory adjunct for a needle or catheter already sited in the presumed epidural space.

The equipment required is often readily available and this technique is relatively simple to use. A pressure transducer, saline filled rigid tubing form part of the standard arterial blood pressure monitoring kit and the same patient monitor can be used.

There is randomized control trial evidence for a reduction in the failure rate as well as improved patient satisfaction in patients with pressure waveform guided epidural catheter placement (PWEP) compared to the conventional loss of resistance method.

Further studies have demonstrated the utility of epidural waveform analysis as a confirmatory adjunct by transducing either the epidural needle or catheter sited in the presumed epidural space following the LOR technique. After injecting saline (5 mL) through the needle and connecting it to a pressure transducer, the presence of waveforms synchronized with arterial pulsations serves as a confirmatory end point. If waveforms are still not present following a further 2.5 mL saline, it is deemed that the needle is not located in the epidural space and removal and reattempt is indicated. However, some waveforms are difficult to assess and false negatives are likely to occur to some extent with the potential for unnecessarily repeated procedures.

Fluoroscopy

Fluoroscopic techniques have been well established to successfully guide needle entry into interlaminar or interspinous spaces followed by standard loss of resistance to enter the epidural space. This is most often used in the context of chronic pain interventions and not for peri-operative epidural placement (Fig. 41.46 and 41.47). Advantages of fluoroscopy include clear identification of the appropriate vertebral level and avoidance of excessive needle to bone contact. Fluoroscopy has also been studied as a confirmatory adjunct for correct catheter placement in the epidural space via contrast injection, though it is not routinely used for this indication.

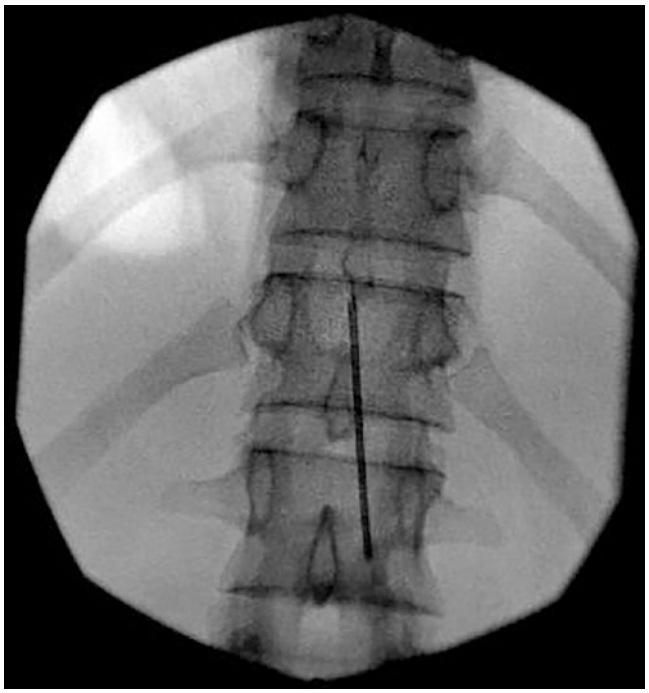

Fig. 41.46 Epidural Needle fluoroscopic guidance. (Reprinted with permission from Philip Peng Educational Series)

The main disadvantage of fluoroscopy is the additional equipment and personnel required for its use. Radiation exposure is also a consideration. Training in fluoroscopic

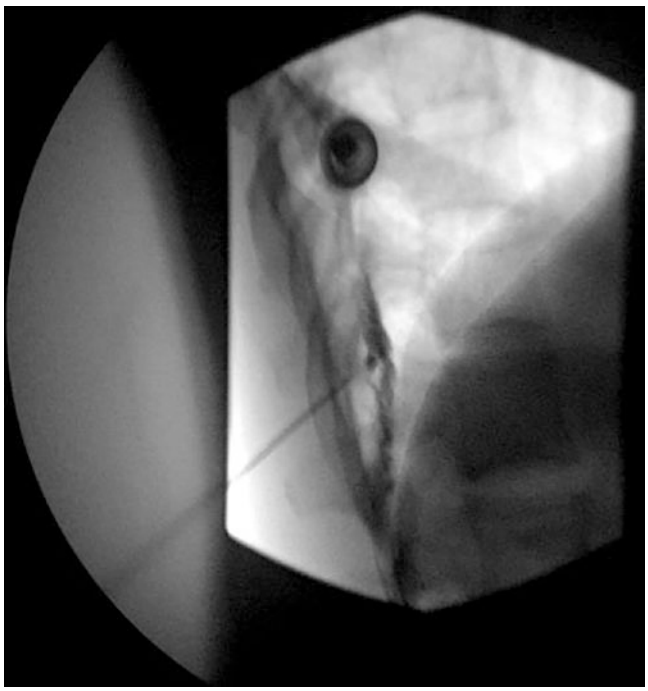

Fig. 41.47 Lateral View: Injection of radiopaque dye. (Reprinted with permission from Philip Peng Educational Series)

guidance of epidural needles is routine in the specialty of chronic pain, but not more widely amongst anesthesiologists. Therefore, the use of fluoroscopy is limited for general surgical settings unless trained staff and equipment are readily available.

Electrical Stimulation

The epidural electrical stimulation test (EEST) or Tsui test involves the application of low-amplitude electrical current to the epidural catheter following its insertion. A motor response in the truncal muscles is sought for thoracic epidural catheters. Response at a current range of 1–15 mA is a positive for correct epidural tip placement, whereas a motor response to a current of <1 mA indicates catheter tip placement in an intrathecal, subdural or foraminal position. A high level of sensitivity is associated with EEST which exceeds that of the local anesthetic test dose method. A further advantage compared to the clinical test dose is speed of testing, with confirmation of catheter position available immediately following placement.

Additional equipment required to conduct the EEST includes a nerve stimulator with a current range of 0.1–15 mA, a pulse width of 0.1–0.2 ms, a pulse frequency of 1–2 Hz, a digital current readout, and appropriate connectors (anode to an ECG electrode and a cathode to a Johans ECG adaptor). A stainless-steel wire reinforced catheter primed with saline or a stimulating catheter is required for conduction.

An additional benefit of electrical stimulation is the ability to determine the vertebral level of the epidural needle tip by correlating it to the motor response. Although this method is reliable and safe, it has not been widely adopted. Certain technical difficulties such as the need for frequent saline flushing and pain/paresthesia during stimulation have been reported. Nonetheless, it provides an objective measure of successful catheter placement which may be particularly useful in a teaching environment.

Practical Tips

Trajectory: While the midline may easily be found by palpation or ultrasound, operator error in terms of needle trajectory is relatively common, particularly in the lateral position. It may be helpful to get the perspective of a colleague or to stand back to identify the correct plane of approach and the needle trajectory.

Inadequate sensory block: this may require repeat dosing if the block fails to reach adequate sensory height after 30 min of the initial dose. Addition of opioids (such as fentanyl) to local anesthetic solution may speed the onset and extend the number of segments blocked.

Missed segments: this may be due to an inadequate volume of initial dose used. A repeat dose often improves this. If the missed segment is unilateral, turning the patient on the spared side before dosing can help. A 2% lignocaine solution with epinephrine is most effective in dealing with missed segments or an inadequate block.

Considerations in Patients with Challenging Anatomy

Performing a neuraxial block can be technically challenging in certain patient groups. This includes patients with a high body mass index, patients with spinal pathology and those who have undergone spinal surgery. Altered anatomy makes performing the block technically challenging, while spinal stenosis or postoperative epidural fibrosis (associated with spinal surgery) can impair the spread of spinal anesthetics in subarachnoid or epidural space, resulting in failed blocks.

Patients with a High Body Mass Index The anthropometric changes associated with obesity can make performing a neuraxial block more challenging. This is due to difficulty in patient positioning, obscured anatomical landmarks, increased depth of ligamentum flavum and the occasional inadequacy of usual equipment, e.g. the needle is too short. Ultrasound may help in the correct identification of the midline and the intervertebral spaces. Ultrasound also estimates

the depth of the epidural space. It has been successfully used to improve the success rate of epidural placement in obese parturients.

Patients with Scoliosis Lateral deviation of the spine is accompanied by the rotation of the vertebral bodies towards the convex side of the curvature, while the spinous processes are rotated towards the concave side. This makes performing a neuraxial block more difficult. Ultrasound assists in identifying the lateral curvature and the degree of rotation. The usual approach to this situation is to perform the block using a paramedian injection on the convex side, which provides a more direct access to the neuraxis. Alternatively, if a midline insertion is used, the needle should be directed in a transverse plane, towards the convex side.

Patients with Previous Spinal Surgery Epidural fibrosis following spinal surgery, altered spinal anatomy, and the possibility of worsening neurological symptoms make this patient subset a challenge. Despite this, there have been several reports and reviews of successful neuraxial blocks in patients with previous spine surgery. While the absence of spinous processes makes it hard to locate intervertebral spaces, laminectomy may actually increase the chances of obtaining a successful dural puncture by increasing the size of the interlaminar gap. However, performing an epidural at the level of previous spinal surgery poses additional challenges due to spinal stenosis immediately above the fusion or decompression and tethering of the dura to the ligamentum flavum by scar formation. The epidural space may also be scarred which reduces the reliability of the loss-of-resistance technique. Thus, performing the epidural injection one or two spaces above or below the level of the surgery is advocated to reduce the chances of accidental dural puncture and ineffective block. Note that scarring of the epidural space may also lead to a patchy block.

Ultrasound can help immensely to locate the intervertebral space, identify the interlaminar window, visualize and estimate the depth of the ligamentum flavum.

Complications of Neuraxial Blocks

Complications arising from a spinal or an epidural anesthetic are mostly cardiovascular and neurological. However, practically they can be classified as early or late.

Early Complications

These include complications seen immediately following a neuraxial block and in the early perioperative period.

Cardiovascular

These are the most prominent complications of a central neuraxial anesthetic, and occur as a consequence of profound sympathetic block.

Hypotension Arteriolar dilatation and venous pooling lead to hypotension, which occurs commonly (16–33%). Risk factors for hypotension after neuraxial blockade include a block above T5, emergency surgery, age greater than 40, and chronic hypertension. Epidural anesthesia is associated with a more gradual fall in blood pressure compared to spinal anesthesia, making it a better choice in certain circumstances. Prophylactic fluid administration (20 mL/kg) and the use of vasopressors such as ephedrine (in 5–10 mg increments) or phenylephrine (50–100 μg increments) can be used to effectively counteract hypotension.

Bradycardia It usually results from a high block, as a consequence of blockade of the cardiac accelerator fibers (T1–T4), or more commonly from a vagal reflex associated with intracardiac stretch receptors in the presence of decreased cardiac filling (Bezold–Jarisch reflex). Apart from a high block, a younger age, ASA class 1 status, preoperative use of beta blockers, and male gender are risk factors for bradycardia. Anticholinergics such as atropine and adrenergics such as ephedrine are commonly used to treat this.

Cardiovascular Collapse Asystole and cardiac arrest following a spinal is a known complication. It is usually preceded by bradycardia resulting from the mechanisms described above.

Nausea and Vomiting This is associated with hypotension (hypoperfusion of the chemoreceptor trigger zone) and the use of opioid adjuncts (direct stimulation of chemoreceptor trigger zone). A sympathetic-parasympathetic imbalance may also have a role to play in the causation of nausea. It can be effectively treated with dexamethasone and ondansetron.

Tissue Trauma and Back Pain Multiple attempts at a neuraxial block lead to trauma to soft tissue and ligaments. This can contribute to persistent back ache. However, other factors may have a role to play as well.

Total Spinal This may result due to inappropriate dosing during a spinal anesthetic, positioning error or unintended passage of local anesthetic from epidural space to subarachnoid space (secondary to an unrecognized dural tap or catheter migration). It manifests as a rapidly ascending motor-sensory block, hypotension, bradycardia, and respiratory compromise. Medullary paralysis may result in a respiratory arrest and loss of consciousness. It is a life-threatening emergency. Management involves prompt recognition, securing the air-

way, ventilation, and supporting the hemodynamics until spontaneous recovery of the patient. To mitigate the risk of aspiration of gastric contents, the airway should be promptly secured with endotracheal intubation. This will require a rapid sequence induction dose of a muscle relaxant (succinylcholine or rocuronium) as the muscles of mastication may still be contracting, hindering effective laryngoscopy. Some advocate the use of a small amount of an induction agent to mitigate the risk of awareness. Ventilation will be required. Profound hypotension may rapidly ensue. Elevation of the legs is sometimes the most immediate intervention available. This should be accompanied by a generous dose of a vasopressor such as phenylephrine and the rapid administration of a fluid bolus. Cardiac arrest may ensure necessitating cardiopulmonary resuscitation.

Subdural Anesthetic This presents as widespread but ineffective and patchy anesthesia (Fig. 41.48). The subdural space does not end at the great foramen as does the epidural space but continues cranially. Warning signs include an unusually high sensory block which develops very slowly (even after 20 min) and a much less marked motor block. The clinical picture resembles that of total spinal anesthesia and is characterized by moderate hypotonia, breathing difficulties with retained consciousness, and often involvement of the cranial and cervical nerves. It may warrant similar intervention to that as total spinal anesthesia (see above).

Trigeminal Nerve Palsy Paresthesia in the area supplied by the nerve and transient weakness of the muscles of mastication is occasionally observed after high epidural anesthesia or subdural spread.

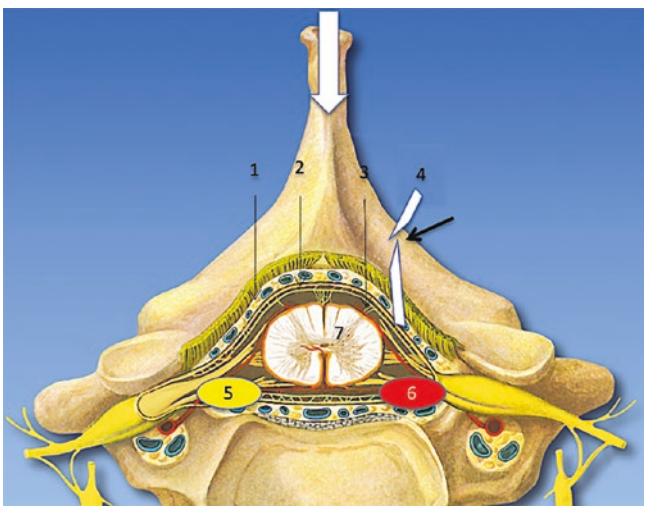

Fig. 41.48 Complications. (1) Intravascular injection, (2) subdural injection, (3) subarachnoid injection, (4) catheter shearing, (5) epidural abscess, and (6) epidural hematoma, and (7) injury to the spinal cord and nerve roots. (Reprinted with permission from Danilo Jankovic)

Horner's Syndrome This is produced after neuraxial anesthesia with a high spread of the injected local anesthetic and block of the sympathetic nerve fibers in the areas of segments T4-C8. Most often, Horner's syndrome is seen after a high spinal or epidural anesthesia in obstetrics and when there is subdural spread of the local anesthetic. Symptoms usually resolve fairly rapidly.

Inadvertent Dural Puncture During Epidural Catheter Insertion This usually presents as a gush of CSF through the epidural needle or upon aspiration through the catheter (Fig. 41.48). Management options include passing a catheter through the puncture made or reattempting the epidural in another space. In over 75% of the cases, use of an epidural needle is associated with the development of post dural puncture headache—this is likely to require a blood patch. There may be a reduction in the incidence of post-dural puncture headache if the catheter remains in the intrathecal space for at least 24 h.

Local Anesthetic Toxicity Inadvertent deposition of drug into a vein or systemic absorption of local anesthetic following epidural infusions may lead to local anesthetic toxicity.

Delayed Complications

These present usually after a few days or weeks of having performed a neuraxial block.

Nerve Injury

The following mechanisms are involved:

Direct Needle Trauma this commonly occurs at the time of performance of the block and is associated with severe paresthesia in the dermatomal distribution of the nerve root injured.

Neurotoxicity All local anesthetics are potentially neurotoxic. Despite this, local anesthetic induced neural damage is rarely seen clinically.

Transient Neurological Syndrome This presents as low back pain that radiates to the lower extremities after a spinal anesthetic. The symptoms last for a week and are treated supportively using simple analgesics. Risk factors such as outpatient procedures, the lithotomy position, obesity, and the use of lidocaine have been implicated in their development.

Cauda Equina Syndrome This presents as motor weakness and loss of bladder and bowel function, following the use of continuous spinal anesthesia. The pooling of local anesthetic around sacral nerves is thought to be the causative mechanism in its development.

Infections Infections such as localized skin infections, a spinal abscess, an epidural abscess or meningitis can rarely occur following a neuraxial anesthetic (Fig. 41.45). A spinal or epidural abscess presents as localized back pain, tenderness upon palpation, with sensory or motor deficits and fever. A magnetic resonance imaging of the vertebral canal is considered best for establishing a diagnosis. Intravenous antibiotics and surgical drainage or decompression may be needed. Diagnosis and definitive treatment should be urgently sought to limit long-term neurological impairment.

Post Dural Puncture Headache (PDPH)

This is a relatively common complication of spinal or an epidural anesthetic. The incidence of PDPH with the use of smaller gauge spinal needle (25–26G) is 0.5–1%, while puncture with an epidural needle (17–18G) results in PDPH in over 75% of cases.

Mechanism The proposed mechanism of the headache is the loss of CSF causing decrease in CSF pressure. This causes sagging of intracranial structures, with consequent traction on pain sensitive structures (such as meninges, cranial nerves, and veins). A second hypothesis suggests that decreased CSF pressure leads to intrathecal hypotension and painful vasodilatation of the intracranial blood vessels. Mainly when the patient is in a standing position, painful areas dilate (meninges, tentorium, vessels) and there is further pain transmission via the cerebral nerves and upper cervical nerves.

Clinical Presentation PDPH presents as a positional headache, worse on sitting up, 12–48 h after a dural puncture. PDPH is bilateral, predominantly frontal-temporal, and dull or throbbing in nature. Its severity varies, and it may be accompanied by associated symptoms such as nausea, vomiting, photophobia, diplopia, and hearing impairment. While younger females and parturients are at a higher risk of PDPH, older males are at a lower risk.

CSF Hypotension Syndrome and Involvement of the Cranial and Cervical Nerves All of the cranial nerves, with the exception of the olfactory nerve, glossopharyngeal nerve and vagus nerve, can be affected by low CSF pressure. The abducens nerve and vestibulocochlear nerve are most frequently affected. The long intracranial course of the abducens nerve leads to traction and consequent irritation of the nerve when there are changes in intracranial pressure. The patient complains of double vision, with parallel horizontal images and difficulties in focusing on objects. When precise audiometric examinations are carried out, unilateral or bilateral hyperacusis (vestibulocochlear nerve involvement) can be observed in 0.4–40% of patients with CSF hypotension syndrome. The prognosis is good.

Differential Diagnosis This includes migraine, tension headache, cervical myofascial pain (particularly in the sternocleidomastoid muscle, with what is known as "pseudospinal headache"), CNS infections (bacterial meningitis), sinus thrombosis (in the second half of pregnancy or in the puerperium, frequently in preeclampsia), and pneumocephalus (if the dura is breached when using the loss of resistance to air epidural insertion technique).

Initial Management This is conservative and includes simple analgesics and oral hydration. The majority of patients experience marked improvement in the symptoms or complete recovery after 5–7 days with this form of treatment. Other drugs such as caffeine, sumatriptan and ACTH have been found useful. Caffeine produces cerebral vasoconstriction and consequent decrease in cerebral blood flow providing a transient relief from headache. ACTH may stimulate the adrenal gland to increase cerebrospinal fluid production. Sumatriptan, a serotonin type 1d receptor agonist, may relieve headache by producing cerebral vasoconstriction.

Invasive Management The gold standard for the treatment of PDPH remains an autologous blood patch (Figs. 41.49 and 41.50). Its mechanism appears to be the tamponade of a dural leak, with subsequent improvement of CSF pressures. It produces a rapid relief of symptoms in between 70 and 98% of patients if performed after 24 h after the dural puncture. Repeating the procedure has a similar success rate.

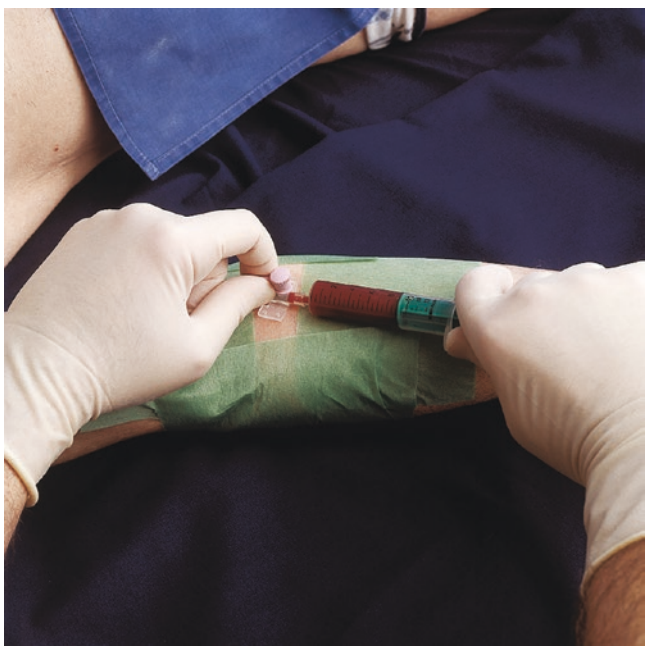

Fig. 41.49 Sterile withdrawal of blood. (Reprinted with permission from Danilo Jankovic)

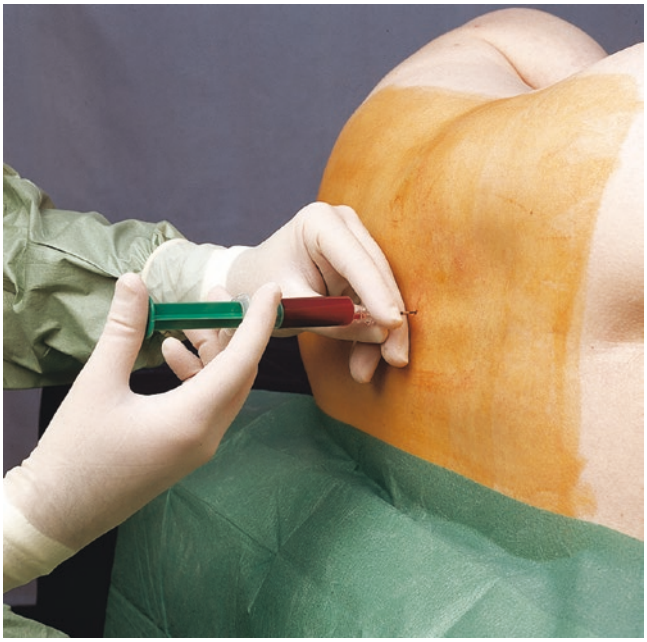

Fig. 41.50 Epidural Injection of homologous blood. (Reprinted with permission from Danilo Jankovic)

Spinal or Epidural Hematoma

Although rare, this is the most feared complication of a central neuraxial block (Fig. 41.45). Because the vertebral canal is a confined space, any bleeding may result in compression of the spinal cord resulting in a sensory-motor loss below the level of the compression. Patients with altered hemostasis and ongoing antiplatelet or anticoagulant therapy are at increased risk of developing a spinal or epidural hematoma. This usually presents as a sensory-motor impairment of unusually prolonged duration. Confusing this with an ongoing effect of local anesthetic often delays the correct diagnosis and management. Back pain and bladder or bowel dysfunction may also point towards the possibility of neural damage. Prompt imaging and neurosurgical consult should be arranged, as the prognosis is poor if the delay between the onset of paralysis and surgical decompression is more than 6–8 h. Guidelines concerning neuraxial anesthesia in anticoagulated patents should be followed to minimize the risks of this devastating complication.

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