Chapter 41

Neuraxial Blocks: Spinal and Epidural Anesthesia

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Introduction

Central neuraxial techniques are among the most reliable regional anesthesia techniques at the disposal of the anesthesiologist. Although they are relatively simple to perform, a thorough knowledge of underlying neuraxial anatomy and factors determining the spread and duration of anesthesia is critical to their success. Also, an understanding of the physiological effects and potential complications of these neuraxial techniques is paramount to ensure safe application of these methods.

Subarachnoid block or *spinal anesthesia* is the administration of an appropriate dose of local anesthetic into the cerebrospinal fluid and the subarachnoid space, which results in rapid onset of dense sensory and motor block that is suitable for surgical anesthesia. *Epidural anesthesia*, on the other hand, involves instillation of local anesthetic into the fat-filled epidural space and results in slower onset and a less-dense sensory and motor block, which is most often used to provide analgesia rather than surgical anesthesia. Spinal anesthesia is generally 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 cervical levels depending upon the desired area of sensory blockade.

Applied Anatomy

A thorough, three-dimensional knowledge of spinal anatomy, including the vertebral column, the vertebral curves, the spinal ligaments, the meninges, and the spinal cord, is essential for performing spinal and epidural anesthesia and is particularly helpful when technical difficulty is encountered. The concept of spinal cord segments, the segmental spinal nerves, and respective dermatomes is also important in understanding the physiological effects of neuraxial techniques.

Surface Anatomy

Surface landmarks are generally used to locate a particular vertebral level. These include the vertebra prominens which is the spinous process of the C7 vertebra, the root of the spine of the scapula corresponding to the T3 vertebra, and the inferior angle of the scapula corresponding to the T7 vertebra. The inferior margin of the 12th rib lies at the level of the L1 vertebra, *Tuffier's line* (the line connecting the iliac crests) crosses the vertebral column at the level of the L4 vertebra, while the posterior superior iliac spine lies at level with S2 (Fig. 41.1a, b) [1, 2]. *However, it is important to note that these are only estimations and various factors including normal anatomic variation, subcutaneous fat, and patient position can render these surface landmarks inaccurate in any given individual* [3–5]. This may be overcome to some extent by the use of ultrasound which can improve the correct identification of intervertebral space levels [5–7].

a

Vertebra
prominens C7

Root of spine
of scapula T3

Inferior angle
of scapula T7

Rib margin 10cm
from midline L1

Superior aspect
of Iliac crest L4

Posterior superior
Iliac spine S2

b

C8
(7th cervicle vertebra)

T7
inferior angle of the scapula

L1
costal margin
10 cm from midline

L4
iliac crest

S2
posterior superior
iliac spine

T4–5
mamilla
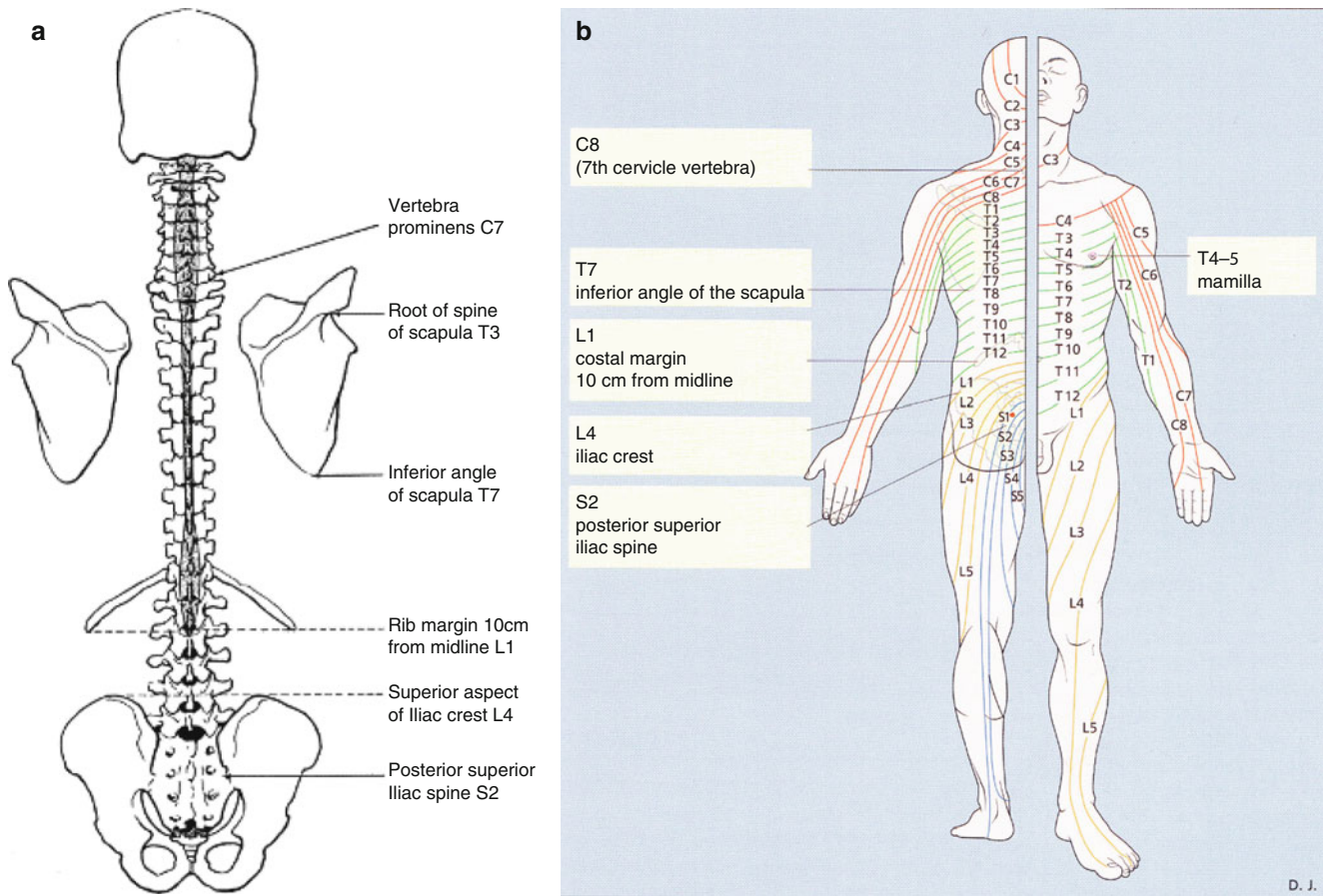
Fig. 41.1 (**a**) The common surface landmarks of the vertebral column. (**b**) The common surface landmarks of the vertebral column (With permission from Danilo Jankovic)

The spinous processes are angled caudally at the thoracic levels. However, they are nearly horizontal at cervical and lumbar levels (Fig. 41.2a–c) [8–10]. *As a result, cranial angulation of the needle is required when performing a thoracic epidural, while needle insertion perpendicular to the skin usually suffices in the lumbar spine.*

Fig. 41.2 Cervical, thoracic, and lumbar spinous processes (With permission from Danilo Jankovic). (**a**) C7 cervical vertebra (vertebra prominens, nuchal tubercle). (**b**) T8 thoracic vertebra. (**c**) L3 lumbar vertebra

The kyphotic thoracic curve and the lordotic lumbar spine determine the spread of subarachnoid local anesthetic in a supine adult. An injection of hyperbaric local anesthetic placed at the height of the lumbar lordosis will spread both caudad and cephalad to a variable extent (Fig. 41.3a, b). The cephalad extent of this spread is limited by the pooling of the solution at the mid-thoracic concavity [11].
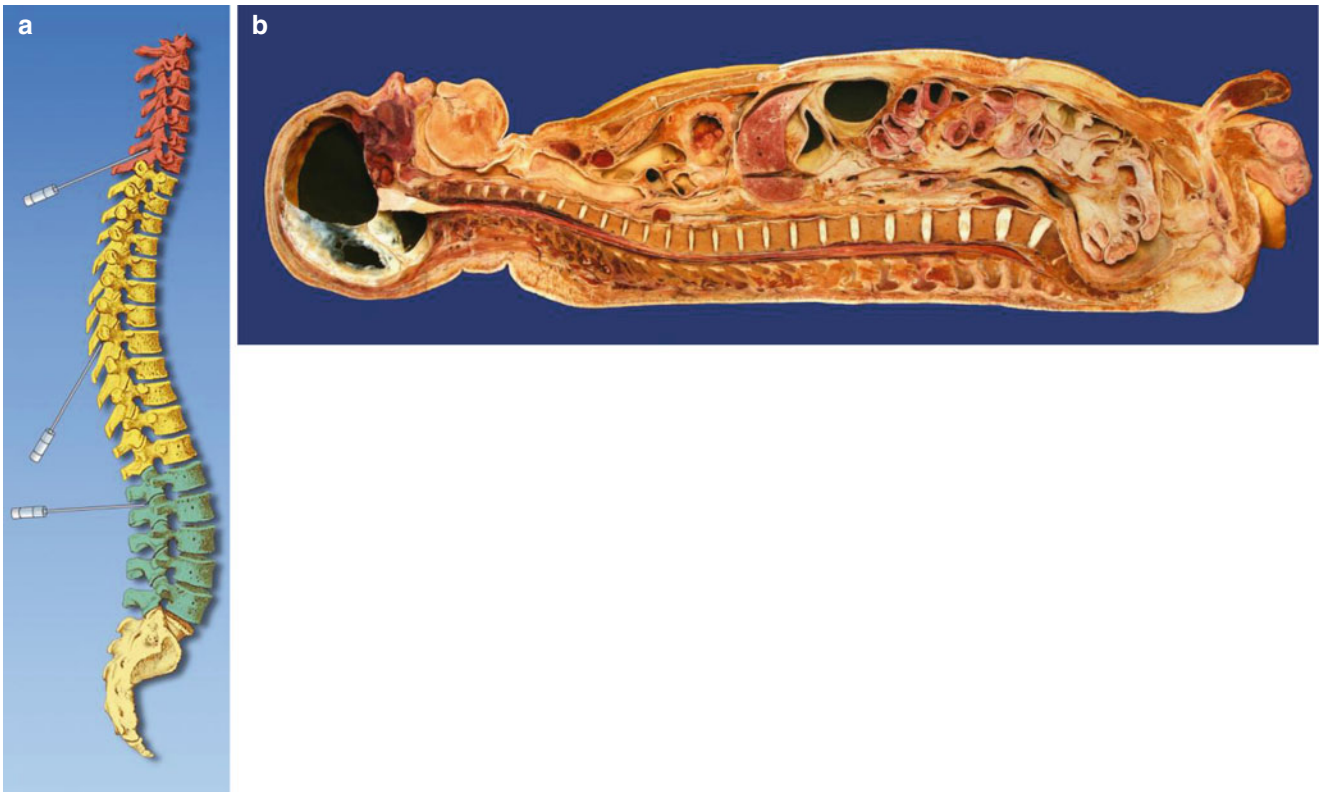
Fig. 41.3 (**a**) Anatomy: cervical, thoracic, and lumbar spine (With permission from Danilo Jankovic). (**b**) Paramedian sagittal section. Cervical, thoracic, and lumbar spine (With permission from Danilo Jankovic)

The three meningeal layers cover the spinal cord and protect it. The *dura mater* (Fig. 41.4) is the outermost meningeal layer and extends from the base of the skull to the second sacral vertebra. It is thickest in the posterior midline and thinner in the lumbar area than the thoracic or cervical levels [12, 13]. The *epidural space* is superficial to this layer and is the target for epidural anesthesia. The *subdural space* lies deep to this layer but superficial to the arachnoid mater.

The *arachnoid mater* lies deep to the dura mater and encloses the *subarachnoid space* and the cerebrospinal fluid (Fig. 41.4). Both spinal cord and spinal nerve roots are exposed to cerebrospinal fluid and thus are the sites of action of local anesthetic deposited in the subarachnoid space during a spinal anesthetic. Cysts in the subarachnoid space have been reported and may be a potential cause of inadequate spinal anesthesia [14, 15].

The *pia mater* is the innermost meningeal layer and covers the spinal cord (Fig. 41.4). The pia mater extends to the tip of the spinal cord and continues as the *filum terminale*, anchoring the spinal cord to the sacrum.
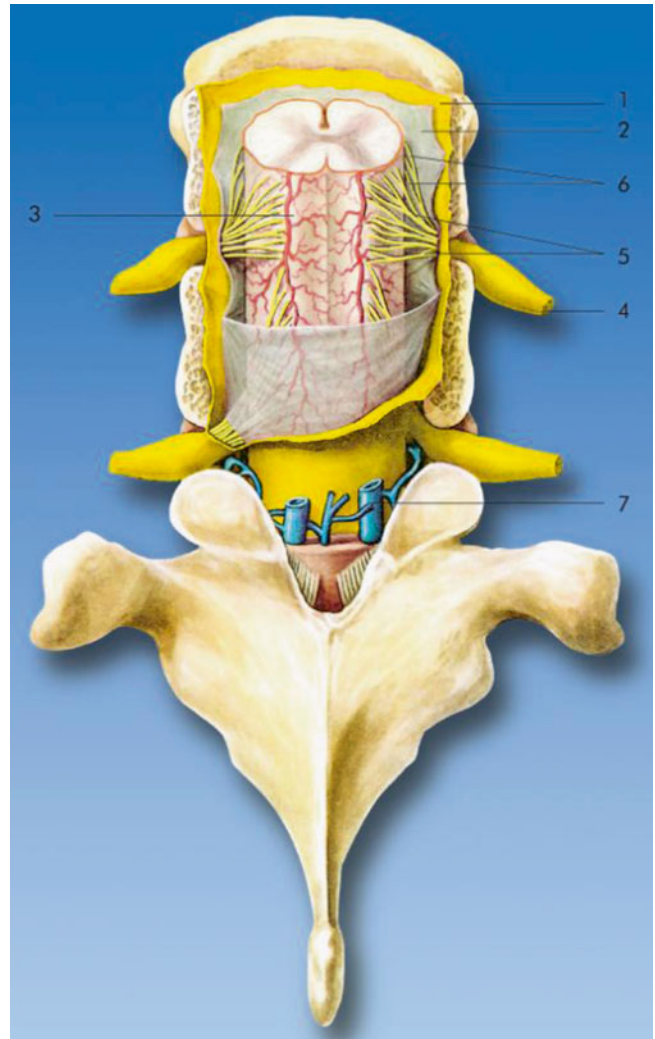
Fig. 41.4 Meninges. (*1*) Spinal dura mater, (*2*) arachnoid mater, (*3*) pia mater, (*4*) spinal nerve, (*5*) dorsal (posterior) nerve root, (*6*) ventral (anterior) nerve root, and (*7*) internal vertebral venous plexus (With permission from Danilo Jankovic)

A needle inserted in the *midline* will traverse the skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space, dura mater, subdural space, and arachnoid mater to access the subarachnoid space (Fig. 41.5a, b). A *paramedian* insertion of the needle, on the other hand, bypasses the supraspinous and interspinous ligaments and can be useful in the older patient with degenerative spine disease and narrowed interspinous spaces.
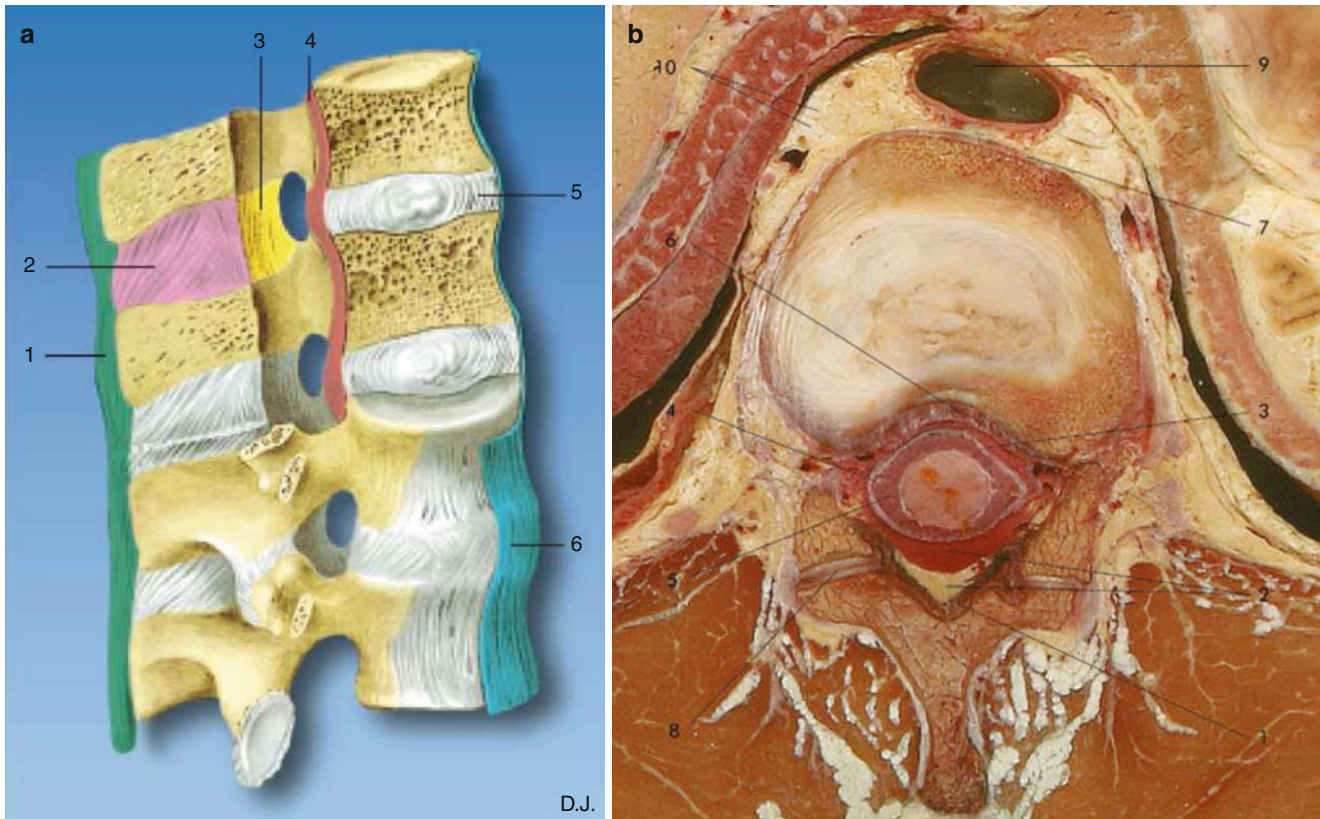
Fig. 41.5 (**a**) Sagittal section of the vertebral column illustrating the ligaments of the spinal cord. (*1*) Supraspinous ligament, (*2*) interspinous ligament, (*3*) ligamentum flavum, (*4*) posterior longitudinal ligament, (*5*) intervertebral disc, and (*6*) anterior longitudinal ligament (With permission from Danilo Jankovic). (**b**) Transverse dissection at the level of T9. (*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 (With permission from Danilo Jankovic)

The length of the spinal cord varies with age. In the fetus, the spinal cord extends to the end of the vertebral column. However, by birth, the terminal end of the cord, the conus medullaris, extends only until L3 due to a faster growth of the vertebrae than the spinal cord. In the majority of adults, the conus ends at L1. *Spinal anesthetics must therefore be performed at the L2–L3 intervertebral space or lower to avoid the risk of spinal cord injury* [16]. The portion of the spinal cord that gives rise to the dorsal nerve root, ventral nerve root, and paired spinal nerves is called the *spinal cord segment*. The area of the skin supplied by a given cord segment and its spinal nerve is termed a *dermatome*. Qualitative assessment of sensory changes within the dermatomes allows rapid estimation of the spread of the local anesthetic within the subarachnoid or epidural space and is used to assess and document the extent of spinal or epidural anesthesia. Table 41.1 lists the most clinically relevant dermatomal levels and their corresponding surface landmarks.

Table 41.1 Surface landmarks and their relevant dermatomal levels (see Chap. 40 for figures)

Dermatomal level	Surface landmark
C8	Little finger
T1–T2	Inner arm
T4	Nipples
T6	Xiphoid
T7	Inferior border of scapula
T10	Umbilicus
T12	Inguinal ligament
L2–L3	Anterior thigh
L3	Patella
L5	Ankle
S1	Heel
S2	Back of the leg, back of the thigh, gluteal region
S3–S5	Perianal region

The ligamentum flavum and interspinous ligaments are *not continuous* (Fig. 41.5a). While the interspinous ligament extends from the spinous process above to the spinous process below, the ligamentum flavum extends from the lamina superior to a given intervertebral space to the lamina inferior to it. Failure of the left- and the right-sided ligamentum flavum to fuse in the midline has been described and may result in difficulty in localizing epidural space using a midline "loss-of-resistance" technique [17].

The epidural space is not a continuous space, but *segmented* along its length (Fig. 41.6) [18]. 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 the dura, while the posterior epidural compartment is divided by dural contact with bone beneath the cephalad 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 epidural drug spread that is occasionally seen [19].
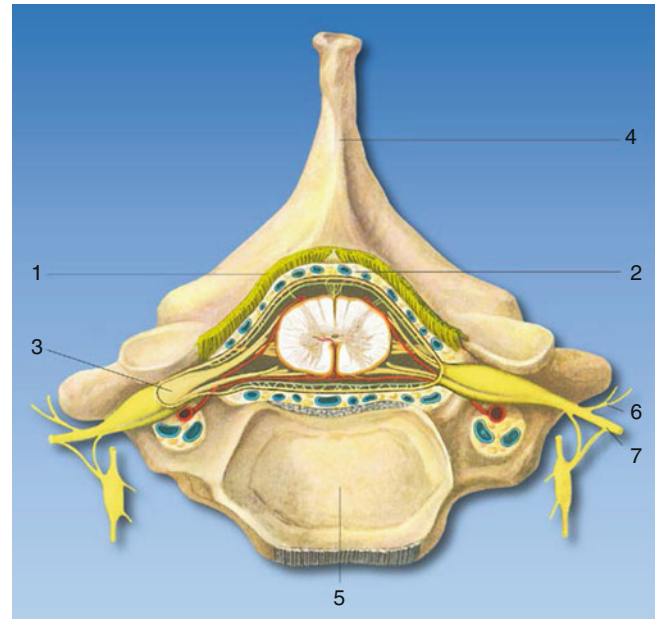

Fig. 41.6 Cross section of the epidural space. (*1*) Ligamentum flavum, (*2*) epidural space, (*3*) spinal ganglion, (*4*) spinous process, (*5*) body of vertebra, (*6*) dorsal branch of spinal nerve, and (*7*) ventral branch of spinal nerve (With permission from Danilo Jankovic)

Epidural fat in the epidural space (see also Fig. 41.5b) may play an important role in the pharmacokinetics of epidurally administered lipophilic drugs by acting as a *reservoir*. This may result in a delayed onset and a longer duration of action [20, 21]. A reduction in the epidural fat with age may partly explain the age-related changes in epidural dose requirements [22].

The depth of the epidural space from the skin varies with *body habitus*, being less in a thin individual and more in an obese or pregnant individual [23, 24]. Ultrasound is a useful tool for measuring this depth and has been shown to correlate well with the actual depth [25].

Physiological Effects of Neuraxial Block

The physiological effects of both subarachnoid and an epidural block are quite similar. However, the effects of an epidural block have a slower onset and are usually segmental in nature, due to the segmental spread of local anesthetic in the epidural space. These effects are summarized below.

Neurological Blockade

The injection of local anesthetic within the intrathecal or epidural space produces nerve blockade. This blockade first affects the smaller-diameter sympathetic fibers, before the larger myelinated sensory–motor fibers [26, 27]. As a result, *autonomic block* manifests before *sensory block*, which in turn precedes the *motor block*. Among the sensory modalities, the sequence of blockade is *temperature*, *pain*, *touch*, *pressure*, and finally *proprioception*.

Block dissipation occurs in the reverse manner with autonomic fibers being the last to recover. In general, more dilute solutions affect the sensory fibers preferentially, while higher concentration is needed to block the motor fibers. Sensory block extends two to four segments higher than motor block, and the sympathetic block extends two to four segments higher than the sensory block. This is termed *differential block* [28].

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 and may be exaggerated in a hypovolemic patient. Hypotension is a result of arteriolar vasodilatation and venous pooling which diminishes preload. Bradycardia is partially due to blockade of cardiac accelerator fibers (T1–T5) [29] but is more often a result of decreased preload which activates cardiac reflexes involving intracardiac stretch receptors [30]. The Bezold–Jarisch reflex in particular is often invoked as an explanation for severe bradycardia and asystole following spinal anesthesia in young healthy adults [31].

In general, the sympathetic block following a spinal anesthetic is more rapid and greater in extent compared to an epidural. Thus, a gradually dosed epidural may be useful in providing hemodynamic stability. Additionally, a high thoracic epidural block (T1–T4) provides coronary vasodilatation and reduces work of the myocardium by reducing afterload and reducing the heart rate [32]. However, this unopposed vagal tone has been thought to contribute to bradycardia, asystole, or laryngospasm [33, 34].

Respiratory Effects

In a patient with normal lung function, neuraxial blocks produce a clinically insignificant impact on respiratory function [35]. However, in high thoracic blockade or in a patient with preexisting respiratory compromise, this effect may be significant. The paralysis of abdominal and intercostal muscles negatively impacts expiratory function causing a reduction in peak expiratory flows, expiratory reserve volume, and maximal minute ventilation. This may manifest as dyspnea. However, these effects are negligible in comparison to the pain relief obtained following thoracic or abdominal surgery, and overall improvement in postoperative outcome and a reduction in postoperative pulmonary complications are observed [36].

Spread of the local anesthetics to cervical segments can affect inspiration by blocking the phrenic nerve and diaphragmatic function. Respiratory arrest following a total spinal may be due to medullary hypoperfusion rather than an effect of local anesthetics per se [35].

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 contracts the bowel and allows better access during abdominal surgery. Also, improved visceral perfusion due to vasodilation may improve healing and contribute to an earlier return of bowel function following surgery [37, 38].

Nausea and vomiting, if observed, are usually secondary to increased vagal tone and hypotension. A higher block (above T5), accompanying hypotension, use of opioids, and a history of motion sickness are risk factors for developing nausea and vomiting [39].

Genitourinary

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

Thermoregulation

Redistribution of heat following sympathetic block results in mild hypothermia. This induces thermoregulatory vasoconstriction and shivering above the level of the neuraxial block [40]. Epidural fentanyl may be used to abolish shivering during anesthesia [41].

Neuroendocrinal Effects

Neuraxial block effectively blocks the afferent innervation from the surgical site and 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). This effect is greater for a lumbar epidural than a thoracic epidural [42]. The magnitude of the stress response correlates with postoperative morbidity, and thus, its attenuation should be of benefit [43].

Indications

Spinal Versus Epidural Anesthetic

Neuraxial techniques (spinal and epidural anesthesia) at the lumbar levels allow for a temporary blockade of nerve conduction in the autonomic, sensory, and the motor fibers. However, it is important to recognize differences between the two. These are summarized in Table 41.2.

Table 41.2 Important differences between a spinal and an epidural anesthetic

Variables	Spinal anesthetic	Epidural anesthetic
Space accessed	Deposition of local anesthetic in subarachnoid space	Deposition of local anesthetic in epidural space
Time needed to perform	Takes less time (since it is usually a single-shot technique)	Takes more time (since it is usually a catheter technique)
Onset	Faster	Slower
Nature of blockade	Denser, therefore mainly employed as an anesthetic technique	Less dense, therefore mainly employed as an analgesic technique. However, with the use of sufficient volume and concentration, an anesthetic block can be produced
Duration	Dependent on dose and agent; fixed duration unless a catheter is inserted	Duration is flexible as a catheter is usually inserted
Cardiovascular effect	Rapid drop in blood pressure	A slower drop in blood pressure

Comparison to General Anesthesia

When compared to a general anesthetic, the central neuraxial techniques offer the following advantages:

- Avoidance of airway manipulation
- Avoidance of side effects of a general anesthetic (sore throat, nausea and vomiting, dental damage, malignant hyperthermia, aspiration of gastric contents, etc.)
- Simple and reliable block
- Predictable physiologic changes
- Minimal metabolic disturbances (in hepatic or renal disease)
- Preservation of consciousness
- Extension into postoperative analgesia

When compared to general anesthesia, neuraxial techniques have been associated with a reduction in cardiovascular adverse events, perioperative pulmonary complications, thromboembolic events, preserved gastrointestinal motility, development of chronic pain, surgical stress response, immune dysfunction, and morbidity and mortality [44–48].

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

Indications

The application of neuraxial anesthesia depends on the following factors:

- The area of surgery
- The type and expected duration of the procedure
- The degree of muscle relaxation required
- The presence of concomitant disease
- The expected blood loss

The relevant indications for spinal and epidural anesthetic are considered in Table 41.3.

Table 41.3 Indications for spinal and epidural anesthesia (also see Fig. 41.7)

| Spinal anesthetic	Epidural anesthetic
Surgical	*Surgical indications*
Spinal anesthesia is particularly advantageous for all types of surgical procedures below the level of the umbilicus	Procedures in the area of the lower extremities, hip joints, and inguinal region
Surgical procedures in the area of the lower extremities, hip joint, and inguinal region	Vascular surgery
Vascular surgery	Upper abdominal and thoracic procedures, in combination with general anesthesia
Prostate and bladder surgery	Urological procedures (prostate, bladder)
Gynecological and obstetric procedures	Gynecological and obstetric procedures
Surgery in the perineal and perianal region	Procedures in the perineal and perianal region
Pain therapy	Interventional radiology
Chemical intraspinal neurolysis with phenol in glycerol or alcohol (in advanced stages of malignant disease)	*Postoperative and post-traumatic pain therapy*
	Usually in combination with local anesthetics and opioids
	Therapeutic block with injection of depot corticosteroids at caudal, lumbar, or cervical levels
	Epidural injection of homologous blood or dextran or fibrin glue patch in post-dural puncture headache
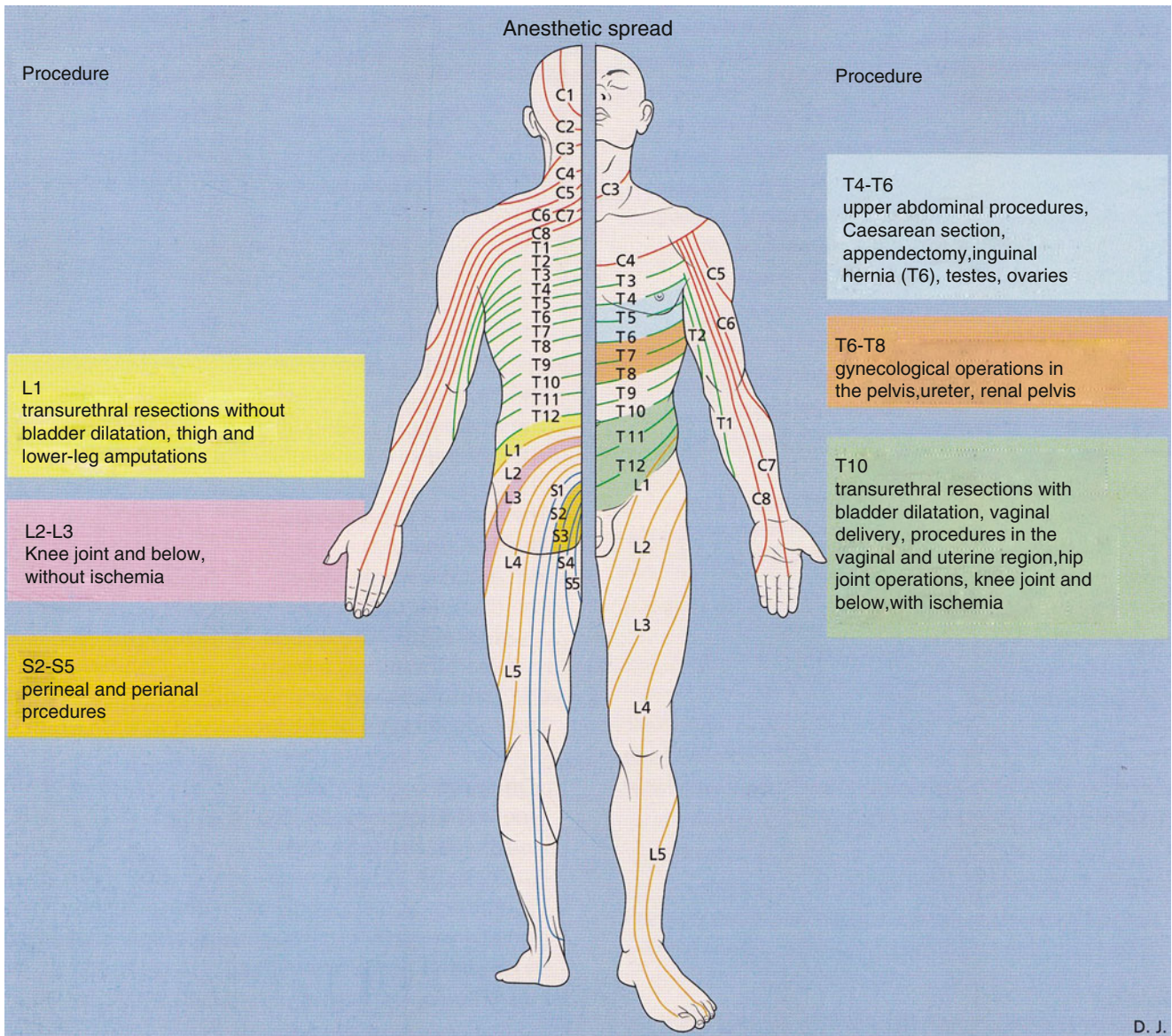
Fig. 41.7 Location of the procedure and required sensory spread of local anesthetic (With permission from Danilo Jankovic)

Contraindications

These are summarized in Table 41.4.

Coagulopathy, whether iatrogenic or idiopathic, is now considered a relative contraindication. According to the consensus statements by the American Society of Regional Anesthesia and Pain Medicine (2010), epidural block can be placed 4 h after the last dose of heparin. NSAIDs including aspirin are not a contraindication to epidural placement provided that catheter placement is uncomplicated (one or two attempts). LMWH should be held at least 12 h before placement of catheter and 2 h after its removal. Epidural placement is relatively safe with international normalized ratio (INR) <1.5. If an epidural vein is punctured, subcutaneous heparin administration should be held at least 2 h and LMWH held at least 24 h. GIIa/IIIb inhibitors should be withheld for at least 4 weeks after epidural placement. Epidural placement is best avoided for 7 days after clopidogrel and 14 days after ticlopidine. For a further review on the use of neuraxial techniques in anticoagulated patients, patients on antiplatelet drugs, or patients with coagulopathy, please refer to the "Executive summary: regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine Evidence-Based Guidelines (Third Edition)" [49].

Table 41.4 Contraindications to central neuraxial block

Absolute	Relative
Patient refusal	Coagulopathy: coagulation disorders or anticoagulant therapy
Sepsis, local infections at the injection site, or immune deficiency	Spinal pathology including severe spinal deformities, arthritis, osteoporosis, intervertebral disc prolapse, spinal canal stenosis, post-spinal surgery, and spinal metastases
Severe decompensated hypovolemia, shock	Unknown duration of surgery
Severe specific cardiovascular diseases of myocardial, ischemic, or valvular origin	Mild valvular disease (aortic stenosis)
Acute cerebral or spinal cord diseases	Preexisting neurological deficits (radiculopathies, peripheral neuropathies, multiple sclerosis)
Increased intracranial pressure	
Indeterminate neurological disease	
Hypersensitivity to local anesthetic agents	

Performing a Spinal Anesthetic

Before performing a spinal anesthetic, a full discussion of the risk–benefit and informed consent should take place.

Preparation and Materials

- Check that the emergency equipment is complete and in working order (intubation kit, emergency drugs); sterile precautions, intravenous access, and anesthetic machine.
- Start an intravenous infusion and ensure adequate volume loading (250–500 ml of a balanced electrolyte solution).
- Vasopressors such as ephedrine, phenylephrine, or meta-raminol should be readily available.
- ECG, noninvasive blood pressure, and pulse oximetry monitoring are essential.
- Skin prep using an alcohol, iodine, or chlorhexidine. Note that 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 [50, 51].
- Local anesthetic for skin infiltration and intrathecal injection.
- *Spinal needles* (Fig. 41.8a–c) are commonly of the following two types:

– *25–27-G spinal needles with conical tip* (pencil-point)—e.g., Sprotte, Pencan, and Whitacre—in current standard use. When the dura is penetrated with these needles, the dural fibers are separated and then closed together again. This reduces the risk of post-dural puncture headache [52, 53].
– *25–27-G spinal needles with Quincke tip*. The needle bevel should be directed laterally during the puncture in order to pass through the dura in a longitudinal direction [54]. A 22-G needle may be used where increased stiffness is desired to facilitate needle redirection—e.g., in older patients with narrowed interlaminar spaces or when there are difficulties with positioning.
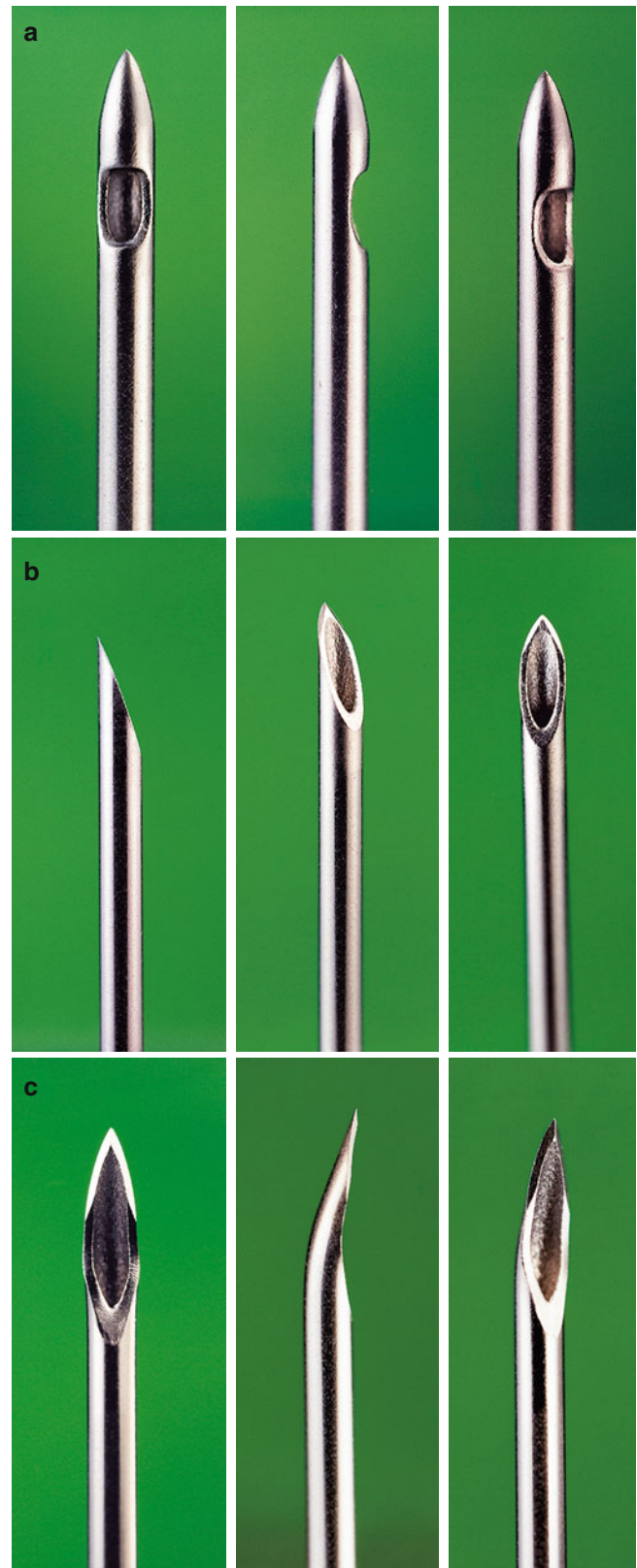
Fig. 41.8 (**a**–**c**) Spinal needles. (**a**) Pencil-point, 25 G. (**b**) Quincke tip, 27 G. (**c**) Atraucan Special Cut, 26 G (With permission from Danilo Jankovic)

Patient Positioning

Optimal patient positioning during puncture and during the fixation phase of the local anesthetic is a prerequisite for successful spinal anesthesia. The following positions may be used:

- Lateral decubitus position
- Sitting
- Prone

In all three positions, it is important to locate the *midline* and to follow it during the entire injection procedure. Lumbar lordosis must be minimized.

Lateral Decubitus Position

The assistant stands in front of the patient. If the anesthetist is right-handed, the patient is placed in the left lateral position. The patient is asked to adopt a *hunchback* position (legs flexed up against the abdomen and chin flexed down onto the chest) in order to flex the lumbar spine and allow optimal expansion of the intervertebral spaces. It is important here for the spine to be parallel and for the intercristal line and the line connecting the two scapular tips to be perpendicular to the operating table (Fig. 41.9).

Advantages

- More comfortable for the patient and thus particularly suitable for frail patients (risk of collapse).
- The reduction in blood pressure is less marked [55].
- When hyperbaric solutions are used, unilateral anesthesia is more easily obtained.
- Can be used in pregnant patients (since the lateral tilt or lateral decubitus position reduces the extent of aortocaval compression) [56].

Disadvantages

- Difficulty may arise in the correct identification of the midline, especially if the pelvis is tilted too anteriorly.

Fig. 41.9 Position: lateral decubitus (With permission from Danilo Jankovic)

Sitting Position

The patient is seated on the edge of the operating table and is supported by an assistant standing in front of him or her (Fig. 41.10). It may also be helpful to provide a padded Mayo stand, an adjustable table, or a similar device for the patient to lean on for additional support.

Advantages

- When palpation of the spinous processes is difficult (e.g., in obese patients or those with spinal deformities), it is easier to locate the midline in the sitting position.

- Facilitates the performance of a saddle block with hyperbaric local anesthetic when anesthesia in only the perineal or perianal region is required.

Disadvantages

- This position may lead to orthostatic hypotension (and risk of collapse) and should be avoided in frail and heavily sedated patients [55].
- More support and assistance may be required to keep patient upright.

Fig. 41.10 Position: sitting (With permission from Danilo Jankovic)

Prone Jackknife

This position is only used in the very rarely practiced hypobaric technique for spinal anesthesia (procedures in the rectum, perineum, sacrum, lower spine) [57]. An assistant and subsequent repositioning of the patient are not required (Fig. 41.11).

Fig. 41.11 Position: prone ("jackknife" position) (With permission from Danilo Jankovic)

Injection Technique

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

Median Approach (Midline)
Landmarks
The injection is carried out in the midline below the L2 segment (conus medullaris), usually between the spinous processes of L2/L3 or L3/L4 (depending on the desired level of anesthesia). The patient is asked to draw the legs tightly up to the abdomen and to place the chin on the chest. A line is drawn from one iliac crest to the other. This connection (Tuffier's line) crosses either the spinous process of L4 (50 %) or the intervertebral space of segments L4/L5. However, this palpatory method alone may be unreliable, and ultrasound may help to correctly identify the vertebral levels [7].

The spinous processes and intervertebral spaces are palpated to identify the *midline*, which is the important landmark. It is recommended that the index and middle fingers of the nondominant hand be used to palpate and identify the chosen interspace, as they can be subsequently used to fix the overlying skin, which is important for precision and accuracy in needle insertion (Fig. 41.12).

Fig. 41.12 Palpation of the intervertebral space (With permission from Danilo Jankovic)

Strict Asepsis
Thorough, repeated, and wide skin prep and drying and covering of the injection site with a drape.

Local Anesthesia
The skin and supraspinous and interspinous ligaments are anesthetized with 1–1.5 ml of a local anesthetic (e.g., 1 % lignocaine). The injection is carried out between the spread index and middle fingers of the left hand (Fig. 41.13). In the patient with less-distinct surface landmarks, the local anesthetic needle may be used to explore the underlying 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 within the interspinous ligament in the midline and not in the paraspinous muscles on either side.

Fig. 41.13 Local anesthesia (With permission from Danilo Jankovic)

Injection

Advancing the Introducer

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 parallel to the operating table and slightly cranially (10°) deep enough for it to sit firmly in the interspinous ligament (Fig. 41.14). It should be ensured that the *midline position* is maintained. After this, the introducer is fixed with the thumb and index finger of the left hand, with the dorsum of the hand lying firmly on the patient's back.

Fig. 41.14 Advancing the guiding cannula (With permission from Danilo Jankovic)

Introducing the Spinal Needle, Puncture
of the Subarachnoid Space

The spinal needle, held between the thumb and index fin-
ger (or middle finger) of the right hand, is introduced
through the interspinous ligament, ligamentum flavum,
epidural space, and dura/arachnoid as far as the subarach-
noid space. Penetration of the ligamentum flavum is usu-
ally 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 (Fig. 41.15). When a Quincke nee-
dle is used, it should be ensured that the needle bevel is
directed laterally, so that the dura is punctured in a longi-
tudinal direction.

Fig. 41.15 Introducing the spinal needle. Puncture of subarachnoid
space (With permission from Danilo Jankovic)

Removing the Stylet

The following may occur here:

- *CSF flows freely*

- The injection needle is advanced 1 mm and fixed between the thumb and index finger of the left hand, which is supported on the patient's back. The desired amount of local anesthetic can now be injected (Figs. 41.16 and 41.17a, b).

- With the single-injection technique, aspiration of CSF (0.1 ml) should be attempted immediately before and after injection of local anesthetic. The subarachnoid injection is made at the rate of 1 ml per 5 s.

- *Blood in the CSF*

- Slightly bloody 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.

- However, backflow of frank blood indicates that the injection needle is likely positioned within a vein. A new attempt at puncture must be made and possibly in a different intervertebral space.

- *No CSF flow*

- Rotation of the needle to all four quadrants and careful aspiration may help. The needle may also be advanced slightly with the stylet in place.

- 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 bone contact suggests that the posterior side of the vertebra or an intervertebral disc has been reached. CSF appears in most cases after the needle has been slightly withdrawn and aspiration has been repeated.

- *Pain or paresthesias during puncture*

- Pain or paresthesia prior to entry into the epidural or intrathecal space is most often due to needle contact with the facet joint, which forms the lateral border of the interlaminar space. 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. If it persists, the needle must be withdrawn slightly or repositioned. When paresthesias occur during the injection, the needle must be repositioned before any further drug is injected.

  The local anesthetic must never be injected without evidence of CSF! The location and distribution of paresthesias arising during the puncture procedure must be recorded.

- Experience shows that failure is usually due to deviation of the needle from the midline or excessive cranial angulation of the needle.

Fig. 41.16 Removing the stylet. Subarachnoid injection (With permission from Danilo Jankovic)
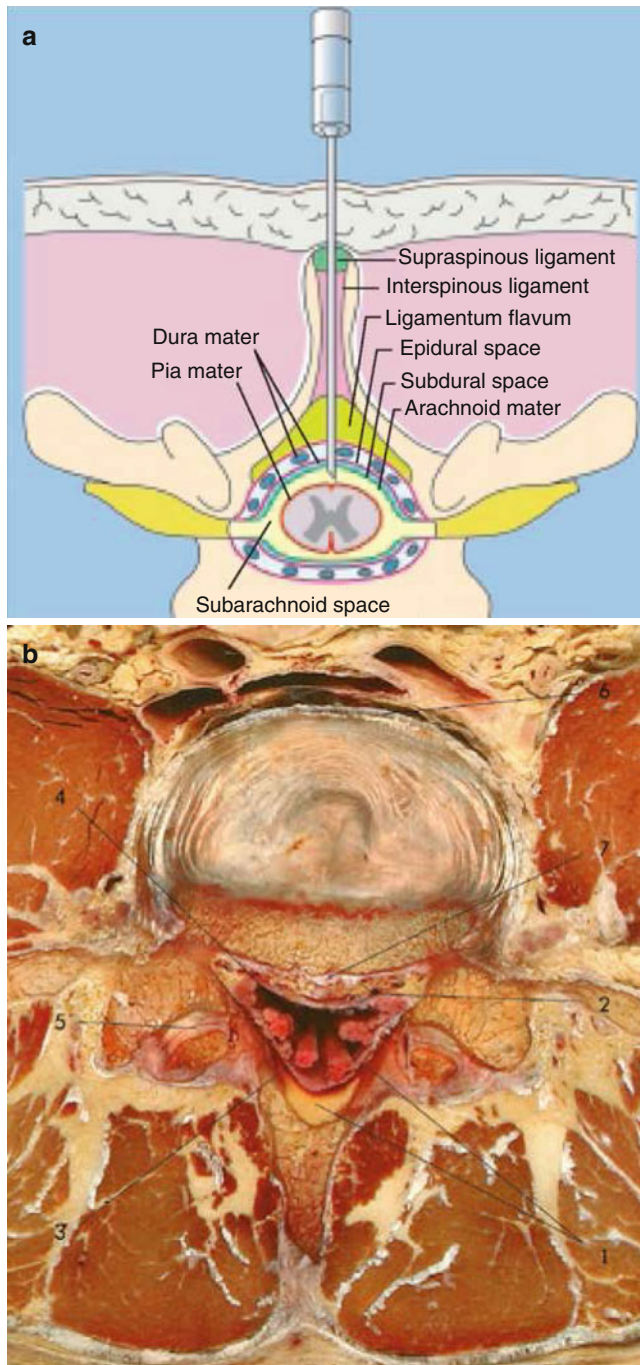
Fig. 41.17 (**a**) Subarachnoid position of the needle (With permission from Danilo Jankovic). (**b**) Transverse dissection at the level of L4/L5. (*1*) Posterior epidural space with fat, (*2*) anterior epidural space with veins, (*3*) spinal dura mater, (*4*) subarachnoid space and cauda equina, (*5*) zygapophysial joint, (*6*) anterior longitudinal ligament, and (*7*) posterior longitudinal ligament (With permission from Danilo Jankovic)

Paramedian Approach (Lateral, Paraspinal)

In this technique (Figs. 41.18 and 41.20), the supraspinous and interspinous ligaments are avoided, so that the ligamentum flavum is the primary target on the way to the subarachnoid space.

Procedure

This technique can be used in all the patient positions mentioned above. Flexion of the spine is not essential. The caudal edge of the spinous process is marked. The injection site is located 1–1.5 cm lateral and caudal to this. The puncture is carried out in a cranio-medial direction, at an angle of about 10–15°. The dura is reached after about 4–6 cm. Most mistakes arise when the needle is angled too cranially or when the needle entry point is too lateral.

This technique can be used in:

- Degenerative changes in the spine
- Older patients with marked calcification of the supraspinous and interspinous ligaments [58]
- Obesity
- Fractures or other pathological conditions in which pain makes it impossible to flex the spine

Taylor's Approach

This lumbosacral approach (Figs. 41.19 and 41.20) is a paramedian injection via the intervertebral space of L5 and S1, the largest interlaminar space in the spinal region.

Fig. 41.18 Paramedian approach (With permission from Danilo Jankovic)

Fig. 41.20 Puncture of the subarachnoid space: (*1*) median, (*2*) paramedian, (*3*) Taylor (With permission from Danilo Jankovic)

Fig. 41.19 Taylor's approach (With permission from Danilo Jankovic)

Procedure

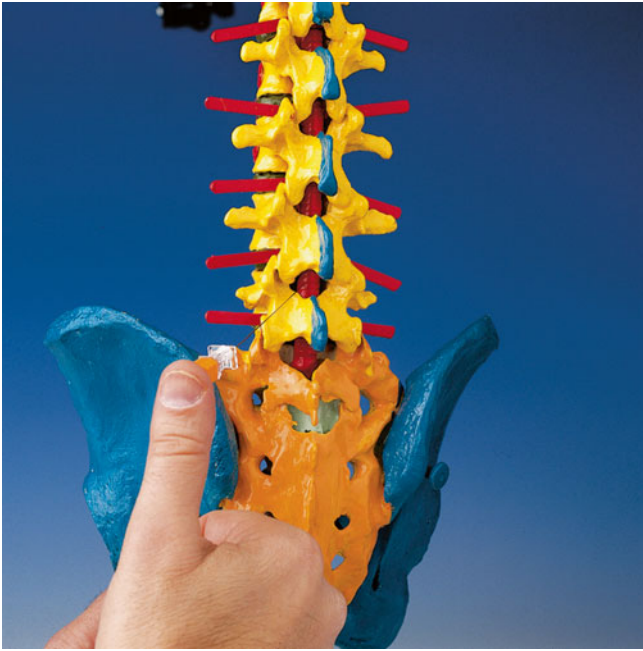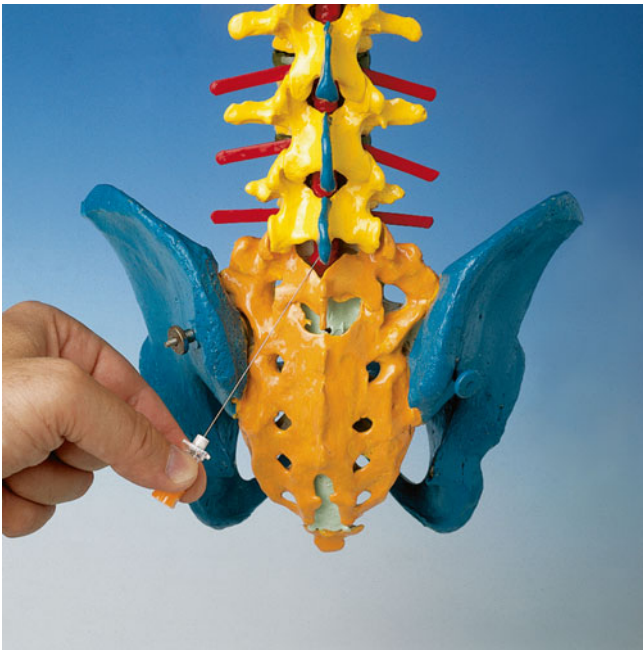The injection site is located about 1 cm medial and about 1 cm caudal to the posterior superior iliac crest. The injection needle is advanced in a cranio-medial direction and at an angle of about 55°. If it touches the periosteum (sacrum), the needle must be withdrawn and its direction must be corrected.

The indications for this access route include procedures in the perineal and perianal region, as spread to the higher spinal levels may not always reliably occur.

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 and orthopedic procedures on the lower extremities

Procedure

• Patient positioning: lateral decubitus position, lying on the side that is to be operated on.
• Injection technique: this is the same as for conventional spinal anesthesia. The opening of the pencil-point needle is rotated to the operating side, and the desired amount of local anesthetic is slowly injected [59]. A hyperbaric solution of local anesthetic such as bupivacaine should always be used for maximum effectiveness.
• Patient position after the injection: the patient remains lying on the side that is to be operated on for about 20 min.

Advantages

• Reduction in the extent of the sympathetic block (by about 70 %), since smaller volumes and slower injection of the local anesthetic mean that fewer spinal segments are involved [60]
• Hemodynamic stability (hypotension is only observed in 5 % of patients)
• Faster recovery from anesthesia
• Suitable for outpatient procedures [61]
• Greater acceptance by patients

Disadvantage

• Strict unilateral anesthesia is only achieved if adequate time 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 [62]
• Postoperative pain relief
• Chronic pain relief (in cancer patients)

Procedure

• The procedure is similar to a standard spinal anesthetic. However, 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. 41.21).

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 [62].
• Ability to prolong spinal anesthetic as needed.

Disadvantages

• Higher risk of post-dural puncture headache in younger population [63].
• Use of small micro-catheters (less than 24 G) may predispose to sacral pooling of local anesthetic leading to *cauda equina syndrome* and is therefore not recommended [64].
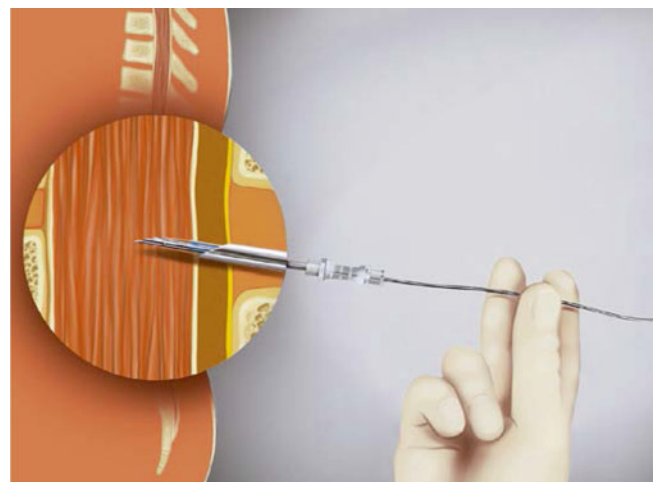

Fig. 41.21 Introducing the catheter in the subarachnoid space (With permission from Danilo Jankovic)

Management of the Patient After Intrathecal Injection

Patient Positioning
The level of the anesthetic spread is controlled by patient positioning measures and 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 cephalad. The patient remains sitting if sacral spread is desired.

Hypobaric Technique
- Hypobaric spinal anesthesia is ideal for perineal and peri-rectal surgeries requiring a prone "jackknife" position, so that the patient does not need to be repositioned (Fig. 41.11).
- The hypobaric technique has also gained popularity in major hip surgery, which is performed in the lateral position. Thus, repositioning of the patient is often not needed when the spinal is placed in the lateral decubitus position, with the operative side nondependent. Compared to iso-baric bupivacaine, a hypobaric solution demonstrated a significant delayed block recession and time until analge-sia, for total hip arthroplasty [65].

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

Fixation Phase
- The phase immediately after injection of the local anes-thetic is particularly critical and requires precise monitor-ing. The fixation phase lasts about 10–15 min.

Patient Monitoring
- Sympathetic block following a spinal anesthetic results in a drop in the blood pressure and heart rate. This may be profound in elderly and volume-depleted patients. 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 [66]. Thus, frequent monitoring of the vitals (heart rate, blood pressure, and oxygen saturation) is advocated during and after the conduct of a spinal anesthetic.
- Supplemental oxygen administration is recommended after a spinal anesthetic, especially if sedation is used for patient comfort.
- End-tidal carbon dioxide monitoring is also used to moni-tor the respiratory rate.
- Postoperatively, the patient should be monitored until the effects of spinal anesthetic have receded.

Block Assessment
- Injecting a local anesthetic into the subarachnoid space blocks *autonomic*, *sensory*, and *motor* function. The main targets of local anesthesia are the posterior roots with the ganglia, the anterior roots of the spinal nerves, the auto-nomic nerve fibers, and mixed neural trunks.
- The spread of the anesthesia should be checked at short intervals (2–5 min) and confirmed (with a cold spray or pinprick) shortly before the start of the operation [67, 68]. The first sign of an effect on the spinal nerve roots is a subjective sensation of *warmth* in the feet. The further development of the block encompasses touch, deep pres-sure, 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 auto-nomic function is the last to recover [28].

Performing an Epidural Anesthetic

Preparation and Materials

Preparation for an epidural anesthetic is similar to that for a spinal block. This has already been discussed in Sect. *Patient Positioning*.

Epidural needles: The epidural needles required to perform an epidural block are generally larger in gauge than spinal needles. Additionally, they may have distinct tip design to facilitate entry into the epidural space and introduction of the catheter. Some of these are already discussed in Sect. *Patient Positioning*. Of these, Tuohy-tip epidural needles are most commonly used.

Positioning of the Patient

An epidural block can be performed with the patient in lateral decubitus or sitting position. While the former is commonly used in obstetric patients, the latter is preferred in other patient groups. Prone position is rarely used. The pros and cons of these positions have been already discussed on p. 514 (Patient Positioning).
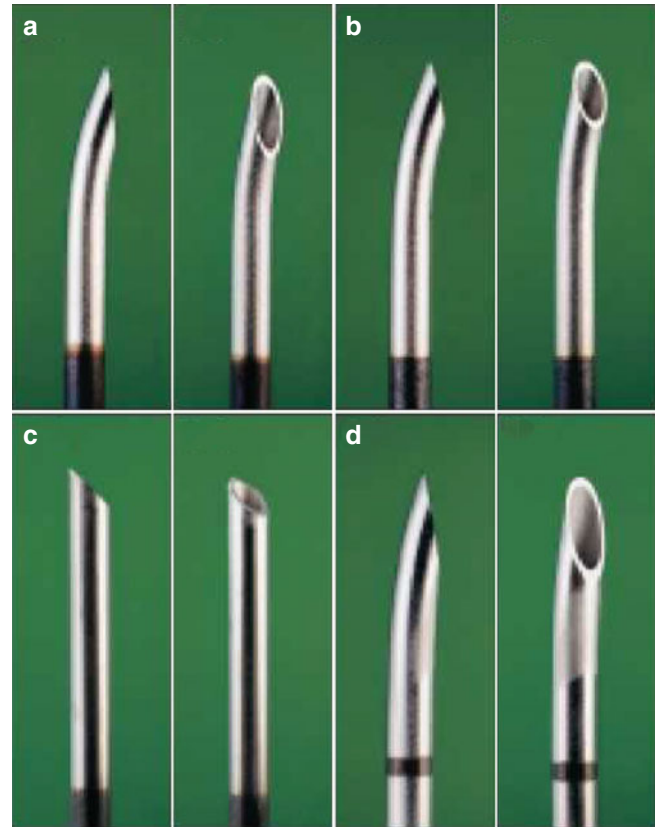
Fig. 41.22 (**a**–**d**) Epidural needles. (**a**) Tuohy, (**b**) Hustead, (**c**) Crawford, (**d**) Weiss (With permission from Danilo Jankovic)

Performing a Lumbar Epidural

Lumbar epidural space may be accessed using a midline approach which is most commonly used or using a paramedian approach. These are discussed below.

Midline Approach
Landmarks
The injection is carried out in the midline below the L2 segment (conus medullaris) (Fig. 41.23a, b), usually between the spinous processes of L2/L3 or L3/L4. The intervertebral space is palpated, and the midline is located to serve as the most important signpost. In the midline, the ligamentum flavum is at its thickest, the epidural space is widest, and the blood vessels are at their smallest [69].

Strict Asepsis
Thorough, repeated, and wide skin prep is done. After drying, the injection site is covered using a sterile drape.
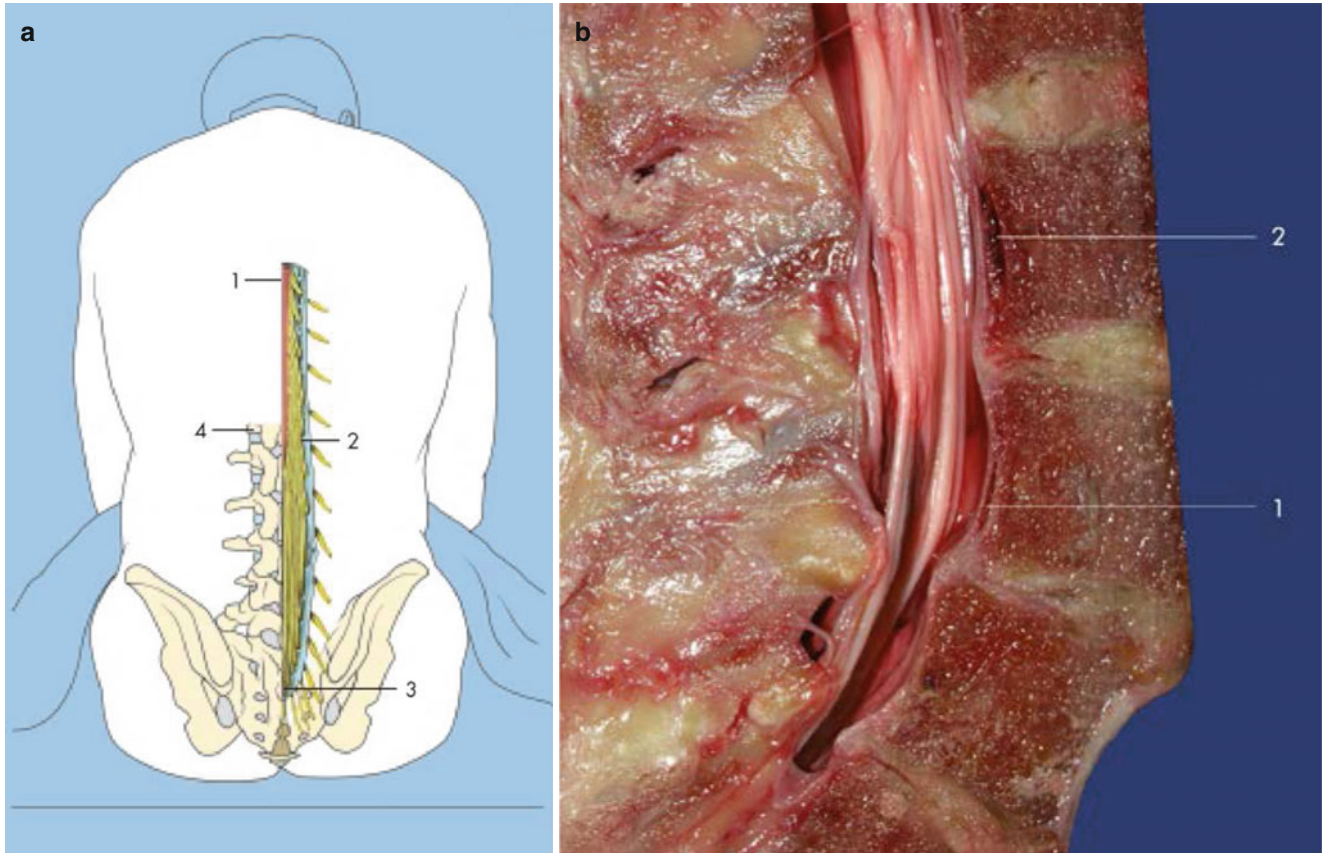
Fig. 41.23 (**a**) Conus medullaris (lower edge of the first lumbar vertebra). (*1*) Conus medullaris, (*2*) cauda equina, (*3*) dural sac, (*4*) L1 segment (With permission from Danilo Jankovic). (**b**) Cauda equina at the level of L2–L5. Paramedian sagittal section. (*1*) Spinal dura mater, (*2*) epidural space (With permission from Danilo Jankovic)

Local Anesthesia

The skin and supraspinous and interspinous ligaments are anesthetized with 1–1.5 ml of a local anesthetic (e.g., 1 % lignocaine). The injection is carried out between the spread index and middle fingers of the left hand (Fig. 41.24).

Needle Insertion

Without moving the spread index and middle fingers of the left hand from the intervertebral space, an epidural needle is fixed between the thumb of the right hand (hub) and the index and middle finger (shaft) and advanced through the skin (Fig. 41.25). After passing the supraspinous ligament, which is about 1-cm thick, the needle, with its bevel directed cephalad or caudad, is slowly advanced a further 2–3 cm

(depending on the anatomy), until it rests firmly in the interspinous ligament. This often results in a "gritty" sensation. The trocar is removed and a low-friction (loss of resistance) syringe is attached (Fig. 41.26).

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 local pain.

After passing the interspinous ligament, the needle must be advanced carefully, millimeter by millimeter, in the direction of the ligamentum flavum.

Fig. 41.24 Local anesthesia (With permission from Danilo Jankovic)
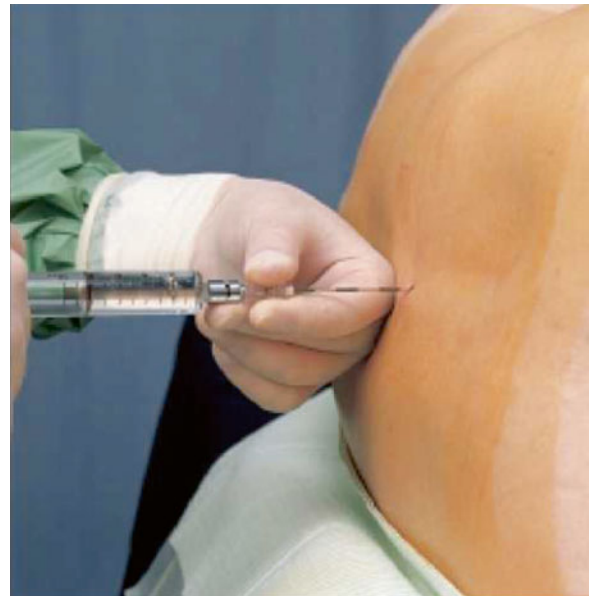
Fig. 41.26 Removing the stylet and attaching a low-friction syringe (With permission from Danilo Jankovic)

Fig. 41.25 Introducing the epidural needle (With permission from Danilo Jankovic)

Puncturing the Epidural Space

The thumb and index finger of the left hand, which is resting with the back of the hand firmly against the patient's back, secure the needle, advance it millimeter by millimeter, and at the same time serve as a "brake" to prevent inadvertent forward movement. The thumb of the right hand applies pressure on the syringe plunger. *Loss of resistance* indicates that the epidural space has been reached. The contents of the syringe are easily injected.

Identification of the epidural space is carried out using the *loss-of-resistance technique* (Fig. 41.27). The following variations on this technique can be applied:

(a) *Saline with an air bubble*: after the interspinous ligament has been reached, the stylet is removed, and a low-friction syringe filled with a saline solution and with a small air bubble in it, serving as a visual indicator, is attached. When the ligamentum flavum is encountered, the air bubble is compressed by pressure on the syringe plunger (Fig. 41.28a); when the epidural space is reached, the bubble returns to its normal, larger shape (Fig. 41.28b). This technique is the most common choice as it provides a good identification of the epidural space and an idea of the force being applied (by the compression of the air bubble).

Fig. 41.27 Identifying the epidural space (loss of resistance) (With permission from Danilo Jankovic)
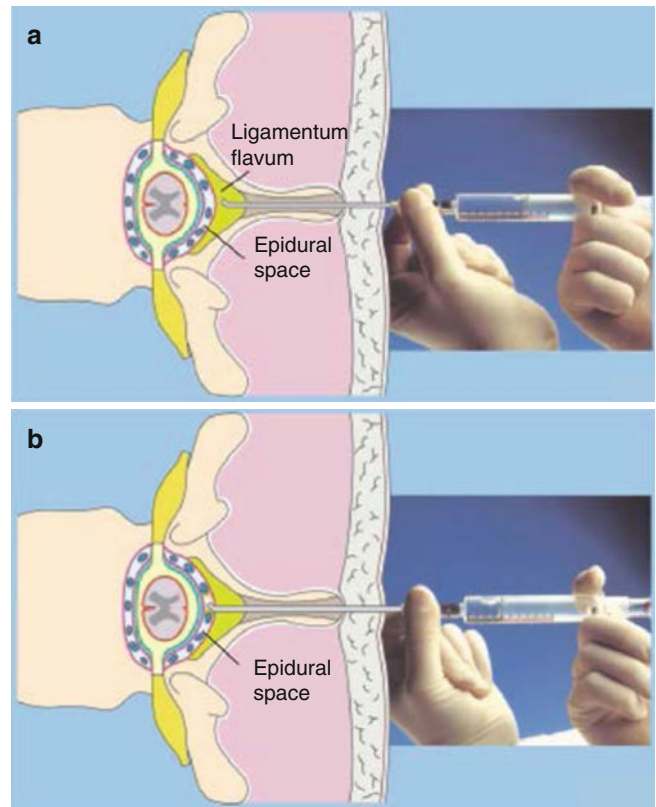
Fig. 41.28 (**a**) Loss-of-resistance technique with saline. The air bubble is compressed by pressure on the syringe plunger (With permission from Danilo Jankovic). (**b**) Loss-of-resistance technique with saline. The epidural space has been reached. The air bubble has returned to its normal, loose shape (With permission from Danilo Jankovic)

(b) *Saline-only technique*: since the introduction of air in the epidural space may lead to "patchy" block, some clinicians prefer to use only saline. The disadvantage of doing so is the inability to objectively judge the amount of force being applied on the plunger.

(c) *Air-only technique*: this technique allows for a more subjective "feel" while identifying the epidural space. It also 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 [70].

(d) *Hanging drop technique*: in this technique, after the interspinous ligament has been reached, a drop of saline is placed within the hub of the needle (Fig. 41.29a). 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 (Fig. 41.29b) [71].
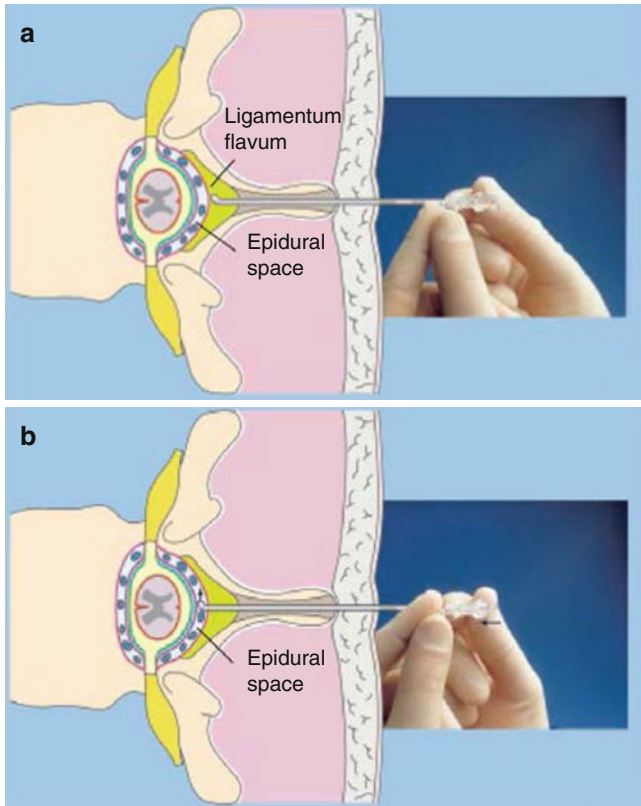
Fig. 41.29 (**a**) "Hanging drop" technique. The epidural needle is positioned in the ligamentum flavum (With permission from Danilo Jankovic). (**b**) "Hanging drop" technique. The epidural space has been reached. The drop is sucked back in (With permission from Danilo Jankovic)

Aspiration and Injection of a Test Dose

Having reached the epidural space, a careful aspiration is carried out to detect CSF or blood while the needle continues to be secured by the thumb and index finger of the left hand, resting with the back of the hand firmly against the patient's back (Fig. 41.30).

After a negative aspiration, a test dose of 3–4 ml of local anesthetic (usually 1.5 % lignocaine) and 15 mcg epinephrine can be injected. This allows detection of intrathecal injection (rapid development of spinal block) or intravascular injection (tachycardia).

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 (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 tachyarrhythmia [72].

Maintaining constant verbal contact with the patient and careful cardiovascular monitoring after a test dose is recommended. If all is well, a further dose of the local anesthetic can be injected.

Fig. 41.30 Aspiration test (With permission from Danilo Jankovic)

Drug Administration

The epidural injection may be performed as a single-shot injection or as a catheter technique (allowing further dosing).

(a) *Single-injection technique*: incremental administration of a local anesthetic is carried out in aliquots of 3–5 ml, waiting 15–20 s between each dose, with intermittent aspiration (Fig. 41.31). After aspiration has been repeated shortly before the end of the injection, the needle is withdrawn and the patient is placed in the desired position.

(b) *Catheter technique*: upon confirmation of the epidural space and negative aspiration, a catheter may be introduced. For this, 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 maximum of 3–4 cm beyond the tip of the needle (Fig. 41.32). Advancing it further than this can lead to lateral deviation of the catheter, with accompanying paresthesias. After placement of the catheter in the desired position, the needle is slowly withdrawn (Fig. 41.33), while at the same time the thumb and index finger of the left hand secure the catheter at the injection site (Fig. 41.34).

Fig. 41.31 Incremental injection of local anesthetic (With permission from Danilo Jankovic)

Fig. 41.33 Withdrawing the injection needle (With permission from Danilo Jankovic)
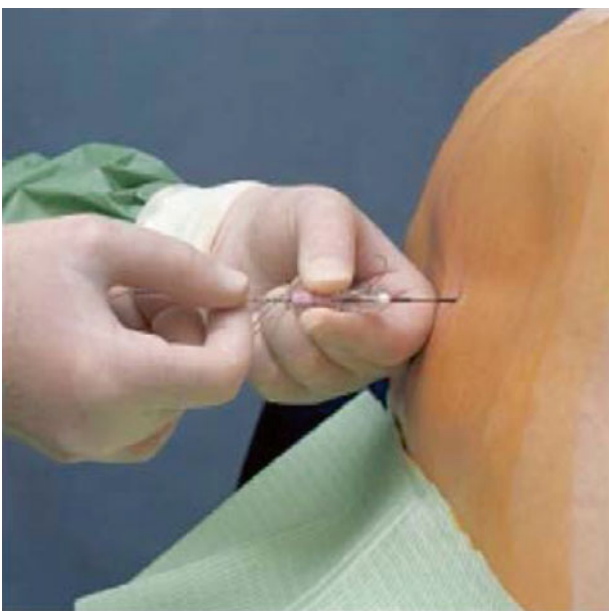
Fig. 41.32 Introducing the catheter (With permission from Danilo Jankovic)

Fig. 41.34 The catheter is secured at the injection site with the thumb and index finger (With permission from Danilo Jankovic)

An adapter is attached to the end of the catheter. The patency of the catheter is tested by injecting 1–2-ml saline (Fig. 41.35). After aspiration, the syringe is 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). A bacterial filter is then attached (Fig. 41.37), and the catheter is secured and dressed to prevent dislodgement and ensure sterility (Fig. 41.38). Fixation of the catheter can be accomplished in a variety of ways, including skin suture or proprietary dressings.

The patient is placed in the desired position and a test dose is administered, as with the single-shot injection. During the waiting period, it is important to maintain verbal contact with the patient and to check the spread of the anesthesia, to exclude the ever-present risk of inadvertent intrathecal injection. After 5 min, the remainder of the dose, adjusted for the individual patient, can be administered on an incremental basis (max. 5 ml each injection) until the desired level of anesthesia is reached.

Fig. 41.35 Injection of 1 ml saline (With permission from Danilo Jankovic)

Fig. 41.37 Placing a bacterial filter (With permission from Danilo Jankovic)

Fig. 41.36 The end of the catheter is placed below the injection site (With permission from Danilo Jankovic)

Fig. 41.38 Securing the catheter and dressing (With permission from Danilo Jankovic)

Troubleshooting

(a) *Escaping fluid*: 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. 41.39), near-neutral pH, higher glucose content, and turbidity with thiopentone help identify the fluid as CSF [73]. If the fluid is not CSF, one can proceed with the procedure.

(b) *Escaping blood*: in this case (Fig. 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.

(c) *Escaping CSF*: 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 (this 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 spread intrathecally through the first dural puncture site and lead to 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 post-dural puncture headache.

(d) *Inability to thread the catheter*: this may happen when a *false* loss of resistance has been encountered in a superficial tissue plane. Injection of local anesthetic at this point will not be effective. Reattempting the injection is the best course, aiming to obtain a convincing loss of resistance.

Fig. 41.39 Escaping fluid: is it cold or warm? (With permission from Danilo Jankovic)

Fig. 41.40 Blood-tinged fluid (With permission from Danilo Jankovic)

Paramedian Approach

This technique, which is independent of lumbar lordosis or the ability of the spine to flex, avoids puncture of the supraspinous ligament and the frequently ossified interspinous ligament. This approach offers a much larger opening into the epidural space than the midline approach.

Indications

- Patients who cannot be positioned easily or cannot flex the spine (trauma/ arthritic)
- Calcified ligament (interspinous)
- Kyphoscoliosis or prior lumbar surgery

Procedure

The puncture site (Fig. 41.41) is located in the selected intervertebral space, about 1.5–2 cm lateral from the upper edge of the lower spinous process. Fan-shaped local anesthesia identifies the depth of the vertebral arches (laminae), which are then marked (4–6 cm). The epidural needle is introduced in a cranio-medial direction at an angle of about 15° to the sagittal level and about 35° to the skin surface, so that it passes the laminae and slides into the interlaminar fissure. The only ligament that needs to be penetrated on the way to the epidural space is the ligamentum flavum. Reaching this is characterized by a *rubbery* resistance. The most important step in this technique is to identify the depth of the ligamentum flavum. The trocar is then removed from the puncture needle, and identification of the epidural space is carried out in the same way as described for the single-shot technique.

Fig. 41.41 Paramedian puncture (With permission from Danilo Jankovic)

Performance of a Thoracic Epidural

The spinous process of lower thoracic vertebrae is directed horizontally; however, those of the upper to mid-thoracic vertebrae are angulated steeply downward (Fig. 41.42a). Thus, while a midline approach suffices at the lower thoracic levels, a paramedian approach is recommended at the upper to mid-thoracic levels. A cross section of structures at T3 is depicted in Fig. 41.42b.
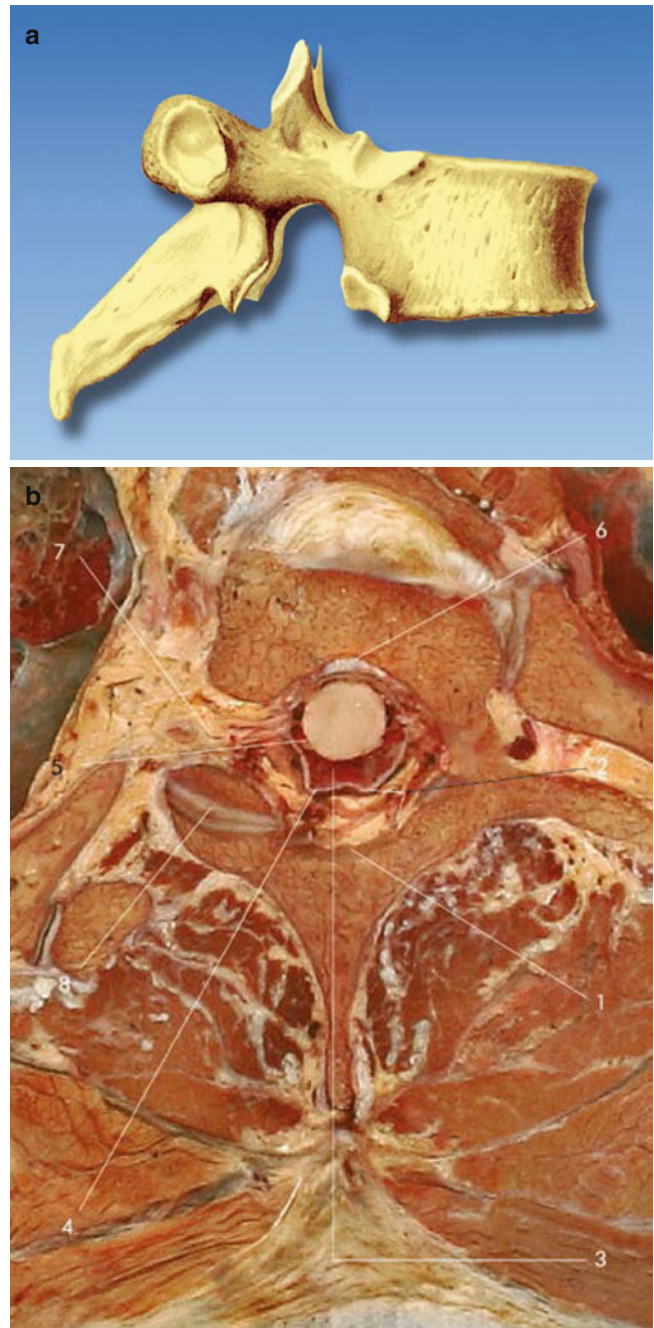
Fig. 41.42 (**a**) Angulation of the spinous processes of upper to mid-thoracic vertebrae (With permission from Danilo Jankovic). (**b**) Transverse dissection at the level of T3. (*1*) Ligamentum flavum, (*2*) epidural space, (*3*) subarachnoid space with spinal cord, (*4*) spinal dura mater, (*5*) spinal pia mater, (*6*) posterior longitudinal ligament, (*7*) neural foramen with spinal nerves, and (*8*) zygapophysial joint (With permission from Danilo Jankovic)

Midline Approach for Lower Thoracic Levels

This is similar to the technique used at the lumbar levels. The patient is usually placed in a sitting position, and monitoring is applied. Intravenous access is established before starting. Landmarks are identified by palpating the spinous processes of the lower thoracic vertebrae. Thorough, repeated, and wide skin prep is applied. After drying, the injection site is covered using a sterile drape. The skin and supraspinous and interspinous ligaments are anesthetized with 1–1.5 ml of a local anesthetic as described earlier. A 16-G Tuohy-tip epidural needle is fixed between the thumb of the right hand (hub) and the index and middle finger (shaft) and advanced through the skin, at an angle of 10–15°

cephalad (Fig. 41.43). After passing the supraspinous ligament, the needle, with its bevel directed cephalad, is slowly advanced a further 2 cm until it rests firmly in the interspinous ligament. The trocar is removed and a low-friction (loss of resistance) syringe is attached. After passing the interspinous ligament, the needle must be advanced carefully, millimeter by millimeter, in the direction of the ligamentum flavum. The thumb of the right hand applies pressure on the syringe plunger. *Loss of resistance* indicates that the epidural space has been reached. Extreme care should be exercised at the thoracic level since the spinal cord lies beneath the dura and can be damaged if the needle tip is advanced beyond the epidural space.

Fig. 41.43 Midline approach for thoracic epidural (With permission from Danilo Jankovic)

Paramedian Approach for Upper to Mid-thoracic Levels

At this level, the puncture site is located about 1–1.5 cm lateral from the caudal edge of the lower spinous process. A fan-shaped local anesthesia infiltration is used to anesthetize the skin and also to identify the depth of the vertebral arches (laminae). The epidural needle is introduced in a *cranio-medial direction* at an angle of about 10–15° to the sagittal level and about 35–45° to the skin surface (Fig. 41.44). The only ligament that needs to be penetrated on the way to the epidural space is the ligamentum flavum.

The trocar is then removed from the puncture needle and identification of the epidural space is carried out using a loss-of-resistance syringe. If a bone is contacted, the needle is withdrawn by 0.5 cm, walked off the bone in a medial/cephalad direction until the ligamentum flavum is pierced.

After accessing the epidural space, a catheter is threaded 3–4 cm in the space akin to that for lumbar levels. However, one should not inject more than 3–4 ml of test dose at a time at thoracic levels as they tend to spread more. Using a larger volume may lead to profound hypotension due to a widespread sympathetic block.

Fig. 41.44 The needle angulation for a mid-thoracic paramedian approach (With permission from Danilo Jankovic)

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

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

Troubleshooting an Inadequate or Ineffective Epidural Block

(a) *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 [74]. An inadequate block in lower segments (L5–S1) may be difficult to troubleshoot in particular.
(b) *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 [75]. A 2 % lignocaine solution with epinephrine is most effective in dealing with missed segments or an inadequate block.

Assessment of the Block

Similar to the subarachnoid block, an epidural block leads to sensory, autonomic, and motor blockade. These can be assessed as follows:

(a) *Sensory block*: this can be assessed by testing for loss of touch, temperature, or pinprick. A differential block is noted between the complete loss of cold sensation (being two dermatomes cephalad) and the complete loss of both pinprick and light touch sensation (being caudal) [76].
(b) *Autonomic block*: this can be subjectively judged by the skin temperature in the involved areas and the degree of blood pressure drop (sympathetic block). Digital plethysmogram and skin conductance are used in research settings to test this objectively.
(c) *Motor block*: this can be assessed by using the Bromage scale for a lumbar epidural and a RAM (rectus abdominis muscle) test for thoracic epidural [77, 78]. These are summarized in Tables 41.5 and 41.6.

Table 41.5 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 41.6 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
40	Can lift only shoulders off the bed
20	An increase in abdominal muscle tension can be felt during effort; no other response seen

Considerations in Patients with Challenging Anatomy

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

Patients with High Body Mass Index

The anthropometric changes associated with obesity make performing a neuraxial block particularly difficult. Difficulty in proper positioning, obscured anatomical landmarks, increased depth of the ligamentum flavum, and the occasional inadequacy of usual equipment (e.g., needle too short) contribute to making neuraxial blocks in obese technically challenging [79]. This can result in a higher incidence of dural punctures while performing epidural anesthesia in morbidly obese patients [80]. Ultrasound helps in the correct identification of midline, intervertebral spaces, and estimates of depth of the ligamentum flavum. It has been successfully used to improve the success rate of epidural placement in obese parturients [81].

Patients with Scoliosis

Lateral deviation of the spine is accompanied by the rotation of the vertebral bodies toward the convex side of the curvature, while the spinous processes are rotated toward the concave side [82]. This makes performing a neuraxial block quite difficult. Ultrasound assists in identifying the lateral curvature and rotation and in its quantifications. 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 [83]. Alternatively, if a midline insertion is used, the needle should be directed in a transverse plane, toward the convex side [84].

Patients with Previous Spine Surgery

Epidural fibrosis following spine surgery, altered spine 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 [85–87].

While the absence of spinous process 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 [88, 89]. 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 patchy block.

Ultrasound can help immensely to locate the intervertebral space, identify the interlaminar window, and visualize and estimate the depth of the ligamentum flavum [90].

Pharmacology of Neuraxial Drugs

Many local anesthetics and other adjuvant drugs are used for the conduct of a spinal anesthetic. A reliably rapid onset, adequate distribution and duration, and timely return of the neurological function make spinal anesthesia a good choice for many procedures. However, the successful application of a spinal anesthetic requires a good understanding of the effects of intrathecal drugs and factors that determine them.

Pharmacokinetics of Intrathecal Local Anesthetics

Determinants of Intrathecal Distribution

The local anesthetic deposited within the subarachnoid space spreads to the nerve via bulk flow. Many factors have been proposed to influence the spread of local anesthetics within the subarachnoid space [91, 92]. These may be classified as:

Characteristics of Injected Drug

(a) *Baricity*: it is defined as the ratio of the density of the local anesthetic solution relative to the patient CSF at 37 ° C. *Isobaric*, hyperbaric, and *hypobaric* solutions have same, greater, and less density than the CSF, respectively. While hyperbaric solutions will sink to the most dependent areas within the subarachnoid space, the hypobaric solutions rise upward toward the nondependent areas. In general, hyperbaric solutions will produce a greater spread than isobaric or hypobaric solutions [93].

(b) *Mass of the drug*: 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 [94]. For

hyperbaric solutions, this may not always be true, with some studies finding no effect [95].

(c) *Effect of additives*: while the addition of vasoconstrictors prolong the block duration, the addition of opioids may increase spread and delay block recession [96, 97].

Technical Considerations

(a) *Patient position*: immediately after, a spinal anesthetic determines the extent of spread under the influence of gravity. This is further influenced by the curvatures of the spine [95, 98].

(b) *Level of injection*: for an isobaric solution, a higher level of injection results in a greater cephalad spread of the block [99]. This is not consistently observed with hyperbaric solutions where the effect of gravity may be more profound [100].

(c) *Needle direction*: turning the needle aperture cephalad may result in a higher spread of the drug, with a shorter duration of action and faster resolution of the block [101]. Cephalad angulation of insertion has shown similar results [102].

(d) *Speed of injection*: has clinically minimal effects.

(e) *Barbotage*: may shorten the time of onset with hyperbaric solutions [103].

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 cephalad spread, and lowering doses is recommended [104, 105].

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:

(a) Concentration of the local anesthetic in the CSF

(b) The surface area of the nerve root exposed to the CSF [106]

(c) The lipid content of the nerve root (since local anesthetics are lipid soluble)

(d) 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:

(a) Vascular absorption of the local anesthetic (this is the most important route) [107]

(b) Escape of the drug to the epidural space, with subsequent vascular absorption [108]

(c) Lipophilicity of the local anesthetic (highly lipophilic drugs such as bupivacaine have a slower elimination due to greater binding with the neuronal tissue) [109]

Determinants of Duration

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

(a) *Physicochemical properties of the local anesthetic chosen*: while prilocaine and 2-chloroprocaine are short-acting agents, lignocaine and mepivacaine are short- to intermediate-acting local anesthetics. Bupivacaine, levobupivacaine, and ropivacaine are longer-acting agents. However, it must be noted that there is wide inter-patient variability.

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

(c) *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 [110].

(d) *Addition of adjuvants*: as mentioned above, the addition of vasoconstrictors and opioids may delay the regression of the block [111, 112].

Intrathecal Local Anesthetics

The physicochemical properties of local anesthetics such as lipid solubility and protein binding impact the duration of block. Depending upon this, these local anesthetics may be classified as follows:

Short-Acting Agents

(a) *Procaine* 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 syndromes (TNS) [113, 114].

(b) *2-Chloroprocaine* 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 [115].

(c) *Prilocaine* 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 [116, 117].

Short- to Intermediate-Acting Agents

(a) *Lignocaine* 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 the higher frequency of TNS observed with its use (15–33 %) [118].

(b) *Mepivacaine* is an amino-amide with similar profile to lignocaine but lower incidence of TNS (3–6 %).

Table 41.7 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	

Long-Acting Agents

(a) *Tetracaine* 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.

(b) *Bupivacaine* 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 the incidence of block failures [119].

(c) *Levobupivacaine*: this less cardiotoxic stereoisomer of bupivacaine is almost identical to bupivacaine in its spinal anesthetic profile [120].

(d) *Ropivacaine* 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 [121].

Dosages and duration of commonly used local anesthetics are summarized in Tables 41.7 and 41.8.

Table 41.8 Dosage with isobaric local anesthetic

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

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

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

(a) *Morphine* 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 mcg, 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 [122]. Higher doses of intrathecal morphine are associated with higher incidence of side effects such as nausea, vomiting, pruritus, urinary retention, and respiratory depression [123, 124].

(b) *Fentanyl* 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 mcg, 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.

(c) *Sufentanil* is a lipophilic opioid used in the dose range of 2.5–7.5 mcg. It has been used in orthopedic surgery and labor analgesia [125, 126].

Vasoconstrictors

These drugs reduce the vascular uptake of intrathecal local anesthetics, thereby prolonging their duration. However, the significant prolongation is observed when vasoconstrictors are added to tetracaine, when compared with their use along with lignocaine or bupivacaine [127]. The recommended dose range of intrathecal *epinephrine* is 0.2–0.3 mg and that of *phenylephrine* is 2–5 mg. Due to delay in return of sacral autonomic function causing delay in the ability to void and increased risk of urinary retention, the use of vasoconstrictors is not recommended in ambulatory surgery [111].

α2-Adrenergic Agonists

α2-Adrenergic agonists such as *clonidine* and *dexmedetomidine* act on α2-adrenergic receptors in *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 [128]. The recommended doses of clonidine is 15–150 mcg (but lower doses are advocated), while that of dexmedetomidine is 3 mcg [129, 130].

Pharmacology of Epidurally Administered Drugs

The precise site of action of epidural local anesthetic is not known. However, they are distributed by resorption into the circulation (via the epidural venous plexus), diffuse through the dura into the CSF, and spread laterally through the intervertebral foramina (associated paravertebral block of the spinal nerves) [131].

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

(a) *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, as opposed to a more selective sensory block produced by using lower concentrations [132].

(b) *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 [133].

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

(d) *Length of catheter in space*: threading an epidural catheter more than 5 cm may cause lateral location of the catheter tip, resulting in missed segments or unilateral block.

(e) *Patient factors*: increasing age, shorter height, and increased body mass index are associated with increased spread, but this is highly variable and cannot be predicted. The epidural spread is not affected by differences in gender.

Epidurally Used Local Anesthetics

Nearly all local anesthetics have been used for epidural block. They 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

Table 41.9 Commonly used local anesthetic agents for a surgical epidural block

Drug and concentration	Usual 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
Etidocaine 1–1.5 %	15–30	10–15	120–240	120	300–480

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 for outpatients. Commonly used agents with doses are mentioned in Table 41.9.

In general, more dilute concentrations suffice for analgesia, while higher concentrations are used for a surgical block. The total dose and volume needed depends upon the surgery and other factors already discussed in section "Management of the patient after an epidural block".

Epidurally Administered Adjuvants

Similar to spinal anesthetic, many adjuvants have been used to improve the quality of an epidural block. These are summarized below.

Epinephrine
In a concentration of 2.5–5 mcg/ml (1:400,000–1:200,000), epinephrine prolongs both the sensory and motor block when added to short- to intermediate-acting local anesthetics [134]. 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 the spinal cord [135]. 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 [136].

Clonidine
Clonidine prolongs the sensory block only, when added to epidural local anesthetics. It is used in doses of 150–300 mcg. Hypotension and sedation are common secondary to systemic uptake.

Opioids
Commonly used epidural opioids include fentanyl (0.5–0.15 mcg/kg), sufentanil (0.3–0.7 mcg/kg), hydromorphone (0.8–1.5 mg), and morphine (4–6 mg) [137].

Bicarbonate
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 [138].

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 caused by the intrathecal local anesthetic.

(a) Hypotension: arteriolar dilation and venous pooling lead to hypotension, which is the most frequent complications (16–33 %) observed [139]. A block above T5, emergency surgery, age greater than 40, chronic hypertension, a combined spinal–general anesthetic, and an intrathecal injection above L2–L3 are risk factors for developing hypotension [39]. Although hypotension mostly follows immediately after the neuraxial block, it may be delayed as well. Epidural anesthetic in general is associated with a more gradual fall of blood pressure, making it a better choice in certain circumstances. Prophylactic fluid administration (20 ml/kg) and use of vasopressors such as ephedrine (in 5–10-mg increments) or phenylephrine (50–100-mcg increments) can be used to effectively counteract hypotension.

(b) Bradycardia: results usually 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. 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 [140]. Anticholinergics such as atropine and adrenergics such as ephedrine are commonly used to treat this.

(c) Cardiac collapse: asystole and cardiac arrest following a spinal is a known complication [34]. It is usually preceded by bradycardia resulting from the mechanisms described above.

Nausea and Vomiting
It is associated with hypotension (hypoperfusion of the chemoreceptor trigger zone) and the use of opioids (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 by dexamethasone and 5-HT$_3$ antagonists (ondansetron) [141].

Tissue Trauma and Back Pain
Multiple attempts at a neuraxial block lead to trauma to soft tissue and ligaments. This can contribute to persistent backache [142]. However, other factors may have a role to play as well.

Total Spinal Anesthetic

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) [143, 144]. 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 life-threatening and requires immediate treatment.

Management: this involves prompt recognition, securing the airway, ventilation, and supporting the hemodynamics till spontaneous recovery of the patient.

- Immediate tracheal intubation (thiopental 1–2 mg/kg b.w. routinely ca. 150 mg i.v.); succinylcholine if appropriate, since the muscles of mastication are not affected
- Ventilation with 100 % oxygen
- Raising the legs
- Rapid volume administration
- Atropine
- Vasopressor
- Dopamine infusion
- Careful cardiovascular monitoring

Subdural Anesthetic

This presents as widespread but ineffective patchy anesthesia (Fig. 41.45) [145]. Subdural injection can never be excluded with certainty. It may occur slightly more frequently after spinal anesthesia or myelography than after epidural anesthesia. The subdural space is at its widest in the cervical region, particularly dorsolaterally. It does not end at the great foramen as does the epidural space but continues cranially.

(a) *Warning signs*: 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.

Trigeminal nerve: trigeminal nerve palsy, with accompanying paresthesias in the area supplied by the nerve and transient weakness of the muscles of mastication with simultaneous Horner's syndrome, has been observed after high epidural anesthesia or subdural spread [146–148].

Horner's syndrome: Horner's syndrome is produced after neuraxial anesthesia with a high spread of the injected local anesthetic and block of very sensitive sympathetic nerve fibers in the areas of segments T4–C8 [148, 149]. Most often, Horner's syndrome is seen after high spinal or epidural anesthesia in obstetrics and when there is subdural spread of the local anesthetic [150]. Relatively rapid resolution of the symptoms is characteristic.

(b) *Differential diagnosis*:

Total spinal anesthesia: this has a dramatic course, unrecordable blood pressure and respiratory arrest, and takes a longer time required for symptoms to resolve.

(c) *Prophylaxis*:

- Individual dosage and dose reduction in older patients, pregnant patients, obese patients, and those with diabetes mellitus or arteriosclerosis
- Incremental injection in epidural anesthesia

Dural Tap

It presents as a gush of CSF through the epidural needle or upon aspiration through the catheter (Fig. 41.45) [151]. 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 development of post-dural puncture headache.

Local Anesthetic Toxicity

Inadvertent deposition of drug into a vein or systemic absorption of local anesthetic following 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

These include the following:

(a) Direct needle trauma: this commonly occurs at the time of performance of the block and is associated with sever paresthesia in the dermatomal distribution of the nerve root injured (Fig. 41.45) [152].

(b) Neurotoxicity: all local anesthetics are potentially neurotoxic [153]. Despite this, local anesthetic-induced neural damage is rarely seen clinically.

(c) 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 lignocaine have been implicated in their development [154].

(d) 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 [155].

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 a localized back pain and 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.
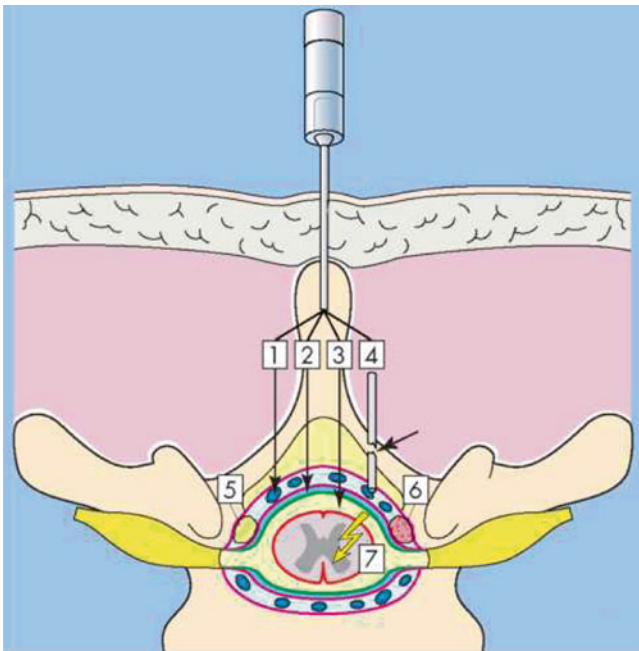

Fig. 41.45 Complications. (*1*) Intravascular injection, (*2*) subdural injection, (*3*) subarachnoid injection, (*4*) catheter shearing, (*5*) epidural abscess, (*6*) epidural hematoma, and (*7*) injury to the spinal cord and nerve roots (With permission from Danilo Jankovic)

Post-dural Puncture Headache (PDPH)

It is a relatively common complication of a 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 [44].

(a) *Mechanism*: the proposed mechanism of the headache is the loss of CSF causing decrease in CSF pressure. This causes sagging of intracranial structure, with consequent traction on pain-sensitive structures (such as meninges, cranial nerves, and veins) [156]. The second hypothesis suggests that decreased CSF pressure leads to intrathecal hypotension and painful vasodilatation of the intracranial blood vessels (known as the "intracranial vascular response") [157]. 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.

(b) *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 [158].

(c) *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 abducent nerve and vestibulocochlear nerve are most frequently affected (Fig. 41.46). The long intracranial course of the abducent 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 [150]. When precise audiometric examinations are carried out, unilateral or bilateral hypoacusis (vestibulocochlear nerve involvement) can be observed in 0.4–40 % of patients with CSF hypotension syndrome [150]. The prognosis is good.

(d) *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 (after accidental dural perforation in attempted epidural anesthesia when using the loss-of-resistance technique with air) [159].

(e) *Initial management* 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 [160–162]. 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 and possibly also increase [beta]-endorphin output [163]. This may thus relieve low CSF pressure and also provide analgesia. Sumatriptan, a serotonin-type 1D receptor agonist, may relieve headache by producing cerebral vasoconstriction [164].

(f) *Invasive management*: the gold standard for the treatment of PDPH remains an autologous blood patch (Figs. 41.47 and 41.48). Its mechanism appears to be the tamponade of dural leak, with subsequent improvement of CSF pressures [165]. It often produces a dramatic relief of symptoms but may need to be repeated occasionally.
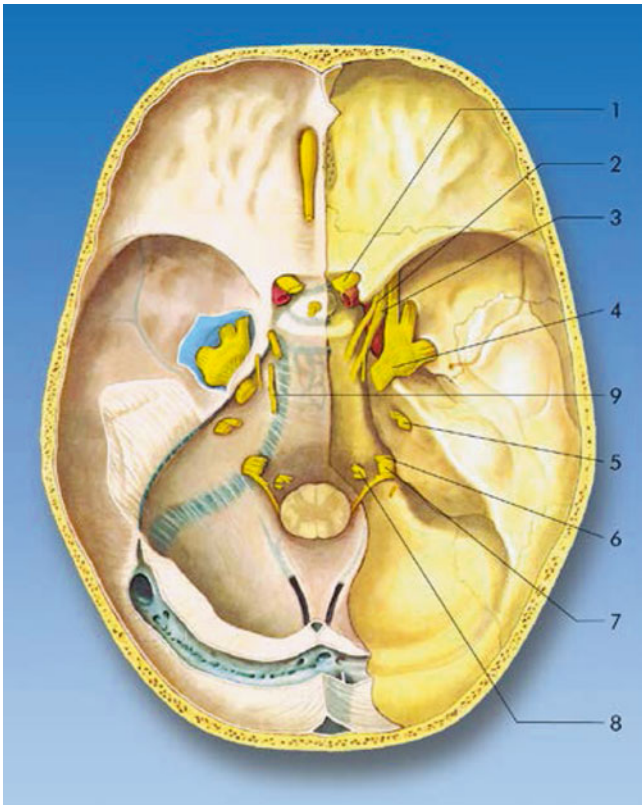
Fig. 41.46 Cranial nerves. (*1*) Optic nerve, (*2*) trochlear nerve, (*3*) trigeminal nerve, (*4*) vestibulocochlear nerve, (*5*) glossopharyngeal nerve, (*7*) vagus nerve, (*8*) hypoglossal nerve, and (*9*) abducent nerve (With permission from Danilo Jankovic)
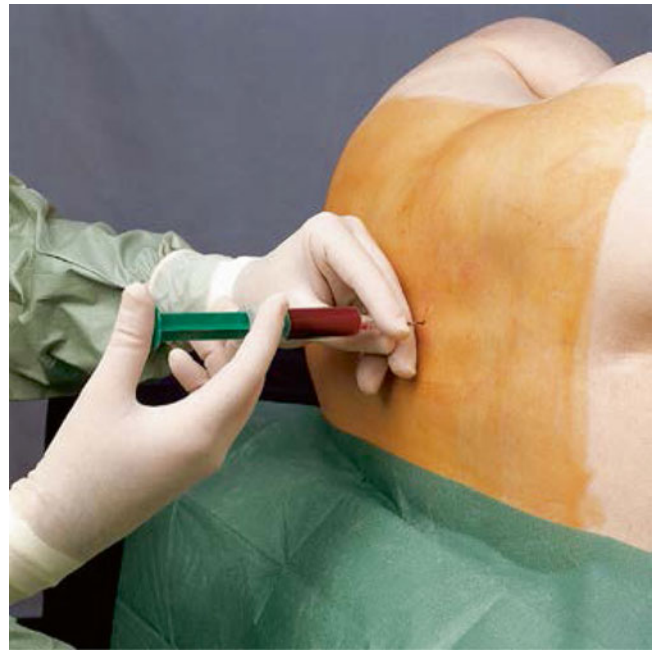

Fig. 41.48 Epidural injection of homologous blood (With permission from Danilo Jankovic)

Fig. 41.47 Sterile withdrawal of blood (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. Patient with altered hemostasis and ongoing antiplatelet or anticoagulant therapy is 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 toward the possibility of neural damage. Prompt imaging and neurosurgical consultation 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 [166]. Guidelines concerning neuraxial anesthesia in anticoagulated patents should be followed to minimize the risks of this devastating complication [167].

Record and checklist

	1.h			2.h		
	15	30	45	15	30	45

mm Hg: 220, 200, 180, 160, 140, 120, 100, 80, 60, 40, 20 / O₂
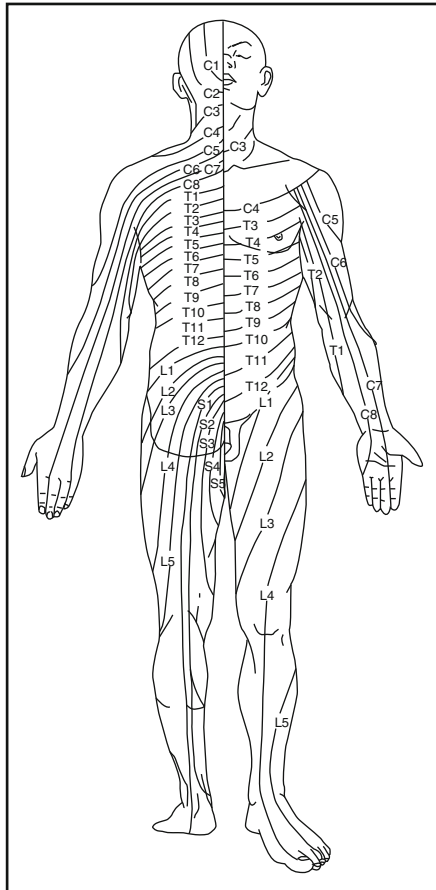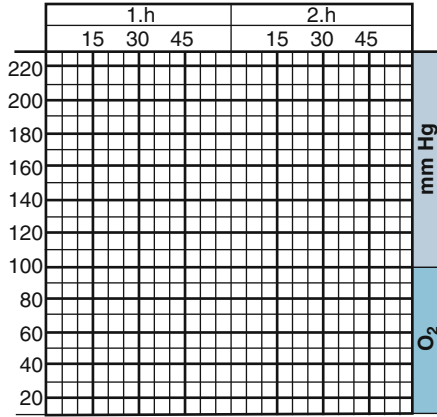
With permission from Danilo Jankovic

Lumbar epidural anesthesia

Name: _____ Date: _____

Diagnosis: _____

Premedication: ☐ No ☐ Yes _____

Neurological abnormalities: ☐ No ☐ Yes _____

Purpose of block: ☐ *Surgical* ☐ *Therapeutic* ☐ *Diagnostic*

Needle: ☐ *Tuohy G___* ☐ *Other ___*

i.v. access, infusion: ☐ *Yes*

Monitoring: ☐ *ECG* ☐ *Pulse oximetry*

Ventilation facilities: ☐ *Yes (equipment checked)*

Emergency equipment *(drugs):* ☐ *Checked*

Patient: ☐ *Informed*

Position: ☐ *Lateral decubitus* ☐ *Sitting*

Access: ☐ *Median* ☐ *Paramedian*

Injection level: ☐ *L3/L4* ☐ *Other _____*

Injection technique: ☐ *Loss of resistance* ☐ *Other _____*

 ☐ *Ultrasound guided* ☐ *Transducer* ☐ *Curved* ☐ *Linear*

Approach: ☐ *In plane* ☐ *Out of plane*

Epidural space: ☐ *Identified*

Aspiration test: ☐ *Carried out*

Test dose: _____ Epinephrine added: ☐ *Yes* ☐ *No*

Check on sensorimotor function after 5 min: ☐ *Carried out*

Abnormalities: ☐ *No* ☐ *Yes* _____

Injection:

☐ Local anesthetic: _____ *mL* _____ %
  (incremental)

☐ Addition: _____ *μg/mg*

Patient's remarks during injection:

☐ *None* ☐ *Pain* ☐ *Paresthesias* ☐ *Warmth*

Duration and area: _____

Objective block effect after 20 min:

☐ *Cold test* ☐ *Temperature measurement before* _____ *°C* *after* _____ *°C*

☐ *Sensory: L* _____ *T* _____

☐ *Motor*

Complications:

☐ *None* ☐ *Pain*

☐ *Radicular symptoms* ☐ *Vasovagal reactions*

☐ *BP drop* ☐ *Dural puncture*

☐ *Vascular puncture* ☐ *Intravascular injection*

☐ *Massive epidural anesthesia* ☐ *Total spinal anesthesia*

☐ *Subdural spread* ☐ *Respiratory disturbance*

☐ *Drop in body temperature* ☐ *Muscle tremor*

☐ *Bladder emptying disturbances* ☐ *Postdural puncture headache*

☐ *Back pain* ☐ *Neurological complications*

Special notes: _____

_____

Record and checklist

	1.h			2.h		
	15	30	45	15	30	45

mm Hg: 220 200 180 160 140 120 100 80 60 40 20 — O₂

With permission from Danilo Jankovic

Lumbar catheter epidural anesthesia

Name: _____ Date: _____

Diagnosis: _____

Premedication: ☐ No ☐ Yes _____

Neurological abnormalities: ☐ No ☐ Yes _____

Purpose of block: ☐ Surgical ☐ Therapeutic

Needle: ☐ Tuohy G___ ☐ Other ___

i.v. access, infusion: ☐ Yes

Monitoring: ☐ ECG ☐ Pulse oximetry

Ventilation facilities: ☐ Yes (equipment checked)

Emergency equipment (drugs): ☐ Checked

Patient: ☐ Informed

Position: ☐ Lateral decubitus ☐ Sitting

Access: ☐ Median ☐ Paramedian

Injection level: ☐ L3/L4 ☐ Other _____

Injection technique: ☐ Loss of resistance ☐ Other _____

  ☐ Ultra sound guided ☐ Transducer ☐ Curved ☐ Linear

Approach: ☐ In plane ☐ Out of plane

Epidural space: ☐ Identified

Catheter: ☐ Advanced 3–4 em cranially

Aspiration test: ☐ Carried out

Catheter end: ☐ Placed deeper than the puncture site

Bacterial filter: ☐

Test dose: _____ Epinephrine added: ☐ Yes ☐ No

Check on sensorimotor function after 5 min: ☐ Carried out

Abnormalities: ☐ No ☐ Yes_____

Injection:

☐ Local anesthetic: _____ mL _____ %
  (incremental)

☐ Addition: _____ μg/mg

☐ Subsequent injection (incremental): _____ mL _____ %

Patient's remarks during injection:

☐ None ☐ Pain ☐ Paresthesias ☐ Warmth

Duration and area: _____

Objective block effect after 20 min:

☐ Cold test ☐ Temperature measurement before_____°C   after _____°C

☐ Sensory: L _____ T _____ ☐ Motor _____
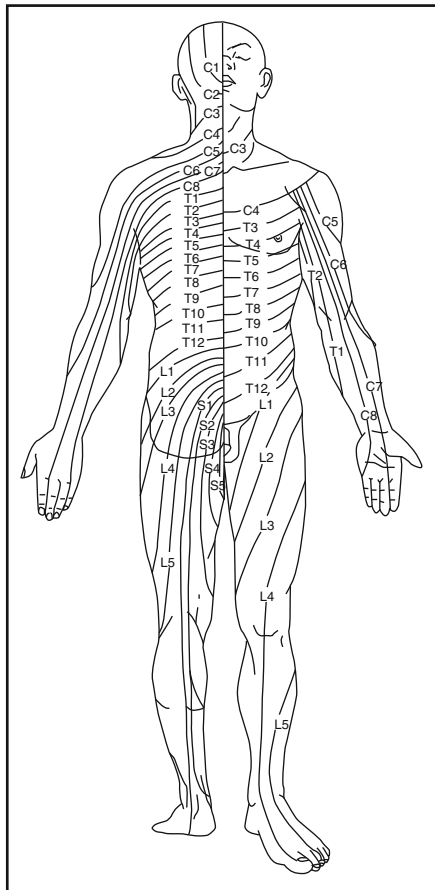
Complications:

☐ None ☐ Radicular symptoms ☐ BP drop ☐ Vascular puncture
☐ Massive epidural anesthesia ☐ Subdural spread ☐ Drop in body temperature
☐ Bladder emptying disturbances ☐ Back pain ☐ Pain ☐ Vasovagal reactions
☐ Dural puncture ☐ Intravascular injection ☐ Total spinal anesthesia
☐ Respiratory disturbance ☐ Muscle tremor ☐ Postdural puncture headache
☐ Neurological complications

Special notes:

_____

Record and checklist

	1.h			2.h		
	15	30	45	15	30	45

220
200
180
160
140
120
100
80
60
40
20

mm Hg

O₂

With permission from Danilo Jankovic

Spinal anesthesia

Name: _____ Date: _____

Diagnosis: _____

Premedication: ☐ No ☐ Yes _____

Neurological abnormalities: ☐ No ☐ Yes _____

Purpose of block: ☐ *Surgical*

Needle: ☐ *Pencil-Point G* _____ ☐ *Quincke* ☐ *Other*

i.v. access, infusion: ☐ *Yes*

Monitoring: ☐ *ECG* ☐ *Pulse oximetry*

Ventilation facilities: ☐ *Yes (equipment checked)*

Emergency equipment *(drugs):* ☐ *Checked*

Patient: ☐ *Informed (behavior after block)*

Position: ☐ *Lateral recumbent* ☐ *Sitting*

Access: ☐ *Median* ☐ *Paramedian* ☐ *Taylor*

Injection level: ☐ *L3/4* ☐ *Other*

CSF: ☐ *Clear* ☐ *Slightly bloody* ☐ *Bloody*

Abnormalities: ☐ *No* ☐ *Yes* _____

Injection technique: ☐ *Traditional* ☐ *Ultrasound guided*

Transducer: ☐ *Curved* ☐ *Linear*

Approach: ☐ *In plane* ☐ *Out of plane*

Local anesthetic: _____ % _____ mg

☐ *Hyperbaric* ☐ *Isobaric*

Addition to LA: _____ % _____ µg/mg

Patient's remarks during injection:

☐ *None* ☐ *Pain* ☐ *Paresthesias* ☐ *Warmth*

Duration and area: _____

Objective block effect after 15 min:

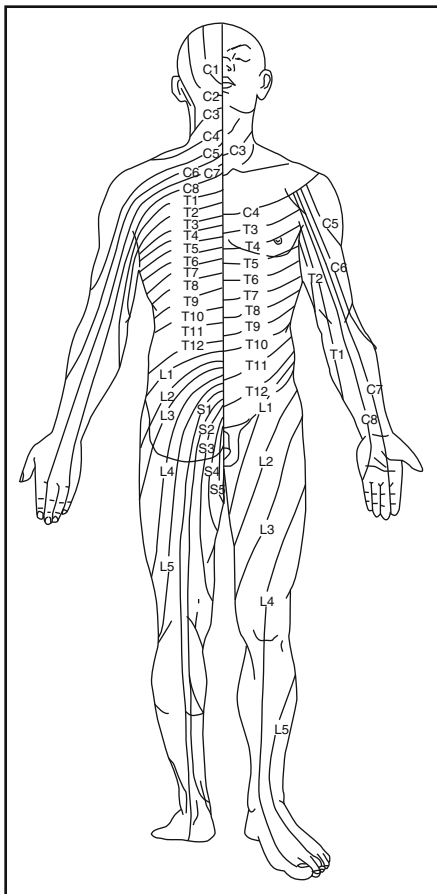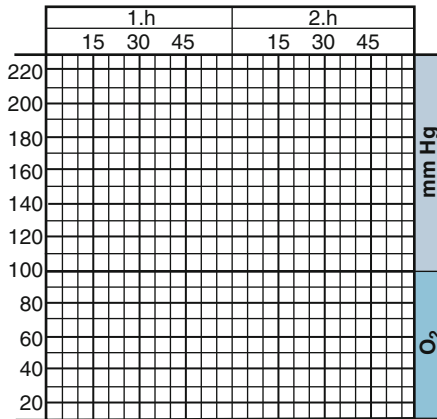☐ *Cold test* ☐ *Temperature measurement before* ____°C *after* ____°C

☐ *Sensory: L* _____ *T* _____

☐ *Motor*

Complications:

☐ *None* ☐ *Pain*

☐ *Radicular symptoms* ☐ *Vasovagal reactions*

☐ *BP drop* ☐ *Total spinal anesthesia*

☐ *Subdural spread* ☐ *Respiratory disturbance*

☐ *Drop in body temperature* ☐ *Muscle tremor*

☐ *Bladder emptying disturbances* ☐ *Back pain*

☐ *Postdural puncture headache* ☐ *Neurological complications*

Special notes:

_____
_____
_____
_____
_____
_____
_____

Record and checklist

Continuous spinal anesthesia

Name: _____   Date: _____
Diagnosis: _____
Premedication: ☐ No   ☐ Yes _____
Neurological abnormalities: ☐ No   ☐ Yes _____

Purpose of block: ☐ *Surgical*   ☐ *Therapeutic (postoperative)*
   Needle: ☐*G* ____ *Tip:* ____ ☐ *Spinal catheter G* _____ *(micro, macro)* _____
i.v. access, infusion: ☐ *Yes*
Monitoring: ☐ *ECG*   ☐ *Pulse oximetry*
Ventilation facilities: ☐ *Yes (equipment checked)*
Emergency equipment *(drugs):*   ☐ *Checked*
Patient: ☐ *Informed*

Position: ☐ *Lateral recumbent*   ☐ *Sitting*
Access: ☐ *Median*   ☐ *Paramedian*
Injection level: ☐ *L3/4*   ☐ *Other* _____
Technique: ☐ *Through-the-needle*   ☐ *Over-the-needle*
Subarachnoid space: ☐ *Identified*
Catheter: ☐ *Advanced 2–3 em*
Aspiration test: ☐ *No*   ☐ *Yes*
Bacterial filter: ☐ *No*   ☐ *Yes*
Abnormalities: ☐ *No*   ☐ *Yes* _____
Injection:
Local anesthetic (isobaric, hyperbaric): _____ *mg* _____ %
   (incremental)
☐ *Opioid* _____ *(µg)*   ☐ *Other* _____ *µg/mg/mL*
☐ *Subsequent injection of* _____ *mL* _____ %

Patient's remarks during injection:
☐ *None*   ☐ *Pain*   ☐ *Paresthesias*   ☐ *Warmth*
Duration and area: _____
Objective block effect after 15 min:
☐ *Cold test*   ☐ *Temperature measurement before* _____°C *after* ____°C
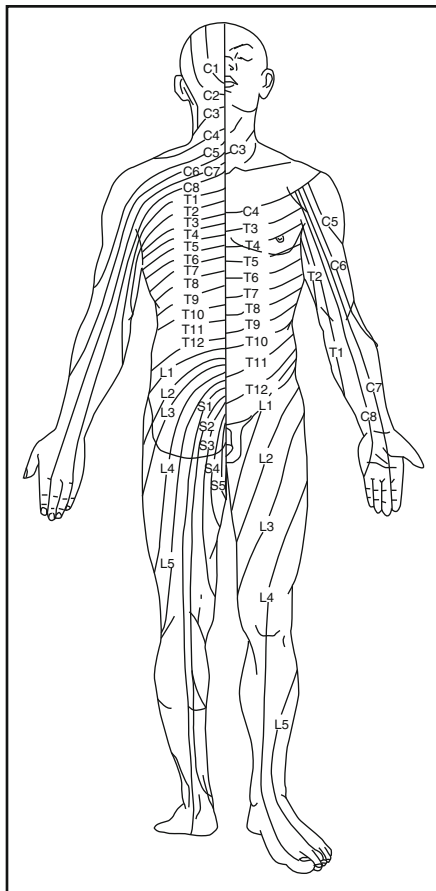☐ *Sensory: L* _____ *T* _____
☐ *Motor*

Complications:
☐ *None*   ☐ *Pain*
☐ *Radicular symptoms*   ☐ *Vasovagal reactions*
☐ *BP drop*   ☐ *Total spinal anesthesia*
☐ *Subdural spread*   ☐ *Respiratory disturbance*
☐ *Drop in body temperature*   ☐ *Muscle tremor*
☐ *Bladder emptying disturbances* ☐ *Back pain*
☐ *Postdural puncture headache*   ☐ *Neurological complications*

Special notes:

_____

With permission from Danilo Jankovic

Record and checklist

Thoracic catheter epidural anesthesia

Name: _____ Date: _____
Diagnosis: _____
Premedication: ☐ No   ☐ Yes _____
Neurological abnormalities: ☐ No   ☐ Yes _____

Purpose of block: ☐ *Surgical*   ☐ *Treatment (postoperative)*
Needle: ☐ *Tuohy G*___   ☐ *Other* ___
i.v. access, infusion: ☐ *Yes*
Monitoring: ☐ *ECG*   ☐ *Pulse oximetry*
Ventilation facilities: ☐ *Yes (equipment checked)*
Emergency equipment (drugs):   ☐ *Checked*
Patient: ☐ *Informed*

Position: ☐ *Lateral decubitus*   ☐ *Sitting*
Access: ☐ *Median*   ☐ *Paramedian*
Injection level: ☐ *T* _____
Injection technique: ☐ *Loss of resistance*   ☐ *Other* _____
  ☐ *Ultra sound guided*   ☐ *Transducer* ☐ *Curved* ☐ *Linear*
Approach: ☐ *In plane*   ☐ *Out of plane*
Epidural space: ☐ *Identified*
Catheter: ☐ *Advanced 3–4 em cranially*
Aspiration test: ☐ *Carried out*
Catheter end positioned lower than the injection site   ☐
Bacterial filter: ☐
Test dose: _____ Epinephrine added: ☐ *Yes* ☐ *No*
Check on sensorimotor function after 5 min: ☐ *Carried out*
Abnormalities: ☐ *No*   ☐ *Yes* _____
Injection:
☐ Local anesthetic: _____ mL _____ %
   (incremental)
☐ Addition: _____ *µg/mg*
☐ Additional injection *(incremental)*: _____ mL _____ %

Patient's remarks during injection:
☐ *None*   ☐ *Pain*   ☐ *Paresthesias*   ☐ *Warmth*
Duration and area: _____
Objective block effect after 20 min:
☐ *Cold test*   ☐ *Temperature measurement before* _____ °C   *after* _____ °C
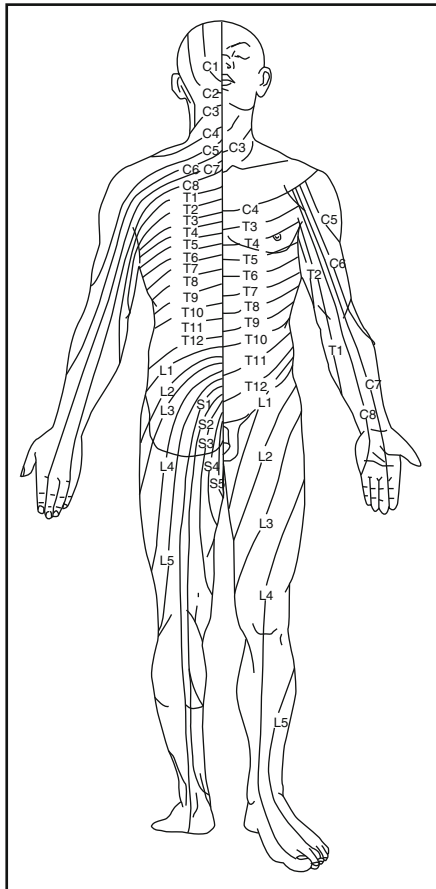☐ *Sensory: L* _____ *T* _____   ☐ *Motor*

Complications:
☐ *None* ☐ *Radicular symptoms* ☐ *BP drop* ☐ *Vascular puncture*
☐ *Massive epidural anesthesia* ☐ *Subdural spread* ☐ *Drop in body temperature*
☐ *Bladder emptying disturbances* ☐ *Back pain* ☐ *Pain* ☐ *Vasovagal reactions*
☐ *Dural puncture* ☐ *Intravascular injection* ☐ *Total spinal anesthesia*
☐ *Respiratory disturbance* ☐ *Muscle tremor* ☐ *Postdural puncture headache*
☐ *Neurological complications*

Special notes:
_____

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