12 Neuraxial Blockade: Epidural Anesthesia

Sreekumar Kunnumpurath, Suneil Ramessur, Adam Fendius, Nalini Vadivelu, and Jasmina Perinpanayagam

Introduction

The first epidural injection was performed in 1901 by Jean-Athanase Sicard and Ferdinand Catheline through the caudal route. The Touhy needle was developed for continuous spinal catheter technique and later adapted for epidural anesthesia by Manual Martinez Curbelo. Its popularity increased due to the potential serious neurological sequelae of spinal injections and the availability of long-acting local anesthetic agents such as bupivacaine

The versatility of epidurals, in their use as a sole anesthetic, supplement for general anesthesia or for analgesia and added benefits in obstetric conditions, makes it a popular regional technique in the USA and UK.

The epidural space can be approached at all levels to provide segmental analgesia and this allows it to have a role in a wide variety of subspecialties including; chronic pain, pediatrics, obstetrics; vascular and even emergency laparotomy patients. Other benefits include attenuating the stress response to surgery, reducing postoperative complications and intraoperative blood loss (and therefore the need for blood transfusion). Reduction in postoperative cardiovascular, respiratory, and metabolic complications, improved wound healing and reduced incidence of venous thrombosis are further advantages [1].

The technique of an epidural can be more challenging than a spinal injection and take longer to perform, the onset of analgesia/anesthesia is longer and the motor blockade is less dense compared to spinal techniques. The incidence of post-dural-puncture headache (PDPH) is significantly higher compared to spinal injections.

Anatomy of the Epidural Space

The epidural space is also known as the extradural or peridural space and extends from the base of the skull to the tip of the sacrum. It encircles the dura from the dural reflections at the foramen magnum cranially down to the sacrococcygeal

S. Kunnumpurath, MBBS, MD, FRCA, FFPMRCA (✉)
Pain Management, Epsom and St. Helier University Hospitals NHS Trust, Carshalton, UK

S. Ramessur, MBBS, BSc(Hons), FRCA, FFPMRCA
Anaesthetics, Guys and St. Thomas' NHS Foundation Trust, London, UK

A. Fendius, MBBS, BSc(Hons), DipIMC, FRCA
Anaesthesia, Oxford University Hospitals NHS Foundation Trust, Oxford, Oxfordshire, UK
e-mail: adam.fendius@ouh.nhs.uk

N. Vadivelu, MBBS, MD, DNB
Department of Anesthesiology, Yale University, New Haven, CT, USA
e-mail: nalini.vadivelu@yale.edu

J. Perinpanayagam, BSc(Hons), MBBS, FRCA
Anaesthetics, St George's University Hospital, London, UK
e-mail: jasmina16@doctors.org.uk

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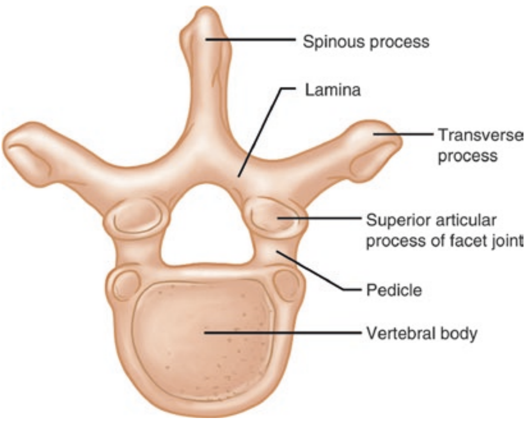

Fig. 12.1 Posterolateral structures

ligament caudally. It is thinnest in the cervical region (2 mm) and thickest in the lumbar region (6 mm).

The vertebral column is made up of 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 3–5 coccygeal vertebrae. The latter two are fused together to form the sacrum and the coccyx, respectively. Though the morphology of the five types of vertebrae differs considerably with regard to size and shape, the basic components for the vertebra remain same. These are the anterior body, lateral pedicles and posterior spinous process. The lamina and the pedicle form the posterolateral structures (Fig. 12.1). The size and shape of the vertebrae vary as we move down along the vertebral column from the cervical to sacral region (see Fig. 12.3), which has implications on the technique of needle insertion into the epidural space. Of notable importance is the variation in angle of the spinous process at the various levels. In the cervical and lumbar regions, the spinous processes are almost horizontal, which permits a midline approach to the space. In the thoracic region, these processes are more acutely angled making a paramedian approach technically easier.

The anatomical borders of the epidural space are superiorly; the foramen magnum, inferiorly; the sacrococcygeal ligament which covers the sacral hiatus and fuses with the coccyx, anteriorly; the vertebral bodies and intervertebral disks and posteriorly the ligamentum flavum.

Ligaments

There are three important ligaments that provide posterior support for the vertebral column and are important when accessing the epidural space.

The *supraspinous* ligament is a continuation of the ligamentum nuchae, which is a thin structure running along the vertebral column joining the tips of adjacent spinous processes. Its thickness increases gradually inferiorly and is maximum in the lumbar region. The *interspinous ligaments* lie beneath the supraspinous ligament and connect adjacent spinous processes. They are thin and inconsequential. The *ligamentum flavum* is a midline structure, which is paired and usually fused in the midline. It is much thicker and offers resistance to a needle passing through it (when the two halves are separate, then it can lead to difficulties in identifying the epidural space by the midline approach with increased risk of dural tap). The *ligamentum flavum* is thinnest in the cervical region and thickens in the thoracic and lumbar region. This is the only ligament that is encountered in the paramedian approach to the epidural space unlike the midline approach where the needle will pass through all three.

Contents of the Epidural Space

The epidural space contains *fat*, *epidural veins*, *spinal nerve roots*, and *connective tissue* (Fig. 12.2). The *epidural fat* lies between the dura and vertebral canal surrounding the spinal cord. It might have a protective role in reducing accidental dural taps during epidural needle insertion. To some extent, this fat can potentially act to modify the effect of drugs injected into the epidural space depending on their lipid solubility. However, the exact role played by this is not very clear. The *epidural venous plexus* is a network of valveless veins known as Batson plexus. They

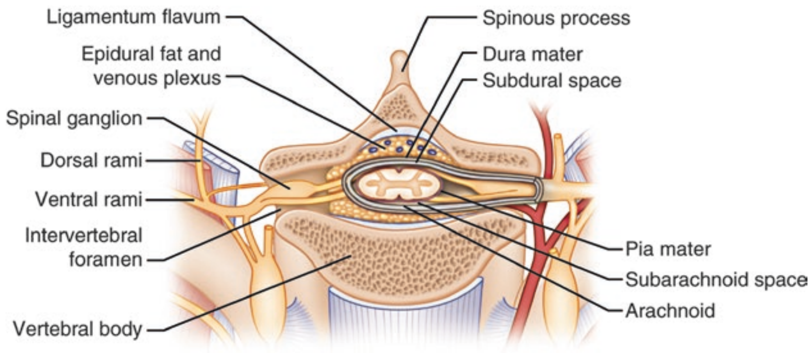

Fig. 12.2 Contents of the epidural space

form a reticular network in the epidural space and transmit pressure fluctuations in the thorax and abdomen as happens during coughing, straining, or during pregnancy. In pregnancy, especially during active labor, these epidural plexuses become highly engorged reducing the volume of the epidural space. The spinal nerve roots lie in the epidural space and, as they exit the spinal cord, carry a short length of the dura, which forms a cuff around these roots. Finally, *the connective tissue* loosely arranged in the epidural space may have some bands and poorly defined septae which can rarely interfere with passing of a catheter or spread of local anesthetic solutions.

Surface Anatomy

Surface landmarks (Table 12.1) and palpation are most commonly used to identify intervertebral level, although both lack accuracy. The vertebra prominens is the most prominent structure noticeable descending down the vertebral column. The other useful surface landmarks are demonstrated in Fig. 12.3. The line joining the superior aspect of the iliac crests is known as Tuffier's line and taken to mark the L4 level.

Table 12.1 Anatomical landmarks for epidural siting

Surface marking	Vertebral level
Vertebra prominence	C7
Root of spine of scapula	T3
Inferior angle of scapula	T7
Rib margin 10 cm from midline	L1
Superior aspect of iliac crest	L4
Posterior superior iliac spine	S2

Special Anatomical Considerations for Caudal Epidural

Although the termination of the spinal cord (conus medullaris) is generally at the level of L2, the cauda equina extends for a variable distance below this (Fig. 12.4) and remains encased within the dural sac, which extends down into the sacral canal. The epidural space can be accessed here, via the sacral hiatus, in the form of caudal epidural anesthesia (Fig. 12.5). The sacral hiatus is the area of S5 (significant individual variability) where the spinous process is absent and can be identified cephalad to the coccyx and in-between the two sacral cornua.

There is significant anatomical variation and in some patients the sacral hiatus lies in close proximity to the anus, which may increase the infection risk of caudal anesthesia.

Physiological Effects of Epidural Blockade

The physiological effects of epidural anesthesia are similar to that of subarachnoid (spinal) anesthesia [2]. The key differences are the onset time

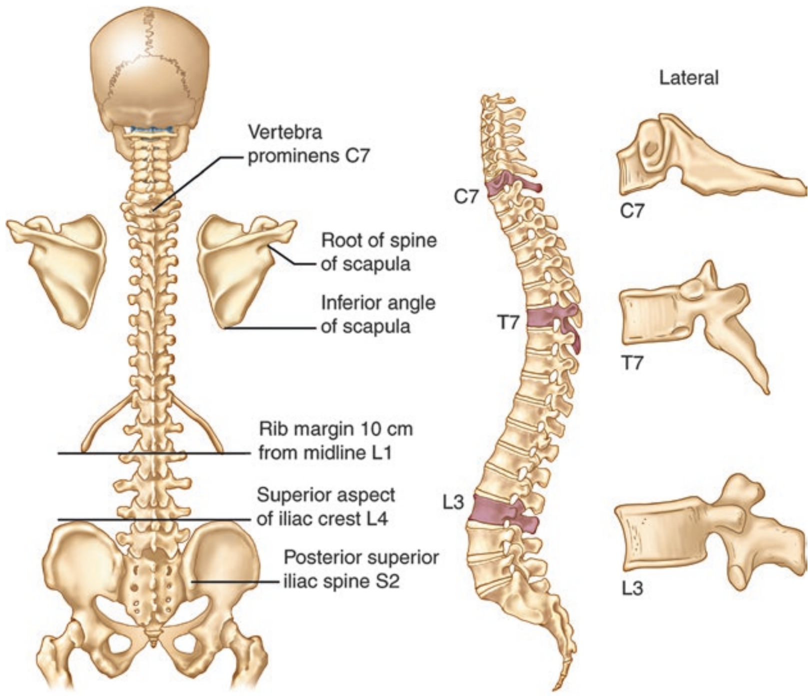

Fig. 12.3 Surface landmarks

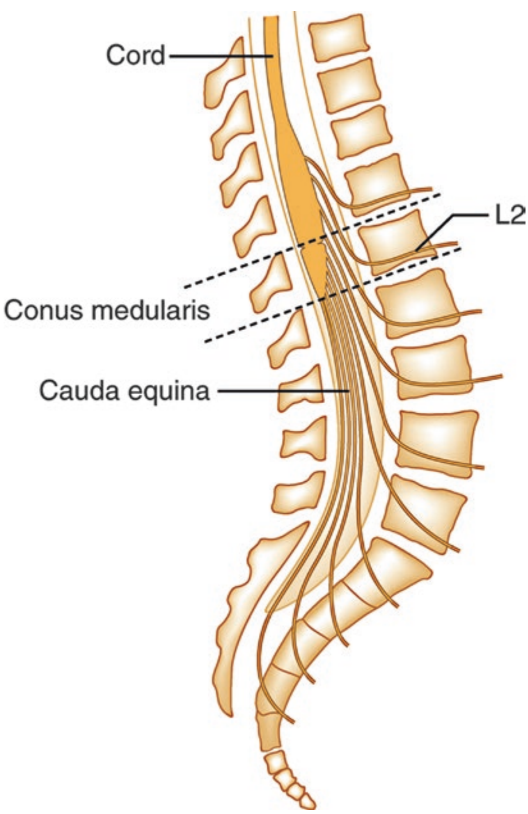

Fig. 12.4 Cauda equine

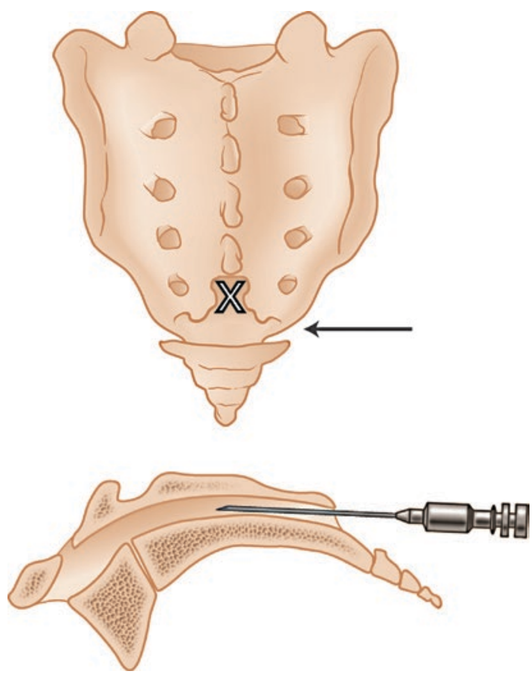

Fig. 12.5 Needle insertion

and the segmental nature of the block produced, due to the restricted epidural spread of the drugs injected. This is an advantage in certain clinical situations (e.g., patients with cardiovascular or respiratory illnesses) where a slower more controlled establishment of blockade is required.

Nervous System

Epidural anesthesia is based on the principle that local anesthetic drugs injected into the epidural space can block spinal nerves at their roots when they leave the spinal cord (Fig. 12.2). Epidural blockade affects both the autonomic and peripheral nervous systems.

Autonomic Nervous System

The sympathetic nerves exit the spinal cord between T1 and L2 and form a sympathetic chain (bilaterally). Blockade of these nerves frequently results in vasodilatation and subsequent hypotension. Higher blocks affecting T1–T5 (cardioaccelerator branches) may result in a reduction in myocardial oxygen demand by reducing inotropy and chronotropy.

Peripheral Nervous System

Epidurals provide a segmental blockade of the peripheral nervous system with caudal and cephalad spread from the point of insertion, the dermatomal distribution of the sensory nerves is shown in Fig. 12.6. This is in contrast to spinal anesthesia, which generally provides complete neural blockade below and, to a variable level, above the level of injection.

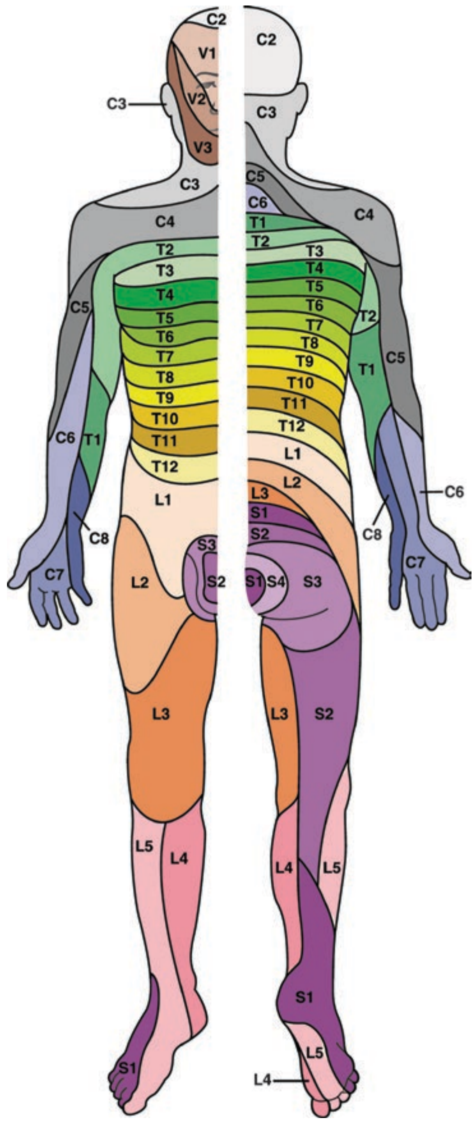

Fig. 12.6 The dermatomal distribution of the sensory nerves

Cardiovascular System

The cardiovascular effects of epidural anesthesia are a result of sympathetic blockade and depend on the level of block and dosage of agents used. Extensive blockade will cause vasodilation, reduced venous return and hypotension as well as reduced adrenal medullary secretions. Compensatory vasoconstriction in the upper body can lead to bradycardia due to the baroreceptor-mediated reflex [3]. In selective lumbar and thoracic epidurals this feature of compensatory vasoconstriction in unblocked segments provides the benefit of hemodynamic stability.

High thoracic blockade affecting T1–T5 will inhibit the cardioaccelerator sympathetic fibers causing bradycardia. This provides a theoretical benefit of reduced oxygen demand, improved coronary perfusion and oxygenation as long as the blood pressure is maintained (spontaneously or pharmacologically).

Respiratory System

There is minimal effect on the respiratory function with epidurals unless the level of block produced is too high. A high thoracic block can affect the function of the accessory muscles of respiration causing distress to patients in the form of difficulty in breathing. Rarely the block can extend above C5 and the phrenic nerve (C3–C5) will be affected causing diaphragmatic paralysis and requiring mechanical ventilation until the block wears off.

The use of epidural analgesia perioperatively improves respiratory function as it provides effective pain relief with minimal motor block, allowing patients to maintain good respiratory function and reduce the risk of respiratory complications such as infection and collapse in the postoperative period.

Gastrointestinal (GI) System

Effects on the GI system are due to blockade of the autonomic nervous system; splanchnic nerve blockade (T5–L1) leads to unopposed parasympathetic activity culminating in increased GI secretions, hypermotility and relaxation of sphincters. These effects can be beneficial in that a small contracted bowel improves access during bowel surgery. An increase in visceral perfusion and early return of postoperative GI motility are preferable following bowel operations. Nausea and vomiting associated with epidural anesthesia are secondary to increased vagal tone and reduction in blood pressure.

Genitourinary System

Epidural anesthesia has no direct effect on renal function; however, a sacral blockade (S2–S4) can lead to urinary retention, requiring catheterization of the bladder.

Effect on Thermoregulation

Shivering is a common feature of epidural injections and the exact mechanism is still not fully known. Suggested mechanisms include vasodilatation and reduction in core body temperature and disruption of the normal thermoregulatory mechanism. The latter is a result of differential nerve blockade allowing selective conduction of cold sensation to the thermoregulatory center or blocking descending inhibitory pathways to the spinal cord.

Indications

These can be broadly divided into three major categories: obstetric anesthesia/analgesia, surgical anesthesia/analgesia and chronic pain interventions.

Obstetric Analgesia

Epidural analgesia has been used for the treatment of labour pains for over 40 years and is considered the gold standard for labor analgesia, despite a number of controversies on its effect on labor.

Epidurals are not only used for analgesia but can also be used to “top up” a block to provide anesthesia for instrumental deliveries, caesarean sections and other operative procedures. They can be sited de novo for elective and emergency procedures where the option to extend and prolong a block will be beneficial especially if extensive postoperative analgesia is anticipated.

The obstetric anesthetists’ association (OAA) has produced an information card to be used when obtaining informed consent for labour epidurals outlining common (failure, hypotension, shivering, post-dural-puncture headache (PDPH) and urinary incontinence), rare (nerve damage), and very rare but serious (infection, hematoma, and paralysis) side effects. These should be discussed at the earliest most appropriate opportunity although the practicality of doing this when patients are in severe distress is questionable.

Adjunct to General Anesthesia

Epidural injections or catheters may be sited preoperatively at various levels in the vertebral column to provide both intraoperative and postoperative analgesia.

Cervical Epidurals

Cervical epidural analgesia (CEA) is a useful technique for surgeries of the upper body however is not commonly used other than the treatment of radicular pain in the upper limbs. The epidural space in the cervical region is narrow with a greater depth of space from the skin compared to lumbar and thoracic regions and has a greater potential for complications. CEA blocks the cardioaccelerator fibers, can partially or completely block the phrenic nerve and needs to be considered in patients with cardiorespiratory disease.

A recent systematic review failed to produce specific recommendations on the use of CEA due to limited evidence and given the significant potential for serious harm the technique should only be performed by experienced providers where there is a strong rationale for its use.

Thoracic Epidurals

These are increasingly being utilized for major abdominal, vascular and cardiothoracic surgery. Thoracic epidural analgesia (TEA) not only provides effective analgesia for the targeted dermatomal site and a selective bilateral sympathetic block, with relative sparing of the lower dermatomes. This facilitates early postoperative ambulation, allows deep breathing and improves postoperative recovery.

The sympathetic block is associated with reduced myocardial oxygen demand and subsequently reduces the risk of postoperative myocardial ischemia. In addition, it reduces the incidence of postoperative ileus and has respiratory function benefits also.

The benefits must be balanced with the risks of performing TEA, particularly in the following patient groups:

1. Shocked patients: in this situation, the loss of sympathetic tone may result in unacceptably severe hypotension with fatal consequences.
2. Patients with potential for major blood loss - the derangement in clotting may make the indwelling epidural catheter a potential risk for epidural hematoma.

Lumbar Epidurals

In addition to use on labor ward as mentioned previously, these can be utilized for abdominal and lower limb surgery. The ensuing sympathetic block can be beneficial in improving tissue perfusion to the lower limbs following vascular or plastic surgery.

The use of a combined spinal–epidural (CSE) technique may be desirable in a procedure where rapid onset, complete anesthesia is required but where the procedure may last longer than the duration of the spinal component alone. In this situation the epidural component may be utilized to prolong the anesthesia without the need to convert to general anesthesia. With CSE higher lumbar level approaches should be avoided to reduce accidental damage to the spinal cord by the spinal needle.

Epidurals can be used to identify landmarks in technically challenging patients due to poor anatomical landmarks or difficult positioning. Here identifying the epidural space with an epidural needle first, followed by the spinal needle through the epidural needle, can rescue the spinal block. This technique avoids multiple attempts and use of lower gauge (thicker) spinal needle can potentially reduce the incidence of PDPH.

Management of Chronic Pain

Steroid injections into the epidural space are frequently used in the treatment of radicular and low back pain. Previously radicular pain was thought to be due to nerve compression; however, more recent work suggests it may be secondary to release of inflammatory markers from damaged intervertebral disks; corticosteroid injection into the epidural space is thought to inhibit this inflammatory process [4]. Delivering the steroids directly to the injured area reduces the systemic effects of steroids and increases the concentration of the drug at the target site. These injections are commonly used to treat nonspecific radiculitis, spinal canal stenosis, and vertebral compression fracture resulting in radicular pain. Its use has also been documented in post-laminectomy syndrome, postherpetic and post-traumatic neuralgia, diabetic neuropathy and myofascial pain.

Spinal Cord Stimulation (SCS) [4]
SCS is supported by randomized controlled trials in the management of failed back surgery syndrome, complex regional pain syndrome, neuropathic pain and ischemic pain. Stimulator electrodes are placed in the epidural space, which can be accessed via a needle or open laminectomy to allow subsequent catheter placement. Spinal cord stimulation has also been used successfully to treat conditions such as urine and fecal incontinence.

Contraindications

Absolute
- Patient refusal
- Local anesthetic allergy
- Infection at the site of injection

Relative
- Shocked patients (hypovolemia, sepsis)
- Aortic stenosis
- Uncooperative patient
- Spinal deformity/previous surgery
- Coagulopathy (sepsis, pharmacological, low platelets, bleeding disorders)
- Risk of major blood loss

There are many clinical scenarios when the risks of the procedure will outweigh the potential benefits and each case needs to be assessed on an individual basis.

Compromised Hemodynamic States

In patients who are shocked (e.g., hypovolemia, trauma, sepsis) and those with a fixed cardiac output (e.g., aortic stenosis and other significant valvular lesions, restrictive cardiac disease) administration of neuraxial blockade can pose serious risks as they are unable to compensate for the fall in systemic vascular resistance (SVR) that ensues once sympathetic blockade has been established following epidural anesthesia. Coronary perfusion will fall and can result in cardiac arrest - resuscitation of such patients is particularly difficult.

Coagulopathy and Bleeding

Patients with uncorrected clotting disorders and major blood loss are at risk of epidural hematoma formation, which is a surgical emergency. The clot must be evacuated without delay to prevent permanent spinal cord damage as a result of increased pressure in the epidural space. The AAGBI has recently published clear guidelines on the timing of performing neuraxial blocks, stopping and restarting anticoagulation and the removal of epidural catheters in patients with coagulation abnormalities.

Infection and Allergy

Local infection or inflammation around the site of desired catheter insertion risks the spread of the infection into the epidural space and in septic patients the risk of spreading infection with an epidural injection is significantly high. History of allergy to the drugs used is another contraindication; however, this can be overcome by using alternate drugs.

Epidural: The Procedures

As with all anesthetic techniques inserting an epidural can be described in terms of pre-procedure, procedure and post-procedure considerations.

Technique of Inserting an Epidural

Pre-procedure
- Pre-assessment
  – History and examination
  – Investigations (coagulation, spinal imaging)
- Optimization
  – Fluid status (correction of abnormalities e.g., dehydration, cardiac failure)
  – Reviewing and stopping anticoagulants
- Consent

Procedure
- Preparation
  – Equipment
  – Drugs: local anesthetics, adjuvants, vasopressors
  – Large bore IV access and connect fluids
  – Aseptic precautions (gown, gloves, hat & mask)
- Prepare the patient:
  – Positioning: sitting, lateral
  – Skin disinfection (0.5% chlorhexidine in alcohol left to dry)
- Monitoring
  – AAGBI standards
  – Skilled assistance
- Sedation/GA
  – This should be established prior to epidural insertion in certain patients
- Anatomical landmarks
  – Identify site of insertion
  – Cover the patient with a sterile fenestrated drape
  – Infiltrate skin with local anesthetic
- Technique:
  – Open the epidural pack onto a sterile trolley, ensuring there is no exposure to disinfectant
  – Flush the epidural catheter, connector and filter with saline and disassemble
  – Insert Tuohy needle through infiltrated area until ligamentum flavum identified
  – Remove inner trocar
  – Use LOR syringe to identify the epidural space
  – Attach the stabilizer and insert the epidural catheter
  – Carefully remove the Tuohy needle keeping catheter at appropriate depth
  – Secure at correct depth
- Testing
  – Give a test dose of local anesthetic
  – Check level of motor and sensory (light touch and cold)

Post-procedure
- Continue monitoring for whole duration of epidural analgesia (AAGBI standards, block density and height)
- Give anesthetic/analgesic by intermittent boluses or continuous infusion

Pre-procedure

The technique must be performed by trained practitioners with skilled assistance only and nurses with specific training and skills in the management of epidural analgesia should be present on wards where epidurals are to be managed.

Pre-assessment

The patient should undergo formal pre-assessment as for a general anesthetic; history, examination, and review of relevant investigations paying particular attention to cardiorespiratory status, anticoagulants and clotting abnormalities and assessment of back and veins. The current recommendations of when anticoagulants should be stopped prior to neuraxial blockade are shown in Table 12.2. Blood results, specifically full blood count and coagulation screen should be reviewed as well as markers of infection. In certain patients, such as those with previous spinal surgery or scoliosis, reviews of spine X-rays or CT scans may be necessary.

Table 12.2 Epidural analgesia and drugs affecting hemostasis: current recommendations

Drug	When to stop
Aspirin	Continue
NSAID	Continue
Heparin	Stop before 4 h
LMWH	Stop before 12 h (prophylactic dose) Stop before 24 h (treatment dose)
Warfarin	Stop before 5 days (INR to be below 1.5)
Clopidogrel	Stop before 1 week (range 5–10 days)
Teicoplidine	Stop before 2 weeks
GIIa/III	Stop before 4 weeks

Optimization

Patients' fluid status should be assessed and preloading or co-loading of crystalloid should take place as well reviewing any anticoagulant medication that needs to stopped, continued, or converted to bridging therapy (in high risk patients) [35].

Consent

Informed consent should be obtained and should include indications, contraindications (relevant to the patient), a description of the procedure, management during the block, risks and benefits and post-procedure management. Patients should be given the opportunity to ask questions, refuse and alternatives should be discussed.

Procedure

In theory epidurals may be inserted at any spinal level but in practice the most common sites are thoracic, lumbar and caudal. The technique is broadly similar for each and here we describe a lumbar epidural and the specific considerations/variations for the other two main types.

Once all of the pre-procedure steps are completed (above) the patient should be moved to an area with appropriate resuscitation and airway monitoring facilities readily available and all equipment and drugs should be checked and prepared. The procedure should be performed using an aseptic technique, skin decontaminated with 0.5% chlorhexidine and left to dry while preparing the equipment taking care that the disinfectant does not come into contact with the equipment or gloves of the practitioner. Large bore IV access (typically 16 gauge venflon) should be sited and connected to fluids prior to starting the procedure. Patients who are likely to be cardiovascularly unstable should have vasopressors and/or inotropes prepared and ready to use.

Equipment

Many centers provide pre-sterilized epidural packs and separate individual kit when the technique needs to modified for a CSE procedure or patient with high BMI. Each individual equipment is described in detail below.

The latest guidelines recommend the use of 0.5% chlorhexidine in 80% alcohol for skin preparation prior to siting an epidural based on evidence of effectiveness and association to neurotoxicity.

Epidural Needles

Although there are a range of available epidural needles (Touhy, Husted, and Crawford), the Touhy needle is the most widely used. The main difference between these needles is the angle of the blunt tip, which varies from 15 to 30° (Fig. 12.7).

A standard Touhy needle consists of an 8 cm metal shaft with markings at 1 cm intervals (to help measure depth of needle tip from the skin) attached to a hub (making the total length 10 cm). A wing or flange is attached to the hub to help in stabilizing the needle during insertion into the epidural space. In some needles the flange is fused with hub and in others it is attached to the needle just prior to the hub.

The Touhy needle has a rounded tip which should be pointed upward and this is called a Huber point. The deflected bevel top makes the cutting surface perpendicular to the needle shaft and is designed to reduce the coring of tissue and septa. The bevel at the tip of the needle reduces the risk of dural puncture and has the effect of directing the epidural catheter cranially during insertion.

The hollow of the needle is occupied by a removable trocar, which does not protrude through the end of the needle and is only removed once the needle is introduced through the skin and immediate soft tissues. The function of the

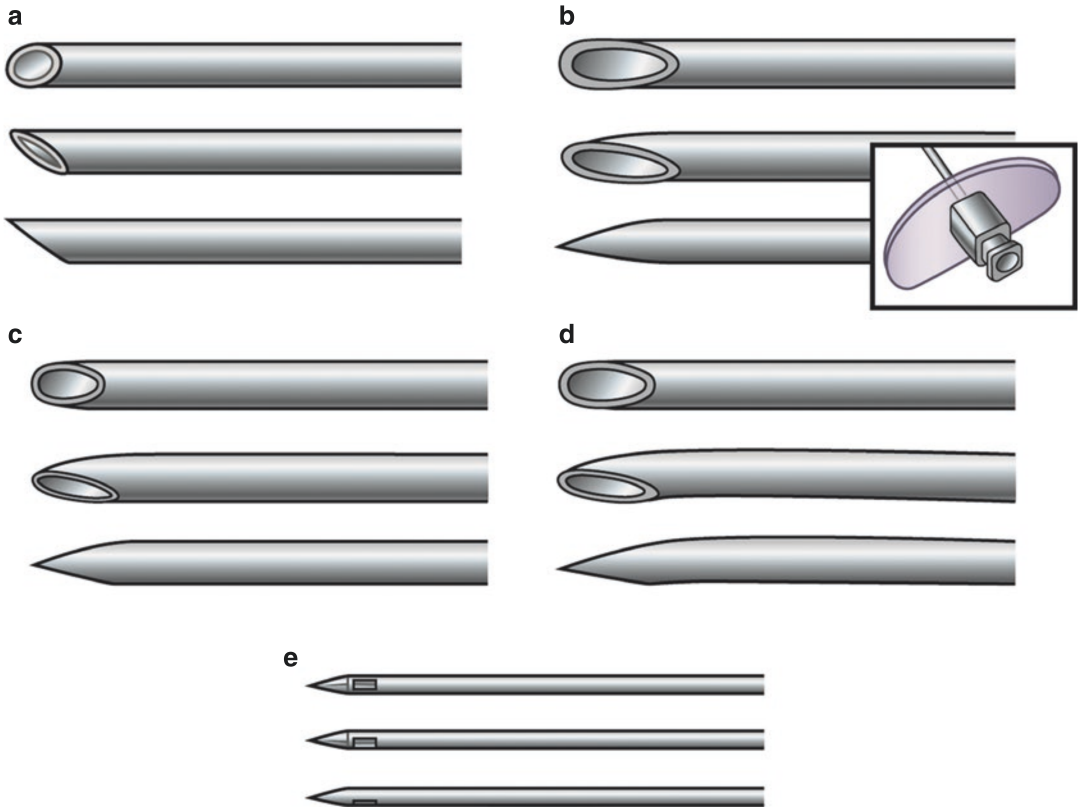

Fig. 12.7 Types of needles and their tips. Inspired by Regional Anesthesia and Analgesia, WB Saunders, Philadelphia

trocar is to prevent a plug of skin or tissue from blocking the needle and many anesthetists will feel for the "grip" of the ligamentum flavum before removing the trocar and connecting the loss of resistance syringe.

Another commonly seen epidural needle is one specifically designed for a needle through needle CSE technique. As well as spinal needle which will protrude through the tip of the Touhy needle, the Touhy needle has a slightly altered tip which will allow the smooth passage of the spinal needle through the end without the slight resistance which may occur if the technique is performed through a standard Touhy needle.

Epidural needles are available in various gauges and lengths; 16, 17, and 18G are the most frequently used and a 10 cm needle is suitable for most adults (a 15 cm needle is available when extra length is required) and separate pediatric sizes are available.

Epidural needles need a greater caliber to allow the easy flow of saline, which is required to detect a loss of resistance. However, it is possible to use smaller caliber spinal needles to access the epidural space in specific situations such as X-ray guided procedures in management of chronic pain conditions including caudal anesthesia in adults.

Epidural Catheters

These are made of either nylon or Teflon, are biologically inert, transparent, and 90 cm long. The distal tip is colored (to help identify it during removal) and may be closed or open; closed tip catheters are claimed to reduce the risk of intravascular injection and have side ports on the distal end. The first 15 cm of the catheter has marking every 5 cm and then there are 1 cm markings from 5 to 15 cm from of the distal end. The proximal open end is connected to the catheter connector, which in turn connects to the filter.

Connectors

Connectors for the epidural catheters come in various designs; some are screw-in and others snap-up. The epidural kits also contain stabilizers that help to facilitate easy passage of catheters through the needle.

Epidural Filters

The pore size of these filters is 0.22 μm in size and helps to remove viruses and bacteria as well as foreign bodies such as glass particles (from ampoules).

Loss of Resistance (LOR) Syringes

Traditionally LOR syringes have been Luer lock syringes, with low plunger resistance allowing easy identification of the sudden loss of resistance as the needle enters the epidural space. However, a recent NPSA alert has meant many centers have or are shifting towards non-Luer devices to reduce the risk of inadvertent intravenous administration of drugs intended for intrathecal/epidural or regional route and vice versa. The syringes are of 10 mL capacity and made of PVC or PP and should be filled with saline prior to attaching the epidural needle.

Aids to Identify Epidural Space

There are a variety of devices used to detect the entry of the tip of the needle into the epidural space, such as pre-filled balloons, spring-loaded syringes, radiological imaging, or ultrasonography but these are not routinely used in clinical practice and are no substitute for technical acquired with clinical practice. In technically challenging cases (e.g., extreme obesity or anatomical abnormality), adjuvants such as X-ray or ultrasound guidance could prove valuable.

Prepare the Patient

The patient should be positioned either sitting or in the left lateral position with the spine fully flexed. Epidurals can also be performed in prone position although this is not a common occurrence. There are advantages and disadvantages to each position and the choice will depend on patient factors, technical factors and operator preference.

In the lateral decubitus position, the patient will be more stable without the need for an assistant to support them and this position allows a greater degree of sedation to be employed. The patient should lie with their back parallel to the edge of the bed/trolley, a pillow should be placed under the head to keep the spine level. The knees should be drawn up to the abdomen with thighs flexed, with the upper arm across the chest and the lower arm projecting 90° from the body. Ideally the patient should adopt a fetal position with the spine maximally flexed to open the spaces between the vertebrae. If necessary, the patient can be asked to increase the flexion by grasping the back of the head/neck and attempting to draw elbows and knees together. In obese patients the lateral position can make identification of the midline more difficult as the tissue midline is distorted by the subcutaneous adipose tissue being displaced by gravity.

In the sitting position, patients should sit up at the edge of the bed, with their feet on a stool or other support. They should start with a straight back, with their chin on their chest, arms hugging a pillow, or on a Mayo table or stand in front of them. It is important they do not lean forward and should arch their back (terminology such as "angry cat" or "slouch" are commonly used). Lateral rotation and flexion of the spine should be avoided and an assistant may help to prevent this and to encourage the patients to keep their shoulders level [5].

The level at which the epidural is inserted should be identified; landmarks that can be used to identify spinous processes and hence vertebral level will be dealt with in the following section (Table 12.3). Evidence has shown that the accuracy of anatomical landmarks is known to be poor and an ultrasound scanner could be helpful in difficult situations.

The bed should be positioned at a height convenient for the operator to work at the insertion level. The midline should be identified and can be marked with an indelible skin marker. The operator should then adopt an aseptic technique, including surgical scrub, face mask, hat, and sterile gloves. There is controversy regarding the use of a face mask [6], however, wearing one has

Table 12.3 Suggested catheter levels for specific surgical procedures

Surgery/procedure	Level of catheter insertion
Procedure in the neck	C6–T1
Mastectomy	T6–T7
Thoracotomy	T4–T6
Upper abdominal	T6–T8
Lower abdominal	T10–T12
Lower limb	L2–L4
Labor/delivery	T10–S4
First stage	T10–L1
Second stage	S2–S4

Adapted from Regional Anaesthesia—The Requisites in Anesthesiology

been shown to reduce the incidence of infection rates during central venous catheterization and the author would continue to advocate their use. Eye protection should also be worn in case of inadvertent aerosolization of local anesthetic during the procedure.

The skin should be prepared with 0.5% chlorhexidine gluconate in alcohol and a sterile fenestrated drape used to isolate the area where the epidural will be inserted. The applied disinfectant should remain in contact with the skin for the recommended duration (e.g., alcohol-based disinfectants should be left to dry on its own).

Monitoring

Monitoring according to AAGBI standards should be implemented prior to and continued after establishment of epidural analgesia. Without guarantee of these basic standards the procedure should not even be attempted.

AAGBI Monitoring Standards

- HR
- Blood pressure
- Respiratory rate
- Sedation score
- Temperature
- Pain score
- Degree of motor and sensory block

Sedation/GA

Sedation is used depending on the situation and when employed the patient should be able to communicate and cooperate with the operator. This optimal sedation can improve patient comfort without losing cooperation. Epidurals are not commonly done under general anesthesia to minimize the risk of complications going undetected (an awake patient can communicate pain or paresthesia on insertion allowing adjustment or resiting).

Anatomical Landmarks

The level of epidural insertion depends on the indication for the epidural as well as patient factors.

The type and site of surgery as well as the purpose of the epidural (Table 12.3) will determine where best to perform the procedure to produce optimum analgesia. The epidural drugs should be injected into the spine at the level corresponding to the dermatome corresponding with the midpoint of surgical incision. When using a catheter, the tip of the catheter should correspond to the midpoint of the surgical incision (this is not very accurate without radiological screening).

Patient factors influence the site of epidural insertion; ease of palpation of spinous processes (obese patients), size of interspinous space (narrow spaces common in elderly patients), presence of localized infection, anatomical and other abnormalities of the spine (e.g., scoliosis, metal rods), previous spinal surgery and level of cooperation. The experience and familiarity of the operator with the technique and availability of adjuvants will also play a role.

Technique

The operator should adopt a good position that is convenient for them; some will work from a standing position, while others work from a sitting position. Building up dexterity and adaptability from early years of training will prove valuable in later years of career.

Preparing the procedure tray in advance is a useful and rewarding habit to learn; the epidural catheter should be connected to the filter and connector and be flushed with saline to ensure patency of the orifices and then each component should be disassembled. The LOR syringe should be tested to ensure free movement and we advocate the use of saline with the syringe being filled with 5–10 mL of saline.

A skin weal should be raised at the target site with local anesthetic (1% or 2% lignocaine) and local infiltration performed to the supraspinous and interspinous ligaments. This needle can be used as a "seeker" to identify the depth to the ligamentum flavum if the patient's body habitus is favorable and also to determine cephalad angulation required to pass between the spinous processes. It can also be used to identify the bony landmarks.

The epidural needle should be connected to the flange and inserted with the stylet in situ and bevel facing cephalad or caudad, perpendicular to the skin in vertical and horizontal planes. Common techniques used for holding and advancing the needle observed by the authors include holding the flanges between thumb and index finger of both hands and bracing the remaining fingers against the back to prevent too rapid advancement, and holding the needle with the thenar eminence at the hub, index and middle finger supporting the needle with thumb held parallel to the axis of the needle. The needle is then slowly advanced until increased resistance is met, representing the ligamentum flavum. The stylet should then be removed and the loss of resistance (LOR) syringe attached and the needle re-angled slightly cephalad.

For loss of resistance to saline (LORS), the non-dominant hand is used to brace against the back (see Fig. 12.8), to stabilize the needle and prevent sudden rapid forward motion. The syringe is held in the dominant hand, and constant pressure is applied to the plunger of the syringe with the thumb as the needle is advanced. While the bevel of the needle is within the ligaments, there will be considerable resistance to pressure, but as the bevel exits the ligamentum flavum and enters the epidural space, there will be a sudden loss of

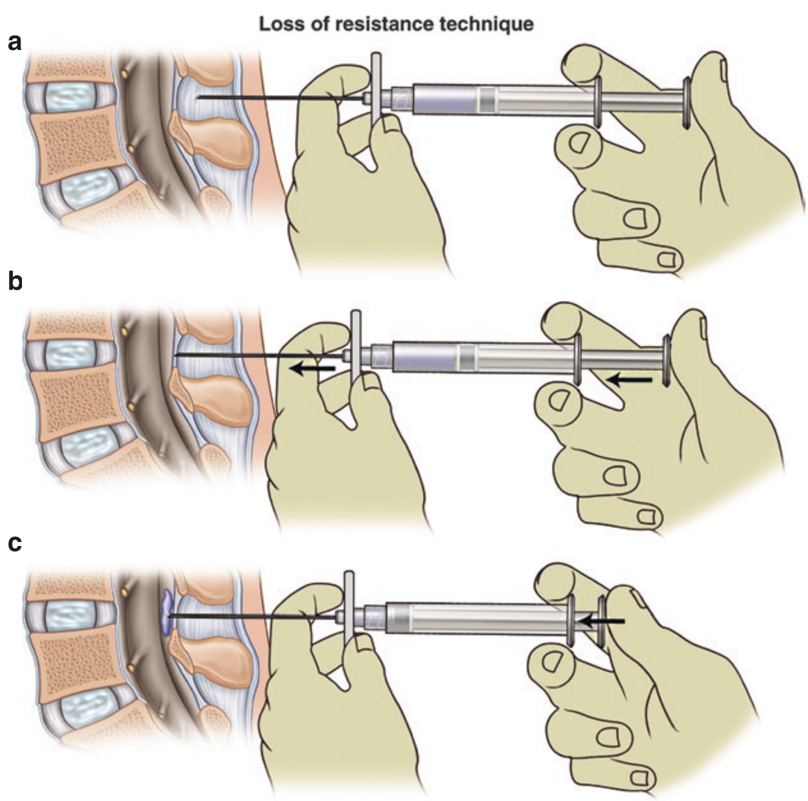

Fig. 12.8 Loss of resistance technique. Inspired by Visser L. Epidural Anesthesia

that resistance, the contents of the syringe will be discharged into the space, and the needle will cease in its forward motion. It is important to warn the patients that they will feel pressure in the back, but they should not feel pain. If they feel pain or discomfort, the operator should ask the patients whether they feel it to left or right, or in the midline, as it may be necessary to reevaluate the direction of insertion of the needle.

Alternatively a technique of intermittent advancement may be used, where the needle is advanced 1–2 mm at a time using the same hold as described for the insertion of the needle, and the plunger of the needle is depressed intermittently to assess for loss of resistance. A small air bubble purposefully introduced into the LOR syringe can help to monitor the pressure inside the syringe. As long as the needle tip is inside the ligamentum flavum, the bubble can be observed to be compressible within the syringe by exerting pressure over the plunger.

Once LOR has occurred, the needle should be advanced 1 mm further to ensure the opening is fully within the epidural space and the syringe removed from the hub, ensuring the needle does not move. A small amount of fluid may now drain from the needle, but should stop after only a few drops. If not, then this may be CSF and dural puncture may have occurred. If fluid runs freely, then definite dural puncture has occurred, and there are several options available to the operator, which will be discussed below. If blood appears in the needle, then it should be withdrawn and either redirected or re-sited depending on assessment of the landmarks. In the absence of blood or CSF, the depth to which the needle has been inserted should be noted. The patient should be told to remain absolutely still to prevent displacement. If a single shot technique is to be used, injection should take place now.

If a catheter is to be inserted, the stabilizer should be placed in the needle hub and the catheter advanced slowly into the epidural space so that 15–18 cm of catheter is within the needle and space, while the needle is stabilized. The patients should be warned that they may feel paresthesia, burning, tingling, or electric shock, but that this should only be transient.

Catheter advancement may be made easier if a 5–10 mL of saline is injected into the space once LOR has occurred, which may separate the tissues slightly to allow passage of the catheter. If the sensation persists after halting advancement, then it may be necessary to remove the catheter and re-site the needle. Withdrawing the catheter through the needle could lead to shearing of the catheter on the bevel and this is not recommended and should be avoided.

The needle is then withdrawn over the catheter, ensuring non-displacement of the catheter. It is recommended that 4–5 cm of catheter be left in the epidural space [7] and the catheter should be withdrawn now to a depth of 4–5 cm plus the depth of the space. For example, if the skin is at the 6 cm mark on the needle, the catheter should be withdrawn to the 10 or 11 cm. The filter and connector should be attached at the proximal end of the catheter using a sterile technique and then aspirated to check for CSF or blood. If blood is freely aspirated, then placement within a blood vessel must be assumed and the catheter should be removed and a new attempt at insertion made.

If CSF is aspirated at any point during the procedure (either via the needle or the catheter), then the option of placing/leaving an intrathecal catheter may be considered. This may then be used to provide spinal anesthesia, with the relevant cautions applied but this technique is beyond the scope of this chapter. Alternatively the catheter can be withdrawn and re-sited. The patient should be warned about the possibility of PDPH and a note of dural puncture should be made in the medical/anesthetic records.

Once the catheter is at the required depth, it should be secured either with a proprietary securing device or a clear transparent dressing. If the latter is used, one or two loose loops of the catheter should be made on the skin so that tension on the catheter will unravel the loops rather than displacing it. A further alternative includes tunnelling the catheter under the skin for a short distance before making the loops. The catheter is then brought over the patient's shoulder and secured in situ with a cloth tape such as Mepore® or Hypafix®.

Testing

A test dose of 3 mL of local anesthetic (with or without 1:200,000 epinephrine equivalent to 15 μm) may now be given and the patient asked to return to the supine position. Monitoring for signs of intravascular injection or intrathecal injection should be done (20% increase in heart rate, fall in blood pressure, spinal anesthesia). It should be borne in mind that sedation may reduce the reliability of the lidocaine only test in an awake patient [8]. If after 5–10 min no signs of either have been detected, then incremental injection of the desired analgesic/anesthetic drugs may occur. Continued observation for signs of systemic toxicity and catheter displacement into the dural space should be continued. Epidural block can take up to 20 min to become fully established.

Block height and density should be assessed at regular intervals. This can be done by using the Bromage scale and by assessing for loss of sensation to cold, touch, and pinprick. The dermatome level at which sensation is lost should be recorded (Table 12.4) [9, 10].

Special Techniques

Loss of resistance to air is another technique for identifying the epidural space. As above, the LOR syringe with 5–10 mL of air inside is attached to the needle hub when the needle is in the interspinous ligament or ligamentum flavum. The wings of the needle are gripped between the thumb and forefinger of both hands with the dorsa of the hand resting against the patient's back and the needle advanced 2 mm at a time. The plunger is gently pressed, and if there is resistance (colloquially termed "bounce"), the needle is very carefully advanced another 2 mm. As the needle enters the epidural space, a sudden "give way" or "click" may be felt. At this point air can be freely injected into the epidural space. The syringe is removed and the catheter threaded as above. Provided great care is taken in advancing the needle it should not pierce the dura. As this technique requires intermittent removal of one hand and testing for LOR, it is relatively slower but probably safer as there is less chance for the needle to overshoot and produce an accidental dural puncture.

A further possible technique is the "hanging drop," where a drop of saline is placed at the end of the needle once the stylet has been withdrawn. As the needle is advanced into the epidural space, the negative pressure that exists within the space withdraws the drop into the needle (due to the denting of the dural by the needle). This technique used to be popular for thoracic epidural injections.

Table 12.4 The Bromage scale (1965)

Degree of block	Bromage criteria	Score (%)
No block	Full flexion of knees and feet	0
Partial block	Just able to flex knees and full flexion of feet	33
Almost complete	Unable to flex knees, some foot flexion	66
Complete	Unable to move legs or feet	100

Thoracic Epidural

The thoracic vertebral spinous processes are much more steeply angled and project further. The dura is more closely aligned to the ligamentum flavum and the spinal cord may lie closer to the dura. The positioning of the patient and the technique of advancement remain substantially the same as for lumbar epidural, but with the proviso that the epidural needle should only be advanced 1 mm at most after LOR.

The paramedian approach is an alternative and may be preferable in the thoracic level and when ligaments are calcified. The needle is inserted 1–2 cm lateral to the spinous process of the more cephalad vertebra. The needle is then advanced perpendicular to the skin until contact is made with the lamina or the pedicle of the vertebra. The needle should then be redirected cephalad 15–30° and medially 15–30° and the needle "walked off" the bone. A loss of resistance technique is then used to detect the epidural space.

Caudal Approach

Here the patient is positioned either in the lateral decubitus or prone position. Sacral hiatus is then identified by palpation. The surface marking of sacral hiatus is that it lies at the apex of an equilateral triangle base of which is formed by the line joining the two posterior superior iliac spines. The hiatus lies in its apex with the sacral cornua on either side. A 22 (or 23)-G needle is then inserted at 45° angle with its bevel facing the operator into the ligament and once the ligament is perforated (felt as a "pop") the needle is advanced at a more acute angle further (2 cm in adults and about 1 cm in children) into the caudal canal (Fig. 12.5). Care should be taken not to advance the needle too much as this will increase the risk of dural puncture. A cannula over the needle technique can also be used where the cannula is left in epidural space after withdrawing the needle. The anesthetic solution is injected after careful aspiration for CSF or blood.

Post-procedure

Epidurals should only be managed in environments with adequately trained staff with access to emergency equipment and drugs required to manage known complications. Epidural solutions can continue to be administered by intermittent bolus injections or continuous infusions.

The patient should continue to be monitored after the anesthetic has been given for signs of local anesthetic toxicity. These include lightheadedness, tinnitus, circumoral and tongue numbness, paresthesiae, visual disturbances, muscular twitching, convulsions, unconsciousness, coma, respiratory arrest and cardiovascular collapse.

Troubleshooting

Difficult Anatomy

In pregnant or obese patients, it may be difficult to identify the midline, especially in the lateral decubitus position and where possible these patients should be asked to adopt the sitting position. It may be helpful, though not necessarily reliable, to ask the patients whether they feel that the operator's hand/needle is in the midline. Alternatively, it may be possible to use ultrasound to identify the midline and interspinous space.

Repeated Contact with Bone

Position is the most common reason for repeated bone contact; the patient should be asked to flex more, or position should be changed from lateral decubitus to sitting or vice versa. Other techniques are to reinsert the needle slightly away from the midline, withdrawing the needle to the subcutaneous tissue level and repositioning the needle at a steeper angle or inserting the needle closer to lower border of the upper spine. In the lateral decubitus position, there is a tendency for the soft tissues to sag under gravity leading to the midline of the back to move away from the spinous processes and this can mislead the operator (happening more frequently in obese individuals).

Difficulty Threading the Catheter

The stabilizer that comes in most commercial packs should be used to aid in inserting the catheter, as it will prevent kinking in the relatively large hub of the needle. Slight rotation of the needle about the longitudinal axis may facilitate insertion. Sometimes, even after obtaining LOR to saline or air, the tip of the needle will be only halfway through the ligamentum flavum making it difficult for the catheter tip to pass into the epidural space; this could be solved by advancing the needle slightly further in.

Fluid or Blood Returns Via the Needle or Catheter

Fluid in the needle or catheter can either be saline, which should stop after a few seconds, or CSF where flow doesn't stop. If flow does stop, then incremental doses of anesthetic should be given while observing the patient for signs of intrathecal block; this applies whether or not a catheter is used. Testing the fluid for glucose using an indicator strip of glucometer can distinguish between CSF and the saline.

Blood in the catheter indicates likely intravascular placement; if blood flow stops on withdrawing the catheter and blood can no longer be aspirated, then the catheter may be used cautiously. This is under the proviso that all doses should be preceded by aspiration to check for blood and should be given incrementally while monitoring the patient very closely for signs of toxicity. The catheter should be flushed with saline before a test dose is given.

Pain on Insertion

A brief sensation of electrical shock or paresthesia on insertion of a catheter is common but if it persists the catheter is likely up against a nerve root and should be withdrawn a few millimeters until the sensation stops. If sufficient catheter remains within the space, then it may still be used otherwise it should be re-sited.

Unilateral Block

The precise cause for this can be difficult to determine; it could be that the tip of the catheter has moved out of the epidural space through the intervertebral foramen (more common when more than 4 cm of catheter is left in the epidural space) or that there are connective tissue septa which theoretically prevent uniform distribution of the local anesthetic solution. This problem is managed by pulling out the catheter so that about 3–4 cm of it remains inside the epidural space and then giving another top-up or by turning the patient on the unblocked side before the top-up and keeping in this position for about 15 min - if this fails then the epidural will have to be re-sited.

Pharmacology of Epidural Blockade

Site of Action of Epidurally Administered Drugs

The exact mechanism of how epidurally administered drugs exert their effects is not fully understood. Hogan [11, 12] demonstrated that the spread of solutions injected into the epidural space results to form a coat around the cylindrical dural sac while some of it passes through the foramina.

There are four potential possibilities for these drugs to exert their observed effects: (1) once injected the drug passes along the intervertebral foramina into the paravertebral space and acts directly on the nerve roots and plexuses, (2) the drug diffuses through the dura into the subarachnoid space, (3) the drug penetrates the dural cuffs of the spinal nerves and interferes with nerve conduction, and (4) the other possible pathway is by axonal transmission. The large network of epidural veins, known as Batson's plexus, also contributes to the systemic absorption of the drugs administered.

Drugs and Doses

At one time or another almost all local anesthetic agents were used for providing epidural anesthesia or analgesia, either alone or in combination with a variety of other drugs ranging from epinephrine to ketamine to opioids. All preparations of any drug used for neuraxial blockade should be preservative free to minimize the risk of neurotoxicity.

Local Anesthetics (LA)

The choice of LA depends on the indication for which the epidural has been sited and the pharmacokinetic effects of each agent. For example, prilocaine and lignocaine will be more beneficial for short procedures whereas bupivacaine and ropivacaine would be preferable for longer procedures and analgesia during labor (Table 12.5).

The duration of LA action in epidural analgesia can be described in terms of "two-dermatome regression" or "complete resolution." The former is the time taken for the block to recede by two dermatomes from its maximum extent, while the latter is the time taken for the sensory block to wear off completely. This is influenced by dural surface area, volume of fat in the epidural space, and velocity of blood flow in the epidural space [13]. The recommended dose and duration of action of commonly used local anesthetics [14]:

Table 12.5 Recommended dose and duration of action of commonly used local anesthetics

Drug	Presentation	Onset of action (min)	Usual dose	Duration of action
Chloroprocaine	As a solution in 2% and 3% concentration	6–12	15–25 mL	40–50 min
Lidocaine	As solution of lidocaine (usually hydrochloride) with or without epinephrine, in concentrations of 1, 1.5 and 2%	10–20	10–20 mL (1%) 10–15 mL (1.5%)	Without epinephrine from 1 to 2 h
			10–20 mL (2%) Depending on site and desired level of block	With epinephrine may be considerably longer
Mepivacaine	As a solution in 1, 1.5 or 2% concentration	3–20	15–30 mL (1%) 10–25 mL (1.5%) 10–20 mL (2%)	2–2.5 h
Ropivacaine	As a solution in 0.2, 0.5, and 1% concentration	5–13	10–20 mL (0.2%) at 30–60 min intervals or infused at 4–14 mL/h 15–30 mL (0.5%) for surgery 15–20 mL (0.1%)	3–5 h
Bupivacaine (and Levobupivacaine, which is equipotent but with fewer cardiotoxic effects)	As a solution in 0.25, 0.5 or 0.75% in 5–10 mL vials or ampoules	5–20	10–20 mL of either concentration at 1–2 h intervals, or infusions of 5–15 mL/h of 0.1% solutions	Up to 2–2.5 h
	As a solution of 0.1% in infusion bags or syringes of 50–500 mL, often with fentanyl 2 μg/mL or 4 μg/mL for epidural infusion			

Chloroprocaine

- Rapid onset (6–12 min)
- Duration of approximately 40–50 min
- Can be used as an infusion
- Available as 2% and 3% concentrations
- Epidural dose 15–25 mL [15]
- Higher doses associated with backache
- Reduced efficacy of adjuvants such as morphine and clonidine

Lidocaine

- Most widely used LA
- Rapid onset (10–20 min)
- Available in range of concentrations including 1, 1.5, and 2%. It has a
- Dose is 10–20 mL of 1%, 10–15 mL of 1.5% or 10–20 mL of 2% depending on site and desired block level
- Duration of action from 1 to 2 h (without epinephrine) [16]
- Tachyphylaxis limits long-term use
- Popular topping-up agent for cesarean sections (alone or with epinephrine and sodium bicarbonate; the latter ensures rapid onset by altering the pH so that more of the unionized drug is available to penetrate the neural tissues)

Mepivacaine

- Available as 1, 1.5, or 2% concentrations
- Onset of action ranges from 3 to 20 min
- Duration of action of up to 2.5 h
- Dose ranges are 15–30 mL 1%, 10–25 mL 1.5%, and 10–20 mL 2% [17–19]

Ropivacaine

- Single isomer
- Moderately rapid onset of action (within 5–13 min)
- Available as 0.2, 0.5, and 1% concentrations (0.2% solution used for analgesia; 10–20 mL at 30–60 min intervals or at infusion rates of 6–14 mL/h)
- For surgery, 15–30 mL of 0.5% or 15–20 mL of 0.10% ropivacaine may be used
- Duration of action 3–5 h [20]
- It does not have any significant motor sparing action as claimed

Bupivacaine

- Available as 0.25 or 0.5 or 0.75% solutions in 5–10 mL vials or ampoules
- Widely available as a 0.1% solution in large volume bags (100–250 mL or more) often with fentanyl 2 or 4 μg/mL for epidural infusion
- Bolus doses of 10–20 mL with repeat dosing at 2-h intervals, depending on desired block
- Infusion rates from 5 to 15 mL/h for the 0.1% solutions [21, 22]
- Levobupivacaine, the levo form, has fewer cardiotoxic side effects without loss of the anesthetic potency [23]

Adjuvant Drugs

There are many drugs which are used to augment or supplement the effects of LA but the following are the commonly used in clinical practice:

Opioids

Opioids are the most commonly used adjuvant drugs; morphine, fentanyl, sufentanil, hydromorphone, and diamorphine have all been used as epidural adjuvants [24–26]. They prolong the duration of analgesia without any effect on the motor system. This effect is mediated by opioid receptors in spinal cord and the recommended infusion regimens are shown in Tables 12.6 and 12.7.

Epinephrine

Epinephrine can be used to increase the depth and duration of block through its effects of local vasoconstriction. This decreases the clearance of the LA from the tissues, allowing a reduced concentration and dose of drug to be administered. The usual concentration of epinephrine is 1:200,000 (5 μm/mL) [27] and it prolongs duration of both sensory and motor blockade. This is a significant feature in the case of LA with short and intermediate duration of action but in contrast this effect is not seen in the case of longer acting LA.

Epinephrine also exerts effects on the α2 adrenergic receptors present in the spinal cord, reducing transmission of nociceptive impulses. In addition to the neuraxial effects, epinephrine produces reduction in systemic vascular resistance as a result of its systemic absorption from the epidural space. This is the result of β2 stimulation of arterial adrenergic receptors which reduces mean arterial pressure leading to a reflex tachycardia.

Clonidine

Clonidine is a selective α-2 adrenergic agonist, which has been used extensively in epidural and spinal anesthesia for many years. Side effects include hypotension, bradycardia, and sedation which should be considered when choosing to use it in certain patients groups (e.g., pediatrics & elderly). It has been used as a sole agent in a dose of 300–600 μg and in conjunction with LA both intra- and postoperatively at doses of 75–150 μg.

Table 12.6 Epidural opioids recommended dose as continuous infusion

Drug	Solution (mg/mL)/(%)	Bolus dose (mg)	Basal infusion (per h)	Breakthrough doses (mg)	Increments in breakthrough (mg)
Morphine	0.1/0.01	4–6	0.5–0.8 mg	0.2–0.3 every 10–15 min	0.1
Hydromorphone	0.05/0.005	0.8–1.5	0.15–0.3 mg	0.15–0.3 every 10–15 min	0.05
Fentanyl	0.010/0.001	0.0005–0.0015	0.0005–0.001 mg/kg	0.010–015 every 10–15 min	0.010
Sufentanyl	0.001/0.0001	0.0003–0.0007	0.0001–0.0002 mg/kg	0.005–0.007 every 10–15 min	0.005
Alfentanyl	0.25/0.125	0.01–015	0.10–0.018 mg/kg	0.25 every 10 min	0.25

Table 12.7 Epidural Opoid-Bupivaine combination administered as infusion

Drug combinations	Solution (%)	Basal infusion (mL/h)	Breakthrough doses mL (interval, min)	Increments in breakthrough (mL of the solution)
Morphine	0.01	6–8	1–2 (10–15)	1
Bupivacaine	0.05–0.1			
Hydromorphone	0.0025–0.005	6–8	1–3 (10–15)	1
Bupivacaine	0.05–0.1			
Fentanyl	0.001	0.1–0.15/kg	1–1.5 (10–15)	1
Bupivacaine	0.05–0.1			
Sufentanyl	0.0001	0.1–0.2/kg	1–1.5 (10–15)	1
Bupivacaine	0.05–0.1			

Adapted from de Leon-Casasola OA, Lema MJ. Postoperative epidural opioid analgesia: What are the choices? Anesth Analg. 1996;83:867–875

Clonidine has been shown to reduce opioid use by 50% and prolong the analgesic effects of local anesthetics by 100% [28].

Ketamine

Ketamine has been used in conjunction with LA and opioids for intra- and postoperative analgesia in doses ranging from 0.5 to 1 mg/h (with morphine) up to 0.25 mg/kg/h (with sufentanil) and single boluses of up to 1 mg/kg have also been used. Potential side effects include dizziness, diplopia, dysphoria, dreams, hallucinations and disorientation, strange sensations, lightheadedness, sleep difficulties and confusion, although these are less common when ketamine is used epidurally (Table 12.8) [29].

Factors Affecting Spread of Drugs in the Epidural Space [30]

Patient Factors

These have minor effects on the epidural spread of local anesthetics:

Age

- In elderly patients intervertebral foraminal narrowing leads to higher spread of anesthetic
- In younger individuals, part of the injected dose moves out through the foraminae

Weight

- Obesity increases the spread of injected drugs (possibly due to raised intra abdominal pressure, as seen in pregnancy, which decreases

Table 12.8 Epidural Adjuvants

Drug	Dose	Effect
Epinephrine	1:200,000 (5 μg/mL)	Increases local vasoconstriction thereby decreasing the clearance of local anesthetic from the tissues. This effect means that often the concentration and dose of drug used can be reduced
Clonidine	300–600 μg as a sole agent	Selective alpha-2 adrenergic agonist
	75–150 μg in combination with local anesthetic (intra- or postoperatively)	Side effects include hypotension, bradycardia, and sedation, and operators should bear this in mind when choosing to use it
		It has been shown to reduce opioid use by 50% and prolong the analgesic effects of local anesthetics by 100%
Ketamine	0.5–1 mg/h (with morphine) up to 0.25 mg/kg/h (with sufentanil). Single boluses up to 1 mg/kg have also been used	Potential side effects include dizziness, diplopia, dysphoria, dreams, hallucinations disorientation, strange sensations, light headedness, sleep difficulties, and confusion, though these are less common when ketamine is used epidurally
	In combination with local anesthesia for caudals 0.5 mg/kg has been used	

the volume of epidural space because of venous engorgement
- These patients require smaller doses, relative to their weight, for a given level of blockade, although there is significant individual variability

Height

- Taller patients require higher although there is significant individual variability

Drug Factors

Total Dose

- This is a *major* factor determining the spread of epidural injections
- Higher doses produce higher level of blockade
- It is impossible to accurately predict the level of blockade for a given dose

Volume

- Greater volumes produce greater spread of anesthetic
- This can lead to reduction in the concentration of the drug if the total dose is kept constant
- This can lead to reduced intensity of epidural block
- When the concentration is maintained, greater volumes increase the dermatomal spread (in a nonlinear fashion)

Technical Factors

Position of Patient

- The position of the patient during injection has a minimal effect.

Site of Injection

- Site of injection is a *major* determinant of spread of epidural drugs
- Thoracic injections require lower dose as the epidural space is narrow in this location
- Caudal injections require higher volumes as there is a greater volume
- The effect is immediate and maximum at the site of injection and spreads cephalad and caudad over time (Fig. 12.9)

Type of Pharmacological Agent

Local anesthetics produce sensory, motor, and sympathetic blockade, while opiates produce analgesia without any of the above effects.

Complications of Epidural Blockade

Complications following epidural can be immediate or delayed as shown below in Table 12.9.

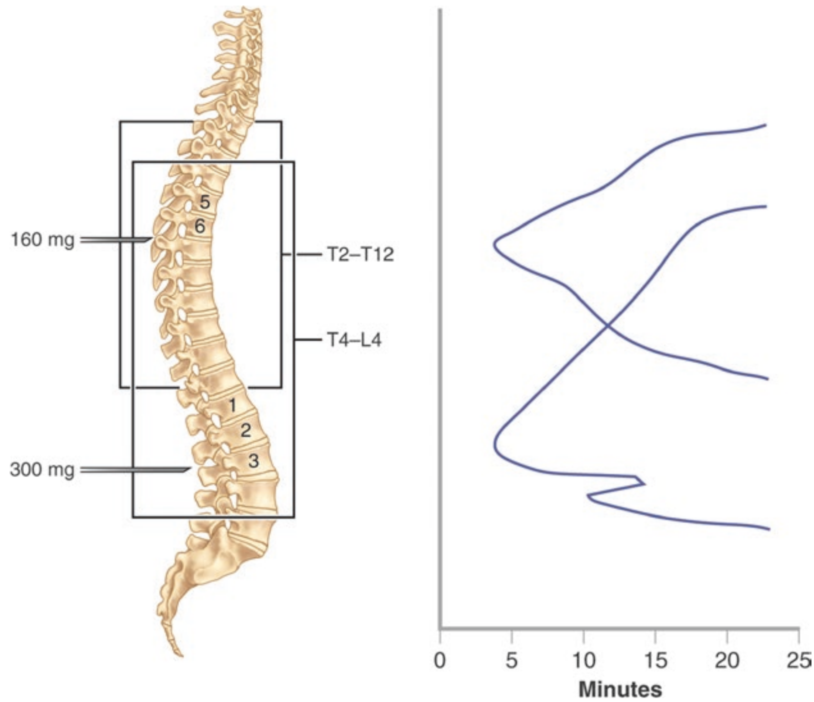

Fig. 12.9 Site of injection and spread of epidural drugs. Inspired by Mulroy MF. Regional anesthesia—an illustrated procedural guide. 3rd ed. Philadelphia, PA: Lippincott.

Table 12.9 Complications of epidural anesthesia

Immediate	Delayed
Nausea and vomiting	Residual neurological damage
Shivering	Post-dural-puncture headache
Itching	Back pain
Trauma	Epidural hematoma
Dural puncture	Epidural abbess
Secondary effects of sympathetic blockade	Arachnoiditis and cauda equine syndrome
Inadvertent intravascular injection of drugs	Retained catheter
Total spinal	
Subdural injection	
Incomplete block	

Immediate Complications

Immediate minor side effects are nausea, vomiting (treat hypotension, antiemetics), shivering (may respond to small doses of pethidine or ketamine) and itching (commonly due to opioids treated with nalbuphine, naloxone, or antihistamines).

Trauma

Poor technique, multiple attempts, poor positioning, and lack of patient cooperation can all contribute to injury of ligaments and soft tissues. Trauma to the vertebrae and intervertebral disks, though rare, is possible. This can be minimized with experience, careful planning, proper positioning, a gentle technique and good communication with the patient. Identification of the epidural space can be facilitated by using aids such as ultrasound.

Neurological Damage

Neurological damage, though rare, can occur during the procedure or as later sequelae. It may be traumatic or the result of inadvertent injection of neurotoxic drugs. Though the damage is produced during the procedure, clinical presentation with persistence of sensory loss or abnormal sensation or as neuropathic pain might be delayed until the effect of epidural injection wears off.

Performing an epidural with the patient awake can minimize this complication and confirmation of diagnosis is by detailed neurological examination and radiological imaging. In many cases of neurological damage, though stressful both for patient and physician, is followed by complete or near complete recovery with only a few cases where the damage is permanent.

Bleeding

Bleeding can potentially occur from any tissue layer all along the path of the needle. If bleeding occurs through the needle, then it may have to be withdrawn and the procedure should be attempted at a different level. Bleeding from catheter can be managed by withdrawing the catheter by a few millimeters and flushing it with saline and repeating process until the catheter becomes clear (beware of catheter being completely pulled out of epidural space, or too little of it being inside; the latter runs the risk of delayed dislodgement) or by resiting at a different level. Initial injections of local anesthetic solutions then need to be administered through the catheter slowly and with frequent aspirations as a precaution.

Dural Tap

This usually presents as a dramatic flow of CSF through the Touhy needle or less frequently after the passage of epidural catheter. Sometimes a dual tap can remain concealed and present later as an inadvertent high spinal or a PDPH; there is a high incidence of PDPH (about 75%) following a dural tap. Management options include performing epidural in another level or converting it into a continuous spinal by inserting an intrathecal catheter (needs to be very careful when administering local anesthetic through this catheter as there is risk of accidental overdosing of local anesthetic).

Sympathetic Blockade

This is truly an excessive physiological effect of the extended epidural blockade.

Hypotension

Hypotension occurs secondary to vasodilatation and subsequent reduction in venous return. It usually has a slow onset in comparison with spinal and is easily treated with fluid loading and/or vasopressors (ephedrine, metaraminol - or phenylephrine). This is exaggerated in the presence of intravascular volume depletion secondary to dehydration or hemorrhage. Epidural epinephrine administered as an additive with local anesthetic can exaggerate this effect by its beta effect.

Bradycardia

Bradycardia is secondary to inhibition of sympathetic cardioaccelerator fibers (T1–T5) and reduced venous return. The treatment, in the presence of hemodynamic compromise, is with vagolytic agents (atropine or glycopyrrolate). Ephedrine by virtue of its effect both on heart rate and on blood pressure is yet another option.

Bronchospasm/Hypoxemia

Bronchospasm, though rare, is a possibility secondary to loss of bronchodilatory effect of the sympathetic system and the unopposed parasympathetic activity.

Hypotension can lead to an increase in pulmonary shunt and lead to *hypoxemia*, which is treated with supplementation of oxygen and by measures to increase blood pressure.

LA Toxicity

Accidental intravascular injection of local anesthetic drugs can lead to a range of side effects from mild symptoms like dizziness and circumoral tingling sensation to life-threatening circulatory collapse and convulsion. Management of this is in the line of airway, breathing, circulation (ABC) and organ support. Intralipid infusion [31] is claimed to be effective in reversing the effects of LA toxicity.

Total Spinal Anesthesia

This is the result of a large volume of LA injected accidentally into the subarachnoid space. Clinical manifestations include profound hypotension, respiratory insufficiency and loss of consciousness. Management is supportive following an ABC approach and a general anesthesia and artificial ventilation may need to be induced until recovery of the block.

Prevention is the best strategy to avoid a total spinal and this is done by giving a test dose before the full dose followed by testing motor functions of lower limbs. As this complication can potentially occur at any point until the epidural is stopped and catheter is removed, it is prudent to administer LA after careful aspiration of the catheter for CSF every time a top-up is given. Often LA solutions in the epidural space that are returning through the catheter can be confused with CSF and testing for the presence of glucose in the CSF is helpful in this situation.

Subdural Injection

The subdural space lies between the dural and arachnoid layers and is a potential space that, unlike epidural space, extends into the cranial cavity. Relatively small volumes of local anesthetic solutions entering the subdural space following injection through a misplaced catheter can produce high levels of blockade. The incidence of these complications is very low [32] (less than 1/1000 epidurals) and associated with slow onset of high block with a predominant sensory blockade and motor sparing. This may be associated with Horner's syndrome. Management is supportive and allows the block to wear off spontaneously.

Inadequate Block

This can present in a variety of ways such as a unilateral or patchy block due to uneven distribution of the local anesthetic solution or pain sensation. Potential causes include epidural catheter tip positioned outside the space, mechanical obstruction to spread of anesthetic solution (for sacral sparing), bands or septae separating the individual nerve roots or the presence of an air bubble into the epidural space (higher in LOR techniques using air not saline). This can be managed by pulling the catheter back, increasing the concentration of local anesthetic solution topping up on the side with reduced block, adding adjuvants such as a narcotic or if all these fail—resiting the epidural.

Delayed Complications

Delayed complications can present at a varying time frame from epidural insertion and most centers routinely institute a policy whereby an anesthetist will follow up patients 24 h post epidural removal to pick up potentially serious complications.

Post-dural-Puncture Headache

This results from leakage of CSF and subsequent reduction in the CSF pressure and is more common following a dural tap. The onset is usually 24–48 h following the dural puncture and can last up to 10 days. It presents as frontal or occipital headache with nuchal extension, characteristically worse on standing and associated symptoms include nausea, tinnitus, hearing loss, photophobia and diplopia.

The initial approach is conservative management with simple analgesia, rehydration (oral or i.v.), abdominal binding and bed rest. Other medications that are found to be of benefit but without significant evidence include caffeine, sumatriptan and ACTH. If this fails, then an epidural blood patch is performed using the patient's own blood. The procedure requires two doctors; one to draw the patient's blood in an aseptic manner, while the other performs the epidural and injects the blood (20 mL or until the patient complains of pressure). The dural rent is sealed off by the subsequent formation of a blood clot and often this produces a dramatic relief of PDPH; however, this may have to be repeated if the headache returns.

Back Pain

Back pain is secondary to local trauma and is common and usually resolves with simple analgesics. Those due to soft tissue hematoma especially in the ligaments take a longer time (6–8 weeks) to resolve. Chronic back pain per se due to tissue (bone, disk, or ligament) injury during epidural injection is possible but very rare.

Epidural Hematoma

This is a rare yet serious delayed complication of epidural neuraxial blockade with an incidence of 1/150,000 (preexisting coagulopathy is a risk factor). Pain may be the first presenting symptom and followed by loss of neurological functions, which is a result of compression of the cord by the expanding hematoma inside the rigid spinal canal. Undue prolongation of residual motor block should raise the suspicion of this condition. Radiological imaging should be undertaken immediately to confirm or rule out hematoma. Surgical decompression should be instituted early (within 6 h) as a delay can cause permanent neurological damage.

Epidural Abscess

Epidural abscess is another rare but serious complication of epidural injection. Risk factors include systemic sepsis and history of intravenous drug abuse. Initially it presents with non-specific symptoms such as fever and backache several days following epidural injection. There may be local tenderness over the spine and later progressing on to sensory loss and paraplegia. Laboratory findings may include elevated white cell count and raised ESR and CRP. Diagnosis is confirmed by MRI and treatment is again urgent surgical decompression and intravenous antibiotics.

Adhesive Arachnoiditis and Cauda Equina Syndrome

This complication has been reported [33, 34] following epidural injections and is the result of neurotoxicity of injectates (e.g., lignocaine, glass particles from ampoules). Clinical features are bowel and bladder disturbances, pain, paresthesia and patchy sensory abnormalities affecting the perineal regions and lower limb. Chemical arachnoiditis due to glass is prevented by not using medications from glass ampoule or using a glass filter for drawing up the injectate. Treatment is conservative and recovery may be incomplete.

Retained Catheter

Excessive lengths of epidural catheter introduced into the epidural space can lead to knotting and removal can be difficult or impossible. Leaving excessive length of catheter inside the epidural space is probably not a good practice. The terminal portion of catheter can break off and get lodged in the epidural space following an attempt to withdraw it through the needle. These catheters can be left in the epidural space without undue fear of tissue reaction as they are implantation tested. However, the patient should be warned of its presence in order to avoid future confusion with regard to the presence of a foreign body.

Clinical Pearls

Successful administration of epidural block begins from the pre-assessment phase right through to cessation of epidural analgesia. Detailed attention to patient selection and thoughtful planning and execution, as well as follow-up of patients, are necessary for a successful procedure with minimal complications.

A summary of the key points relating to epidural anesthesia:

Pre-assessment

Specifically Explore

History

- Symptoms of autonomic neuropathy
- Hypovolemia
- Features of local infection or sepsis
- Coagulopathy (INR < 1.5 is acceptable)
- Medications affecting haemostasis (Table 12.2)

Examination

- Airway assessment (potential for failure or complications)
- Spine (ease of palpation of spinous processes)
- Back (assess any abnormality and evidence infections/tattoos)
- Venous access

Investigations

- FBC
- Coagulation screen

Procedure

Surface Anatomy

- The depth of the epidural space is most shallow in the lumbar region deepest in the cervical region
- Vertebral flexion in the cervical and lumbar spines means making the patient maximally flex is beneficial
- Thoracic vertebrae only permit rotation so flexion makes little difference.

Preparation

- Check and prepare emergency drugs and GA equipment
- Maintain verbal contact with patient at all times (can give early warning of immediate/ imminent complications and anility to speak is a good sign of adequate cerebral perfusion)
- Proper positioning can make the procedure far easier
- Palpating the thoracic spines downward helps identify landmarks in obese individuals.
- LA needle can be used as a seeker needle in technically challenging cases
- Test all epidural catheters prior to insertion
- Full aseptic technique should be followed at all times including even when topping up

Procedure

- Avoid rotating the Touhy needle inside the epidural space to help in threading the epidural as this can produce dural tear with subsequent passage of catheter into the subdural space

Complication

Bloody Tap

- Avoid administering heparin for 2 h and LMWH for 24 h
  Subdural Injection
- Can manifest as patchy epidural block, high or total spinal
- Rapid injections can force the LA into the subdural space, while slow injections lead to epidural spread

Neurological

- Performing the epidural awake is the safest option as the patient can guide the operator in avoiding nerve damage

Catheter Migration

- Aspirating the catheter for blood and CSF is mandatory before each top-up (failure to do so can end in a catastrophe)

Review Questions

1. Regarding epidural analgesia the following statement is correct:
   (a) Reduces postoperative mortality
   (b) There is a reduction in venous thrombosis
   (c) It increases catecholamine release
   (d) Can lead to metabolic dysfunction
2. Epidural space extends from:
   (a) Cranial cavity to sacral foramina
   (b) Foramen magnum to lower border of L2
   (c) Foramen magnum to sacrococcygeal ligament
   (d) Foramen magnum filum terminale
3. Epidural space is thinnest in:
   (a) Cervical region
   (b) Thoracic region
   (c) Lumbar region
   (d) Caudal region
4. Regarding surface markings, the following statement is NOT true:
   (a) Vertebra prominence corresponds to C8 vertebra
   (b) Inferior angle of the scapula corresponds to T7 vertebra

(c) Superior aspect of iliac crest corresponds to L4 vertebra
(d) Posterior superior iliac spine corresponds to S2 vertebra

5. When performing thoracic epidural injection:
   (a) It is always performed by a paramedian approach
   (b) Midline approach is impossible because of the acute angulation of the thoracic spinous processes
   (c) It is possible to perform it by inserting the needle in the midline at an acute angle
   (d) Motor blockade produced at this level can paralyze the diaphragm
6. When performing a caudal epidural injection, the structures through which the needle passes through are:
   (a) Skin, subcutaneous tissue, supraspinous ligament, interspinous ligament, and ligamentum flavum
   (b) Skin, subcutaneous tissue, sacrococcygeal membrane and ligamentum flavum
   (c) Skin, subcutaneous tissue, interspinous ligament, and sacrococcygeal membrane
   (d) Skin subcutaneous tissue and sacrococcygeal membrane
7. A 75-year-old man with a history of ischemic heart disease (IHD) is undergoing hip arthroplasty under epidural. His base line heart rate and mean arterial pressure (MAP) prior to anesthesia were 75/min and 100 mm of Hg, respectively. After administration of epidural you notice that his heart rate has dropped to 55/min and MAP to 50 mm of Hg. Choose the most logical intervention:
   (a) There is no need for any intervention as the reduction in heart rate has reduced the myocardial oxygen demand
   (b) Atropine is indicated for bradycardia
   (c) Hypotension need not be treated as it helps to reduce blood loss
   (d) Treat hypotension as the reduction in myocardial oxygen demand will be offset by reduced oxygen supply secondary to hypotension
8. All of the following are true regarding epidural blockade except:
   (a) A reduction in heart rate can be due to blockade of cardioaccelerator fibers
   (b) A reduction in heart rate can be due to baroreceptor-mediated reflex bradycardia
   (c) Reduction in blood pressure due to vasodilatation reduced venous return and reduced adrenal cortical secretions
   (d) Selective lumbar or thoracic blockade has the benefit of providing hemodynamic stability as a result of compensatory vasoconstriction in unblocked segments
9. Which of the following effect is NOT caused by epidural blockade?
   (a) Parasympathetic blockade leading to reduction in blood pressure and nausea
   (b) Small, contracted bowel
   (c) Increased upper GI motility
   (d) Increased GI secretions
10. Electrodes for spinal cord stimulation are place in:
   (a) Subarachnoid space
   (b) Subdural space
   (c) Intrathecal space
   (d) Epidural space
11. The following is an absolute contraindication for epidural blockade:
   (a) Coagulopathy
   (b) Patient refusal
   (c) A bleeding patient
   (d) A septic patient
12. You are performing an epidural catheter insertion for labor analgesia. The epidural space is identified at a depth of 6 cm. A catheter is then passed and on withdrawing the Touhy needle the marking at the skin corresponds to 15 cm. The length of catheter remaining inside the epidural space probably is:
   (a) 15 cm
   (b) 10 cm
   (c) 9 cm
   (d) 11 cm

13. The structures negotiated by a Touhy needle during the paramedian approach are:
    (a) Skin, subcutaneous tissue, paraspinous muscles, and ligamentum flavum
    (b) Skin, subcutaneous tissue, interspinous ligament, and ligamentum flavum
    (c) Skin, subcutaneous tissue, paraspinous muscles, and interspinous ligament
    (d) Skin, subcutaneous tissue, supraspinous ligament, and ligamentum flavum
14. When epinephrine is used as an additive in epidural anesthesia:
    (a) The dose of local anesthetic should be reduced to avoid drug toxicity
    (b) It increases the depth of neural blockade
    (c) There is a rapid systemic absorption of the drugs injected which is indicated by an increase in heart rate
    (d) A sudden increase in heart rate indicates successful epidural deposition of the drug
15. The following statement is NOT true regarding PDPH:
    (a) CSF pressure is low
    (b) The treatment of choice is immediate blood patch
    (c) Can present with cranial nerve symptoms
    (d) Its relation to posture is characteristic

Answers

1. b—Epidural analgesia reduces the stress response to surgery by providing effective analgesia, which is beneficial for cardiovascular, respiratory, and metabolic functions. There is a reduction in postoperative hypercoagulable state, which in turn reduces the incidence of deep vein thrombosis. Though there is a reduction in postoperative morbidity, there is no evidence for reduction in mortality after surgery.
2. c
3. a—It is 2 mm in thickness at the cervical region and 5–6 mm in the lumbar region.
4. a—There is no C8 vertebra though there is C8 nerve root.
5. c—Though paramedian approach is relatively easy to perform, a midline approach can also be used to administer thoracic epidural injection. Motor blockade at thoracic level does not affect diaphragmatic function as the innervation of diaphragm is by the phrenic nerve, which originates at cervical level (C3–C5).
6. d—There is no ligamentum flavum over the sacral hiatus as it fuses with the caudal lamina.
7. d—Though reduction in heart rate reduces myocardial oxygen demand, oxygen supply will be maintained only if MAP is maintained. In the presence of IHD, it is safe not to allow the MAP to drop below 20% of the base line value.
8. c—Reduction in blood pressure is due to a reduction in adrenal *medullary* secretions.
9. a—Sympathetic blockade leads to unopposed vagal dominance.
10. d
11. b—All the others are relative contraindications.
12. c
13. a—Paramedian approach avoids both supraspinous and interspinous ligaments, and hence, it is easier by this approach in the elderly who may have calcified ligaments.
14. b—Epidural epinephrine produces local vasoconstriction and decreases systemic absorption of local anesthetic, and hence, a higher dose of local anesthetic can be used. A sudden increase in heart rate indicates the intravascular injection of the drug (into epidural veins).
15. b—First line of treatment for PDPH is bed rest, simple analgesics, and hydration. If this fails then epidural blood patch is indicated.

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