Applied epidural anatomy
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Key points
Clinicians performing epidural procedures should have a good knowledge of the relevant anatomy.
Radiological screening is helpful for difficult epidural entry.
Maximal neck flexion can almost double the depth of the cervical epidural space.
Spinal endoscopy adds another dimension to epidural catheterization. At present, its main application is in relation to the management and diagnosis of chronic radicular pain.

Anatomy of the epidural space

Vertebral column
There are 24 individual vertebrae: seven cervical, 12 thoracic and five lumbar. The five (fused) sacral vertebrae and the coccyx (made up of 3–5 rudimentary vertebrae) are not always classed as being a part of the vertebral column. Vertebral anatomy varies according to each level. The atlas and the axis are highly atypical and the first ‘recognizably normal’ vertebra is C3. Atlas and axis anatomy are relevant to anaesthetists in that the odontoid process (dens) of the axis should be closely applied (2–3 mm) to the anterior arch of the atlas in flexion and extension (the gap is filled with cartilage). Rheumatoid arthritis and trauma may affect this relationship and the ability to recognize the relevant anatomy on lateral radiographs is important.

From C3 downwards, the vertebrae (although they vary) have a recognizable anterior body, posteroslateral pedicles (Latin for ‘little feet’), transverse processes and posterior laminae (‘thin layers’), which fuse to form the spinous processes. The spinal canal enclosed within these structures is also known as the epidural space, apart from the central portion occupied by the dural sac and its contents. The dura mater contains the arachnoid mater. Between the arachnoid and the pia mater, which is applied to the spinal cord, is cerebrospinal fluid. As the vertebral column grows, it leaves behind the spinal cord so that by adulthood the cord ends at the lower border of L1 (although this can vary by one vertebra). The dural sac generally ends at the lower border of S1, although it leaves behind the filum equina.

Spinal nerves exit at each level and are numbered according to the thoracic, lumbar or sacral vertebra above. As there are eight cervical spinal nerves and seven vertebrae, the nerves in this region only are numbered according to the vertebra below. The only exception is spinal nerve C8 that leaves between vertebra C7 and T1.

Epidural space
The boundaries of the epidural space are summarized in Table 1 and the definitions of the cervical, thoracic, lumbar and sacral regions are defined in Table 2. The epidural space contains fat, the dural sac, spinal nerves, blood vessels and connective tissue (Table 3).

Blood supply
Inside the spinal canal there is an anterior and posterior arterial (and venous) arcade formed from the spinal arteries entering at each level through the interventricular foramina. These arise from the vertebral arteries superiorly and then thoracic and the lumbar aorta. They anastomose with the anterior spinal artery, running on the surface of the spinal cord arising initially from the vertebral arteries at the circle of Willis. The nerve root (with the...
exception of the dorsal root ganglion) has a poor blood supply compared with the spinal cord. There is a watershed area half way along its length where branches from the conus medullaris meet the supply from the thoracic and lumbar arteries. Despite anastomoses throughout the vertebral canal, arterial trauma can compromise the blood supply of the cord itself.

Venous drainage is via the valveless vertebral venous plexus of Batson, which, fortunately for the epiduralist, is predominantly an anterior spinal canal structure. The posterior venous plexus is variable in size at the lumbar level but generally increases in the thoracic and cervical areas.2 Drainage is into the intracranial venous sinuses and, at a local level, into the thoracic and lumbar veins through the intervertebral foramina. The veins in the lumbar area drain into the ascending lumbar veins lying on the anterior surface of the transverse processes. These empty into either the iliac veins inferiorly or the hemiazygous or azygous veins on the left and right, respectively. As the whole system is valveless, increased intrathoracic or intra-abdominal pressure (e.g. ascites, pregnancy) can lead to major congestion and vessel enlargement within the spinal canal.

Nerve supply

The spinal canal and its contents have their own innervation. The anterior dura is heavily innervated;2 fortunately for spinal anaesthesia, the posterior dura is sparsely supplied. The nerve supply of the spinal canal is via direct branches from the sympathetic chain and via the sinu-vertebral nerves that originate from the rami communicantes. The periosteum is pain sensitive but the ligamentum flavum is not.

Lymphatics

Lymphatics are present around the region of the nerve root and function to remove foreign material. They are absent in the nerve root itself.

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### Table 3: Contents of the epidural space

<table>
<thead>
<tr>
<th>Structure</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td>Fat</td>
<td>Varies in direct proportion to the rest of the body.1 Not uniform in distribution; exists in bands at level of intervertebral foramina</td>
</tr>
<tr>
<td>Dural sac</td>
<td>Ends at approximately S2. Contains the spinal cord (to the lower border of L1) and cauda equina</td>
</tr>
<tr>
<td>Spinal nerves</td>
<td>In pairs. Dorsal root ganglia in lateral recesses</td>
</tr>
<tr>
<td>Vessels</td>
<td>See text</td>
</tr>
<tr>
<td>Connective tissue</td>
<td>Variable dorsomedian folds, median fold. After leakage of nucleus pulposus, surgery or previous epidural catheterization may be heavy scar tissue</td>
</tr>
</tbody>
</table>

### Table 4: Epidural space location according to vertebral level

<table>
<thead>
<tr>
<th>Level</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>Loss of resistance poorly appreciated as the ligamentum flavum is thin and soft.1 ‘Hanging drop’ method in the sitting position often employed. Depth of space only 1.5–2 mm at C7. Increases to 3–4 mm with neck flexion.2 Should be performed by the experienced practitioner only.</td>
</tr>
<tr>
<td>Thorax</td>
<td>Kyphotic apex at T6. Slight right scoliosis common and normal. Avoid midline approach between T5–T8</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Enter if possible below L2 to avoid the cord.2</td>
</tr>
</tbody>
</table>

*Distance from ligamentum flavum to dura.*

### Table 5: Overview of methods of epidural entry

<table>
<thead>
<tr>
<th>Method</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Interlaminar (transflaval)</td>
<td>The ‘usual’ method. Loss of resistance methods. Can use 'hanging drop’ or other techniques in the cervical region.</td>
</tr>
<tr>
<td>Transforaminal</td>
<td>Directs solution to the anterior epidural space. Radiological guidance mandatory. Specialist use only</td>
</tr>
<tr>
<td>Transsacral</td>
<td>Simple entry, aspiration and injection. Up to 40% in the adult incorrectly placed without radiological guidance4</td>
</tr>
<tr>
<td>Direct vision</td>
<td>Spinal endoscopy</td>
</tr>
<tr>
<td>Paravertebral</td>
<td>Frequent epidural blockade5</td>
</tr>
</tbody>
</table>

### Locating the epidural space

The standard methods of detection of entry into the epidural space will not be discussed in detail here; they are covered in many other texts. Some helpful suggestions are offered according to the anatomical level of entry (Table 4). The various methods are summarized in Table 5.

### Pathology affecting epidural entry

Anatomical abnormalities affecting epidural catheterization are either congenital or acquired. Congenital abnormalities that cause difficulties include achondroplasia, congenital adolescent scoliosis and spina bifida. The use of epidurals in achondroplasia and congenital adolescent scoliosis is controversial. As spina bifida is frequently associated with a meningocoele, which may be close to the surface, and with the failure of fusion of the laminae with attendant ligamentum flavum abnormalities, epidural location should not be attempted. Acquired difficulties include ligamentum flavum hypertrophy, often contributing to spinal stenosis, foraminal stenosis and disc prolapse. The latter two are not contraindications, but could make satisfactory entry or catheterization difficult. X-ray guidance may be of help.

The effect of previous epidural catheterization, spinal level and respiration on epidural space structures (as determined by epiduroscopy) is summarized in Table 6.

### Epiduroscopy

Although receiving considerable recent attention, spinal endoscopy or epiduroscopy is not a new technique. It has been carried...
out since the 1930s using rigid instruments and transflaval approaches. Nowadays, most epiduroscopy is carried out using flexible instruments introduced through the sacrococcygeal route providing a direct path to more cranial structures.

Spinal endoscopy is different from other imaging techniques in that it has a major interactive element with the patient, allowing examination of appropriate areas, which may be causing pain. Examination of the contents of the dural sac is easy as they are suspended in clear cerebro-spinal fluid. With recent advances in instrumentation, especially involving fully steerable, flexible instruments, along with a saline delivery system, a multilevel detailed examination of the epidural space can be satisfactorily achieved. High quality views aid the examiner in exactly identifying the nerve roots that may be implicated in pain generation.9 10

Conditions that have so far been diagnosed using this technique include: cysts and tumours, fibrosis, ischaemia and tethering of nerve roots, arachnoiditis, tuberculosis meningitis and acute and traumatic events associated with epidural catheterization.

References


See multiple choice questions 78–80.