Failed spinal anesthesia: Mechanisms, management, and prevention

An essay submitted for partial fulfillment of the master degree in anesthesiology

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Contents

List of Figures

List of Tables

Introduction

Although spinal (subarachnoid or intrathecal) anesthesia is generally regarded as one of the most reliable types of regional block methods, the possibility of failure has long been recognized **(*Ben-David et al., 1995)* .**

Dealing with a spinal anesthetic which is in some way inadequate can be very difficult; so, the technique must be performed in a way which minimizes the risk of regional block. Thus, practitioners must be aware of all the possible mechanisms of failure so that, where possible, these mechanisms can be avoided ***(Lacassie, et al.)2005,***.

This research has considered the mechanisms in a sequential way: problems with lumbar puncture; errors in the preparation and injection of solutions; inadequate spreading of drugs through cerebrospinal fluid; failure of drug action on nervous tissue; and difficulties more related to patient management than the actual block ***(Lang, et al.,2005).***

Options for managing an inadequate block include repeating the injection, manipulation of the patient's posture to encourage wider spread of the injected solution, supplementation with local anesthetic infiltration by the surgeon, use of systemic sedation or analgesic drugs ***(Fettes 2009).***

Anatomy of the vertebral column

The spinal, or vertebral, column is made up of thirty-three vertebrae, of which twenty-four are discrete vertebrae and nine are fused in the sacrum and coccyx. ***(Fig.1-1)***

In the embryo the spine is curved into a gentle C shape but, with the extension of the head and lower limbs that occurs when the child first holds up its head, then sits and then stands, secondary forward curvatures appear in the cervical and lumbar region, which produce the curves of the fully developed spinal column***.(Harold Ellis 2006)***

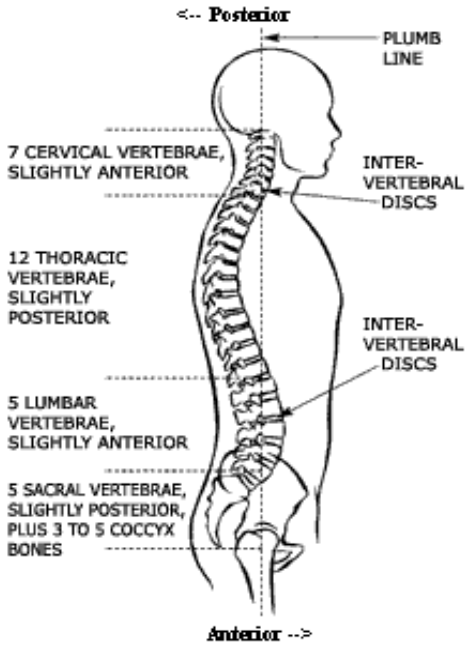
Typical vertebra:

The basic vertebral pattern ***(Fig.1-2)*** is that of a body and of a neural arch surrounding the vertebral canal.

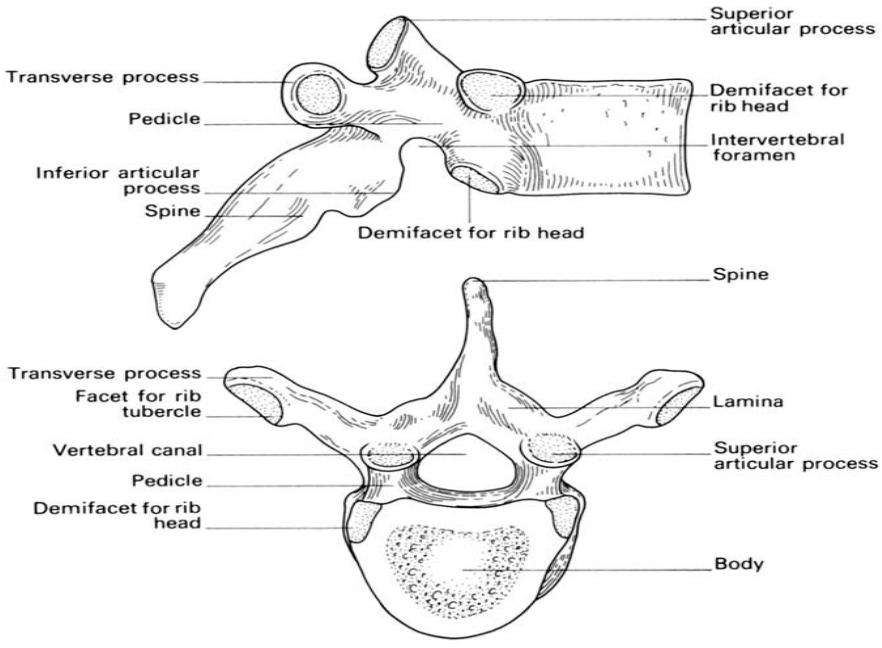
The neural arch is made up of a pedicle on either side, each supporting a lamina which meets its opposite posteriorly in the midline. The pedicle bears a notch above and below which, with its neighbour, forms the Tintervertebral foramen. The arch bears a posterior spine, lateral transverse processes and upper and lower articular facets.

The intervertebral foramina transmit the segmental spinal nerves as follows:

C1–7 pass over the superior aspect of their corresponding cervical vertebrae, C8 passes through the foramen between C7 and T1, and all subsequent nerves pass between the vertebra of their own number and the one below.



(Fig.1-1) Vertebral column



(Fig. 1-2) typical thoracic vertebra

The intervertebral joints:

The spinal column is made up of individual vertebrae which articulate body to body and their articular facets. Although movement between adjacent vertebrae is slight, the additive effect is considerable. Movement particularly occurs at the cervicodorsal and dorsolumbar junctions; these are the two common sites of vertebral injury ***(Harold Ellis 2006)***.

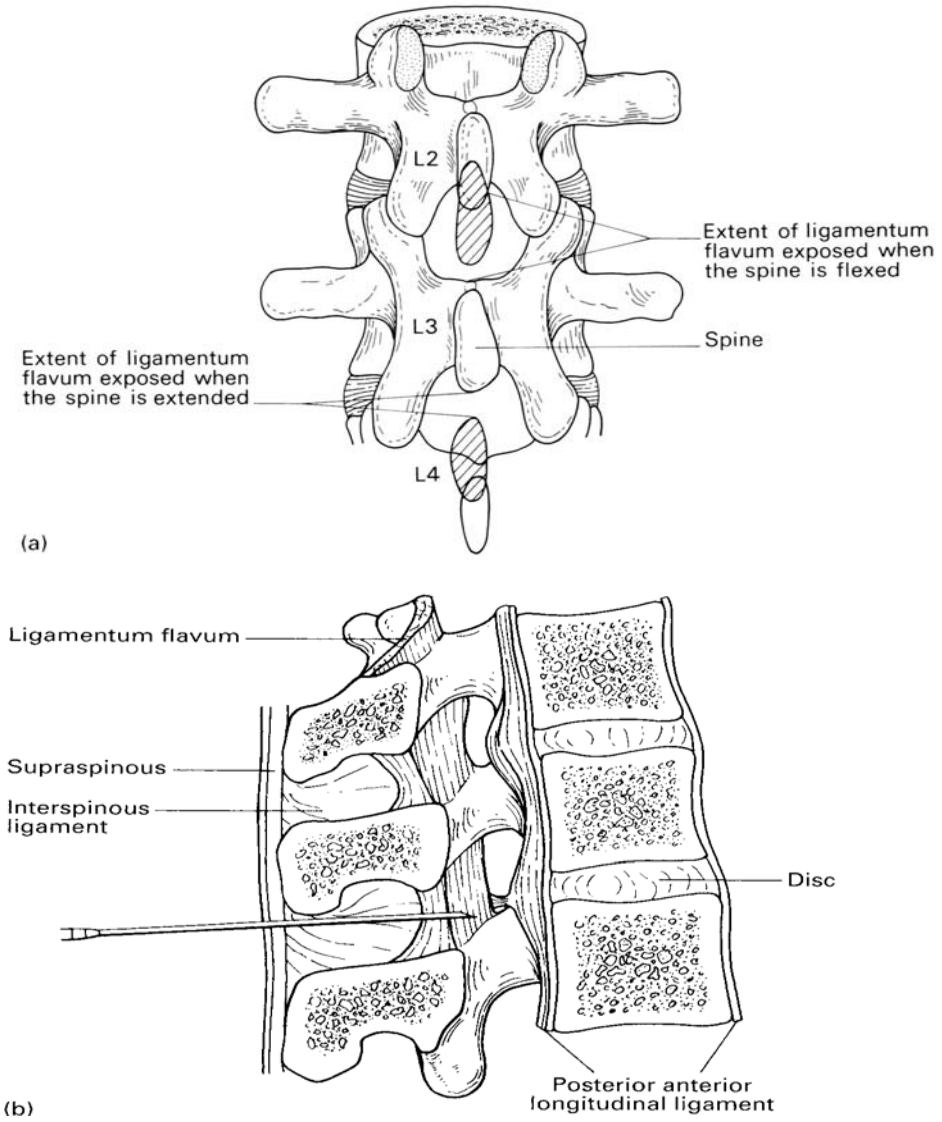
The vertebral ligaments:

The vertebral laminae are linked by the ligamentum flavum of elastic tissue, the spines by the tough supraspinous and relatively weak interspinous ligaments, and the articular facets by articular ligaments around their small synovial joints. All these ligaments serve to support the spinal column when it is in the fully flexed position.

Running the whole length of the vertebral bodies, along their anterior and posterior aspects respectively, are the tough anterior and posterior longitudinal ligaments.***(Fig.1-3)***

The vertebral bodies are also joined by the extremely strong intervertebral discs .These each consist of a peripheral annulus fibrosus, which adheres to the thin cartilage plate on the vertebral body above and below, and which surrounds are gelatinous semifluid nucleus pulposus. The intervertebral discs constitute approximately a quarter of the length of the spine as well as accounting for its secondary curvatures.

In old age, the discs atrophy, with resulting shrinkage in height and return of the curvature of the spine to the C shape of the newborn. ***(Harold Ellis 2006).***



(Fig.1-3) (a) The lumbar interlaminar gap when the spine is flexed; this anatomical fact makes lumbar puncture possible. The locations of the spines of L2 and L4 in the extended position are shown cross-hatched. (b) The anatomy of lumbar puncture.

Contents of the vertebral canal:

The spinal canal (or vertebral canal or spinal cavity) is the space in vertebrae through which the spinal cord passes. It is a process of the dorsal human body cavity. This canal is enclosed within the vertebral foramen of the vertebrae. In the intervertebral spaces, the canal is protected by the ligamentum flavum posteriorly and the posterior longitudinal ligament anteriorly. The hollow spinal canal contains the spinal cord, and its coverings (meninges), fat, connective tissue, and blood supply of the cord. ***(Jürgen Harms 2007).***

1)The spinal cord:

The spinal cord is a long, thin, tubular bundle of nervous tissue and support cells that extends from the brain (the medulla specifically), Inferiorly, it tapers into the conus medullaris from which a prolongation of pia mater, the (filum terminale), descends to be attached to the back of the coccyx.

The spinal cord extends down to the space between the first and second lumbar vertebrae; it does not extend the entire length of the vertebral column. It is around 45 cm long (18 inches) in men and around 43 cm (17 inches) long in women. The enclosing bony vertebral column protects the relatively shorter spinal cord.

The spinal cord functions primarily in the transmission of neural signals between the brain and the rest of the body but also contains neural circuits that can independently control numerous reflexes and central pattern generators. The spinal cord has three major functions:

A). Serve as a conduit for motor information, which travels down the spinal cord.

B). Serve as a conduit for sensory information, which travels up the spinal cord.

C). Serve as a center for coordinating certain reflexes.

(Maton, 1993).

Structure of the cord:

The human spinal cord is ovoid-shaped, and is enlarged in the cervical and lumbar regions. The cervical enlargement, located from C4 to T1, is where sensory input comes from and motor output goes to the arms. The lumbar enlargement, located between T9 and T12, handles sensory input and motor output coming from and going to the legs.

In cross-section, the peripheral region of the cord contains neuronal white matter tracts containing sensory and motor neurons. Internal to this peripheral region is the gray, butterfly-shaped central region made up of nerve cell bodies. This central region surrounds the central canal, which is an anatomic extension of the spaces in the brain known as the ventricles and, like the ventricles, contains cerebrospinal fluid***(Maton, 1993).***

The spinal cord has a shape that is compressed dorso-ventrally, giving it an elliptical shape. The cord has grooves in the dorsal and ventral sides. The posterior median sulcus is the groove in the dorsal side, and the anterior median fissure is the groove in the ventral side. Running down the center of the spinal cord is a cavity, called the central canal. **(Fig.1-4)** ***(Maton, 1993)***.

The three meninges that cover the spinal cord-the outer dura mater, the arachnoid mater, and the innermost pia mater-are continuous with that in the brainstem and cerebral hemispheres. Similarly, cerebrospinal fluid is found in the subarachnoid space ***(Maton, 1993)***.

The cord is stabilized within the dura mater by the connecting denticulate ligaments, which extend from the enveloping pia mater laterally between the dorsal and ventral roots. The dural sac ends at the vertebral level of the second sacral vertebra. ***(Maton, 1993).***

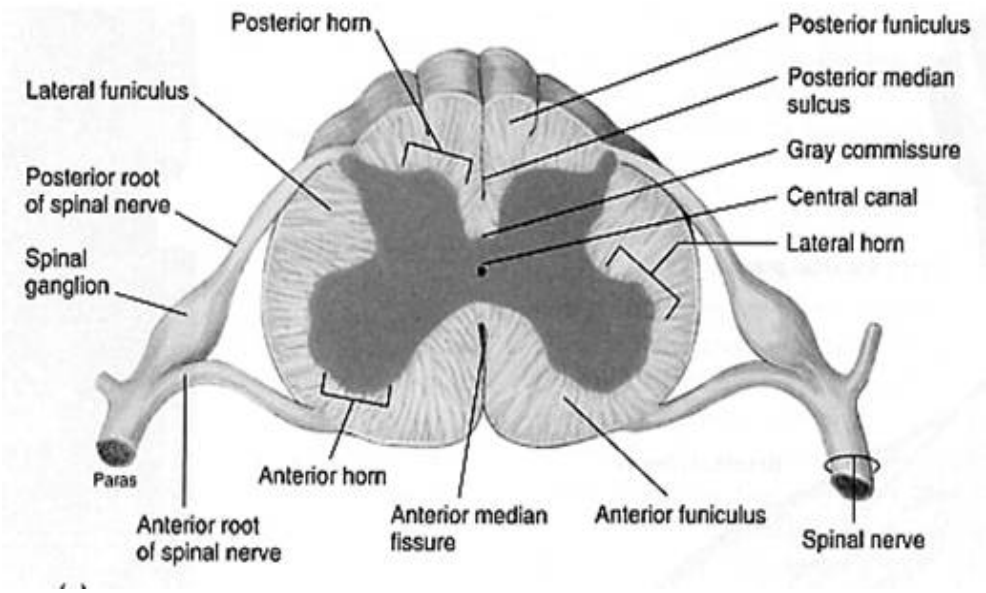


Fig.(1-4): cross srction of the spinal cord.

Blood supply of the cord:

1: Arterial supply:

Anterior and posterior spinal arteries which both decsends from the level of the foramen magnum.

- The anterior spinal artery is a midline vessle lying on the anterior median fissure. Formed by the union of a branch from each vertebral artery. It supplies the whole of the cord infront of the posterior grey column.
- The posterior spinal arteries comprise one or two vessels on either side derived from the posterior inferior cerebellar arteries, they supply the posterior grey and white columns on either side.

These arteries are reinforced serialy by spinal branches of the vertebral, deep cervical, intercostal, lumber, ilio-lumber and lateral sacral arteries.

These vessels pass through the intervertebral foramena along the ventral and dorsal nerve roots which they supply.

2: Venous drainage:

A plexus of anterior and posterior spinal veins that pass along the nerve roots through the intervertebral formaina to drain into segmental veins:

- Vertebral veins in the neck.
- Azygos veins in the the thorax.
- Lumber veins in the abdomen.
- Lateral sacral veins in the pelvis.

(Harold Ellis 2006).

2)Spinal meninges:

The spinal cord, like the brain, is closely ensheathed by the pia mater. This is thickened on either side between the nerve roots to form the denticulate ligament, which passes laterally to adhere to the dura. ***(Fig.1-5)***

Inferiorly, the pia continues as the filum terminale, which pierces the distal extremity of the dural sac and becomes attached to the coccyx. The arachnoid mater lines the dura matter, leaving an extensive subarachnoid space, containing cerebrospinal fluid (C.S.F.), between it and the pia ***(Harold Ellis 2006)***.

Both pia and arachnoid are continued along the spinal nerve roots ***(Harold Ellis 2006)***.

The dura itself forms a tough sheath to the cord. It ends distally at the level of the 2nd sacral vertebra. It also continues along each nerve root and blends with the sheaths of the peripheral nerves. ***(Harold Ellis 2006).***

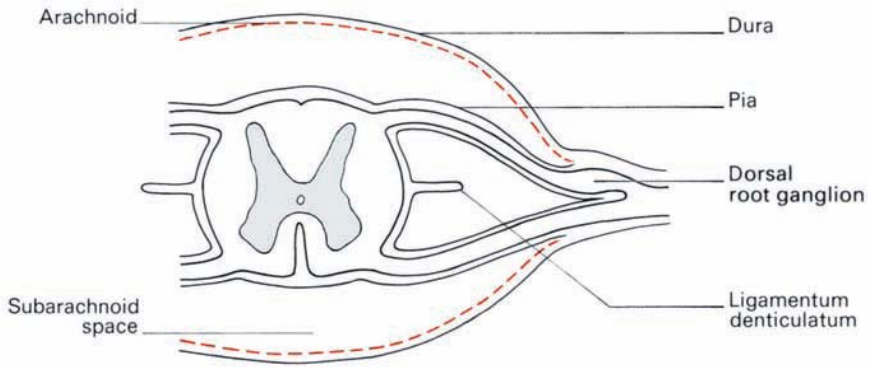


Fig. (1-5): spinal meninges.

Dura mater:

The spinal cord, like the brain, is surrounded by the three meninges. The dura mater extends from the foramen magnum to the sacrum and coccyx. The dura is attached to the foramen magnum and the periosteium covering the uppermost cervical vertebrae and their ligaments. Through the remainder of the vertebral canal, the dura is not attached to the vertebrae, being separated by the epidural (or peridural or extradural) space, which contains fat and the internal vertebral venous plexus. In caudal analgesia, an anesthetic solution injected into the sacral hiatus diffuses upward into the epidural space.

This may be used in surgical procedures relating to pelvic and perineal regions. Extensions of dura (dural sheaths) surround the nerve roots and spinal ganglia, and continue into the connective tissue coverings (epineurium) of the spinal nerves.

Arachnoid mater:

The arachnoid invests the spinal cord loosely. Continuous with the cerebral arachnoid above, it traverses the foramen magnum and descends to about the S2 vertebral level. The subarachnoid space, which contains cerebrospinal fluid (C.S.F.), is a wide interval between the arachnoid and pia.