INTRODUCTION

Continuous spinal anesthesia (CSA) is the technique of producing and maintaining spinal anesthesia with small doses of local anesthetic which are injected intermittently into the subarachnoid space via an indwelling catheter. The concept was described first in 1907 by Dean, a British surgeon who wrote of placing a needle in the subarachnoid space and leaving it in situ so that repeated doses of local anesthetic could be injected ***(Dean, 1907).***

CSA is considered a longstanding anesthetic technique that could be used for surgery of the lower limbs and lower abdomen. It is an underutilized technique in modern anesthesia practice. Compared with other techniques of neuraxial anesthesia as single-dose spinal anesthesia and continuous epidural anesthesia, it has shown several advantages such as administration of local anesthetics in small incremental doses titrated to the individual patient's needs, reduced requirements of local anesthetics and thus decreased systemic toxic effects, ensured cardiovascular stability, and extended anesthesia by supplemental application of spinal local analgesics when surgery is unexpectedly extended ***(Maurer et al., 2003).***

Whereas traditional single-shot spinal anesthesia usually involves larger doses, a finite, unpredictable duration, and greater potential for detrimental hemodynamic effects including hypotension, and epidural anesthesia via a catheter may produce lesser motor block and suboptimal anesthesia in sacral nerve root distributions ***(Moore, 2009).***

The combined spinal–epidural technique (CSE) has become increasingly popular in recent years. It can be defined as the intentional injection of drug into the subarachnoid space and the placement of a catheter into the epidural space as part of the same procedure ***(Kar-Binh Ong et al., 2007).***

Epidural and spinal blocks are well-accepted regional techniques, but they have several disadvantages. The CSE technique can reduce or eliminate the risks of these disadvantages. CSE block combines the rapidity, density, and reliability of the subarachnoid block with the flexibility of continuous epidural block to extend duration of analgesia. The CSE technique is used routinely at many institutions, particularly for major orthopedic surgery and in obstetrics ***(Rawal et al., 2000).***

Aim of Study

This study is aimed at comparing the efficacy of continuous spinal anesthesia technique versus combined spinal epidural technique in knee surgeries and the potential adverse effects for both techniques.

REVIEW OF LITERATURE

Anatomy

The **vertebral column**, also known as the spinal column or spine, consists of a sequence of vertebrae, each of which is separated and united by an intervertebral disc. Together, the vertebrae and intervertebral discs form the vertebral column. It is a flexible column that supports the head, neck, and body and allows their movements. It also protects the spinal cord, which passes down the back through openings in the vertebrae ***(Openstax, 2016).***

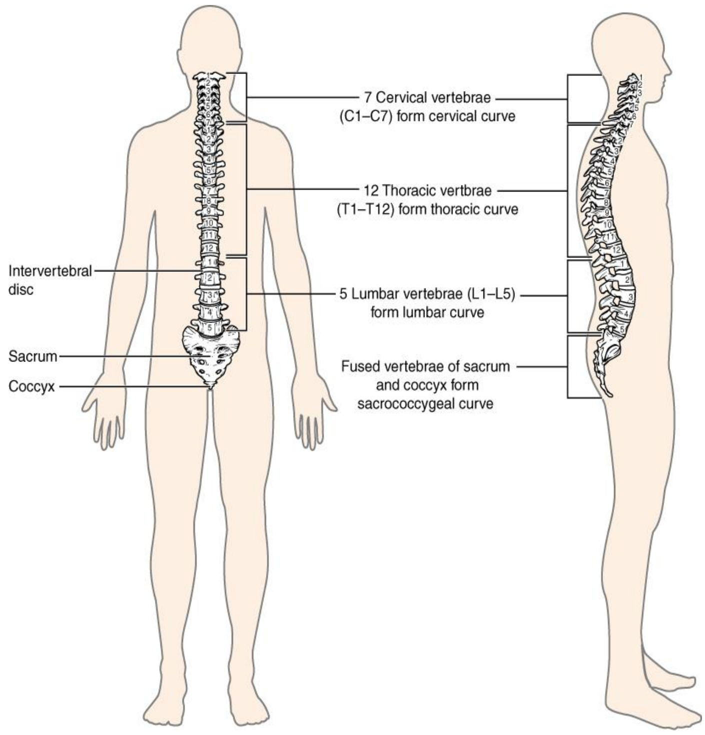

Figure (1): ***Vertebral Column.*** The adult vertebral column consists of 24 vertebrae, plus the sacrum and coccyx. The vertebrae are divided into three regions: cervical C1–C7 vertebrae, thoracic T1–T12 vertebrae, and lumbar L1–L5 vertebrae. The vertebral column is curved, with two primary curvatures (thoracic and sacrococcygeal curves) and two secondary curvatures (cervical and lumbar curves) ***(Openstax, 2016).***

The vertebral column originally develops as a series of 33 vertebrae, but this number is eventually reduced to 24 vertebrae, plus the sacrum and coccyx. The vertebral column is subdivided into five regions, with the vertebrae in each area named for that region and numbered in descending order. In the neck, there are seven cervical vertebrae, each designated with the letter "C" followed by its number. Superiorly, the C1 vertebra articulates with the occipital condyles of the skull. Inferiorly, C1 articulates with the C2 vertebra, and so on. Below these are the 12 thoracic vertebrae, designated T1–T12. The lower back contains the L1–L5 lumbar vertebrae. The single sacrum, which is also part of the pelvis, is formed by the fusion of five sacral vertebrae. Similarly, the coccyx results from the fusion of four small coccygeal vertebrae. However, the sacral and coccygeal fusions do not start until age 20 and are not completed until middle age ***(Openstax, 2016).***

The adult vertebral column does not form a straight line, but instead has four curvatures along its length **(Figure 1).** These curves increase the vertebral column's strength, flexibility, and ability to absorb shock. When the load on the spine is increased, the curvatures increase in depth to accommodate the extra weight. They then spring back when the weight is removed. The four adult curvatures are classified as either primary or secondary curvatures. Primary curves are retained from the original fetal curvature, while secondary curvatures develop after birth. During fetal development, the body is flexed anteriorly into the fetal position, giving the entire vertebral column a single curvature that is concave anteriorly. In the adult, this fetal curvature is retained in two regions of the vertebral column as the thoracic curve, which involves the thoracic vertebrae, and the sacrococcygeal curve, formed by the sacrum and coccyx. Each of these is thus called a primary curve because they are retained from the original fetal curvature of the vertebral column. A secondary curve develops gradually after birth as the child learns to sit upright, stand, and walk. Secondary curves are concave posteriorly, opposite in direction to the original fetal curvature. The cervical curve of the neck region develops as the infant begins to hold their head upright when sitting. Later, as the child begins to stand and then to walk, the lumbar curve of the lower back develops. In adults, the lumbar curve is generally deeper in females ***(Openstax, 2016).***

Within the different regions of the vertebral column, vertebrae vary in size and shape, but they all follow a similar structural pattern. A typical vertebra will consist of a body, a vertebral arch, and seven processes **(Figure 2).** The body is the anterior portion of each vertebra and is the part that supports the body weight. Because of this, the vertebral bodies progressively increase in size and thickness going down the vertebral column. The bodies of adjacent vertebrae are separated and strongly united by an intervertebral disc. The vertebral arch forms the posterior portion of each vertebra. It consists of four parts, the right and left pedicles and the right and left laminae. Each pedicle forms one of the lateral sides of the vertebral arch. The pedicles are anchored to the posterior side of the vertebral body. Each lamina forms part of the posterior roof of the vertebral arch. The large opening between the vertebral arch and body is the vertebral foramen, which contains the spinal cord. In the intact vertebral column, the vertebral foramina of all of the vertebrae align to form the vertebral (spinal) canal, which serves as the bony protection and passageway for the spinal cord down the back. When the vertebrae are aligned together in the vertebral column, notches in the margins of the pedicles of adjacent vertebrae together form an intervertebral foramen, the opening through which a spinal nerve exits from the vertebral column **(Figure 3)**. Seven processes arise from the vertebral arch. Each paired transverse process projects laterally and arises from the junction point between the pedicle and lamina. The single spinous process (vertebral spine) projects posteriorly at the midline of the back. The vertebral spines can easily be felt as a series of bumps just under the skin down the middle of the back. The transverse and spinous processes serve as important muscle attachment sites. A superior articular process extends or faces upward, and an inferior articular process faces or projects downward on each side of a vertebrae. The paired superior articular processes of one vertebra join with the corresponding paired inferior articular processes from the next higher vertebra. These junctions form slightly moveable joints between the adjacent vertebrae. The shape and orientation of the articular processes vary in different regions of the vertebral column and play a major role in determining the type and range of motion available in each region ***(Openstax, 2016).***

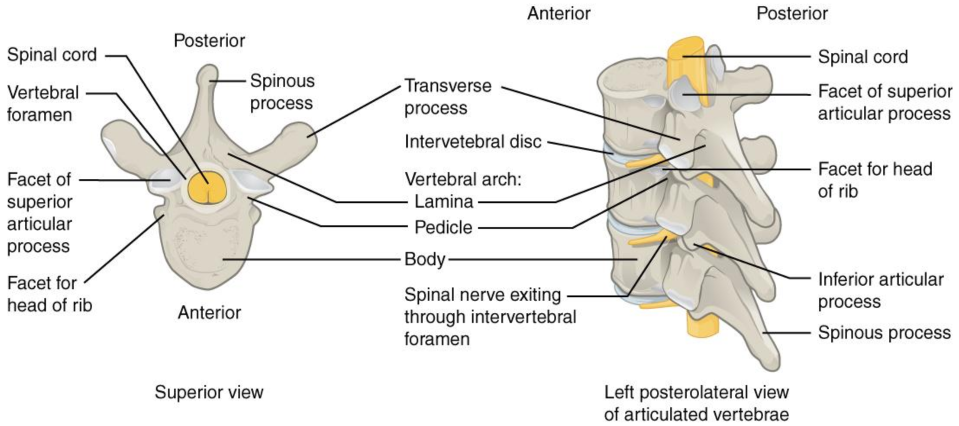

Figure (2): ***Parts of a Typical Vertebra.*** A typical vertebra consists of a body and a vertebral arch. The arch is formed by the paired pedicles and paired laminae. Arising from the vertebral arch are the transverse, spinous, superior articular, and inferior articular processes. The vertebral foramen provides for passage of the spinal cord. Each spinal nerve exits through an intervertebral foramen, located between adjacent vertebrae. Intervertebral discs unite the bodies of adjacent vertebrae ***(Openstax, 2016).***

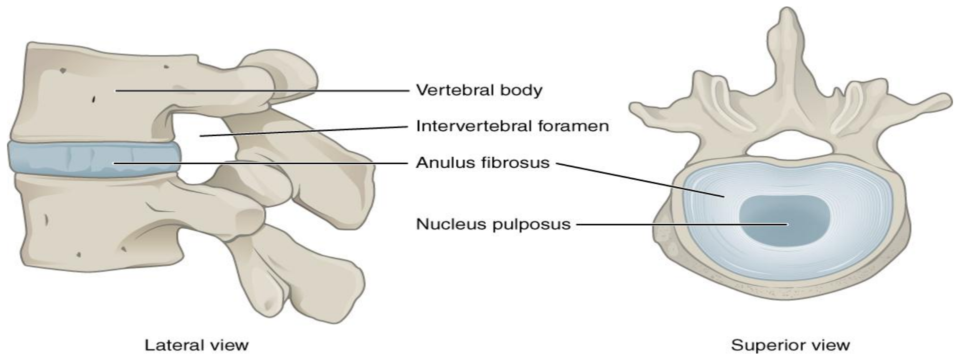

Figure (3): ***Intervertebral Disc.*** The bodies of adjacent vertebrae are separated and united by an intervertebral disc, which provides padding and allows for movements between adjacent vertebrae. The disc consists of a fibrous outer layer called the annulus fibrosus and a gel-like center called the nucleus pulposus. The intervertebral foramen is the opening formed between adjacent vertebrae for the exit of a spinal nerve ***(OpenStax, 2016).***

The bodies of adjacent vertebrae are strongly anchored to each other by an intervertebral disc. This structure provides padding between the bones during weight bearing, and because it can change shape, also allows for movement between the vertebrae. Although the total amount of movement available between any two adjacent vertebrae is small, when these movements are summed together along the entire length of the vertebral column, large body movements can be produced. Ligaments that extend along the length of the vertebral column also contribute to its overall support and stability. An intervertebral disc is a fibrocartilaginous pad that fills the gap between adjacent vertebral bodies. Each disc is anchored to the bodies of its adjacent vertebrae, thus strongly uniting these. The discs also provide padding between vertebrae during weight bearing. Because of this, intervertebral discs are thin in the cervical region and thickest in the lumbar region, which carries the most body weight. Intervertebral discs are also flexible and can change shape to allow for movements of the vertebral column. Each intervertebral disc consists of two parts. The annulus fibrosus is the tough, fibrous outer layer of the disc. It forms a circle (anulus = “ring” or “circle”) and is firmly anchored to the outer margins of the adjacent vertebral bodies. Inside is the nucleus pulposus, consisting of a softer, more gel-like material. It has a high water content that serves to resist compression and thus is important for weight bearing. With increasing age, the water content of the nucleus pulposus gradually declines. This causes the disc to become thinner, decreasing total body height somewhat, and reduces the flexibility and range of motion of the disc, making bending more difficult. The gel-like nature of the nucleus pulposus also allows the intervertebral disc to change shape as one vertebra rocks side to side or forward and back in relation to its neighbors during movements of the vertebral column. Thus, bending forward causes compression of the anterior portion of the disc but expansion of the posterior disc ***(Openstax, 2016).***

Adjacent vertebrae are united by ligaments that run the length of the vertebral column along both its posterior and anterior aspects **(Figure 4).** These serve to resist excess forward or backward bending movements of the vertebral column, respectively. The anterior longitudinal ligament runs down the anterior side of the entire vertebral column, uniting the vertebral bodies. It serves to resist excess backward bending of the vertebral column. The supraspinous ligament is located on the posterior side of the vertebral column, where it interconnects the spinous processes of the thoracic and lumbar vertebrae. This strong ligament supports the vertebral column during forward bending motions. Additional ligaments are located inside the vertebral canal, next to the spinal cord, along the length of the vertebral column. The posterior longitudinal ligament is found anterior to the spinal cord, where it is attached to the posterior sides of the vertebral bodies. Posterior to the spinal cord is the ligamentum flavum (“yellow ligament”). This consists of a series of short, paired ligaments, each of which interconnects the lamina regions of adjacent vertebrae. The ligamentum flavum has large numbers of elastic fibers, which have a yellowish color, allowing it to stretch and then pull back. Both of these ligaments provide important support for the vertebral column when bending forward ***(Openstax, 2016).***

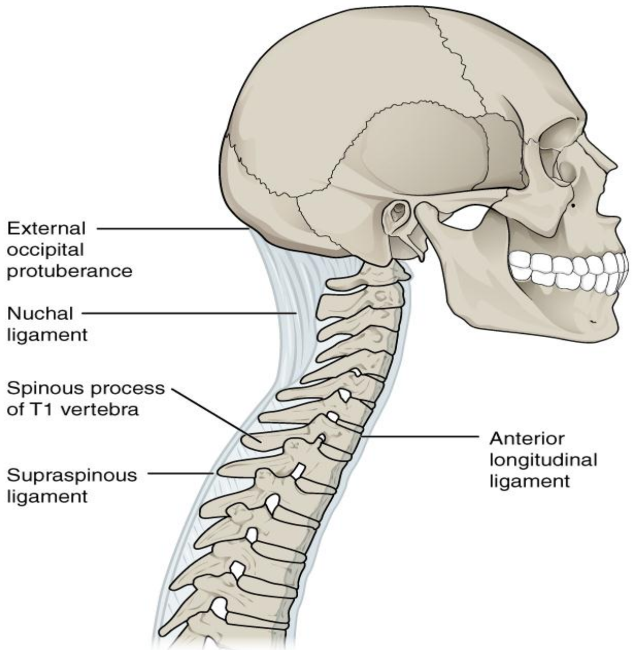

Figure (4): Ligaments of Vertebral Column. The anterior longitudinal ligament runs the length of the vertebral column, uniting the anterior sides of the vertebral bodies. The supraspinous ligament connects the spinous processes of the thoracic and lumbar vertebrae. In the posterior neck, the supraspinous ligament enlarges to form the nuchal ligament, which attaches to the cervical spinous processes and to the base of the skull ***(Openstax, 2016).***

The **spinal cord**, about 45 cm in length, extends from the foramen magnum, where it is continuous with the medulla oblongata, to the level of the first or second lumbar vertebra

(The range is T12 to L3). Below that level, the vertebral canal is occupied by spinal nerve roots and meninges. A fibrous strand, the filum terminale, continues from the spinal cord down to the coccyx (**Figure 5)** ***(O'Rahilly, 2008).***

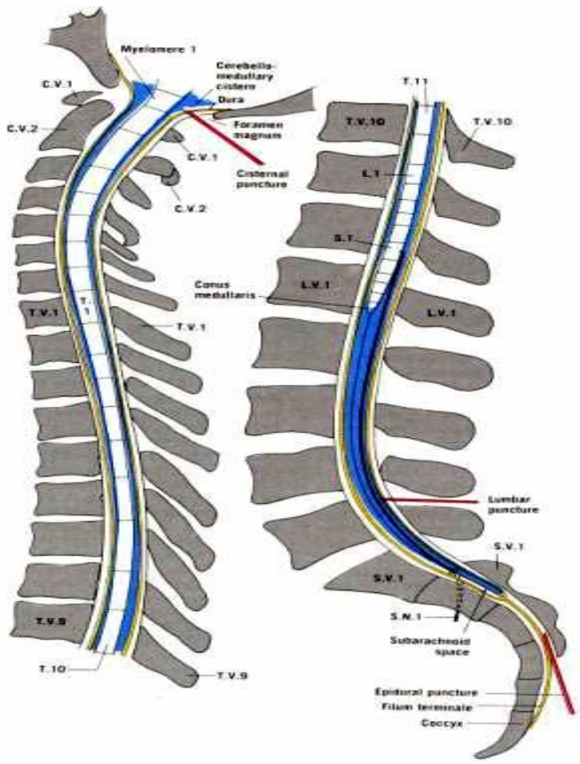

Figure (5): Median section of the vertebral column, showing the different levels of the vertebral bodies, myelomeres, and spinous processes. The spinal cord ends at the Ll/2 vertebral level and the subarachnoid space at S1/2 level. Cisternal, lumbar, and epidural punctures are shown. As an example of a spinal nerve, the S1 nerve can be seen arising from myelomere S1 opposite the T12 vertebra, descending (as part of the cauda equina), and emerging from the first sacral foramen ***(O'Rahilly, 2008).***

The spinal cord presents a cervical and a lumbar enlargement at the levels of attachment of the nerves to the limbs. The inferior most end of the cord is conical and is termed the conus medullaris. The coccygeal nerves are attached to it. The cord presents a posterior median sulcus and an anterior median fissure, lateral to which the dorsal and ventral root filaments are attached **(Figure 6 and 7).** The segment of spinal cord to which a given pair of dorsal and ventral roots is attached is a myelomere **(Figure 6).** Because the adult spinal cord does not extend down as far as the vertebral column does, the lower myelomeres are not opposite their correspondingly numbered vertebrae. Thus myelomere S1 is opposite the T12 vertebra **(Figure 5)** ***(O'Rahilly, 2008).***

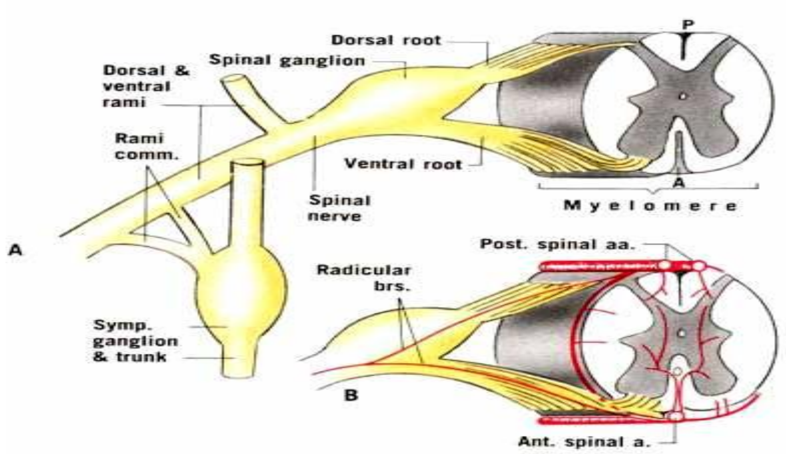

Figure (6): A myelomere of the spinal cord, and one of its two associated spinal nerves. In A: A, anterior median fissure; P, posterior median sulcus. B shows the arterial supply to the cord ***(O'Rahilly, 2008).***

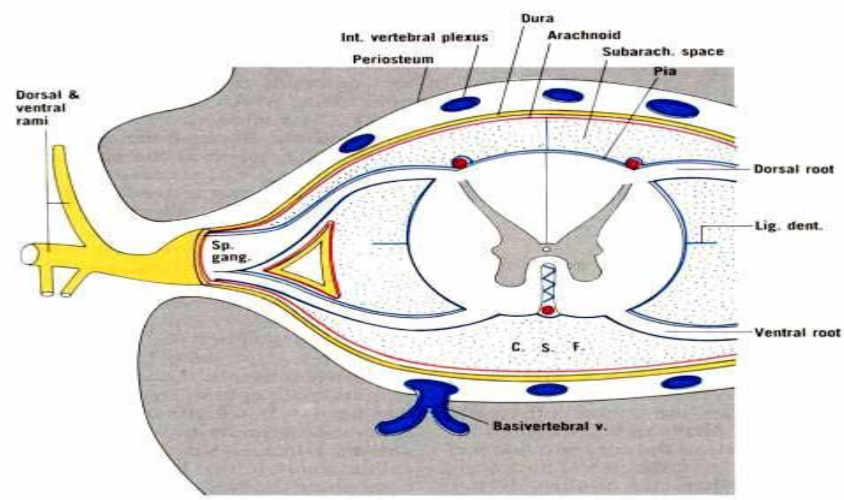

Figure (7): Horizontal section of the spinal cord showing the meninges. The dura is in yellow, the arachnoid in red, and the pia in blue. The anterior and posterior spinal arteries are shown. C.S.F., cerebrospinal fluid in the subarachnoid space ***(O'Rahilly, 2008).***

Each dorsal root presents a swelling, the spinal (dorsal root) ganglion, which lies near or within the intervertebral foramen. Distal to the ganglion, each dorsal root combines with the corresponding ventral root to form a spinal nerve **(Figures 6 and 7).** There are 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. The first pair of spinal nerves emerges between the atlas and the skull; hence C1 to 7 nerve roots leave the vertebral canal above the correspondingly numbered vertebrae. C8 emerges below the C7 vertebra, and all the remaining spinal nerves leave inferior to the corresponding vertebrae. The nerve roots below L1, and those which occupy the vertebral canal inferior to the cord, resemble a horse's tail and hence are collectively called the "cauda equina" **(Figure 8)** ***(O'Rahilly, 2008).***

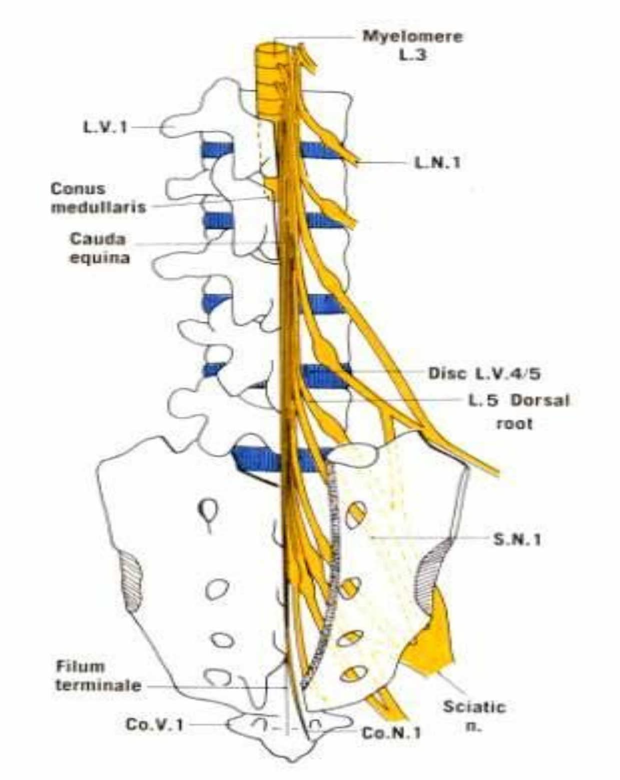

Figure (8): The spinal cord and cauda equina in situ. Posterior aspect, made visible by a laminectomy on the right-hand side. The dorsal rami are omitted. The intervertebral discs are shown in blue. It can be seen that prolapse of disc L4/5, for example, would be likely to damage L5 roots ***(O'Rahilly, 2008).***

The spinal cord contains the descending motor tracts and the ascending sensory tracts. The cervical and lumbar enlargements contain the neurons that supply the limbs. The cervical part of the cord contains motor neurons giving rise to the spinal part of the accessory nerve and contains the neurons that supply the diaphragm. The thoracic and upper lumbar parts of the cord contain preganglionic sympathetic neurons, and the sacral cord contains parasympathetic preganglionic neurons giving rise to pelvic splanchnic nerves ***(O'Rahilly, 2008).***