1. SPINAL CORD: GROSS AND GENERAL SPINAL CORD MALFORMATIONS

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Draft 1

In the first part, we explore the overall structure and organization of the spinal cord. This includes a detailed examination of its gross anatomy, such as the spinal cord's segments, the protective meninges, and the surrounding vertebral column. We will also cover common spinal procedures, offering insights into standard practices and techniques used in spinal surgeries. Understanding these foundational elements is crucial for grasping the complexities of spinal cord functions and pathologies.

Case 1

Presentation

A patient presents with a complaint of severe back pain. He is a student who recently completed a period of intensive studying, involving prolonged sitting at his desk. The patient acknowledges being in poor physical condition. On the day following his exams, he decided to clean his room, which he had neglected during his study period. While attempting to lift and move his desk to vacuum the floor, he experienced a sudden, sharp back pain that radiated to his right lower leg. In distress, he called 911. Paramedics responded promptly and transported him to the neurological department, fortunately you are the neurosurgeon on call.

Relavant Anatomical Background

This case involves a lumbar disc herniation. To fully comprehend this condition, it's essential to first understand the basic structure and organization of the spinal cord.

The spinal cord is housed within the vertebral canal, which is part of the vertebral column, and is protected by three layers of tissue called the meninges. See Figure 7. Structurally, the spinal cord resembles a cylindrical extension of the brain, beginning at the brain's base and extending down to the lumbar region of the vertebral column.[1]

The spinal cord is organized into nerve roots, each of which exits through openings in the vertebral column. An example of such an opening can be seen in Figure 1.

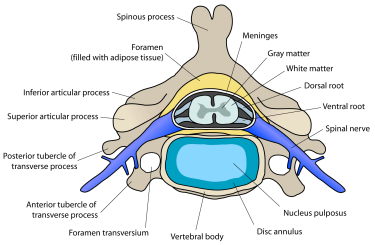

Figure 1. A figure showing a cross section through a vertebral bone [1].

[1] Difference between the vertebral column, vertebral canal and the spinal cord.

Vertebral Column: The bony structure that encases and protects the spinal cord.

Vertebral Canal: The space within the vertebral column through which the spinal cord passes.

Spinal Cord: The bundle of nervous tissue contained within the vertebral canal.

Throughout the entire length of the spinal cord, there are 31 pairs of spinal nerves, each consisting of an anterior (ventral or motor) root and a posterior (dorsal or sensory) root. Each of these roots also contains a dorsal root ganglion, which houses the cells that give rise to both peripheral and central nerve fibers, as shown in Figure 2.

Lumbar Disk Herniation

Returning to the medical student's injury, the herniation occurred on the right side and was relatively small. This herniation took place between the L5 and S1 levels of the spinal cord, resulting in compression of the posterior (dorsal) roots. Figure 3 illustrates the varying severities of disc herniations. It is clearly visible how the contents of the intervertebral disks may compress the spinal nerves. See Figure 4 for a visualization. The symptoms may be motor or sensory function abnormalities.

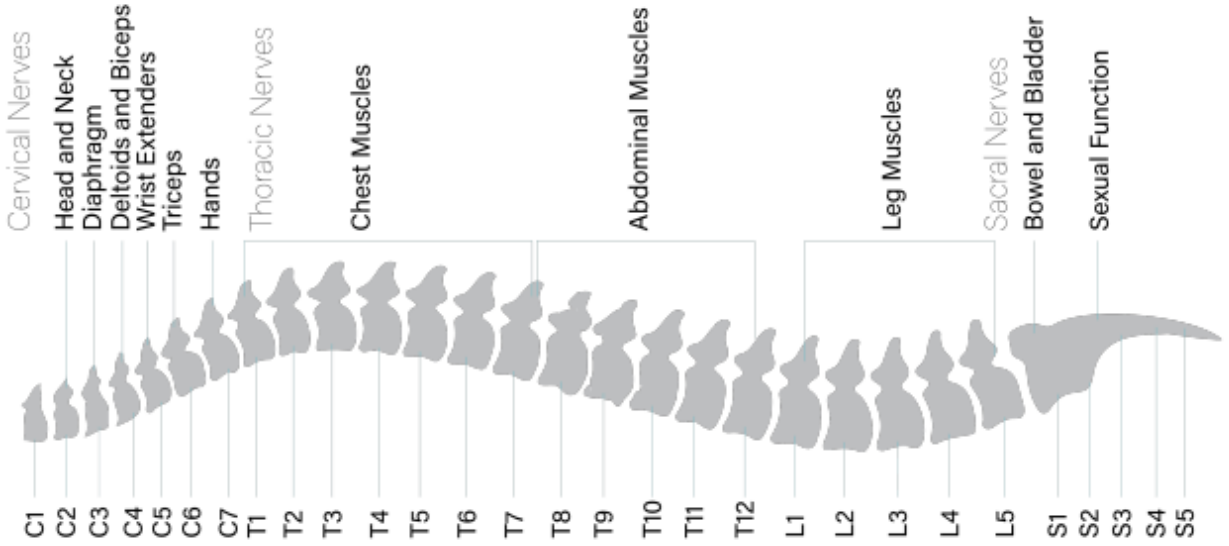

Figure 2. The vertebral column and spinal nerves exiting from it [2].

Lumbar disk herniations occour most commonly in the lumbar region[2] as a relatively mobile part of the spinal cord meets the relatively immobile sacral part of the spinal cord. This area is also more common as the entire weight of the head and the thorax and the weight lifted by the upper limb is transmitted towards the legs through this region.

Figure 3 shows the pathology. The blue part in the intervertebral disk is the nucleus pulposus while the while part is the annulus fibrosus. The nucleus pulposus can be seen being squeezed into the cavity of the spinal cord where it compresses the nerves.

[2] see Figure 2

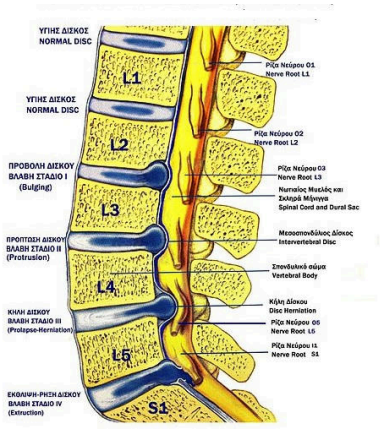

Figure 3. Lumbar Disk Herniation visualization [3].

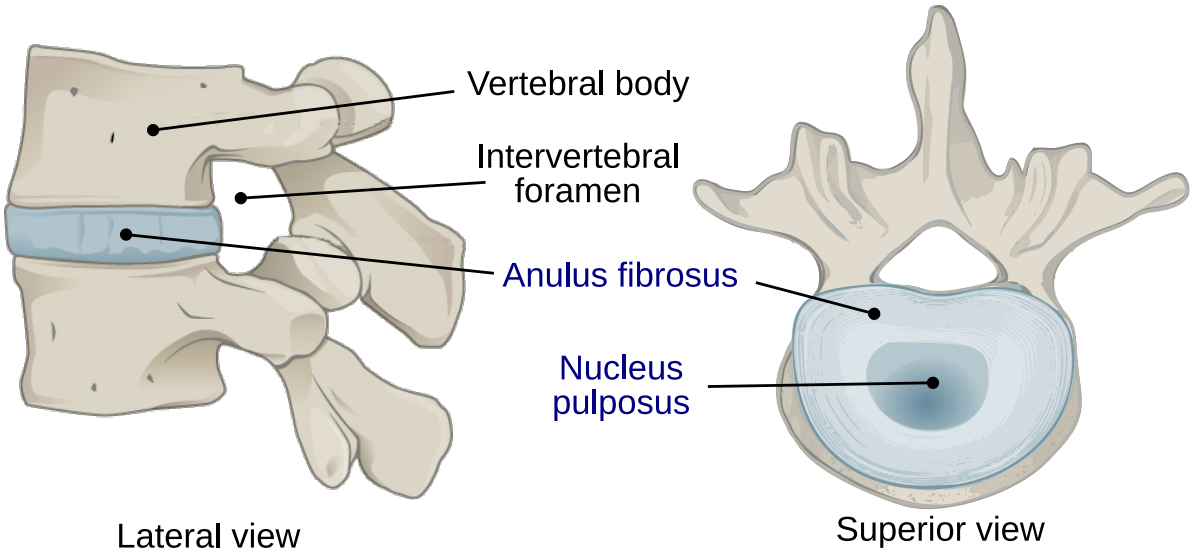

Figure 4. Views of the Intervertebral disk. The substance that can cause hernia (nucleus pulposus) is clearly visible and labelled [4].

This can lead to pain being felt in the leg on the side where the nerve is being compressed. As was the case of our student, his spinal nerves L5 and S1 were most probably compressed leading to him experiencing the pain. His condition is known as 'Sciatica'[3].

[3] Compression of the sensory roots will lead to pain being felt while compression of the motor roots will produce weakness of the muscles.

Case 2

Presentation

A man was involved in a motor vehicle accident, sustaining a head-on collision. First responders observed that his breathing was severely compromised. What is the major muscle controlling respiration and how is injury to the spinal cord related to breathing?

Relavant Anatomical Background

The major muscle controlling respiration is the Diaphragm. It is located below the lungs and can be seen in Figure 5. Its contraction leads to the increase in volume of the thoracic cavity which causes the lungs to fill up with air[4].

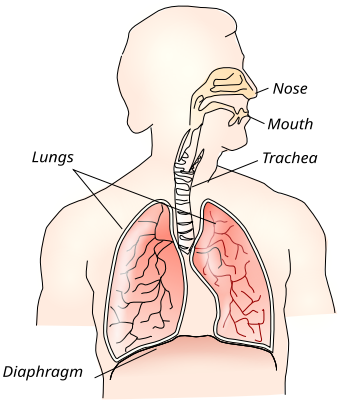

Figure 5. Diagram showing the position of the diaphragm [5].

[4] Further anatomical details of the diaphragm are beyond the scope of this book but more information can be found in Gray's Basic Anatomy section on Thorox and the heading is Diaphragm

The spinal nerves C3 to C5. These are the nerves that exit from the cervical spinal cord levels of 5th, 6th and 7th vertebrae. A major point to note here is that the spinal nerve C3, for example, exits from the level C5. See table[5]. which are known as phrenic nerves innervate the diaphragm. If the spinal cord is damaged above this level, control of the diaphragm is lost which could lead to death.

Case 3

Presentation

A person complains of continuous and severe headaches, high fever, stiff neck and drowsiness[6]. As a neurologist, how do you manage the patient?

Relavant Anatomical Background

The person is suspected of having meningitis. It is an inflammation of the layers covering the brain and the spinal cord. Figure 7 shows the layers over the surface of the brain.

The layers in order from outside to inside are:

1. Dura Mater
2. Arachnoid Mater
3. Pia Mater

The Dura Mater is the toughest outer covering over the brain. It lies directly beneath the bone[7]. The Arachnoid Mater contains the subarachnoid space[8]. The Pia Mater is a thin layer that directly covers the surface of the brain and is usually transparent.

A lumbar puncture procedure may be performed to withdraw a sample of CSF to check for infections (such as meningitis in our case) or to inject drugs in response to infections or induce anesthesia[9].

One extremely important feature of our spinal cord is that the nervous tissue (of adults) ends at the level of L1 vertebra but the subarachnoid space (containing the CSF) extends until the level of S2[10]. A needle inserted into this space here, will generally not damage the spinal nerves as they will be pushed to one side owing to the fact that there is a lot of space here for the spinal cord.

[5]

Vertebrae	Spinal Nerve
Cervical vertebrae	Add 1
Upper thoracic vertebrae	Add 2
Lower thoracic vertebrae	Add 3
10th thoracic vertebra	L1 and 2
11th thoracic vertebra	L3 and 4
12th thoracic vertebra	L5
First lumbar vertebra	Sacral and coccygeal spinal nerves

[6] Most of the times headaches and fever are common complaints from patients and can be safely treated by prescribing an over-the-counter painkillers but if they accompany neurological symptoms, such as drowsiness or excessive sleeping or confusion, then a neurologist must take precautions to rule out more serious underlying causes.

[7] Seeing Figure 7 will help to visualize the concepts here.

[8] Where the CerebroSpinal Fluid is circulating.

[9] This is the case for having a painless childbirth. The mother will not feel the contraction during the first stage of labour. For more details, search for 'Caudal Analgesia for Labour'.

[10] For a visualization of specific levels of the spinal cord, refer to Figure 2

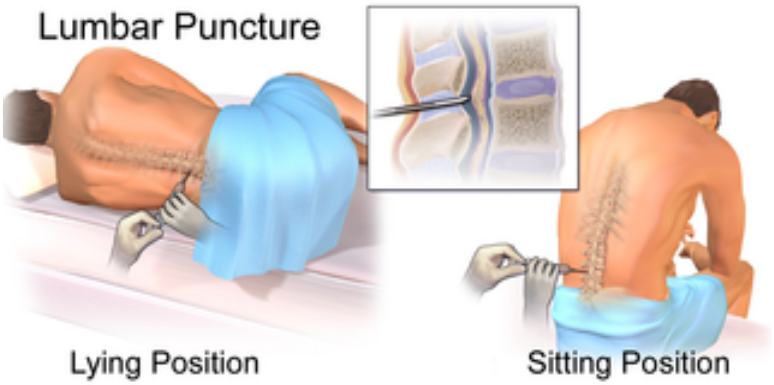

Figure 6. To obtain a sample of CSF, a lumbar puncture or a spinal tap may be performed. [6].

Figure 8 shows the level of the lumbar puncture procedure. At the level of L4, the illiac crest of the illiac part of the hip bone can be felt. This a safe site for this procedure.

After administering a small amount of local anesthetic, the physician can insert a spinal needle just above the L4 spinal level. The depth of needle insertion varies depending on the patient's physique. For example, in a child, the needle may only need to be inserted approximately 1 cm, while in an obese adult, it may need to be inserted up to 10 cm into the lumbar spine.

This needle is then used to collect a small sample of cerebrospinal fluid (CSF) for laboratory examination. Additionally, the CSF pressure can be measured by attaching a manometer to the spinal needle. Deviations from the normal CSF pressure, which typically ranges from 60 to 150 mm of water, can indicate various medical conditions. Elevated or reduced CSF pressure may be associated with specific neurological or systemic disorders.

Some causes of elevated CSF pressure are: Intracranial Masses, Hydrocephalus, Infections, Trauma, Vascular Issues, Idiopathic Intracranial Hypertension (IIH), Toxins and Metabolic Disorders. Some causes of lowered CSF pressure are: CSF Leak, Dehydration, Overdrainage of CSF, Certain Medications[11].

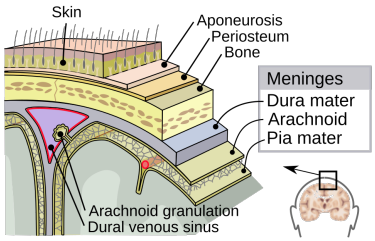

Figure 7. Image with the 3 coverings of the nervous system labelled. Namely the Dura, Arachnoid and Pia Mater. The subarachnoid space (the web-like space between the Arachnoid and Pia Mater) is also visible [7].

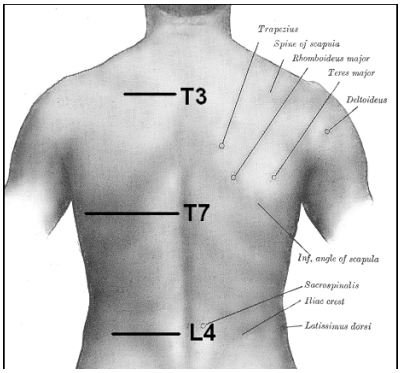

Figure 8. An image showing imporatant vertebral column levels [8].

[11] As a side note, the specific causes of elevated and lowered CSF pressure will be discussed in detail in their respective chapters. For instance, intracranial masses, such as brain tumors, can obstruct CSF flow pathways, resulting in increased pressure. Similarly, hematomas, which are accumulations of blood within the cranial cavity, can compress brain tissue and subsequently elevate CSF pressure.

References

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