Review Article
Open Access
CrossMark

Clinical anatomy of the spine for pain interventionist

Abstract

Pain interventionist emphasizes particular attention to the spinal anatomy. Spine pain generators differ from intervertebral disc to facet joint or ligaments. Injection at these critical structures requires a complete visualization of anatomical location. Spinal cord injury or intravascular injections are the serious complications of spine pain intervention. Understanding the neurovascular anatomy of the spinal column prevents misfortune injection and its unwanted complications. The purpose of this study is to review spine anatomy and responsible pain generators and to verify the importance of anatomy in preventing pain injections complication.

Keywords: anatomy, spine, pain injection

Volume 10 Issue 4 - 2018

Helen Gharries
Anesthesiologist, Pain Fellow, Milad Hospital, Iran

Correspondence: Helen Gharries, Anesthesiologist, Pain Fellow, Milad Hospital, Sattarkhan, District2, Tehran Province, Iran, Tel +989129306577, Email helengharaei@gmail.com

Received: February 14, 2018 | **Published:** July 23, 2018

Abbreviations: IVD, Intervertebral discs; SAP, superior and inferior articular process, Z Joint, zygapophyseal joint, CSF, cerebrospinal fluid, IVF, intervertebral foramen; APD, PAD, posterior and anterior primary division; RMN, recurrent meningeal nerve; SNS, sympathetic nervous system; DRG, dorsal root ganglion; posterior PLL, longitudinal ligament; NP, nucleus pulposus; PDPH, post-dural puncture headache; ICP, intracranial pressure

Introduction

Pain interventionists have always interested in investigating the anatomy of the spinal column. A detailed description of these structures offers more insights on diagnosing clinical symptoms and choosing best approaches. Most anatomical structures that are susceptible to injury and overcome the usual clinical symptoms of spine pain mentioned in this article. The purpose of this study is to review spine anatomy and responsible pain generators and to verify the importance of these buildings in preventing pain injections complication.

Discussion

The spine comprises 24 vertebrae: 7 cervical (C1-7), 12 thoracics (T1-12) and 5sacral (L1-5). Lumbar 5 vertebrae place on the sacral bone, which composed of 5 fused segments. The coccyx comprises 3-5 fused segments, and it suspends at the end of the sacrum. This bone complex has 361 joints. These joints include synovial joints, symphysis joints, and joints between vertebrae, ribs, sacrum, and coccyx (Figure1). Each vertebra comprises two parts: body and arch (posterior arch). The body is a large anterior part that supports the body's weight. Intervertebral discs (IVD) interconnect the bodies. The posterior arch made of special parts. The laminae, superior and inferior articular process (SAP, IAP), transverse process and spinous process. The pedicle is a thin section of the anterior part of the posterior arch. Because the pedicles are smaller than the body, a groove is on the top and bottom of each pedicle (vertebral notch). Intervertebral foramen (IVF) bound by these notches, vertebral body and zygapophyseal joint (Z joint).The lamina is continua of the pedicle from the anterior to the posterior and forms the major posterior part of the vertebral arch and connect to the spinous process. Vertebral foramen is a hole between the vertebrae which encircle by pedicle, laminae, spinous process and body. The vertebrae canal (spinal canal) creates by vertebral foramen on each which the spinal cord passes through it. The transverse process project out from the pedicle lamina junction on each side of the body. They are anteriorly oblique to Z joint and beyond the pedicle in sagittal and coronal plane in the cervical region. The transverse processes of the thoracic vertebrae are posteriorly oblique and located behind the articular process and IVF and have the articulation with ribs. The transverse process of lumbar vertebra located in the front of the articular process and in the posterior of pedicle and IVF. SAP&IAP like transverse process arises from the pedicle laminate junction.SAP faced posteriorly and IAP faced anteriorly. Z joint created by the articulation of the SAP and IAP) (Figures 2-4).[1]

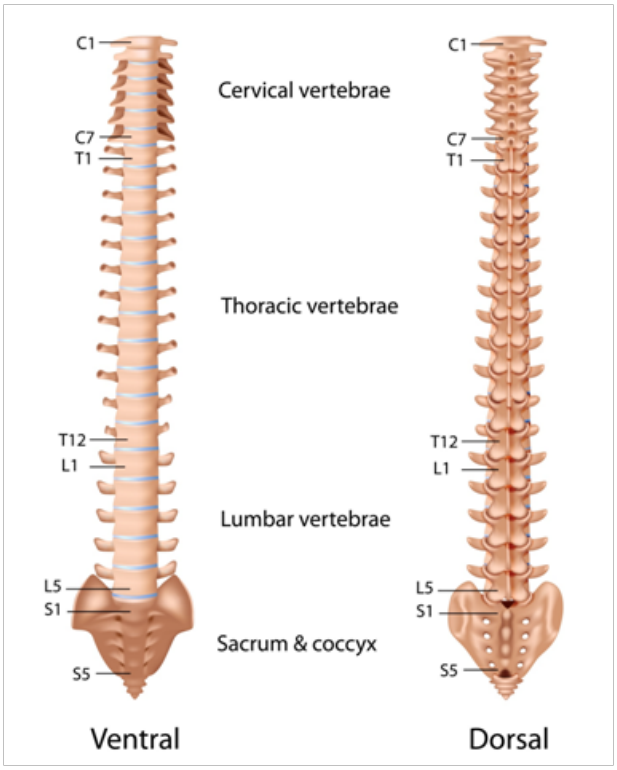

Figure 1 vertebral column.

Neuroanatomy

The spinal cord is located in the vertebral canal. From above, it is connected to the middle cerebrum and becomes narrower at the end. The spinal cord is protected by vertebra, ligaments, cerebrospinal fluid (CSF) and membranes called meninges. Thirty-one pairs of nerve connected to the spinal cord which called spinal nerves and innervation neck, body, and extremities. The spinal nerves merge from

the posterior and anterior root in an IVF. The posterior root (dorsal root) transmits the sensory information and the anterior root (ventral root) transmits motor information. Each spinal nerve is divided into posterior and anterior ramus or division (APD, PPD) which are mixed sensory and motor nerves (Figure 5).

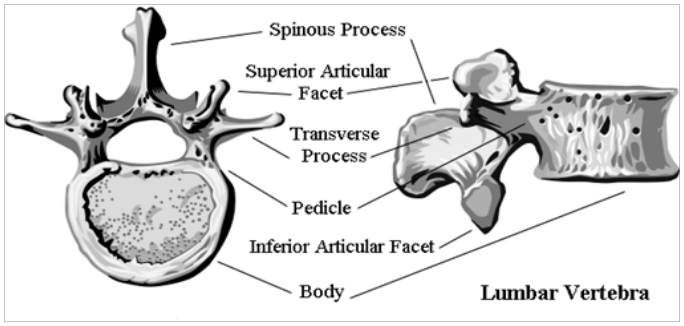

Figure 2 lumbar vertebrate

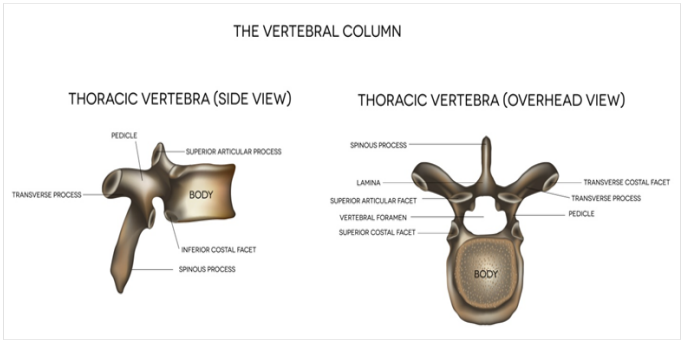

Figure 3 Thoracic vertebrate.

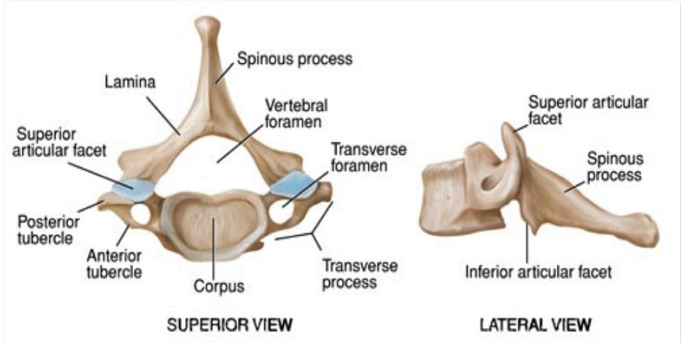

Figure 4 Cervical vertebrate.

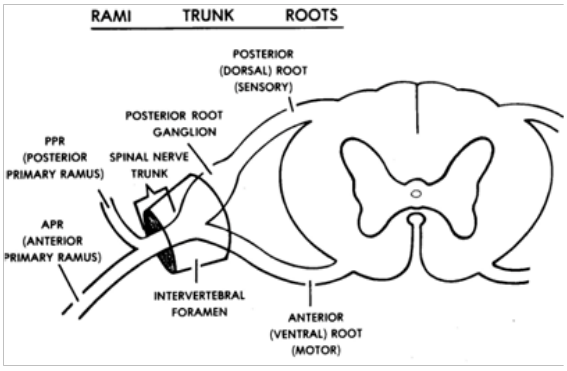

Figure 5 Anterior and posterior primary divisions of the spinal nerve.

The origin of the spine pain is from APD, PPD and recurrent meningeal nerve (RMN) or sinuvertebral nerve and sensory fibers of the sympathetic nervous system (SNS). All of these nerves are in dorsal root ganglion (DRG) and in IVF (Figure 6). Sensory fibers that associated with RMN and SNS transfer pain from the somatic structures of the anterior spine and pass through APD to DRG. Strain or spasm of quadratus lumborum, psoas major, intertransversalii muscle and structures which innervated by lumbar plexus stimulate pain. The transverse process also innervated by APD and its fracture or bruise motive pain. APD also transmit referral pain from gluteal, inguinal and lower extremity. Structures which innervated by PPD are also sources of pain: deep back muscle, posterior longitudinal, interspinal and flavum ligaments, deep and superficial fascia and facet joints. The medial branch of the PPD after entrapment or stimulation causes a backache or weakness of the lumbar muscles.Structures that innervated by RMN include posterior periosteum of the vertebral and the disk and the epidural fat and veins, and the posterior longitudinal ligament (PLL) and the anterior surface of spinal dura mater. The periosteum stimulation by vertebral fracture or neoplasm causes pain. Disc rupture or herniation is a source of pain via RMN. The sympathetic innervations to the periosteum of the anterior and lateral aspect of the vertebral body and disc, the anterior longitudinal ligament are also sources of pain generation. Pain from the first four neck vertebra refers to the head and cause headaches and occipital pain that refer to the orbital and frontal regions (Table 2).[2]

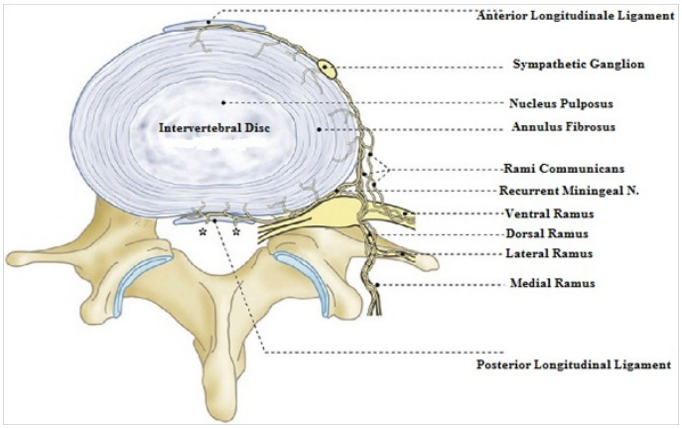

Figure 6 Anatomy of spine pain generator nerves.

Damaging or interrupting any peripheral nerve causes biochemical and neurophysiologic changes in the nerve and surrounding tissues and reduces the nerve or ganglion endurance to the pain and causes them fire automatically. On the other hand, any decrease in blood flow to the myelinated nerves leads to decreased myelination and nerve ectopic firing that interpreted in the brain as sharp, radiating or burning pain. Ischemia of the PPD and its medial and lateral branches lead to increases pain even in the absence of nociceptive stimulus through ectopic firing. Spinal cord Nerve roots and ganglia, especially the lower part, are sensitive to pressure and inflammation. The pain severity and radicular nature of it depend on the amount of pressure. The pressure on the ganglion causes the edema by intravenous congestion. It reduces the blood flow to the nerves cell body and the ischemia is felt as radicular pain which is dermatomal. The chemicals released from the nucleus pulposus (NP) also cause ganglia and root inflammation and radicular pain. It reduces the neural conduction velocity until 1 week and takes 8weeks to recover. Cauda equina is even more sensitive to compression pressure as a result of

spinal stenosis and may result in unusual sensation (rubbery or not belong to him) in limb or limbs. Anterior and posterior roots receive innervations from nervi nervorum that are sensitive to stretching and cause the straight leg raise test (SLR) become positive after pressure on the nerve. Because the ganglion and the anterior root are in close proximity, pressure on the ganglion causes pressure on the anterior root and therefore muscle weakness, which is commonly seen in radicular pain. Serotonin and neurotransmitters that release from the platelets during inflammation cause vasodilatation. However, in patients with chronic pain that has chronic stress on the roots and ganglion, this is not the case, which causes the contraction of the vessels, and these patients gradually became less sensitive to acute compression.[3]

Table 1 Pain Generator Structures and Responsible Nerve

Responsible nerve	Pain generator structures
Anterior Ramus (APD)	Referral Pain From Structure Innervated By Lumbar Plexus (Gluteal, Inguinal And Lower Extremity) Psoas Muscle Quadrates Lumborum Muscle Intertransversalii Muscle Transverse Process
Posterior Ramus (PPD)	Deep Muscle Of Back Posterior Longitudinal Ligament Interspinouse, Supraspinouse, Intertransverse Ligaments & Ligament Flavum Deep And Superficial Fascia Facet Joints Periosteum Of Posterior Vertebral Arch
Recurrent Meningeal Nerve(RMN)	Posterior Longitudinal Ligament Anterior Surface Of Spinal Dura Mater Periosteum Of Posterior Aspect Of Vertebral Body Posterior Aspect Of Intervertebral Disc Epidural Adipose Tissue And Veins
Sympathetic Trunk And Gray Rami Communicants	Periosteum Of The Lateral And Anterior Aspects Of The Vertebral Bodies Lateral And Anterior Aspect Of The Intervertebral Disc Anterior Longitudinal Ligament

Table 2 Spinal cord segments

Spinal cord level	Corresponding segment
Cervical	1level Higher
Upper Thoracic	2 Level Lower
Lower Thoracic	3 Level Lower
Lumbosacral	T10-L1

When the disk degenerates, more sensory nerves penetrate into the disk, and the degeneration of the disk stimulates the posterior, lateral and anterior of the disc and causes nociceptive pain. PLL strain during sever hyperflexion or by disc protrusion cause pain. The chemicals that come out of the protruding disk or disc protrusion compression itself at the anterior aspect of the dura mater cause referral abdominal pain. Although the IVD does not have any vessels, after disc herniation, there is the inflow of the vascular branches from the ligaments and epidermal space into it. These new vessels have been created due to inflammation caused by released chemicals from NP, and neovascularization absorbs the inflammatory materials to restore repair process. With the repair of inflammation, the amount of hydration of the protruding part of the disc has changed and within a few weeks pressure from the root and ganglion is removed and the pain is reduced. The NP protrusion is a dynamic process. Complete desorption and sign & symptom relief take 2months to 1 year from the onset of pain.[4] The damaged disk has a lot of sensory nerves compare to a normal disk. These innervations are due to nerve ingrowths after the injury that by releasing the substances P cause discogenic pain. Due to the complete innervations of the discs, discogenic pain appears differently. It can appear in the groin or lower extremity (due to RMN) or in the viscera (due to SNS).[5] Facet joint has reached sensory innervations and could be a source of radicular pain. Joint arthritic degeneration reduces the nerve output hole (IVF) and exerts pressure on it. On the other hand, released chemicals from the inflamed joint irritate nerve root. The disc degeneration changes the mobility of the facet joint and along with decreasing disc space causes pressure on the joint and somatic pain. So, somatic and radicular pain arises simultaneously with the origin of the Z joint.[6] Each pair of spinal nerves is associated with a segment of the spinal cord. There are 31 pairs of spinal nerves and 31 spinal cord segments. Segments name based on the spinal nerves: 8 cervical, 12 thoracics, 5 lumbar, 5 sacral and 1 coccygeal. Seven cervical spinal nerves exit from IVF on the top of the same vertebra. And because of this, cervical spinal nerves are greater than the number of cervical vertebrae (8 compare to 7.) The spinal cord segments are not necessarily at the same level of the vertebra. And since the spinous process is used as a diagnostic landmark of the spinal cord segments, in the cervical region it is corresponding to the following segment, in the upper thoracic to two lower segments and in the lower thoracic to the 3 lower segment. For example, the cervical spinous process of C5 is a landmark for the C6 segment and spinous process of the T3 for the T5 segment and spinous process of T10 for the L1 segment. The L1 to coccygeal segments that containing the lower limb nerves, is about the spinous process of T10-L1 (Table 2).

Although the spinal cord ends in L1, the neural roots form the spinal nerves and in accordance with their segments leave the same IVF that included IVF under the L2. Therefore, the lower segments are longer because they have to travel longer to reach their same IVF. So the L5 roots are the tallest and most oblique nerves. The sums of the roots of the long lumbosacral that go downwards to the IVF name cauda equina. There are two large areas of the spinal cord. One in C3-T2 that includes segments that go to the neck and one in the L1-S3 which innervated lower limbs.(7) None of the internal branches of the PPD give a nerve to the skin and the lateral branches of PPD of T11-L3 called "cluneal" innervate skin of the buttock.[8] In 40% of the normal patients, the anatomical(vertebra) and physiological(spinal cord) location of the middle line is different (1.2-2mm).[9] The spinal cord ends around L1(sometimes T11-12 or L3). The end of the spinal cord is cone shaped and called the conus medullaris. Its length to the end of the conus medullaris is between 42-45cm in the middle height woman and man.[5]

Clinical pearl

Sometimes during the intradiscal procedure, may have the blood get out of the needle into the disc which can be due to neovascularization.

Clinical pearl

Multifidus muscle with reach innervations is the cause of pain during spinal paramedian needle approach.

Clinical pearl

Entrapment of cluneal nerve cause localized pain on the iliac crest with distribution to the buttocks, and is the origin of pain during iliac crest harvesting.

Clinical pearl

Knowing the anatomical location of the segments relative to the vertebra is clinically valuable. For example, clinical presentation of a patient who suffers from the L1 fracture is different from one with the T10 vertebral fractures. The first one causes damage to the upper lumbar segments, but the second one causes damage to the lower sacral and coccygeal segments with different clinical signs and symptoms.

Clinical pearl

Since there is no spinal cord under the L2, the trauma or disc herniation does not affect the spinal cord. The spinal injections are safer under L2.

Clinical pearl

It is very important to be familiar with these segments for implantation of the spinal cord stimulator and intrathecal and epidural drug delivery pump.

Clinical pearl

The dermatomal pattern of radicular pain is variable. Pain caused by pressure on the root or ganglion is deeper. It is consistent with the myotomal or sclerotomal distribution of the peripheral nerves. It can, therefore, be felt above, below, outside or inside the corresponding dermatome.

Meningeal membranes

These are 3 layers that surround the brain and the spinal cord. The outer layer called dura mater and is separated from the vertebrae by the epidural space. Epidural space consists of connective tissue, fats, venous network and fibrous bands called meningovertebral ligaments. Below the dura, there is vascular arachnoid. The outer layer of arachnoid consists of flat cells that are impermeable to the CSF and bloodstream. Below this layer, there is an intermediate layer composed of a collagen and leptomeningeal cells. This layer acts as a fluid flow regulator of CSF in subarachnoid space that is between arachnoid mater and the pia mater (innermost meningeal layer). The pia mater composed of one or two layers of the flat cell. It separated from the spinal cord by the subpial space. Two specific features of the piamater are the right and left denticulate ligaments and the filum terminalis that make the spinal cord stable in the vertebral canal. The subarachnoid space located below the arachnoid and filled with CSF. The fluid secreted by the choroid plexus in the brain's ventricles.The CSF flow depends on the pulse of the large arteries in the subarachnoid space, vertebral column movements, body position and the intrapleural and intraperitoneal pressure and respiratory movements (Figure 7).[10] The CSF pressure is 80-180 mm Hg. The volume of intracranial brain tissue, intracranial blood, and CSF is constant. Increasing each of these volumes must compensate by the rest otherwise and the intracranial pressure (ICP) will rise. Tumors and hematoma in this site increase the pressure. Dura and arachnoid drew from under the conus medullaris to the lower edge of the S2 (sometimes S1 or S4). The filum terminale extends about 20 cm from the tip of the conus medullaris to the posterior aspect of the coccyx. The first 15 cm is inside the dural sac and the coccygeal ligament is from S2 to the coccyx. The CSF volume is 80-150 cc, but it is lower in obese people due to higher abdominal pressure. The average CSF volume at the cervical level is 19(14-27), at thoracic level 37 (22-57) and in the lumbar region is 25(11-38).[5,11,12]

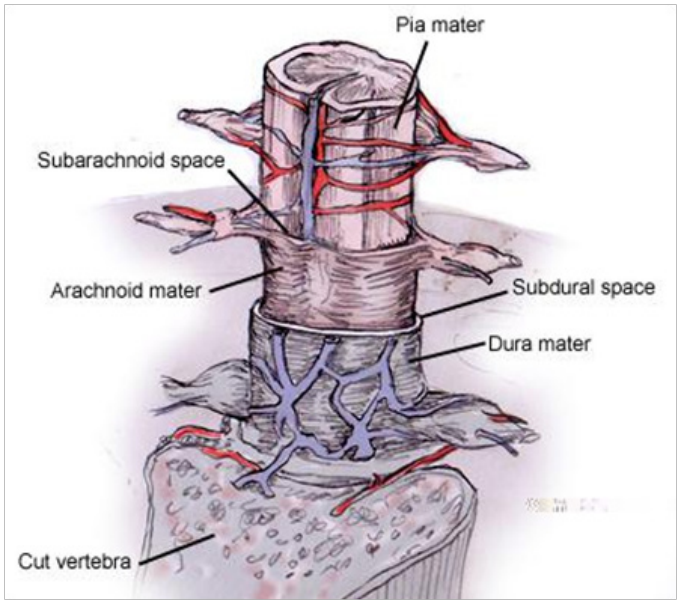

Figure 7 Meningeal layers.

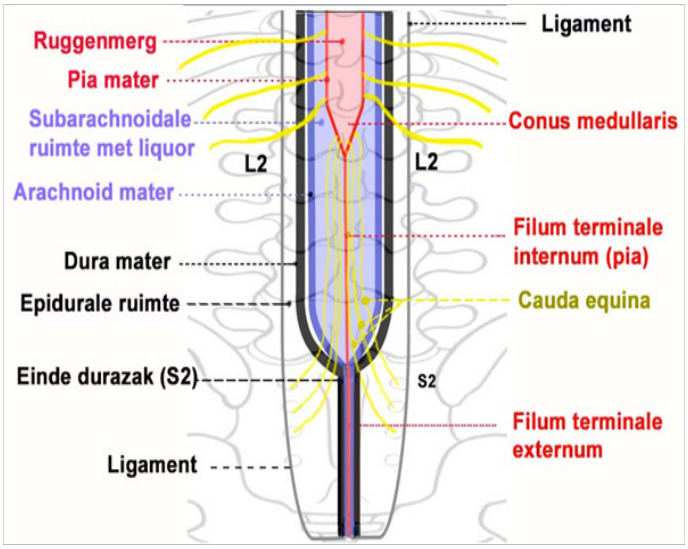

Figure 8 Cauda equine.

Citation: Gharries H. Clinical anatomy of the spine for pain interventionist. *J of Anes & Criti Care Open Access*. 2018;10(4):131–136.
DOI: 10.15406/jaccoa.2018.10.00378

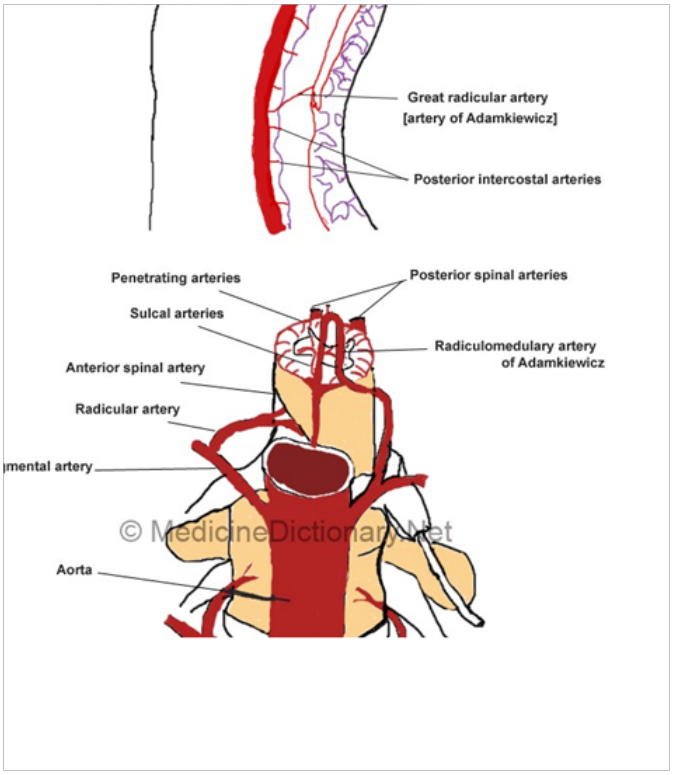

Figure 9 Radiculomedulary arteries.

Clinical pearl

It is important to consider the factors influencing the CSF flow in treating the post-dural puncture headache (PDPH) after spinal or epidural block.

Clinical pearl

Fibrosis of the intermediate layer due to inflammation of subarachnoid space cause chronic arachnoiditis.

Clinical pearl

The inner surface of the dura and the outer layer of arachnoid continuing on and there is no real subdural space. Since the dura cells are weak, they break up during surgery or trauma and create an artificial subdural space. Really there is a physiological subdural space that is a lymphatic space and is associated with the central lymphatic system.It is responsible for CSF reabsorption and guidance of metastatic cancer cells and pathologic organisms.

Clinical pearl

The size of the epidural space or the distance between the ligament flavum and dura is different, the largest one at L2 is 5-6mm, in thoracic region 3-4mm and in C7 1.5-2mm. The larger space, the fewer complication of the pain injection.

Clinical pearl

CSF volume is an important factor for drug distribution in intrathecal drug delivery system.

Clinical pearl

Since cauda is floating in CSF, during injection into the subarachnoid space, the needle does not contact the roots.If the needle contacts the cord, it will cause a long-term neurological defect in the lower extremity. It causes pain, weakness, and atrophy of the muscles, loss of sensation and absence of ankle reflex and foot drop. So, the spinal needle must insert from the lower lumbar vertebrae.

Clinical pearl

Do not guide the needle more than S2 during caudal injection, because there is the possibility of dural perforation and PDPH.[13]

Clinical pearl

In cases of increased ICP, the spinal injection contraindicated. Because the removal of fluid from the CSF causes the cerebellum vacuumed and herniation in the foramen magnum and death.

Spine vasculature

The spinal cord takes blood from the branches of the vertebral artery and the segmental vessels. The vertebral artery is a subclavian artery branch. It enters posterior cranial fossa through the 6 upper cervical transverse foramina and foramen magnum to forme anterior spinal artery (ASA). Although the spinal arteries originate from the skull cavity, the segmental vessels that contribute to the blood flow of the spinal cord originate from the outside of the spinal cord. Segmental arteries originate from the cervical part of the vertebral artery, the ascending and deep cervical arteries, the posterior intercostals arteries and lumbar arteries. These vessels enter the vertebral canal through an IVF. Each of the 31 pairs of spinal branches of the segmental arteries enters its own IVF and divided into three branches. The anterior and posterior branches supply the dura-mater, ligaments and bone tissue of the canal. The third branch of the neuro-spinal artery, along with the spinal nerves, is divided into two anterior and posterior branches as the medullary or radiculomedulary artery. These arteries are only 5 to 10, so they do not correspond to the spinal cord segments of their own name. Anterior radiculomedulary supply the lower cervical and upper thoracic regions. The anterior radiculomedulary arteries originating from the posterior intercostal and lumbar are only on the left side due to the position of the aorta. Both the anterior radiculomedulary arteries of the right and left connect the ASA. The anterior and posterior radiculomedulary arteries have small branches(less than 0.2mm) to the respective and neighboring roots as radicular arteries. A posterior radiculomedulary artery gives branches to DRG. Since spinal artery alone cannot supply spinal cord blood, the radiculomedulary arteries are very important. The spinal anterior artery supply anterior 2/3 of the spinal cord, the rest of the spinal cord supply by the posterior spinal artery and the pial plexus. The largest anterior radiculomedulary artery is the Adamkiewics artery. Although most radiculomedulary arteries have 0.2-0.8 mm diameter, the diameter of this artery is 0.5-1.49mm and enter from the left to the vertebral column. It is a branch of posterior intercostal and lumbar arteries in lower thoracic and upper lumbar region(T8-L5).[14] There is a radiculomedulary branch in every centimeter of the cervical region, in the lumbosacral region there are 5-12 radiculomedulary branches with larger diameter, but in the thoracic region there are only 2-6 branches. The radiculomedulary arteries in upper and middle portions of the thoracic segments (T4-T6) are rare, and this is why this part is highly susceptible to ischemia.[15]

Citation: Gharries H. Clinical anatomy of the spine for pain interventionist. *J of Anes & Criti Care Open Access.* 2018;10(4):131–136.
DOI: 10.15406/jaccoa.2018.10.00378

The spinal cord venous system locates in the epidural space and on the spinal cord. It consisted of 6 longitudinal veins; 3anterior and 3 posterior (anteromedian spinal, anterolateral and anterior radiculomedulary and similar branches on the posterior side). Radiculomedulary veins supply cord and roots. Ten to twenty anterior radiculomedulary veins empty the epidural venous plexus. There is a large radiculomedulary vein (vena radiclularis Magna) in the lumbar region which path with one of the left neural roots in about T11-L3 segments. There is also a large posterior radiculomedulary vein around the L1-2 roots. The posterior radiculomedulary vein takes a branch of the preganglionic venous plexus on the DRG.[16,17] This venous system does not have a valve and the vessels are in free anastomosis so that the tumors easily metastasis to the brain and the vertebrae (e.g.prostate, lung, breast, thyroid gland).[8,18]

Clinical pearl

Since the lumbar region of the radiculomedulary artery located to the left, injections of the lumbar region are better to do from the right side to have fewer complications.

Clinical pearl

Since the Adamkiewics artery is the only artery that gives a lot of blood flow to the spinal cord of the lumbosacral region, it is clinically important. Unfortunately and rarely the radiculomedulary blood flow during the pain injections is cut off. During transforaminal injection, radicular artery should monitor for the possibility of the complications due to steroid injection into this artery, which is closely related to the ASA. Any disruption of the spinal cord blood flow is clinically important, causing cell necrosis and ischemia and serious functional deficit and clinically presented as ASA syndrome. ASA syndrome characterizes by a sudden bilateral loss of pain and temperature below the spinal lesion level, with the preservation of vibration and position sensation, loss of motor function (usually paraplegia) and absence of urine and stool control.

Clinical pearl

Spine injection in T4-T6 is more hazardous due to less blood supply.

Clinical pearl

The long-term intraosseous blood pressure of the vertebral vessels associated with low back pain.

Clinical pearl

Because the preganglionic venous plexus is very close to the dura, it is affected by any outside pressure, such as the herniated disks which will change the permeability of the vessels. The endoneurial edema and chronic venostasis if continued, will increase the sensitivity and endoneurial fibrosis and ectopic fibers of the ganglion and chronic pain.

Clinical pearl

Everything in epidural space (e.g. metastatic tumor) can damage the spinal cord through impeding of venous return and vasogenic edema.

Conclusion

By studying this article you can organize your information about the science of spine pain intervention. I hope this review will give you a wider perspective on the pain injections, and lead you to newer and more secure approaches.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

References

1. Joshua A. Waxenbaum; Bennett Futterman. Anatomy, Back, Vertebrae, Cervical. *StatPearls*.
2. Sizer PS Jr, Phelps V, Matthijs O. Pain Generators of the Lumbar Spine. *Pain Pract*. 2001;1(3):255–273.
3. Piomelli D, Sasso O. Peripheral gating of pain signals by endogenous analgesic lipids. *Nat Neurosci*. 2014;17(2):164–174.
4. Andrade P, Hoogland G, Teernstra OP, et al. Elevated levels of TNF-α and TNFR1 in recurrent herniated lumbar discs correlate with chronicity of postoperative sciatic pain. *Spine J*. 16(2):243–251.
5. Malas MA, Seker M, Salbacak A, et al. The relationship between the lumbosacral enlargement and the conus medullaris during the period of fetal development and adulthood. *Surg Radiol Anat*. 2000;22(3-4):163–168.
6. Kim JS, Ali MH, Wydra F, et al. Characterization of degenerative human facet joints and facet joint capsular tissues. *Osteoarthritis Cartilage*. 2015;23(12):2242–2251.
7. Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice. 41st ed. USA: Elsevie; 2016.
8. Tubbs RS, Levin MR, Loukas M, et al. Anatomy and landmarks for the superior and middle cluneal nerves: application to posterior iliac crest harvest and entrapment syndromes. *J Neurosurg Spine*. 2010;13(3):356–359.
9. Barolat G. Experience with 509 plate electrodes implanted epidurally from C1 to L1. *Stereotact Funct Neurosurg*. 1993;61(2):60–79.
10. Aurboonyawat T, Pereira V, Krings T, et al. Patterns of the Cranial Venous System from the Comparative Anatomy inVertebrates. Part III. The Ventricular System and Comparative Anatomy of the Venous Outlet of Spinal Cord and Its Homology with the Five Brain Vesicles. *Interv Neuroradiol*. 2008;14(2):125–136.
11. Huff T, Dulebohn SC. Neuroanatomy, Cerebrospinal Fluid. StatPearls Publishing. 2017.
12. Edsbagge M, Starck G, Zetterberg H, et al. Spinal Cerebrospinal Fluid Volume in Healthy Elderly Individual. *Clin Anat*. 2011;24(6):733–740.
13. Kim SG, Yang JY, Kim DW, et al. Inadvertent Dural Puncture during Caudal Approach by the Introducer Needle for Epidural Adhesiolysis Caused by Anatomical Variation. *Korean J Pain*. 2013;26(2): 203–206.
14. Biglioli P, Spirito R, Roberto M, et al.The anterior spinal artery: the main arterial supply of the human spinal cord--a preliminary anatomic study. *J Thorac Cardiovasc Surg*. 2000;119(2):376–379.
15. Duggal N, Lach B. Selective vulnerability of the lumbosacral spinal cord after cardiac arrest and hypotension. *Stroke*. 2002;33(1):116–221.
16. Esses SI, Moro JK. Intraosseous vertebral body pressures. *Spine*. 1999;17(6 Suppl):S155-S159.
17. Parke WW, Whalen JL. The Vascular pattern of the human dorsal root ganglion and its probable bearing on a compartment syndrome. *Spine*. 2002;27(4):347–352.
18. FitzGerald MJT. Clinical Neuroanatomy and Neuroscience. 6th ed, USA: Saunders; 2001.

Citation: Gharries H. Clinical anatomy of the spine for pain interventionist. *J of Anes & Criti Care Open Access*. 2018;10(4):131–136.
DOI: 10.15406/jaccoa.2018.10.00378