SPINAL CORD- A CADAVERIC STUDY

Vijayamma K. N[1], Ushavathy P[2], Margret William[3]

[1]Professor, Department of Anatomy, Believers Church Medical College, Thiruvalla, Kerala.
[2]Associate Professor, Department of Anatomy, Government Medical College, Kottayam, Kerala.
[3]Junior Resident, Department of Anatomy, Government Medical College, Kottayam, Kerala.

ABSTRACT

BACKGROUND

Spinal cord is situated within the vertebral canal extending from the lower end of the medulla oblongata at the upper border of first cervical vertebra. In early foetal life, it extends throughout the length of the vertebral canal, and at the time of birth, it reaches the level of third lumbar vertebra. In adult, it ends at the lower border of first lumbar vertebra and thereafter continued as filum terminale, which gets attached to tip of coccyx. Spinal cord is covered by three protective membranes called spinal meninges, diameter, arachnoid and pia mater. The diameter and arachnoid mater extent up to second sacral vertebra and the pia mater forms filum terminale and extend at the tip of coccyx.

MATERIALS AND METHODS

Forty spinal cord cadaveric specimen were studied by dissection method after exposing the vertebral canal. The roots of spinal nerve were sectioned on both sides and the cord is released along with its coverings. The dura and arachnoid mater were incised longitudinally and the subarachnoid space, blood vessels, nerve roots, ligament denticulata, cervical and lumbar enlargements were observed. The blood vessels including radicular arteries were also studied photographed.

RESULTS

The spinal cord is a highly vascular structure situated within the vertebral canal, covered by diameter, arachnoid mater and pia mater. Spinal dura is thicker anteriorly than posteriorly. The pia mater forms linea splendens, which extend along the whole length of the cord in front of the anterior median fissure. The average length of the cord is 38 cm. The length and breadth of cervical enlargement was more compared to lumbar enlargement. The number of rootlets in both dorsal and ventral roots accounts more in cervical compared to other regions of the cord. The ligament denticulata is a thin transparent bands of pia mater attached on either sides of the cord between the dorsal and ventral roots of spinal nerves. The tooth like extensions are well developed in cervical and upper thoracic region and become thin in the lower thoracic and lumbar regions. The last tooth of the ligament elongated and tendinous. The cord was surrounded by rich vascular plexus and seen more towards the lower and posterior aspect.

CONCLUSION

Spinal cord is a highly vascular neuronal structure situated within the vertebral canal covered with meninges and anchored by ligamentum denticulatum on either sides. It has a unique vascular anatomy. The anterior and posterior radicular arteries provide very crucial role in the vascular supply of the cord. Arteria radicular magna was observed in 70% of specimens, of which 50% at T11 segmental level. A profuse vascular anastomosis was observed around the cord between the branches of anterior and posterior spinal arteries supplemented by radicular arteries in the lumbar and sacral segments of the cord.

KEYWORDS

Spinal Cord, Ligamenta Denticulata, Filum Terminale, Conus Medullaris, Spinal Arteries, Arteria Radicularis Magna.

HOW TO CITE THIS ARTICLE: Vijayamma KN, Ushavathy P, William M. Spinal cord- A cadaveric study. J. Evid. Based Med. Healthc. 2018; 5(3), 265-270. DOI: 10.18410/jebmh/2018/54

BACKGROUND

The spinal cord is a cylindrical cord like structure occupying in the anterior two thirds of the vertebral canal covered by meninges. The spinal diameter appears to be thicker anteriorly than the posterior aspect and extend up to the level of second sacral vertebra. The arachnoid was found to be thin and transparent and also extend up to second sacral vertebra. The subarachnoid space contained one anterior spinal artery in relation to the anterior median fissure and two posterior spinal arteries in the poster lateral sulcus. The lower part of the cord is surrounded by vascular plexus. The subarachnoid space surrounding cauda equina is enlarged to form lumbar cistern. The pia mater is modified to form 21 pairs of tooth-like extensions named ligamentum denticulatum, which helps to anchor the cord to inner surface of the dura. These triangular process were emerged between the dorsal and ventral roots. They are small and numerous at cervical level and large and less numerous at thoracic levels. In the lower thoracic regions, it get attached

Financial or Other, Competing Interest: None.
Submission 25-12-2017, Peer Review 02-01-2018,
Acceptance 10-01-2018, Published 13-01-2018.
Corresponding Author:
Dr. Ushavathy P,
Associate Professor, Department of Anatomy,
Government Medical College, Kottayam-686008, Kerala.
E-mail: ushamck@gmail.com
DOI: 10.18410/jebmh/2018/54

to dura by fibrous bands. There are school of thought that anterior and posterior nerve roots were affected by abnormal tension in the ligament.[1] The average length of filum terminale measures about 18 cm length in adult and 5 cm at birth and provides a connecting link between conus medullaris and coccyx, which stabilises the entire cord. The spinal nerves were formed by anterior and posterior roots, which are made up of 10-12 rootlets and passes through the intervertebral foramen. The lower lumbar sacral and coccygeal roots are long and forms cauda equina and together with filum terminale occupies inside the lumbar cistern. A condition called cauda equine syndrome in which any compression may cause radicular pain, bowel/bladder dysfunction and saddle anaesthesia of the lower extremities weakness at the level of lumbar and sacral roots. The spinal accessory nerve arises by rootlets from the sides of the cord from upper 4-5 spinal segments. There are five longitudinal arteries around the cord formed from spinal arteries, reinforced by spinal twigs from segmental arteries. These radicular arteries are large at first thoracic and eleventh thoracic levels and called arteries of Adamkiewicz. These radicular arteries are important in the vascular supply of the cord.[2] Any damage to Adamkiewicz artery will result in decreased perfusion of thoracoabdominal region of spinal cord due to the lack of collateral blood flow and poor anastomosis to this region.[3]

MATERIALS AND METHODS

Spinal cord was studied by exposing the vertebral canal during routine dissection classes. Forty specimens including four full-term foetuses were subjected to the study. Roots of spinal nerves were sectioned on both sides and the cord was isolated along with the meninges. The diameter was inspected and cut longitudinally along its length and visualise the arachnoid mater, blood vessels, nerve roots of spinal nerve and origin of spinal accessory nerve. The ligamentum denticulatum were numbered and observed its attachments. The conus medullaris and filum terminale were also studied. The weight and length of the cord were measured. The length and breadth of cervical and lumbar enlargements were measured and tabulated. The anterior spinal arteries, posterior spinal arteries, radicular arteries and corresponding veins were observed and photographed.

OBSERVATIONS AND RESULTS

The spinal cord is an elongated neuronal cord with a minimal flattening anteroposteriorly and lodged within the upper two-thirds of the vertebral canal in close contact with the anterior aspect of the vertebral column covered by meninges. The cord was anchored by the roots of spinal nerves on either side and by the attachment of filum terminale to the coccyx (Figure 1).

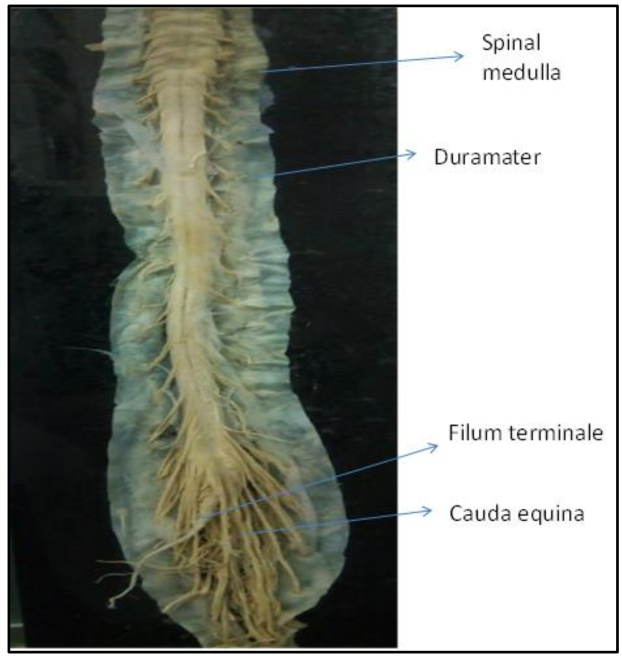

Figure 1. Showing Cauda Equina and Filum Terminale

The average weight measured was 30 g and length 38 cm. The filum terminale having a length of 19.5 cm and passing through sacral canal along with coccygeal nerve and attached to tip of coccyx. It was thin and straight in 80% of specimens, whereas in 20% of cases, it was fairly thick and fleshy. The dura mater was found to be thicker in the anterior lateral aspects of the cord and is thin posteriorly. The spinal cord is surrounded by vertebral venous plexus surrounding the anterior and posterior aspects within the vertebral canal (Figure 2). The arachnoid mater was very thin and transparent. The pia mater is closely adherent to the substance of the cord and modified to form a transparent thread-like structure called linea splendens that extend along the anterior median fissure throughout the length of the cord. The ligamenta denticulata were seen as two transparent bands of pia mater on either side of the cord (Figure 3) extending between the anterior and posterior root of spinal nerves. Twenty one pairs of tooth-like processes were seen extending from it to get attached to the inner surface of the dura mater. This triangular extensions were small and more numerous at the cervical level and less in number at the thoracic level. The tooth becomes more elongated and thread like when reached the lower part of the cord measuring about 21-26 mm length. The filum terminale also appears to be a thin thread-like structure in 80% of cases (Figure 4), whereas in 20% cases, it was found to be cord like resembling whip-like structure (Figure 5) accompanied by terminal part of anterior spinal artery.

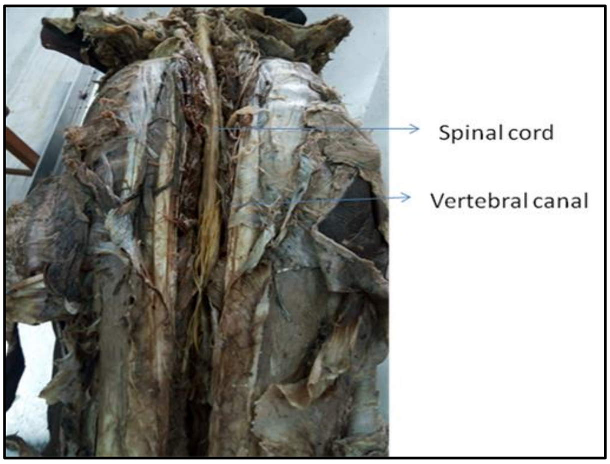

Figure 2. Showing Spinal Cord inside the Vertebral Canal

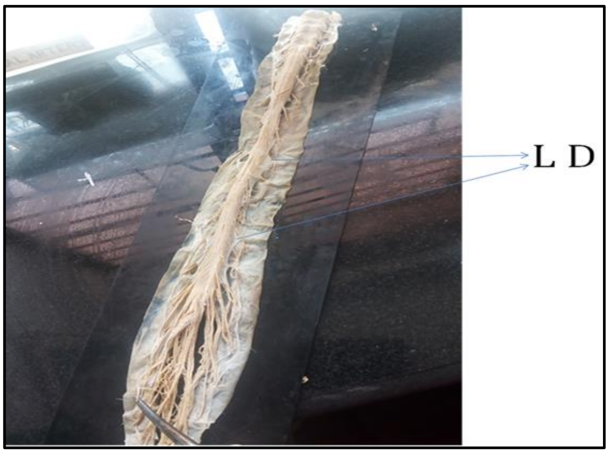

Figure 3. Showing Ligamentum Denticulatum (LD)

Figure 4. Showing Filum Terminale (FT) with Coccygeal Nerves

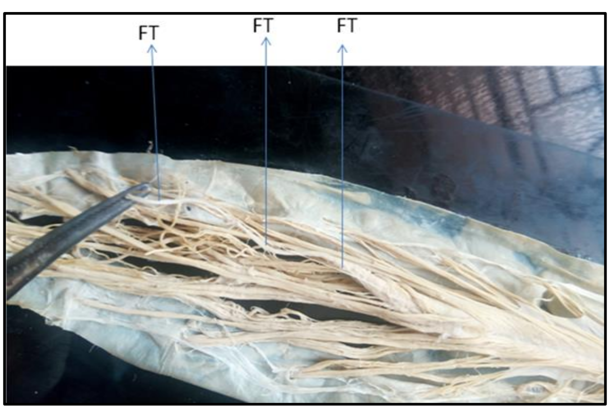

Figure 5. Showing Filum Terminale Embedded among the Cauda Equina

Figure 6. Showing the Spinal Cord of Full-Term Foetus Exposing Cauda Equina and Filum Terminale (FT)

Figure 7. Showing Vascular Plexus

Figure 8. Showing Adamkiewicz Artery (Arteria Radicularis Magna)

Figure 9. Showing Tortuous Posterior Spinal Arteries (PSA)

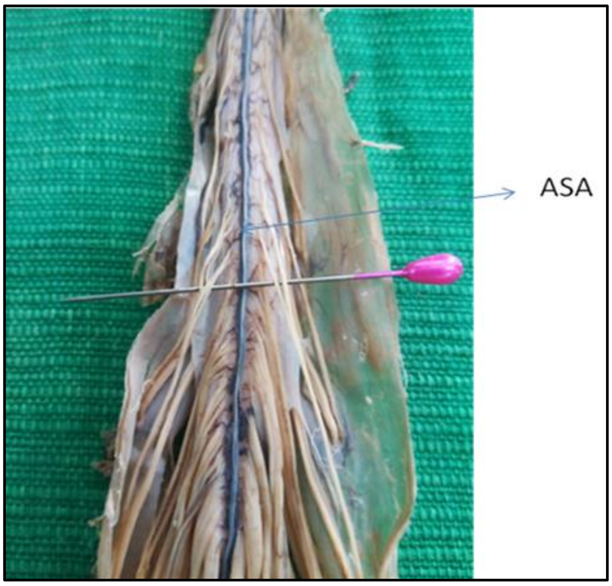

Figure 10. Showing Anterior Spinal Artery

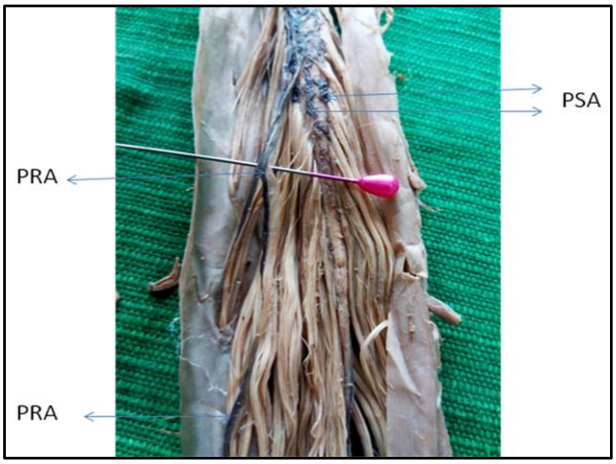

Figure 11. Showing Posterior Radicular Arteries (PRA) at L1 and T11 joining with Posterior Spinal Artery (PSA)

Figure 12. Showing Anterior Spinal Artery accompanied by Descending Branch of AKA

The conical lower end of the spinal cord forms conus medullaris, which gives origin to three to four filaments of coccygeal nerves (Figure 4). In this study, it was found that the length of filum accounts for half of the total length in adults, whereas in newborn (Figure 6), it measures only one-third of the total length and made up of dense connective tissue covered by pial sheath.

	Group I	Group II	Group III	Group IV
Length (cm)	30-35	36-40	41-45	45-50
Number of cases	3	27	10	0

Table 1. Showing Length of Spinal Cord Group I-IV

In the present study, the specimens are grouped into three according to the length (Table 1) and it was found that 90% (27 cases) belongs to the category of group II having a length of 36-40 cm. The average length of filum terminale was 18 cm and appears as fibrous thread-like structure throughout the length. In two specimens (5%) cases, it appears to be thick and cord like resembling a whip-like structure. The anterior spinal artery accompanies it at the terminal end.

	Group I		Group II		Group III	
	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)	Length (cm)	Diameter (cm)
Cervical enlargement	5.5	1.4	6.9	1.3	7.2	1.3
Lumbar enlargement	4.8	0.8	5.4	1.1	5.3	1.1

Table 2. Showing Dimensions of Cervical and Lumbar Enlargement

The cervical enlargement is more compared to lumbar enlargement in length and diameter. Measures about 7 cm length and 1.4 cm thickness. The lumbar enlargement was found to be 5.5 cm in length and 1.1 cm thickness (Table 2). It was observed from the present study that as the length of the cord increases, the dimensions also increased. The spinal nerves are seen arising from the cord by two roots, anterior and posterior by the fusion of rootlets. The rootlets are multiple (12-16) in the cervical enlargement and lesser in number in the lumbar enlargement. Cervical enlargement formed by C3-T2 spinal segments and lumbar enlargement by L1-S3 segment. The spinal accessory takes origin from upper four cervical segments in all cases.

Blood supply of spinal cord arise from one anterior and two posterior spinal arteries supplemented by segmental or radicular arteries. The anterior spinal artery is single and straight, arise from vertebral arteries by two roots and join together to form single vessel in all cases. It runs through the anterior median fissure lying in front of linea splendens and extend up to the tip of coccyx. The segmental arteries are 8-10 in number, which divides into anterior and posterior radicular arteries. The anterior radicular arteries runs along with anterior root of spinal nerves and enters vertebral canal and joins with anterior spinal artery. It forms plexus around the anterior aspect of the cord along with accompanying veins. This plexus are more pronounced on the lower thoracic and lumbar segments of the cord (Figure 7). The anterior radicular arteries are larger in size and is called arteria radicularis magna (artery of Adamkiewicz) was found in 70% of total specimens. The present study shows that 50% of these arteries were found at the level of T11. The arteria radicularis magna were also observed at T1, T10, T12 and L1 segments of the cord. The posterior radicular arteries were seen at T11 segment level is 20% and this artery having the same size as arteria radicularis magna was seen on the left side (17.5%) at the same level (Table 3). It was also observed that when anterior radicular artery is prominent, the posterior radicular artery was thin or seen a segment above or below (Figure 8).

The posterior spinal arteries are two in number, which originates from the posterolateral aspects of the vertebral arteries of right and left side and runs on posterolateral aspects of the spinal cord. The arteries descends separately in cervical region and at the lower end of the cervical enlargement fuse to form plexus on the posterior aspects of the cord. The posterior spinal arteries are found to be tortuous in its course (Figure 9) unlike anterior spinal artery, which was straight in its course Figure (10). Single posterior spinal artery was also found in 2 specimens (5%). The large posterior radicular arteries was seen at level of L1 in 2 specimens (5%) in which large anterior radicular arteries were also seen three segments above at T10 on the right side (Figure 11). An arteria radicularis magna joins with anterior spinal artery at T10 segment divides into an ascending and descending branches (Figure 12) and the descending branch accompanies anterior spinal artery up to the tip of the coccyx.

Segment Level	Right Anterior	Right Posterior	Percentage	Left Anterior	Left Posterior	Percentage	Total Cases	Total Percentage
T1	1	0	2.5%	0	3	7.5%	4	10%
T10	1	0	2.5%	1	0	2.5%	2	5%
T11	4	1	12.5%	16	7	57.5%	28	70%
T12	1	0	2.5%	2	0	5%	3	7.5%
LI	0	0	0	2	1	0	3	7.5%

Table 3. Showing the Percentage of Large Radicular Arteries at Different Spinal Segment

DISCUSSION

The spinal cord is an elongated cylindrical nerve cord situated within the vertebral canal covered by three layers of meninges. The spinal diameter is thick and is firmly adherent to periosteum of foramen magnum above and periosteum of the lower border of the second sacral vertebra below. The extensions of the dura along the roots of spinal nerves through the intervertebral foramen forms a thick cuff-like investment over it and later fuses with the epineurium of the spinal nerves. Unlike peripheral nerves, cauda equina nerve roots lack perineurium to hold the injured end together during attempts were made to suture it.[4] The epidural anaesthesia is given to the space around the dura and vertebral canal at a desired site in such a way that the anaesthetic fluid diffuses through the dural sheath and the nerve gets anaesthetised. The diameter invest the cauda equina as a sac-like structure and loosely invest the structures and subarachnoid space is ballooned out to form lumbar cistern. The roots are ensheathed by thick dural investment at the level of its exit at the corresponding intervertebral foramen. There are school of thought that the anterior and posterior nerve roots are affected by abnormal tension in the ligamentum denticulatum, which are attached to the inner surface of the dura mater. The high extensibility of the ligament need less force to rapture them as its strength is less in cervical region.[5] A longitudinal linear band of pia mater, linea splendens runs along the anteromedian fissure, which extend throughout the length of the cord and support the anterior spinal artery.[6] It is uniform in thickness, seen as whitish shining fibrous membrane and can be easily peeled off along with anterior spinal artery. The white matter gradually ceases towards the end of spinal cord (Figure 6, 7) and gray matter blends into a single mass, the conus medullaris. Below the conus, the pia mater is continued as the filum terminale, which runs along with the lower spinal roots and together forms the so called cauda equina. In cauda equina syndrome, there is compression of the roots of lower lumbar, sacral and coccygeal nerves by prolapsed intervertebral disc or by extradural tumour and is characterised by severe root pain, saddle anaesthesia, lower motor neurone type of paralysis and late bowel and bladder retention.[7] The compression of conus medullaris is usually presented with sudden onset of low back pain and bowel and bladder dysfunction and motor weakness. There may be congenital abnormalities, e.g. spina bifida, lipomata or diastematomyelia, the conus may extend below the lower border of L1 often with a tethered filum terminale.[8] The central herniation of the disc may compress the cord segment itself, while the lateral herniation affect the roots of spinal nerves.

The source of blood supply and distribution are constant in most of the specimens. The cord depends on the three longitudinal arterial channels, namely one anterior spinal and two posterior spinal arteries supplemented by radicular arteries. The radicular arteries of varying size and length were seen embedded along with the nerve roots. They are found in the lower cervical, lower thoracic and upper lumbar regions and larger enough to reach the anterior median fissure to anastomose with anterior spinal artery as medullary feeder arteries. The present study also reveals medullary feeder arteries in these regions and more on the left side. The longitudinal arteries cannot supply the whole length of the cord without the input from segmental medullary feeder vessels, especially true of Adamkiewicz artery in supplying lower part of the cord. A profuse anastomosis was observed around the cord between the branches of the anterior and posterior spinal arteries supplemented by radicular arteries in the lumbar and sacral segments of the cord. This observation of rich anastomotic channels offer an alternative pathway for arterial flow under conditions of stress.[9] The artery of Adamkiewicz, the large anterior radicular artery was observed in 70% of the total 40 specimens, of which 52.5% are found on the left side. It is important to identify the location of AKA during surgical treatment of aortic aneurysm to prevent damage, which would result in insufficient blood supply to the spinal cord.[10]

The arteria radicularis magna was also observed at T1 segment in 7.5% specimens (Table 2) on the left posterior aspect joining with posterior spinal artery. The same specimen shows arteria radicularis magna at T10 spinal segment (Figure 11). The profuse anastomotic network of vessels are observed more on the lower segments of the cord especially more on the posteriomedian aspects suggest the anastomose between branches of subclavian artery cranially and hypogastric arteries caudally.[11] This provide a compensatory flow to the spinal cord whenever there occurs occlusion of large caliber routes, but it was an established fact that the central perforating and pial vessels, which supply the cord are end arteries and there is no anastomoses at the capillary beds.[12] There was a rich anastomotic circle found within the spinal canal in the loose connective tissue of extra dural space with greatest concentration in the cervical and lumbar region. They are formed from the branches of segmental arteries and offer alternative pathways of flow in conditions of stress and after ligation of segmental arteries of one side. A knowledge of blood supply to the spinal cord is important when planning for the treatment of diseases involving aorta. Anterior spinal artery is crucial to the vascularisation of spinal marrow and anterior and lateral funiculi. Anterior and posterior spinal arteries are interconnected with ascending and descending branches of radicular arteries.[13]

CONCLUSION

The spinal cord can be damaged without any radiological evidence of vertebral injury in site where vertebral canal is narrowed as seen in thoracic region or due to osteoarthritic changes, which is more in the cervical region. Direct or indirect vascular lesions can cause ischaemic damage to spinal cord. Thus, the inherent anatomic features of the cord and vertebral canal makes the spinal cord more vulnerable to compressive and ischaemic insult than other parts of central nervous system. The cauda equina syndrome can result due to spinal canal stenosis at lower level or extradural tumour and disc prolapse. The present study reveals that the arterial vasocorona is abundant in the lower segment of the cord. The enlarged radicular arteries were seen in the lower cervical and at first lumbar segmental level play an important role in the vascular supply of the cord. Knowledge of blood supply of human spinal cord is very essential in operations for correction of severe scoliosis, since there is a high incidence of paraplegia following surgical correction.

REFERENCES

[1] Polak K, Czyz M, Scigala K, et al. Biochemical characteristics of the porcine denticulate ligaments in different vertebral levels and cervical spine: preliminary result of an experimental study. J of Mechanical Behavior of Biomedical Materials 2014;34:165-170.

[2] Tveten L. Spinal cord vascularity III. The spinal cord arteries in man. Acta Radiol Diagn (Stockh) 1976;17(3):257-276.

[3] Prince EA, Ahn SH. Basic vascular neuroanatomy of the brain and spinal: what the general interventional radiologist needs to know. Semi Intervent Radiol 2013;30(3):234-239.

[4] Hart AM, Terenghi G, Wiberg M. Neuronal death after peripheral nerve injuries and experimental strategies for neuroprotection. Neurol Res 2008;30(10):999-1011.

[5] Moore KL, Dalley AF, Agur AMR. Clinically oriented anatomy. 7th edn. New York: Lippincott Williams and Wilkins 2006.

[6] Ramasamy MV. Ram's text book of human anatomy for dental students. New Delhi: Jaypee Brothers Medical Publishers 2010.

[7] McCarthy, Aylott CE, Grevitt MP, et al. Cauda equina syndrome: factors affecting long-term functional and sphincteric outcome. Spine (Phila Pa 1976) 2007;32(2):207-216.

[8] Baron EM. Spinal cord and Spinal nerves gross anatomy. Chap- 43. In: Standring S, ed. Grays anatomy. 41st edn. New York: Elsevier 2015.

[9] Lazorthes G, Gouaze A, Zadeh JO. Arterial vascularization of the spinal cord. Recent studies of the anastomotic substitution pathways. J Neurosurg 1971;35(3):253-262.

[10] Yoshioka K, Niinuma H, Ohira A, et al. MR angiography and CT angiography of the artery of Adamkiewicz: non-invasive preoperative assessment of thoracoabdominal aortic aneurysm. Radiographics 2003;23(5):1215-1225.

[11] Griepp EB, Di Luozzo G, Schray D, et al. The anatomy of the spinal cord collateral circulation. Ann Cardiothorac Surg 2012;1(3):350-357.

[12] Bolton B. The blood supply of spinal cord. J Neurol Psychiatry 1939;2(2):137-148.

[13] Melissano G, Chiesa R. Advances in imaging of the spinal cord vascular supply and its relationship with paraplegic after aortic interventions. A review. European Journal of Vascular and Endovascular Surgery 2009;38(5):567-577.