

Linea alba conus medullaris: a stable anatomical landmark for thecaloscopic procedures

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ABSTRACT

Denticulate ligament and filum terminale are two eminences of spinal pia mater which bind together and form a unit that supports and protects the spinal cord. The purpose of this study was to prove the relationship between denticulate ligament and filum terminale and find out the anatomic structure of their interconnection on conus medullaris.

For this post-mortem study we used 10 fresh cadavers, which were previously used for downward orientated thecaloscopic procedures. The cadavers were placed in prone position and the spine was dissected at the level of L1-L2 spinal processes. Dura mater was opened after thecaloscopic exploration and the anatomy of the content of thecal sac was further investigated. We assessed endoscopically in every cadaver that filum terminale is the anatomical continuation of denticulate ligament.

Macroscopically, the denticulate ligament after having given its last eminence, continues forming an externally visible white line of tissue on each side of conus medullaris, which we named "*linea alba medullae spinalis*" or "*linea alba conus medullaris*", a structure which ends forming the filum terminale. *Neuroanatomy*; 2006; 5: 17–19.

Key words [denticulate ligament] [filum terminale] [spinal pia matter] [conus medullaris] [thecaloscopy]

Introduction

Pia mater is the meningeal envelope that firmly adheres to brain and spinal cord surface and invests the vessels passing into the parenchyma. It is a very thin fibrous membrane, covered on its outer surface by a sheet of flat polygonal, impermeable to fluid, cells. Spinal pia mater is firmer and less vascular, but like the cerebral pia it consists of an external "epi-pia" containing larger vessels and an internal "pia-glia" or "pia intima" intimately adherent to the spinal cord. Between "epi-pia" and "pia-glia" are some vessels and clefts containing a number of blood vessels. It enters the anterior median fissure, lining its walls with an intervening open meshwork of fine fibrous strands. A longitudinal fibrous band, the *linea splendens*, extends along the anterior midline. *Ligamenta denticulata* are on each side of spinal cord. Beyond the *conus medullaris* the pia matter continues as the *filum terminale*.

For performing thecaloscopic procedures stable anatomical landmarks are necessary [1, 2]. One such landmark of great anatomical significance is the denticulate ligament. From our operative experience and thecaloscopic research, came up the questions where the denticulate ligament ends up, what its course is after having given the last of its processes and how it is continued on the conus medullaris before forming filum terminale.

Material and Methods

The post-mortem study was carried out in 10 fresh cadavers used for thecaloscopic procedures. Cadavers were placed in the prone position. A longitudinal skin and aponeurotic incision was made and the paravertebral muscles were detached. The spinal processes and the L1-L2 laminal levels were removed and the dural sac was exposed. Then the dura was micro-surgically opened and the endoscope (Storz of outer diameter 2.8 mm, 37 cm in length with one working channel of 1 mm) was inserted. After endoscopic identification and performance of thecaloscopic inspection, the dura was opened micro-surgically and the uncontained anatomic structures were identified macroscopically. The ventral and the dorsal lumbar and sacral spinal rootlets were then separated. After having removed the dorsal spinal rootlets we followed the last process of the denticulate ligament at its medial border, on each side of conus medullaris and downwards to the filum terminale.

Results

In all the studied cadavers, filum terminale was found to be the anatomical continuation of denticulate ligament. Spinal pia mater was continued on every side of conus medullaris as a white band.

Thecaloscopically, the denticulate ligament cannot be visualized in the regular endoscopic approach as the level of endoscope insertion used is between L1 and L2 spinal processes. If the endoscope is rotated 180 degrees,

the direction of inspection is toward the conus. Using copious amounts of irrigation and separating the nerve rootlets at the lateral aspect of conus medullaris, the denticulate ligament can be identified. Macroscopically, the denticulate ligament after having given its last process forms an externally visible white line on each side of conus medullaris (*linea alba medullae spinalis* or *linea alba conus medullaris*) and ends up to form filum terminale (Figs. 1, 2).

Discussion

Denticulate ligament is a fibrous sheath situated on each side of the spinal cord between the ventral and dorsal spinal nerve roots, has a medial border continuous with the spinal pia mater and a lateral border having series of triangular processes, fixed at intervals to the dura mater. There are 19-23 processes on each side. The first process crosses behind the vertebral artery and is separated by the artery from the first cervical ventral root. The last process is between the exits of the twelfth thoracic and first lumbar spinal nerves or between the first and second lumbar spinal nerves. The superior processes have a cranial and the inferior a caudal orientation. In the superior cervical and thoracic myelon these processes are found 1-2 mm dorsally from the nerve roots while in the lumbar ventrally. The denticulate ligament with pia and dura mater build up a unit, which helps the ventral flexion and the dorsal extension of the spinal cord during

spinal movements. Filum terminale is a fibrovascular tag with an abundance of glial cells and neurons containing a large vessel, 20 cm long, less than 2 mm in diameter, which becomes smaller across its course in the lumbar subdural space. The greater part, 15 cm in length, is free in the subdural space and the last 5 cm are enclosed in the filum durae mater spinalis, which leave the sacral canal through the sacral foramen to adhere the periost of the second lumbar vertebrae [3-7].

The structure of the pia mater is that of loose connective tissue, containing collagen, elastin and reticulin fibers with flat mesotheliocytes like those of the arachnoid; the cells are considered to be fibrocytic elements by some, especially where they form several layers interleaved with reticulin fibers, next to the central nervous system. Here the innermost cells are apposed to convoluted basal lamina, which lies between them and the adjacent end-feet astrocytes. This relationship is so close that the internal stratum of the pia, with the basement membrane and glial processes, are sometimes combined as "pia-glia" or "pia-intima", to differentiate it from the rest of the membrane, the "epi-pia", which is the pial striatum regarded as arachnoid by some. On the spinal surface the more external connective tissue layer of the pia, the "epi-pia", is more developed than on the cerebral surface, were it is not easily identified [4].

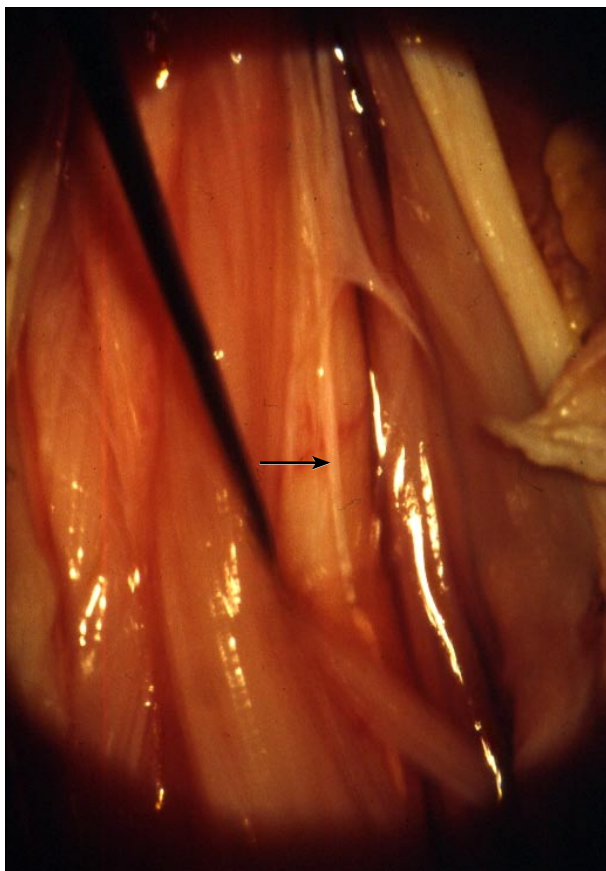


Figure 1. Externally visible fibrous white line of pia mater on each side of conus medullaris. Color version of figure is available online.

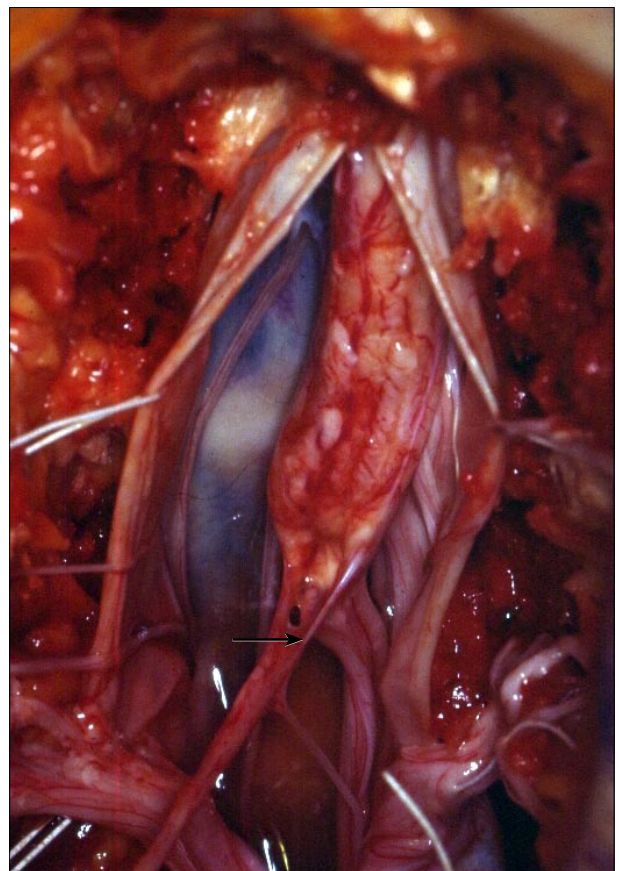


Figure 2. The termination of the fibrous white line of pia mater is on the filum terminale. Color version of figure is available online.

From a recent study [8] we know that the denticulate ligaments do not inhibit cord motion to such discrete areas of the cord as once thought. The ligaments are stronger in the cervical region, they decrease in strength as the spinal cord descends and are more resistant to caudal compared with cephalad stresses in the cord. Anterior and posterior motion is constrained by these ligaments but to a limited degree, especially as one descends inferiorly along the cord.

Dentate ligaments do limit the movements of the spinal canal in a cephalo-caudal direction in the confines of the spinal cord, and are sufficiently loose to allow the spinal cord to rest on the ventral surface when the position of the body is prone, and to rest on the dorsolateral wall when the position is supine [9]. “*Linea alba conus medullaris*” maybe transmits this movement behavior and response to filum terminale.

This interconnection between the two eminences of pia mater, “*linea alba conus medullaris*”, helps for the

integrity of spinal cord motion as a unit, which keeps spinal cord stable, especially caudally, although the force of spinal movements. This band, “*linea alba conus medullaris*” probably transmits the tension of dentate ligament to filum, without alternating the movement response of caudal part of spinal cord.

Conclusion

The aim of the study was to investigate the course of the denticulate ligament after having given the last of its processes. On evaluating the results we have drawn the following conclusions: The last process of the denticulate ligament is continued medially on each side of conus medullaris, forming an externally visible white line, which ends up in the filum terminale. This band of pia mater probably helps for the maintenance of the integrity of spinal cord response during spinal movements.

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