A morphometric cadaver study of the anterior lumbar epidural space

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Abstract

Introduction Free disc fragments end often up in the concavity of the anterior epidural space. This space consists of two compartments. The discrepancy between the impressive magnetic resonance imaging findings, clinical symptoms in patients and the problem of treatment options led us to the anatomical determination of anterior epidural space volumes.

Materials and methods For the first time, the left and right anterior epidural volume between the peridural membrane and the posterior concavity of the lumbar vertebral bodies L3–S1 were determined for each segment. A CT scan and a polyester resin injection were used for the in vitro measurements.

Results The volumes determined in human cadavers using this method ranged from 0.23 ccm for L3 to 0.34 ccm for L5. The CT concavity volume determination showed this increase in volume from cranial to caudal, as well.

Conclusion This volume is large enough to hold average-sized slipped discs without causing neurological deficits. A better understanding of the anterior epidural space may allow a better distinction of patient treatment options.

Keywords Anterior epidural space spinal anatomy · Lumbar disc herniation · Free disc fragment

Introduction

Back pain is a very common disease in the western world and is responsible for a high number of economic losses caused by the inability to work. In a high number of cases, a herniated vertebral disc causes the pain. Large disc fragments tend to cause intense back and leg pain often without or only slight motor weakness. Especially, large herniated discs tend to sequester. After a longer period of pain with impaired working ability this patient group is often reluctant to tolerate the pain any longer and thus, asks for surgery. The spine surgeon must make the decision to operate on the patient or to follow a conservative therapy regime. Finally at the end of the sequestering process, the migrated disc fragments stay in the anterior epidural space. The capacity of the anterior epidural space depends on its volume and determines the closeness between dural sac and sequestrum. A close contact would lead to ongoing pain in contrast to only slight contact between the slipped disc and the neurological structures. This anterior epidural volume is not known yet.

Therefore, we examined human cadaver spines to determine the volume of the space containing disc parts, for the first time.

Anatomical structures anterior to the dura in the lumbar spinal canal, related to clinical problems, have been described, previously, by several authors [1, 2, 4, 5, 8, 9, 18, 22, 26, 27, 30–32, 34]. The posterior longitudinal ligament (PLL) is well known and demonstrated in anatomical textbooks. It is a typical and denticulated flat ligament showing a broad attachment at the level of the lumbar intervertebral discs and a narrower course across the mid-portion of the concave posterior wall of the vertebral bodies [1, 32].

A midline septum between the PLL and the dorsum of the vertebral body divides the posterior concavity into a

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right and left compartment. The sagittal membrane results in a typical T- or Y- shaped aspect of the PLL complex in transverse magnetic resonance images [18, 32]. During migration, sequestered disc fragments usually stay on one side of the midline septum in one compartment [18, 22, 30].

The peridural membrane is a little known fibrovascular sheath which incorporates the posterior longitudinal ligament [1, 4, 14, 35] and covers the posterior concavity of the vertebral body. The peridural membrane is medially attached to the free edge of the PLL and stretches out laterally to insert at the lateral wall of the spinal canal. The membrane does not cover the back of the anulus fibrosus; it is prevented from doing so by the posterior longitudinal ligament as it expands laterally over the back of the disc [1]. This thin membrane is translucent, and looking through it, one recognizes the epidural venous plexus and the interposed fatty tissue [30]. Manipulation in the retrovertebral area during surgery often leads to heavy venous bleeding. When herniated disc fragments dislocate from the disc level upwards or downwards, they slip under the peridural membrane. This membrane has to be opened during surgery to extract the slipped disc.

Hoffmann's ligaments stretch between the dura and the superficial layer of the PLL [1, 8, 30, 34]. They hold the dura in the spinal canal, which is important after wide posterior decompression [35]. These meningovertebral ligaments show a large interindividual difference [25, 32].

The anterior epidural space (AES) is a fairly well-defined space anteriorly limited by the concavity of the vertebral body and posteriorly by the PLL and the peridural membrane.

Anatomically, this space is the fossa vertebralis dorsalis. It consists of two compartments behind the vertebral body separated by the PLL and the sagittally aligned midline septum [1, 25, 30, 32, 35]. When disc fragments move from the donor disc in the superior (42%) or inferior (40%) direction, the displaced disc components are most frequently found (94%) in the right or left half compartment of the AES under the peridural membrane [30]. Although the anterior epidural space is a fairly well-defined anatomical structure, it has not been investigated yet. Its ability to contain detached disc fragments is especially unknown, because volume measurements have never been performed until now.

Materials and methods

Twenty-five fresh frozen cadaver lumbar spines were investigated by gross anatomical dissection and an X-ray was performed to exclude deformities, previous spine surgery, fractures or other diseases. The age range of the specimens appeared to be between 59 and 86 years. The male gender dominated in 84%.

All cadaver spines were examined by a Siemens CT scan. The compartments of the anterior epidural space were measured using a method first described by Larsen [20, 21]. The distances between the vertebral dorsal plane and the upper disc as well as the lower disc were measured, to reconstruct the sagittal plane. In addition, the depth of the recess was measured (Fig. 1). These data allow in the reconstruction of the sagittal plane. The sagittal area was determined in a multiple-step procedure. From the center of each vertebra, the areas to the pedicle were calculated using the Siemens image processing software Magic View™. The partial volumina determined were added to the total volume of the “fossa corporis vertebralis dorsalis” equivalent to the anterior epidural space. The evaluation was performed for each spine segment.

During the subtle preparation, all posterior structures were removed until the posterior longitudinal ligament and the peridural membrane were reached. The compartments of the anterior epidural space in the concavity of the vertebral bodies on both sides of the PLL and the midline septum were carefully preserved, as well as the complete content of the anterior epidural space which consists mainly of soft compressible epidural fat and veins. To measure the volume of the anterior epidural space between the concavity of the vertebral body and the peridural membrane, a polyester resin was used to fill the space. According to Husemeyer and White [10], the method was adequate to investigate the epidural space. The polyester resin (Technovit™) was injected fluid and cured time dependent. The resin was injected into the right and left compartment of every lumbar vertebral body. During the injection process, it was important that no leakage or bulging of the peridural membrane took place (Fig. 2).

Fig. 1 Volumetry of the compartments on each side by CT reconstruction of the sagittal plane according to the method described by Larsen [20, 21]

Fig. 2 Injection process (1) midline, (2) cannula in the posterior concavity of the vertebral body

After setting, the polyester resin was removed easily and the volume was determined, using the principle of water displacement. Since the volumes to be determined were small, a density measurement hydrometer was used with an accuracy of 1/10,000 g. To avoid an interaction with resin adherent air bubbles, the measurement was performed hermetically sealed in propanol. These results were corrected for the propanol density.

Finally, we were able to evaluate 196 anterior epidural spaces L3–S1 on both sides of the 25 cadaver spines. Four compartments could not be measured because of preparatory difficulties.

Results

The evaluation by computer tomography reconstruction showed increasing volumes ranging from cranial to caudal. We determined the following: L3 0.57 (± 0.21), L4 0.68 (± 0.20), L5 0.66 (± 0.22) and S1 0.76 (± 0.29) ccm. Only the average volume difference between L3 and the other segments was significant, as the other average volume showed no significant differences.

The Technovit polyester resin volumetry showed an increasing content of the anterior epidural space from cranial to caudal regarding the results for L3 0.23 (± 0.136), L4 0.20 (± 0.12) to L5 0.34 (± 0.16) and S1 0.33 (± 0.17) ccm. The differences between the volume L3 and the volumes L4 and L5 were significant ($p < 0.05$). The average volume differences of the other segments were not statistically significant.

Discussion

The anterior epidural space between the dura mater and the posterior concavity of the lumbar vertebral bodies is divided into different compartments into which protruded

herniated disc fragments can dislocate. Besides the posterior longitudinal ligament (PLL), the other anatomical structures in the anterior epidural space are not known well, meaning the peridural membrane covering the concavity of the vertebral body and the midline septum dividing the anterior epidural space in a right and left compartment in particular. Until now, the volume of these compartments was unknown. The relationship between these volumes and the size of the slipped disc fragments migrating upwards or downwards from the donor disc into the posterior concavity of the vertebral body was also unknown.

Our polyester resin volumetry and the CT evaluation of these compartments showed a great variability of volumes ranging from 0.23 to 0.34 ccm for the anatomical volumetry and from 0.57 to 0.76 ccm for the CT determination. The difference between both methods is caused by the tissue in the anterior epidural space and irregularities of the bone surface which cannot be considered in the CT as in the anatomical procedure.

According to the MRI measurements of Kawaji [13], herniated disc fragments have an average volume of 0.49 ccm during the painful first phase and 0.21 ccm after a few days. These volumes confirm our own observations about volumes of lumbar disc herniations [16, 34].

In conclusion, the anteveterebral epidural space is obviously large enough to hold average-sized free disc parts. Patients complain about pain and neurological symptoms at the moment, the herniation takes place and the fragment contacts nerve roots during the process at the disc level. At disc level, the anatomical space is narrower than in the retrovertebral concavity. When the fragment passes into the anteveterebral epidural space and reaches its final position in the right or left compartment, the patient's pain and most of the neurological symptoms are significantly reduced [16]. The residual neurological deficits, such as a slight motor weakness, loss of sensitivity or reflexes are due to the initial process, as material progresses through small clefts [33] and drops out of the disc. These observations show that the presented symptoms are not a sign of an actual nerve root compression by the disc material lying in the posterior concavity.

Hence, spinal surgery would no longer automatically improve symptoms when the passage process is finished. In contrast, it must be considered that at this time a surgical procedure is difficult, because disc sequestrs in the retrovertebral concavity are neither easy to localize nor to extract [16, 24]. The accidental intraoperative traction of the dura and the nerve roots during surgery, as the fragment is trying to be reached, can result in excessive venous bleeding from the peridural membrane or accidental dura lesions [19].

Isolated slipped disc parts in the anterior epidural space of the vertebral body have a good chance to be resorbed

spontaneously, especially because of the good vascular supply in this area [18]. The extruded disc material in the spinal canal provokes an inflammatory response of the epidural tissue, including the neural elements [24, 29]. Finally, an enzymatic resorption and phagocytosis occurs [3, 6, 7, 11, 12, 15, 23, 28].

The resorption is even easier and faster when the extruded disc material consists of soft nucleus material, in contrast to anulus or pieces of the endplates [17].

Our morphometric anatomical studies allow a better understanding of the natural history of disease and explain the clinical experience that free disc fragments in the posterior concavity of vertebral bodies often cause only mild clinical symptoms even if imaging is sometimes impressive.

In conclusion for clinical purposes, the MRI report should include information about the size as well as the consistency and water content of the dislocated disc material. In case of an anterior epidural space disc fragment, additional information about the vertebral concavity in relation to the mass of the dislocated disc material would be helpful. If the disc fragment fits into the concavity as in most cases, surgery is not mandatory, especially when clinical symptoms are not adequate. On the other hand, when the dislocated disc fragment mismatches the retrovertebral concavity or when disc parts slip into the lateral recess between nerve root and pedicle a surgical decompression should be considered regarding the neurological findings too.

Conflict of interest None.

References

- Bogduk N (1997) Clinical anatomy of the lumbar spine and sacrum, 3rd edn. Churchill Livingstone, London
- Crock H (1983) Practice of spinal surgery. Springer, Berlin
- Deyo R, Weinstein J (2001) Low back pain. *N Engl J Med* 344:363–370
- Domisse GF (1975) Morphological aspects of the lumbar spine and lumbosacral regions. *Orthop Clin North Am* 6:163–175
- Fick R (1904) Anatomie und Mechanik der Gelenke: 81. Gustav Fischer, Jena
- Haro H, Kato T, Komori H, Takahashi M, Shinomiya K (2001) The mechanism of angiogenesis in herniated disc resorption. *Abstr Edinburgh ISSLS*:13
- Hirabayashi S et al (1990) A dorsally displaced free fragment and histologic findings. *Spine* 15:1231–1233
- Hofmann M (1898) Die Befestigung der Dura mater im Wirbelkanal. *Arch Anat Physiol* 403–412
- Hogan Q (1991) Lumbar epidural anatomy. *Anaesthesiology* 75:767–775
- Husemeyer RP, White DC (1980) Topography of the lumbar epidural space. A study in cadavers using injected polyester resin. *Anaesthesia* 35:7–11
- Karpinnen A, Haapea M, Vanharanta H, Tervonen O (2004) Determinants of disc herniation resorption one year follow up. *Abstr 252, Porto ISSLS*:606
- Kato T, Haro H, Komori H, Shinomiya K (2003) The cascade of the spontaneous herniated disc resorption process. *Vancouver ISSLS*:12
- Kawaji Y, Uchiyama S, Yagi E (2001) Three dimensional evaluation of lumbar disc hernia and prediction of absorption by enhanced MRI. *J Orthop* 6(6):498–502
- Kikuchi S, Hasue M, Nishiyama K et al (1984) Anatomic and clinical studies of radicular symptoms. *Spine* 9:23–30
- Kobayashi S, Baba H et al (2005) Effect of mechanical compression on the lumbar nerve root: localization and changes of intradiscal inflammatory cytokines, nitric oxide and cyclooxygenase. *Spine* 30:1699–1705
- Kraemer J (2008) Intervertebral disc diseases, 3rd edn. Thieme, Stuttgart
- Kraemer J (1995) Natural course and prognosis of intervertebral disc diseases. *Spine* 20:635–639
- Kraemer J, Koester O (2003) MR imaging of the lumbar spine. Thieme, Stuttgart
- Kraemer R, Wild A, Haak H, Herdmann J, Kraemer J (2004) Microscopic lumbar discectomy. In: Herkowitz H (ed) The lumbar spine. Lippincott, Philadelphia, pp 453–463
- Larsen JL (1985) The posterior surface of the lumbar vertebral bodies—part 1. *Spine* 10:50–58
- Larsen JL (1985) The posterior surface of the lumbar vertebral bodies—part 2: an anatomic investigation concerning the curvatures in the horizontal plane. *Spine* 10:901–906
- Mc Culloch J, Young P (1998) Essentials of spinal microsurgery. Lippincott Raven, New York
- Nakai S, Maehara H, Asai T (2000) A study of the mechanisms of spontaneous regression of lumbar disc herniation using surgical specimen: The appearance of apoptosis and the role of macrophages in the extruded intervertebral disc. *Abstr Adelaide ISSLS*:95
- Olmarker K, Rydevik B (1993) Biochemical influence of nucleus pulposus on cauda equine nerve roots. *Spine* 18:1425–1432
- Parkin I, Harrison G (1985) The topographical anatomy of the lumbar epidural space. *J Anat* 141:211–217
- Postacchini F (1998) Lumbar disc herniation. Springer, Berlin
- Rauschnig W (1987) Normal and pathological anatomy of the lumbar root canals. *Spine* 12:1008
- Rydevik B, Myers R, Powell H (1989) Pressure increase in the dorsal root ganglion following mechanical compression: closed compartment syndrome in nerve roots. *Spine* 14:564–566
- Saal A, Saal J (1989) Nonoperative treatment of herniated lumbar intervertebral disc. *Spine* 14:431
- Schellinger D, Manz HJ, Vidic B, Patronas NJ, Deveikis JP, Muraki AS, Abdullah DC (1990) Disk fragment migration. *Radiology* 175(3):831–836
- Schmorl G, Junghans H (1968) Die gesunde und die kranke Wirbelsäule in röntgenbild und klinik, 5th edn. Thieme, Stuttgart
- van Roy P (2000) Anatomy of the lumbar canal. In: Gunzburg R, Szpalski M (eds) Lumbar spinal stenosis. Lippincott, Philadelphia, pp 7–25
- Tampie C, Drake J, Callaghan J, McGill S (2007) Progressive disc herniation. *Spine* 32(25):2869–2874
- Willburger R, Ehiosun U, Kuhnen C, Kraemer J, Schmid G (2004) Clinical symptoms in lumbar disc herniations and their correlation to the histological composition of the extruded disc material. *Spine* 29:1–6
- Wiltse LL, Fonseca AS, Amster J, Dimartino P, Ravessoud FA (1993) Relationship of the dura, Batson's plexus, and a fibrovascular membrane lying on the posterior surface of the deep layer of the posterior ligament. An anatomical, radiologic and clinical study. *Spine* 18(8):1030–1043