Location of the Lumbar Dorsal Rami – a Plastination Cross Section Study

MIRCEA-CONSTANTIN SORA[1], PATRICIA FEIL[2], MAXIMILLIAN BINDER[1], PETRU MATUSZ[3]*, HORIA PLES[4]
[1]Plastination Laboratory, Microscopy & Advanced Optical Imaging, Medical University of Vienna, Schwarzspanierstr. 17, Vienna 1090, Austria,
[2]Department of Surgery, Division of Pediatric Surgery, Medical University of Vienna, Währinger Gürtel 18-20, Vienna 1090, Austria,
[3] "Victor Babes" University of Medicine and Pharmacy Timisoara, Department of Anatomy, 2 Eftimie Murgu Sq., 300041Timisoara, Romania,
[4] "Victor Babes" University of Medicine and Pharmacy Timisoara,Department of Neurosurgery, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania.

In order to perform standardized diagnostic and operative techniques the knowledge of the anatomical setup is essential. The main goal of our study was to determine the position of the lumbar dorsal rami of the spinal nerve at the level of the articular process, as well as the position of the surrounding structures. Plastinated slices with 1.5 mm thickness are produced out of five non-pathologic vertebral columns. Subsequently the slices were digitalized and processed anatomically and topographically. The gained data of digitalization offered in the next step the possibility to determine the localization of the spinal nerve and its medial branch as well as to build an anatomical three-dimensional computer model of the region. The plastinated slices produced by E12-technique showed intact and unimpaired anatomical structures and highly transparent tissue. This base was used for the analysis and measurement of structural episodes and for the three-dimensional reconstruction of a lumbar moving segment. The constructed 3D-model displays the morphology of the region in the same quality as the cadaver specimen. Based on our anatomic data, the dorsal ramus of the spinal nerve passes very closely to the neck of the superior articular process at the level of the cranial border of the transverse process. Anatomic characteristics should be kept in mind when denervation techniques of the zygapophyseal joints are performed, thereby reducing the risk of injury to the dorsal ramus.

Keywords: plastination, ramus medialis nervus spinalis, E12 technique, radiofrequency facet denervation

Low back pain is a widespread symptom in an old growing population. The overall lifetime prevalence of back pain exceeds 70% in all industrial countries. The consequences of this pain include loss of 1.4 working days per person / per year; 10-15% of all sickness absence is related to back pain [1]. Back problems are also responsible for 25% of all disabling occupational injuries, with an estimated 12 million people in the workforce with low back impairment, and 5 million with disability on the basis on back problems [2]. There are various reasons for this symptom, but the most common are degenerative processes of the spine. The significance of lumbar zygapophyseal joints as a source of low back pain has been well documented. One of the most effective techniques to treat this pain, by patients that had exhausted conservative treatments such as physical therapy, back braces, NSAIDs and analgesics, is the percutaneous denervation. By applying a probe into the angle between the superior articular and the transverse process the medial branches of the dorsal rami could be denervated through radiofrequency [3, 4] or cryodenervation [5]. After passing the intervertebral foramen the spinal nerve divides into its branches: the anterior ramus, the posterior (dorsal) ramus and the rami communicantes. The dorsal rami (posterior primary) of the spinal nerve divide into medial and lateral branches. Lateral branches supply the longissimus and iliocostalis muscle. The medial branch passes near the articular process and end in the multifidus [6 - 8]. The medial branch runs at the junction of the root of the transverse process with the root of the superior articular process [9]. Along its course the medial branch supplies with two sets of branches the zygapophyseal joints. These articular nerves have no formal name. They are referred to herein as the proximal and distal zygapophyseal nerves, according to their origin from the medial branch [9].

The aim of this study is to locate the position of the lumbar dorsal branch of the spinal nerve and the establishment of a 3D reconstruction model of the motion segment based on plastinated slices. The position of the lumbar dorsal branch was investigated without moving any structures, by using the plastination method in order to find a safe zone to place the cannula for denervation.

Experimental part

One male human spine was used for this study. The spine was selected with exclusions for known pathology and there was no sign of any surgery found. The cadaver age was 65 years. The spine was removed starting at the level of the 12th thoracic vertebra and ending at the level of the second sacral vertebra. The tissue block was frozen at –80°C for one week and afterwards we plastinated it conform to the standard ultra-thin E12 slice plastination method [10-13].

Freeze substitution is the standard dehydration procedure for plastination. Shrinkage is minimized when cold acetone is used. The tissue block is placed into a -25°C freezer and then submerged in cold (-25°C) technical quality 100% acetone for dehydration. Degreasing was

* *email: matusz@umft.ro; Tel.: 0729 016260*

performed by using methylene chloride. Impregnation was performed using the following epoxy (Biodur E12, Heidelberg, Germany) mixture: E12 (resin)/ E6 (hardener)/ E600 (accelerator). When impregnation is completed, the tissue block is removed from the vacuum chamber. A mold is constructed of Styrofoam and lined with polyethylene foil and the tissue block inserted. The mold containing the impregnated specimen and resin-mix is placed in a 65°C oven for four days to harden the resin-mix. The tissue/resin block is cooled to room temperature and the mold removed. A contact point diamond blade saw, Exact 310 CP (Exact Apparatebau GmbH, Norderstedt, Germany) is used for cutting the block. The hardened E12 block was cut into 1.5 ± 0.26 mm. Finally the caudal surfaces of the plastinated slices were scanned into a computer using an EPSON GT-10000+ Color Image Scanner. In every scan we included a ruler as a calibration marker. For measurements we used the UTHSCSA IMAGE TOOL v.2.0 for Windows software (The University of Texas Health Science Center in San Antonio). Each measurement was done three times and an average value was calculated. The measurements of the selected structures were taken from the borders of these (fig. 1). Statistics were done with the SPSS 11.0 for Windows software. Descriptive statistic was performed to calculate the means and standard deviations. Once scanned, these images (jpeg format) were loaded into WinSURF (SURFdriver 4.0; http://www.surfdriver.com) and traced from the monitor [14, 15]. Once all contours were traced, the lumbar motion segment was reconstructed and visualized. After reconstruction, the measuring tool available in WinSURF was used to record height, width, and depth measurements from the model.

Results and discussions

The thin 1.5 mm slices produced were transparent and hard, with good optical qualities. The finished E12 slices provided excellent anatomic detail down to the microscopic level (figs. 2, 3). The measured sites onto the transparent plastinated slices were performed at the level of the cranial border of the transverse process and at the level of the intervertebral disc.

Data of the planimetric measurements obtained through plastination of the lumbar spine are shown in tables 1 and 2. The shrinkage rate of the slices was calculated having a range from 2.95 to 4.30% and the measured values were adjusted accordingly. The anatomical structures of the lumbar region were easily identified and the borders were traced rapidly and reliably.

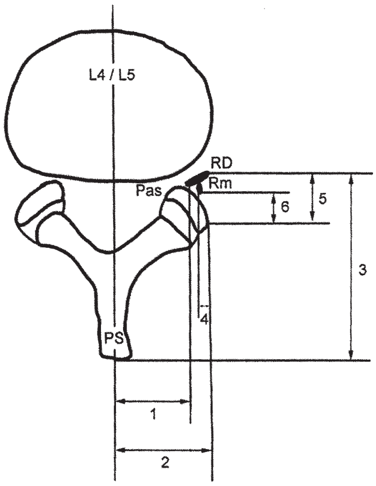

Fig. 1. Diagram indicating the sites at which the listed measurements were taken at the level of the intervertebral disc.
1 = Distance between the spinous process and the dorsal ramus (PS – RD), 2 = Distance between the spinous process and the superior articular process (PS – Pas), 3 = Distance between the spinous process and the dorsal ramus (PS – RD), 4 = Distance between the superior articular process and medial branch in lateral direction (Pas – Rm), 5 = Distance between the superior articular process and the dorsal ramus (Pas – RD), 6 = Distance between the superior articular process and medial branch in ventral direction (Pas – Rm)

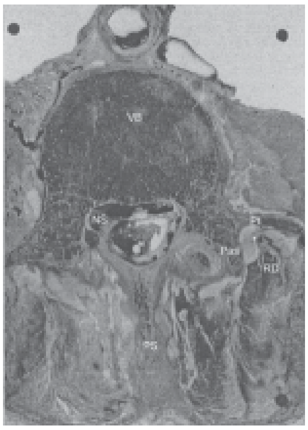

Fig. 2. Cross section of the spine at the level of the lumbar transverse process, where: NS: Nervus spinalis; RD: Dorsal ramus; Pas: Superior articular process; PS: Processus spinosus; Pt: Transverse process; VB: Vertebral body.

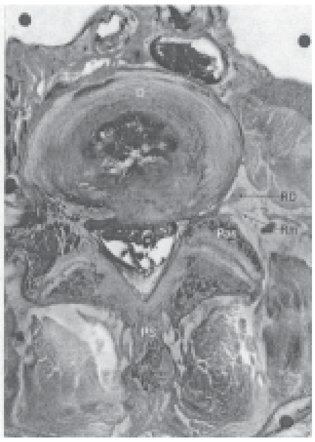

Fig. 3. Cross section of the spine at the level of the intervertebral disc, where: D: Intervertebral disc; RD: Dorsal ramus; Rm: medial branch; Pas: Superior articular process; PS: Processus spinosusm

Table 1
MEASUREMENTS OF THE DISTANCES AT THE LEVEL OF THE CRANIAL SIDE OF THE TRANSVERSE PROCESS

Distances	Abbreviations	Mean ± SD (mm)	Range (mm)
Distance between the spinous process and the superior articular process	PS - Pas	25.03 ± 0.12	24.95 to 25.13
Distance between the superior articular process and the dorsal ramus	Pas - RD	5.01 ± 0.11	4.84 to 5.05
Distance between the dorsal ramus and the tip of the transverse process	RD - Pt	8.14± 0.21	8.06 to 8.23
Distance between the spinous process and dorsal ramus	PS - RD	33.25 ± 2.1	29.08 to 25.29
Distance between the superior articular process and the dorsal ramus	Pas - RD	9.43 ± 1.12	7.21 to 12.54
Distance between the tip of the transverse process and the dorsal ramus	Pt – RD	9.95 ± 0.26	9.67 to 10.18

Distances	Abbreviations	Mean ± SD (mm)	Range (mm)
Distance between the spinous process and the dorsal ramus	PS - RD	19.49 ± 0.14	19.39 to 19.66
Distance between the spinous process and the superior articular process	PS - Pas	22.15 ± 0.4	21.95 to 22.46
Distance between the spinous process and the dorsal ramus	PS - RD	44.69 ± 0.21	44.32 to 45.17
Distance between the superior articular process and medial branch in lateral direction	Pas - Rm	2.21 ± 0.22	2.04 to 2.46
Distance between the superior articular process and the dorsal ramus	Pas - RD	13.34 ± 0.12	13.29 to 13.39
Distance between the superior articular process and medial branch in ventral direction	Pas – Rm	8.51 ± 0.43	8.05 to 8.91

Table 2
MEASUREMENTS OF THE DISTANCES AT THE LEVEL OF THE INTERVERTEBRAL DISC

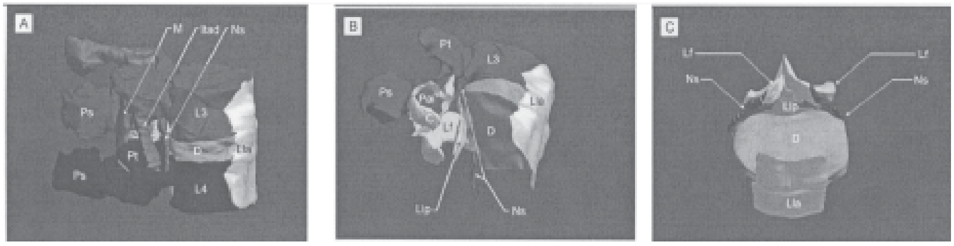

Fig. 4. 3D reconstruction of the motion segment by using the plastinated slices. A – Right lateral view. B – Right inferior-lateral view. C – Antero-superior view. One can notice- Ps: Processus spinosus; Pt: Processus transversus; Pai: Processus articularis inferior; M: Musculus multifidus; Itad: Musculus intertransversus anterior dexter; Ns: Nervus spinalis; D: Intervertebral disc; Lla: Ligamentum longitudinale anterior; Llp: Ligamentum longitudinale posterior; Lf: Ligamentum flavum; C: Capsula articularis articulatio zygapophysialis

The plastinated slices distinctively displayed nerves, muscles, vessels, bones of the lumbar region. Once scanned and loaded into WinSURF, automatic edge detection was used to quickly collect tissue borders or contours. The 3D motion segment model generated displays a morphology that corresponds qualitatively to the actual cadaver specimen (fig. 4). The reconstructed images were of high quality; especially the spatial positions and complicated adjacent relationships of various lumbar structures shown in direct viewing as displayed in the background of the bony substance.

Pain emerging from the lumbar facet joints is a common cause of low back pain in the adult population. The first to describe this syndrome in 1911 was Golthwaite and Ghormley was the first to define the term “facet syndrome” in 1933 [16, 17]. The prevalence of this pain syndrome varies in different studies from less than 5% to 90%, being dependent on diagnostic criteria and selection methods [18-23]. The complications and side effects of radiofrequent denervation techniques have been previously described by Kornick et al. The most common occurring complications were transient, localized burning pain and self-limiting back pain, each occurring with a frequency of 2.5% per procedure [24]. Ogsbury et al., and Cohen and Raja described in their studies local burns and motor weakness as a possible complication [25, 26]. In order to decrease the prevalence rate of complication a better location of the dorsal ramus of the spinal nerve is desired. Most of the studies which investigated the position of the dorsal ramus of the spinal nerve were done through dissection [27-29]. During this procedure the investigated structure could have been displaced from their original position through manipulation during dissection.

In the recent past, the E-12 plastination method was used as a research tool, not only for slice plastination studies with the development of three-dimensional reconstructions, but also for the preservation and the representation of human or animal specimen for education and demonstration. In contrast to anatomic preparation, the structures and spatial relationships of the tissues were not altered by plastination. The plastinated body slices can provide a unique insight into the human body. It is possible to show the smallest structures, e.g. capsule, ligaments, fascia, nerves, and vessels, and their correlation and composition to the neighboring structures in great detail. Moreover, with the help of the plastinated specimen anatomic-topographic structures can be measured, and based on the results conclusions can be drawn for surgical purposes. By using the plastination method morphological measurements can be performed easily and accurately [30] since tissues are maintained in a non-collapsed and non-dislocated state. By slicing the motion segments in 1.5 mm steps, exact information about the dorsal ramus of the spinal nerve are obtained more accurately than by careful dissection of this structure. Due to our measurements the ramus dorsalis is predicted to be 9.43 ± 1.12 mm anterior and 5.01 ± 0.11 mm lateral to the neck of the superior articular process at the level of the cranial border of the transverse process. At the same level the ramus dorsalis is located 8.14 ± 0.21 mm medial to the tip of the transverse process and 33.25 ± 2.12 mm anterior to the tip of the spinous process. Passing caudally and backwards the dorsal ramus dorsalis is located at the level of the intervertebral disc 13.34 ± 0.12 mm anterior to the superior articular process. At the same level the medial branch of the ramus dorsalis is located here 8.52 ± 0.43 mm anterior and 2.21 ± 0.22 mm medial to the lateral border of the superior articular process.

An additional possibility in viewing the lumbar motion segment is the 3D reconstruction by using the plastinated slices (fig. 4A, 4B and 4C). The capability of reconstructing individual and combined images of lumbar motion segment structures, viewing them from all surgical angles, and allowing for accurate measurement of their spatial relationships provides an important and useful research tool. The reconstructed model can also be used for residency education, planning an unusual surgery, and for the development of new surgical approaches. The 3D reconstruction presented here allows interpretation of the sectional images in their 3D context and thus improves understanding of the radiologic sections [31]. Computer models and animations of anatomical features are becoming increasingly attractive as a means to communicate complex spatial relationships and concepts effectively [32]. Although many educational animations are based on artistic renderings, more recent applications are using virtual representations derived from actual cadaveric material [33, 34]. A logical advantage of these models is that they provide a greater sense of realism, which increases the amount of perceived information. One can envision anatomy lectures consisting of only 3D models without 2D images [35]. The production of plastinated slices and collecting data for digitalization needs a lot of time and effort but offers in return an excellent and high-resolution base for the analysis and reconstruction of finest structures. The 3D-model enables displaying individual structures freely. Thus the reconstruction offers consequent advantages in the conveyance of complex anatomic-topographical correlations of the region that can be utilized for university education, for preparation of surgical interventions and for the development of new surgical techniques.

Conclusions

Based on our anatomic data, the dorsal ramus of the spinal nerve passes very closely to the neck of the superior articular process at the level of the cranial border of the transverse process. Anatomic characteristics should be kept in mind when denervation techniques of the zygapophyseal joints are performed, thereby reducing the risk of injury to the dorsal ramus.

References

1. BOACHIE-ADJEI, O., Evaluation of the patient with low back pain. Postgraduate Medicine., 1988, 84(3):110-119.
2. WALL, PD., MELZACK, R., Textbook of Pain, 3rd ed. Churchill Livingstone, New York., 1994, pp.441-442.
3. BOKDUK, N., LONG, DM., Percutaneous lumbar medial branch neurotomy: a modification of facet denervation. *Spine.,* 1980, 5(2):193-200.
4. CHOU, R., ATLAS, SJ., STANOS, SP., ROSENQUIST, RW., Nonsurgical interventional therapies for low back pain: a review of the evidence for an american pain society clinical pratice guideline. Spine., 2009, 34(10):1078-1093.
5. BIRKENMAIER, C., VEIHELMANN, A., TROUILLIER, H., HAUSDORF, J., DEVENS, C., WEGENER, B., JANSSON, V., von SCHULZE PELLENGAHR, C., Percutaneous cryodenervation of lumbar facet joints: a prospective clinical trial. Int Orthop., 2007, 31(4):525-530.
6. STANDRING, S., ELLIS, H., BERKOVITZ, BKB., GRAY, H. (eds.), Gray's Anatomy: The Anatomical Basis of Clinical Practice, 40th Ed. Edinburgh: Elsevier Churchill Livingstone., 2008, p.756.
7. PELLERIN, M., KIMBALL, Z., TUBBS, RS., NGUYEN, S., MATUSZ, P., COHEN-GADOL, AA., LOUKAS, M., The prefixed and postfixed brachial plexus: a review with surgical implications. Surg Radiol Anat., 2010, 32(3):251-260.
8. LOUKAS, M., ABEL, N., TUBBS, RS., MATUSZ, P., ZURADA, A., COHEN-GADOL, AA., Neural interconnections between the nerves of the upper limb and surgical implications. J Neurosurg., 2011, 114(1):225-235.
9. BOGDUK, N., LONG, DM., The anatomy of the so-called "articular nerves" and their relationship to facet denervation in the treatment of low back pain. J Neurosurg., 1979, 51(2):172-177.
10. SORA, MC., GENSER-STROBL, B., RADU, J., LOZANOFF, S., Three-dimensional reconstruction of the ankle by means of ultrathin slice plastination. Clin Anat., 2007, 20(2):196-200.
11. SORA, MC., MATUSZ, P., General considerations regarding the thin slice plastination technique. Clin Anat., 2010, 23(6):734-736.
12. SORA, MC., MATUSZ, P., Study of the vascular architecture of bones using the plastination technique. Clin Anat., 2012, 25(2):258-259.
13. SORA, MC., JILAVU, R., MATUSZ, P., Computer aided three-dimensional reconstruction and modeling of the pelvis, by using plastinated cross sections, as a powerful tool for morphological investigations. Surg Radiol Anat., 2012, 34(8):731-736.
14. LOZANOFF, S., Accuracy and precision of computerized models of the anterior cranial base in young mice. Anat Rec., 1992, 234(4):618-624.
15. MOODY, D., LOZANOFF, S., SURFdriver a practical computer program for generating three-dimensional models of anatomical structures using a PowerMac. Clin Anat., 1998, 11(2):133.
16. GOLDTHWAITE, J., The lumbosacral articulation: an explanation of many cases of lumbago, sciatica, and paraplegia. Boston Med Surg J., 1911, 365–372.
17. GHORMLEY R., Low back pain with special reference to the articular facets, with presentation of an operative procedure. JAMA., 1933, 101(23):1773–1777.
18. DESTOUET, JM., GILULA, LA., MURPHY, WA., MONSEES, B., Lumbar facet joint injection: indication, technique, clinical correlation, and preliminary results. Radiology., 1982,145(2):321–325.
19. LAU, LS., LITTLEJOHN, GO., MILLER, MH., Clinical evaluation of intra-articular injections for lumbar facet joint pain. Med J Aust., 1985,143(12-13):563–565.
20. LEWINNEK, GE., WARFIELD, CA., Facet joint degeneration as a cause of low back pain. Clin Orthop Relat Res., 1986, 213:216–222.
21. MORAN, R., O'CONNELL, D., WALSH, MG., The diagnostic value of facet joint injections. Spine., 1988,13(12):1407–1410.
22. MURTAGH, FR., Computed tomography and fluoroscopy guided anesthesia and steroid injection in facet syndrome. Spine., 1988,13(6):686–689.
23. LONG DM, BENDEBBA M, TORGERSON WS, et al. Persistent back pain and sciatica in the United States: patient characteristics. J Spinal Disord., 1996, 9(1):40–58.
24. KORNICK, C., KRAMARICH, SS., LAMER, TJ., TODD SITZMAN, B., Complications of lumbar facet radiofrequency denervation. Spine., 2004, 29, (12):1352–1354.
25. OGSBURY, JS. 3RD, SIMON, RH., LEHMAN, RA., Facet "denervation" in the treatment of low back syndrome. Pain., 1977, 3(3):257–263.
26. COHEN, SP., RAJA, SN., Pathogenesis, diagnosis, and treatment of lumbar zygapophysial (facet) joint pain. Anesthesiology., 2007, 106(3):591–614.
27. BOGDUK, N., WILSON, AS., TYNAN, W., The human lumbar dorsal rami. J Anat., 1982, 134(Pt 2):383–397.
28. BOGDUK, N., The innervation of the lumbar spine. Spine., 1983, 8(3):286–293.
29. LAU, P., MERCER, S., GOVIND, J., BOGDUK, N., The surgical anatomy of lumbar medial branch neurotomy (facet denervation). Pain Med., 2004, 5(3):289-298.
30. SORA, MC., GENSER-STROBL, B., The sectional anatomy of the carpal tunnel and its related neurovascular structures studied by using plastination. Eur J Neurol., 2005, 12(5):380-384.
31. HÖHNE, KH., PFLESSER, B., POMMERT, A., RIEMER, M., SCHIEMANN, T., SCHUBERT, R., TIEDE, U., A new representation of knowledge concerning human anatomy and function. Nature Med., 1995, 1(6):506-511.
32. DEV, P., MONTGOMERY, K., SENGER, S., HEINRICHS, WL., SRIVASTAVA, S., WALDRON, K ., Simulated medical learning environments on the internet. J Amer Med Informatics Assoc., 2002, 9(5):437-447
33. NEIDER GL, SCOTT JN, ANDERSON MD., Using QuickTime virtual reality objects in computer-assisted instruction of gross anatomy: Yorick the VR Skull. Clin Anat., 2000, 13(4):287-293.
34. LOZANOFF, S., LOZANOFF, BK., SORA, MC., ROSENHEIMER, J., KEEP, MF., TREGEAR, J., SALAND, L., JACOBS, J., SAIKI, S., ALVERSON, D., Anatomy and the access grid: exploiting plastinated brain sections for use in distributed medical education. Anat Rec B New Anat., 2003, 270(1):30-37.
35. TRELEASE R B., Anatomical informatics: Millenial perspectives on a newer frontier. Anat Rec., 2002, 269, (5):224-235

Manuscript received: 3.10.2014