Analysis of the Posterior Ramus of the Lumbar Spinal Nerve

The Structure of the Posterior Ramus of the Spinal Nerve

Toshiyuki Saito, M.D., Ph.D.,* Hanno Steinke, Ph.D.,† Takayoshi Miyaki, V.M.D., Ph.D.,‡ Shiro Nawa, M.S.,§ Kanae Umemoto, B.S.,§ Kunihisa Miyakawa, M.D.¶
Norimitsu Wakao, M.D., Ph.D.,# Ken Asamoto, M.D., Ph.D.,** Takashi Nakano, M.D., Ph.D.**

ABSTRACT

Background: Knowledge of neural anatomy is fundamental for safe, efficacious use of regional anesthesia. Spinal column procedures, such as a facet joint block, require an accurate understanding of neural pathways relative to anatomic structure. Since Bogduk’s report it has been known that human lumbar posterior ramus of the spinal nerve (PRSN) comprises three, equally sized primary branches. However, inconsistencies and controversy remain over the exact locations and pathways of the peripheral portions of the PRSN branches. In this study, the authors investigated the detailed anatomy of the human PRSN.

Methods: The authors performed ventral dissection in seven cadavers to determine the layout of the PRSN between T10 and L4 spinal segments. They captured three-dimensional images with a laser scanner. For fine detail analysis, specimens from another cadaver were subjected to a modified Spalteholz technique to render all nonnerve tissue transparent. Computer graphics were used to create a three-dimensional structural model.

Results: All three PRSN branches emanated from an ipsilateral origin and passed posterior to the transverse process. The medial PRSN branch consistently passed between the mammillary and accessory processes under the mammilloaccessory ligament. The intermediate branch passed between the longissimus and iliocostalis muscles and extended to the skin. The lateral branch traveled far lateral from the origin.

Conclusions: The authors created a 3D model of the PRSN in the lumbar segment, which may be useful for planning surgical approaches to dorsal areas of the vertebral column. In addition, this knowledge may improve the accuracy of procedures involving the spinal column, particularly radiofrequency neurolysis of the facet joint.

What We Already Know about This Topic

• The posterior ramus of the spinal nerve is often targeted in the treatment of pain, yet there is controversy regarding its anatomy.

What This Article Tells Us That Is New

• Using dissection and three-dimensional reconstruction in seven cadavers, the detailed anatomy of the posterior ramus of the spinal nerve in the lumbar space is described.

Knowledge of the anatomy of the posterior ramus of the spinal nerve (PRSN) is essential for anesthetists to safely and successfully perform a facet joint block. In the major textbooks of anatomy, the PRSN is described as having two major initial branches: the lateral branch and the medial branch.1-4 In some textbooks, however, the description of PRSN anatomy is less clear.5-11 This lack of attention reflects the traditional view of anatomists that these nerves have no clinical significance. However, during the last 30 yr, increasing clinical attention has been paid to these nerves, both in the diagnosis and treatment of low back pain and in the understanding of disability after spinal surgery. Anatomy textbooks have not kept pace with this interest.

In 1982, Bogduk et al.12 reported that the lumbar dorsal rami formed not two but three branches: a medial, a lateral, and an intermediate branch. This observation has not permeated textbooks of anatomy, although ironically some texts describe two branches but illustrate three.9,10 At present there are some textbooks that include confusing descriptions of the PRSN.5,10 Because the anatomy of the PRSN is fundamental for anesthesia practice, we studied the disposition of the PRSN in thoracic and lumbar segments. In a previous article, we confirmed and extended Bogduk’s report by finding...
three branches of the PRSN in both the lumbar and thoracic segments,13 and we proposed the existence of three muscular units in the back of the body each supplied by a separate branch of the PRSN.14 We consider the transverse, accessory, and mammillary processes of the vertebral body and the three branches of PRSN resulting in three muscle–nerve compartments: the multifidus, longissimus, and the iliocostalis. On the basis of these data, we know that the human PRSN divides into three branches in both the lumbar and thoracic segments. What remains unknown is the peripheral course of these three branches. The current study investigates their topography by dissecting and tracking them in scan of cadaveric specimens.

Materials and Methods

We studied the PRSN in eight donated human cadavers at the Aichi Medical University Department of Anatomy. Of these eight cadavers, seven were included in the dissection study, and one was used for study by transparent specimen. Aichi Medical University has its Institutional Review Board at Aichi Medical University, Nagakute City, Aichi Prefecture, Japan.

All donors gave directed consent that their cadavers were to be used in teaching or for research projects at the Institute for Anatomy.

Study of Formaldehyde-fixed Cadavers

The seven cadavers were fixed in a 3% formaldehyde solution. The thoracolumbar vertebral column and the surrounding muscles were dissected from each body. We chose the ventral approach as described by Bogduk et al.12 to obtain a detailed image of the total nerve layout but modified it according to the study by Saito et al.13 The abdominal contents were first removed. The vertebral bodies were then separated from their pedicles and lifted away from the spinal canal. This exposed the neural elements of the spinal canal and their relationship to the pedicles, intervertebral foramina, and posterior elements of the spine for detailed inspection. Figure 1A shows the stage where half of the vertebral body was just removed to visualize the main stem of the spinal nerve (SN) of one side. Using this procedure, each SN and the main ramifications of its posterior ramus were identified easily. The ventral aspects of the spinal canal were opened to visualize the dural sac and the coverages to the SNs, whose branches could be easily followed. The pedicle of the vertebral arch was subsequently removed with the corresponding transverse process after examining them (fig. 1B, pink and blue parts). Nerves were then photographed, including the ventral rami, and the ramifications of the dorsal rami were tracked to the erector spinae divisions and to the skin. Each PRSN was ultimately dissected from its origin, and every branch was followed for as long as possible.

Three-dimensional data were acquired with the ERGOscan-laser scanner (Creaform, Québec, Canada) and CATIA software (Dassault Systèmes, Vélizy-Villacoublay Cedex, France) (fig. 2). The data were further processed with 3D computer graphic software (Light Wave 3D, NewTek Inc., San Antonio, TX). We scanned the region of PRSN by the ERGOscan-laser scanner after dissecting PRSN. The laser scanner gives a 3D image of the structure as the distance from the scanner to the exposed surface of PRSN. After acquiring the surface structure, the PRSN was isolated from the whole view with the CATIA software by erasing the polygons of the data, which represented surrounding tissue. A large number of measurements were required to record a 3D image of the PRSN structure. Then, we further dissected lumbar vertebrae. The shapes of the vertebrae were also scanned. We calibrated the zero point of the laser scanner.
Capture of 3D data with laser scans of the spinal nerve and of the posterior ramus of the spinal nerve. The bodies of the cadavers were put on the three-dimensional (3D) axis. Data were processed with the 3D software. The device: ERGOScan-Laser Scanner (Creaform, Levis, Canada) scans the surface of the material. Data are stored as the distance from the device to the surface of the structure.

To interpret the segmental data by the laser scanner, we also made sketches of how the SN and PRSN were situated in the vertebral structures of each segment.

Study of Transparent Specimen

We produced 2-cm thick slices of transparent specimens from the blocks of lumbar vertebra together with the surrounding connective tissue and stained nerves, using an adaptation of the Spalteholz technique. Blocks of lumbar vertebra together with the surrounding muscle intact were dehydrated in acetone at −25°C, followed by vacuum extraction of the acetone and impregnation with oil. The oil rendered the muscles transparent, when the oil had the same refraction index as the muscles (n = 1.37), but the nerves retained a higher refractive index (n = 1.40) and, therefore, became visible. These findings in the transparent specimen helped us to refine the 3D anatomy of the PRSN in the erector spinae.

Creation of the Whole 3D Data

The structure of the PRSN was visualized in a computer by graphic design in a 3D manner. The fragments of laser scanner data in the CATIA software were transferred to Light Wave 3D software. The fragments of data from each individual about PRSN and the lumbar vertebrae were digitally interconnected to re-create the whole anatomy of PRSN in the lumbar segments while referring to the information obtained in the sketch and the transparent specimen. The 3D coordinates data of PRSN and the vertebrae from seven cadavers were averaged, because the same points of the isolated structure were merged by averaging operation. The shape of the PRSN was colored yellow, and the vertebrae were colored white.

Results

Dissection

After the removal of the vertebral bodies using the ventral approach, we were able to open the vertebral canal to display the meninges covering the ventral side of the spinal cord and of the SNs (fig. 1A). After the junction of the ventral and dorsal roots, each SN divides into one ventral and one dorsal ramus. The ventral approach to the SN revealed the origin and major branching of the PRSN without injuring the PRSN.

Findings of the PRSN

Figure 3 shows the origin of the PRSN from the second lumbar nerve. It forms the vertical pillar of a T whose horizontal arms are the SN stem and the anterior ramus. From this finding, we infer that the PRSN is a branch, whereas the SN and the anterior ramus of the SN form a continuous stem. We identified the three major branches originating from the PRSN, thus confirming the findings of Bogduk et al. The lateral branch entered the iliocostalis. The two other branches cover the posterior side of the vertebral column. The intermediate branch is related to the longissimus/multifidus system and to the skin. The medial branch reached the area near the spinous process and the facet joints, as has been described by Bogduk et al. In the current study, we observed that the medial branch extended to the subjacent segments.

Every branch of the posterior ramus was followed and traced from its origin until it became invisible. At each stage of dissection, we scanned the layout of the PRSN by the Laser-Scanner. Because the Laser-Scanner measured the distance from the scanner to the surface of the material, we
isolated the layout of the periphery of the PRSN to store the data. The data of PRSN obtained by the Laser-Scanner were stored in the CATIA software.

We created transparent specimens of the region of interest for satisfactory analysis. Vertebral bone, fat tissue, and most of the muscle substance were made transparent. The material of the nerve tissue could be recognized by its faint colors and reflections. Because connective tissue and muscles remained intact in the slices, we could use this information to make refinements regarding the nerve patterns. Figure 4 shows the layout of the periphery of the three branches of the PRSN at L1 vertebra. It is clear how the three branches run in the erector spinae. In figure 4A, the three branches of the right PRSN at T12 SN can be seen. In the periphery of the medial branch, the branch is located posterior to the vertebral arch (arrow B). The intermediate (arrow C) and the lateral (arrow D) are going to the compartment of longissimus and of iliocostalis. Figure 4B shows the SN and PRSN of L1 segment. We can also see the periphery of the medial branch from T12 segment (B). Figure 4D shows the branching of the PRSN of the right L1 SN. The medial branch (B) is turning around the superior articular process of L2 vertebra on the bony floor between the mammillary and the accessory processes.

With the sketch, by the connection of the fragmented data by the Laser-Scanner, and with the interpretation of the transparent specimen, a view of the 3D anatomy of the PRSN was rendered by means of a computer graphic drawing program (fig. 5A and B).

**Discussion**

It is traditionally taught that the PRSN divides into two branches, the medial and lateral branches. However, in 1982, Bogduk et al. reported that there was triple ramification of the PRSN between the L1 and L4 segments in humans, and that L5 had a different layout from the formerly described duplication. Before this report, Bogduk et al. had already reported similar triplication in some animals. In our previous studies, we confirmed this observation in nonhuman mammals and humans and extended it to the thoracic segments. We hypothesize that the reason for the discrepancies is the dissection by the traditional mode via the dorsal approach. Such an approach breaks the nerve layout before the dissection can reach the

Fig. 4. Transparent specimens produced using the modified Spalteholz technique: Cranial views of a horizontal section at L1 (A–C) and at L2 (D) vertebrae. (A) Three divisions of the left PRSN, which itself arises from the SN, are seen in this section. The green arrow D: a section of the lateral branch reaching the lateral compartment. The red arrow C: sections of the intermediate branch of PRSN reaching the intermediate compartment. The blue arrows B: sections of the medial branch of the PRSN reaching the medial compartment. The medial nerve was transected where it has just crossed the lower facet joint. The dashed line; the midline. The arrow marked “Ventral” indicates the ventral direction. The level of the horizontal section is presented in (C). (B) The disposition of the nerves at lower horizontal transection of L1. The arrow marked “A” indicates the anterior branch. The arrow P: PRSN. (C) The levels of the horizontal section in A and B at the level of L1 vertebra. (D) The anatomy of the PRSN of the right L1 SN. P: PRSN at the L1. D: the lateral branch. C: the intermediate branch. B: the medial branch. The dashed line; the midline. Ventral with arrow; the ventral direction. PRSN = posterior ramus of the spinal nerve; SN = spinal nerve; SP = the spinous process; Sap = the superior articular process of the L2 vertebra; Iap = the inferior articular process of the L1 vertebra.
proximal ramification. We believe it is most likely that, previously, the intermediate branches have been regarded simply as muscular branches of the lateral branches. In addition, previous anatomists might have preferred to study the ventral branch of SN, and focused less on PRSN, thereby not paying attention to its detailed anatomy. The current study confirms that the lumbar PRSNs each form three branches. These branches are each systematically related to a muscle and to the osseous elements from which these muscles arise. The medial branches enter the multifidus muscle, which arises from the lumbar mammillary processes. The intermediate branches enter the longissimus muscle, which arises from the lumbar accessory processes. The lateral branches enter the iliocostalis, which arises from the lumbar transverse processes. By confirming the observations of Bogduk et al., the current study calls for textbooks of anatomy to be updated in the way that they portray the lumbar PRSN. This anatomy does not lack clinical relevance. The variations seen in the presentation of the PRSN in textbook figures should be corrected.

Anatomy of PRSN

Figure 5A and B shows two 3D images resulting from the digital visualization based on our dissection work. From the stem of PRSN, three branches originate. All branches pass the region behind the ipsilateral transverse process.

The Lateral Branch

The lateral branch of PRSN is related to the iliocostalis. After it originated from the stem of PRSN at the superior side of the ipsilateral transverse process of the lower vertebra, it goes dorsally and laterally. The branch crosses the back of the transverse process. In regard to the periphery, the branch goes to the area far lateral to the spine. The lateral branch passed through the iliocostalis and emerged through the dorsolateral edge of the muscle to become the cutaneous nerve. It is known that the cutaneous branches of the lateral branch of the first to third lumbar segments become the superior clunial nerves.

The Medial Branch

The medial branch originates from the stem of the PRSN on the superior side of the transverse process of the lower vertebra as the other two branches do. After the origin, the medial branch takes a posteromedial direction. After passing through the area posterior to the origin of the transverse process, the branch always passes on the bony floor under the mammilloaccessory ligament. Then, it delivers branches to the upper and lower facet joints before providing branches to the multifidus muscle. The mammilloaccessory ligament is a collagen-rich part of the origin of the longissimus and iliocostalis muscles. The ligament covers, fixes, and protects the medial branch as a strong bundle, which contains the medial branch in a fat tissue cover. The medial branch supplies motor fibers to the multifidus muscle while it runs along the spinous process and interspinous ligament in the multifidus muscle. The extension of the main stem of the medial branch produces fine branches in the subcutaneous region to supply the cutaneous region near the midline. The close region of the skin to the midline is bilateral supply.

The Intermediate Branch

The intermediate branch originates from the stem of PRSN on the superior side of the transverse process of the lower vertebra as do the other two branches. After its origin, the course of the branch was always between the courses of medial and lateral branches. The intermediate branch has a long trunk between the longissimus and the iliocostalis before it reaches the skin. There, it sends a variable pattern of branches supplying a wide cutaneous area lateral to that innervated by the medial branch (fig. 5A, blue arrow).
Clinical Relevance and Radiofrequency Neurolysis of the Facet Joint Pain

The global relevance of this anatomy pertains to retraction of the back muscles during the conduct of spinal surgery. At their proximal ends, the PRSNs and their branches are fixed. Retracting the back muscles laterally to gain access to the vertebral column and its contents risks stretching these nerves, and thereby injuring them. 36

A more focal clinical relevance pertains to the conduct of percutaneous radiofrequency neurotomy of the medial branch. 36-38 The objective of this procedure is to denervate the facet joint innervated by the targeted nerve. 39 The block or neurolysis must be performed before the medial branch delivers small branches to the upper and lower facet joints. The medial branch lies consistently between the accessory and the mammillary processes in the lumbar region; the neurolytic cannula should direct to the origin of the transverse and the superior articular process. Recently, Bogduk reported how the tip of the neurolytic cannula is best positioned to perform neurolysis where the medial branch nears the mammilloaccessory ligament. 40 The direction of the cannula is better set parallel to the medial branch, because the cannula denervates the tissue around the needle, not at the tip of the needle. Inserting the electrode too far from the origin of the transverse process risks capturing the intermediate branch and perhaps even the lateral branch. Coagulation of the medial branch denervates the multifidus muscles, because the medial branch supplies motor fiber to the multifidus muscle while it delivers sensory fibers to the facet joint. 41 However, a clinical study found that coagulation of the medial branch produced no detectable disability. 42 Despite extensive denervation of the multifidus, the patients had no symptoms and remained relieved of their back pain. 43

Limitations of the Study

The study has some limitations. First, the final 3D model was a composite, with coordinate locations based on averaged coordinates from the seven cadavers. Although some uncertainties in the data occurred in individual cadavers, in general, the data from other cadavers were sufficient to support the final composite model. However, the composite model may retain some points of uncertainty. Second, the existence of the intermediate branch has been reported rather recently. The anatomy of the branch is under study on many phases. The block or neurolysis delivered sensory fibers to the facet joint.

In conclusion, we created a three-dimensional model of the PRSN in the lumbar segments. We reconfirmed Bogduk’s report that three branches emanated from the main stem of the posterior ramus. This 3D model may be useful for planning surgical approaches to the dorsal areas of the vertebral column, and it may facilitate the success of radiofrequency neurolysis of the facet joint.

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References

ANESTHESIOLOGY REFLECTIONS FROM THE WOOD LIBRARY-MUSEUM

After Dosing and Dozing: A Photoportrait of James Matthews Duncan

After self-experimenting with chloroform on November 4, 1847, three Scotsmen collapsed: Professor James Young Simpson and his colleagues George S. Keith and James Matthews Duncan (1826–1890, portrayed above against a Duncan clan tartan). According to a surgical colleague, Simpson awoke from this first self-chloroforming to discover “Duncan beneath a chair; his jaw dropped, his eyes staring, his head bent half under him; quite unconscious, and snoring in a most determined and alarming manner.” A loyal assistant to Simpson, “Matthews” Duncan supported his wife and their 13 children with his successful obstetric practice. After being passed over to fill Simpson’s vacant chair at the University of Edinburgh, Duncan revolutionized obstetrical education at London’s St. Bartholomew’s Hospital. When Duncan died, Queen Victoria telegraphed the Widow Duncan that the “country and Europe have lost one of their most distinguished men, and one who will be sorely missed.” (Copyright © the American Society of Anesthesiologists, Inc.)

George S. Bause, M.D., M.P.H., Honorary Curator, ASA’s Wood Library-Museum of Anesthesiology, Park Ridge, Illinois, and Clinical Associate Professor, Case Western Reserve University, Cleveland, Ohio. UJYC@aol.com.

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