



Third primary branch of the posterior ramus of the spinal nerve at the thoracolumbar region: a cadaveric study

Toshiyuki Saito¹ · Hanno Steinke² · Niels Hammer^{3,4,5} · Zhong-Lian Li¹ · Shinichi Kawata¹ · Muneyoshi Yasuda⁶ · Norimitsu Wakao⁷ · Hideki Koyasu⁸ · Masahiro Itoh¹

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Abstract

Purpose Spinal column procedures require an accurate understanding of neural pathways relative to the anatomic structure. Since Bogduk's report in 1982, it has been known that the human lumbar posterior ramus of the spinal nerve (PRSN) comprise not two but three primary branches at least in some lumbar segments. The purpose of the current study was to examine the existence of the three primary branches in the thoracic and lumbar segments.

Methods In this study, we investigated the anatomy of the human PRSN in the thoracic and lumbar segments. Ventral dissection was performed in eight cadavers to determine the anatomy of the PRSN between T1 and L5.

Results At the distal end of a given PRSN, the PRSN divided into three primary branches—medial, intermediate and lateral—in 196 out of 272 segments in the thoracic and lumbar regions in eight cadavers. The medial branch supplied the spinalis compartment, and reached the skin. The lateral branch supplied the iliocostalis muscle compartment, and reached skin. The intermediate branch supplied the longissimus muscle and the area between the medial and the lateral branch, which was a seemingly shorter branch.

Conclusion The triplication of the primary branch of the PRSN is considered not uncommon. The third branch should be recognized in the literature and in textbooks.

Keywords Thoracic spinal nerve · Lumbar spinal nerve · Posterior ramus · Intermediate branch · Ventral approach · 3D scanner

Abbreviations

ARSN	Anterior ramus of the spinal nerve
IB	Intermediate branch
LB	Lateral branch
MB	Medial branch
PRSN	Posterior ramus of the spinal nerve
SN	Spinal nerve

Introduction

Most anatomy textbooks describe the posterior ramus of the spinal nerve (PRSN) as having two major branches, namely the lateral branch (LB) and the medial branch (MB) [2, 4, 8, 11, 12, 14, 15, 18, 20, 22, 24–26, 31, 32, 37, 39, 40, 42–45]. In 1982, Bogduk reported a classification mentioning the third branch as an intermediate branch (IB) that directly emanated from the stem of the PRSN and was distinct from the MB and LB in the lumbar segments [6]. The adoption of the ventral approach for dissection of the spinal column

✉ Toshiyuki Saito
toshis@nms.ac.jp

¹ Department of Anatomy, Tokyo Medical University, Tokyo, Japan

² Institute of Anatomy, Leipzig University, Leipzig, Germany

³ Department of Anatomy, Otago University, Otago, New Zealand

⁴ Department of Trauma, Orthopedics and Plastic Surgery, University Hospital of Leipzig, Leipzig, Germany

⁵ Faunhofer Institute for Machine Tools and Forming Technology, Dresden, Germany

⁶ Department of Neurosurgery, Aichi Medical University, Nagoya, Japan

⁷ Department of Orthopedics, Aichi Medical University, Nagoya, Japan

⁸ Koyasu Hospital of Neurosurgery, Yokohama, Japan

following Bogduk's procedure enabled our group to report the existence of an IB in the thoracic segments in 2006 [36].

Here we performed anatomical dissection using the ventral approach to obtain more detailed information about primary branching of the PRSN. With the ventral approach, we examined how many primary branches exist in each segment between T1 and L5. It was further assessed if the third branch shows morphological characteristics similar to those of the medial and lateral branches, including if the primary branches of the PRSN originate at the same time at the terminal end of the PRSN. The muscles supplied by the primary branches were also examined. Additionally, the length and diameter of the PRSN at each segment, and the diameter of the primary branches at T10 were measured.

The anatomy of the PRSN innervating paravertebral muscles is important for spinal stability [8, 48]. Surgical procedures for the treatment of spinal deformities include a paramedian approach through the paravertebral muscles. An inappropriate surgical corridor may damage the PRSN, thereby causing postoperative muscle atrophy with subsequent back pain [5]. It is therefore of great importance to understand the anatomy of the PRSN in relation to the soft tissue to preserve muscular competence around the spinal column.

The aim of this study was to revisit the anatomical distribution of the PRSN to define its precise topographic anatomy on different segments including knowledge on how the erector spinae muscles are innervated.

Materials and methods

Dissections were performed on eight adult cadavers (mean age 86 years, range 73–99 years) (three females, five males) obtained from Tokyo Medical University. All the cadavers were donors who had provided direct and informed consent for their bodies to be used for teaching or research projects at the Institutes of Anatomy. The reasons for their deaths were pneumonia, cerebral infarction, heart failure, and Parkinson's disease. 16 mediosagittally sectioned body halves were thus examined; every segment between T1 and L5 was analyzed for PRSN branching (total of 272 PRSNs).

Dissection

The eight cadavers were embalmed using a 3% formaldehyde solution. The thoracolumbar vertebral column with surrounding muscles was resected en bloc, and vertebral bodies were sagittally sectioned. The ventral approach described by Bogduk et al. and later modified by Saito et al. permitted us to uncover the entire nervous tissue layout [7, 36]. The thoracic and abdominal contents were removed. The vertebral bodies were then separated from their pedicles and lifted away from

the vertebral canal. This step exposed the neural elements of the vertebral canal and their relationship to the pedicles, the intervertebral foramina, and the posterior elements of the vertebral column, allowing a detailed inspection. Figure 1 shows the stage at which the left half of the vertebral bodies was removed to visualize the SNs on one side. Using this procedure, the SNs could be followed from the spinal cord (SC) to the periphery. The vertebral canal was cleaned ventrally to visualize the dural sac and the coverage of the SNs, whose branches could easily be visualized. The pedicles of the vertebral arches were subsequently removed with the corresponding transverse processes and ribs in the thoracic segments, with the corresponding costal processes in the lumbar segments [34, 35]. The proximal region of the SNs was more easily accessed by our ventral approach than by conventional dorsal dissection. The posterior branches terminated at erector muscles. Nerves, including the anterior rami, were photographed using an Olympus Digital Camera (model No. TG-830, Tokyo, Japan). The ramification of the PRSNs was tracked to the erector spinae divisions and to the skin. We determined whether

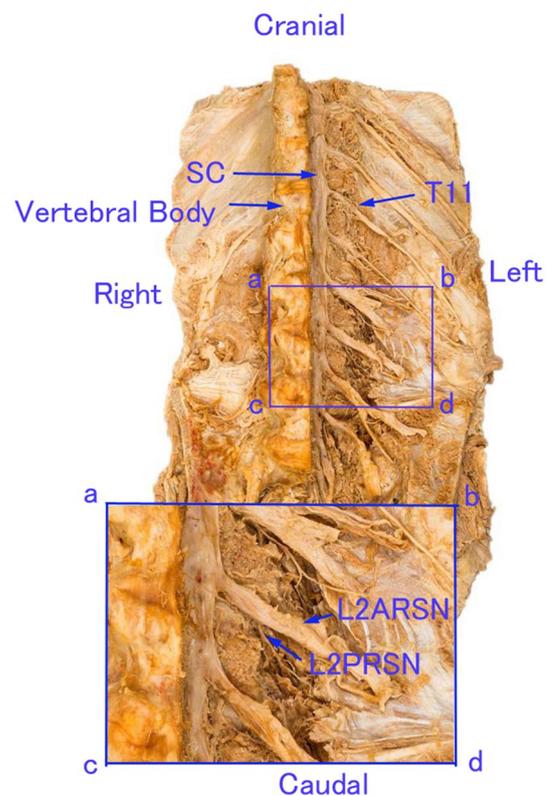


Fig. 1 Back of a cadaver from ventral view. Back view from ventral. The vertebral bodies were sagittally halved so that the origin of the spinal nerve could be seen. The 11th thoracic and 2nd lumbar SNs are each marked with labels, respectively. For readers to understand easier, a part of the view is enlarged in the inset. The square points a–d correlate to the inset a–d. The PRSNs are offshoots of the ARSNs and the spinal nerves (SNs). SN spinal nerve, PRSN the posterior ramus of the spinal nerve, ARSN anterior ramus of the spinal nerve

it divided by duplication or by triplication, based on whether two or three branches arose at the same posterior ramus. Each PRSN was dissected from its origin, and every branch was followed for as long as possible. The length and diameter of the PRSN, and the diameter of each primary branch were measured with a slide caliper (Mitutoyo Co., N10R, Tokyo). The primary branches were examined to identify the nerve tissue. Hematoxylin–eosin was used for staining.

Producing scanned digital images

To clarify the precise shape of the sprouting part of the primary branches of the PRSNs, we used a light-reflection laser scanner (Artec Eva/MHT, Nagoya, Japan). The light-reflection laser scanner can capture the surface shape of PRSN during its isolation. Dissection may produce triplication from a duplicated branch due to accidental splitting of one branch into two. To avoid incorrect analysis, the laser scanner is useful because the device can capture the structure when only a part of the surface is opened, before it is fully isolated from the surrounding tissue. The 3D digital data were processed with Artec Studio 9 software (Data Design Group, Nagoya, Japan), and further processed with the 3D computer graphic software LEIOS (Data Design Group, Nagoya, Japan) for data trimming.

The scanner produces a 3D image of the structure as a function of the distance from the scanner to the exposed surface of the PRSN. After the surface structure was acquired, the PRSN was isolated from the whole view within the LEIOS software by erasing the polygons of the structures that were not part of the PRSN. The opened nerve surface is a part of the whole nerve. Repeated measurements of PRSN segments were used to produce the entire 3D image of the PRSN. The scanned data in LEIOS were transferred to Light Wave 3D software (New Tek Inc., San Antonio TX, USA). Using Light Wave software, each individual PRSN scan was digitally integrated with other scans referring spinal cord and bony structure in the digital three-dimensional scale to recreate the anatomy of the entire PRSN.

The light-reflection scanner captured the shape of the exposed surface, i.e., the proximal surface. The surface of the distal side could not be captured, because the distal side of the soft nerve was already deformed, when the entire structure was fully dissected. Because the nerve has a tube-like shape, we produced a tube-like nerve, adopting the Rail Extrude command in Light Wave connecting disc-shaped planes.

Results

Dissection of the PRSN

The 16 body halves from eight cadavers were examined at each segment between T1 and L5 for the study of PRSN.

A total of 272 PRSNs were analyzed. The ventral approach to each SN revealed its origin and major branches without injuring its peripheral part. Each SN was followed through the intervertebral foramen, which made it easy to identify the SN segment. An example of a PRSN at the 10th thoracic segment (T10) is shown in Fig. 2, with three primary branches arising directly from the PRSN. When fully dissected, three primary branches can be seen. The MB turned around to the area behind the vertebral column. The IB was observed on the more cranial side than the LB in the lateral view, because it supplied the more cranial area within the body segment than did the other two branches. The PRSN was 2.2 mm thick, and the MB and the IB were only 0.9 mm and 1.0 mm thick, respectively. The LB thickness was 1.5 mm.

The pattern of primary branching (bifurcation or triplication) of the spinal nerves was symmetrical in the investigated 136 pairs of spinal nerves. The three primary branches were identified histologically to distinguish from the other organs (Fig. 3).

The PRSNs in thoracic segments

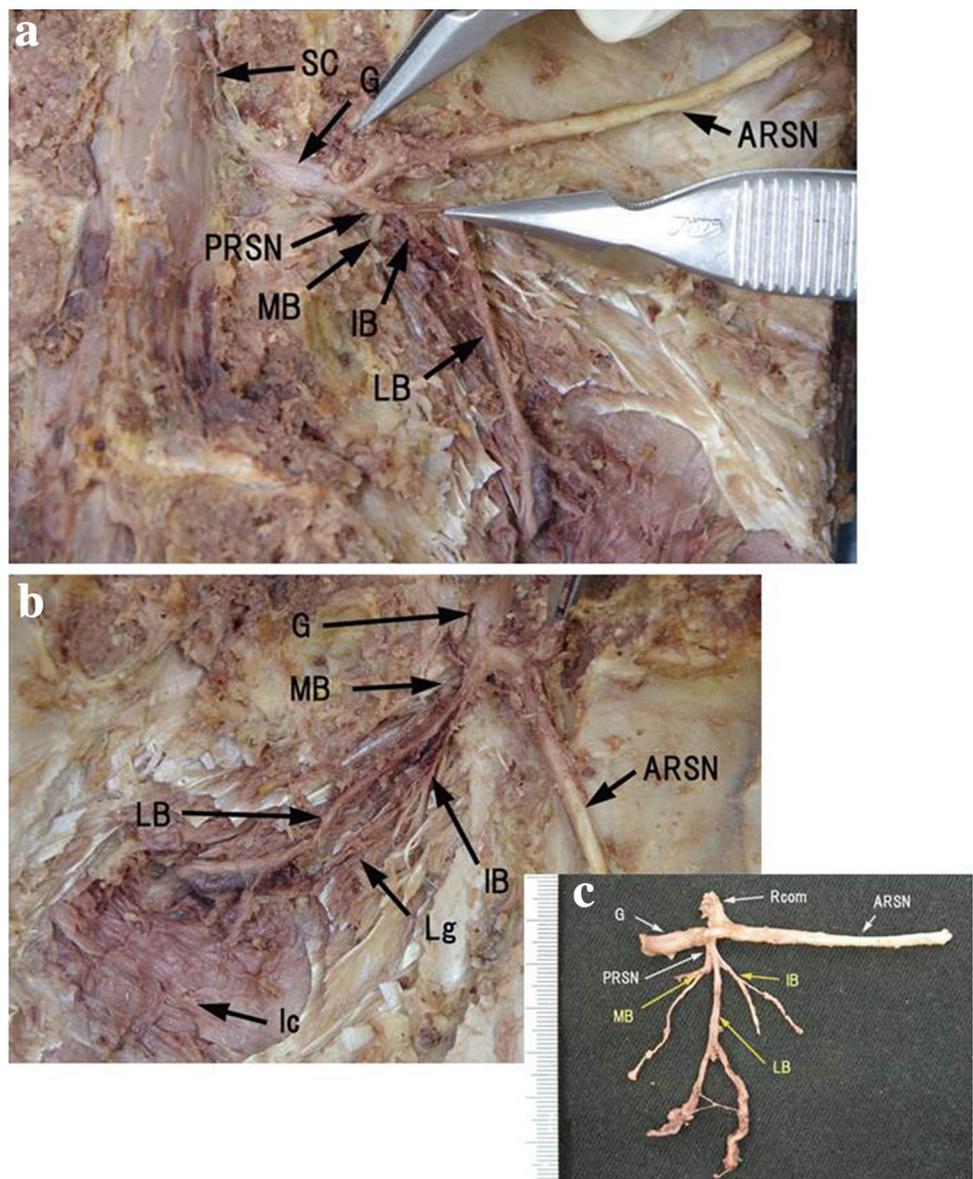
The number of PRSNs showing triplication and duplication varied in the different segments (Table 1). In total, at primary branching, 124 PRSNs showed triplication and 68 showed duplication. We found that, in the investigated cohort, the distribution of PR branching modes along the vertebral column was uneven. For segments T7, and T8, all PRSNs produced three primary branches. Duplications occurred mainly in the upper thoracic segments and occasionally in the lower thoracic segments.

The three primary branchings of the PRSN at T1, T3, and T11 are shown in Fig. 4a, b, d. A sharp angle was formed by the PRSNs with a straight line of the SN stalk and the anterior ramus at its origin. Of the primary branches, the MB innervated the spinalis muscle, the LB innervated the iliocostalis muscle, and the IB innervated the longissimus muscle. When fully dissected, the shapes of PRSNs were the same as that of the exemplary PRSN at T10 (Fig. 2).

At T4, T5, and T6, the majority of the branching mode was duplication. Then, we took a duplication example at T5 (Fig. 4c). The blue arrow indicates the medial branch of the lateral branch, which is often seen in the mode of duplication. It is not a member of the primary branch.

Three primary branches were behind the rib of the next caudal segment. The size of the PRSNs varied in different segments. The length and diameter of the PRSNs were measured, and are shown in Table 2. The length of the PRSN was at most 10.9 mm.

Fig. 2 PRSN at T10. The PRSN, SC, G, and SN at T10 are shown. **a** Anterior view. Three primary branches (MB, IB, LB) are seen from the PRSN. **b** Lateral view. The proximal part of the three branches could be observed arising almost at the same point. Although the LB and the IB could be followed to the periphery, the MB was difficult to follow at this dissection stage. **c** The fully dissected PRSN of the 10th thoracic SN. The periphery of the MB can be seen after full dissection. The IB is seen lateral to the LB in its isolated form. *SN* spinal nerve, *PRSN* the posterior ramus of the spinal nerve, *ARSN* anterior ramus of the spinal nerve, *SC* spinal cord, *MB* medial branch of the PRSN, *LB* lateral branch of the PRSN, *IB* intermediate branch of the PRSN, *Rcom* ramus communicans of the spinal nerve, *G* spinal ganglion covered by dura, *Ic* Iliocostal muscle, *Lg* Longissimus muscle



The PRSN in the lumbar segments

The majority of the lumbar segments showed triplication. 72 PRSNs showed triplication while 8 showed duplication (Table 1). All of the L3, and L4 segments showed triplication. We found triplication also at L5 after our sequential dissection.

Exemplary primary branching patterns of the PRSNs at L1, L3, and L5 segments are shown in Fig. 5. The pattern of primary branching (bifurcation or triplication) of the spinal nerves was symmetrical. No laterality was observed also in the lumbar segments. When fully dissected, the shapes of PRSNs were the same as the shapes at T10. A sharp angle was formed by the PRSNs with a straight line of the SN stalk and the anterior ramus at its origin. The branching point of

the three primary branches was behind the costal process of the next caudal segment.

The size of the PRSNs varied in different segments. The lengths and diameters of these lumbar PRSNs were measured, and are shown in Table 2. At L4 and L5, the PRSNs were longer than 5 mm in length.

In the lumbar segments, the primary PRSN branches diverged into many sub-branches after they originated. However, in the lumbar segments also, the basic disposition of the PRSNs was the same as that of T10. The MB innervated the spinalis and multifidus, the LB innervated the iliocostalis, and the IB innervated the longissimus muscle. In the lumbar segments, the LB has long cutaneous end that reaches lateral area, while the MB reached the area of the skin nearing the spinous process and the zygapophyseal

Fig. 3 Histological finding of the origin of the three primary branches of PRSN. A proximal part of primary branches of PRSN in a case was sliced, a case with three primary branches of PRSN was chosen. The three primary branches are identified as nerves. In the view, the 1st lumbar ARSN was also sliced because it was in the vicinity. Staining: hematoxylin–eosin. *PRSN* the posterior ramus of the spinal nerve, *ARSN* anterior ramus of the spinal nerve, *MB* medial branch of the PRSN, *LB* lateral branch of the PRSN, *IB* intermediate branch of the PRSN



Table 1 Mode of primary branching of spinal nerve

Segment	Triplication	Duplication
T1	14	2
T2	10	6
T3	8	8
T4	4	12
T5	2	14
T6	4	12
T7	16	0
T8	16	0
T9	14	2
T10	14	2
T11	10	6
T12	12	4
L1	14	2
L2	14	2
L3	16	0
L4	16	0
L5	12	4

16 PRSNs of all segments were investigated (unit: PRSNs)

joints of the vertebrae. The IB innervated the area between the MB and the LB, terminating in the longissimus muscle.

The primary branching examined with a laser scanner

The near surface of the PRSNs was captured by a light-reflection scanner. After unnecessary surrounding tissues were removed, the surface of the nerve tissue was scanned. The near surface of the 11th PRSN in a cadaver is shown as an example in Fig. 6. The partial data were connected

with each other to reproduce the whole PRSN after repeated scanning.

Exemplary PRSN images of 7th thoracic and 3rd lumbar PRSNs are shown in Fig. 7. With an adequate angle, the scanned images show the origin of triplication clearly. The three primary branches sprouted at the same time from the terminal end of the PRSN. They directed to the three different muscle compartments. The MB passed between the mammillary and accessory processes, and reached the spinalis muscle compartment. At T7, the LB supplied the iliocostalis muscle compartment, and terminated. At L3, the LB was long, and reached the skin supplying the iliocostalis muscle. The IB at T7 was long and supplied the longissimus compartment, reaching the vicinity of the skin. The IB at L3 was directed a little cephalically providing many secondary small branches to supply tissue in the longissimus muscle compartment.

Discussion

Many textbooks do not give a clear description of the PRSN anatomy, which seems to reflect the traditional view that the PRSN has no clinical significance [2, 11, 13, 14, 18, 21, 24, 30, 37–39, 44, 45]. On the other hand, some textbooks state that the PRSN divides into two branches, but show illustrations depicting three branches [9, 22, 29, 43, 47]. Over the last 30 years, there has been increasing clinical attention to these nerves in the context of diagnosis and treatment of low back pain, and in terms of preventing disabling sequelae after spinal surgery. Anatomy textbooks have not kept pace with this development. Only the latest versions of Gray's Anatomy have updated the description of the PRSN by including a description of the IB [3, 28].

Fig. 4 Primary branching at the terminal end of the PRSN at various segments of the thoracic region. **a** at T1, **b** at T3, **c** at T5, **d** at T9. In the pictures **a**, the right side of the PRSNs are seen. At other segments, the left sides of PRSNs are shown. From the inferolateral view, the IB can be seen more laterally than the LB (picture **c**). *PRSN* the posterior ramus of the spinal nerve, *IB* intermediate branch of the PRSN, *LB* lateral branch of the PRSN, *ARSN* anterior ramus of the spinal nerve. *Ic* Iliocostal muscle. *Lg* longissimus muscle, *G* spinal ganglion covered by dura, *MB* medial branch of the PRSN, *LB* lateral branch of the PRSN, *IB* intermediate branch of the PRSN

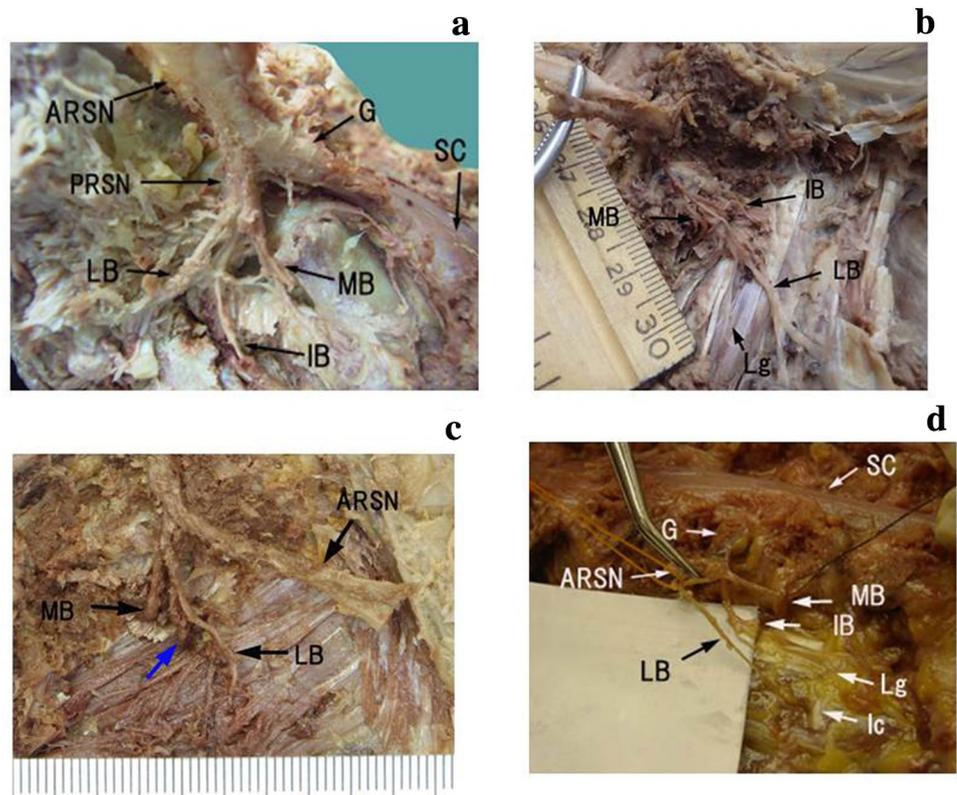


Table 2 Length and diameter of the PRSN (average \pm SD mm)

Segment	Length	Diameter
T1	10.2 \pm 1.5	3.2 \pm 0.9
T2	8.4 \pm 1.8	2.0 \pm 0.3
T3	7.2 \pm 2.0	1.9 \pm 0.2
T4	4.2 \pm 1.4	1.9 \pm 0.2
T5	4.4 \pm 1.2	1.9 \pm 0.1
T6	4.2 \pm 1.1	1.9 \pm 0.2
T7	4.3 \pm 1.0	2.0 \pm 0.1
T8	4.2 \pm 1.0	2.1 \pm 0.1
T9	4.1 \pm 1.1	2.2 \pm 0.1
T10	3.0 \pm 0.9	2.4 \pm 0.5
T11	2.8 \pm 0.9	2.4 \pm 0.7
T12	2.4 \pm 0.5	2.5 \pm 0.6
L1	5.3 \pm 2.0	2.2 \pm 0.5
L2	3.8 \pm 1.3	2.6 \pm 0.3
L3	4.4 \pm 1.0	3.0 \pm 0.5
L4	6.0 \pm 1.2	2.8 \pm 0.4
L5	6.6 \pm 1.6	1.7 \pm 0.1

Triplication as the primary branching pattern for the PRSN

This study found that, in 196 out of 272 PRSNs, three primary branches arose from the PRSN between the T1 and L5

segments. Therefore, it was found to be quite common for an IB to arise from the PRSN together with an MB and an LB. The pattern of primary branching was symmetrical in every nerve segment in all investigated individuals.

In the investigated cohort, the distribution of PR branching modes along the vertebral column was uneven, with triplication of all cases examined for segments T7, T8, L3 and L4 only. Figure 8 is the bar graph derived from Table 1. Duplications occurred mainly in the upper thoracic segments. Between T4 and T6, the PRSNs mostly showed duplication. Triplication is found frequently in the lower thoracic and lumbar segments. Because there are three muscular compartments behind the vertebral column, it is not surprising that there can be three primary branches, innervating those muscle compartments [40]. Mekonen et al. have investigated the development of the dorsal intrinsic muscles of human embryos. According to them, the intrinsic muscles start to develop as epaxial portions of myotomes at the 16th Carnegie Stage (CS16) to form two longitudinal columns extending until segment L2, which will later become innervated by the posterior branches of the growing spinal nerves [23]. At CS17, each dorsal muscle column splits into a medial and lateral muscle column. After both columns are divided, the lateral part of the medial column and the medial part of the lateral column fuse to form the intermediate column (future longissimus muscle). This intermediate column first appears in the lumbar region, then gradually

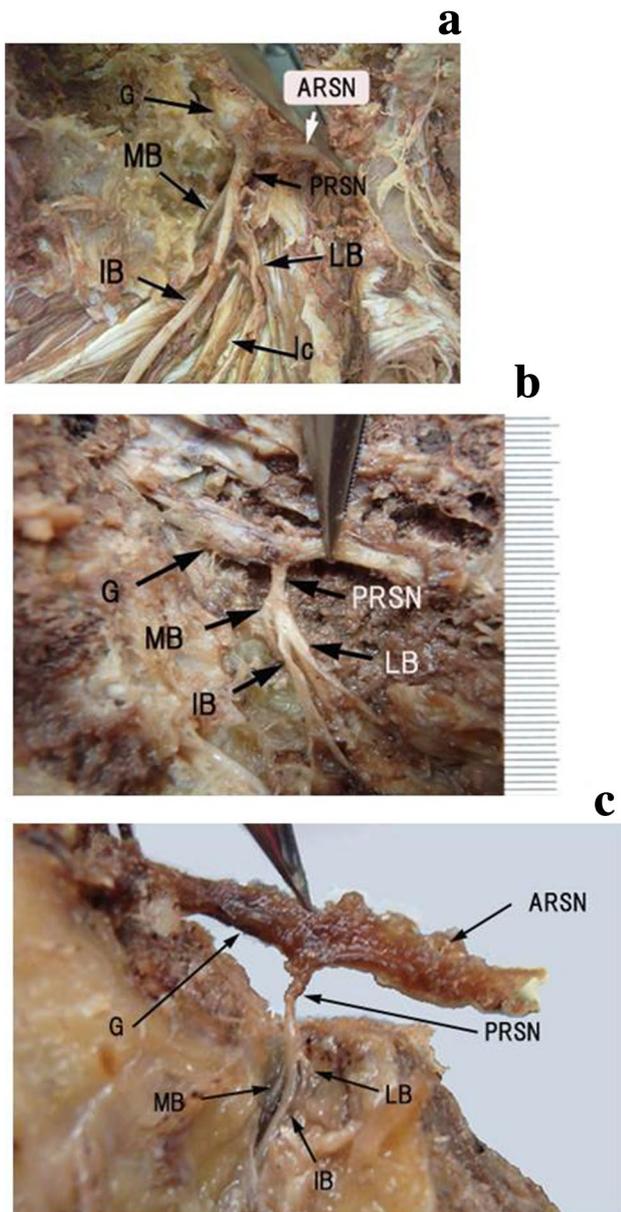


Fig. 5 Primary branching at the terminal end of the PRSN in lumbar segments. **a** at L1, **b** at L3, **c** at L5. In the pictures **a**, **b**, the left sides of the PRSNs are seen. At L5, the right side of PRSNs is shown (upper view). PRSN the posterior ramus of the spinal nerve, G spinal ganglion covered by dura, Ic Iliocostal muscle, LB lateral branch of the PRSN, IB intermediate branch of the PRSN

expands to the lower thoracic region of the CS18 embryo. The nerves accordingly follow the development of the three muscle columns. We hypothesize that this expansion may explain the high prevalence of triplication in the lower thoracic and lumbar segments. In an old article on the intercostal artery, Adachi [1] reported different mode origins of the artery. He reported that the common stem was found more frequent in upper thoracic segments. The frequency has the

same distribution as the duplication. Our observation on the posterior rami of the spinal nerve, and Adachi's observation of the intercostal artery seem to show the relation between the nerve and artery to the construction of the erector spinae muscle.

Nomizo et al. [27] reported that the iliocostalis muscle has different positions in different animals. After their report, we also observed PRSN having a different triplication pattern in dolphins [33]. In animals, the location of the iliocostalis muscle in the body trunk is different. The iliocostalis is located more laterally in animals. The LB to the iliocostalis muscular compartment sprouts out separated from the PRSN. Therefore, the anatomy of the PRSN in humans was found to be different from animals. The current concept of the PRSN having two primary branches may have been drawn from animal studies.

We confirmed that MBs always reach the skin near the tip of the spinous processes, while LBs reach the skin covering the iliocostalis muscle. The IBs terminated in the longissimus without reaching the skin. This observation is in accordance with the fact that there are only two parallel rows of cutaneous branches on the back of the body. The IBs are shorter, and remain deeper in the soft tissue. However, it is also noteworthy that the IBs neighbor a meridian point of acupuncture [46].

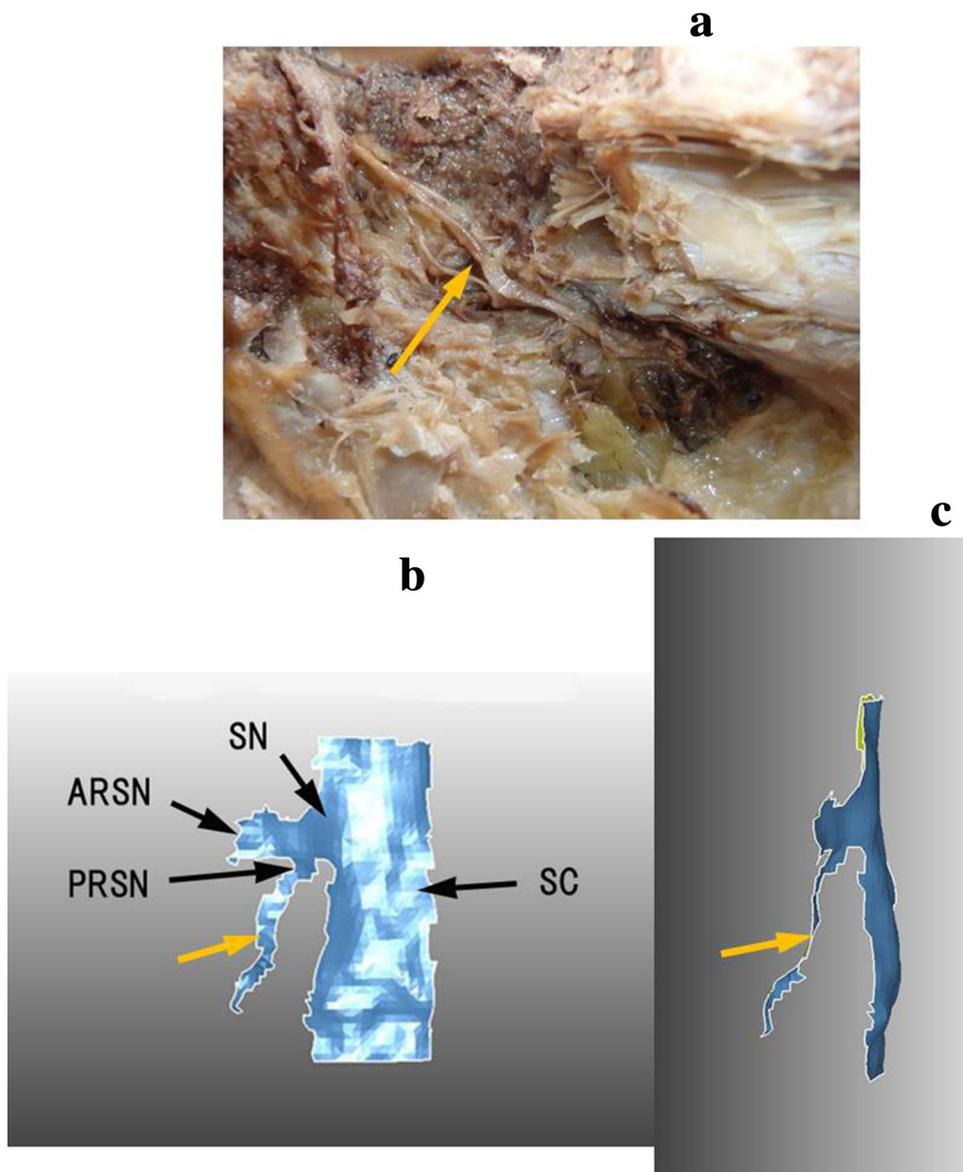
Clinical relevance

Direct damage of PRSN produces spinal instability as described in the introduction. In the field of anesthesia, the paramedian approach to the epidural space requires a corridor through the paramedian muscles including the longissimus and semispinalis muscles. Sufficient local anesthesia and safe epidural puncture require a precise knowledge of the anatomy of the PRSN to avoid direct damage, and pain and fear behind the spine in the patients. Because of the lack of information about the anatomy on the PRSN to anesthesiology, an inaccurate image of the anatomy of the PRSN was drawn in a journal of anesthesiology [Anesthesiology (2014): vol. 121, no. 5, cover page]. It is obviously preferable to deliver correct anatomy for better clinical practice.

In oriental medicine, the PRSN and its branches might play a role in afferent path of reflex in acupuncture [46]. In acupuncture texts, the meridian points are aligned parallel to the spine [16]. The area is the same area where the IB or LB spread. The IBs of different segments possibly produce communicating branches between segments [7, 41]. The net by the IB branches may play a role as an afferent input area to produce sympathetic responses.

For neurolysis in orthopedics, the primary branches of the PRSNs are the main target for controlling persistent dorsal pain. For a permanent block, the anatomy of PRSN is particularly important to find corridors to insert devices to

Fig. 6 A raw scanned data of 11th PRSN of a cadaver. The near surface of SC, SN, the proximal part of ARSN, PRSN, and LB is captured by the light-reflection scanner. Dissected PRSN (a), scanned near surface (b), and its rotation (c) are shown to present raw digital data. The dissected right PRSN was photographed from the lateral direction. The yellow arrows indicate LB of 11th thoracic PRSN. PRSN the posterior ramus of the spinal nerve, SC spinal cord, SN spinal nerve, ARSN anterior ramus of the spinal nerve, LB lateral branch of the PRSN



reach a point to block [19]. It is also important to provide a sufficient block with a limited paralyzed area [6].

Extension of the current concept

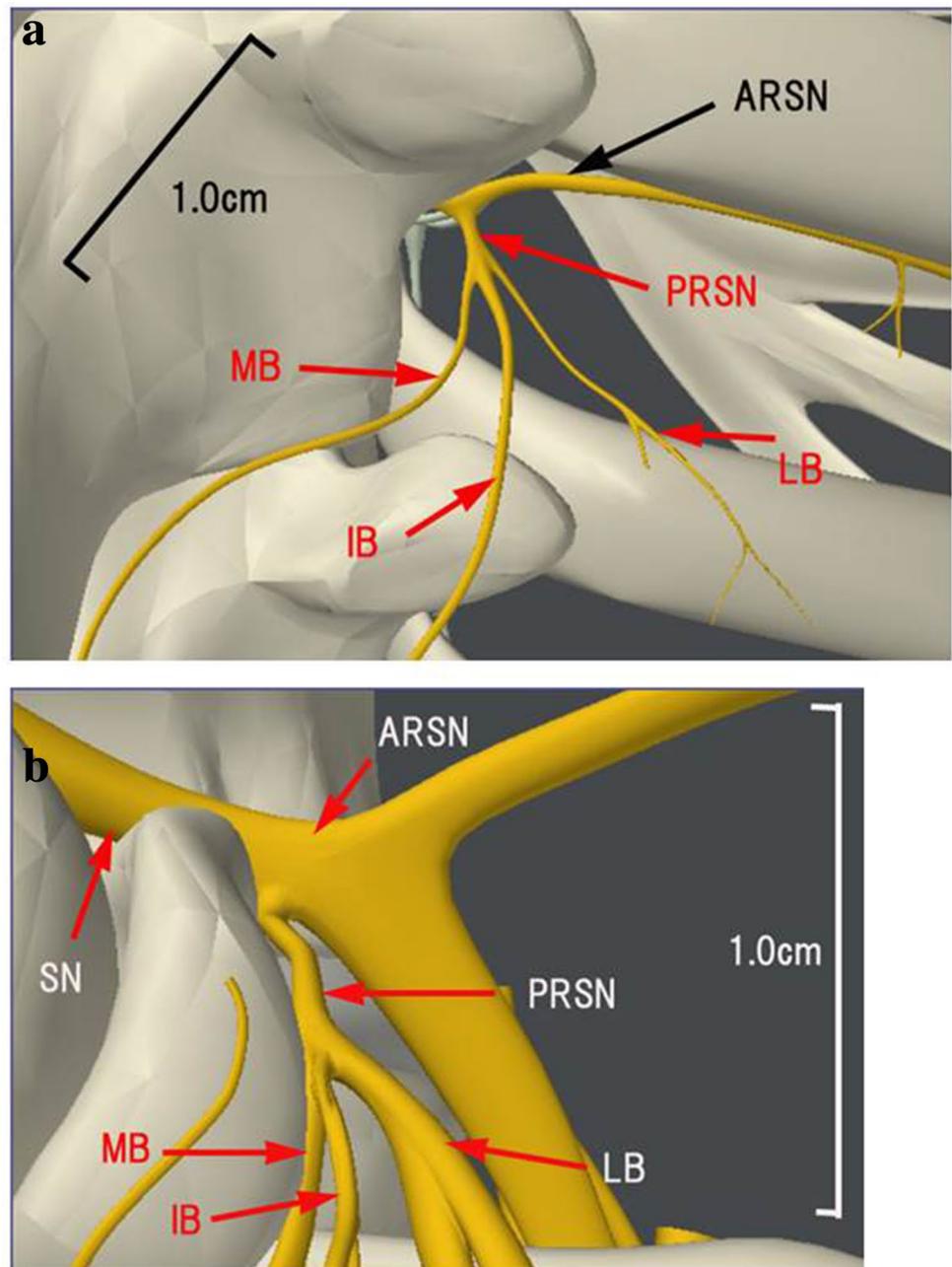
The current lack of understanding about the PRSN anatomy has resulted in confusing descriptions.

For example, Ishizuka et al. described the “topographic anatomy of the posterior ramus of the thoracic spinal nerve” in their study of dorsal pain, and reported that the PRSN showed bifurcation [17]. However, at the same time they observed a “third” branch, which they termed “descending branch”. They described how the stem of the PRSN had one descending branch before bifurcating. Their version of the anatomy of the PRSN reflects several common misconceptions. First, it shows confusion regarding

the number of branches which originate from the stem of the PRSN. They claim that “the descending branch” originates from the stem of the PRSN, therefore, this branch is in fact a third branch. Second, the terminology that they used for their “descending branch”. We cannot find the term “descending branch” in Terminologia Anatomica [10, 12]. To prevent further possible confusion, a precise description of the PRSN is necessary.

In the description about the PRSN, the term “dorsal rami” are conventionally used [20, 32, 42, 44, 45]. However, Terminologia Anatomica assures the use of the medical term “posterior ramus (i)” only, although Terminologia Neuroanatomica permits the term [10, 12]. Discussion with correct words is important; the commission of Terminologia Anatomica should clarify this term and the fact

Fig. 7 Views of integrated T7 and L3 PRSNs of one cadaver. Integrated scanned data at T7 and L3 data are shown. The mode of primary branching and anatomy of three primary branches are shown (**a**, **b**). At L3, a part of MB is covered by the mammillary process of L4 because the primary branching point of the PRSN is in the vicinity (**b**). The lateral branch of the L3 PRSN is a superior clunial nerve. *MB* medial branch of the PRSN, *PRSN* the posterior ramus of the spinal nerve, *LB* lateral branch of the PRSN, *IB* intermediate branch of the PRSN



that the PRSN divides into three main branches, at least in the thoracolumbar region.

The length of the PRSN

The length of the PRSN was measured in this study, and varied in the different spinal segments. The upper thoracic and the lumbar PRSNs were long with the T1 PRSN being the longest (10.2 ± 1.5 mm), whereas PRSNs in the middle and lower thoracic segments were shorter. The length was at most 12 mm, however, we see many textbooks draw PRSN longer [2, 10]. It remains unclear where they observed the

long PRSNs. It is forbidden to dissect without preservation in the country, it is possible that the tissue shrunk during preservation. The values may be larger without preservation. However, we observed neither significant shrinkage in the cadavers, nor signs of texture waves after shrinkage in the tissues.

Sub-branch (secondary branch of PRSN)

The identity of the sub-branch is not examined and discussed in this report. In the case of duplication, we always observed medial sub-branch from the LB (Fig. 4, blue arrows).

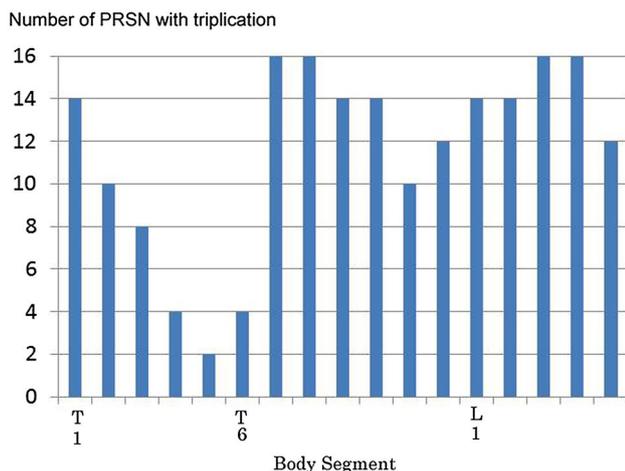


Fig. 8 Bar graph derived from Table 1. The number of PRSNs which showed triplication is shown. The branching of the PRSN showed either triplication or duplication at each segment

However, the medial sub-branch was occasionally observed in cases with triplication. Further thorough study is required.

Study limitation

The main limitation of this study is the number of cadavers. We could study only eight Japanese cadavers. Careful dissection of each segment required of us significant time. With these subjects, we cannot claim that the cadavers represent the whole human population. Therefore, we could neither use statistical analysis nor provide percentages in the results.

Conclusion

This systematic study of the anatomy of the PRSN in the lumbar and thoracic segments revealed that 196 of 272 PRSNs (i.e., 98 pairs of 136 SNs) examined showed triplication. Therefore, the IB may not be considered as an uncommon structure or a rare variation.

We consequently propose that the IB should be recognized in the literature and in textbooks as a member of the primary branches of the PRSN. We hope that the intermediate branch of the posterior ramus of the spinal nerve in the thoracic segments will be called Saito–Steinke’s nerve as well as Bogduk’s nerve in the lumbar segments.

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Author contributions TS designed the research, performed dissection, collected and analyzed the data, and wrote the manuscript. HS helped to create the study plan, performed dissection, and helped the description of the manuscript. NH pursued microscopic examination for the identification of the nerve tissue. ZL, SK helped the dissection and helped camera work. MY, NW and HK commented during the study planning, helped preparatory study, and analyzed the data. MI approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest related to the given study.

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