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Microsurgical anatomy of the dorsal cervical rootlets and dorsal root entry zones

A. Karatas[1], **S. Caglar**[2], **A. Savas**[2], **A. Elhan**[3], and **A. Erdogan**[2]

[1] Department of Neurosurgery, Fatih University School of Medicine, Ankara, Turkey
[2] Department of Neurosurgery, Ankara University School of Medicine, Ankara, Turkey
[3] Department of Anatomy, Ankara University School of Medicine, Ankara, Turkey

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Summary

Background. Detailed anatomical knowledge of the dorsal cervical rootlets and dorsal root entry zones (DREZ) is important for the diagnosis and treatment of cervical myeloradiculopathy and surgical management of pain. There are far fewer micro-anatomical studies of this area than gross anatomical studies. This study presents several anatomical points regarding the dorsal cervical rootlets and dorsal root entry zones.

Method. Fifteen adult formalin-fixed cadaveric spines from C1 to T1 were used to observe the posterior structures. They were studied under the surgical microscope following en bloc laminectomy and foraminotomy. The morphological features of the dorsal root entry zones and dorsal rootlets were determined. The distance from the midline to the DREZ, the longitudinal length of the DREZ in the spinal canal, the length of the dorsal rootlets, the number of dorsal rootlets and the intersegmental anastomoses between the dorsal rootlets were measured.

Findings. The distance from the midline to the DREZ ranged from 1.1 to 4.7 mm. Longitudinal length of the dorsal rootlets ranged 4.3–17.7 mm. The shortest length of the dorsal rootlets ranged between 5–28 mm, and longest lengths of the dorsal rootlets ranged 6.8–30.3 mm. The number of dorsal rootlets ranged from 2–13. Between the C2–T1 dorsal rootlets, 142 connections out of 30 intersegments were noted.

Conclusions. The distance from the midline to the DREZ decreased in the lower cervical spine. The longest longitudinal length of the DREZ was at the C5 level. The length of the dorsal rootlets was increased in the lower cervical spine. The average number of dorsal rootlets tended to increase in the lower cervical spine. Anastomoses were most often found between C6–7 and C5–6 dorsal rootlets. Knowledge of the anatomical features of dorsal cervical rootlets and dorsal root entry zones is essential for a surgeon to avoid injuring the neural structures. This knowledge is a must not only to avoid complications but also for the success, safety and effectiveness of microsurgical operations of the pathological conditions like posterior myeloradiculopathy and pain treatment such as DREZ operations.

Keywords: dorsal cervical rootlet; dorsal root entry zone (DREZ); DREZ-otomy, intersegmental anastomotic rootlets; microsurgical anatomy; cervical spinal cord.

Introduction

Detailed anatomical knowledge about the cervical spine and cord is important for the diagnosis and treatment of cervical myeloradiculopathy and many other diseases. This knowledge is also necessary for a safe posterior cervical stabilization and for the dorsal root entry zone (DREZ) operation as an important component of pain surgery. Surgical procedures for cervical radiculopathy have been performed through either an anterior or a posterior approach [1, 2, 4, 7, 17, 20, 24]. Exposure of the cervical nerve roots from the posterior approach provides the advantage of direct visualization of the nerve root and the spinal cord [2, 8, 17]. Although many investigators have studied the gross anatomy of the cervical spine, these observations were undertaken in this study by thin section techniques. The microsurgical dissections were performed under a surgical microscope similar to routine operation techniques. DREZ operation (DREZ-otomy) is a specific, careful microsurgical dissection, and adequate neurophysiological orientation is the main factor for success. The DREZ operation is used by surgeons for the treatment of central neuropathic pain. Postherpetic neuralgia, postparaplegic pain, pain after traumatic plexus avulsions and phantom pain are included in this pain group [5, 6, 13, 18, 21]. We report in this study the microsurgical anatomy of the dorsal cervical rootlets and DREZs. The objective of the study was to provide detailed microanatomical data about the dorsal cervical rootlets and cervical DREZs.

Methods and materials

This study was based on the dissection of 15 Formalin-fixed human cadaveric spines. All cadavers were males, and age at death ranged between 43 and 67 years. Specimens with severe deformities were excluded. The cadaveric specimens of the cervical spine from the occipital bone to the first thoracic vertebra were obtained. The cadavers were placed in the prone position. All the soft tissues were dissected from the cervical spine. Foraminotomies and en bloc laminectomies were done with rongeur and air drills under a surgical microscope (Carl Zeiss, Germany), and posterior aspects of the spinal canal were studied. Dura and arachnoid mater were opened, exposing spinal cord, dorsal rootlets, DREZ. The microsurgical dissection of the cervical spinal canal was photographed through a surgical microscope. Symmetric structures were measured bilaterally. All measurements were made using a caliper accurate to 0.1 mm. All dissections and measurements were performed by the same neurosurgeon and anatomist. Descriptive statistics analysis was used to determine mean, standard derivation (SD) and minimum-maximum values.

The following structural and topographic aspects of the posterior cervical spine and cord were studied: 1. The morphological features of the DREZ and the distance from the midline to the DREZ; 2. The longitudinal length of the DREZ in the spinal canal; 3. The shortest and longest lengths of the dorsal rootlets; 4. The number of dorsal rootlets; 5. The intersegmental anastomoses between the spinal dorsal rootlets.

Results

All of the anatomical parameters are shown in Tables 1–4.

The dorsal rootlets enter the spinal cord along the posterolateral sulcus. The distance from the midline to the DREZ ranged from 1.1 to 4.7 mm (Fig. 1). The distance from the midline to the DREZ decreased in the lower cervical to the upper thoracic spinal cord and also lay close to the midline. The longest distances from the midline were found at C2 and C3 levels. The longitudinal length of the DREZ was measured in the spinal cord. The longest longitudinal length was at C5 level and shortest at C2. Longitudinal length of the dorsal rootlets ranged 4.3–17.7 mm (Fig. 2). The shortest and longest lengths of the dorsal rootlets were measured (from DREZ to interradicular septum) (Fig. 2). The shortest and longest lengths of the dorsal rootlets were increased in the lower cervical region. The shortest length of the dorsal rootlets ranged between 5–28 mm, and longest length of the dorsal

Table 1. *The distance from the midline to the DREZ and the longitudinal length of the DREZ in the spinal canal*

Level	Distance from midline, (mm) (mean ± SD, range)		Longitudinal length, (mm) (mean ± SD, range)	
	Right	Left	Right	Left
C2	3.9 ± 0.4 (2.9–4.5)	3.9 ± 0.5 (2.8–4.6)	6.9 ± 1.9 (4.3–8.7)	6.5 ± 1.4 (4.6–8.1)
C3	3.5 ± 0.6 (2.6–4.7)	3.4 ± 0.7 (2.6–4.6)	11.1 ± 1.8 (8.2–13.9)	12.3 ± 3.7 (7.2–17.1)
C4	3.0 ± 0.6 (2.3–3.9)	3.1 ± 0.4 (2.3–3.5)	11.8 ± 1.5 (10.1–14.0)	12.3 ± 1.3 (10.2–14.2)
C5	2.7 ± 0.7 (1.9–3.8)	3.0 ± 0.7 (1.9–3.9)	12.5 ± 1.5 (10.1–14.2)	13.0 ± 2.5 (10.3–17.7)
C6	2.8 ± 0.6 (1.8–3.8)	2.8 ± 0.7 (1.8–3.7)	11.2 ± 2.0 (7.4–13.1)	10.4 ± 2.2 (7.2–13.0)
C7	2.5 ± 0.5 (1.6–3.3)	2.7 ± 0.6 (1.5–3.3)	10.5 ± 2.0 (8.1–13.2)	10.8 ± 1.2 (8.6–12.2)
C8	2.2 ± 0.6 (1.1–2.8)	2.1 ± 0.6 (1.1–2.6)	10.4 ± 2.0 (8.4–12.9)	10.5 ± 2.1 (8.3–13.5)

Table 2. *The length of the dorsal rootlets*

Level	The shortest and longest lengths of the dorsal rootlets, (mm) (mean ± SD, range)			
	Right		Left	
C2	7.8 ± 1.7 (5.0–9.4)	9.5 ± 2.6 (7.3–14.2)	8.0 ± 1.7 (5.4–10.1)	8.7 ± 1.7 (6.8–11.6)
C3	13.1 ± 3.5 (10.2–20.0)	14.8 ± 5.0 (9.0–25.2)	13.5 ± 3.1 (9.0–18.8)	15.1 ± 4.2 (10.9–22.1)
C4	12.3 ± 3.0 (9.2–16.6)	12.0 ± 3.4 (7.8–17.7)	12.6 ± 2.3 (10.0–16.2)	13.8 ± 4.6 (8.5–22.4)
C5	12.2 ± 3.3 (8.5–15.9)	12.3 ± 4.9 (7.0–20.7)	12.4 ± 2.7 (9.2–17)	14.7 ± 4.9 (8.6–23.5)
C6	13.2 ± 3.2 (8.9–17.4)	14.9 ± 4.3 (10.2–21.8)	15.2 ± 2.6 (11.7–19.0)	16.1 ± 4.3 (10.4–23.6)
C7	16.1 ± 3.8 (11.3–22.1)	17.6 ± 4.3 (13.3–24.5)	16.5 ± 2.8 (13.4–20.6)	18.9 ± 4.3 (14.0–25.0)
C8	19.8 ± 5.3 (12.5–28.0)	20.2 ± 6.4 (14.1–30.3)	19.7 ± 3.2 (16.8–26.2)	21.6 ± 5.6 (14.8–30.3)

Table 3. *The number of dorsal rootlets*

Level	Number of Dorsal Rootlets (mean ± SD, range)	
	Right	Left
C2	5.0 ± 2.0 (2–8)	5.1 ± 1.4 (2–6)
C3	7.4 ± 1.2 (6–9)	7.7 ± 1.4 (5–9)
C4	8.4 ± 1.9 (6–11)	8.1 ± 2.2 (5–11)
C5	8.1 ± 1.2 (7–10)	8.2 ± 1.7 (6–11)
C6	8.3 ± 2.9 (6–13)	9.2 ± 2.2 (7–13)
C7	8.4 ± 2.2 (6–12)	7.8 ± 3.1 (5–13)
C8	8.4 ± 2.5 (6–13)	8.0 ± 3.2 (5–13)

Table 4. *The incidence of anastomoses between the dorsal rootlets*

Level	Dorsal rootlets (totals, %)
C2–3	22 (15.49)
C3–4	23 (16.20)
C4–5	20 (14.08)
C5–6	24 (16.90)
C6–7	26 (18.31)
C7–8	17 (11.97)
C8–T1	10 (7.04)

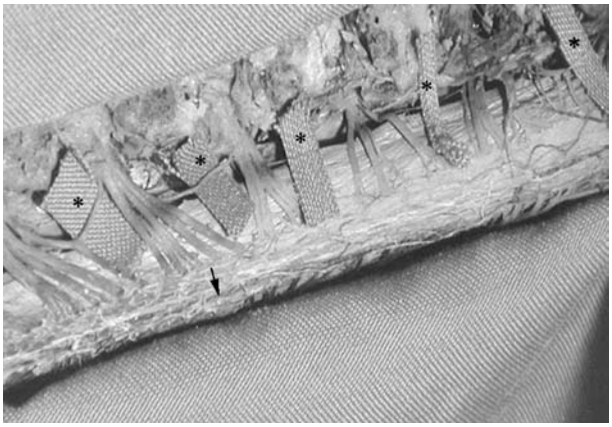

Fig. 1. Photographs showing the anastomoses between the dorsal spinal rootlets. (*) Arrow showing the distance from the midline to the DREZ

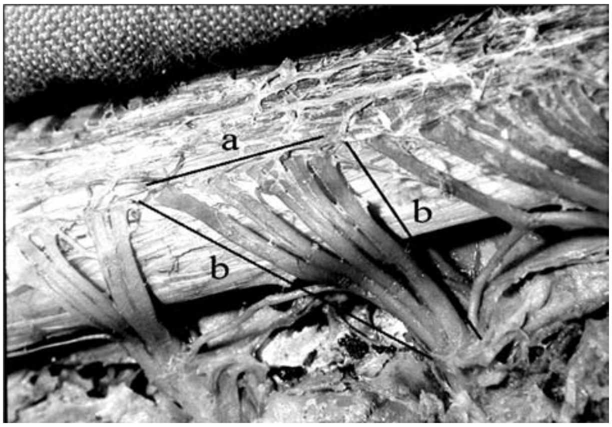

Fig. 2. Photograph of the longitudinal length of the DREZ (*a*). Photograph of the length of the dorsal rootlet (*b*)

rootlets ranged 6.8–30.3 mm. The number of dorsal rootlets ranged from 2–13. The minimum number of dorsal rootlets was found at level C2, and the maximum number at levels C6, C7, and C8. The average number tended to decrease in the upper cervical spinal cord. The intersegmental anastomoses between the dorsal spinal rootlets were examined with a surgical microscope (Fig. 1). Between the C2–T1 dorsal rootlets, 142 connections out of 30 intersegments were noted. There were 73 connections on the right and 69 on the left. There were 22 connections between C2–3, 23 connections between C3–4, 20 connections between C4–5, 24 connections between C5–6, 26 connections between C6–7, 17 connections between C7–8, 10 connections between C8–T1. Anastomoses were most often found between C6–7 and C5–6 dorsal rootlets. There was not an appreciable difference in frequency at any level from C2 to C5.

Discussion

The treatment for cervical myeloradiculopathy may be medical, surgical or both, and there are basically two approaches to the cervical spine – anterior and posterior [2, 7, 17]. Through the posterior approach, the spinal cord and nerve roots are decompressed without limitation via laminectomy and foraminotomy. Whichever approach is selected, neurosurgeons must be knowledgeable regarding the microsurgical anatomy of cervical nerve roots and intervertebral foramina to achieve an effective and safe decompression at operation and to avoid complications. The primary goal in the posterior approach must be to avoid damage to the spinal cord and the spinal nerve roots [1]. Use of instrumentation in posterior cervical stabilization has gradually increased. There is currently insufficient information about the clinical outcome and complications using new techniques. Anatomical studies about the spinal cord and nerve roots are also not sufficient.

The other important procedure for posterior cervical spine surgery is the DREZ operation. The origins of central neuropathic pain are substantia gelatinosa and DREZ. DREZ lesions have been used to reduce intractable pain resulting from avulsion of plexuses, postherpetic neuralgia, phantom pain following amputation of an extremity and spinal cord injury. These deafferentation states may lead to intractable pain, usually described as burning in character and persistent, and to hyperpathia despite patients' having had nerves destroyed and usually severe sensorial deficits localized in the pain area [11, 12, 22]. Treatment of this pain with drugs, sympathectomy, rhizotomy, chordotomy and neurostimulation is more difficult. Lesion of the DREZ has shown positive results in pain associated with deafferentation. The surgical technique of the DREZ operation can be described as follows: the dura and arachnoid are opened after laminectomy and then the appropriate dorsal rootlets affecting the spinal and adjacent levels are treated by DREZ coagulation. The lesions are made at 1 mm intervals along the affected DREZ [13]. Postoperative neurological deficits can be avoided by careful dissection and bearing in mind that the anatomy of the rootlets varies. Identification of the DREZ area is difficult, particularly in traumatic root avulsions. Data from this study may thus be of value during DREZ operations. The DREZ lesion is a suitable treatment modality for chronic pain if the pain is severe and intractable to other nonlesional methods.

Kuba *et al.*, in a study of 18 cadavers between C5–T1, found the distance from the midline to the DREZ to be

2.5–4.5 mm, and the longest distance was found at level of C6 [9]. This distance was 1.1–4.7 mm at the level of C1–T1 in our study. The distance from the midline to the DREZ decreased in the lower cervical spine. The longest distance from the midline was found at C2 and C3. In the same study, Kuba *et al*. found the longitudinal length of the DREZ to be 6–14 mm, and it decreased in the lower cervical spine [9]. Longitudinal length of the DREZ in our study was 4.3–17.7 mm. The longest longitudinal length of the DREZ was at the C5 level, and the shortest was at C2. From the C5 level, the longitudinal length of the DREZ was decreased in both rostral and caudal directions in our study.

Tanaka *et al*., in a study of 18 cadavers between the C4–T1, showed the length of dorsal rootlets gradually increased from the rostral to the caudal direction at the level of C5–C8, and the length of rootlets was 14–26 mm at C5–C8 rootlets [23]. Kuba *et al*. found the average length of the shortest and longest rootlets was increased in the lower cervical spine in 18 cadavers between C5–T1 (shortest length 2–21 mm, longest 11–29 mm) [9]. We found the shortest length to be 5–28 mm and the longest to be 6.8–30.3 mm. The length of posterior rootlets increased towards the lower cervical spine.

Sindou *et al*. reported the average number of rootlets to be 4 at C2–C4 and 6 at the C5–C8 dorsal roots [21]. In Tanaka *et al*.'s study, it was determined that each of the C5–C8 dorsal roots consisted of 8–12 bundles of rootlets [23]. Kuba *et al*. found the number of dorsal rootlets to be between 5–16, and it was decreased from the rostral to the caudal direction on 18 cadavers between C5–T1 [9]. Dorsal rootlets were found in 2–13 bundles at the level of C2–C8 in our study. The least number of rootlets was found at C2 and the most at C6, C7 and C8. Our results showed that the average number tended to decrease in the upper cervical spinal cord.

Intersegmental anastomosis is one of the important factors to consider in the diagnosis of spinal cord disorders. Some investigators have reported intersegmental anastomoses in the cervical dorsal roots. It is not always possible to localize the level of cervical pathology accurately on the basis of clinical signs and symptoms [10, 14–16, 19]. If a cervical root is injured, small segments of neigbouring roots may be injuried as well. For this reason, clinical localization might occur one segment above or below the true pathological localization [10]. These observations may explain the clinical variation and overlapping sensory symptoms caused by nerve root compression in the cervical spine [3, 9, 10, 14, 19, 23]. Weigner, in 1901, conducted the first anatomical study which determined the anastomoses between the upper cervical dorsal roots and spinal accessory nerve [10, 16, 19]. Schwartz (1956) showed 1–6 anastomoses between the dorsal rootlets, and Pallie (1959) showed 3–8 anastomoses [15, 19]. Schwartz found anastomoses between the cervical dorsal roots, and in most cases a connection was observed between C6 and C7. Perneczky *et al*., in a study on 40 cadavers, observed in most cases a connection between C6 and C7 [16]. Marzo *et al*. found far fewer connections between C7–C8 and C8–T1 and the most at C5–C6 on 54 cadavers studied between C2–T1 [10]. Kuba *et al*. found the most connections between C5–C6 and fewer between C8–T1 on 18 cadavers studied between C4–T1 [9]. Tanaka *et al*. found a high incidence of intradural connections among the dorsal rootlets of C5–C6 and C6–C7 segments and far less at C8–T1 on 18 cadavers between the C4–T1 [23]. In our study, the most anastomoses were found between the cervical dorsal roots at C6–C7 (18.3%) and C5–C6 (16.9%), and far fewer connections were found between C8–T1 (7%). There were 73 connections on the right and 69 on the left. The connections between the dorsal rootlets were mostly between the C6–C7 and C5–C6. Therefore, neurological, physiological and radiological findings were carefully examined together for the pathology at these levels. Symptoms might not demonstrate the true pathological level; thus, the surgeon should also examine one level higher and lower.

Conclusions

Understanding the microanatomy of the dorsal cervical rootlets and DREZ is important in the surgical attempts in this region such as the DREZ operation. We emphasize that neurosurgeons must have a thorough knowledge of the microsurgical anatomy and measurements of the dorsal cervical rootlets and DREZ.

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Comments

This paper concerns a detailed micro-anatomical study of the dorsal cervical rootlets and dorsal root entry zone. The information provided by this accurate analysis can make a useful contribution to the understanding and to the treatment of cervical myeloradiculopathies. The knowledge of the anatomical variability of the cervical rootlets, obtained with microdissection technique, is in fact an essential prerequisite in the surgical planning and treatment of cervical disease, particularly during DREZ operations. The study is conducted with care and analyses all the anatomical aspects of the region: morphology, distance from the midline, length and number of the rootlets and intersegmental anastomoses. This is an interesting study, well organised and rigorous in the experimental setting. The results obtained are compare with those reported by the relatively scarce literature so far available, and represent a valuable tool for the microsurgical approach to the cervical DREZ.

Massimo Scerrati
Ancona, Italy

This is a detailed anatomical study of the dorsal cervical roots with precise data that might be added to the existing literature and be helpful for a variety of specialists in neurology, clinical neurophysiology imaging and surgery. Sometimes there are (apparent) discrepancies between clinical symptoms and signs and/or electrophysiological (EMG) findings on the one hand and site of pathology on the other. This can be explained by the differences in levels between DREZ and exit of the corresponding root from dural sheath and foramen; the length of dorsal root is longer at the lower cervical levels. Also length of DREZ is longest at C5. Even more so there are distribution re-arrangements through interrootlet and interradicular anastomoses, as pointed out by the authors.

Accurate knowledge of root anatomy may be useful for Imaging specialists, especially when they have to interpret MRI or iodine-CT of spinal cord and spinal roots. Of course surgeons dealing with spine and spinal cord surgery should be aware of the precise microsurgical anatomy. Therefore the authors of this work should be acknowledged for their fine study.

Marc Sindou
Lyon

Correspondence: Dr. Ayse Karatas, Department of Neurosurgery, Helsinki University Central Hospital, Topeliuksankatu 5, 00260 Helsinki, Finland. e-mail: ayse.karatas@hus.fi