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A cadaveric study of the cervical nerve roots and spinal segments

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Abstract

Purpose The purpose of this study was to anatomically measure the width of the cervical nerve root and spinal cord segment in addition to clarifying the anatomical characteristics of the cervical nerve root.

Methods We assessed 132 cervical nerve roots obtained from 11 cadavers. A total of 11 cervical spines from C3 to C8 were directly evaluated using digital calipers. The patients from whom the cadaveric specimens were obtained ranged from 79 to 90 years of age at the time of death. Four measurements were taken: the width at the entry of the spinal nerve in the vertebral foramen (WE), the maximum width of the spinal nerve (MW) and the length of the spinal segment on the ventral (LV) and dorsal rootlets (LD).

Results The mean values of the WE from C3 to C8 were 5.5, 5.6, 6.0, 5.8, 4.8 and 4.3 mm, respectively. The value of C8 was significantly smaller than that of C3, C4, C5 and C6. The mean values of the MW from C3 to C8 were 5.6, 6.0, 6.4, 6.7, 6.3 and 6.0 mm, respectively. The mean values of the LV from C3 to C8 were 12.1, 12.5, 12.6, 12.7, 11.8 and 10.6 mm, respectively. The value of C8 was significantly narrower than that of C4, C5 and C6. The mean values of the LD from C3 to C8 were 12.1, 13.3,

13.6, 12.2, 11.0 and 10.6 mm, respectively. The value of C8 was significantly narrower than that of C4 and C5.

Conclusions We anatomically measured the width of cervical nerve roots and spinal segments. The spinal segment of C8 was significantly narrower than some of the roots located in the middle of the cervical spine, and this characteristic continued to the entry of the root in the vertebral foramen, although the difference disappeared at the maximum width point of the root.

Keywords Anatomy · Cervical nerve root · Spinal segment

Introduction

It is necessary to know the detailed anatomical information of the spinal cord as well as the nerve root in order to make a clear diagnosis and select the suitable treatment for cervical spine disorders. Moreover, in recent years, the use of posterior instrumentation, such as fixation with lateral mass screws and pedicle screws, has become popular for treating unstable cervical spines resulting from trauma, spinal tumors and degenerative disorders. However, there are several potential risks for the spinal cord, in addition to vertebral artery and nerve root injury, associated with screw fixation.

Many anatomical studies on the cervical nerve root have been conducted; however, most authors evaluated the length and angle of the nerve root or rootlet. Although some authors [1–3] assessed the diameter of the nerve root using ultrasonography and magnetic resonance imaging (MRI), to our knowledge, there are no previous reports describing the relationship between the width of the

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cervical nerve root and each spinal segment using cadavers. The purpose of this study was therefore to anatomically measure the width of the cervical nerve root and spinal cord segment, in addition to clarifying the anatomical characteristics of the cervical nerve root.

Materials and methods

The present report details the quantitative surface anatomy of the craniocaudal cervical nerve root and each spinal segment. This information was obtained based on a study of 132 cervical nerve roots of 11 formalin-fixed Japanese cadavers (two males and nine females). A total of 11 cervical spines from C3 to C8 were evaluated directly using digital calipers. C1 and C2 nerve roots were excluded, because we could not find the original structure in some of the roots. The patients from whom the cadaveric specimens were obtained ranged from 79 to 90 years of age at the time of death (mean age 82 years) and had no gross deformities, such as scoliosis or kyphosis. The cervical spines were harvested from the cadavers. The C3–C8 nerve roots were exposed from behind the neck, after which the nerve roots were opened from the vertebral canal as far as the foramen exit site, and the thickness of each nerve root was measured. Next, the dura mater and spinal cord were cut caudal to the C8 spinal segment and then rolled up from the caudal end, after which the dura mater was cut open to measure the spinal segment. Paired structures were measured bilaterally. The linear measurements obtained using digital calipers were accurate to 0.01 mm. All parameters were measured three times by the first author (R.K.), and the mean was used as the final value. The research protocol for this study was approved by our Institutional Review Board.

Four measurements were taken: the width at the entry of the spinal nerve in the vertebral foramen (WE), the maximum width of the spinal nerve (MW, Fig. 1a) and the length of the spinal segment on the ventral rootlets (LV) and dorsal rootlets (LD, Fig. 1b).

The mean value and standard deviation for each parameter were calculated. To estimate the differences between the width of the nerve or spinal segment across all measured levels, a one-way analysis of variance (ANOVA) with Scheffe's test was used. Statistical significance was considered to be present at $P < 0.05$. All statistical analyses were conducted using the Statistical Package for the Social Sciences software program (version 21.0 J; SPSS, Chicago, IL, USA).

Results

The results for various parameters from C3 to C8 are shown in Table 1. The mean values of the WE from C3 to C8 were 5.5, 5.6, 6.0, 5.8, 4.8 and 4.3 mm, respectively. The value of C8 was significantly smaller than that of C3, C4, C5 and C6. The value of C7 was also significantly smaller than that of C5 (Table 2). The mean values of the MW from C3 to C8 were 5.6, 6.0, 6.4, 6.7, 6.3 and 6.0 mm, respectively. The value of C6 was significantly wider than that of C3 (Table 2).

The mean values of the LV from C3 to C8 were 12.1, 12.5, 12.6, 12.7, 11.8 and 10.6 mm, respectively (Table 3). The value of C8 was significantly narrower than that of C4, C5 and C6 (Table 4). The mean values of the LD from C3 to C8 were 12.1, 13.3, 13.6, 12.2, 11.0 and 10.6 mm, respectively (Table 3). The value of C8 was significantly narrower than that of C4 and C5. The value of C7 was also significantly narrower than that of C4 and C5 (Table 4).

Fig. 1 **a** WE width at the entry of the spinal nerve in the vertebral foramen, MW maximum width of the spinal nerve, P pedicle, VA vertebral artery. **b** LV length of the spinal segment on the ventral rootlets, LD length of the spinal segment on the dorsal rootlets

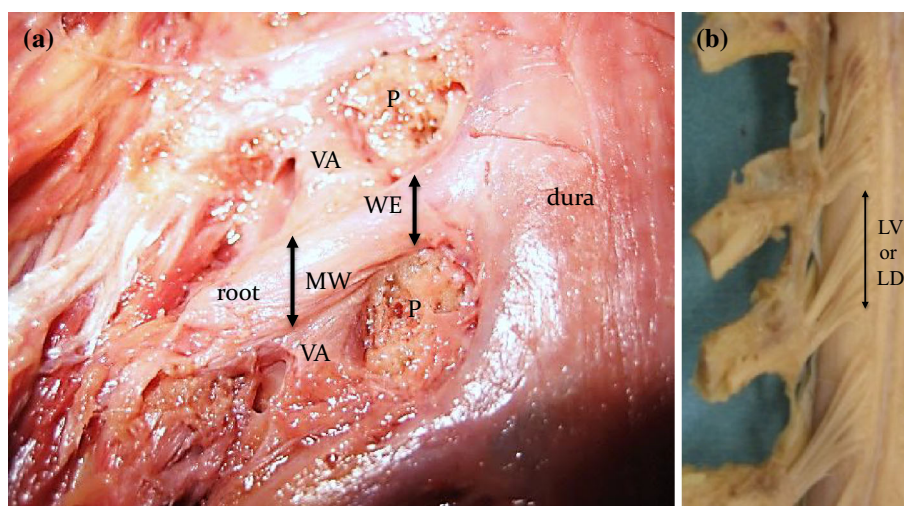


Table 1 Measurements of the dimensions of the cervical nerve root from C3 to C8

	WE (mm)	MW (mm)
C3	5.5 ± 0.9	5.6 ± 0.9
C4	5.6 ± 1.3	6.0 ± 1.1
C5	6.0 ± 1.1	6.4 ± 1.1
C6	5.8 ± 1.0	6.7 ± 0.9
C7	4.8 ± 0.8	6.3 ± 1.0
C8	4.3 ± 0.7	6.0 ± 1.1

WE width of the entry of the spinal nerve in the vertebral foramen, MW maximum width of the spinal nerve

Table 2 Multiple comparisons of each parameter (*P* value)

	WE	MW
C3/4	0.99	0.88
C3/5	0.62	0.28
C4/5	0.84	0.91
C3/6	0.96	<0.05
C4/6	0.99	0.46
C5/6	0.98	0.96
C3/7	0.57	0.42
C4/7	0.33	0.97
C5/7	<0.02	0.99
C6/7	0.12	0.91
C3/8	<0.02	0.80
C4/8	<0.01	0.99
C5/8	<0.01	0.96
C6/8	<0.01	0.58
C7/8	0.66	0.99

Bold values indicate better results

Table 3 Measurements of the dimensions of the spinal segment from C3 to C8

	LV (mm)	LD (mm)
C3	12.1 ± 1.2	12.1 ± 1.5
C4	12.5 ± 1.1	13.3 ± 1.6
C5	12.6 ± 2.8	13.6 ± 1.8
C6	12.7 ± 1.6	12.2 ± 1.8
C7	11.8 ± 1.6	11.0 ± 1.8
C8	10.6 ± 1.6	10.6 ± 2.0

LV length of the spinal segment on the ventral rootlets, LD length of the spinal segment on the dorsal rootlets

Discussion

Matsuoka et al. [1] examined the diameter of the C5, C6 and C7 nerve roots using ultrasonography in 35 healthy volunteers and noted that the mean value of the diameter was largest in the C7 nerve root. Takeuchi et al. [2] also

Table 4 Multiple comparisons of each parameter (*P* value)

	LV	LD
C3/4	0.99	0.41
C3/5	0.97	0.18
C4/5	0.99	0.99
C3/6	0.95	0.99
C4/6	0.99	0.54
C5/6	0.99	0.26
C3/7	0.99	0.59
C4/7	0.92	<0.01
C5/7	0.83	<0.01
C6/7	0.76	0.46
C3/8	0.16	0.18
C4/8	<0.05	<0.01
C5/8	<0.03	<0.01
C6/8	<0.02	0.12
C7/8	0.40	0.98

Bold values indicate better results

examined the diameter of these nerve roots using ultrasonography in live specimens and noted that the largest nerve root was at C6 and that the C5 nerve root was significantly thinner than the other nerve roots. They speculated that the reason for this difference was the use of different measurement methods and the small number of subjects. In the present study, we directly measured the width of the cervical nerve root from C3 to C8 and found that, at the entry of the each nerve root in the foramen, the width of the C8 nerve root was significantly smaller than that of the other nerve roots, except for C7, although these differences were not observed for the maximum width of the nerve root. Chiba et al. [4] determined the pattern of myotome innervation of the forearm muscles based on the clinical and electromyographic findings in patients with C8 or T1 lesions and noted C8-dominant innervation of the flexor carpi ulnaris, flexor digitorum profundus of the little finger and digit extensors. Furthermore, the first dorsal interosseous and abductor digiti minimi muscles appear to be innervated by both the C8 and T1 roots. Therefore, many forearm muscles were innervated by the C8 root. Karatas et al. [5] also noted that the maximum number of rootlets is at levels C6, C7 and C8; therefore, although the C8 nerve root included significantly less of the length of the spinal segment and width of the spinal nerve at the entry in the vertebral foramen, it included many rootlets at its maximum width. We speculate that this pattern of innervation in many muscles makes the difference at the entry point of the vertebral foramen disappear at the maximum width of the C8 root.

Regarding the width of the spinal segment, we found some previous papers [5–7] describing this issue. For

example, Shinomiya et al. [6] investigated the width of the spinal segment from C5 to C8 using cadavers and noted that the width of the C6 was the widest, while that of C8 was the narrowest, and that the widths of C5 and C6 were significantly wider than those of C7 and C8. Karatas et al. [5] also measured the widths from C2 to C8 using cadavers and found that the longest longitudinal length was at the C5 level, while the shortest was at the C2 level. In the current study, the width of the spinal segment of C8 was significantly narrower than that of some of the roots located in the middle cervical spine on both the ventral and dorsal sides. Furthermore, the width of C7 on the dorsal side was also significantly narrower than these nerve roots. Therefore, our findings are consistent with the results of Shinomiya et al. [6] However, regarding the occurrence of radiculopathy, we should therefore consider not only the width of the nerve root, but also the relationship to the surrounding bony anatomy.

To our knowledge, no previous reports have described the relationship between the width of each cervical nerve root and the spinal segment. The current results showed that the width of the spinal segment of C8 is significantly narrower than some nerve roots and that this characteristic continued to the entry site in the vertebral foramen, although the difference disappeared at the maximum width point of the root.

We should note some limitations of this study. Although we directly measured each segment of the nerve root, the number of cadavers was limited. Furthermore, we cannot measure each segment of the nerve root using fresh cadaver, since it is not easy to collect them in our country. This fact may therefore have affected our results. In addition, although Heinemeyer et al. [8] noted that the nerve size does not correlate with the subject's height, weight or age, we cannot provide standardized values based on the body size of the cadaver. Finally, since cervical spine anatomy (e.g., canal size) is known to differ between races, this may also have affected our results.

In conclusion, we anatomically measured the width of the cervical nerve root and spinal cord segment. The spinal segment of C8 was significantly narrower than some roots located in the middle of the cervical spine, and this characteristic continued to the beginning of the root, although the difference disappeared at the maximum width point of the root.

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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