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Morphology of Nerve Rootlets and Spinal Segments in the Lumbosacral Region: An Anatomical Study.

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ABSTRACT

The objective of the present study was to investigate the number of the spinal nerve rootlets and to determine the length of the spinal segments in the lumbosacral region of the spinal cord. Meticulous dissection was performed to expose the nerve rootlets. The nerve rootlets were macroscopically counted in the lumbosacral region and also communications between the nerve roots. The length of the spinal segments was measured in the lumbosacral region using vernier caliper. The data was analyzed statistically. The mean number of dorsal rootlets of the fifth sacral segment was significantly less compared to L5, S1, S2 and S3 segments. The dorsal rootlets were found to be thinner than ventral rootlets in the lower segment, however the ventral rootlets tend be thinner in the higher segments investigated. The present study also observed that the mean length of the third lumbar segment was highest and thereafter the length reduced gradually until the fifth sacral segment. The mean number of dorsal rootlets was more compared to the ventral rootlets on both right and left sides. There was a highly significant difference in the mean number of ventral and dorsal nerve rootlets in all the spinal segments investigated, except for third lumbar segment on the right side and third and fourth lumbar segments on left side. The morphometric data of the present study will be enlightening to the orthopedicians and neurosurgeons during their surgical practice. The details are also required to the neuroscientists and the researchers.

Keywords: dorsal nerve roots, nerve root communication, spinal segment, ventral nerve roots.

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INTRODUCTION

The anatomy of the lumbosacral region of the spinal cord is of considerable significance due to its higher clinical relevance. Morphological studies using human cadavers and radio imaging techniques were focused mainly on the correlation between spinal segments and vertebral spines and also relations of spinal nerve roots with intervertebral discs. The lengthy spinal nerve roots of the lumbar and sacral region of the cord form 'cauda equina' on their way to respective intervertebral foramina. In addition to motor and sensory fibres these nerve roots also carry parasympathetic fibres to pelvic organs.

Information regarding the number of ventral and dorsal nerve roots in this region of the cord is inadequate. Kim et al., [1] presented their morphological study focusing relationship between cervico-thoracic regions of the spinal cord with vertebral bodies. In their study the number of spinal nerve roots, their entry and exit zones were measured. But it was confined only to the cervico-thoracic region of the cord. The anatomy of the lumbar dorsal nerve roots is important in understanding the low back pain-lumbar dorsal ramus syndrome [2]. In addition the entry zone of dorsal nerve roots into spinal cord is important as they carry several modalities of sensation which includes pain. The numbers of dorsal rootlets are not same for each spinal nerve. When patients with cancer, spinal cord lesions, peripheral nerve lesions don't respond to conservative treatment DREZotomy is considered to be the procedure which selectively destroys nociceptive fibres alone and preserves other sensations [3, 4]. Among the rootlets entering the spinal cord the medial rootlets carry touch and pressure sensation while lateral rootlets carry pain and temperature sensation. A sound knowledge of these dorsal entry zones in lower lumbar region is not adequately addressed. Hence in the present study we have evaluated the morphometric analysis of dorsal entry zone which is of surgical importance. Similarly the number of ventral nerve roots emerging from the spinal cord for each spinal nerve varies. Functionally in addition to motor fibres, they also carry preganglionic sympathetic fibres.

In addition to this the vertical length of the spinal segment in the lower lumbar and sacral region was measured. This portion of the spinal cord corresponds to T11 to L1 spines in adults. This portion of the spinal cord is mainly concerned with motor and sensory functions of the lower extremities and also certain pelvic organs, specially providing parasympathetic fibres. The S2, S3 and S4 regions of the spinal cord act as spinal micturition centre. In evaluating dysfunctions of pelvic organs, the knowledge about gross anatomy of the lower lumbar and sacral segments of the spinal cord is paramount.

One of the important aspects to consider in the detection of spinal cord disorders is the connection between adjacent spinal segments. Impingement and/or inflammation of nerve roots (ventral or dorsal) causes neurologic symptoms in the corresponding region (myotome or dermatome) supplied by the affected nerve root. This is referred as radiculopathy. In spite of having advanced techniques like magnetic resonance imaging (MRI), computed tomography (CT) and myelography which give better picture about the anatomical structure of the spinal nerve roots, at times the results achieved from these imaging techniques do not match with the EMG recordings [5, 6, 7]. Similar disparity was also present between myelographic studies and EMG findings with respect to the actual number and sites of roots avulsed. This is because of communication between adjacent spinal rootlets which is responsible for the differences between clinically estimated extent of radiculopathy vs. radiological findings. Hence a careful anatomical estimation of nerve root communication would provide better insight in understanding these clinical disparities in nerve root lesions.

The horizontal distance between right and left posterior nerve roots (entry zone) and also the horizontal distance between right and left anterior nerve roots (exit zone) were measured in this study. This provides information regarding the width of the posterior and anterior white column of the spinal cord respectively.

The morphological knowledge of the spinal nerve rootlets and the spinal segments is important to understand the pathophysiological conditions of the spinal cord. Due to this clinical implication, the present study was conducted by using the anatomical specimens. The objective of the present study was to investigate the morphological characteristics of spinal nerve rootlets and the spinal segments in the lumbosacral regions of the spinal cord.

MATERIALS AND METHODS

The present study included 6 adult human cadavers. The cadavers which exhibited, visible abnormalities of the vertebral column were excluded from the present study. The cadavers were fixed in 10% formaldehyde solution. The spinal cords were extracted from the cadavers by performing the meticulous dissection. (Fig. 1). Following observations (parameters) were considered.

- The numbers of rootlets (both ventral & dorsal) were carefully counted macroscopically. The counting was performed by the same person twice to avoid the inter observer error.
- The vertical lengths of the spinal cord segments were measured using vernier caliper. The length of each spinal cord segment was defined as the root attachment length plus the upper inter-root length (Fig. 2). The relation between the spinal segment and that of the number of rootlets were readily determined.
- Communication between the adjacent nerve roots
- The horizontal distance between right and left posterior nerve roots (entry zone) and also the horizontal distance between right and left anterior nerve roots (exit zone) were calculated for third lumbar (L3) and fifth sacral (S5) segments.

RESULTS

The present study observed that the mean number of ventral rootlets on both right and left sides did not show any consistency either in increasing or decreasing order. Even statistically no significant difference was observed, between mean number of ventral rootlets of all the segments investigated on both right (p=0.228) and left sides (p= 0.0297). The mean number of dorsal rootlets showed significant difference among the various segments on right side but not on the left side (p=0.0954). The mean number of dorsal rootlets of the fifth sacral segment was significantly less compared to S1 (p<0.001), L5 & S3 (p<0.01) and S2 (p<0.05) segments.

Table 1: Mean number of spinal nerve rootlets in the lumbosacral region of the spinal cord. Values are expressed as mean number ±SE (n=6). Comparison between number of ventral Vs dorsal rootlets, **=p<0.01, ***=p<0.001

Spinal segment	Right side		Left side	
	Ventral roots	Dorsal roots	Ventral roots	Dorsal roots
L3	3.83±0.6	4.33±0.33	3.66±0.42	4.33±0.61
L4	3.33±0.33	5±0.36**	3.66±0.49	4.5±0.50
L5	3.66±0.42	5.83±0.47***	3.66±0.42	5.5±0.34***
S1	3.33±0.33	6.16±0.47***	3.33±0.33	5.66±0.21***
S2	2.83±0.30	5.5±0.22***	2.82±0.16	5.66±0.42***
S3	3.16±0.47	5.83±0.40**	2.66±0.21	5.0±0.25***
S4	2.83±0.47	4.66±0.49**	2.66±0.33	4.16±0.47***
S5	2.33±0.21	3.5±0.34***	2.33±0.21	4.16±0.79***

Table 2: Mean horizontal distance between the right and left entry zone (posterior nerve roots) and exit zone (anterior nerve roots). Values are expressed in cm ± SE

Third Lumbar segment (L3)		Fifth Sacral segment (S5)	
Posterior entry zone	Anterior exit zone	Posterior entry zone	Anterior exit zone
0.75±0.07	0.66±0.04	0.98±0.60	0.26±0.02

The mean number of dorsal rootlets was more compared to the ventral rootlets on both right and left sides. The dorsal rootlets were found to be thinner than ventral rootlets in the lower segment, however the ventral rootlets tend be thinner in the higher segments investigated (Fig. 1). There was no significant difference observed between the mean number of ventral and dorsal rootlets of the right side with that of the left side (p>0.05) in all the segments evaluated. However there was a highly significant difference (p<0.001) in the mean number of ventral and dorsal nerve roots in all the spinal segments investigated, except for third lumbar segment on the right side and third and fourth lumbar segments on left side (Table 1). The coccygeal segment did not present any ventral rootlets, but there was a single dorsal root on each side in all the spinal

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cords examined (Fig. 4). The present study also observed that the mean length of the third lumbar segment was highest and thereafter the length reduced gradually from third lumbar to fifth sacral segment (Fig. 3).

In addition to these findings it was also observed that adjacent nerve roots are connected to each other. Such nerve root communication was highest between the dorsal nerve roots compared to the ventral nerve roots. On the dorsal aspect communication between S1 and S2, followed by S3 and S4 were maximum. On the ventral aspect such communication was highest between S4 and S5 nerve roots.

Figure 1: Human cadaveric spinal cord showing the spinal nerve rootlets (segregated and bundled).

Figure 2: Measurement of the spinal segments using digital Vernier Caliper

Figure 3: Mean length of the spinal segment in the lumbosacral region of the spinal cord. Values are expressed as mean length in mm ±SE (n=6)

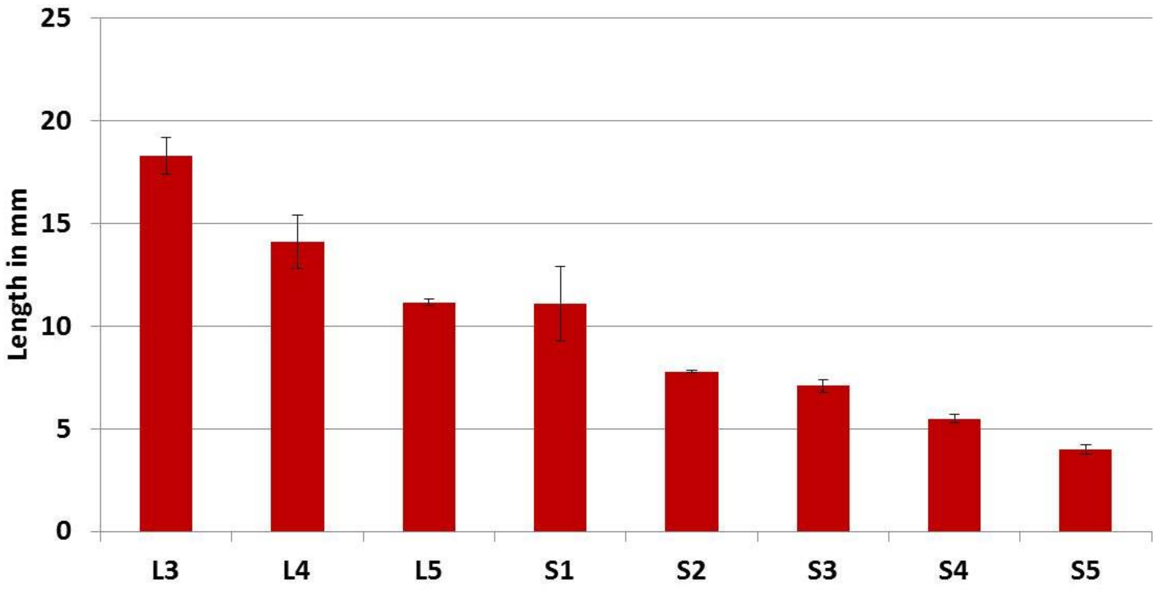
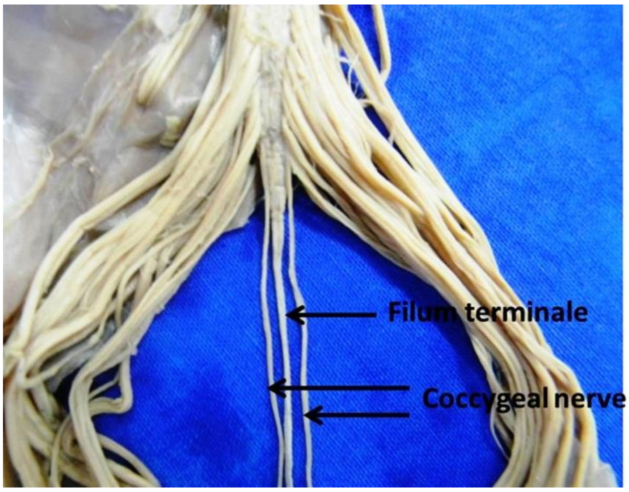


Figure 4: Distal end of the human cadaveric spinal cord, the filum terminale and the coccygeal nerves are shown.



The mean horizontal distance between right and left posterior nerve roots (entry zone) was 0.75cm (±0.07) at the level of L5 segment. At the level of S5 segment, the mean distance was 0.98 cm (0.60). These two values did not differ significantly. The mean distance between right and left anterior nerve roots (exit zone) was 0.66cm at the level of L5 segment. At the level of S5 segment, the mean distance was 0.26 cm (Table-2). This indicates, towards the terminal portion of the spinal cord the right and left ventral nerve roots appear more towards the midline.

DISCUSSION

The clinical significance of the morphometry of spinal segments has been well described [6]. Based on the morphometric data, the possibility of pathological conditions of the spinal cord like the compression or atrophy can be diagnosed after comparing with the normal morphometric data of the spinal segment [8]. It has been discussed that the quantitative distance and the spinal cord regeneration are related [9]. The selective sacral roots rhizotomy is the commonly employed method to treat neurogenic bladder in spinal cord injury. The procedures like sacral posterior rhizotomy and the sacral anterior roots stimulation require the basic anatomical knowledge about the lumbosacral nerve rootlets [10]. The morphological knowledge of the spinal nerve rootlets will help in understanding neurological complications associated with spinal cord injuries. The morphological knowledge of the nerve rootlets helps in the understanding, myelopathy due to pathologies of spinal cord and the radicular pains. It has been described that, it is hard to standardize the anatomy of the spinal nerve rootlets due to their variation in shape and size [11].

The present study examined the nerve rootlets of the lumbosacral region and their number. The spinal segment vertical length was also determined. It was observed that the dorsal rootlets were higher in number in comparison to the ventral rootlets. It was also observed that the nerve rootlets of the right and left sides were not originating at the similar level within the spinal segment. There is some difference within a spinal segment on its right and left sides with respect to the origin of the nerve rootlets. This may lead to the change in the dermatome with respect to the right and left lower limbs.

The present study observed that the spinal segment vertical length was longer in the L3 segment compared to lower segments investigated. The length is least in the S5 segment. There was a gradual decline in the length of the each segment from L3 to S5. The L4, L5 and S1 spinal segments were longer because of their contribution in the formation of the lumbar and sacral plexus.

Majority of the earlier studies with respect to communication between the spinal nerve roots were confined to cervical and thoracic region [7, 12, 13]. In the present study we also observed more number of communications between dorsal nerve roots compared to ventral nerve roots. On the dorsal aspect communication between S1 and S2, followed by S3 and S4 were maximum. The different clinical manifestations presented by different patients can be explained by these dorsal nerve root communications. At times this may confuse physicians with unexpected findings of altered sensory dermatome levels different from the usual pattern of segmental innervation because of these communications. These communications should be identified before performing intradural rhizotomies or else their functional contributions will be missed. Awareness about the communications between the dorsal rootlets of the spinal nerves would immensely help the clinicians to accurately identify the level of pathology on the basis of clinical signs and symptoms [14, 15]. Due to these communications, when a dorsal rootlet is injured, small segments of the adjacent rootlets may be involved too. Because of this, clinical localization may be done one segment above or below the pathological condition. Imaging techniques are unable to show these communications as yet. Therefore, the present study aims to alert clinicians of such communications.

The anterior exit root zone progressively moved medially as we traced caudally in the sacral region. The mean distance between right and left anterior exit zone was 0.66 cm at L3 and 0.26 cm in S5 segments. This is owing to the narrowing of the ventral horns of the spinal cord in the distal sacral segments. The medialization of anterior exit zone was observed before in the studies confined to the cervical region [16]. Herniation of intervertebral disc in medial direction can compress these anterior exit zone rootlets and cause radicular pain even without stenosis of intervertebral foramina. The posterior nerve root entry zone did not show any statistical difference between L3 and S5 segment, but the mean distance was more than that of anterior exit zone. This is owing to the large posterior horns of the spinal cord in the sacral region of the spinal cord.

CONCLUSION

We believe that the morphometric data of the present study will be enlightening to the orthopedicians and neurosurgeons during their surgical practice. The details are also required to the neuroscientists and the researchers. This will help in the standardization of neurosurgical technique and would help in comparing the studies from different geographic locations. The knowledge is essential to understand the pathophysiology of the nerve root compression and its consequences. The limitation of the present study is the smaller sample size of the cadavers studied. The data may be more accurate with the larger sample size. Future implication of the present study would include studying the nerve rootlets by looking at the MRI films. All the spinal segments in the cervical, thoracic, lumbar and sacral region of the spinal cord can be examined.

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