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Original Article

Examination of the Level of Conus Medullaris Termination Using Magnetic Resonance Imaging

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ABSTRACT

Introduction: Recognition of the level of the conus medullaris termination (CMt) is of clinical importance for avoiding iatrogenic injuries during spinal anesthesia and lumbar puncture. Although CMt levels have been examined in a variety of studies, they vary in classical textbooks and literature studies. The aim of this study was to investigate the level of CMt and its correlation to gender, age, and body mass index (BMI) using magnetic resonance imaging (MRI) in healthy individuals and those with lumbar disc herniation.

Methods: The lumbar MRIs of 341 subjects, including healthy individuals (F: 123, M: 68) and those with lumbar disc herniation (F: 105, M: 45), were retrospectively examined, and the CMt levels were determined.

Results: It was found that CMt levels were most commonly located at upper 1/3 of the L1 vertebral body in both healthy individuals and those with disc herniation groups. No statistically significant difference was observed between the two groups evaluated. In addition, no significant mean level of CMt, weight, height, and BMI difference existed between the two groups.

Conclusion: In the literature, the highest level of CMt is seen as being at the intervertebral disc between T11 and T12 vertebrae, while the lowest level of the CMt is seen as being at lower 1/3 of the L3 vertebral body. Consequently, we are of the opinion that the L3-4 or L4-5 intervertebral spaces should be preferred to lower the complication rate in procedures such as spinal anesthesia and lumbar puncture.

Keywords: Conus medullaris, level of conus medullaris termination, magnetic resonance imaging

INTRODUCTION

The spinal cord extends from the foramen magnum to the sacrum in the fetus at the beginning of the second trimester and, subsequently, ascends.[1–3] At the time of birth, the level of the conus medullaris termination (CMt) is at the L2 vertebral body or above.[3] In its final position, it is generally located around the L1 vertebral body during the adult life.[4] This change is explained by the fact that the CMt does not truly "*ascend*" within the vertebral canal and that there is a differentially increased growth of the vertebral column (more rapid) relative to the spinal cord (slower).[1]

Recognition of the CMt level is of clinical importance for avoiding iatrogenic injuries during spinal anesthesia, lumbar puncture, and tethered cord syndrome.[5] Diagnostic lumbar puncture is one of the invasive tests frequently used in medicine.[6] Although serious complications are rarely encountered during this procedure, many temporary or permanent damages may occur.[7–9] More dramatically, complications with fatal outcomes have also been reported in the literature.[10]

One of the most important concerns during the needle placement for the spinal anesthesia is the damage of the conus medullaris (CM).[11] Damage to the spinal cord can be caused by incorrect identification of the lumbar vertebrae.[7,8] On the other hand, even if the lumbar space is correctly identified, patients with lower CMt levels can be expected to be at higher risk of damage to the CM.[11] Manzone et al.[3] stated that the normal rate of medullary ascent during the fetal period until reaching its final level has not been fully clarified.

Because of its clinical importance, the level of CMt has been examined in many previous studies. In these previous studies, it has been examined using ultrasounds,[12–16] magnetic resonance imaging (MRI),[3,5,11,17–42] cadavers,[43–47] both cadavers and MRI,[48–51] intraoperative neurophysiological testing (mapping and monitoring),[52] fetus MRIs,[1,53] and a combination of cadaver dissection, ultrasonography, and MRI.[54] By the same token, it is believed that the actual position of CMt is probably better assessed using MRI than cadavers.[11,34] Furthermore, CMt levels have been studied in various pathologies, such as adolescent

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idiopathic scoliosis as a peripheral neuropathy,[20] lumbar spinal stenosis,[18] ankylosing spondylitis,[31] skeletal dysplasia,[35] severe idiopathic scoliosis,[38] and Chiari I malformation.[40]

According to a study by Nasr,[50] although numerous MRI and cadaver studies about CMt levels have been carried out, a few studies have made comparisons in terms of age and gender. On the other hand, in the literature, the relationship between the level of CMt and the body mass index (BMI) has been evaluated in very few studies.[19,33] Moreover, Lin et al.[11] stated that despite the fact that disc herniation is common in the general population, the effect on the level of CMt of the disc herniation has not been well investigated.

The aim of this study is, therefore, to investigate CMt levels and their correlation to gender, age, and BMI using MRI in both healthy individuals and those with lumbar disc herniation.

METHODS

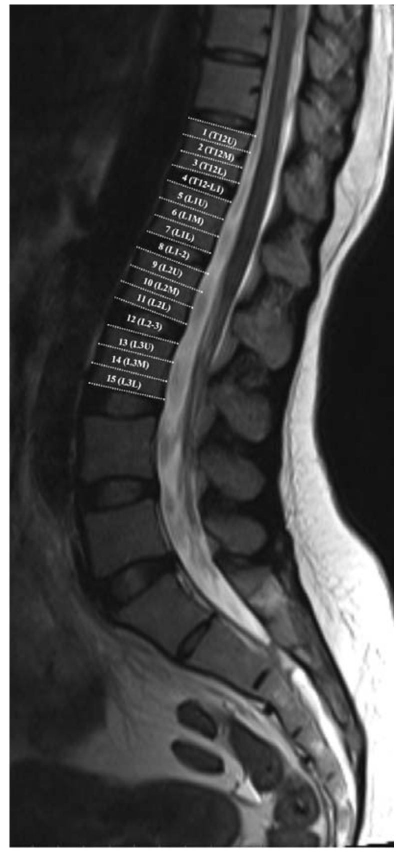
The images of patients admitted to the Physical Therapy and Rehabilitation Outpatient Clinic of Dr. Ersin Arslan Education and Research Hospital for the diagnosis and/or treatment of lower back pain, hip pain, and lumbar radiculopathy pain between 2017 and 2019 were retrospectively examined. Data regarding the diagnosis, gender, age, weight, and height of these patients were obtained from the patient registries and MRI reports. BMIs were calculated based on the height and weight information available. The approval of Gaziantep University Clinical Trials Ethics Committee was obtained before the study commenced (Decision date and number: 2019/14).

In this study, MRIs of 750 patients were evaluated. A total of 409 patients were excluded from the study due to MRIs featuring artifacts that would prevent the detection or measurement of the reference points, it not being possible to clearly observe the CMt in the MRI, the patient having a tumor, infection, ischemia, congenital spine abnormality, or deformity, there being missing or inconsistent demographic information, or the patient having previously undergone surgery in the lumbosacral area. Individuals with no pathologies who presented to the clinic without any complaint (they are considered as healthy individuals) and patients with protruding disc herniation were included in the study. One hundred ninety-one individuals (F: 123 and M: 68) were examined in the normal group, and 150 individuals were examined in the group diagnosed with protruding disc herniation (F: 105 and M: 45).

Main Points

- Recognition of the CMt level is clinical importance for avoiding iatrogenic injuries during spinal anesthesia, lumbar puncture and tethered cord syndrome.
- Although the levels of CMt have been examined in a variety of studies, the levels given in classical textbooks and the literature are very different.
- In the literature, the highest level of CMt is seen as being at the intervertebral disc between T11 and T12 vertebrae, while lowest level of it is at the L3L.
- We believe that the L3-4 or L4-5 intervertebral spaces should be preferred to lower the complication rate in procedures such as spinal anesthesia and lumbar puncture.

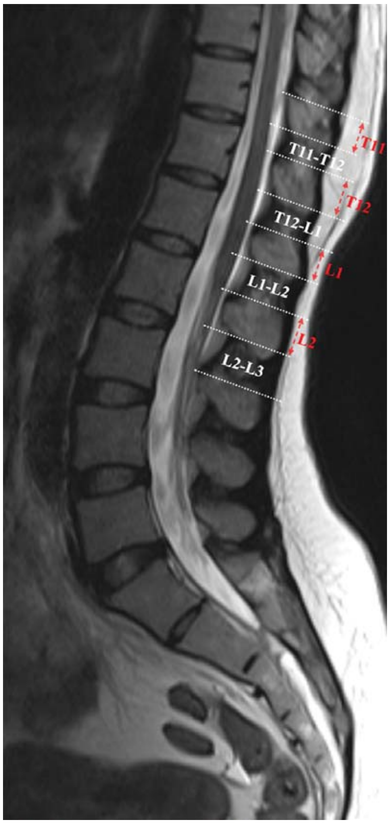
Figure 1. Demonstration of the method for determining the level of CMt with vertebral bodies and intervertebral discs.



MRIs were taken with a GE Signa (GE Medical Systems, Milwaukee, WI, USA) 1.5 Tesla instrument. The slice thickness was 5 mm in sagittal and 4 mm in transverse images. The T1 and T2 sequences of the images were examined using the RadiAnt DICOM Viewer 5.5.1 program. The levels of CMt were determined by being correlated with the transverse section and examined on the midsagittal section. All scans were obtained in the supine position. In each MRI used, the CMt level was clearly visualized on the midsagittal section.

The level of CMt was examined according to its relationship with adjacent vertebrae or intervertebral discs, as in the previous studies.[5,11,17,18,21] The level of CMt was defined at the level of the surrounding vertebrae or intervertebral discs. Each vertebral body at the level of CMt was divided into three equal parts (*U:* upper 1/3, *M:* middle 1/3, and *L:* lower 1/3). When the CMt level coincided with the intervertebral disc, it was considered a separate part. In other words, CMt level was determined at four different levels as three different parts of a vertebral body and an intervertebral disc (Figure 1). For statistical analysis, numbers

Figure 2. Demonstration of the method for determining the level of CMt with spinous processes and interspinous spaces.



1-15 were given from the upper 1/3 of the T12 vertebral body (T12U) to the lower 1/3 of the L3 vertebral body (L3L), similar to the study by Liu et al.[24] Additionally, using a transverse line from the level of CMt to the spinous process of the vertebrae, the level of CMt was also determined according to its relationship with the spinous process (Figure 2).

Statistical Analysis

Conformity to normal distribution of numerical data was tested using the Shapiro–Wilk test. The Student-t test was used to compare the normally distributed variables in two groups. Correlations between categoric variables were tested with the Chi-square test and correlations between numerical variables were tested with Pearson's correlation coefficient. SPSS 22.0 software package was used for the analyses (IBM SPSS Corp.; Armonk, NY, USA). $P < .05$ was considered significant.

RESULTS

The CMt levels of 228 females (mean age: 39.52 ± 11.10) and 113 males (mean age: 37.67 ± 12.23) between the ages of 18 and 66 were examined in both healthy individuals and those with disc herniation. No statistically significant difference existed between age and genders ($P = .164$). The mean level of CMt and mean values of the age, weight, height, and BMI of the individuals examined are given in Table 1. There was a statistical difference between the healthy individuals and those with disc herniation in terms of age ($P = .001$). No statistically significant difference at the level of CMt, weight, height, and BMI existed between the two groups ($P = .468$, .235, .094, and .060, respectively).

The mean value of the levels of CMt was 5.81 ± 2.26 in the healthy individuals and 5.63 ± 2.27 in patients diagnosed with lumbar disc herniation. It was found that CMt levels most commonly located at L1U with a standard deviation shorter than the height of the vertebral body. There was no statistically significant difference between the genders in terms of CMt levels (Table 2). Results of the CMt levels in both genders and in both groups are given in Table 3 and Figure 3.

In the healthy individuals, it was detected that there were no correlations between the level of CMt and weight and BMI, that there was a very weak positive correlation between the CMt level and age ($P = .017$, $r = 0.173$), and that there was a very weak negative correlation between the CMt level and height ($P = .017$, $r = -0.179$). This result demonstrates that the mean level of CMt tends to lower as age increases, and it tends to rise as height increases.

In the group of patients diagnosed with lumbar disc herniation, no correlations were detected between the CMt level and weight, height, and BMI values ($P = .309$, .747, and .201, respectively), while a weak positive correlation with age was observed ($P = .022$, $r = 0.188$). This result demonstrates that as the age increases, the level of CMt falls down.

Finally, using a transverse line from the level of CMt to the spinous process of the vertebrae, the level of CMt was also determined according to its relation with the spinous process. The highest level of CMt is seen as being at the level of the spinous process of T11 vertebrae, while the lowest level of the CMt is seen as being at the between the spinous processes of L2 and L3 vertebrae. The mean levels of CMt in both groups were at the level of spinous process of the L1 vertebrae. No correlations were detected between the level of CMt according to its relation with the spinous process and weight, height, and BMI values ($P = .450$, .353, and .186, respectively), while a weak positive correlation with age was observed ($P = .039$, $r = 0.169$), almost the same way with its relationship of the vertebral bodies and intervertebral discs. Additionally, a positive, very strong correlation was detected between the two methods ($P = 0.001$, $r = 0.853$).

DISCUSSION

Ko[55] stated that although the CM is located between the level of the T12-L1 intervertebral disc and L1-2 intervertebral disc, it contains approximately 10 spinal nerve pairs (L1-S5). Kingwell et al.[56] reported that the neurological structures affected by CM lesions are significantly different from those affected by cervical or thoracic spinal cord lesions. On the other hand, it is stated that although the literature on thoracic and lumbar spinal cord traumas are extensive, the number of studies investigating CM lesions is limited. Additionally, Kingwell et al.[56] stated that, in cases where CM lesions have been investigated, it is assumed

Table 1. The Level of CMt, Age, weight, Height, and BMI Values of the Healthy Individuals and Patients with Disc Herniation

	Healthy individuals				Patients with disc herniation			
Parameter	**M**	**F**	**T**	***P***	**M**	**F**	**T**	***P***
Level of CMt	5.56 ± 2.36	5.94 ± 2.20	5.81 ± 2.26	.291	5.31 ± 2.53	5.76 ± 2.15	5.63 ± 2.27	.266
Age	34.68 ± 11.20	37.07 ± 11.02	36.22 ± 11.11	.154	42.20 ± 12.43	42.38 ± 10.55	42.33 ± 11.10	.927
Weight (kg)	80.02 ± 12.46	70.08 ± 14.41	73.66 ± 14.52	.001*	76.82 ± 12.83	74.85 ± 12.18	75.44 ± 12.37	.372
Height (mm)	172.98 ± 5.97	160.40 ± 6.83	164.82 ± 8.88	.001*	171.18 ± 7.05	159.72 ± 6.01	163.22 ± 8.25	.001*
BMI (kg/m^2)	26.80 ± 4.28	27.26 ± 5.39	27.10 ± 5.02	.557	26.17 ± 3.83	29.43 ± 5.10	28.44 ± 4.97	.001*

*Significant difference.
BMI, body mass index; M, male; F, female; T, total; kg, kilogram; mm, millimeter; m: meter.

Table 2. A Comparison of the Mean Level of CMt Values Between the Group the Healthy Individuals and Patients with Disc Herniation

	F	**M**	***P***
Healthy individuals	5.94 ± 2.20	5.56 ± 2.36	.261
Patients with disc herniation	5.76 ± 2.15	5.31 ± 2.53	.266
Total	5.86 ± 2.17	5.46 ± 2.42	.125

M, male; F, female.

that the CMt at the level of L1 or L2 vertebrae despite its level being known to vary.

Procedures such as lumbar puncture, spinal, or epidural anesthesia should be performed taking the level of CMt into consideration.[5,24] It is essential to be familiar with the morphology and variations of CM to avoid puncturing the CM with the needle.[57] CM damage may result in complications including as pain,[8,58,59] loss of reflexes,[8] motor loss in the lower extremities,[8,60] urinary dysfunction,[8,58] sexual dysfunction,[56,58] loss of sensation,[8,60] dysesthesia,[8] paresthesia,[58] paraplegia,[60] drop foot,[8,9] lower motor neuron syndrome,[56] flaccid muscle tone,[56] atrophic changes,[56] and spinal cord ischemia.[61] Although these complications are generally temporary, it has been reported that permanent complications can occur.[7] Loss of sensation, loss of motor function, hypoesthesia, urinary dysfunction, loss of balance while walking usually heal within a few weeks[62] and drop foot, and hypoesthesia usually heal within a few months.[7] Additionally, pain, hypersensitivity, and paresthesia[63] are complications that are usually permanent. Moreover, Greaves[10] stated that fatal complications may also occur. Reynolds[8] reported seven different patients who were found to have suffered neurological damage following spinal and combined spinal epidural anesthesia. Reynolds[8] remarked that the needle administered to the spinal region should not be administered above the level of L3 vertebra. Despite the fact that most CM-related complications result from the procedure of the procedure at higher levels, it is also known that the level of CMt may be lower than expected. Actually, the lowermost levels of CMt were reported at L3U,[5,24,34] L3M,[64,65] and L3L[48] in healthy individuals. In the present study, the lowermost levels were detected at L3M in the healthy individuals and at L3L in the patients with disc herniation.

The information on the level of CMt differs between anatomy and neurology textbooks and the literature. In the textbooks, the mean levels of CMt are stated to be at L1M,[66] L1 or L2 vertebrae,[67–69] L1L,[70] L1 vertebrae,[71–73] L2 vertebrae,[74] and intervertebral disc between the L1 and L2 vertebrae.[75] However, mean levels of CMt were stated to be at the level of L1 vertebra in the 39th edition of *Gray's Anatomy*[76] and *Gray's Clinical Neuroanatomy*,[71] between the L1 and L2 vertebrae in the 40th edition of *Gray's Anatomy*,[77] and at the level of L1M in the 41st edition of *Gray's Anatomy*,[4] showing variations. In the literature, the level of CMt has been examined in many studies[5,11,17–19,21,24–31,33,34,36–38,45,48–51,78] (Table 4). While some of these studies[5,17,19,21,24,25,28,37,48–51] examined healthy individuals, some also included patients with pathologies such as lumbar spinal stenosis,[18] adolescent idiopathic scoliosis,[20] ankylosing spondylitis,[31] and Chiari I malformation.[40] Others compared healthy individuals with a variety of groups.[11,27] In these studies, a very wide range of levels of CMt were reported. The highest possible point of the level of CMt in the healthy individuals was reported by Sevinç et al.[36] and Demiryürek et al.[5] to be T11-12 intervertebral disc, and the lowest level of CMt was reported in the present study and by Kwon et al.[48] to be the L3L. In the literature, the level of CMt has not been detected to be lower than the L3 vertebra. We also think that, similarly to Kwon et al.[48] and Yedavalli et al.,[57] the L3-L4 or L4-L5 intervertebral spaces are more suitable for the lumbar puncture. There are mobile nerve roots in this region located in the cerebrospinal fluid. Therefore, the risk of injury from needle sting is low.[57]

Table 3. The Levels of CMt Values in the Healthy Individuals and Patients with Disc Herniation

		Healthy individuals			Patients with disc herniation		
Level no.	Level	M	F	T	M	F	T
1	T12U	3 (4.4%)	3 (2.4%)	6 (3.1%)	2 (4.4%)	3 (2.9%)	5 (3.3%)
2	T12M	3 (4.4%)	4 (3.3%)	7 (3.7%)	2 (4.4%)	5 (4.8%)	7 (4.7%)
3	T12L	7 (10.3%)	7 (5.7%)	14 (7.3%)	6 (13.3%)	6 (5.7%)	12 (8.0%)
4	T12-L1	9 (13.2%)	18 (14.6%)	27 (14.1%)	7 (15.6%)	17 (16.2%)	24 (16.0%)
5	L1U	11 (16.2%)	26 (21.1%)	37 (19.4%)	9 (20.0%)	17 (16.2%)	26 (17.3%)
6	L1M	13 (19.1%)	18 (14.6%)	31 (16.2%)	9 (20.0%)	16 (15.2%)	25 (16.7%)
7	L1L	9 (13.2%)	13 (10.6%)	22 (11.5%)	3 (6.7%)	16 (15.2%)	19 (12.7%)
8	L1-L2	7 (10.3%)	13 (10.6%)	20 (10.5%)	3 (6.7%)	16 (5.7%)	19 (12.7%)
9	L2U	4 (5.9%)	17 (13.8%)	21 (11.0%)	2 (4.4%)	6 (%)	8 (5.3%)
10	L2M	1 (1.5%)	3 (2.4%)	4 (2.1%)	1 (2.2%)	2 (1.9%)	3 (2.0%)
11	L2L	-	1 (0.8%)	1 (0.5%)	-	1 (1.0%)	1 (0.7%)
12	L2-L3	-	-	-	-	-	-
13	L3U	-	-	-	-	-	-
14	L3M	1 (1.5%)	-	1 (0.5%)	-	-	-
15	L3L	-	-	-	1 (2.2%)	-	1 (0.7%)
Total		68 (100%)	123 (100%)	191 (100%)	45 (100%)	105 (100%)	150 (100%)

M, male; F, female; T, total.

These intervertebral spaces can be found through palpation, following the line starting from the top of the iliac crest and intersecting with the spine at a straight angle.[78]

Relationship between the CMt Level and Age

Whereas many studies[5,17,22,24,25,27,29,33,34,48–50] report not having found any correlation between the level of CMt and the age, Ugale et al.[41] reported that the level of CMt tends to rise with age. Karabulut et al.[21] reported that the CMt level tends to rise with age in the females, while no correlation with the age was found in the males. Conversely, it was found in some studies[28,37,78] that the level of CMt falls down as age advances, similarly to the present study. This probably results from the fact that the nucleus pulposus undergoes dehydration and degeneration, or the height of the vertebral body decreases with age. Nevertheless, the level of CMt displayed a significantly positive but very weak correlation with the age in the present study, similar to the previous studies.[37,78] Therefore, we believe that larger populations should be studied to better understand the correlation between age and CMt level.

Relationship between the CMt Level and Gender

Lin et al.[11] stated that, interestingly, all reports on spinal anesthesia-related spinal cord damage published to date have included female patients, and that this is probably due to the fact that females are affected more by changes in bone density as a result of vertebral body pathologies. Similar to this opinion, all of the seven complications reported by Reynolds[8] were detected in females. Lin et al.[11] detected no statistically significant correlation between gender and level of CMt in healthy individuals and patients with lumbar vertebral compression fracture. However, they detected a statistically significant difference in patients with disc herniation, disc bulging, and thoracic vertebral compression fracture and found that the average level of CMt was lower in females. Additionally, some other studies[5,24,32,37,46,64,65,78] determined that the average level of CMt was significantly lower in females statistically. On the other hand, many studies[17,19,22,25,27–29,33,34,36,44,45,48–50] did not reveal any statistically significant difference between the genders, as is the case with the present study examining both healthy individuals and patients with disc herniation. Mbaba et al.[25] reported that the probable reason for these variations are to be as the different sample sizes studied and geographical variations in the literature.

Relationship between CMt Level and BMI

To the best of our knowledge, there are very few studies[19,33] in the literature that examine the relationship between the level of CMt and BMI. In the present study, there was no significant relation between BMI and the level of CMt, similar to

Figure 3. Demonstration of the levels of CMt (a: T12U, b: T12M, c: T12L, d: T12-L1, e: L1U, f: L1M, g: L1L, h: L1-L2, i: L2U, j: L2M, k: L2L, l: L3M, m: L3L).

the results obtained by Binokay et al.[19] and Rostamzadeh et al.[33] Furthermore, Schlotterbeck et al.[79] reported that an increase in BMI did not affect the success of lumbar puncture. On the other hand, care should be taken while performing lumbar puncture in obese individuals, as the landmarks used to determine the anatomy of the lumbar region, such as the Tuffier's line and the spinous process, may not be clearly defined.[78,80]

Relationship between CMt Level and Disc Herniation

The level of CMt has been examined in many pathological cases in the literature. The level of CMt may extend to L4

Table 4. A Comparison of the Level of CMt Values with Those in the Literature

Study	Specimen	Gender	n	Age	Level no	Mostly	T11–12	T12U	T12M	T12L	T12–L1	L1U	L1M	L1L	L1–2	L2U	L2M	L2L	L2–3	L3U	L3M	L3L
Demiryürek et al.[5]	MRI	M	296	20–69		T12–L1	-	2 (0.68%)	7 (2.36%)	14 (4.73%)	83 (28.04%)	40 (13.51%)	49 (16.55%)	37 (12.5%)	50 (16.89%)	6 (2.03%)	2 (0.68%)	3 (1.01%)	1 (0.34%)	2 (0.68%)		
		F	343			L1–L2	1 (0.29%)	-	4 (1.17%)	10 (2.92%)	60 (17.49%)	41 (11.95%)	56 (16.33%)	61 (17.78%)	70 (20.41%)	23 (6.71%)	10 (2.92%)	6 (1.75%)	1 (0.29%)	-		
Lin et al.[11]	MRI*	M + F	65	38 ± 9.7	6.5 ± 1.85			-														
	MRI†	M + F	130	54 ± 13.9	6.6 ± 1.96																	
Liu et al.[24]	MRI‡	M + F	585	20–74	6.74 ± 2.08****			1 (0.17%)	3 (0.51%)	21 (3.59%)	64 (10.94%)	90 (15.38%)	94 (16.07%)	103 (17.61%)	82 (14.02%)	74 (12.65%)	31 (5.30%)	13 (2.22%)	8 (1.37%)	1 (0.17%)		
	MRI□				6.55 ± 2.09****			1 (0.17%)	9 (1.54%)	26 (4.44%)	63 (10.77%)	102 (17.44%)	87 (14.87%)	99 (16.92%)	92 (15.73%)	56 (9.57%)	35 (5.98%)	11 (1.88%)	3 (0.51%)	1 (0.17%)		
	MRI**				6.81 ± 2.11****			1 (0.17%)	6 (1.03%)	21 (3.59%)	51 (8.72%)	95 (16.24%)	99 (16.92%)	93 (15.90%)	79 (13.50%)	81 (13.85%)	37 (6.32%)	13 (2.22%)	9 (1.54%)	-		
Saifuddin et al.[34]	MRI	M	231	46 (16–85)	7.1****				9 (1.70%)	20 (3.97%)	33 (6.55%)	57 (11.31%)	69 (13.69%)	127 (25.2%)	82 (16.27%)	60 (11.9%)	27 (5.36%)	14 (2.78%)	5 (0.99%)	1 (0.2%)		
		F	273		6.6****																	
Karabulut et al.[21]	MRI	M	607	40.57 ± 15.38				1 (0.1%)	8 (1.0%)	6 (0.7%)	81 (7.8%)	132 (14.3%)	165 (17.9%)	142 (15.4%)	272 (29.5%)	54 (5.9%)	47 (5.1%)	13 (1.4%)	1 (0.1%)			
		F	314	43.72 ± 15.01																		
Morimoto et al.[27]	MRI*	M + F	310	15–44		L1M		2 (0.7%)	2 (0.7%)	12 (3.9%)	55 (17.7%)	63 (20.3%)	65 (21%)	54 (17.4%)	41 (13.2%)	11 (3.6%)	5 (1.6%)	-				
	MRI††		28			L1U		-	1 (3.6 %)	4 (14.3 %)	8 (28.6%)	10 (35.7%)	3 (10.7%)	1 (3.6%)	-	1 (3.6%)	-	-				
	MRI‡‡		41			L1L		-	-	1 (2.44 %)	2 (4.88%)	4 (9.76%)	3 (7.32%)	12 (29.27%)	6 (14.63%)	6 (14.63%)	6 (14.63%)	1 (2.44%)				
Kwon et al.[48]	MRI*	M	140	42.3 ± 16.0		L1M				1 (0.5%)	28 (13.3%)	32 (15.2%)	52 (24.8%)	45 (21.4%)	34 (16.2%)	6 (2.9%)	9 (4.3%)	3 (1.4%)	-	-	-	-
		F	108																			
	Cadaver*	M	49	56.0 ± 14.9		L2U				2 (1.7%)	8 (6.8%)	6 (5.1%)	11 (9.3%)	11 (9.3%)	16 (14.0%)	23 (19.0%)	14 (12.0%)	10 (8.5%)	11 (9.3%)	1 (0.8%)	4 (3.4%)	1 (0.8%)
		F	18																			
Arai et al.[17]	MRI*	M + F	602			L1M																
Moussallem et al.[29]	MRI*	M	70	≥18		L1U		1	5	7	7	24	5	6	12	3						
		F	71					2	1	5	12	22	15	5	6	3						
Rostamzadeh et al.[33]	MRI*	M	199			L1L																
		F	151																			
Mbaba et al.[25]	MRI*	M	92	39.56		L1M			4 (4.17%)	-	1 (1.04%)	11 (11.46%)	35 (36.47%)	14 (14.59%)	3 (5.13%)	13 (13.54%)	11 (11.46%)	3 (3.13%)	-	1 (1.04%)		
		F	85						3 (3.13%)	3 (3.13%)	2 (2.5%)	7 (8.75%)	39 (48.75%)	4 (5.0%)	6 (7.5%)	8 (10%)	5 (6.25%)	3 (3.13%)	-			

Table 4. (Continued)

Study	Specimen	Gender	n	Age	Level no	Mostly	T11–12	T12U	T12M	T12L	T12–L1	L1U	L1M	L1L	L1–2	L2U	L2M	L2L	L2–3	L3U	L3M	L3L
Nasr[49]	MRI*	M	100	43.2 ± 11.9		L1L																
		F	100	39.8 ± 12.1		L1–L2																
	Cadaver*	M	40		L1L ± 1.91	L1L																
		F	20		L1L ± 1.87	L1L																
Nasr[50]	MRI*	M	100	43.2 ± 11.9		L1L																
		F	100	39.8 ± 12.1		L1–L2																
	Cadaver*	M	40		L1L ± 1.91	L1L																
		F	20		L1L ± 1.87	L1L																
Mourlion et al.[28]	MRI*	M	39	48.97 ± 14.66		L1L																
		F	38	45.57 ± 13.33		L1L																
Kim et al.[78]	MRI*	M	347	≥20		L1L																
		F	343			L1–L2																
Soleiman et al.[37]	MRI*	M	338	49.43 (7–85)	5.94	L1U																
		F	297		6.58	L1U																
Qu et al.[31]	MRI*	M	80	36.6 (17–57)		L1M		-	-	3 (3%)	6 (6%)	18 (18%)	22 (22%)	21 (21%)	19 (19%)	8 (8%)	2 (2%)	1 (1%)	-			
		F	20																			
	MRI†††	M	86	34.6 (17–65)		L1M		1 (1%)	1 (%1)	6 (6.3%)	13 (13.5%)	8 (8.3%)	22 (22.9%)	16 (16.7%)	16 (16.7%)	8 (8.3%)	3 (3.1%)	1 (1%)	1 (1%)			
		F	10																			
Sun et al.[38]	MRI*	M	58	14.9		L1L				2 (1.7%)	5 (4.2%)	18 (15%)	20 (16.7%)	36 (30%)	16 (13.3%)	13 (10.8%)	6 (5%)	3 (2.5%)	1 (0.8%)			
		F	62																			
	MRI□□□	M	32	14.7 (12–18)		L1L			1 (0.4%)	4 (1.7%)	7 (2.9%)	28 (11.7%)	41 (17.1%)	70 (29.2%)	43 (17.9%)	20 (8.3%)	18 (7.5%)	4 (1.7%)	4 (1.7%)			
		F	208																			
Sevinç et al.[36]	MRI*	M	157	45 ([18]–[80])		T12–L1	-	-	2 (1.3%)	4 (2.5%)	33 (21%)	16 (10.2%)	29 (18.5%)	19 (12.1%)	29 (18.5%)	12 (7.9%)	13 (8.3%)	-	-			
		F	207			L1–L2	1 (0.5%)	2 (1%)	1 (0.5%)	8 (3.9%)	18 (8.7%)	22 (10.6%)	38 (18.4%)	40 (19.3%)	49 (23.7%)	11 (5.3%)	15 (7.2%)		2 (1%)			

Table 4. (Continued)

Study	Specimen	Gender	n	Age	Level no	Mostly	T11–12	T12U	T12M	T12L	T12–L1	L1U	L1M	L1L	L1–2	L2U	L2M	L2L	L2–3	L3U	L3M	L3L
Binokay et al.[19]	MRI*	M	443	47.5 ± 16.5		L1M		8 (1.8%)	16 (3.6%)	42 (9.5%)	36 (8.1%)	76 (17.2%)	97 (21.9%)	76 (17.2%)	27 (6.1%)	33 (7.4%)	15 (3.4%)	11 (2.5%)	1 (0.2%)	5 (1.1%)		
		F	756	48.5 ± 14.5		L1M		5 (0.7%)	23 (3%)	61 (8.1%)	64 (8.5%)	125 (16.5%)	203 (26.9%)	132 (17.5%)	40 (5.3%)	42 (5.6%)	30 (4.0%)	22 (2.9%)	1 (0.1%)	8 (1.1%)		
Ba et al.[18]	MRI†††	M	124	48.8	6.84 ± 2.17****	L1L			7 (3%)	15 (6.4%)	31 (13.2%)	30 (12.9%)	16 (6.8%)	53 (22.6%)	37 (15.8%)	9 (3.8%)	8 (3.4%)	5 (2.1%)	16 (6.8%)	7 (3%)		
		F	110																			
Naqshi et al.[30]	MRI*	M + F	100	18–65		L1L					4 (4%)	10 (10%)	15 (15%)	38 (38%)	5 (5%)	14 (14%)	7 (7%)	6 (6%)	1 (1%)			
Moon et al.[26]	MRI	M + F	187	2–94		L1L		1	0	4	12	25	33	40	28	23	11	8	2			
Gatonga et al.[45]	Cadaver	M + F	112	20–80		L2U				(5.5%)	-	(12.7%)	(3.6%)	(18.2%)	-	(9.1%)	(20.0%)	(25.5%)		(3.6%)	(1.8%)	
Van Schoor et al.[51]	MRI□□		26	13–20		L1L																
	MRI***		55	21–29		L1L																
Present study	MRI*	M	68	34.68 ± 11.20	5.56 ± 2.36			3 (4.4%)	3 (4.4%)	7 (10.3%)	9 (13.2%)	11 (16.2%)	13 (19.1%)	9 (13.2%)	7 (10.3%)	4 (5.9%)	1 (1.5%)				1 (1.5%)	
		F	123	37.07 ± 11.02	5.94 ± 2.20			3 (2.4%)	4 (3.3%)	7 (5.7%)	18 (14.6%)	26 (21.1%)	18 (14.6%)	13 (10.6%)	13 (10.6%)	17 (13.8%)	3 (2.4%)	1 (0.8%)				
	MRI†	M	45	42.20 ± 12.43	5.31 ± 2.53			2 (4.4%)	2 (%4.4)	6 (13.3%)	7 (15.6%)	9 (20%)	9 (20.0%)	3 (6.7%)	3 (6.7%)	2 (4.4%)	1 (2.2%)	-	-	-	-	1 (2.2%)
		F	105	42.38 ± 10.55	5.76 ± 2.15			3 (2.9%)	5 (4.8%)	6 (5.7%)	17 (16.2%)	17 (16.2%)	16 (15.2%)	16 (15.2%)	16 (15.2%)	6 (5.7%)	2 (1.9%)	1 (1.0%)	-			

*Normal.
†Disc herniation.
‡Neural position.
□Flexion.
**Extension.
††Patients with sacralization of the fifth lumbar vertebrae.
‡‡Patients with lumbarization of the sacrum.
□□Adolescence.
***Early adulthood.
†††Thoracolumbar kyphosis.
‡‡‡Lumbar spinal stenosis.
□□□Adolescent idiopathic scoliosis.
****Standardization was ensured using numbers specified in our study instead of numbers in these studies.

vertebrae in adults with asymptomatic and undetected diastematomyelia.[9] Besides that, tight filum terminale syndrome is associated with an abnormally positioned CM below the intervertebral disc between the L2 and L3 vertebrae.[81] On the other hand, although lumbar disc herniation is the most common type of disc herniations,[82] a detailed review of the literature showed that there are few studies that investigate the relationship between the level of CMt and disc herniation.[11] Similarly, to Lin et al.,[11] the present study also detected that there was no statistically significant difference on the CMt level between healthy individuals and patient with disc herniation.

Relationship between Level of CMt Level and the Spinous Process

In lumbar applications, it is required to advance forward between the spinous processes to access the lumbar cistern. Doherty and Forbes[6] stated that one of the most important bony landmarks during this procedure is the spinous process of the L4 vertebra. It is observed in the literature that the CMt level is usually evaluated based on the relationship between the vertebral bodies and the intervertebral discs. However, no study investigating the relationship between the spinous process and CMt level was found, despite the fact that the spinous process is one of the most important bony landmarks. In the present study, both vertebral bodies and intervertebral discs and spinous processes were used to determine the level of CMt. A positive, very strong correlation was detected between the two methods ($P = .001$ and $r = 0.853$). This correlation demonstrates that the two methods support each other.

Limitations

As this is a retrospective study, the ethnic features of the individuals were not evaluated. The evaluations were performed using a standard section thickness of 5 mm for the sagittal sections and 4 mm for the transverse sections. The CM may seem to be terminating on a slightly higher level if it is located between these image sections. To prevent this, the sagittal and transverse sections were examined in correlation with each other.

CONCLUSION

Although the levels of CMt have been examined in a variety of studies, the levels given in classical textbooks and the literature are very different. In the literature, the highest level of CMt is seen as being at the intervertebral disc between T11 and T12 vertebrae, while the lowest level of it is at the L3L. We are of the opinion that the L3-4 or L4-5 intervertebral spaces should be preferred to lower the complication rate in procedures such as spinal anesthesia and lumbar puncture.

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