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Original Article

The Tip Level of the Conus Medullaris by Magnetic Resonance Imaging and Cadaver Studies in Korean Adults

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Abstract : The spinal cord is part of the central nervous system, and its caudal end is named as the conus medullaris. Many researchers have reported the tip level of the conus medullaris by magnetic resonance imaging studies; others by cadaver dissection. The tip level of magnetic resonance imaging studies seemed to be higher than that of cadaver studies.

We evaluated the tip level the conus medullaris with magnetic resonance imaging and cadaver dissection in Korean adult population. MR data were scanned with T1-weighted, mid-sagittal magnetic resonance imaging of 248 living persons (mean age, 42.3±16.0 years; range, 12-85 years) and cadaver data were collected by dissections of 118 cadavers (mean age, 56.0±14.9 years; range, 16-94 years). The mean level of conus tip was found to be at the middle third of 1st lumbar vertebra (range, lower third T12 - lower third L2) from magnetic resonance imaging study and the upper third of 2nd lumbar vertebra (range, lower third T12 - lower third L3) from cadaver dissection study. The tip level of conus medullaris from magnetic resonance imaging study was higher than that from cadaver dissection study ($p<0.05$).

Keywords : Spinal cord, Vertebra, MRI, Korean

Introduction

The central nervous system is composed of the brain and spinal cord. The spinal cord is in charge of transporting the afferent and efferent information between brain peripheral nervous system. The caudal end of the spinal cord is called conus medullaris. The anatomical understanding about the tip level of the conus medullaris is essential for the lumbar puncture or other procedures in the clinical field. Thus, many investigators evaluated the tip level of the conus medullaris. In the studies using magnetic resonance imaging (MRI), the tip level of the conus medullaris ranged from vertebra T11 to vertebra L3, average about L1 level [1-4]. Many reports and textbooks based on cadaver dissection studies described that the level of termination of the conus medullaris ranges between the T12 vertebra and L3 vertebra, average about L1-2 intervertebral disc level [5-10] or upper third of L2 [11].

Despite of these previous efforts of researchers, no definite correlation was found between MRI and cadaver studies. There was a potential agreement or a recognized tendency for the tip of the conus medullaris. Termination level of the spinal cord by MRI studies is higher (to the head) than cadaver studies (Table 1). In addition to that,

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Table 1. Comparison of the tip level of the conus medullaris in different populations.

Method	Population	Average tip level	Authors (publication year)
MRI	American	L1 (mean)	Wilson and Prince (1989)
MRI	British	L1 lower third (mean)	Saifuddin et al. (1998)
MRI	Turkey	T12-L1 intervertebral disc (mode)	Demiryurek et al. (2002)
MRI	Korean	L1 lower third (median)	Kim et al. (2003)
MRI	Korean*	L1 middle third (mean)*	
Cadaver	Thai	L1-L2 intervertebral disc (mean)	Boonpirak et al. (1994)
Cadaver	White	between upper border of L1 and L2 (mode)	McCotter (1916)
Cadaver	American	L1 lower third - L2 upper third (mode)	Needle (1935)
Cadaver	American	L1-L2 intervertebral disc (?) (mean)	Reimann and Anson (1944)
Cadaver	Japanese	L2 upper third (mean)	Hara (1987)
Cadaver	Korean*	L2 upper third (mean)*	

*, this study

previous studies were reported mainly in western countries [1-3,5-11].

Therefore, we investigated the tip level of conus medullaris both of adult cadavers and of living human using MRI in Korean population to provide anatomical basis of Koreans.

Materials and Methods

MRI study

In order to determine the tip level of the conus medullaris in living human, the MRI data of 248 subjects (140 male, 108 female; mean age 42.3±16.0 years, range 12-85 years) were used in this study. The age in male (37.7±13.8 years) was significantly lower than that in female (48.3±16.8 years) ($p<0.05$). All subjects were Korean. Although some of them had mild low back pain, visual inspection by a radiologist was performed resulting in no structural abnormality or deformity (e.g. scoliosis).

The MRI machines were 1.5T Magnetom vision (Siemans, Erlangen, Germany) and 1.0T Horizon LX (GE Medical system, Milwaukee, WI, U.S.A). The protocols used were T1 (TR/TE=480/14 msec), T2 (40000/112), FOV (280×220 mm), matrix number (512×256), slice thickness 4 mm, interval 0.1 mm and T1 (TR/TE=500-700/20-25 msec), T2 (3300-4300/90-120), FOV (260×260 mm) in Magnetom vision, matrix number (256×192), slice thickness 5 mm, interval 0.3 mm in Horizon LX, respectively.

The tip point of the conus medullaris was defined as the most distal point of the cord that could be visualized on the sagittal plane, based on T1 image. A line perpendicular to the long axis of the cord was used to locate the conus level and define the relation with the adjacent vertebrae. The vertebral body was divided into three equal portions (upper, middle, and lower one-thirds; U1/3, M1/3, L1/3, respectively) and the intervertebral disc was considered as a separate portion (Fig. 1A). The lowest vertebral body separated from the sacrum by a complete intervertebral disc was designated as fifth lumbar vertebra.

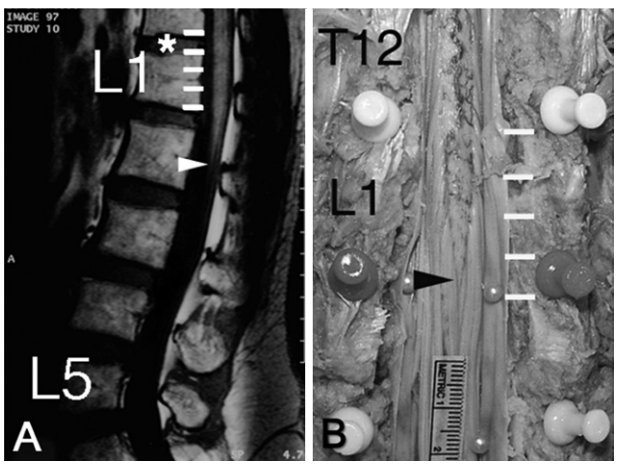

Fig. 1. The vertebral body and intervertebral disc were divided into the equal portions in MRI image (A) and cadaver dissection (B). The arrow head indicates the tip level of the conus medullaris.

Cadaver dissection

Sixty-seven cadavers (49 male, 18 female; mean age 56.0±14.9 years, range 16-94 years) were dissected in cadaver dissection study. The difference of age between male (57.7±14.9 years) and female (51.4±14.3 years)

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has no statistical significance ($p=0.127$).

In the prone position, superficial and deep back muscles were removed along the vertebral column. The laminectomy was performed using an electrical saw, and then the dura and arachnoid maters were removed. The tip point of the conus medullaris was determined at the transforming point to the filum terminale. The vertebral body was divided into three equal portions (upper, middle, and lower one-thirds; U1/3, M1/3, L1/3, respectively) and the intervertebral disc was defined as a separate portion (Fig. 1B).

One female cadaver had the conus medullaris fibrolipoma syndrome, and therefore, was excluded in this study.

Statistical analysis

Independent *t*-test and correlation analysis were performed to reveal difference between groups with covariates of age and sex by SPSS version 21 (SPSS Inc, Chicago, IL, USA). Different MRI data were considered as a result from the same scanner because of careful visual inspection and confirmation by a radiologist and anatomists. The *p* value of less than 0.05 was considered as statistical significance. All data were expressed as mean ± standard deviations.

Results

Table 2 showed that the mean level of the conus tip was the middle third of the L1 vertebra in MR study (range, lower third T12 - lower third L2). The termination level in male was significantly higher than that in female ($p<0.05$). There was no significant correlation in the mean level of conus tip with age ($r=-0.160$, $p=0.12$).

In a cadaver dissection study, the mean level of the conus tip was upper third of L2 vertebra (range, lower third T12 - lower third L3). No statistical difference of the termination level between in male and female was found ($p=0.911$). There was no significant correlation in the mean level of conus tip with age ($r=-0.028$, $p=0.821$).

Table 2. Distribution level of tip of the conus medullaris based on MRI and cadaver studies.

Vertebral level	MRI study		Cadaver study	
	Number	%	Number	%
lower third T12	1	0.5	2	1.7
Disc T12-L1	28	13.3	8	6.8
upper third L1	32	15.2	6	5.1
middle third L1	52	24.8	11	9.3
lower third L1	45	21.4	11	9.3
Disc L1-L2	34	16.2	16	14
upper third L2	6	2.9	23	19
middle third L2	9	4.3	14	12
lower third L2	3	1.4	10	8.5
Disc L2-L3	−	−	11	9.3
upper third L3	−	−	1	0.8
middle third L3	−	−	4	3.4
lower third L3	−	−	1	0.8
Total	210	100%	118	100%
Mean level of conus tip	L1 middle third*		L2 upper third*	

*$P<0.05$

Discussion

In present study, we found that the mean tip of the conus medullaris in MRI was higher than that in cadaver dissection (middle third L1 in MRI versus upper third L2 in cadaver). Moreover, age and mean level of the tip of the conus had no correlation both in MR and cadaver studies. Although we found no sex difference in cadaver dissection, MRI revealed that male tip was higher than female.

Previous MR studies had similar results from our MR study with small variation (Table 1). The location of conus medullaris was revealed by MRI of 100 young adults (range, 21-40 years) [1]. The average location was at vertebra L1 with range from T11-T12 to L2-L3. The T1-weighted, midline, sagittal MRI studies of 504 adult patients were assessed to identify the tip of the conus medullaris [2]. The mean conus position was the lower third of L1 (range from the middle third of T12 to the upper third of L3). Demiryurek et al. [3] revealed that the level of the conus medullaris was most commonly located at the T12 - L1 intervertebral disc level in 639 patients using MR imaging. In Korea, Kim et al. (2003) reported that the conus medullaris was positioned at L1-lower (median), ranged from T12-upper to L3-upper, with MR imaging study [4]. Basically, methodological, racial, and age differences among studies should be considered, developmental difference in spinal cord generation might not be important or revealed in MR imaging which made this study similar to previous MR studies. Sex difference in present MR study could be explained by different mean age between male and female. Because old female might have volume changes of reduction in their vertebral bodies due to aging process.

With respect to cadavers, Hara reported that the average

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caudal level of cord termination located at the intervertebral disc between L1 and L2 vertebrae or upper third of the L2 vertebra from the cadaver dissection study [11]. In 44 (23.4%) among 188 adults, the caudal level was at upper third of the L2 vertebra. In 37.2% of Thai adults (129 cadavers), the spinal cord ended between L1 and L2 lumbar vertebrae [10]. These findings were not far from our cadaver data, which might be explained by gross consistency with little difference of cadaver studies among countries. The age of adults might be a factor affecting the extent of the spinal cord [11]. In our study, however, there was no significant correlation in the mean level of conus tip with age in cadaver dissection study. In many standard books, the tip level of the conus medullaris is at the intervertebral disc between the L1 and L2 lumbar vertebrae [8,9]. There were, however, no exact descriptions about method whether MRI or cadaver dissection in some books. Because MRI scanner was developed in the 1970s, their data in the books were assumed to be based on cadaver dissection studies.

Although there are some differences of the tip level according to reports, no definite differences from race or population are confirmed. However, the tip level of the conus medullaris is not seen lower than the third lumbar vertebra in all reports. Therefore, the L3-L4 intervertebral disc space is acceptable for the standard lumbar puncture level in the clinical fields.

We could not understand and reveal exactly why the tip level of conus from MRI study was higher than that from cadaver dissection study. Barson reported that the level of the termination of the conus medullaris in cadaver might be changed by the extension and flexion of the spinal skeleton [12]. Any changes such as the rigor mortis might be related to this difference. In addition to that, the fixative effect on vertebral muscle and intervertebral disc might shorten the vertebral column, might influence the tip level of conus medullaris. For more exact comparison in the further study, MRI and cadaver dissection studies should have the same subject which might be helpful to reveal this methodological difference.

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해부와 자기공명영상으로 분석한 한국 성인의 척수원뿔 말단부 위치

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간추림 : 척수는 중추신경계의 한 부분으로, 척수의 아래쪽 끝의 이름은 척수원뿔이다. 여러 연구자들이 척수원뿔의 끝 부분을 자기공명영상 연구를 통해 보고하였고, 다른 연구자들은 시신해부연구를 통해 보고하였다. 자기공명영상 연구의 결과가 시신연구 결과보다 더 높은 위치에 있는 것으로 보인다.

우리는 자기공명영상과 시신해부연구를 동시에 진행하여 척수원뿔의 높이를 알아내었다. 자기공명영상은 T1 강조영상이고 정중시상면의 248명을 대상으로 하였다(평균나이 42.3±16.0세, 범위 12~85세). 시신연구는 118구의 시신을 해부하였다(평균나이 56.0±14.9세, 범위 16~94세).

척수원뿔의 평균 높이는 자기공명연구에서 L1 척추뼈의 중간 정도였다(범위, T12의 아래 1/3에서 L2의 아래 1/3까지). 그리고 시신연구에서는 L2 척추뼈 몸통의 위 1/3 높이에 위치하였다. 척수원뿔의 말단 끝이 자기공명영상에서 시신연구보다 더 높은 위치로 나타났다($p<0.05$).

찾아보기 낱말 : 척수, 척추, 자기공명영상, 한국인

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