Prospective Study

The Distance from Skin to Cervical and High Thoracic Epidural Space on Chinese Adults as Read from MRI

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Background: A few studies on the depth from the skin to the cervical epidural space (DSES) have been reported from the United States, South Korea, Japan, and Taiwan. There are no published reports from mainland China.

Objectives: The goal of this study was to collect standard data on Chinese adults from mainland China in a large medical center with a wide geographical range of patients.

Study Design: A prospective study.

Setting: Department of Anesthesiology, Pain Medicine, and Critical Care Medicine, Aviation General Hospital of China Medical University.

Methods: The survey included 410 patients. Measurements were made of DSES, the dural sac, and the spinal cord by automatic measuring ruler on transverse and sagittal images of the cervical spine at the C5-6, C6-7, C7-T1, T1-2, and T2-3 intervertebral space obtained by magnetic resonance imaging (MRI). We also obtained the width of the epidural space by measuring the distance from the (LF) to the dural sac.

Results: DSES at C5-6, C6-7, C7-T1, T1-2, and T2-3, respectively, was 4.69 ± 0.84 cm, 5.14 ± 0.98 cm, 5.56 ± 1.03 cm, 5.81 ± 0.94 cm, and 5.76 ± 0.86 cm on T2W (weighted) MRIs obtained in the sagittal plane (mean ± SD). The distance at C5-6, C6-7, and C7-T1 in transverse images was 4.67 ± 0.86 cm, 5.18 ± 1.02 cm, and 5.55 ± 0.97 cm, respectively. All measured distances from the skin to the epidural space were significantly greater in men than in women. Multivariate regression analysis revealed significant partial correlation between DSES and (BMI).

Limitation: Limitations include the absence of healthy individuals as well as the influence of the difference in neck positioning during the MRI examination vs. active epidural puncture.

Conclusion: DSES varied with the cervical intervertebral level in those patients studied from the population of mainland China. The greatest DSES was noted at C7-T1 in men and T1-2 in women, and the least was at C5-6 in both men and women. DSES had a significant relationship with neck circumference and BMI in both genders. We suggest that the DSES be measured with MRI before performing epidural puncture. The lower cervical and upper thoracic intervertebral spaces appear to provide a greater margin of safety for epidural puncture.

Key words: Cervical epidural space, magnetic resonance imaging

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Cervical epidural puncture is quite useful (1,2); however, the risks associated with it are extremely high with the anatomical variances in the cervical spine (3-8). Knowledge of the epidural anatomy, especially the key distance from the ligamentum flavum (LF) to spinal cord, would be helpful when performing cervical epidural punctures and thus reduce the possibility of accidental injury. All of the data currently available comes from the United States, South Korea, Japan, and Taiwan. There are no published reports from mainland China. To provide this necessary reference information, we analyzed the depth from the skin to the epidural space (DSES) at 5 levels of the spine in Chinese adult patients.

Methods

This sampling survey included 410 adult patients (165 men and 245 women) who underwent a magnetic resonance imaging (MRI) examination (Siemens NOVUS 1.5T) of the cervical spine at Aviation General Hospital between June 2012 and August 2012. With a standard deviation of preliminary measurement results at 1.03, the level of significance was set at 5% (2-sided analysis) with 90% power and the allowable error δ at 0.1 cm. Therefore, the required sample size for this study would be:

$$N = (1.96 \times 1.03/0.1)^2 = 408$$

Consent was obtained from all patients prior to participation. Data collected included patient's gender, age, height, weight, body mass index (BMI), neck circumference, birthplace, ethnicity, and a history of cervical spondylosis.

We focused on C5-6, C6-7, C7-T1, T1-2, and T2-3 spaces because on MRI of the cervical spine these are the most caudal levels that can be clearly seen on standard cervical MRIs. Epidural spaces above C6 are difficult to identify on axial and sagittal MRI views as reported by Aldrete et al (9). The study was limited to adults who consented to participate. Seriously injured patients who were unable to stand unassisted were excluded. Also patients whose images were unclear were excluded.

Each patient was asked to take off his or her shoes prior to measuring height and weight. BMI was calculated and neck circumference was measured using soft measuring tape at the level of cricoid cartilage.

Using an integral automatic centimeter ruler, the following measurements were taken:

1. Distance from the skin to the inner line of the LF. This was measured at a point perpendicular to the skin.
2. Skin to the dorsal surface of the dural sac.
3. Skin to the dorsal surface of the spinal cord taken at C5-6, C6 -7, C7-T1, T1-2, and T2-3 intervertebral levels, as seen on the most midline cut of the sagittal T2W images (Fig. 1).

In addition, we also calculated:

4. Distance from LF to the dural sac (LF-DS).
5. Distance from LF to the spinal cord (LF-SC).

Scanning restrictions limited the measurements to the distance on the transverse views at C5-6, C6 -7, and C7-T1 (Fig. 2).

Results were expressed as mean ± SD and range. Graphs of distances at different intervertebral spaces were diagrammed and standard deviation of the mean values was calculated. The analysis of correlation between the distances for each level and the age, height, weight, BMI, and neck circumference was performed using multivariate regression analysis. The difference

Fig 1. *Sagittal view of a T2W image of the cervical spine in a patient weighing 70 kg. The epidural space measurements are as follows (double arrow): C5-6 = 53.5 mm, C6-7 = 55.1 mm, C7-T1 = 55.2 mm, T1-2 = 58.7 mm, T2-3 = 64.0 mm. T = tongue. The C5-T3 vertebral bodies are noted with the respective numbers: 5, 6, 7, 1 , 2, and 3. Large black arrow points to the spinal cord.*

in distances between men and women were analyzed by independent sample t-test and statistical significance was defined as $P < 0.05$. All analyses were performed using SPSS 13.0.

Results

The diagnosis of 410 patients (165 men and 245 women) involved in our research are summarized in Table 1. The number of patients diagnosed with cervical spondylosis was 291, which accounted for 71.0% of the diagnosis. The demography of the patients is shown in Table 2.

The distances between skin and LF are summarized in Fig. 3. The DSES at C5-6, C6-7, C7-T1, T1-2, and T2-3 intervertebral spaces are 4.69 ± 0.84 cm, 5.14 ± 0.98 cm, 5.56 ± 1.03 cm, 5.81 ± 0.94 cm, and 5.7 6± 0.86 cm, respectively, as measured on sagittal images; and 4.67 ± 0.86 cm, 5.18 ± 1.02 cm, and 5.55 ± 0.97 cm, respectively, as measured on transverse images.

The minimum and maximum cervical epidural depth was 2.98 cm at C5-6 in women and 8.00 cm at C7-T1 in men (Table 3). The distance from the skin to the epidural space showed significant statistical differences between men and women at each of the measured levels ($P < 0.001$).

The main results of the step-wise regression are shown in Table 4. There was no significant partial correlation between the DSES and age. The best correlation was found between the distance from the skin to the epidural space and BMI according to the standardized coefficients. The most significant partial correlation coefficient was 0.551 at C7-T1 on transverse images (Table 4).

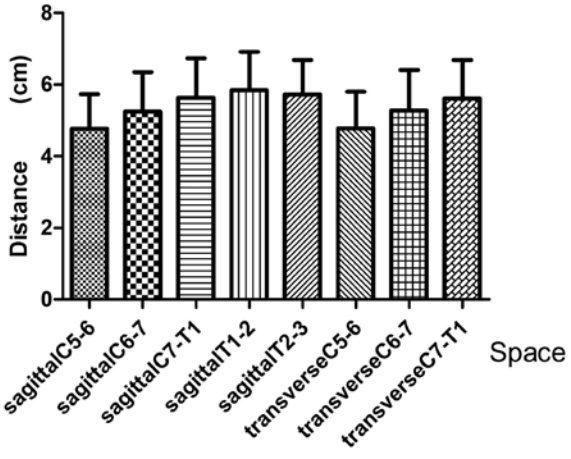

Fig. 3. *Distances between skin and ligamentum flavum. Error bars indicate the standard deviation.*

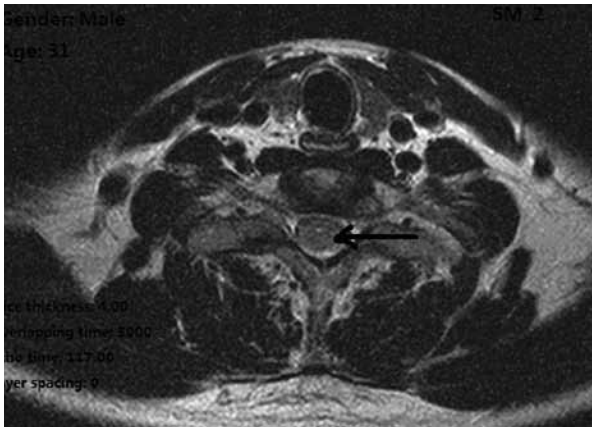

Fig 2. *Transverse view of a T2W image of the cervical spine on the C7-T1 level in a patient weighing 70 kg. The measurements are as follows: The skin to LF (double arrow) = 55.2 mm, LF to DS = 0.43 mm, LF to SC = 3.95 mm. Large black arrow points to the spinal cord.*

Table 1. *Diagnoses for all patients.*

Disease	No. of Patients (%)
Cervical spondylotic radiculopathy	119 (29.0%)
Mixed cervical spondylosis	84 (20.5%)
Sympathetic cervical spondylosis	80 (19.5%)
Cervical spondylotic myelopathy	11 (2.7%)
Myofascial pain syndrome	24 (5.9%)
Frozen shoulder	19 (4.6%)
Headache	14 (3.4%)
Atypical pain syndrome	38 (9.3%)
Trauma	19 (4.6%)
CRPS	2 (0.5%)
Total	410 (100%)

CRPS: complex regional pain syndrome

Table 2. *Demographics of the patients receiving MRI.*

	Mean ± SD	Range
Age (years)	50.1 ± 13.9	18.0 – 85.0
Height (cm)	162.0 ± 8.5	138.0 – 188.0
Weight (kg)	67.0 ± 12.3	38.5 – 111.0
BMI (kg/m2)	25.5 ± 3.9	16.2 – 40.1
NC (cm)	36.4 ± 3.4	29.0 – 47.9

BMI: body mass index, NC: neck circumference

Table 3. *The distance from the skin to the epidural space at 5 levels of the spine in men and women.*

	Men	Women	*P* Value
N	165	245	
Sagittal C5-6	5.15 ± 0.76 (3.49 – 6.74)	4.39 ± 0.75 (2.98 – 6.68)*	< 0.001
Sagittal C6-7	5.52 ± 0.93 (3.58 – 7.30)	4.89 ± 0.93 (3.36 – 7.43)*	< 0.001
Sagittal C7-T1	5.89 ± 1.03 (3.60 – 8.00)	5.34 ± 0.97 (3.50 – 7.80)*	< 0.001
Sagittal T1-2	6.07 ± 0.99 (3.60 – 7.90)	5.64 ± 0.86 (3.73 – 7.93)*	< 0.001
Sagittal T2-3	6.07 ± 0.91 (4.11 – 7.80)	5.55 ± 0.76 (3.95 – 7.56)*	< 0.001
Transverse C5-6	5.10 ± 0.78 (3.29 – 6.85)	4.40 ± 0.79 (2.90 – 6.90)*	< 0.001
Transverse C6-7	5.55 ± 0.98 (3.44 – 7.74)	4.93 ± 0.97 (3.15 – 7.37)*	< 0.001
Transverse C7-T1	5.85 ± 0.98 (3.99 – 7.75)	5.34 ± 0.90 (3.62 – 7.57)*	< 0.001

Data are mean ± SD, Range
*Significantly differ from men

Table 4. *The partial correlation coefficients between distance from the skin to the epidural space, and age, height, weight, BMI, and NC.*

	C5-6		C6-7		C7-T1		T1-2	T2-3
	sagittal	transverse	sagittal	transverse	sagittal	transverse	sagittal	sagittal
Age (years)	-	-	-	-	-	-	-	-
Height (cm)	-.219	-	-	-	-	-	-	-.329
Weight (kg)	.345	-	-	-	-	-	-	.443
BMI (kg/m2)	-	.423	.512	.539	.548	.551	.550	-
NC (cm)	.307	.499	.438	.394	.374	.322	.335	.221

BMI: body mass index, NC: neck circumference, Statistical significance for $P < 0.01$ was noted.

From the same estimates, we found that the distance from LF to DS ranged from 0.42 mm to 0.46 mm, with a mean of 0.43 mm. The distance from LF to SC ranged from 2.49 mm to 4.35 mm, with a mean of 3.13 mm (Figs. 4, 5). The distance from the LF to SC increased as one moved caudally. The longest mean distance was 4.35 mm at the T2-3 level.

Discussion

To facilitate successful cervical epidural puncture few studies on the DSES had been reported. Only one study utilized cervical spine MRIs in the evaluation (9). No data has been reported involving the Asian mongoloid population.

Aldrete et al (9) conducted research on DSES in 100 American Caucasian patients with MRI. The result showed that the distance from LF to DS ranged from 3 mm to 5 mm, and from the LF to SC, it ranged from 7 mm to 10 mm. These measurements were wider than the results in our research. Our research reveals that the risk of performing cervical epidural puncture might be higher for patients in mainland China, especially in women. In the cervical spine, DSES varies from space to space, but the depth from LF to DS and LF to SC is greatest at C7-T1. In addition, the incidence of dural puncture is 3 times higher in patients with 2 – 4 cm of lumbar epidural space depth than in patients with 4 – 6 cm of epidural depth (4,8), while the greatest DSES was noted at T1-2. The C7-T1 and T1-2 intervertebral spaces appear to provide a greater margin of safety for cervical epidural punctures.

An epidural puncture was conducted and the DSES was measured in Korean (4), Taiwanese (10), and Japanese patients (11). Our results show the mean distances

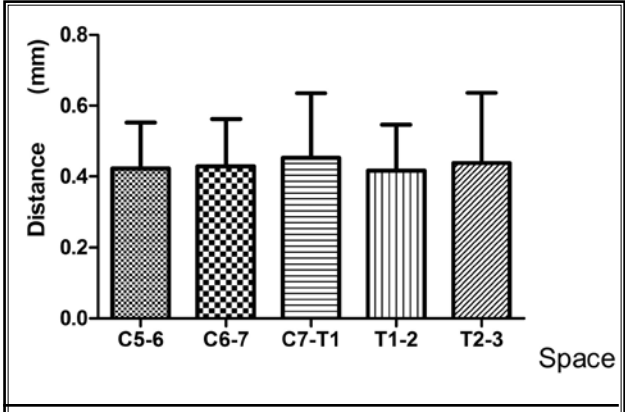

Fig. 4. *The mean distance from LF to DS in sagittal films. Error bars indicate the standard deviation.*

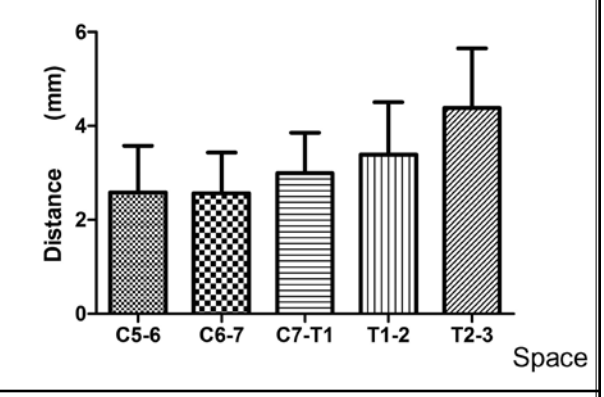

Fig. 5. *The mean distance from LF to SC in sagittal films. Error bars indicate the standard deviation.*

at different vertebral spaces are wider in our study than those in previous studies. The difference might result from differences in cervical spine positioning, race, or could be secondary to errors in measurements on MRI. Additionally, the identification of LF, DS, and SC could be problematic during active puncture, making it difficult to analyse the safest intervertebral space for actual punctures.

In previous studies, weight was mentioned as a significant correlative factor; however, in our study the significant factors proved to be BMI and neck circumference. However, the DSES measurements were correlated with multiple variables and there was co-linearity between BMI and height, as well as weight. As reported (12), co-linearity in linear regression is a serious problem. The statistical approach used in previous studies by simple regression analysis could seriously distort the model. Accordingly, we believe that multivariate regression analysis is a more valid method to assess the correlation between these variables and the DSES.

Limitation

There is a limitation in our study. The patients in our study were in the supine position for their MRI, but were in the sitting position, bent forward, with the forehead resting on a table while the epidural puncture was performed, as a result, the data obtained from MRI and epidural puncture may be inconsistent.

Conclusion

In our study of 410 patients from mainland China, the DSES at C5-6, C6-7, C7-T1, T1-2, and T2-3, respectively, are 4.69 ± 0.84 cm, 5.14 ± 0.98 cm, 5.56 ± 1.03 cm, 5.81 ± 0.94 cm, and 5.76 ± 0.86 cm as measured on sagittal T2W MRIs. The distance at C5-6, C6-7, and C7-T1 on transverse images was 4.67 ± 0.86 cm, 5.18 ± 1.02 cm, and 5.55 ± 0.97 cm, respectively. The level of C7-T1 and T1-2 appear to provide the greatest margin of safety for epidural puncture. Since DSES varies at different levels of the spine in the same patient and also varies from patient to patient at the same spine level, and because cervical epidural punctures are at increased risk for serious complications including dural puncture and spinal cord injury, using pre-procedural MRI measurements may significantly reduce complications. In active punctures, knowledge of the DSES improves the success of cervical epidural punctures. Thus we recommend measuring the DSES using MRI before performing epidural punctures.

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