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Evaluation of the Distance between the Epidural Puncture Point and the Thoracic Cavity Using CT Images in Japanese Adults

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Abstract

Objective: Thoracic epidural anesthesia has a risk of unexpected thoracic perforation when deepening the epidural needle toward the epidural space. In this study, we measured the distance from the estimated epidural puncture point to the bilateral thoracic cavity in the thoracic vertebral images from computed tomography.

Methods: Forty Japanese adult patients were examined. Computed tomography images were obtained from electronic medical records, and an internal electronic ruler was used for the measurement. The estimated point of puncture was set at approximately 1.5 cm lateral from the midline of the spinous process on the skin. The distance from the estimated epidural puncture point of skin to the epidural space and to the bilateral thoracic cavities was measured. Measurements were taken at the 6^{th} and 10^{th} thoracic vertebral levels of males and females, respectively.

Results: There was no significant difference between the distance to the epidural space (46.4 ± 5.6 mm) and to the ipsilateral thoracic cavity (48.3 ± 6.5 mm). On the other hand, the distance to the contralateral thoracic cavity (65.6 ± 6.7 mm) was significantly longer than the distance to the epidural space in patients of either sex at each vertebral level (P=0.000). The difference between the distance to the epidural space and that to the contralateral thoracic cavity was 19.2 ± 4.7 mm, with a 95% confidence interval of 17.7 to 20.7 in all subjects.

Conclusion: Perforation of the thoracic cavity may occur even though the depth of the epidural needle was assumed to be at an acceptable distance after the typical loss of resistance was felt. The risk of thoracic perforation should be recognized with every thoracic epidural puncture.

Keywords: Computed tomography; Epidural anesthesia; Epidural needle; Epidural catheterization; Epidural misplacement; Thoracic cavity; Thoracic perforation

Introduction

Thoracic epidural anesthesia is a widely used anesthetic technique providing excellent intra and postoperative analgesia. However, due to the blindly inserted Tuohy needle, there is a risk of the needle tip deviating from the target position and causing epidural catheter misplacement. There are several case reports regarding unexpected intrathoracic catheter insertion [1-10].

Based on these reports, the details of epidural puncture level, approach, misplacement site, and depth of the epidural needle from the skin to the epidural space are shown in Table 1. In most failure cases, a typical loss of resistance was felt when the epidural needle reached the epidural space (in fact, thoracic cavity) [3-6,11]. Interestingly, epidural catheter misplacement in the thoracic cavity was observed not only in the paramedian approach but also in the median approach [1,7-9]. In addition, even though the puncture point should be shifted to either the left or right lateral side in the paramedian approach, in some reports, the incorrect insertion was spreading to the contralateral thoracic cavity (Table 1) [4,6,10]. The depth from the skin to the epidural space when misplacement occurred was 5 cm to 8 cm; however, more than half of the reports are not mentioned. There were no reports to evaluate the depth related to the thoracic perforation.

Previous reports warn of the risk of unexpected perforation of the thoracic cavity, however, it is difficult to differentiate the intrathoracic catheter misplacement at the time of the epidural needle deepening toward the epidural space. It might be helpful to know each of the distances from the epidural puncture point to the bilateral thoracic cavities. The distance from the epidural puncture point to the ipsilateral or contralateral thoracic cavity was expected to be longer than the distance to the epidural space; however, there had been no such reports previously.

In this study, therefore, we measured the distance from the estimated epidural puncture point to the epidural space and the bilateral thoracic cavities and evaluated the differences of the distances in the thoracic vertebral images from computed tomography.

Materials and Methods

This observational study approved by the Ethical Committee of the Miyazaki University Hospital and was performed in accordance with the ethical standards in the Declaration of Helsinki. This study was also registered with the University Hospital Medical Information Network (UMIN) clinical trials registry (ref: UMIN000026223).

Author	#	Epidural puncture level	Approach (shifted side of puncture point)	Misplacement site of thoracic cavity	Described needle depth from the skin to the epidural space (cm)
Belani et al.	1	T7-T8	median	left	ND
Sundary et al.	2	T7-T8	paramedian (ND)	right	ND
Zaugg et al.	3	T6-T7	paramedian (right)	right	7
*Shime et al.	4	T7-T8	paramedian (left)	right	ND
Inoue et al.	5	T5-T6	paramedian (ND)	right	ND
Inoue et al.	5	T6-T7	paramedian (ND)	right	ND
Inoue et al.	5	T7-T8	paramedian (ND)	right	ND
*Furuya et al.	6	T5-T6	paramedian (right)	left	8
Wadhwa et al.	7	T6-T7	median	right	5
Patermann et al.	8	T8-T9	median	right	7
Eti et al.	9	T6-T7	median	left	ND
*Lin et al.	10	T8-T9	paramedian (left)	right	5

Table 1: Representative case reports regarding the intrathoracic misplacement of an epidural catheter. ND: No Data; *Indicates incorrect contralateral thoracic catheter insertion from the epidural puncture point; #Reference number.

Subjects for the present study were selected from adult patients who underwent thoracic computed tomography (CT) scanning for their surgery between November 2014 and June 2015. For CT scanning, a 64-detector-row scanner (SOMATOM Definition AS+, Siemens Medical, Erlangen, Germany), 120 kVp, and Siemens automatic exposure control system (CARE Dose4D) were used. Transaxial CT image data consisted of 5 mm sections through the thoracic region.

Patients who met the inclusion criteria of age (20 years and over), height (standard height ± 10 cm), and weight (standard weight ± 10 kg) were included. Patients, who were judged by examiners to have obvious anatomical abnormalities in the spine, including scoliosis, were excluded. Recent standard physiques of Japanese adults were referenced from the official data released by the Statistics Bureau of Japan (male: 167.3 cm, 66.0 kg; female: 154.2 cm, 53.0 kg; www.stat.go.jp). In consideration of anatomical differences of epidural space due to sex and vertebral level, measurements were taken at the 6^{th} and 10^{th} thoracic vertebral levels of males and females, respectively (divided into four groups). CT images with a reconstruction thickness of 5 mm were obtained from DICOM (Digital Imaging and Communications in Medicine) viewer software (Shade Quest/ViewC, Yokogawa Medical, Tokyo, Japan). The CT image was displayed with a setting of window level and widths of 55 and 350 Hounsfield Units, and an internal electronic ruler was used to measure the distances, which are detailed below.

In the thoracic epidural procedure, advancing the epidural needle should be contact with the transverse process or the lamina of the thoracic vertebra [12]. Then the needle is walked off the lamina medially, and the loss of resistance or the hanging drop technique is used to identify the epidural space. In this study, the distance from the skin to the epidural space was measured at the transverse process levels of the thoracic vertebrae (Figure 1, left). Since the paramedian approach is thought to be mainly used with thoracic epidural anesthesia in clinical practice, the estimated point of puncture was set at approximately 1.5 cm lateral from the midline of the spinous process on the skin.

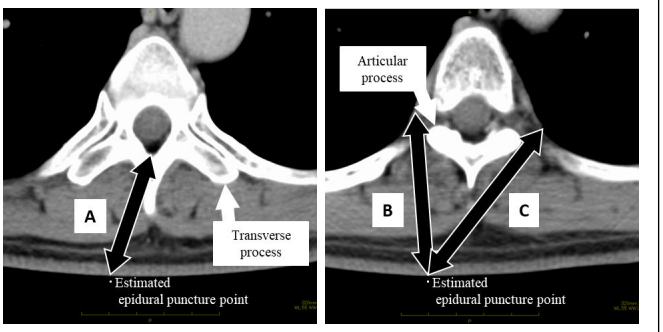

Figure 1: Typical computed tomography images of the 6^{th} thoracic vertebral level. Left: transverse process level. Right: superior articular process level in the 6^{th} thoracic vertebra. The black arrows represent the distance from the estimated epidural puncture point of the skin to the epidural space in the paramedian approach (A), the ipsilateral thoracic cavity (B), and the contralateral thoracic cavity (C).

Indeed, it is uncertain how the epidural needle will lead into the thoracic cavity. However, it is hypothesized based on the vertebral anatomical structure that a Tuohy needle should deviate from the lamina and may pass through the margins of the right or left articular processes when the needle reaches the thoracic cavity in failure cases [13]. According to this hypothesis, the distance from the estimated epidural puncture point of the skin to the bilateral thoracic cavities was measured at the level of the superior articular process clearly detected in CT images (Figure 1, right). Thoracic cavity on the same side with the estimated epidural puncture point shifted laterally was defined as ipsilateral, and that on the opposite side was defined as the contralateral thoracic cavity.

Statistical Analysis

Statistical software (JMP 11, SAS Institute, NC, USA) was used for sample size calculation and data analysis. The sample size was calculated based on a standard deviation (SD) of the distance from the skin to the epidural space of 7 mm, as obtained in a previous study [14]. To detect a 15 mm difference between the distance from the estimated epidural puncture point to the epidural space and to the contralateral thoracic cavity, considering an alpha error of 0.05 and a study power of 0.8, a sample size of 10 was required for each group. Data were tested for normal distribution using the F-test. Student's t-

test was used to examine the significance of differences between the distances. Statistical significance was considered as a two-sided P value of <0.05. The results were expressed as the mean with SD.

Results

Table 2 shows the baseline characteristics of patients and the measurements.

In all subjects, the distance from the estimated epidural puncture point of the skin to the epidural space (46.4 ± 5.6 mm, mean ± SD) and to the ipsilateral thoracic cavity (48.3 ± 6.5 mm) was approximated. In each group separated by sex and vertebral levels, there was no significant difference between the distance from the skin to the epidural space and the distance from the skin to the ipsilateral thoracic cavity (Table 2). The difference between the distance from the skin to the epidural space and the skin to the ipsilateral thoracic cavity was 1.9 ± 3.7 mm with a 95% confidence interval of 0.6 to 3.0 in all subjects.

	Male		Female	
	N=10	N=10	N=10	N=10
Patient characteristics				
Age (years)	62.0 ± 4.7	62.6 ± 5.1	62.3 ± 5.5	63.1 ± 10.9
Height (cm)	168.1 ± 5.7	168.3 ± 3.7	156.0 ± 2.6	156.6 ± 4.1
Weight (kg)	66.5 ± 4.5	65.7 ± 8.2	53.7 ± 5.1	53.4 ± 7.0
Distance from skin to epidural space or thoracic cavity				
Thoracic vertebral level	6^{th}	10^{th}	6^{th}	10^{th}
Epidural space (mm)	51.5 ± 4.2	47.9 ± 5.1	42.9 ± 4.3	43.3 ± 4.3
Ipsilateral thoracic cavity (mm)	54.5 ± 5.5	49.8 ± 5.0	43.3 ± 5.2	45.5 ± 4.1
Contralateral thoracic cavity (mm)	70.5 ± 4.7*	70.7 ± 4.1*	60.4 ± 4.7*	60.8 ± 4.8*
Difference† (mm)	19.0 ± 4.9	22.8 ± 5.1	17.5 ± 4.0	17.5 ± 3.2
95% confidence interval of difference	15.5, 22.5	19.1, 26.4	14.6, 20.4	15.2, 19.8

Table 2: Patient characteristics and measurements. Data expressed as mean ± standard deviation. *P<0.05 *vs.* epidural space; †The difference between the distance from the skin to the epidural space and that to the contralateral thoracic cavity.

On the other hand, the distance from the skin to the contralateral thoracic cavity (65.6 ± 6.7 mm, in all subjects) was significantly longer than the distance from the skin to the epidural space (P=0.000 in all separated groups of males at the 6^{th}, males at the 10^{th}, females at the 6^{th}, and females at 10^{th} level) (Table 2). The difference between the distance from the skin to the epidural space and from the skin to the contralateral thoracic cavity was 19.2 ± 4.7 mm with a 95% confidence interval of 17.7 to 20.7 in all subjects.

Furthermore, at both vertebral levels, the distances from the skin to the epidural space, to the ipsilateral thoracic cavity, and to the contralateral thoracic cavity were significantly shorter in the females than in the males (P=0.000, 0.000, and 0.001 in groups at the 6^{th} and P=0.045, 0.050, and 0.001 in groups at the 10^{th} level, respectively).

Discussion

It has been pointed out that erroneous insertion of the epidural catheter may occur frequently. Hogan et al. reported that approximately 10% of epidural catheters were displaced from the intervertebral foramen to the paravertebral tissue [15]. CT myelography has revealed a high rate of cases of contrast media leakage into the subdural cavity [16]. It has been suggested that the tip of a Tuohy needle can easily reach the subdural cavity, especially in a thoracic epidural puncture using the paramedian approach [16,17].

In most cases, epidural erroneous puncture into the thoracic cavity is confirmed when thoracotomy is performed by surgery [1-10]. During an epidural procedure, it is impossible to distinguish between the thoracic cavity and the epidural space in order to obtain the signs of reaching the epidural space, such as loss of resistance, even if the chest cavity is incorrectly punctured [1-10]. Mis-puncture of the thoracic cavity with an epidural needle brings the possibility of developing serious complications based on anatomical features, namely, the fact that the lungs and aorta are located near the spine [18]. Despite the danger suggested, the depth of the epidural needle reach into the thoracic cavity had never been evaluated. In this study, CT images showed that the distance from the skin to the thoracic cavity on the puncture side was nearly the same as the distance from the skin to the epidural space in the paramedian approach. Therefore, there is a risk of perforation of the ipsilateral thoracic cavity even though the needle depth from the skin to the epidural space was assumed to be an acceptable distance after the typical loss of resistance was felt.

Meanwhile, because the distance to the contralateral thoracic cavity is 19 mm longer than the distance to the epidural space, the epidural needle may be less likely to reach the contralateral thoracic cavity than the ipsilateral thoracic cavity. It was difficult to specify the exact occurrence frequency; however, based on our literature survey, the incidence on the ipsilateral side was considered high. On the other hand, for a patient with a typical physique targeted in this study, the length of the 18-gauge epidural needle commonly used (e.g., Pelican® epidural needle, length 80 mm, B. Braun Medical Inc., Melsungen, Germany) is sufficient to reach the thoracic cavity on the contralateral side as well as on the ipsilateral side. The needle insertion from the outside at a large angle and placement of overly long catheters were risk factors for reaching the contralateral thoracic cavity [6,19]. Shime et al. have also considered that the large angle from the sagittal plane at the time of puncture may have caused intrathoracic migration through the intervertebral foramen of the opposite side [4]. According to these findings, when an epidural needle is inserted more than 15 mm to 20 mm beyond the assumed distance based on the patient's physique, or when the needle is positioned at a large angle to perform the paramedian approach, anesthesiologists should be keep in mind the potential risk of perforating the thoracic cavity not only on the same side but also on the opposite side from the epidural puncture point.

In this study, there might be insufficient points for accuracy, reproducibility, or universality in the distance measurements. As for the limitations of this study, no obese subjects were enrolled. Indeed, epidural puncture of obese patients is often difficult, and it may be useful to evaluate the distance from the skin to the epidural space or thoracic cavity using CT images of obese patients. Furthermore,

evaluation of the distance was performed using only two-dimensional CT images. The precision of the distance measurements will be affected by the rotation and deformation of vertebral bodies, such as thoracic kyphosis/lordosis or scoliotic curvatures, or changes in the CT scan angle and slice thickness. A three-dimensional (3D) assessment was not conducted in this study. 3D reconstruction would have been useful in making distance measurements to ensure that the projected needle path and distance are reproducible even when there is an anatomical abnormality in the spine. Then, we did not use a Tuohy needle to measure the actual depth from the skin to the epidural space or to the thoracic cavity; however, it is known that the distance from the skin to the epidural space measured from the CT image strongly correlates with the actual puncture distance [14,20].

Conclusion

This study was the first study on the distance from the epidural puncture site to the thoracic cavity. The distance to the epidural space and the distance to the thoracic cavity were almost the same on the ipsilateral side and significantly longer on the contralateral side. Since this study was a simple measurement using a CT image, the actual distance remained unknown. Even if an accurate depth is found, it will be difficult to distinguish between the epidural space and the chest cavity. However, our findings on approximation in the distance to the epidural space and to the thoracic cavity obtained from CT images should serve as a reminder of the risk of unexpected thoracic puncture. The possibility of puncture of either the ipsilateral or contralateral thoracic cavity by a Tuohy needle and the risk of serious complications should be taken into account in all epidural punctures.

Ethics Approval and Consent to Participate

This study was approved by an internal ethics committee of the Miyazaki University Hospital; it was carried out in accordance with the recommendations of the Declaration of Helsinki.

Human and Animal Rights

No animals were used in this study. Research procedure of subsequent human beings are all committee of ethical standards on human experimentation (institutional and national), and were consistent with the 1975 Declaration of Helsinki, which was revised in 2008.

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