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Comparison of Thoracic Epidural Pressure in the Sitting and Lateral Decubitus Positions

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Background: **The hanging drop technique identifies the epidural space using the negative pressure of this space. Although the hanging drop technique is popular at the thoracic level, there is still controversy on the negative epidural pressure at this level. The authors hypothesized that the epidural pressure is more consistently negative in the sitting position than in the lateral decubitus position at the thoracic level.**

Methods: **This study compared the epidural pressures of 28 awake patients in the sitting (sitting group, n = 14) or lateral decubitus (lateral group, n = 14) position. The T5–T6 epidural pressure was measured using a closed pressure measurement system connected to a Tuohy needle.**

Results: **All of the thoracic epidural pressures in the sitting group were negative (median, −5 mmHg; range, −18 to −1; mean, −7.2; SD, 6.3), in contrast to the lateral group (median, 5 mmHg; range, −4 to 13; mean, 5.1; SD, 4.4). The thoracic epidural pressure in the sitting group was significantly lower than in the lateral group (*P* < 0.001).**

Conclusions: **The thoracic epidural pressure is more negative in the sitting position than in the lateral decubitus position. These results suggest that the patient should be sitting when the hanging drop technique is used to identify the epidural space.**

THE hanging drop technique identifies the epidural space using the negative pressure of this space and has been used successfully without major modifications since its introduction in the 1930s.[1] Although the hanging drop technique may be used mostly at the thoracic level, there is some controversy regarding the negative epidural pressure at this level. In previous studies where closed pressure measurement systems were used,[2,3] the thoracic epidural pressures were commonly positive and the median values were also reported to be positive. These results may be inconsistent with the long and successful use of the hanging drop technique.

However, in these two studies, the epidural pressures were measured in the lateral decubitus position instead of the sitting position, where thoracic epidural anesthesia is usually performed. Moreover, at the lumbar level, the 30% head-up position decreases the epidural pressure to half that at the supine position.[4]

We hypothesized that the epidural pressure is more consistently negative in the sitting position than in the lateral decubitus position at the thoracic level. To test this hypothesis, the epidural pressure was measured and compared at the thoracic level in the sitting and lateral decubitus positions.

Materials and Methods

After receiving approval from the Institutional Review Board of Seoul National University Hospital (Seoul, Korea) and informed patient consent, 28 patients scheduled to undergo an elective thoracotomy and thoracic epidural anesthesia for postoperative pain control were enrolled in this study. The exclusion criteria consisted of general contraindications for epidural anesthesia (an allergy to any of the local anesthetic agents, coagulopathy, infection at the proposed insertion site, patient refusal, neurologic or neuromuscular disease, and previous spinal surgery), pregnancy, a large abdominal mass, and obstructive lung disease. The patients were assigned randomly to one of the two groups according to computer-generated sequence numbers until there were at least 14 patients assigned to each group: a sitting group and a lateral group. In both groups, the patients were awake and had spontaneous ventilatory status during the study. When conducting epidural anesthesia, the patients in the sitting and lateral groups were placed in the sitting and lateral decubitus positions, respectively.

Identification of the epidural space and measurements of the epidural pressure were performed, as outlined by Okutomi *et al.*[2,3] Briefly, a 17-gauge Tuohy needle (Arrow International Inc., Reading, PA) was placed in T5–T6 supraspinous ligament or ligamentum flavum, using the paramedian approach. The stylet was then removed, and the needle was filled with saline and connected to a pressure transducer. The saline reservoir was placed at the level of the transducer without a pressure bag to prevent saline from being evacuated into the epidural space. The zero level was set at the insertion point of the needle with a laser leveling device (fig. 1A). The Tuohy needle was advanced slowly until a tactile sensation of give with a precipitous decrease in the displayed pressure was noted. The identification of the epidural space was confirmed by the typical wave form, which consists of small cardiac oscillations superimposed on the greater respiratory oscillations. After identifying the epidural space, the depth of needle insertion was measured. At the same time, the angle of the needle was measured with respect to gravity (fig. 1A). The needle was then held immobile for 120 s to stabilize the

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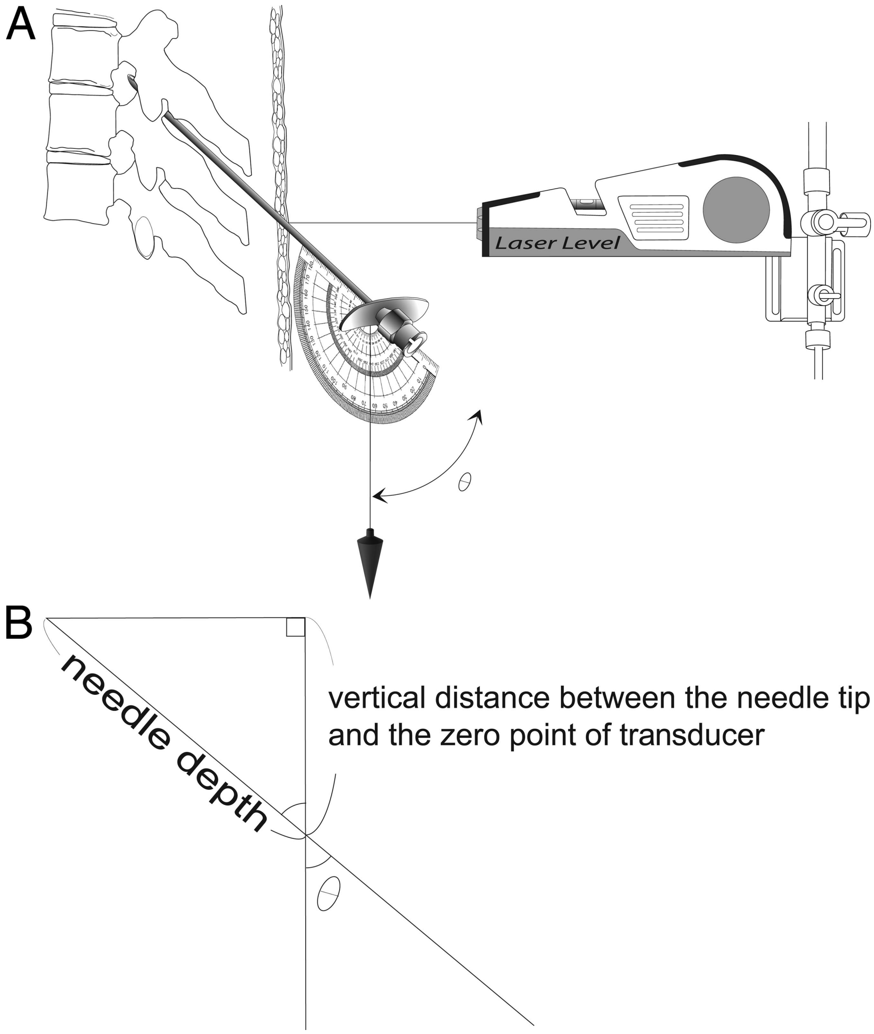

Fig. 1. (*A*) Illustration of the method used to set the zero level with laser leveling device and for measuring the needle angle with respect to gravity. (*B*) The diagram shows that the vertical distance between the transducer and needle tip can be calculated from the needle depth and angle against gravity. Distance = needle depth × cos (angle against gravity).

epidural pressure. After stabilization, the mean pressure was recorded. The measured pressure was then corrected to the epidural pressure at the needle tip (fig. 1B) using the following formula:

$$\text{Epidural pressure} = \text{measured pressure} - [\text{needle depth} \times \cos(\text{measured angle}) \times 0.735],$$

where 0.735 is a unit conversion factor (1 cm H_2O = 0.735 mmHg).

After recording the pressure, a 19-gauge single open end hole epidural catheter (Arrow International Inc.) was inserted. The patient was turned to the supine position, and local anesthetics were injected to the epidural catheter. After 15 min, adequate analgesia to a pinprick was assessed, and general anesthesia was induced.

Statistical Analysis

Statistical analyses were performed using the computer software SPSS (version 12.0; SPSS Inc., Chicago, IL). The demographic data were analyzed using a Student *t* test, with the exception of male and female distribution, which was analyzed using a Fisher exact test. The epidural pressures of the two groups were analyzed using a Student *t* test. *P* values less than 0.05 were considered significant.

The sample size calculations were based on the data published by Okutomi *et al.*,[3] who reported a mean epidural pressure at the T7–T8 level of 3.7 mmHg and an SD of 3.2 in the lateral decubitus position. Therefore, a pressure difference of at least 4 mmHg should be generated for the mean epidural pressure to be negative in the sitting position. A minimal sample size of 12 patients per group is needed to demonstrate a difference of 4 mmHg, with $\alpha = 0.05$ and $\beta = 0.20$. Therefore, 14 patients per group were examined to compensate for possible dropouts.

Results

Twenty-eight patients were examined, and epidural anesthesia was performed successfully in all patients. Table 1 shows that the demographic data were similar in both groups, except the sex ratio.

Table 1. Demographic Data of the Patient Groups

	Lateral Group (n = 14)	Sitting Group (n = 14)
Age, yr	58.4 (15.4)	54.0 (10.6)
Weight, kg	64.2 (9.3)	64.4 (6.3)
Height, cm	164.0 (7.6)	168.3 (5.4)
BMI, kg/m^2	23.9 (2.9)	22.7 (1.5)
Male:female	10:4	14:0

Data are reported as mean (SD), except for male:female ratio.
BMI = body mass index.

The median epidural pressure was −5.0 mmHg (interquartile range, −13 to −2; range, −18 to −1; mean ± SD, −7.2 ± 6.3) in the sitting group and 5 mmHg (interquartile range, 4 to 7; range, −4 to 13; mean ± SD, 5.1 ± 4.4) in the lateral group (fig. 2). The epidural pressure was significantly lower in the sitting group than in the lateral group ($P < 0.001$). All epidural pressures measured in the sitting group patients were negative. In two cases (one case in each group), precipitous decrease of pressure resulted in the initial negative pressure as previously described by Okutomi *et al.*[3] (fig. 3). The initial negative epidural pressures were −16 and −14 mmHg in the sitting and lateral groups, respectively.

Discussion

The main finding of this study is that thoracic epidural pressure was much lower in the sitting position than in the lateral decubitus position. All of the thoracic epidural pressures in the sitting position were negative in contrast to those in the lateral decubitus position. Moreover, an initial negative pressure in the epidural space, which has been reported previously,[2,3] was rarely observed (2 of the 28 patients).

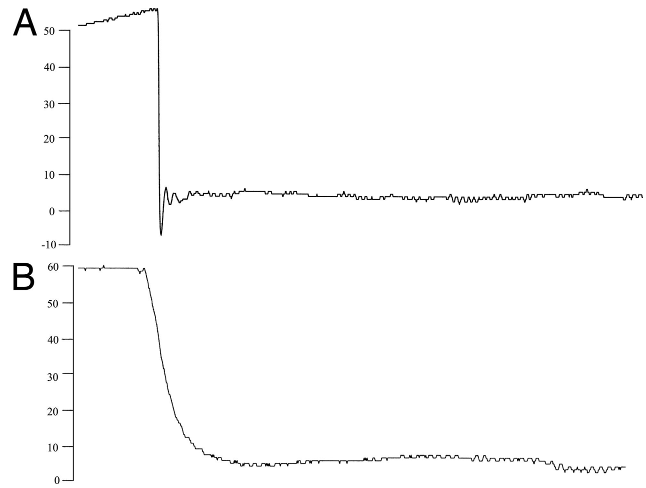

Fig. 3. Waveforms of the epidural pressure with an initial negative pressure (*A*) and without an initial negative pressure (*B*).

The hanging drop technique relies on the subatmospheric epidural pressure to draw saline into the needle hub, whereas the loss of resistance technique relies on detection of the ability to inject saline as the needle tip penetrates the ligamentum flavum. Although the loss of resistance technique might be the most popular technique, the hanging drop technique might be a better choice for several reasons at the thoracic levels. First, gaps in the ligamenta flava are frequent especially at the cervical and higher thoracic levels than at the T3–T4 level.[5] Because the loss of resistance technique uses an abrupt decrease in resistance when a Tuohy needle passes through ligamentum flavum, this gap may make the loss of resistance technique difficult and risky. Second, during the hanging drop technique, two hands can be used to grip the epidural needle, which allows stability and control as the needle is advanced.[6]

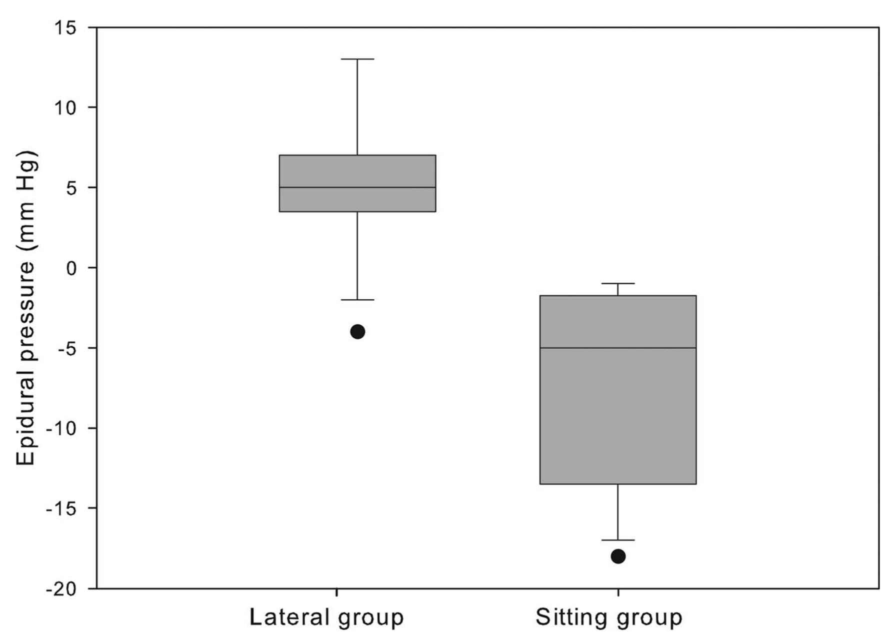

Fig. 2. The box and whisker plot compares the epidural pressure in the lateral and sitting groups. The *box boundaries* show the 25th–75th percentiles, the *lines* within the boxes indicate the median, the *whiskers* above and below the boxes indicate the 10th–90th percentiles, and the *dots* show the outliers.

Because thoracic epidural anesthesia is commonly performed in the sitting position, it is particularly important to measure negative epidural pressure in that position, and no previous study measured thoracic epidural pressure in the sitting position using a closed pressure transducer system. Although Usubiaga *et al.*[7] reported no difference between the thoracic epidural pressure in the lateral decubitus and sitting positions, the heterogeneity in subjects and measurements precluded a statistical treatment of the data.[2] In addition, in the study by Usubiaga *et al.*,[7] the closed measurement system was not used, and the zeroing position of the transducer was not described. Moreover, although Usubiaga *et al.* reported that the thoracic epidural pressure is mainly subatmospheric in both the lateral decubitus and sitting positions, this is inconsistent not only with our current study but also with other previous studies[2,3] in which the closed measurement systems were used.

In this study, an initial negative pressure was observed in only 2 of the 28 cases. However, in the previous study by Okutomi *et al.*,[3] there was a downward peak for all patients, and this resulted in negative pressures in 10 of the 13 patients. In addition, the epidural pressure was then quickly equilibrated and returned to a positive pressure in 12 of these 13 patients. Okutomi *et al.*[3] expected that such an initial negative pressure at the moment of epidural puncture may be an artifact caused by a mechanism such as tenting of the dura. However, in the study by Telford and Hollway,[8] this initial negative pressure was not described and found on the figure of pressure tracing when the needle entered the epidural space, as in most cases of our study. The shape of the epidural needle may be a factor that causes the initial artifactitious negative pressure. A less curved needle, such as one used in our study, may penetrate the ligamentum flavum more smoothly, without artifactitious effect such as dura tenting or ligamentum flavum retraction. Regardless of the mechanism, we believe that such an initial negative pressure may not occur and should not be relied on for the hanging drop technique.

Because the negative pressure of the epidural space was described by Janzen[9] in the 1920s, there has been controversy regarding the mechanism. Although the mechanism of negative epidural pressure was not examined in our current study, the result of this study provides some clues. In previous studies, artifacts by dura tenting[9] or ligamentum flavum retraction,[10] and the balance of forces defined in the Starling equation between the epidural fat and the ligamentum flavum,[11] were suggested to be responsible for the generation of negative epidural pressure. However, in our study, all of the thoracic epidural pressures were negative in the sitting position, and epidural pressure determined in the lateral decubitus position was positive in most patients. It is difficult to expect that the previous suggested mechanisms occur only in the sitting position but not in the lateral decubitus position. Moreover, the initial negative pressure, which was considered to be an artifact from dura tenting or ligamentum flavum retraction, was observed in only 2 of the 28 patients.

Negative epidural pressure in the sitting position may be generated by the following mechanism: In the epidural space, there is the epidural plexus. In the sitting position, the blood in the veins is distributed to the lower part of the body due to gravity, and the volume of the epidural plexus at the thoracic level may decrease. This decrease in volume may subsequently cause a decrease in epidural pressure. The dural sac filled with cerebrospinal fluid may also cause a similar effect. However, further study on this hypothesis is needed.

There are several limitations to this study. One is that the thoracic epidural pressures in the sitting and lateral decubitus positions were measured in different individuals. This is because it may be hazardous to change the position of a patient who has a needle inserted in the epidural space. The other limitation is the small number of subjects studied. By the "rule of three," the maximum chance of positive epidural pressure from our results would be 21%. However, this rule is adequate when the total number of observation is more than 30, and our number of observation is 14. So, the original formula should be used, and the maximum chance of positive epidural pressure would be 19%.[12] Moreover, in our study, the sex ratios of the included patients were different between two groups. There were four and zero females in the lateral and sitting groups, respectively. However, we could not find any reports or theories in which sex may independently affect the epidural pressure, and the sex imbalance of our study is not expected to influence our study conclusions.

In conclusion, the thoracic epidural pressure is more negative in the sitting position than in the lateral decubitus position. These results suggest that the hanging drop technique should be performed with the patient in the sitting position instead of the lateral decubitus position.

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