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Cervical Epidural Pressure Measurement

Comparison in the Prone and Sitting Positions

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ABSTRACT

Background: The hanging drop technique is used for identifying the cervical epidural space, using its negative pressure. However, it is doubtful whether the epidural space intrinsically exhibits a negative pressure. We designed this study to test the hypothesis that the cervical epidural pressure (CEP) is significantly higher in the prone position than in the sitting position. To evaluate this hypothesis, we measured and compared 30 CEP values in the prone and sitting positions.

Methods: We measured and compared 15 CEPs in the prone group and 15 in the sitting group using a closed pressure measurement system under fluoroscopic guidance.

Results: All CEPs in the prone group were consistently positive (median, 10 mmHg; range, 4.8–18.7; mean ± SD, 10.5 ± 4.4) in contrast to the sitting group (median, −0.3 mmHg; range, −2.4–7.9; mean ± SD, 0.5 ± 2.8). CEPs in the prone group were significantly higher than in the sitting group ($P < 0.001$).

Conclusion: CEP was found to be significantly higher in the prone position than in the sitting position. Furthermore, CEPs were not consistently negative even in the sitting position. These results suggest that the hanging drop technique is inappropriate for identifying the cervical epidural space in either the prone or sitting positions.

What We Already Know about This Topic

- The hanging drop method to identify the cervical epidural space assumes a negative pressure that may not occur in all patients and patient positions.

What This Article Tells Us That Is New

- In 15 patients receiving cervical epidural injections in the prone position, epidural pressure was positive in every case, and in another 15 in the sitting position, it was not uniformly negative.
- The hanging drop method may not identify the epidural space in all patients, particularly when they are in the prone position.

CERVICAL epidural steroid injections (CESIs) are used worldwide for the conservative management of head, neck, and upper extremity pain.[1–3] When performing CESIs, proper identification of the epidural space is imperative to minimize the risk of dural puncture, which is associated with potentially catastrophic complications, such as permanent spinal cord injury.[4–7]

To identify the cervical epidural space, practitioners occasionally use the hanging drop (HD) technique,[8] which identifies the epidural space using its negative pressure.[9] However, it is doubtful whether the epidural space intrinsically exhibits a negative pressure. In previous studies, in which closed pressure measurement systems were used,[10–12] epidural pressure (EP) was commonly found to be positive at the thoracic level in the lateral decubitus position and to be consistently negative only in the sitting position.[10] These results suggest that EP is influenced by body position, and that patients should be seated when the HD technique is used. However, to our knowledge, no report or peer-reviewed article has been conducted on the topic of cervical epidural pressure.

Accordingly, we designed this study to test the hypothesis that CEP is significantly higher in the prone position than in the sitting position. To evaluate this hypothesis, we measured

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and compared CEPs in prone and sitting groups using a closed pressure measurement system under fluoroscopic guidance.

Materials and Methods

We conducted an open-labeled, randomized, comparative study. CEP measurements were taken in 30 patients scheduled for CESIs.

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (Sungnam-si, Kyonggi-do, Republic of Korea) and was registered with Clinical Trials (Ref: NCT01009385). Assessments and procedures were carried out at a university-based pain clinic. All participants were given extensive written and verbal information about the trial, and of its potential benefits and risks, before they provided written consent.

The inclusion and exclusion criteria are listed in table 1 and patient selection and allocations to the prone and sitting groups are described the flow diagram in figure 1. An independent researcher performed the group allocations using a computer-generated random list.

All epidural injections were performed by one pain clinician (J.M.), using the midline approach at the C6–C7 level, where fluoroscopic lateral images showed no overlap with adjacent structures of the torso or arms in the prone or sitting positions. During CESI, patients in both groups were asked to place their heads on the table (a small headrest was placed under the forehead) and to flex their necks fully, which maximally widens the C6–C7 interlaminar space. After aseptic preparation and skin infiltration with 1% lidocaine, a 20-gauge Tuohy needle with attachable wing (Tae-Chang Industrial Co., Kongju, Republic of Korea) was inserted in the midline with a tunnel view parallel to the trajectory of the spinous processes under fluoroscopic guidance using anteroposterior images. When the needle was firmly grasped, a lateral image was taken to ensure that the needle tip was positioned in the C6–C7 supraspinous or interspinous ligament. EP measurements were then taken using a closed measurement system.[12] In brief, a saline reservoir was placed at the level of the transducer (Autotransfuser®; Acemedical, Kyonggi-do, Republic of Korea) to prevent saline from flowing into the epidural space. The zero level was set at the needle insertion point using a laser-leveling device. After removing of the stylet in the Tuohy needle, the needle was filled with saline and connected to the pressure monitoring system equipped with a disposable transducer *via* an 80-cm long polyvinyl chloride tube also filled with saline. Maintaining the same trajectory in the lateral plane, we advanced the epidural needle very slowly holding the attachable wing in place with our thumbs and index fingers under fluoroscope guidance using lateral images. The high pressure was observed during passage through the ligament flavum. The needle should not be advanced beyond the spinolaminar line. A tactile sensation of give with a precipitous decrease in the displayed pressure was noted just as the needle was entered the epidural space. The bevel of the needle was considered to have entered the epidural space when a typical waveform was observed, which consisted of small cardiac oscillations superimposed on greater respiratory oscillations. The needle was then held immobile in the epidural space for 120 s to allow the epidural pressure to stabilize, and CEP was measured.

Table 1. Inclusion and Exclusion Criteria

Inclusion criteria
(1) Age 20 to 80 yr
(2) Cervical radicular pain caused by herniated nucleus pulposus, spinal stenosis, or other conditions, including herpes zoster-associated pain and sprain for more than 3 months
(3) Axial cervical pain consisting of generalized neck symptoms, zygapophysial joint pain, or interscapular pain
(4) Pain intensity ≥ 5 of maximum 10 NRS
(5) Failure to improve with conservative treatment
(6) Cervical epidural location of needle confirmed by the fluoroscopic images
Exclusion criteria
(1) Acute infection
(2) Patient refusal
(3) Previous cervical spine surgery
(4) Structural spinal deformities
(5) Rapidly worsening pain, numbness, weakness, hyperreflexia, changes in bladder function, and other neurological symptoms that should prompt a reevaluation and surgical evaluation
(6) Pregnancy
(7) Allergy to contrast media or drugs to be used in the procedure

NRS = numerical rating scale.

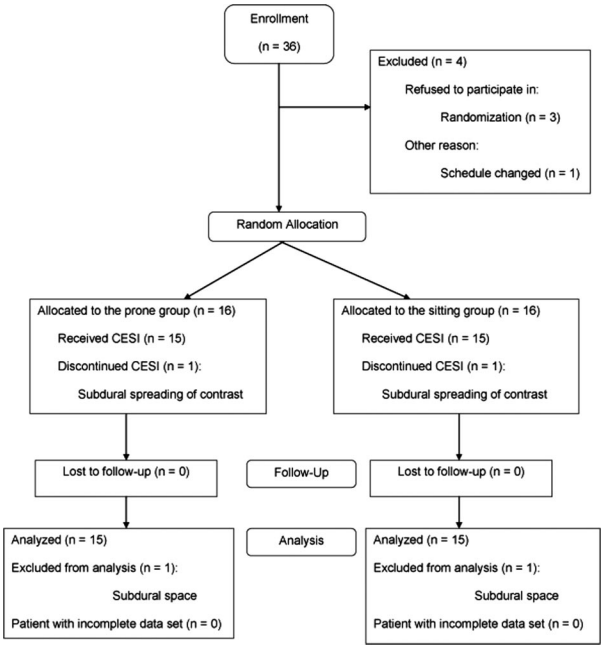

Fig. 1. Flow diagram showing enrollment, random allocation, follow-up, and analysis. The diagram shows the number of participants in each intervention group. CESI = cervical epidural steroid injection.

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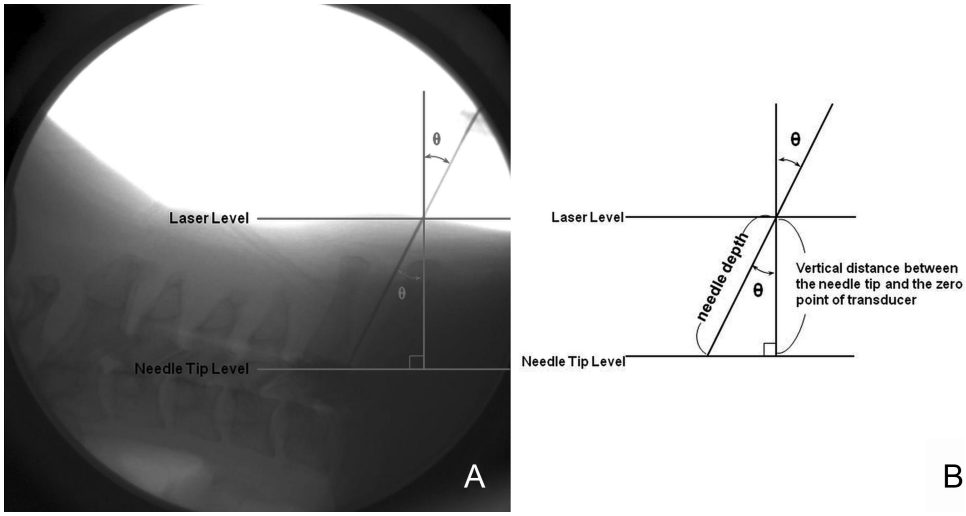

Fig. 2. (*A*) Lateral fluoroscopic images of cervical epidural puncture performed at the C6–C7 interspace. θ is the angle of the needle with respect to the gravity. (*B*) The diagram shows that the vertical distance between the transducer and needle tip can be calculated from the needle depth and angle against gravity. Distance = needle depth × cos(angle against gravity).

The greatest positive pressure generated during needle passage through the ligament flavum, the initial negative pressure measured on entering the epidural space, and measured CEP were recorded by an anesthesiologist unaware of study details. The same anesthesiologist then recorded needle depth and needle angle with respect to the gravity (fig. 2A). The measured CEP values were corrected to EP valued at the needle tip (fig. 2B) using the following formula: Epidural pressure = measured pressure + [needle depth × cos(measured needle angle) × 0.735], where 0.735 is a unit conversion factor (1 cm H_2O = 0.735 mmHg). In addition, neck flexion angle was measured using a goniometer placed on the C7 spinous process with respect to the line between the occiput and the upper thoracic spinous process on lateral fluoroscopic image.

Final needle positions were checked to ensure that the needle was at or only slightly beyond the spinolaminar line in the lateral fluoroscopic radiograph and midline in the anteroposterior radiograph. A syringe contained contrast medium (Omnipaque® 300 [iohexol, 300 mg of iodine per ml]; GE Healthcare, Piscataway, NJ) was attached to low-volume extension tubing and flushed. Before attaching the extension tubing, the Tuohy needle was disconnected from the pressure monitoring system equipped with a disposable transducer, and a drop of contrast was placed in the needle to flush out any air. Then, under live fluoroscopy, contrast was injected evaluating for epidural flow and ensuring no vascular pattern. If a venous pattern occured, the needle was withdrawn and repositioned, but its CEP was excluded from the data analysis. If an arterial pattern or a myelographic pattern indicating subarachnoid injection occurred, CESIs were abandoned and their CEPs were excluded. If contrast was confirmed to flow epidurally along the spinolaminar line creating a dorsal stripe, the needle was readjusted and a solution (5 ml) containing 10 mg triamcinolone acetonide suspension (Tamcelon®; HanAll Pharmaceutical Co., Ltd., Seoul, Republic of Korea), 1.5 ml of 0.75% levobupivacaine hydrochloride (Chirocaine®; Abbott Korea Ltd, Seoul, Republic of Korea), and 3.5 ml of normal saline (0.9% NaCl) was then slowly infused under live fluoroscopy. After the procedure, patients were observed for adverse effects, and a neurologic examination was performed in a recovery room by a specially trained nurse in each case.

Statistical Analysis

The sample size calculations were based on the findings of a previous study, which reported a mean EP at the T5–T6 level of −7.2 ± 6.3 mmHg in the sitting position and −5.1 ± 4.4 mmHg in the lateral decubitus position.[10] Based on a type 1 error of 0.05, a type 2 error of 0.1, and a two-sided test, at least seven patients per group were required for the analysis, but because we were unaware of pressure ranges in the cervical epidural space, we included 16 patients per group. An independent reviewer provided statistical analysis using SPSS version 15.0 (SPSS, Chicago, IL). Fisher exact test was used to compare frequency differences in the two groups; the Mann–Whitney U test was used to calculate statistical differences in continuous variables; and Spearman's correlation coefficients were used to examine the relationship between CEP values and the measurements of the subjects. Analysis of covariance, adjusted for neck flexion angle as a covariate, was used to compare CEPs in the two groups. *P* values of less than 0.05 were considered statistically significant.

Results

Thirty-six patients treated in October and November 2009 were enrolled; among them, 32 patients were randomly allocated to the prone and sitting groups (fig. 1). However, two patients (one in each group) who showed a typical waveform of the epidural space were excluded because the needle tip was found to be located in the subdural space on the lateral and anteroposterior fluoroscopic images. No CESI was per-

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Table 2. Demographics of Patients

	Prone Group (n = 15)	Sitting Group (n = 15)
Age, yr	57.5 ± 15.8	46.3 ± 15.3
Weight, kg	59.9 ± 14.9	61.5 ± 11.0
Height, cm	159.4 ± 9.9	163.7 ± 10.4
Male/Female	4/11	7/8
Duration of Symptoms, mo	5.8 ± 4.7	5.7 ± 5.2
Indications for CESI		
Herniated Nucleus Pulposus	4	3
Spinal Stenosis	2	2
Herpes Zoster-associated Pain	1	1
Sprain	8	9
Neck Flexion Angle (°)	18.6 ± 9.7*	9.3 ± 4.7

Data are reported as mean ± SD or number of patients.
* $P < 0.05$ *vs.* sitting group.
CESI = cervical epidural steroid injection.

formed in these two patients. No significant clinical or demographic differences were found between the two groups except for neck-flexion angle (table 2).

Median EP was 10.0 mmHg (interquartile range, 6.4–13.6; range, 4.8–18.7; mean ± SD, 10.5 ± 4.4) in the prone group and −0.3 mmHg (interquartile range, −1.3–2.0; range, −2.4–7.9; mean ± SD, 0.5 ± 2.8) in the sitting group (fig. 3). Ten EPs in the sitting group were negative and five were positive. All 15 EPs in the prone group were positive. According to the Mann–Whitney U test, mean CEP in the prone group was significantly higher than in the sitting group ($P < 0.001$). Furthermore, mean neck-flexion angles differed in the two groups ($P = 0.01$). Spearman's correlation analysis revealed a moderate degree of correlation between CEP and neck flexion angle ($r = 0.53$, $P = 0.004$). Therefore, analysis of covariance was used, adjusted for neck flexion angle as a covariate. Consequently, a significant difference was found between mean CEPs in the two groups ($P = 0.005$) (table 3).

Table 3. Association between Cervical Epidural Pressure and Covariates

	ANCOVA	
Variables	*F* Value	*P* Value
Neck Flexion Angle	0.689	0.415
Body Position	9.457	0.005
Neck Flexion Angle X Body Position	0.041	0.841

F value shows the strength of association of body position and cervical epidural pressure by analysis of covariance (ANCOVA) regression analysis.

A high positive pressure (from +35 mmHg to +283 mmHg) was observed during needle passage through the

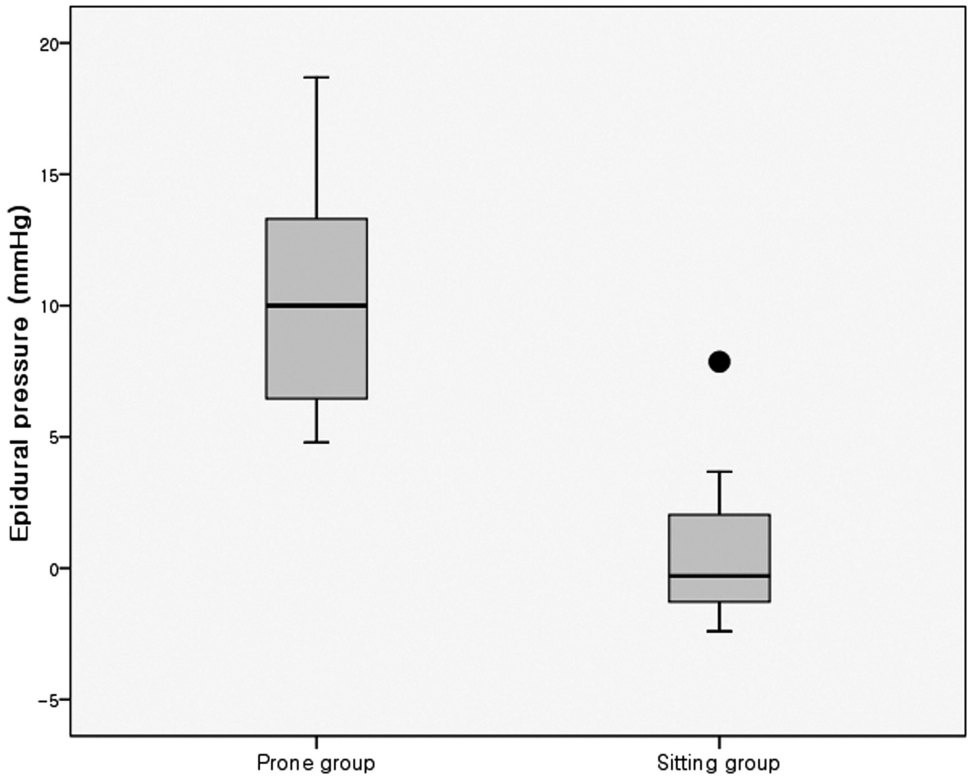

Fig. 3. The difference in epidural pressure between the prone and sitting groups. Data are shown as box-and-whisker plots. Cervical epidural pressure in the sitting group was lower than in the prone group ($P = 0.005$). *Box boundaries* show 25th to 75th percentiles; *lines within boxes* indicate medians, *whiskers above and below boxes* indicate 10th to 90th percentiles, and a *dot* shows the outlier.

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ligamentum flavum. However, at the moment of epidural puncture, high negative pressures (range, −27.0 to −2.0 mmHg) were observed for a few seconds in seven cases, as has been previously reported.[12] However, in these patients, epidural pressure soon stabilized at −2.4 to +4.0 mmHg within 120 s.

Reported complications at follow-up examinations were minor and transitory: headache episodes, 2 of 30; facial flushing, 2 of 30; and transient pain, 3 of 30.

Discussion

The present study is the first to report CEP values measured using a closed pressure measurement system. In particular, CEP was found to be significantly higher in the prone position than in the sitting position. Furthermore, all CEPs in the prone group were consistently positive, whereas in the sitting group, median CEP was almost zero.

Cervical epidural punctures are occasionally performed using the HD technique,[8,13] which depends on a negative EP to draw saline into the needle hub. Furthermore, the subatmospheric nature of CEP has been suggested to be an excellent, reliable indicator of epidural needle placement.[13] However, we found that all 15 CEPs measured in the prone position and 5 of 15 in the sitting position were positive, which implies that the HD technique is inappropriate for performing CESIs.

Negative pressures are believed to be generated by either tenting of the dura caused by an advancing blunt needle[14] or to the retraction of the ligamentum flavum.[15] Furthermore, they have been suggested to be more important than absolute pressures within the epidural space when the HD technique is used.[16] However, the ligamentum flavum in the cervical region is relatively thin and frequently is not fused at the midline.[17] Furthermore, we observed an initial negative pressure in only 7 of the 30 subjects. Despite the fact that we used a less curved needle, which may have penetrated the ligamentum flavum more smoothly and thereby may have induced fewer artifactual effects, such as dura tenting or ligamentum flavum retraction,[10] we believe that EP is often nonnegative in the cervical spine; thus, a negative CEP should not be crucial for the HD technique.

In a previous report, EP was found to be more negative in the sitting position than in the lateral decubitus position, and EPs in the sitting position were found to be consistently subatmospheric.[10] This suggests that EP differences in different patient positions are generated by gravity. That is to say, blood in the epidural plexus and cerebrospinal fluid in the dural sac are redistributed on changing body positions, and the sitting position favors a negative EP. We presume that this phenomenon is also applicable to CEP; thus, CEP should be consistently negative, and theoretically more negative than thoracic EP, at least in the sitting position. However, we found that median CEP in the sitting position was greater than the median thoracic EP reported previously (measured using a closed pressure measurement system),[10] and that CEP in the sitting position was not always subatmospheric. The reasons for this difference can be speculated upon. While performing a CESI, the cervical spine should be flexed to open the interlaminar space as widely as possible. Previous studies have suggested that rapid, large increases in EP could be produced by compression of the jugular vein[18] or by neck flexion.[19] Anatomically, the epidural veins are concentrated in the anterolateral portion of the epidural space,[20] but in the presence of an obstruction to venous run-off, the mid-posterior epidural space is likely to contain large, distended, high-pressure veins, which would reduce the volume of the entire posterior epidural space. Indeed, the epidural space may play a role as a cushion and absorb pressures generated by an over-distended epidural venous plexus. In the cervical region, the smaller cervical epidural space[20] could reduce this cushioning effect compared with the epidural space at the thoracic level. We believe that this is the reason why CEP was not found to be consistently negative in the sitting position.

Whether neck flexion increases CEP is debatable. In a previous report,[21] cranial spread of contrast medium was found to be significantly increased by neck flexion, and it has been speculated that the decrease in EP observed after flexion at the lumbar level[22] could also occur after flexion at the cervical spine level.[21] However, it has never been claimed that neck-flexion angle affects contrast spread.[23] In one study, it was suggested that an anterior shift of the posterior aspect of the dura during neck flexion probably results in a transient negative pressure in the posterior spinal canal, and consequently increases venous volume within the posterior epidural venous plexus,[24] which we believe could increase CEP.

The present study could be criticized for a failure to control neck-flexion angle in the two groups. However, a supplementary study failed to reveal any change in neck-flexion angle after patient repositioning. Evidently, further study of the relationship between CEP and neck-flexion angle is needed.

Several other study limitations warrant consideration. First, differences between EPs in different body positions may have been better analyzed by comparing among individual patients rather than between patient groups. However, there are risks associated with changing the position of a patient with a needle inserted in the cervical epidural space. Second, the possible relations between pathologic conditions at the C6–C7 level and CEP were not investigated because patient numbers were limited. Furthermore, in each case, different amounts of contrast medium were injected to confirm needle tip location in epidural space; thus, we could not evaluate whether contrast flow was affected by pressure recording. Accordingly, we suggest that additional investigations be undertaken to examine relations between CEP and pathologic conditions at the C6–C7 level and contrast flow rates.

In summary, we found that CEP was significantly greater in the prone position than in the sitting position. Further-

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more, CEPs were not consistently negative even in the sitting position. These results suggest that the HD technique is inappropriate for identifying the cervical epidural space in the prone or sitting positions.

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