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Position-Related Variability of CSF Opening Pressure Measurements

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ABSTRACT

BACKGROUND AND PURPOSE: Normative data for CSF OP have previously been established with patients in the LD position. During fluoroscopically guided LP procedures, radiologists frequently obtain these OP measurements with patients prone. In this prospective study, our goal was to determine the variability of OP measurements as a function of patient positioning and to assess whether there is a relationship with patient BMI.

MATERIALS AND METHODS: Consecutive patients reporting for fluoroscopically guided LP or myelography were enrolled. OP was measured with the patient in 3 positions, with the order of the technique randomized: prone with table flat, prone with table tilted until the hub of the needle was at the level of the right atrium, and LD with the needle hub at the level of the spinal canal. The BMI of each patient was calculated. The Wilcoxon signed-rank test and linear regression analysis with bivariate fit of difference were used for analysis.

RESULTS: OP measurements with the patient in the prone position were significantly elevated compared with those in the LD position, with mean differences of 2.7 ($P < .001$) and 1.6 cm H_2O, ($P = .017$) for prone flat and prone tilted, respectively. There was no significant difference in OP measurements for the prone flat versus prone tilted positions ($P = .20$). There was no correlation between BMI and observed differences (LD-flat: $R^2 = 0.00028$; LD-tilt: $R^2 = 0.00038$; prone-tilt: $R^2 = 0.00000020$).

CONCLUSIONS: Measuring OP with the patient in the prone position may result in overestimation of CSF pressure. Table tilt did not significantly impact mean prone OP. Radiologists should specify exact patient positioning when reporting OP measurements.

ABBREVIATIONS: BMI = body mass index; LD = lateral decubitus; LP = lumbar puncture; OP = opening pressure

OP measurement is a frequently requested portion of the diagnostic lumbar puncture. These OP measurements are clinically useful for establishing diagnoses and monitoring therapy, ranging from normal pressure hydrocephalus to pseudotumor cerebri.

When lumbar punctures are performed without fluoroscopic guidance, patients are typically placed in the LD position. Normal OP values have been established with patients in this position.[1,2] However, lumbar punctures with fluoroscopy are typically performed with the patient prone, and OP measurements are most often obtained in the prone position.[3]

At our institution, 3 techniques are used to measure OP, depending on the preference of the operator performing the lumbar puncture, with fluoroscopic guidance. In 1 technique, the OP is measured with the patient prone and the table flat. In another technique, the head of the bed is elevated until the hub of the needle is estimated to be at the level of the right atrium. With the third technique, the patient is rolled into the LD position with legs extended and the pressure is measured from the hub of the needle.

In this prospective study, our aim was to evaluate the variability of OP measurements as a function of patient positioning and to determine whether there is a relationship with BMI.

MATERIALS AND METHODS

Patient Selection

Institutional review board approval with written consent was obtained for this Health Insurance Portability and Accountability Act–compliant prospective study. Patients scheduled for myelography or LP with fluoroscopic guidance in the section of neuroradiology were considered for inclusion. Patients were excluded for mental incapacity or dementia that made them unable to give informed consent, if sedation or general anesthesia was used during the procedure, or if patients were unable to cooperate or might require restraint during the procedure. Minimum age for inclu-

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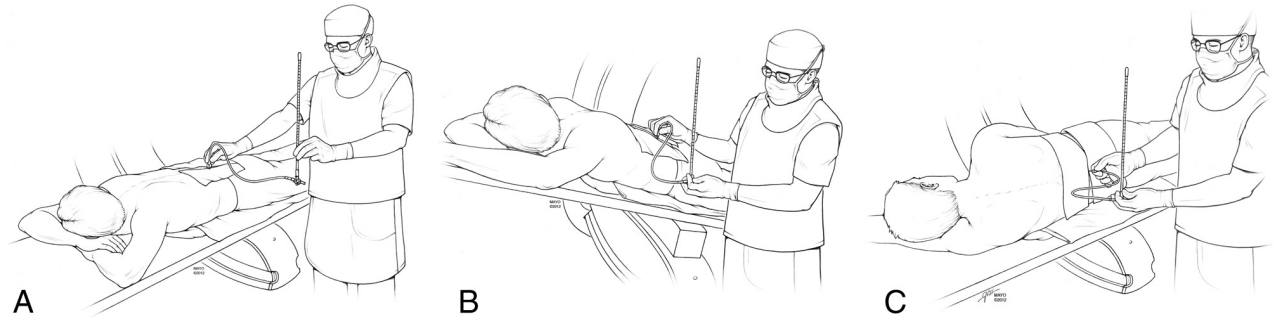

FIG 1. Patients were placed in 3 positions for OP measurement: patient prone with table flat (*A*), patient prone with table tilted until the needle hub was estimated to be at the level of the right atrium (*B*), and patient in lateral decubitus position with needle hub estimated to be at the level of the spinal canal (*C*).

sion was 18 years. Sixty-seven of 83 patients approached during this time period were enrolled in the study between June 2011 and May 2012.

LP and OP Measurement Technique

All procedures were performed by a board-certified radiologist, 1 of 11 neuroradiology staff members, or 1 of 5 neuroradiology fellows supervised by 1 of these staff members. A spinal needle (20- or 22-gauge; 90, 127, or 152 mm in length) was placed into the subarachnoid space in the lumbar spine with fluoroscopic guidance with the patient prone. No bolster or pillow was used beneath the patient's abdomen. Following placement of the spinal needle, OP was obtained with the patient in 3 positions (Fig 1). The order in which the measurements were collected was randomized to adjust for potential carryover effect or drop-out due to fatigue during the maneuvers. Randomization envelopes were provided to the radiologist at the beginning of each procedure, indicating the order of patient positioning during OP measurements. In all cases, the patient was coached to breath in a slow relaxed manner without breath-holding or Valsalva.

In the flat prone position, the OP was obtained with the patient prone and the table flat. The manometer was attached to the needle hub or connecting tubing, and the length of the spinal needle was added to the column of fluid in the manometer for the OP measurement. OP was measured when the column of fluid in the manometer stopped rising and respiratory fluctuation began. In the tilted prone position, the head of the bed was elevated until the hub of the needle was estimated to be at the level of the right atrium, approximated by reference to the midaxillary line just below the nipple, and the OP was measured from the hub of the needle. In the LD position, the spinal needle was first placed with the patient prone; after we confirmed the subarachnoid position, the patient was rolled into the left LD position. The patient was asked to extend his or her legs and breathe normally, and the patient was positioned so that the hub of the needle was at the estimated level of the spinal canal. The OP was measured at the level of the spinal canal from the hub of the needle.

For all patients, the weight, height, BMI, gauge and length of spinal needle used, and complications/adverse events were recorded.

Statistical Analysis

Statistical analysis was performed by using a software package (JMP version 9.0; SAS Institute, Cary, North Carolina). The OPs obtained sequentially across each patient were treated as matched data for statistical analysis with the differences between OP values analyzed via the Wilcoxon signed-rank test. Linear regression analysis with bivariate fit of difference was used to analyze potential correlation between BMI and the different techniques. A Student *t* test was used to analyze potential differences in opening pressure related to needle gauge. A P value $< .05$ was considered statistically significant.

RESULTS

Patient and Procedure Characteristics

Of 67 patients who agreed to participate in the study, 12 (18%) were excluded during the study for the following reasons: 4 had OPs that were not measurable in any position, 3 could not roll on their sides due to discomfort (the discomfort was present before needle placement), 1 patient became ill and the lumbar puncture was not performed, 1 patient changed his mind during the procedure, 1 study was terminated by the radiologist due to difficulty with needle placement, 1 patient had a negative OP measurement recorded, and 1 patient had the needle bend after placement in the LD position (the needle was removed without difficulty and the study was terminated).

Of the 55 of 67 (82%) patients recruited who completed the study, 24 (44%) were men and the average age was 56 years (age range, 20–80 years). BMI could be calculated for 52 (95%) patients. Average BMI was 31 (range, 21–49). There were 24 (44%) LPs and 31 (56%) myelograms (2 cervical, 4 thoracic, 15 lumbar, 5 entire spine, 3 cervical and lumbar, and 2 thoracic and lumbar). A 20-ga spinal needle was used in 33 (60%), and a 22-ga, in 22 (40%). The spinal needle was 90 mm in length in 42 (76%), 127 mm in 1 (2%),152 mm in 9, (16%), and was not recorded in 3 (5%) patients. There were no complications during these OP measurements.

OP Measurements

The mean OP in the prone flat position was 15.3 ± 4.8 cm H_2O; in the prone tilted position, it was 14.2 ± 5.9 cm H_2O; and in the LD position, it was 12.6 ± 4.8 cm H_2O. There was a significant difference between the LD position and the 2 prone positions, with

Mean OP measurements for each position and differences in measurements between positions

	Mean OP ± SD (cm H_2O)	*P* Value
Prone flat	15.3 ± 4.8	
Prone tilt	14.2 ± 5.9	
LD	12.6 ± 4.8	
Difference between prone flat and prone tilt	1.1 ± 0.80	.20
Difference between LD and prone flat	2.7 ± 0.69	.001
Difference between LD and prone tilt	1.6 ± 0.67	.017

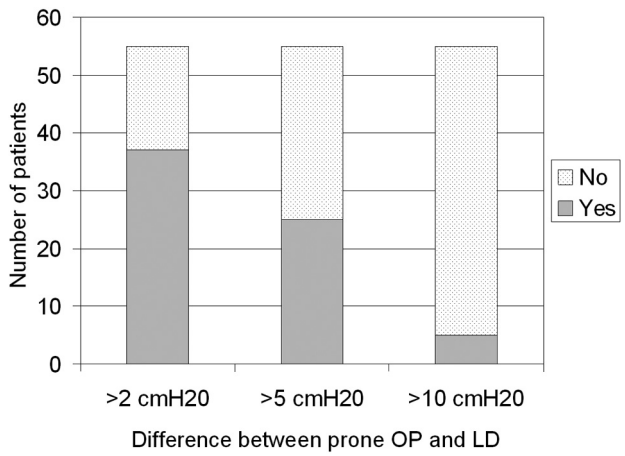

FIG 2. Number of patients in whom the OP measurement in either prone position (table flat or table tilted) was greater than the LD OP measurement by more than 2 cm H_2O, 5 cm H_2O, or 10 cm H_2O.

the measurements in the prone flat and prone tilted positions elevated by means of 2.7 ± 0.69 cm H_2O ($P < .001$) and 1.6 ± 0.67 cm H_2O ($P = .017$), respectively (Table). The OP measurements in the prone flat position were a mean of 32% higher than those in the LD position (SD ± 51%), and OP measurements in the prone tilted position were a mean of 18% higher than those in the left LD position (SD ± 42%). As reflected in the SDs, there was variability, and in 4 (7%) patients, the OP measurement in the LD position was higher than the measurements in either prone position. There was no significant difference between the OP measurements in the prone positions (table flat and table tilted; $P = .20$). Forty-seven of 55 (85%) patients had a difference (either positive or negative) of at least 2 cm H_2O between the LD and 1 or both of the prone positions. In 37 (67%) of these 55 patients, 1 of the prone positions resulted in an overestimation of ≥2 cm H_2O compared with the LD position (Fig 2). In 15 patients (27%) with low OP (<10 cm H_2O) in the LD position, the OP in the prone position would have been categorized as normal (10–25 cm H_2O). In 1 patient (2%) with normal OP in the LD position, the OP in the prone position would have been categorized as high (>25 cm H_2O).

There was no statistically significant correlation between BMI and OP measurement differences between groups (LD-flat: $R^2 = 0.00028$; LD-tilt: $R^2 = 0.00038$; prone-tilt: $R^2 = 0.00000020$). There was no statistically significant correlation between needle gauge and OP measurement differences between groups (LD-flat: $P = .07$; LD-tilt: $P = .79$; prone-tilt: $P = .07$).

DISCUSSION

In the current prospective randomized study, we demonstrated that measuring OP in the prone position can lead to overestimation of CSF pressure compared with that measured in the LD position. In two-thirds of patients, we noted a difference of ≥2 cm H_2O overestimation of OP in 1 or both of the prone positions compared with the standard LD position. These findings indicate that the OP should be recorded in the LD position whenever possible and that clinicians should be made aware when the OP reading is performed with the patient prone. If an OP is measured prone, tilting of the table so that the needle hub is at the level of the right atrium does not significantly affect the OP.

Previous studies have noted several factors that may increase OP during lumbar puncture, including sedation or anesthesia,[1,4] Valsalva maneuvers,[5] uncooperative patients requiring restraint,[6] and flexion versus extension of the legs and body.[6-9] Authors have suggested that increased CSF pressure may be seen with changes in body position due to increases in venous pressure, which is related to cerebral perfusion pressure and, therefore, CSF pressure.[9] Other authors have shown that the prone position increases intraocular pressure, which correlates with central venous pressure, implying that prone positioning increases venous pressure.[10] These findings suggest that the prone position leads to increased CSF pressure by increasing central venous pressure. Our current study adds to this previous literature, because we observed increased CSF OP in the prone position.

Previous literature has also shown a small but statistically insignificant correlation between patient BMI and OP.[2] In our own study, we found no significant association between BMI and the OP measurement variation between positions. However, our study may not have had sufficient statistical power to detect a small correlation between BMI and measurement variation between the prone and LD positions.

A limitation of the study is the lack of precision in patient positioning with the table tilted. This technique relies on estimation that the needle hub is at the level of the right atrium and may vary by operator. This concern is supported by the greater measurement variation noted in this position. However, we believe this accurately reflects the variability of patient position when this technique is used in clinical practice. Estimation of the needle placement at the level of the spinal canal in the LD position is similarly imprecise. Another limitation was the relatively small sample size, so the power to detect differences between prone positions was limited. Additionally, there were multiple different operators who may use slightly different techniques for OP measurements, and it was not possible to determine whether the results are reproducible for a single operator or between operators.

CONCLUSIONS

Measuring OP with patients in a prone position can lead to elevated measurements compared with the LD reference values. The authors advocate repositioning patients in the LD position if possible when measuring OP or reporting that the OP was obtained with the patient prone.

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