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Original Contributions

Is Lateral Decubitus or Upright Positioning Optimal for Lumbar Puncture Success in a Teaching Hospital?

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□ **Abstract—Background: Lumbar puncture is a common procedure performed by emergency physicians and trainees. The optimal patient positioning for lumbar puncture procedures has not been studied adequately. Objectives: We performed a prospective randomized study in an urban, level I academic trauma center. Patients of all ages were included. Patients were randomized to either lateral decubitus or upright positioning. Patient demographic characteristics, level of physician training and experience, number of needle insertions and redirections, need for repositioning, alternative operator use, and laboratory results of the cerebrospinal fluid were recorded. We compared the success rate of each position as our primary outcome measure. We also evaluated number of needle insertions and re-directions and success rates based on experience and patient age. Results: A total of 116 patients were enrolled, with 55 patients assigned to lateral decubitus and 61 to upright position for initial lumbar puncture attempt. Spinal fluid was obtained successfully in 47 of the lateral decubitus group (85.5%; 95% CI 73.8–92.4%) vs. 49 (80.3%; 95% CI 68.7–88.4%) in the upright assignment group. Comparable results were also obtained for first-pass success, number of failures, and number of bloody taps. Postgraduate year 2 residents or those with 31–50 previous lumbar punctures had the highest success rates at 94.3% (95% CI 81.2–98.4%) and 90.3% (95% CI 75.1–96.7%), respectively. Conclusions: Lateral decubitus and upright positioning for emergency lumbar puncture yielded equal success rates in emergency physicians and trainees. © 2022 Published by Elsevier Inc.**

□ **Keywords—Lumbar puncture; Procedure; Positioning; Medical education**

Introduction

Emergency physicians are often required to perform lumbar punctures during their practice and training. Success rates for this procedure range broadly across the literature. It is not uncommon for the physician to have to make multiple attempts to receive an adequate amount of cerebrospinal fluid (CSF) for processing. Unsuccessful attempts may lead to additional complications, such as longer procedure times, use of more sedation, increased patient discomfort, increased risk for infection, and increased odds of contaminating the CSF with blood or other products. Ultimately unsuccessful lumbar punctures can lead to unnecessary testing, delayed antibiotic administration, longer times to emergency department admission, longer hospital admissions, and increased mortality (1,2).

There are many procedural variations that may impact success of lumbar punctures. The optimal positioning for lumbar puncture procedures has not been adequately studied in emergency physicians. The technique is traditionally taught to be performed with the patient in the lateral decubitus position, with upright position reserved for the more difficult cases or for failure in the lateral decubitus position (3). The lateral decubitus position is the preferred position for obtaining opening pressure, as normative opening pressure data have been published and studies suggest changing position may increase opening pressure values (4).

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Success rates for lateral decubitus compared with upright positions are unknown. Studies that attempt to answer this question are limited to the pediatric population, anesthesia patients, or are retrospective or observational in nature (5,6). Analysis of the impact of patient position on the success and complication rates of lumbar puncture may provide physicians with data on optimal positioning for performing and teaching lumbar punctures. We sought to determine whether lateral decubitus or upright positioning leads to higher success rates for lumbar puncture in all patient populations seen within an academic, tertiary care, teaching hospital emergency department.

Materials and Methods

Study Design

We conducted a randomized prospective trial to evaluate the impact of patient position on success rate of lumbar puncture. We randomized patients to be placed in either the lateral decubitus position or upright position for this procedure. This study protocol was approved by our Institutional Review Board.

Setting and Population

We conducted this study at a single emergency department at a level I urban trauma center with an emergency medicine training program. The department has an annual census of combined pediatric and adult patients of approximately 145,000 patients. As a training site with multiple Accreditation Council for Graduate Medical Education–accredited residency programs, rotating residents included emergency and pediatric residents ranging from postgraduate year (PGY) 1 through 3. All patient care was supervised by board-certified academic emergency physician attendings who are core teaching faculty.

Selection of Participants

Patients of all ages were eligible for enrollment if they were deemed to require a lumbar puncture by the treating physician as part of their clinical evaluation. We included a convenience sample any time of a day that a researcher was present. Pregnant patients and neonates, defined as age younger than 3 months, were included in this study. We excluded patients if they were intubated, incarcerated, unable to sit or recline to lateral decubitus positioning, or if opening pressure measurement necessitated lateral decubitus positioning. We enrolled patients over a 1-year period. Using an α level of 0.05 and a power of 90% to detect a 5% difference, we derived a calculated sample size of 116 patients.

Study Protocol

We enrolled eligible patients after obtaining informed consent from the patient or guardian. Patients were randomized using a random number table to either lateral decubitus or upright position for the initial lumbar puncture attempt.

Assignments were concealed in a sealed packet with the assigned initial position revealed only after the patient was entered into the study. We collected patient demographic data, including age, sex, race, and indication for lumbar puncture. The trainee physician then performed the lumbar puncture according to the randomized position.

Lumbar puncture was performed by emergency medicine or pediatric residents, all under supervision by board-certified emergency physicians. A maximum of five needle insertions were permitted before either another physician attempted or alternative positioning for the procedure was required. An insertion was defined as an entry through the skin with the spinal needle directed toward the spinal canal.

Immediately after the procedure, the physician performing the lumbar puncture recorded the data. Procedural data were recorded, including number of insertions, number of needle redirections, use of local anesthetics or sedation, and need for repositioning or alternative operator (another physician) for the lumbar puncture. A needle redirection was defined as a re-aiming and advancement of the spinal needle during an insertion without withdrawal out of the skin. Results of laboratory studies on the CSF were recorded and included amount of fluid obtained, cell count, Gram stain, and culture results.

Outcomes

The primary outcome was successful lumbar puncture. We defined lumbar puncture success as obtainment of at least 1.5 mL CSF, which is the minimum volume required by our laboratory for complete fluid analysis. We did not use first-pass success rate as the primary outcome because we believed this to be arbitrary among learners of the procedure. The procedure was deemed unsuccessful if no CSF was obtained, the patient had to be repositioned into the alternative position not selected, or a change of operator was necessary. Secondary outcomes included first-pass success rate, number of insertions, number of redirections, and number of blood contaminated taps. First-pass success rate was defined as obtaining fluid from a single insertion with or without redirection. We defined a blood contaminated tap as CSF containing > 1000 RBC/mm^3, a commonly used cutoff within the literature (7). As an academic institution, we

also used these data to report on trends of educational components related to lumbar puncture success rate.

Data Analysis

Study authors entered all data into a Microsoft Excel database. The primary analysis evaluated the success of lumbar puncture based on position. Secondary analysis included evaluation of number of insertions, redirections, PGY level, preferred positioning, or blood contaminated tap based on positioning. We performed statistical testing using Microsoft Excel, version 16.57. Statistics were confirmed using VassarStats online software and were verified by our statistician (L.P.) (8). We used χ^2 testing to compare proportions between groups. We used 95% CIs to demonstrate statistical significance. Findings were considered statistically significant if the p value was < 0.05.

Results

A total of 120 patients were enrolled over an approximately 1-year period; 4 patients were excluded due to incomplete data collection. The lateral decubitus group contained 55 patients and the upright positioning group contained 61 patients. There were no significant differences between the two groups with regard to age, residency training level of lumbar puncture operator, or numbers of previously performed lumbar punctures by the operator (Table 1). Only 6 patients in total received any type of sedation in the form of intranasal or oral versed. The success rates for the upright and lateral decubitus positions were similar for those with sedation, 2 of 2 (100%) and 3 of 4 (75%), respectively, compared with those without sedation, 45 of 52 (86.5%) and 40 of 47 (85.1%), respectively (Table 2). The majority of lumbar punctures were performed with local anesthetic, with use in 101 patients. Similarly, there was no significant impact on success with the use of local anesthetic, with success in 84 of 101 (83.2%) patients receiving lidocaine and in 12 of 15 (80%) patients who did not receive lidocaine. Ultrasound or radiographic guidance was not used for any of the study patients. When considering age, there was a higher success in the upright position for adults and lateral decubitus for neonates and infants, although this did not achieve statistical significance. For patients younger than 18 years, there was a success rate of 80.5% (95% CI 70.3–87.8%) compared with those older than 18 years, who had a success rate of 87.2% (95% CI 73.2–94.4%). Only 3 patients in this study were older than 65 years. Indications for lumbar puncture included evaluation for infection in 99 patients (85.3%) and exclusion of subarachnoid hemorrhage in 17 patients (14.7%). No patient in this study was confirmed to have subarachnoid hemorrhage, but 26 patients (22%) had meningitis (85% aseptic).

Table 1. Characteristics of Study Subjects and Operators.

Characteristics	Lateral Decubitus (n = 55)	Upright (n = 61)
Age, y, mean/median	14.6/2.3	16.1/2.5
Age < 90 d, n (%)	23 (41.8)	28 (45.9)
Age 90 d–3 y, n (%)	5 (9.1)	3 (4.9)
Age 3–18 y, n (%)	9 (16.4)	9 (14.8)
Age > 18 y, n (%)	18 (32.7)	21 (34.4)
Indication for LP, n (%)		
SAH	7 (12.7)	10 (16.4)
Meningitis	48 (87.3)	51 (83.6)
Level of training, n (%)		
PGY1	11 (16.4)	14 (18)
PGY2	15 (27.3)	20 (32.8)
PGY3	29 (52.7)	27 (44.3)
Previous successful LP, n (%)		
<10	4 (7.3)	4 (6.5)
11-30	15(27.3)	12 (19.7)
>30	36 (65.4)	45 (73.8)

LP = lumbar puncture; PGY = postgraduate year; SAH = subarachnoid hemorrhage.
No statistical difference was evident between groups.

In the lateral decubitus assignment group, spinal fluid was obtained successfully in 47 patients (85.5%; 95% CI 73.8–92.4%) vs. 49 patients (80.3%; 95% CI 68.7–88.4%) in the upright assignment group (Table 2, Figure 1). There were 20 failures to obtain CSF upon initial method with the assigned resident. After failure of initial method, change in operator or change in position was attempted. In the lateral decubitus group, 5 patients with initial failures underwent change of position and three of these were due to change of operator. In the upright group, 7 patients underwent a change of position, with 2 of those being dictated by the change of operator. The success from these changes is listed in Table 2. Of the 20 patients in whom obtaining CSF failed based on initial assigned position, 13 (65%) were younger than 3 months.

Number of insertions, redirections, and blood contaminated results were also obtained (Table 2, Figure 2). CSF was obtained from the first needle passage in 35 patients (63.6%; 95% CI 50.4–75.1%) in the lateral decubitus group and 34 patients (55.7%; 95% CI 43.3–67.5%) in the upright group. There was no difference in the number of insertions or redirections between groups. A bloody tap was obtained in 15 patients (27.3%; 95% CI 17.3–40.2%) of the lateral decubitus group and 14 patients (23.0%; 95% CI 14.2–34.9%) of the upright group.

Table 2. Primary and Secondary Outcomes.

Outcomes	Lateral Decubitus (n = 55)	Upright (n = 61)
Success		
With first needle passage, n (%); 95% CI	35 (63.6); 50.4–75.1	34 (55.7); 43.3–67.5
With assigned position, n (%); 95% CI	47 (85.5); 73.8–92.4	49 (80.3); 68.7–88.4
With operator change, n	4	8
With position change, n	3	3
No. of insertions, mean/median/mode	2/1/1–5	2/1/1–5
No. of redirections, mean/median/mode	3/1/1–31	3/2/1–12
Bloody taps		
Uncontaminated tap, < 1000 RBCs/mm^3, n (%); 95% CI	39 (70.9); 57.9–81.2	46 (75.4); 63.3–84.5
Contaminated tap, > 1000 RBCs/mm^3, n (%); 95% CI	15 (27.3); 17.3–40.2	14 (23.0); 14.2–34.9
Total unsuccessful, n (%)	1 (1.8)	1 (1.6)
Success by age, n/N (%); 95% CI		
< 90 d	19/23 (82.6); 62.3–93.0	20/28 (71.4) 52.3–84.7
90 d–3 y	5/5 (100.0); 56.6–100.0	2/3 (60); 20.8–93.9
3 y–18 y	8/9 (88.9); 56.5–98.0	8/9 (88.9); 56.5–98.0
> 18 y	15/18 (83.3); 60.8–94.2	19/21 (90.5); 71.1–97.4
Success with sedation use,* n/N (%); 95% CI		
With	3/4 (75); 30.1–95.4	2/2 (100); 34.2–100
Without	40/47 (85.1); 72.3–92.5	45/52 (86.5); 74.7–93.3
Success with lidocaine use, n/N (%); 95% CI		
With	38/45 (84.4); 71.2–92.3	46/56 (82.1); 70.2–90.0
Without	9/10 (90); 59.6–98.2	3/5 (60); 23.1–88.2

* Four patients in lateral decubitus and 7 patients in upright did not indicate whether sedation was given.

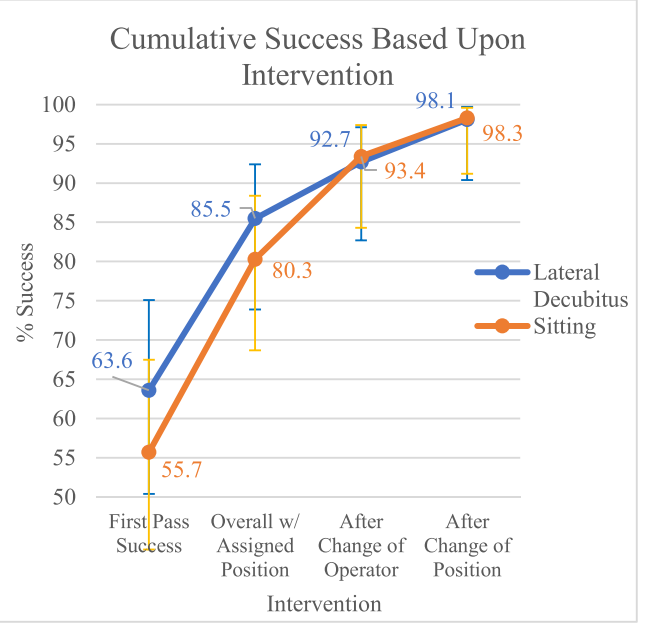

Figure 1. Cumulative success based on intervention.

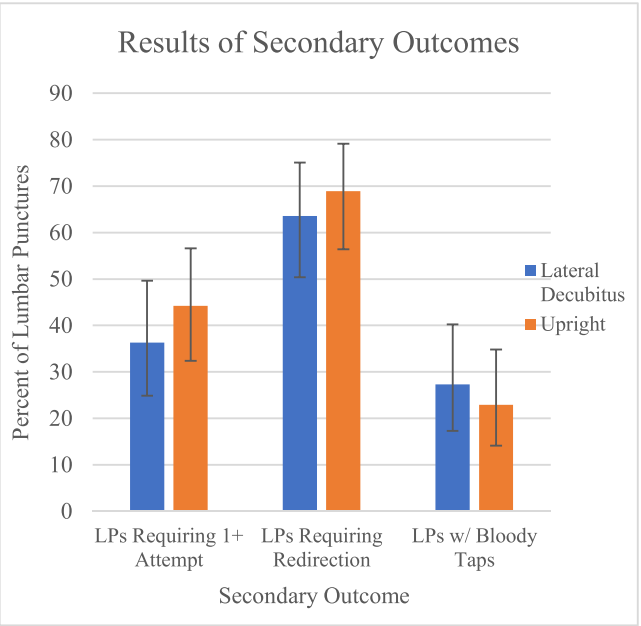

Figure 2. Results of secondary outcomes for all lumbar punctures (LPs).

Table 3. Outcomes by Level of Training, Experience, and Preference.

Variable	Successful LPs, n (%)	Unsuccessful LPs, n (%)
Level of training		
PGY1	16 (72.7)	6 (27.3)
PGY2	33 (94.3)	2 (5.7)
PGY3	47 (79.7)	12 (20.3)
No. of previous successful LPs		
< 10	5 (62.5)	3 (37.5)
11–30	23 (85.2)	4 (14.8)
31–50	28 (90.3)	3 (9.7)
> 50	40 (80)	10 (20)
Preferred position vs. assigned		
Concordant	60 (85.7)	10 (14.3)
Discordant	36 (78.3)	10 (21.7)

LP = lumbar puncture; PGY = postgraduate year.

Only four of the lumbar punctures in the entire study were performed by pediatric residents and the remaining were performed by emergency medicine residents. Of lumbar puncture operators, PGY-3 residents had completed more lumbar punctures prior to the study and performed most of the lumbar punctures within the study. When looking at overall success rates for the lumbar punctures performed within this study, PGY-2 residents had the highest success rate at 94.3% (95% CI 81.2–98.4%) (Table 3). In addition, residents who had completed either 11–30 previous lumbar punctures or 31–50 previous lumbar punctures had the highest success rates at 85.2% (95% CI 67.5–94.1%) and 90.3% (95% CI 75.1–96.7%), respectively, in comparison with those who performed < 10 or > 50 previously. It was also noted that residents performed equally well whether they were assigned to their preferred position (concordant) at a success rate of 85.7% (95% CI 75.7–92.1%) vs. being assigned to the position they were less comfortable using (discordant) at a success rate of 78.3% (95% CI 64.4–87.7%).

Discussion

Despite its daily use in most emergency departments, optimal position for performing successful lumbar puncture has not been well defined in the literature previously. To our knowledge, this is the first randomized study in emergency department patients to evaluate the impact of positioning on success rates. Based on the results of this study, we found no difference in rate of success, whether the patient was positioned in lateral decubitus or upright when lumbar puncture was attempted. A previous randomized study in anesthesia patients demonstrated no difference between lateral decubitus or upright positioning on this procedure, however, in that study, there was a third group that demonstrated higher success in patients with lateral decubitus positioning with a 45-degree head up tilt (6). Our study is unique in that it only included emergency department patients who may have other complicating factors, such as active infection, vomiting, altered sensorium, or other factors that may limit patient cooperation.

Emergency physicians are usually forced to evaluate and treat patients without the benefit of fasting, sedation, or a presurgical assessment. Interestingly, the success rates in each of the groups in our study were comparable with success rates in the anesthesia study.

Although our study did not prove one position more successful than the other, it challenges the traditional teaching of lateral decubitus as the preferred initial position. This information provides the clinician, educator, or trainee with the ability to place the patient in a position appropriate for the clinical setting or at the patient's preference without altering the success rate of the procedure. These results suggest that learning how to perform lumbar punctures in both lateral decubitus and upright positioning equips a physician to use either position appropriately and successfully in their future. In addition, we showed no differences in first-pass success, number of insertions, or blood-contaminated taps, signifying that neither position is more harmful to the patient than the other.

This study provided data on resident performance with lumbar puncture. Unsurprisingly, the PGY-3 residents had performed the most lumbar punctures prior to the study and performed the most lumbar punctures within the study. This may be attributed to our educational setting in which the majority of the sickest patients within our emergency department are routed first to the PGY-3. Interestingly, our PGY-2 class had the highest success rate overall. PGY-2 residents may have performed better in this sample because they are more likely to receive attending supervision during the procedure, they are more cautious secondary to having less experience with the procedure, or have more time than the PGY-3 class to prepare and perform the procedure. In addition, it is likely that the most complicated lumbar punctures are referred to the PGY-3. Residents who previously performed 31–50 lumbar punctures achieved a 90% success rate in this procedure. This cutoff value reflects findings in a similar study in which physicians with 50+ lumbar punctures had fewer traumatic taps (9).

Physicians assigned to either their preferred position or the position they were less comfortable with performed equally well. This suggests that attempts to perform the procedure in a different way than previously preferred will not impact immediate results. As discussed previously, an ability to do lumbar punctures in either position based on anatomy or patient preference is important and adaptability in procedures is a valuable skill. The trends presented may be impactful in both the practice and training of emergency physicians.

Limitations

A few notable weaknesses to this study exist. We acknowledge there are other variables that impact the success of lumbar puncture that were not addressed in this research. Many variables seem potentially important, including the ability of the patient to cooperate, body mass index (BMI), use of pediatric holder and their level of experience, bevel orientation of needle, use of local anesthesia, use of sedation medication, and abnormalities in anatomy. Several studies have evaluated the impact of anesthetic use, needle size and length, and timing of stylet removal (5,10–12).

Although this is the first randomized trial of emergency department patients of all ages for lumbar puncture positioning, we did not match controls based on age, BMI, or operator experience. In retrospect, future studies should consider using matched groups in a randomized study to account for this. In addition, our providers self-reported number of needle insertions and re-directions, which potentially introduced a bias. Providers, however, did not have to identify themselves in the data collection form in hopes that this would reduce bias. Also, there is no reason for us to suspect that rate of bias for this would be increased in one positioning group over another. In the future, a second provider or recorder could be used to accurately count and report these attempts. Another limitation is that our limited study size did not allow us to determine a statistically significant difference between age groups. We recognize that there are certainly differences based on patient age that affect lumbar puncture setup, performance, and overall success. We identified a trend suggesting that the upright positioning was more successful for adults and the lateral decubitus position was more successful for children. We performed a subgroup analysis to evaluate these subgroups and there was no significant difference. We acknowledge that an overall small sample size and subsequent smaller subgroup size make it difficult to interpret the data further. The goal of this study was to be generalizable to an ED population that sees both adults and children and, therefore, we cannot answer the question of whether positioning of different age groups would have different success rates. Regardless of the limitations, this study is one of the only randomized studies of emergency department patients to assess the efficacy of different positions for lumbar puncture. Lastly, this study did not use first-pass success rate as a primary outcome; however, these success rates were comparable. We acknowledge the definition for success as being less than or equal to five insertions may not be acceptable in all clinical settings.

Conclusion

We conclude that lateral decubitus and upright position for emergency lumbar puncture yields similar success rates. This allows providers to position the patient as nec-

essary for the clinical situation or for comfort. These results impact how lumbar puncture should be performed and taught.

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ARTICLE SUMMARY

1. Why is this topic important?

Lumbar puncture is a commonly performed procedure in the emergency department with many practice variations, including position of patient. Knowing which patient positioning leads to highest success with the least difficulty is beneficial to all emergency physicians and their patients.

2. What does this study attempt to show?

This study compares upright and lateral decubitus positioning of patients during a lumbar puncture procedure to determine whether one position is more optimal than the other.

3. What are the key findings?

Patient positioning does not impact success of a lumbar puncture procedure.

4. How is patient care impacted?

Lumbar puncture can be an uncomfortable procedure for patients to withstand. Choosing a position of the patient for the procedure can be based on any number of factors, including patient age, body habitus, mental status, intubation status, patient preference, and more. Physicians and patients can feel comfortable choosing a position based on these other factors, knowing that ultimately the patient's position will not impact the success rates of the procedure overall.