Ultrasound for Routine Lumbar Puncture

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Abstract

Objectives: The objective was to determine if use of ultrasound (US) by emergency physicians (EPs) to localize spinal landmarks improves the performance of lumbar puncture (LP).

Methods: This was a prospective, randomized, controlled study conducted in a county teaching hospital. Subjects, adults 18 years of age or older who were to receive LPs for routine clinical care in the emergency department (ED), were randomized either to undergo US localization of the puncture site or to have the puncture site determined by palpation of spinal landmarks. Primary outcomes were the number of needle insertion attempts and success of the procedure. Secondary outcomes were pain associated with the procedure, time to perform the procedure, number of traumatic taps, and patient satisfaction with the procedure.

Results: One-hundred patients were enrolled in the study, with 50 in each study group. There were no significant differences between the two groups in terms of age, sex, body mass index (BMI), indication for LP, or ease of palpation of landmarks. For both primary outcomes and secondary outcomes there were no significant differences between those undergoing US localization and those with palpation alone.

Conclusions: These data do not suggest any advantage to the routine use of US localization for LP insertion, although further study may be warranted to look for benefit in the difficult to palpate or obese patient subgroups.

Ultrasound (US) of the spine has been used in several different clinical applications in the adult, including evaluation for spinal canal stenosis,1 intervertebral disc disease,2-3 diurnal change in disc height,4 and interspinous space widths in different anatomic positions,5 as well as assess optimum approach and depth of needle placement and spinal blood vessel location for epidural catheter placement.6-14 US has also been shown to reduce the pain and number of needle insertion attempts associated with epidural catheter placement.6,13

In neonates, US has been used to evaluate the cause of failed lumbar puncture (LP) and to estimate the likelihood of success of further LP attempts.15 Spinal anatomy, including the spinal cord and surrounding structures, is much easier to image in neonates than adults because the vertebral bones are not yet fully calcified. In the adult spine, acoustic shadowing from vertebral bone obscures much of the anatomy of the spine. US can, however, identify the space between spinous processes and has been shown to aid the performance of LP in adults whose landmarks are difficult to palpate16 or who have failed previous attempts at LP.17 In two studies, US was able to identify spinal landmarks important for successful LP in a significant majority of patients, even in the obese population.18,19 Only one other study we are aware of evaluated the benefits of using US for LP in a randomized controlled trial.20

When evaluating the emergency department (ED) patient for possible subarachnoid hemorrhage (SAH), cerebral spinal fluid (CSF) analysis is often used to rule out SAH not seen on imaging studies. In these cases, if the emergency physician (EP) is unable to obtain CSF via LP, a specialist must be consulted to perform the
procedure under imaging guidance. This consultation results in a delay in diagnosis and adds significant time to the ED visit. In addition, if the EP is not accurate in determining the vertebral interspinous space by manual palpation, the patient may undergo several attempts at needle insertion before the procedure is either successful or efforts are terminated due to failure. Multiple attempts are likely to cause increased pain and decreased patient satisfaction and may also result in a higher proportion of traumatic taps. Traumatic taps are problematic in that they may simulate the appearance of SAH on CSF analysis and obscure the detection of CSF leukocytosis.

We hypothesized that US might reduce the number of needle insertion attempts required for success as well as improve the success rate of LP. We also hypothesized that if the number of needle insertion attempts required for a successful LP decreased, there might be a concomitant decrease in the pain associated with the procedure, improvement in patient satisfaction with the procedure, and decrease in the proportion of traumatic taps.

METHODS

Study Design
We conducted a prospective, randomized, controlled trial to compare LP performed with and without US localization of spinal landmarks. The institutional review board at the participating hospital approved the study, and all patients or their proxies gave prospective written informed consent prior to participation.

Study Setting and Population
Our study was conducted in the adult ED at Harbor-UCLA Medical Center. Harbor-UCLA Medical Center is a county teaching hospital and trauma center serving primarily a medically indigent patient population. The adult ED is one of four emergency care areas in the hospital and has an annual census of 45,000 patients. The combined annual census of all emergency care areas is 87,000 patients.

The study group consisted of a convenience sample of adult patients (age 18 years or older) undergoing LP for any clinical indication. We excluded patients younger than 18 years, those who could not give informed consent and did not have proxies who could give consent, and those who declined to participate. All physicians performing LPs (the “operators”) were housestaff from the emergency medicine (EM) training program, non-EM housestaff on rotation in the adult ED, or EM faculty. Operators had to have performed at least 10 previous successful LPs by their own report, a number we chose arbitrarily to represent experience with the LP procedure. Operators had varying degrees of experience with performing US examinations, from no documented experience to over 100 documented examinations. Investigators did not participate as operators.

Study Protocol
Patients all received standard ED evaluation and care. Once consented, patients were randomized in equal proportions to one of the two study groups by opening the next serially numbered envelope containing a random study group assignment. Envelopes were prepared under the direction of one of the investigators (RJL) who did not participate as either an operator or a data collector. One treatment group received US by the operator to identify the interspinous space before insertion of the spinal needle, while the other group underwent usual manual palpation for spinal landmarks by the operator prior to needle insertion. Patients were enrolled by, and all data were collected and recorded by, a single investigator (DP) who was notified via pager when a patient needing an LP was in the adult ED. Except for brief absences, DP was available around the clock. The enrolling investigator was initially a PGY3 (senior) resident with significant US experience who graduated during the study period and became an US fellow at our institution. DP was present during the entire procedure.

US Technique
Patients randomized to the US group underwent US localization of the interspinous space by the operator prior to LP. The US examination was performed by positioning the patient in the lateral recumbent or sitting position based on operator preference. A 3.5-MHz convex array or a 7.5-MHz linear array probe from an Aloka SSD 1400 US machine (Aloka, Wallingford, CT) was placed on the midline lower back at the L3–L4 level (identified by drawing an imaginary line perpendicular to the lumbar spine at the level of the iliac crests). The exact midline was identified by scanning in a transverse plane and visualizing the shadow of a spinous process (Figure 1). Using a surgical skin marking pen or a regular ink pen on skin cleansed with an alcohol swab, a longitudinal ink line was drawn on the midline. If the patient’s position was changed, the location was remarked.

The interspinous space was located next by scanning in the longitudinal plane directly over the midline. The spinous processes were identified by their repeating pattern of concave downward echogenic borders with acoustic shadowing, occurring at the same depth as the midline shadowing noted on the transverse view. The interspinous space exists between the spinous process shadows (Figure 2). A transverse ink line was drawn on the skin at the middle of the interspinous space. The probe was removed and the two ink lines were extended on the skin so that they intersected. The intersection of the two lines indicated the site for LP needle insertion. The patient was then prepped and draped in the usual fashion and LP was performed at the site localized.

Patients randomized to LP without US were prepped and draped steriley and the LP was performed in the usual fashion by manually palpating the back for an entry site. Operators were trained in the localization technique by the investigator at the time of patient enrollment. Using an area of the patient’s spine away from where the LP would be performed, the investigator demonstrated the US anatomy of the spine and marking technique to the operator. This training time was not included when the duration of the LP was measured. The operator then independently performed the localization of the LP site in the presence of, but without help from, the investigator. If the operator had previously received instruction as
part of the study, he or she could forgo repeat instruction. Operators were allowed to decide the best position for any given patient, upright or recumbent, in which to perform the LP.

For both groups, if initial efforts failed to return CSF, operators could attempt the LPs at different interspaces. In the US group, this required the operator to repeat US at the new interspace. The operator was allowed to decide when to terminate the procedure due to failure in both study groups. If the first operator failed to obtain CSF, the procedure was classified as a failure and the patient was offered all other appropriate options for completion of the LP. Other options included performance of the procedure by a more senior EM resident or by an EM faculty physician, localization by US (if the patient was randomized to the palpation group) or by palpation if randomized to the US group, or fluoroscopy.

Outcome Measures
Our primary outcome measures were the number of needle insertion attempts required for procedural success and success of the LP procedure as evidenced by return of an adequate nontraumatic CSF sample (defined as CSF return of at least 1 mL with less than 500 red blood cells per high-power field in the absence of a diagnosis that would cause bleeding into the CSF). A needle insertion attempt was defined as any needle advancement after new skin entry or any needle advancement after partial needle withdrawal. Our secondary outcomes were the time required for each procedure, whether or not the LP was traumatic, any pain associated with the procedure (measured on a 10-cm visual analog scale), and patient satisfaction with the procedure (measured on a five-point Likert scale ranging from “very dissatisfied” to “very satisfied”). Procedure time was defined as the time from first puncture of the skin to first return of CSF. We also collected information regarding patient physical characteristics, including ease in palpating spinal landmarks (a structured estimate by the operator), the indication for LP, volume of local anesthetic used, and each patient’s final diagnosis.
Data Analysis
We collected data prospectively at the time of LP using a closed-response data collection tool. Data were entered into a Microsoft Access database (Version 2003, Microsoft Corporation, Redmond, WA). We analyzed the data with SAS (Version 8.2, SAS Institute, Cary, NC) and Stata SE (Version 8.0, StataCorp, College Station, TX) statistical software. Categorical data are presented as percentages, and proportions are compared using odds ratios (ORs) with 95% confidence intervals (CIs) or Fisher’s exact test. Numerical data are presented as medians with interquartile ranges (IQRs). We used the Wilcoxon rank sum test to compare numerical variables.

The primary endpoint for which the trial was powered was the number of needle insertion attempts, and this endpoint was tested at a two-tailed 5% level. The success of the LP procedure was also labeled as a primary endpoint and tested at the two-tailed 5% level, albeit with lower statistical power. No correction (e.g., Bonferroni correction) was made for the conduct of two comparisons. We calculated that with 50 patients in each treatment group, there was a 90% power to detect a difference in the number of needle insertions of at least 1.0 between the groups, assuming a standard deviation (SD) of ±1.5 insertions.

RESULTS
To our knowledge, at the time of our study there were no other published randomized controlled trials evaluating the use of US for LP in adults. From January 2003 to August 2004 we enrolled 100 patients requiring LP in the adult ED. Patient flow through the protocol is diagrammed in Figure 3. Fifty patients were randomized to each of the two study groups. The patients’ median age was 40 years (IQR = 31 to 48 years) and 46% were male. The majority of the operators were EM housestaff in their second or third postgraduate years of training. Forty-four different physicians served as first operators for the 100 enrolled patients. No operator enrolled more than 11 patients; 24 operators enrolled only one patient each.

There were no significant differences between the two study groups in terms of age, sex, body mass index (BMI), ease of palpation of landmarks, or indication for LP (Table 1). Procedural success, one of the primary outcomes, was achieved in 39 patients (78%) in the palpation group and 38 patients (76%) in the US group (p = 0.81; OR = 1.0, 95% CI = 0.35 to 2.88; Table 2). Two patients in the US group and one in the palpation group had traumatic taps. For the second primary outcome, needle insertion attempts, there was also no significant difference, with the US group having a median of three attempts (IQR = 1 to 8) and the palpation group having a median of five attempts (IQR = 1 to 10, p = 0.24).

There were no significant differences in pain associated with the procedure, patient satisfaction with the procedure, or median procedure time (data not shown).

After finding no differences in the primary outcomes between the two groups, we performed an unplanned subgroup analysis of patients whose landmarks were either difficult to palpate or not palpable (n = 51), since the utility of US may be enhanced in this subgroup of patients. This post hoc analysis revealed no differences in procedural success (US group 17 of 22, 77%; and palpation group 18 of 29, 62%), number of needle insertion attempts, or visual and analog pain scale scores (Table 3). No other subgroup analyses were performed.

We also looked at the subgroup of patients with higher BMIs. There were no differences in number of needle insertion attempts between patients with

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Figure 3. Patient flow through the protocol. CSF = cerebrospinal fluid; LP = lumbar puncture; US = ultrasound.
Table 1
Comparison of Patients in the US and Palpation Treatment Groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>US (n = 50)</th>
<th>Palpation (n = 50)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Male</td>
<td>23 (46)</td>
<td>23 (46)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>27 (54)</td>
<td>27 (54)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>42 (33–50)</td>
<td>39 (31–46)</td>
<td>0.49</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.0</td>
<td>26.2</td>
<td>0.34</td>
</tr>
<tr>
<td>(24.0–33.3)</td>
<td>(23.4–31.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indication for LP</td>
<td></td>
<td></td>
<td>0.38</td>
</tr>
<tr>
<td>Possible SAH</td>
<td>18 (36)</td>
<td>23 (46)</td>
<td></td>
</tr>
<tr>
<td>Possible meningitis</td>
<td>29 (58)</td>
<td>25 (50)</td>
<td></td>
</tr>
<tr>
<td>Altered mental status</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3 (6)</td>
<td>1 (2)</td>
<td>1.0</td>
</tr>
<tr>
<td>Patient position*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recumbent</td>
<td>31 (63)</td>
<td>31 (63)</td>
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</tr>
<tr>
<td>Upright</td>
<td>18 (37)</td>
<td>18 (37)</td>
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<tr>
<td>Palpation difficulty</td>
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<tr>
<td>Easily palpable</td>
<td>28 (56)</td>
<td>21 (42)</td>
<td></td>
</tr>
<tr>
<td>Difficult to palpate</td>
<td>14 (28)</td>
<td>19 (38)</td>
<td></td>
</tr>
<tr>
<td>Unable to palpate</td>
<td>8 (16)</td>
<td>10 (20)</td>
<td></td>
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<tr>
<td>Volume of anesthetic (mL)</td>
<td></td>
<td></td>
<td>0.66</td>
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<td>First operator level</td>
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<tr>
<td>PGY1</td>
<td>6 (12)</td>
<td>9 (18)</td>
<td>0.32</td>
</tr>
<tr>
<td>PGY2</td>
<td>29 (58)</td>
<td>22 (44)</td>
<td></td>
</tr>
<tr>
<td>PGY3</td>
<td>14 (28)</td>
<td>19 (38)</td>
<td></td>
</tr>
<tr>
<td>Faculty</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

Data reported as n (%) or median (IQR). BMI = body mass index; IQR = interquartile range; LP = lumbar puncture; PGY = postgraduate year; SAH = subarachnoid hemorrhage; US = ultrasound.

*Position not recorded in two patients.

Table 2
Outcomes for All Patients

<table>
<thead>
<tr>
<th>Outcome</th>
<th>US (n = 50)</th>
<th>Palpation (n = 50)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle insertion attempts</td>
<td>3 (1–8)</td>
<td>5 (1–10)</td>
<td>0.24</td>
</tr>
<tr>
<td>Procedural success</td>
<td>38 (76%)</td>
<td>39 (78%)</td>
<td>0.81</td>
</tr>
<tr>
<td>Traumatic taps</td>
<td>2 (5.0%)*</td>
<td>1 (2.5%)*</td>
<td>1.0</td>
</tr>
<tr>
<td>Satisfaction score</td>
<td>5 (4–5)</td>
<td>5 (4–5)</td>
<td>0.18</td>
</tr>
<tr>
<td>Pain VAS (cm)</td>
<td>1.4 (0.3–5.1)</td>
<td>2.1 (0.5–5.4)</td>
<td>0.71</td>
</tr>
<tr>
<td>Procedure time for successful</td>
<td>1.4 (1.0–3.0)</td>
<td>1.8 (0.7–5.0)</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Data are reported as median (IQR) or number (%). CSF = cerebral spinal fluid; IQR = interquartile range; US = ultrasound; VAS = visual analog pain scale.

*Percentage of all taps that yielded CSF, which is the sum of successful procedures and traumatic taps.

BMI ≥ 27 kg/m² (the median BMI for all patients) and the study population as a whole. The US subgroup (n = 27) had a median number of attempts of 4 (IQR = 2 to 6) and the palpation subgroup (n = 23) had a median of 6 (IQR = 2 to 14, p = 0.12). For those with BMI ≥ 32 kg/m² (the 75th percentile for all patients), the US subgroup (n = 15) had a median of 4 attempts (IQR = 2 to 6), and the palpation subgroup (n = 10) had a median of 5.5 attempts (IQR = 2 to 14, p = 0.54).

**DISCUSSION**

Our study failed to demonstrate improvement in any of the measured parameters when US was used to assist LP in an unselected population of adult patients. The original power calculation was based on a difference in the number of needle attempts of one and a SD of 1.5; however, an inspection of the IQRs reported in Table 2 shows that the variability in the number of needle insertions was substantially greater than expected. This decreases the power to detect a small difference. It should be noted that this study was not powered to find a difference in the subgroup of patients whose landmarks were difficult to palpate or could not be palpated or who had an elevated BMI.

The brief instruction method we used is atypical for most diagnostic US uses in the ED, where physicians generally undergo didactic education followed by significant practice with US, suggested at 25 to 50 exams.²¹ It has been suggested that more limited training and experience is sufficient for procedural US, although nothing as brief as we used.²¹ It is possible to tell from this study whether US localization does not benefit the outcomes we studied or the training method we used is inadequate, although the technique is simple enough that adding further instruction or experience seems unlikely to improve competence.

The only similar study published to date, by Nomura et al.,²⁰ came to a different conclusion than ours: that US showed a significant advantage over traditional landmark localization for the performance of LP. Although their success rate was similar to ours in the group of patients who did not receive US (73% vs. 78%), they had a significantly higher rate of success in their US group (96% vs. 76%). There are several significant differences between our study and that of Nomura et al. They had 46 enrollees compared to our 100, and in their study all US localization of landmarks was

Table 3
Outcomes for Patients With Difficult to Palpate or Unpalpable Spinal Landmarks

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>US (n = 22)</th>
<th>Palpation (n = 29)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle insertion attempts*</td>
<td>4 (2–6)</td>
<td>6 (2–14)</td>
<td>0.28</td>
</tr>
<tr>
<td>Procedural success</td>
<td>17 (77%)</td>
<td>18 (62%)</td>
<td>0.25</td>
</tr>
<tr>
<td>Traumatic taps</td>
<td>1 (5.6%)*</td>
<td>1 (5.3%)*</td>
<td>1.0</td>
</tr>
<tr>
<td>Satisfaction score</td>
<td>5 (4–6)</td>
<td>5 (4–5)</td>
<td>0.47</td>
</tr>
<tr>
<td>Pain VAS (cm)</td>
<td>1.1 (0.1–5.0)</td>
<td>3.0 (0.6–7.2)</td>
<td>0.24</td>
</tr>
<tr>
<td>Procedure time for successful</td>
<td>1.6 (1.2–3.2)</td>
<td>2.0 (1.1–5.0)</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Data are reported as median (IQR) or number (%). CSF = cerebral spinal fluid; IQR = interquartile range; US = ultrasound; VAS = visual analog pain scale.

*Percentage of all taps that yielded CSF, which is the sum of successful procedures and traumatic taps.
performed by investigators who were expert sonographers. In our study the caregivers performed the examinations, which we feel more accurately reflects real practice. Nomura et al. used only PGY2 or higher physicians to perform LPs. Fifteen percent of LPs in our study were performed by PGY1 house staff, although all physicians performing LPs had to have at least 10 successful LPs prior to the study. It is notable that patients included in the US cohort of Nomura et al. may have had a lower BMI than ours, as they report a mean BMI of 26.1 kg/m² in this group, compared to our median of 29 kg/m². Comparison is hampered by comparing means to medians.

In the group that included all patients, our success rate was similar whether we used US or not. We also found similar success rates when we looked specifically at patients who were identified as having more difficult to palpate landmarks (those whose landmarks were classified as either “difficult to palpate” or “unable to palpate”). Those with difficult to palpate landmarks may be a better population to apply US to. This finding correlates well with the observation of Stiffler et al.18 that US is able to identify landmarks in 75% of obese patients. Unfortunately the small number of patients in this subgroup limits our ability to interpret this difference. Further study of this subgroup is warranted to determine if these differences are real.

LIMITATIONS

We did not blind patients to the use of US, so it is impossible to determine how the mere performance of the US influenced outcomes, especially those outcomes that were subjective (pain and satisfaction). Enrollment was done by convenience sample and was dependent on the investigator (DP) being contacted by physicians in the adult ED. The total number of patients undergoing LP in the adult ED during the study period is not known, but was likely much higher than the number of patients enrolled. Thus, it is possible that there was a selection bias and the study population did not accurately represent the population of adult ED patients undergoing LP.

We choose to conduct individual operator training as a brief session contemporaneous with the enrollment of the patient and performance of the procedure. We chose this method because we believe that the procedure was so easy to learn that it did not require any significant experience to master, and this technique of training at the bedside is one that is common in clinical medicine. Although we did not measure operators’ previous experience with the localization technique, it is novel, it was not taught anywhere else that we know of at the time of the study, and we had not begun routinely teaching it outside of the study protocol. It is highly unlikely any of the operators had any experience with the technique prior to their first enrollment in the study. Operators who had instruction in the technique during enrollment of previous patients could forgo further instruction on subsequent patients or undergo further instruction if they felt it necessary. It is possible that operators with more practice with the localization technique or more experience with US, or with LPs in general, might have shown significant differences in the measured outcomes. We did not attempt a multivariable analysis to account for these differences.

There was a delay between the time of data collection and submission of this manuscript of approximately 10 years. Although we do not believe that there were any substantial changes in either the technology or the technique of using US during the intervening period, the delay makes it more difficult to compare our results to more current investigations.

CONCLUSIONS

We found no advantage to the routine use of ultrasound, taught by brief bedside instruction, prior to performing lumbar puncture. It is possible that ultrasound is beneficial when limited to patients whose spinal landmarks are not easy to palpate, but a study focused on this population is needed to address this question. Currently, ultrasound localization of spinal landmarks may be best reserved for patients who have difficult to palpate landmarks or have already failed attempts at lumbar puncture by the palpation method.

We acknowledge the administrative support of the Los Angeles Biomedical Institute at Harbor-UCLA Medical Center. The authors acknowledge the assistance of Vitali Kononov, MD, in translating the article “Application of the Method of 2-Dimensional Echospondylography for Determining Landmarks in Lumbar Punctures,” by Bogin et al from Russian to English. This important early work has been underrecognized in the English literature. We also acknowledge the assistance of Christina Campbell, RN, FNP, and Vedika Kumar in the preparation of the manuscript.

References


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**Video Presentations from the SAEM Annual Meeting 2013**

Forty three of the presenters from this year’s Annual Meeting in Atlanta recorded brief presentations of their research with AEM’s Dynamic Emergency Medicine Editor, Scott Joing. See the highlights of some of the meetings best research. They can be viewed at:

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