JOURNAL of SCIENCE & MEDICINE

# A Retrospective Study of Ultrasound Guidance for Diagnostic Lumbar Punctures

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## Abstract

Lumbar puncture (LP) is a common procedure in various medical specialties to aid in diagnosis, despite the relatively high occurrence of complications, of which post-LP headache is most notable. Ultrasonography, as an adjuvant to osseous palpation, may increase the success rate and decrease the rate of post-LP headache. Through a retrospective chart review of all patients who underwent an LP in the past year at the Wake Forest School of Medicine Diagnostic Neurology Laboratory, LP success rate and post-LP headache rate were compared between those who had ultrasound guidance prior to the procedure and those who did not. A total of 109 individuals were included in the review, with 95 having ultrasound guidance and 14 without. LP success rates were similar between the groups, but the ultrasound group had a lower rate of post-LP headache compared to the non-ultrasound group when assessed by patient phone calls (12.8% vs. 25.0%, p=0.289) and visits to the emergency department (3.9% vs. 8.3%, p=0.334) for headache, though these differences did not reach statistical significance. Further examination of the benefit of ultrasound guidance should be explored through a randomized clinical trial with cost efficacy included as an outcome measure.

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Financial Support: No outside funding was acquired to complete this study.

## Introduction

Lumbar puncture (LP) is a diagnostic procedure which has become ubiquitous in modern medicine spanning multiple specialties, including neurologists, radiologists, oncologists, emergency physicians, and internists who continue to rely on its aid in diagnosis.[1] It is typically still performed by osseous palpation as was first described in 1891 by Quincke.[2] From a complications standpoint, post-LP headache is the primary post-procedural drawback, which occurs in approximately 30% of LP procedures.[3] It is thought that post-LP headache occurs due to low intracranial pressure resulting from leakage of cerebrospinal fluid from the dural sac.[4] The main intra-procedural complication is a failure to obtain cerebrospinal fluid due to the needle not being correctly guided into the dural sac. Both of these problems occur at a higher rate in patients who have difficult to palpate osseous landmarks, which is more common

in the obese population (body mass index (BMI) > 30).[5,6] Specifically, the increased rate of post-LP headache is thought to be related to the increased number of needle passes needed for correct placement as BMI increases.[6]

With respect to imaging, ultrasonography demonstrates numerous advantages over other modalities, including but not limited to portability, cost, null radiation exposure, and real -time viewing of internal structures.[7] These advantages have made ultrasound useful in various applications, extending its reach into emergency rooms and intensive care units to improve diagnostic accuracy and efficacy of procedures, such as in the placement of central venous catheters and anesthetic injections.[8,9] For the same reasons, ultrasound is now being proposed as an adjuvant to palpating osseous landmarks in planning an LP. It has been recently noted that the use of ultrasonography to guide an LP increases the success rate and decreases the complication rate of the procedure; however, these studies did not concurrently assess both parameters.[10-12] Results spanning both data sets in a single study would be useful for predicting and reducing common LP complications and maximizing healthcare cost efficacy. Due to our increasing experience with LPs and ultrasonography, we sought to determine the LP success and post-LP headache rate between individuals who had osseous landmarks identified by ultrasound prior to the procedure and those who did not, through a retrospective chart review at a single institution over a 15-month period. The exploratory data compiled is telling to any future prospective study in this area of research.

## Materials and Methods

*Data Collection*

Following approval from the Institutional Review Board, the electronic medical record (EMR) system was queried for all individuals who underwent an LP in the Wake Forest School of Medicine Diagnostic Neurology Laboratory from March 2013 to June 2014. March 2013 was chosen as the starting date because it was then that all outpatient LPs in the Neurology Department began occurring in the Diagnostic Neurology Laboratory. June 2014 was chosen as the end date because it was then that research data collection began for retrospective review. This search yielded a total of 109 patients. Once a patient was identified, all electronic documents were reviewed through a retrospective chart analysis as follows. First, the following descriptive data on each individual was collected: age, sex, race, weight, height, and body mass index (BMI). Second, information regarding the LP procedure and post-procedural complications was ascertained for each individual: the indication for the LP, the physician conducting the LP (14 physicians perform this procedure in the lab), use of ultrasound as a guide, LP procedure success (judged on return of cerebrospinal fluid), post-LP phone call to the Diagnostic Neurology Laboratory due to headache (headache phone call), and post-LP hospital admission or Emergency Department (ED) visit due to headache (headache ED visit).

## Ultrasound Use in the LP Procedure

The use of ultrasound was optional for every LP conducted in the laboratory during the specified time frame. Its use was determined by the physician conducting the procedure and was based off of the potential difficulty of the procedure. In general, it was used more frequently in more difficult cases. A more challenging procedure could be due to, but not limited to, a history of lower back pathology or surgery, difficult to palpate osseous landmarks, or decreased flexibility. If the physician elected to use ultrasound, scanning of the low back was conducted prior to the procedure with the patient lying in the lateral decubitus position with a Biosound MyLab 25 device (Esaote, Genoa, Italy) and 18 MHz linear array transducer. First, scanning was done

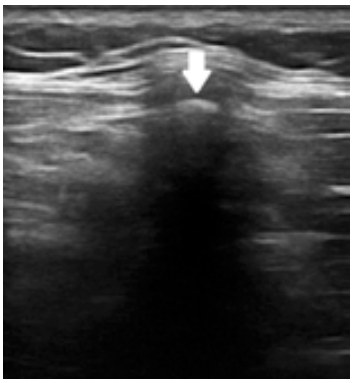

**Figure 1. Axial ultrasound image of lumbar spine.** The bump in the white lines represents the spinous process (white arrow) of the L3 vertebra. This ultrasound image demonstrates the ability of this technology to aid in finding osseous landmarks prior to the lumbar puncture. (Picture was taken by investigators during study).

axially to identify lower lumbar spinous processes (Figure 1). Once the L3, L4, and L5 spinous processes were identified axially, the probe was rotated 90 degrees to obtain a sagittal view of the L3/4 and L4/5 interspinous spaces (Figure 2). These were qualitatively assessed for distance and the larger space was the one chosen for needle insertion. Once a sagittal view of the interspinous space was replicated, a wooden dowel was placed underneath the middle of the probe to make a small indent on the patient's back, thus marking the space for future needle insertion. The ultrasound probe was then removed and the procedure began. Each LP was of similar method and utilized an 18 gauge Quincke bevel spinal needle.

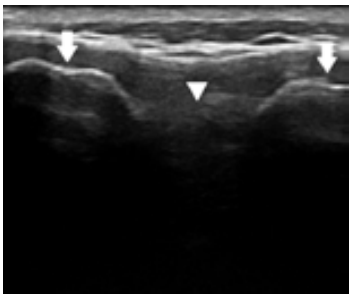

**Figure 2. Sagittal ultrasound image of lumbar spine.** The thin white lines on the left and right represent the spinous processes (white arrows) of L3 and L4, respectively. The L3/4 interspinous space (white arrowhead) is also visible. This ultrasound image demonstrates the ability of this technology to aid detection of osseous landmarks prior to the lumbar puncture. (Picture was taken by investigators during study).

## Statistical Analysis

The 109 subjects were evaluated to determine if ultrasound guidance for an LP improved procedural headache rates. In general, categorical variables were calculated as percentages and frequencies, and continuous variables were calculated as means and standard deviations. Multivariate nominal logistic regression controlling for age, BMI, gender, indication for LP, and physician conducting procedure was used to examine the association between use of ultrasound guidance and the success rate and post-LP headache rate. An alpha of 0.05 was selected as significant prior to the initiation of the study.

## Results

Of the 109 individuals, there were 95 individuals in the ultrasound group (87.1%) and 14 in the non-ultrasound group (12.9%). Table 1 illustrates the patient demographic data between the two cohorts. Categorical and continuous variable statistical analyses showed discrepancies between groups to be insignificant ($P > 0.05$).

With respect to intra-procedural and post-procedural complications, the ultrasound group showed a slightly decreased LP success rate, but a noticeably improved (decreased) post-LP headache rate (in those LP procedures that were successful) as compared to those in the non-ultrasound group (Table 2). Specifically, the non-ultrasound group had headache phone call and headache ED visit rates twice that of the ultrasound group (25.0% vs. 12.8% and 8.3% vs. 3.9%, respectively). Despite these absolute discrepancies, the differences in post-LP headache rates did not reach statistical significance ($P > 0.05$) (Table 2). Success and post-LP headache rates did not differ amongst physicians ($P > 0.05$).

**Table 1.** Demographic Data of Subjects in Ultrasound and Non-Ultrasound Groups

| | Ultrasound Group | Non-Ultrasound Group | p-value |
|---|---|---|---|
| Total patients, n | 95 (87.1%) | 14 (12.9%) | -- |
| Age (mean ± s.d.[a]) | 48.2 ± 17.4 | 53.1 ± 20.0 | 0.441 |
| Female | 61 (64.2%) | 11 (78.6%) | 0.374 |
| Caucasian | 74 (77.9%) | 11 (78.6%) | 0.954 |
| African-American | 17 (17.9%) | 3 (21.4%) | 0.826 |
| Other Race | 4 (4.2%) | 0 (0%) | 0.500 |
| BMI[b] (mean ± s.d.[a]) | 31.6 ± 7.8 | 30.6 ± 5.5 | 0.917 |

[a]Standard Deviation \ [b]Body Mass Index

**Table 2.** Lumbar Puncture Success Rate and Post-Procedural Headache Rates

| | Ultrasound Group | Non-Ultrasound Group | p-value |
|---|---|---|---|
| LP[a] Success | 78 (82.1%) | 12 (85.7%) | 0.895 |
| Post-LP[a] phone call for headache | 10 (12.8%) | 3 (25.0%) | 0.289 |
| Post-LP[a] ED[b] visit for headache | 3 (3.9%) | 1 (8.3%) | 0.334 |

[a]Lumbar Puncture \ [b]Emergency Department

## Discussion

This study evaluated 109 subjects who underwent an LP with or without ultrasound guidance prior to the procedure. LP success rates were very similar between these two groups. The ultrasound group had a lower complication rate as measured by headache phone call and headache Emergency Department visit rates, though this did not reach statistical significance. There are factors that could explain why the LP success rate did not increase in the ultrasound group, as it did in the Shaikh and Nomura trials.[10,11] First, the use of ultrasound was at the discretion of the providing physician. Since its use is considered only helpful, it can be reasonably inferred that ultrasound guidance was used on the majority of the more challenging patients, as determined by the physician conducting the LP. Challenging LP patients could harbor possible impediments to LP success such as past lumbar spine surgery, history of scoliosis, subcutaneous tissue distribution affecting osseous palpation, less flexibility, or more anxiety. Not only did this proposed benefit most likely account for the disparate sample sizes, but this task of potentially taking on more difficult patients with ultrasound could explain the absence of an increased LP success rate in the ultrasound guided group. Secondly, 14 different physicians performed these procedures over the course of the 15 months. Therefore there was potential variation in procedural skill level as both residents and attendings performed the LPs; however, individual success and post-LP headache rates did not differ amongst providers.

Although ultrasound might increase the LP success rate in the general population as a whole, as evident in the Shaikh and Nomura studies, there is somewhat conflicting evidence in the obese population. Nomura et al. displayed a significant improvement in LP success rate with ultrasound when looking at obese patients alone. On the other hand, Stiffler et al. found that the effectiveness of ultrasound as an adjuvant to osseous palpation for an LP is inversely proportional to the patient's BMI; however, osseous landmarks were still able to be observed by ultrasound 75% of the time in obese patients.[13] BMI remains an important consideration when using ultrasound for LP guidance. As ultrasound experience in assessing the lumbar spine improves, it is expected that ultrasound may be increasingly helpful in guiding lumbar punctures in obese patients.

With respect to the post-LP headache complication analyses, one primary factor limits the extent to which this data can have broad implications. Since this was a pilot retrospective review, the headache information for each patient was based on the presence or absence of documented patient contact in the EMR; whether or not they called due to headache or presented to the ED with a headache. Subsequently, it is impossible to say with certainty that every patient who experienced a headache was cataloged in the database, as some who experienced a headache may not have reported it. However, there is evidence to suggest that the majority of the headache complications were in fact reported. As previously stated, the normal frequency of post-LP headaches is about 30%, which correlates with the non-ultrasound group headache phone call rate at 25%.[3] This similarity between the retrospective post-LP headache phone call and the post-LP headache rate reported in literature is reassuring that most patients who experienced a headache were in fact accounted for. Therefore, it is certainly possible the decreased post-LP headache phone call rate in the ultrasound group (12.8%) indeed represents a true decrease in the post-LP headache rate by roughly 50%, when compared to the 30% headache rate found in previous studies. Furthermore, the similar trending in headache rates across two methods of assessment (phone calls and ED visits) provides support to their validity. We do not have any reason to suspect that reporting rates of headaches, via documentation of phone calls or of ED visits, would have systematically differed between the two groups. Interestingly, the Honarbakhsh trial, while showing a decrease in overall complication rate in the ultrasound-guided group, did not show any absolute decrease in headache rate in the ultrasound-guided group.[12] Varied results between that study and the presented data here make this pilot study all the more essential to the call for future prospective studies.

While there was a notable difference in headache rate between the two groups, statistical significance was not reached. This could be due in part to the disparity of sample sizes. The small size of the non-ultrasound group certainly limits the power of the study and the ability to attain statistical significance; however, the absolute doubling of post-LP headache rates between the two groups despite such a size disparity suggests there may be a true difference that warrants further investigation.

Despite the limitations, the results of this study remain informative. The trending of the post-procedural headache data, specifically that the non-ultrasound group experienced headache phone call and ED visit rates more than twice that of the ultrasound group, suggests ultrasound may prove to be an effective guide for LP in a more controlled prospective study. Such a study would investigate LP success rate, LP complication rate, number of needle passes, and cost-effectiveness between ultrasound and standard approaches in a prospective format. As physicians' skills and ultrasound devices continue to improve, the use of ultrasonography may prove to be a paradigm shift for this age-old, ubiquitous procedure.

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