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Ultrasonography-Guided Lumbar Punctures Effect on Success Rate in Infants

Patricia Dorian

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Ultrasonography-Guided Lumbar Punctures Effect on Success Rate in Infants

Abstract

**Background:** Lumbar puncture (LP) is a common diagnostic procedure performed in emergency departments for febrile infants in order to rule in or rule out bacterial meningitis. A traditional LP procedure is accomplished by palpating for anatomical landmarks in order to place the needle in the correct location. Similar to venous catheterization, ultrasonography has been used as a non-invasive tool to locate these landmarks and mark their location on the skin of the patient. Several adult studies have been performed in order to analyze the success rate of traditional versus ultrasonography-assisted LPs and have shown increased success in the ultrasonography groups. The goal of this review is to analyze studies done on infants and discern if they have a similar or better success rate with ultrasonography assistance.

**Methods:** An exhaustive search of the literature was conducted on the following search engines: Web of Science, MEDLINE-Ovid, MEDLINE-PubMed, and Google Scholar. Key terms used included: ultrasonography, infant, lumbar puncture, and randomized control trial. All articles found went through an eligibility criteria and were analyzed using the GRADE assessment tool.

**Results:** Two randomized control trials were found to match the criteria. The first study included 128 infants with 64 in each group - traditional and ultrasound-assisted LPs. LP success rate within 3 attempts was 75% in the ultrasound-assisted group versus 44% in the traditional group. In the second study, 43 infants were enrolled with 21 infants in the ultrasound-assisted LP group and 22 in the traditional LP group. Final results showed a 95% success rate in the ultrasound group versus 68% in the traditional group.

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**Keywords:** Infant, ultrasonography, lumbar puncture, and ultrasound-assisted
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Ultrasonography-Guided Lumbar Punctures

Effect on Success Rate in Infants

Patricia Dorian

A Clinical Graduate Project Submitted to the Faculty of the
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Pacific University
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Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography

[redacted]
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List of Abbreviations

LP       Lumbar Puncture
CSF      Cerebral Spinal Fluid
RBC      Red Blood Cell
CNS      Central Nervous System

Ultrasonography-Guided Lumbar Punctures Effect on Success in Infants
BACKGROUND

Neonatal meningitis is seen in about 0.25-1.0 per 1000 live births.\textsuperscript{1} Although this seems like a small number, it is significant due to the deadly outcomes meningitis can have for infants. In the emergency department, infants can present with unspecified symptoms such as fever, poor feeding, and inconsolability. In order to properly rule out or diagnose bacterial meningitis or other deadly central nervous system (CNS) infections, emergency department providers must obtain cerebral spinal fluid (CSF) from the subarachnoid space for analysis via lumbar puncture (LP). Unsuccessful rates for traditional LPs in the pediatric population, have been reported to be as high as 40%-50% in some cases.\textsuperscript{2} In order to make the correct diagnosis and ultimately give the best treatment, success rates need to be as high as possible.

During the LP procedure, neurological injury is avoided by entering any space below the 1st and 2nd lumbar vertebrae where the spinal cord ends, this area is known as the conus medularis. In traditional LPs, anatomical landmarks are used to access the area between the 3rd and 4th lumbar vertebrae while the patient is curled up in the left lateral or seated position. Manual palpations of the superior most portion of the posterior iliac crest allows for the estimation of the level of the 4th lumbar spinous process. In a study about the accuracy of manual palpation of LP landmarks in neonates, it was found that in 36% of cases the “LP sight was identified higher than intended” and the beginning of the conus medularis had varying positions in patients as well. With these varying locations, the
odds of causing neurological damage increases which calls for an even more accurate way of performing LPs.

Ultrasonography continues to have a growing popularity in the healthcare field especially most recently in procedures like jugular, subclavian, and femoral vein catheterization, as a way to avoid neurovascular damage. In addition, improved success rates have been seen in these complicated procedures over the standard anatomical palpation technique. In a meta-analysis of adult ultrasonography imaging for LPs and epidural catheterizations, conclusions stated that ultrasound assistance helped increase the success rates for both procedures. Plus, it was found that the number needed-to-treat to prevent one failure was 16 ultrasound-guided procedures. After analyzing secondary outcomes, a reduction of traumatic procedures, and needle redirecting was seen as well.

Success rates become even more important in the infant population due to the increased difficulty as the patient population age decreases. In a study by Baxter et al, “factors associated with resident LP success” was researched in infants 12 months and under. One factor found to decrease success rates was patient’s age; infants 3-12 months old were found to have an 88% overall success rate while infants 6-12 weeks had 78% and under 6 weeks dropped down to a 66% success rate. Correctly obtaining CSF fluid can change the course of an infant’s care and stay at the hospital. In a retrospective cross-sectional study on hospitalization rate for unsuccessful LP versus successful in febrile infants, only 18.1% of the successful LP group were hospitalized; whereas the unsuccessful group had a 72.3% hospitalization rate. Regardless of hospitalization, both
groups were observed to have similar serious bacterial infection rates, thus enhancing the importance of successful LPs in order to rule out a serious infection like bacterial meningitis. Unnecessary hospitalizations, and increased healthcare costs, procedures, antibiotic use, and parental stress may avoided through increased success rates of LPs for critical diagnostic studies in the infant population.

Ultrasonography-assisted LP is a new tool emerging for the use in the infant population. For complicated LPs that are unsuccessful the first time, next day fluoroscopy-guided LP procedures have been used traditionally thus exposing the patient to radiation and increasing cost for the more invasive procedure. Ultrasound can be accessed quickly without exposing the patient to radiation, while avoiding the extra cost and hospital stays as well. Due to the many factors discussed above, reaching the highest success rates for LP procedures becomes crucial in the infant population in order to achieve the highest standard of care. Currently, two research studies have been conducted to analyze the effectiveness of using the ultrasound machine to mark the proper skin site for LP insertion in the infant population; these studies will be analyzed and discussed in more depth below.

**METHODS**

An exhaustive search of the literature was conducted on the following search engines: Web of Science, MEDLINE-Ovid, MEDLINE-PubMed, and
Google Scholar. Key terms used included: ultrasonography, infant, lumbar puncture, and randomized control trial. Inclusion criteria encompassed studies written in English, randomized control trials, studies on infants 6 months and younger, and studies with the primary outcome of successful lumbar puncture. Exclusion criteria included adult studies and studies beyond 5 years old. Articles were analyzed using the GRADE criteria (see Table 1).¹¹

RESULTS

The search for articles yielded 130 results. After eliminating duplicates, 2 articles²,¹⁰ met eligibility criteria and were relevant studies. Both articles found were randomized control trials.

Neal et al

This study² was published in May of 2017. It was a “prospective, non blinded, randomized, controlled trial.” The goal was to assess the effectiveness of using ultrasonography to mark the location of needle placement for the LP versus traditional palpation of anatomical landmarks. The study was performed in a large urban pediatric emergency department over a 20-month period. Inclusion criteria comprised of infants 6 months and younger receiving an LP. Excluded were any infants with a known spinal cord abnormality, and infants with non-English speaking parents.²

After informed consent was completed, “a block randomization sequence was generated” in order to sort the patients into the test group and control group.
An allocation concealment was used to contain the assignments, and the clinician performing the LP was chosen before the assignment group was revealed. Over the 20-month period, 833 infants met eligibility criteria; yet, 581 patients were excluded due to patient factors, 115 due to the unavailability of the sonographer, and 9 due to refused consent. There were 128 patients who remained and were randomly sorted into 2 groups of 64 patients, the traditional LP group and ultrasound-assisted LP group. Both groups had similar characteristics including age in days, gestational age, race, weight, and time LP was performed; only a baseline sex difference and first attempt LP position differed in each group due to randomization. In addition, only 1 patient did not receive the LP in the ultrasound group due to patient decompensation, yet was still included in the results. Lastly, every patient received local lidocaine infiltration as part of the standard of care in the hospital.²

In the ultrasound group, the skin markings included a vertical line representing the termination of the conus medularis with an intersecting horizontal line representing the intervertebral space. Clinicians were instructed that the intersection of these lines was the space in which the LP should be attempted. In order to verify accuracy and quality control, all images and clips taken during ultrasound imaging of patients were sent to a board-certified pediatric radiologist.²

A successful first attempt LP, as defined by “CSF obtained with RBC count less than 1,000/mm³,” was considered the primary outcome. A secondary outcome included a successful LP within 3 attempts with or without the clinician changing in between attempts. Full removal and reinsertion of the spinal needle
was defined as an attempt, whereas redirecting the needle in the skin did not count as a second attempt. Traumatic taps or CSF collected with less than 10000/mm³ RBCs was considered another secondary outcome. All attempts were done by a total of 107 clinicians with varying levels of LP experience graded on a scale from 0 to 50(+). The two study groups had a similar comparison of clinician skill.²

Final results (Table 2) of the primary outcome revealed the ultrasonography group to have a success rate of 58% versus the 31% in the traditional group. Success within 3 attempts increased in the ultrasound group to a 77% success rate and the traditional group to a 44% success rate. A greater provider experience grade increased the success rate as well, but did not have a statistical significance. In addition, providers with the least experience had a higher success rate in the ultrasound-assisted group.²

Similar lengths of stay in the hospital and length of antibiotics was observed in both groups, but 8 patients in the traditional group needed repeat LPs and only 2 patients in the ultrasonography group needed repeat LPs including the patient who originally did not receive an LP from the beginning of the study. Overall, there was a 31% increase in success with a 95% CI of 15% to 47% within 3 attempts when comparing the traditional group to the ultrasound assisted group.²

Gorn et al
The second study analyzed was published in January 2017 and a prospective, non-blinded, randomized, control trial as well. The study was conducted in an urban pediatric emergency department over an 11 month period. Similar to the other study discussed, the goal was to assess the effectiveness of ultrasound-assisted LPs versus traditional LPs in the infant population. Infants 60 days or younger receiving an LP were enrolled in the study. Exclusion criteria included any patients with known spine abnormality and patients with a ventriculoperitoneal shunt.

After consent was obtained, a total of 68 patients met eligibility criteria with only 43 patients enrolled due to the absence of an investigator for the remaining 25 patients. For the 43 patients enrolled, 21 were placed in the ultrasound group, and 22 were placed in the standardized group. A total of 23 patients in each group was the goal for the authors but could not be achieved due to the early termination of the study. “Personal academic demands” for some of the authors caused the early termination of their study. “A standard block randomization technique” was used to sort the patients into the 2 groups. Characteristics including weight, age, gestational age, and gender were similar in both groups. The primary outcome was a successful LP. Definition of a successful LP included “obtaining at least three 0.5mL CSF samples for analysis and a CSF RBC count of less than 10000 cells/mm3.” No secondary outcomes were looked at in this study.

Unlike the previous study, all patients enrolled had an ultrasound study done to analyze the landmarks for research purposes, but skin markings were
only done on the ultrasound group. The skin markings were the same in the previous study with the vertical conus medularis line intersecting with the horizontal intervertebral line. In addition to the skin markings, this study calculated the maximum depth in which the needle should be inserted and marked the spinal needle with a sterile pen to avoid potential damage or a traumatic LP.\textsuperscript{10}

Results (Table 2) for this study showed a success rate of 95\% in the ultrasound group versus 68\% in the traditional group. In addition, the 25 patients not enrolled due to lack of an investigator were retrospectively analyzed and found to have a success rate of 72\% with traditional LPs. The number-needed-to-treat was calculated as 3.7 with a 95\% CI of 2.02-24.18.\textsuperscript{10}

**DISCUSSION**

Both of these studies\textsuperscript{2,10} sought to answer the question on whether or not infant LP success rate increased with the use of ultrasound-assisted skin markers over traditional palpation of landmarks. Although they were small studies, both proved to have an increased success rate for the infants undergoing the ultrasound procedure. Due to the physical marking of the skin needing to be present, there was no way of blinding the providers to the group they were randomized into, which became a limitation discussed in both studies.\textsuperscript{2,10} Though in the Gorn et al study,\textsuperscript{10} patients who did not make it into the study, who received traditional LPs, were retrospectively studied, and their success rate correlated with the success rates of the traditional LP group in the study, thus supporting the argument that the lack of blinding did not have an influence on the study.\textsuperscript{10}
Standardization of the LP technique was not universal in both studies.\textsuperscript{2,10} Providers have the option of removing the stylet early before advancing fully into the subarachnoid space or pushing all the way through without removing the stylet till the subarachnoid space is entered. In addition, patients can be positioned in either a lateral decubitus or sitting position for the procedure. Lastly the use of topical lidocaine for local anesthesia was only required in the Neal et al study\textsuperscript{2} while left as an option in the Gorn et al study.\textsuperscript{10} Provider preference dictated these options, but this either did not influence the results or the data for these factors was not collected.

Unlike the provider preference, provider experience did have an influence on the success rate especially in the teaching hospital. During the Neal et al study,\textsuperscript{2} around half of the LPs performed were done by providers with little to no experience in LP procedures and this study “observed a low proportion of success in the control group, which could have artificially inflated the absolute difference between the control and the ultrasonography arm.” As a result, the results might not be applicable in healthcare settings where providers have more experience.\textsuperscript{2} Furthermore, the applicability might be limited as well due to the fact that each study was performed in a pediatric emergency department. With such a specialized population, the healthcare providers have specific training and skills meant for the pediatric population including the sonographers. Smaller hospitals that do not see a large pediatric population might not be able to duplicate the ultrasonography study due to the decreased experience or limited resources.\textsuperscript{2,10}
CONCLUSION

Overall, the results from these studies assessing the effectiveness of ultrasound-assisted LPs in the infant population show increased success rates. There is still need for more studies on larger scales in order to prove effectiveness since these studies were in small populations. With increased success rates, infants can be treated correctly and might avoid unnecessary hospitalization leading to more procedures, increased cost, and increase parental worry. Ultrasound itself is a safe, non-invasive way to initially achieve a successful LP that could potentially be applied as a standard of care similar to venous catheter placement.
References


### Table 1: Quality Assessment of Reviewed Articles

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Downgrade Criteria</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neal et al(^2)</td>
<td>RCT</td>
<td>Not Serious(^a)</td>
<td>Not Serious</td>
</tr>
<tr>
<td>Gorn et al(^10)</td>
<td>RCT</td>
<td>Serious(^a,c)</td>
<td>Not Serious</td>
</tr>
</tbody>
</table>

\(^a\)Lack of blinding but no downgrade due to the objectivity of measured outcomes  
\(^b\)Small sample size  
\(^c\)Trial was stopped early
Table 2: Summary of Findings

<table>
<thead>
<tr>
<th></th>
<th>Neal et al²</th>
<th>Gorn et al¹⁰</th>
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<tbody>
<tr>
<td></td>
<td>Ultrasound Group 64 Patients</td>
<td>Traditional Group 64 patients</td>
</tr>
<tr>
<td>Successful attempt*</td>
<td>48 (75.0%)</td>
<td>28 (43.8%)</td>
</tr>
<tr>
<td>Unsuccessful attempt</td>
<td>16 (25.0%)</td>
<td>36 (56.3%)</td>
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*Percentages in the Neal et al study² based on success within 3 attempts. Gorn et al study¹⁰ did not specify how many attempts were made in their success group. g