



Original Contribution

Emergency physicians can easily obtain ultrasound images of anatomical landmarks relevant to lumbar puncture[☆]

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Abstract

Introduction: Although ultrasound has been used in administering epidural anesthesia, it is unknown if emergency physicians (EPs) can obtain ultrasound images useful for lumbar puncture.

Objective: The objective of the study was to determine EPs' ability to apply a standardized ultrasound technique for visualizing landmarks surrounding the dural space.

Methods: Two EPs sought to identify relevant anatomy in emergency patients. Visualization time for 5 anatomical structures (spinous processes or laminae, ligamentum flavum, dura mater, epidural space, subarachnoid space), body mass index, and perception of landmark palpation difficulty were recorded.

Results: Seventy-six subjects were enrolled. Soft tissue and bony anatomical structures were identified in all subjects. Mean body mass index was 31.4 ± 9.8 (95% confidence interval, 29.1–33.6). High-quality images were obtained in less than 1 minute in 153 (87.9%) scans and in less than 5 minutes in 174 (100%) scans. Mean acquisition time was 57.19 seconds; SD, 68.14 seconds; range, 10 to 300 seconds.

Conclusion: In this cohort, EPs were able to rapidly obtain high-quality ultrasound images relevant to lumbar puncture.

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1. Introduction

First performed in 1891 by Quincke, diagnostic lumbar puncture (LP) is a critical and frequently performed procedure for emergency physicians (EPs) [1]. Performed incorrectly, an LP can insert unnecessary diagnostic uncertainty into a clinical situation and even cause harm to a patient. Procedural complications may arise when LP is

performed by clinicians without clear understanding of the related anatomy, and it has been shown that accurate identification of anatomical landmarks by palpation is significantly impaired in patients with an elevated body mass index (BMI) [2,3]. Because recent estimates suggest that at least 65% of adults in the United States are overweight or obese, new methods of increasing the accuracy of anatomical landmark identification before LP may be useful for EPs [4].

The use of ultrasound technology for landmark identification before LP was first described in 1971 by Bogin and Stulin and appears in a Russian-language medical journal [5]. English-language publications from the anesthesia literature demonstrate the successful use of ultrasound in

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the identification of anatomical landmarks in the administration of epidural and spinal anesthesia [6-9]. Recently, Peterson and Abele reported 2 cases of the use of bedside ultrasound to identify spinous processes and the interspinous space in situations of difficult emergency department LP [10]. This beginning evidence suggests that EPs can use bedside ultrasound to enhance LP performance as well. Theoretically, ultrasound can provide all the information essential to a successful LP, as follows: (1) a point for needle introduction, (2) the angle needed to approach the subarachnoid space (SAS), and (3) the distance the needle must traverse to obtain cerebrospinal fluid (CSF). Whether EPs without specialized ultrasound training can quickly obtain high-quality ultrasound images of soft tissue and bony landmark anatomy relevant to LP in a variety of emergency department patients is unknown.

The purpose of this investigation was to address the following 3 research questions. First, can EPs use ultrasound to gather this information on a wide variety of patients? Second, can ultrasound image acquisition be completed in a timely manner such that it will not hinder patient flow? Finally, are EPs able to quickly collect relevant images in subjects with elevated BMI and/or difficult-to-palpate landmarks?

2. Methods

2.1. Study design

This study was a prospective, observational trial examining the ability of EPs to obtain ultrasound images of anatomical landmarks relevant to LP in a convenience sample emergency department patients. The investigation

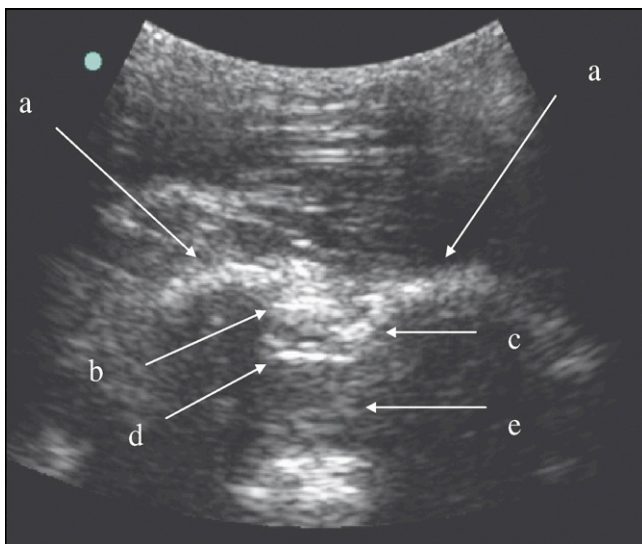


Fig. 1 Paramedian approach image obtained with curved array probe (a, lamina; b, ligamentum flavum; c, epidural space; d, dura mater; e, subarachnoid space).

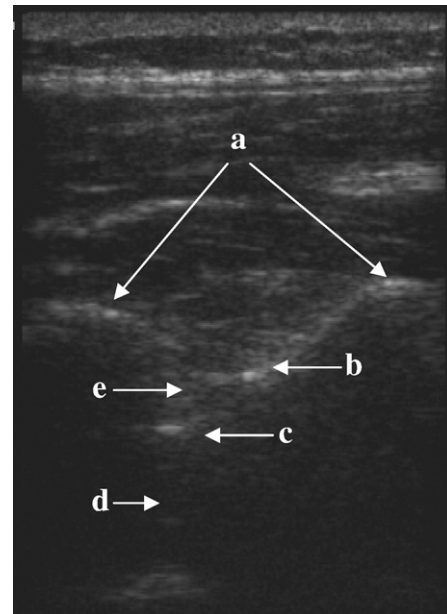


Fig. 2 Paramedian approach image obtained with a linear array probe (a, lamina; b, ligamentum flavum; c, dura mater; d, subarachnoid space; e, epidural space).

was exempted by the Institutional Review Board, and the requirement for written informed consent was waived.

2.2. Setting and study population

The study was conducted in the department of emergency medicine of an academic referral center with an emergency medicine residency training program. The center's annual emergency department census was approximately 53 000 patients at the time of the study.

Adult (≥ 18 years of age) patients who presented in the center's emergency department were eligible for study inclusion without regard to their presenting complaint on a convenience basis when the study investigators were present to collect data. Patients were excluded from participation if they were unable to speak English or if they were unwilling to participate in the study protocol.

2.3. Study protocol

Before initiation of the study, 2 EPs (1 resident physician and 1 attending physician) studied ultrasound images previously published by Grau and colleagues describing sonographic spinal anatomy [8,9,11]. Approximately 10 practice scans were performed before study enrollment began by each EP, and sonographic targets were identified a priori as follows: spinous processes, laminae, ligamentum flavum, dura mater, epidural space, and SAS Figs. 1–5. The locations of the spinous processes and the laminae were considered potentially useful in determining the site of spinal needle insertion. The locations of the ligamentum flavum, dura mater, epidural space, and SAS were thought to be useful in determining both the distance from the subject's skin to the

CSF and the angle of needle insertion (by mimicking the ultrasound probe angle used to visualize the structures).

The study was conducted when the physician investigators were available to conduct the study procedures separately from their usual clinical duties. Subjects were enrolled during a 3-month period in 2004. Patients in the emergency department who were waiting during the various phases of their treatment (eg, waiting for test results or radiographs) were approached by the investigators for possible study inclusion. Those who agreed to participate were placed in either a lateral recumbent or sitting position. A total of 6 images were obtained from each subject, including midline, right, and left paramedian views, using the 2 ultrasound probes described below Figs. 1–3. To assess interrater reliability on image acquisition between the study physicians, a series of scans on 10 of the subjects was conducted by both physicians, 1 physician immediately after the other, but blinded to each other’s results.

Standardized data collection forms were used to record all data including subject age, sex, height, weight, time to acquisition of each image, and success or nonsuccess of the scan. Subject BMI was calculated from the standard metric formula: $BMI = \text{weight in kilograms} / \text{height in meters} \times \text{height in meters}$.

As in a traditionally performed LP, palpation of the iliac crests and spinous processes was performed by the study physicians. Physician perception of the ease of landmark palpation was graded on a 4-point scale, displayed in Fig. 6.

An image was considered successful in a midline scan if the spinous processes and at least 1 deep soft tissue structure (eg, ligamentum flavum or dura mater) were visualized. An image was considered successful in a paramedian orienta-

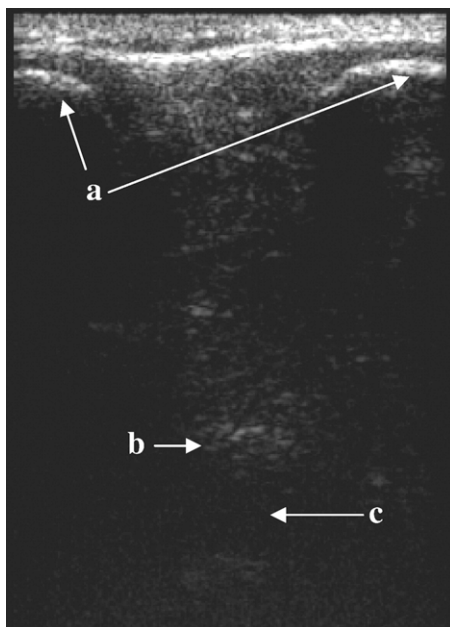
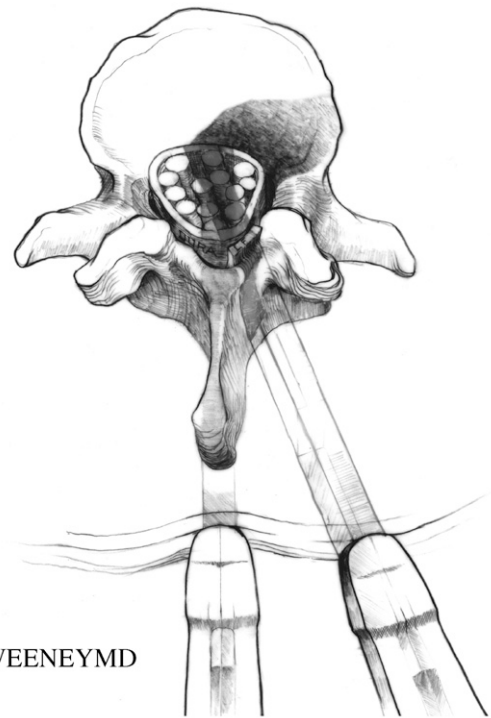


Fig. 3 Midline approach image obtained with linear array probe (a, spinous processes; b, dura mater/ligamentum flavum; c, subarachnoid space).



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Fig. 4 Vertebral body illustration, midline and paramedian approaches.

tion if the laminae and at least 1 deep soft tissue structure were visualized. An image was classified as high quality if at least 4 of 5 possible structures were identified. Finally, images must have been acquired in less than 5 minutes to be considered as successfully obtained.

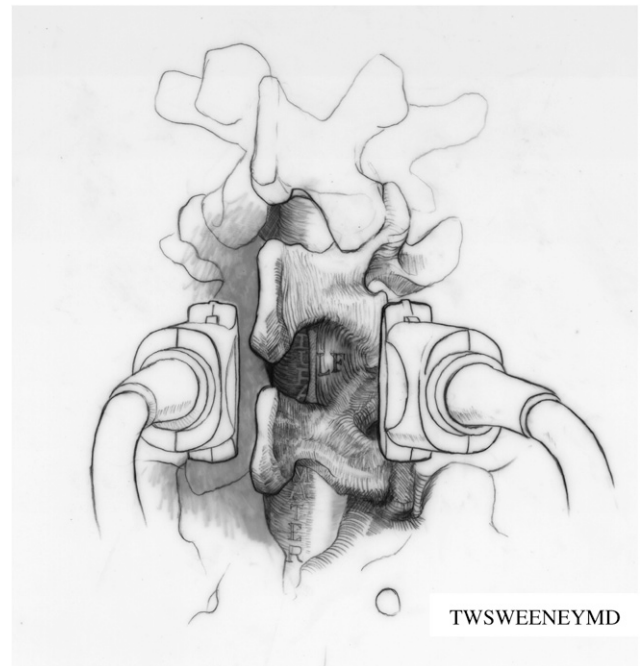


Fig. 5 Spinal anatomy illustration, midline and paramedian approaches.

Easy = light palpation of iliac crests; spinous processes identified by sight.
Moderate = light to deep palpation of iliac crests; light palpation of spinous processes
Difficult = Deep palpation of iliac crests and spinous processes
Impossible = iliac crests or spinous processes not able to be palpated

Fig. 6 Physician perception of ease of landmark palpation.

2.4. Measurement

All ultrasound scans were performed using a SonoSite Titan (SonoSite, Inc, Bothell, WA) ultrasound machine. Both a 7.5-MHz linear probe and a 3-MHz curvilinear probe were used.

2.5. Data analysis

All data were analyzed using the SPSS 11.0 (SPSS, Inc, Chicago, IL) statistical software. Descriptive statistics including mean, standard deviation, and 95% confidence intervals (CIs) were calculated. The independent samples *t* test was used to compare means between groups. The Cohen κ statistic was calculated to determine interrater agreement on image acquisition between the physician investigators.

3. Results

Seventy-six subjects were enrolled in the study and completed the protocol. No subject was unable to tolerate the entire study protocol. The study population characteristics are described in Table 1. Interrater agreement between the physicians on image acquisition was 0.920, indicating very strong agreement.

3.1. EP ability to acquire images

The EPs successfully obtained sonographic images in all 76 subjects. *High-quality images*, defined as the identification of at least 4 of 5 relevant structures, were obtained in 73 (96.1%) subjects. Using a midline approach with a 3.0-MHz curved array probe and a 7.5-MHz linear probe, the spinous processes and ligamentum flavum were identified in 74 (97.4%) and 71 (93.4%) of subjects, respectively. Real-time images differentiating the ligamentum flavum and dura mater, and thus the epidural space, were observed. Study physicians were not able to capture still images differentiating these structures using a midline approach. Using a paramedian approach with a 3.0-MHz curved array probe, the laminae and ligamentum flavum were identified in 76 (100%) subjects, whereas with a 7.5-MHz linear probe, these structures were identified in 74 (97.4%) subjects. The 2 subjects whose structures were not identified by the 7.5-MHz linear probe had BMIs of 58.6 and 73.1. Table 2 displays the differences in the identification of the anatomical structures dependent upon probe type and sonographic approach.

3.2. Image acquisition time

Mean time to obtain the best scan possible in patients with a midline approach was 54.7 ± 58.0 seconds (95% CI, 41.3-68.1) using the 3.0-MHz curved array probe and 60.5 ± 54.5 seconds (95% CI, 48.1-73.0) using the 7.5-MHz linear array probe. Mean time to obtain the best scan possible in patients with a paramedian approach was 45.1 ± 44.0 seconds (95% CI, 34.9-55.4) using the 3.0-MHz curved array probe and 56.8 ± 57.0 seconds (95% CI, 43.8-69.9) using the 7.5-MHz linear array probe. No statistically significant differences in acquisition time were found based on sonographic approach or probe type.

3.3. Elevated BMI

Anatomical landmarks traditionally palpated before LP were rated as difficult or impossible to palpate in approximately half (36, 47.4%) of subjects (Table 1). Thirty-five subjects (46.1%) had a BMI of at least 30. A statistically significant relationship between BMI and the ability to palpate landmarks (Kruskal-Wallis χ^2 , 51.659; *df* = 3; *P* = .000) was found, with palpation difficulty increasing as BMI increased. When comparing time to image acquisition in those with BMI of at least 30 with those with BMI not exceeding 29, statistically significant differences were noted independent of sonographic approach or probe used. Table 3 displays differences in acquisition based on BMI.

4. Discussion

To our knowledge, this investigation is the first to examine the ability of EPs to use ultrasound to identify anatomical landmarks pertinent to LP in a wide variety of patients. Although the aforementioned work published by Peterson and Abele described the use of bedside ultrasound to assist in emergency department LP by visualizing bony structures, these bony landmarks serve only as the starting point for needle insertion, giving no further information about how to obtain CSF from the SAS [10]. These authors reported using ultrasound to identify the spinous processes and interspinous space using a transverse and sagittal

Table 1 Subject characteristics

	n (%)	Mean (SD)	95% CI
Sex			
Male	41 (54)	–	–
Female	35 (46)	–	–
Age	–	48.5 (20.5)	43.8-53.2
BMI	–	31.4 (9.8)	29.1-33.6
Palpation ease			
Easy	14 (18.4)	–	–
Moderate	26 (34.2)	–	–
Difficult	20 (26.3)	–	–
Impossible	16 (21.1)	–	–

Table 2 Differences in identification of structures with varied probe and approach

Midline approach			Paramedian approach		
Structure	Curved array, n (%)	Linear array, n (%)	Structure	Curved array, n (%)	Linear array, n (%)
Spinous process	76 (100)	76 (100)	Laminae	76 (100)	76 (100)
Ligamentum flavum	74 (97.4)	71 (93.4)	Ligamentum flavum	76 (100)	74 (97.4)
Dura mater	65 (85.5)	61 (80.3)	Dura mater	73 (96.1)	73 (96.1)
Epidural space	59 (77.6)	49 (64.5)	Epidural space	72 (94.7)	70 (92.1)
SAS	61 (80.3)	55 (72.4)	SAS	74 (97.4)	73 (96.1)
High-quality images	65 (85.5)	60 (78.9)	High-quality images	73 (96.1)	73 (96.1)
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)
Time, s	54.7 ± 58.0	60.5 ± 54.0	Time, s	45.1 ± 44	56.8 ± 57.0

High-quality images are defined as the ability to identify 4 of 5 possible structures.

orientation of the lumbar spine. Used in this manner, ultrasound becomes the “hands” of the physician in identifying bony landmarks.

In our study, we demonstrated the ability of EPs to consistently identify deep soft tissue structures in addition to bony landmarks. Whether using ultrasound or palpation to identify superficial bony structures, we gain important information on the site of needle insertion. However, by visualizing deep soft tissue structures, we know the end point of needle insertion. This additional information allows the physician sonographer to visualize and calculate both needle angulation and depth. Using both of these data points, we can begin to use the full potential of ultrasound for the LP procedure.

Our findings reaffirm those of Grau and colleagues that the sagittal paramedian approach is superior for viewing spinal anatomy [12]. Intuitively, the more anatomical elements that are seen, the greater the physician’s confidence in the process. With curved and linear probes, all deep soft tissue landmarks were seen in 94.7% and 92.1% of subjects, respectively, using a sagittal paramedian approach. Contrast this to curved and linear probes in a sagittal midline approach, where 77.6% and 64.5% subjects, respectively, had all structures identified. This is likely due to the small sonographic window between the spinous processes. In fact, we found it difficult to differentiate between the ligamentum flavum and dura mater (and thus the epidural space) in a midline approach. This was demonstrated in that we could not successfully obtain a still image that clearly differentiated these structures.

With obesity becoming more prevalent in general American society as well as in the emergency department patient population, ultrasound may be needed more frequently to be the hands of the physician in finding superficial bony landmarks. Although BMI does correlate with our ability to palpate, it did not affect our ability to successfully image the spinal anatomy of our subjects. It should be noted, however, that we did demonstrate longer mean times to obtain adequate images in those with elevated BMI.

4.1. Limitations and future questions

Several important limitations of this study should be discussed. First, data were obtained by 2 EPs who were working independently. There was no third party to record data or time while the imaging procedure was taking place. In addition, the difficulty of palpation, the adequacy of the image, and the accurate identification of landmarks were not verified by a third party. Second, the authors have had no formal training in obtaining these sonographic images. Finally, there is limited literature, including few images, about lumbar sonography in adults for procedural anesthesia. We are unaware of a cadaver study that correlates the actual images obtained with a dissected cadaveric structure, therefore ensuring the accuracy of the sonographic images.

The anesthesia literature demonstrates that ultrasound in combination with spinal and epidural anesthesia has shown statistically significant reductions in procedure failure, complications, and pain, while improving patient satisfaction scores [8,9,13]. It remains unknown whether ultrasound

Table 3 Image acquisition and BMI by ease of palpation

Ease of palpation	n (%)	Mean BMI	Mean acquisition time (s)	High-quality images
Easy	14 (18.4)	21.9 ± 2.2; 95% CI, 20.7-23.2	32.2 ± 14.7; 95% CI, 28.2-36.2	53/56 (94.6%)
Moderate	26 (34.2)	27.8 ± 5.1; 95% CI, 25.7-29.8	44.3 ± 42.8; 95% CI, 35.9-52.6	95/104 (91.3%)
Difficult	20 (26.3)	31.4 ± 4.0; 95% CI, 29.6-33.3	48.6 ± 34.4; 95% CI, 40.9-56.3	75/79 (94.9%)
Impossible	16 (21.1)	45.3 ± 9.8; 95% CI, 40.1-50.6	109.5 ± 85.7; 95% CI, 87.9-131.1	49/64 (76.6%)

Ease of palpation refers to physician perception of difficulty palpating anatomical landmarks as displayed in Fig. 1.

will have the same benefits for emergency department LP, and further studies in this area are warranted. In addition, how important depth, trajectory, and other details about soft tissue structures are in the success of obtaining CSF fluid will require further study.

5. Conclusions

In this cohort of emergency department patients, EPs were able to rapidly obtain high-quality ultrasound images of spinal anatomy relevant to LP. In subjects with elevated BMI, the time to obtain high-quality images was longer but remained feasible for the emergency department setting.

Acknowledgment

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