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Diagnostic and interventional ultrasonography in neonatal and infant lumbar puncture

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Abstract *Background.* Lumbar puncture (LP) may be unsuccessful clinically, prompting image-guided LP by radiologists.
Objective. To investigate the utility of ultrasound (US) in diagnosing the cause of failed LP and in guiding LP.
Materials and methods. Neonates and infants referred for image-guided LP underwent spine US of the thecal sac. When indicated, image-guided LP was performed.
Results. Forty-seven evaluations and interventions were performed in 32 patients. All patients were initially evaluated after failed blind LP attempts. Twenty-three of the initial US studies showed intrathecal and/or epidural echogenic hematoma, which obliterated the CSF space; 5 showed minimal fluid, and 4 had normal examinations. LP was deferred or cancelled in 14 cases based upon initial US findings. Image-guided LP was performed 32 times in 19 patients. US guidance was used in 26, fluoroscopy in 3, and fluoroscopy with US assistance in 3. Using US, LP was performed in 9 patients with no visible CSF: 2 samples were sufficient for culture only. Six patients had minimal CSF US: 4 provided usable CSF samples. Clear CSF space was seen in 11: all had successful LP.
Conclusions. US can disclose the cause of failed LP, can help determine whether or not to intervene further, and can provide guidance for LP.

Introduction

Lumbar puncture (LP) for cerebrospinal fluid (CSF) sampling is a routine procedure in the evaluation of fever and sepsis in the neonate and infant [1–3]. The presence of CSF infection often determines the choice and duration of antibiotic therapy and can have prognostic implications for patient outcome. LP can often be accomplished without difficulty in the office, emergency department, or hospital ward. Occasional difficulties arise, however, which then prompt requests for image-guided LP by the interventional radiologist, traditionally using fluoroscopy.

After failing to obtain CSF from several patients despite fluoroscopically appropriate needle placement, we evaluated the spine and thecal sac with ultrasound (US). Subsequently, we used US prospectively to evaluate the thecal sac prior to LP, as well as using US to provide image guidance for LP.

Materials and methods

Neonates and infants referred for image-guided lumbar puncture were prospectively evaluated over a 36-month period. Patients were typically referred after failed LP attempts by the referring clinical service, although some patients were referred if there was a prior history of difficult access or if there were known or suspected spinal abnormalities. All patients had spine US performed with high-resolution linear array transducers using either an HDI 5000 (ATL, Bothell, Wash.) or Sequoia (Acuson, Mountain View, Calif.) ultrasound unit. Examinations concentrated on the presence or absence of normal clear CSF in the thecal sac below the conus. The presence of intrathecal blood and epidural hematoma was assessed. Depending on the clinical situation, US appearance, and discretion of the interventional radiologist, LP was performed or deferred. LP was performed under sterile conditions in the interventional radiology suite, usually with conscious sedation. The choice of prone or lateral decubitus patient position was the choice of the individual interventional radiologist. If LP was performed, the imaging modality used (fluoroscopy or US), the success or failure in obtaining a sample, and the character of the sample were re-

corded. Clinical records were reviewed to obtain the number of prior clinical failed LP attempts and size of LP needle used and the adequacy of image-guided LP CSF samples for laboratory and microbiological analysis. The review was approved by the Children's Hospital Human Subjects Research Committee.

Results

Forty-seven encounters occurred in 32 patients during the study period. All patients were initially referred for image-guided LP after failed blind LP by the clinical service. Failed clinical LP occurred 6 h to 4 days prior to radiological evaluation. Indications for performing LP in these patients included evaluation of fever, sepsis, and seizures. Mean patient age at first patient encounter was 22 ± 18 days (range 3–86 days). In reviewing patient charts, only 17 of 32 had documentation of the number of clinical attempts, with a mean of 3.8 ± 1.3 needle passes (range 2–7), utilizing either 21 G or 22 G spinal needles with stylets. The 15 remaining patient encounters were follow-up evaluations in these same patients.

US of the spine was performed in all 32 patients referred for image-guided LP after failed blind LP attempts. US findings fell into three categories: complete obliteration of the CSF space by epidural or intrathecal collections, minimal visible CSF, or essentially normal. Twenty-three patients had complete obliteration of the CSF space within the thecal sac. In 12 of 23, heterogeneous echogenic material was seen in the epidural space compressing the thecal sac and displacing CSF (Fig. 1). In 3 of 23 the echogenic material appeared to be primarily intrathecal (Fig. 2), and in 5 of 23 there was material both within the thecal sac and epidural space. In 3 of 23 patients, the lack of CSF was reported, but no specific comment on the presence of a compressing collection was made. Of the 5 patients with minimal visible CSF, 2 had small pockets of echogenic and presumably bloody CSF, and 3 had small areas of clear CSF despite thecal compression from an epidural collection. Four patients were essentially normal, showing good CSF within the thecal sac without significant epidural collection.

After initial US evaluation, the decision to defer or perform image-guided LP was made by the interventional radiologist based upon the imaging findings and the patient's clinical status. Of the 23 patients with no visible CSF at US, LP was deferred in 14, and 9 patients underwent image-guided LP. No sample was obtained in one, and in eight only blood was returned. Two of these bloody samples were sent for studies and were sufficient for culture (both negative); the other six samples were not sent. Of the five patients with minimal CSF visualized at US, four patients underwent image-guided LP and one was deferred. Two samples returned CSF sufficient for routine studies, and two returned bloody fluid, one of which was adequate for culture. Of the four pa-

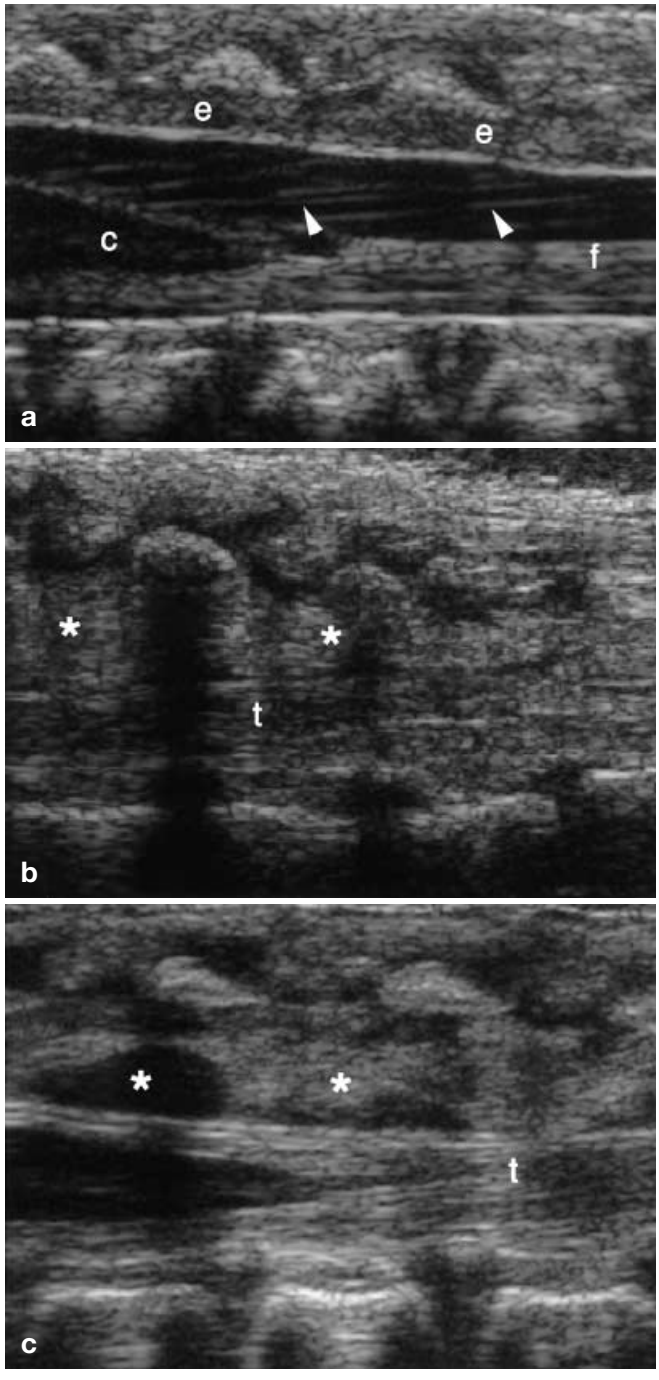

Fig. 1 a Longitudinal US image of a normal spine showing the conus (*c*), normal epidural space (*e*), filum terminale (*f*), and nerve roots (*arrowheads*) within normal anechoic CSF. **b** Longitudinal US image after failed LP showing abnormal echogenic material, presumably hematoma, dorsal to the thecal sac (*), causing compression of the thecal sac (*t*). No CSF is seen. **c** Longitudinal US image after failed LP showing a more heterogeneous collection (*), possibly representing blood or blood and CSF, again causing compression of the thecal sac (*t*). Again, no intrathecal CSF is seen

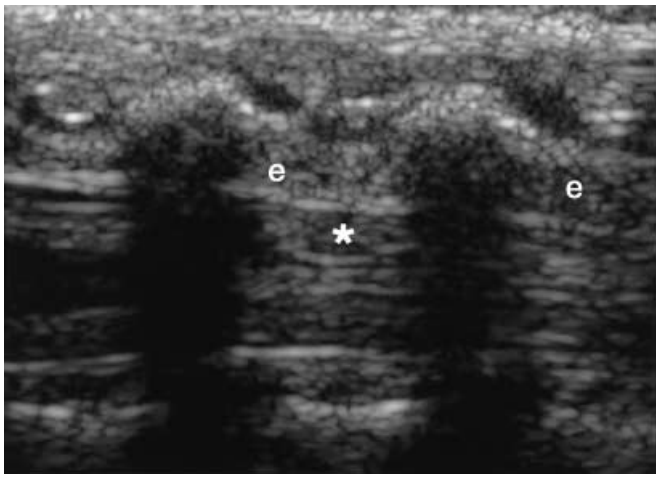

Fig. 2 Longitudinal US image after failed LP showing a normal epidural space (*e*), but abnormal echogenic material within the thecal sac (*)

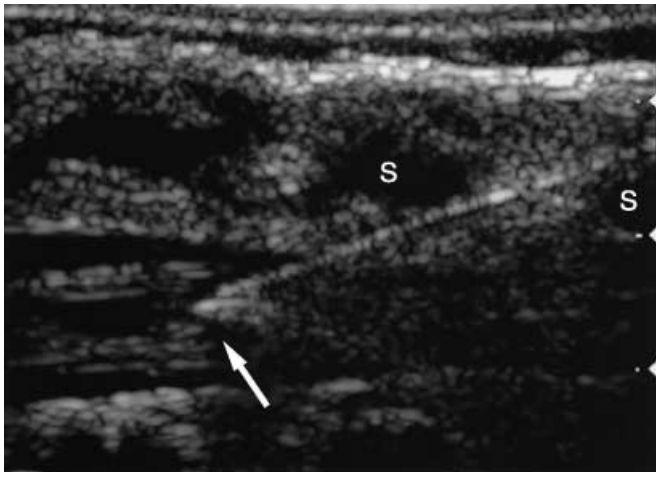

Fig. 3 Longitudinal US image during image-guided LP. The needle has been placed via a slight parasagittal approach between the hypoechoic spinous processes (*s*), with the needle tip clearly seen within the thecal sac (*arrow*)

tients with clear-appearing CSF at US, all four were successfully tapped, with three yielding non-bloody xanthochromic fluid.

Seven patients underwent follow-up procedures. Six of these patients had initially unsuccessful or deferred attempts at image-guided LP. Four patients underwent an additional five image-guided LPs between 3 and 4 days after initial US evaluation to eventually obtain usable CSF samples. One patient had 2 additional procedures, the last of which yielded a small amount of CSF that was insufficient to perform herpes polymerase chain reaction testing, necessitating direct ventricular puncture by the neurosurgical service. The other two patients had bloody fluid obtained at their first image-guided LP sufficient only for culture and clinically required follow-up CSF analysis. US of these two patients showed no demonstrable CSF, and LP did not yield usable samples. Six additional successful image-guided LPs were performed in two of these patients for long-term follow-up of herpes meningitis.

Image-guided LP was performed 32 times in 19 patients. US guidance was used in 26 (Fig. 3), fluoroscopic guidance was used in four, and a combination of US and fluoroscopy was used in three. US-guided LP provided usable samples in 15 of 26 encounters. However, in the 11 encounters where the thecal sac was normal in appearance with clear CSF present, US guidance was always successful. In six encounters where minimal or bloody CSF was present, US-guided LP provided usable CSF samples in four.

Discussion

LP is part of the routine evaluation of neonates and young infants suspected of having sepsis and of children with suspected meningitis [1–4]. While LP is usually performed without difficulty clinically, in the neonate the incidence of traumatic or unsuccessful LP is approximately 50 % [5]. In these cases referral for image-guided LP is sometimes necessary. Fluoroscopy has been the usual modality used for LP guidance. However, fluoroscopy provides guidance in one plane only, cannot directly visualize the thecal sac, and exposes the patient to ionizing radiation. Ultrasound-guidance for interventional procedures is commonplace, as US provides real-time guidance in three dimensions, allowing direct visualization of the needle and confirmation of precise placement. US has long been proven to be diagnostically useful in the infant spine [6–11], as the incompletely ossified posterior elements allow an acoustic window to the thecal sac and cord structures [10].

Subarachnoid and subdural hemorrhage after lumbar puncture has been well described in adults, who usually have associated neurologic symptoms [12–14]. The magnetic resonance imaging (MRI) findings have been described in adults, as well as in children and adolescents [15,16]. Koch and Egelhoff [16] reported 12 pediatric patients (including one neonate) presenting with neurologic symptoms after LP who demonstrated epidural collections on MRI which compressed the thecal sac. Atabaki [15] reported similar MRI findings in three additional pediatric patients. While US of the spine in infants has shown epidural collections [17,18] and debris in the thecal sac [19], to our knowledge the US diagnosis of post-LP hemorrhage has not been reported. As seen with MRI [15,16], US showed that these collections typically obliterate the thecal sac by posterior compression causing displacement of CSF, precluding sampling by

lumbar puncture. Possible sources for this hemorrhage include the epidural venous plexus as well as radicular veins accompanying nerve roots within the thecal sac [20].

We have thus found US to be valuable in assessing the thecal sac prior to our LP attempts. The very low success rate in obtaining diagnostically useful samples in patients without a definable CSF space (2 of 14 sufficient for culture, but not studies such as PCR) has led us to delay LP until such time as the hematoma has resolved sufficiently to allow reaccumulation of CSF. While not specifically examined or recorded, our anecdotal experience suggests that it usually requires 2–4 days for this to occur.

US guidance has replaced fluoroscopy as our modality of choice for LP. While US has been used for vertebral biopsy [21] and has been suggested as being useful in guiding myelography in congenital anomalies of the spine [22], we have not seen description of its use in performing LP. Fluoroscopy images in only one plane, whereas US allows three-dimensional guidance in real time and avoids ionizing radiation. Precise needle depth and position are directly visible, and cord structures can be identified and avoided. A direct midline sagittal approach is typically used with the patient either in a lateral decubitus or prone position, with the needle guided between spinous processes into the thecal sac (Fig. 3). If there is a great deal of acoustic shadowing from the spinous processes in an older infant, a parasagittal approach can be used. The advantages of US are particularly important in those children with very small CSF collections that require precise localization and needle placement. In the six LPs performed in patients with minimal CSF, four returned samples sufficient for culture and two samples were sufficient for all studies. These samples would not have been obtainable without US guidance, which thus helped to expedite patient management.

Conclusion

Ultrasound of the spine after failed clinical LP often discloses epidural and/or intrathecal hematoma, which allows us to avoid futile LP attempts. When LP is performed, US guidance allows accurate needle placement into even small collections of CSF, while avoiding patient radiation exposure, and has become our guidance method of choice.

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