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Ultrasound in Emergency Medicine

EFFECT OF BEDSIDE ULTRASOUND ON MANAGEMENT OF PEDIATRIC SOFT-TISSUE INFECTION

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□ Abstract—Background: Superficial soft-tissue infections (SSTI) are frequently managed in the emergency department (ED). Soft-tissue bedside ultrasound (BUS) for SSTI has not been specifically studied in the pediatric ED setting. Objective: To evaluate the effect of a soft-tissue BUS evaluation on the clinical diagnosis and management of pediatric superficial soft-tissue infection. Methods: We conducted a prospective observational study in two urban academic pediatric EDs. Eligible patients were aged < 18 years presenting with suspected SSTI. Before BUS, treating physicians were asked to assess the likelihood of subcutaneous fluid collection and whether further treatment would require medical management or invasive management. A trained emergency physician then performed a BUS of the lesion(s). A post-test questionnaire assessed whether the physician changed the initial management plan based on the results of the BUS. Results: BUS changed management in 11/50 cases. After initial clinical assessment, 20 patients were designated to receive invasive management, whereas the remaining 30 patients were designated to receive medical management. Management changed in 6/20 in the invasive group. In the medical group, 5/30 patients changed management. BUS had a sensitivity of 90% (95% confidence interval [CI] 77–100%) and specificity of 83% (05% CI 70–97%), whereas clinical suspicion had a sensitivity of 75% (95% CI 56–94%) and specificity of 80% (95% CI 66–94%) in detecting fluid collections requiring drainage. Conclusions: BUS evaluation of pediatric SSTI may be a useful clinical adjunct for the emergency physician. It changed management in 22% of cases by detecting subclinical abscesses or avoiding unnecessary invasive procedures. © 2010 Elsevier Inc.

□ Keywords— ultrasonography; children; soft-tissue infections; point of care; emergency medicine

INTRODUCTION

Pediatric superficial soft-tissue infections (SSTIs) are a common presenting complaint in the emergency department (ED) setting and can range from localized cellulitis to an abscess with purulent drainage. Often there is diagnostic uncertainty whereby the treating physician may not be able to identify the extent of infection. In addition, there are a variety of treatment options ranging from discharge with no treatment to surgical incision and drainage. When the examination is suspicious but not obvious for an abscess, classic teaching recommends blind needle aspiration at the area in question to evaluate

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for a subcutaneous fluid collection (1,2). The benefits of this blind approach are limited by the potentially unnecessary pain and anxiety for children and their caregivers.

Emergency physicians have been utilizing goal-directed ultrasound for 20 years to quickly help answer important clinical questions at the bedside. The ultrasonographic features of cellulitis and abscesses have been well described in both the radiology literature and a leading emergency ultrasound text (3–6). In the adult emergency medicine literature, it has been shown that bedside ultrasound (BUS) imaging of SSTIs is more accurate than the clinical examination alone, and leads to a significant change in clinical management (7,8). This application has recently been added to the core emergency ultrasound applications endorsed by the American College of Emergency Physicians due to its safety and clinical utility (9). However, like many other core ultrasound applications, these studies did not include the pediatric population.

To our knowledge, there has not been any prospective study in children to assess the utility of bedside ultrasonography in patients presenting with SSTIs. Children with SSTIs have differing co-morbidities and body habitus than an adult population, which may not allow generalization from adult BUS studies. For example, 37% of the population in one previous adult study had a history of intravenous (i.v.) drug use and 16% were diabetic (8).

Although the majority of emergency ultrasound literature has focused on the adult population, there is a growing interest in pediatric applications of BUS (10,11). Specific to SSTIs, recent abstracts have suggested that there is only moderate (κ = 0.48) inter-rater agreement between pediatric emergency physicians for physical examination findings that constitute an abscess, and only 76% sensitivity in the clinical detection of a drainable fluid collection in children (12,13).

The aim of this study was to ascertain the impact of bedside ultrasonography in the diagnosis and clinical management of pediatric SSTI. We also sought to compare the relative sensitivity and specificity of BUS and the clinical examination of SSTI to detect fluid collections requiring drainage.

MATERIALS AND METHODS

Study Design

We conducted a prospective observational study using a convenience sample of patients younger than 18 years presenting to the ED with suspected SSTI. We obtained written consent from the child's guardian and assent from children older than 8 years. The study was approved by institutional review boards from both study hospitals.

Setting and Population

The study was conducted from February 2007 until December 2007 at two urban university-affiliated teaching hospitals in New England with dedicated pediatric EDs and a combined annual census of 71,000. Both centers have fellowship programs in Pediatric Emergency Medicine.

Selection of Participants

All patients younger than 18 years old presenting with an area of SSTI were eligible for enrollment when a trained emergency physician ultrasonographer was available. This group consisted of a pediatric emergency medicine fellow and an ultrasound-trained attending at both participating institutions. All ultrasonographers received a 30-min didactic from an emergency ultrasound fellowship-trained physician on soft-tissue ultrasound, and had performed at least 50 BUS examinations and at least five soft-tissue ultrasound examinations. The determination of a SSTI was made by the treating clinician and typically included skin lesions with erythema, warmth, induration, and tenderness. The treating clinician sometimes was the study ultrasonographer during periods of single-physician coverage in the pediatric ED. Exclusion criteria included signs of obvious abscess such as palpable fluctuance or purulent drainage as assessed by the treating clinician.

Data Collection and Processing

After informed consent, the researcher recorded the pretest management plan of the treating physician. Management was considered *medical* if it included oral or i.v. antibiotics, and *invasive* if it included needle aspiration, incision and drainage, or surgical consultation. Physicians were also asked via Likert scale (range 0–5) to assess the likelihood of a fluid collection, with zero indicating the lowest and five indicating the highest likelihood. A trained ultrasonographer then performed a focused soft-tissue examination of the patient's SSTI, looking for signs of a fluid collection. The ultrasound examination, including measurements of the affected area(s), was performed using a linear array 8–13 MHz transducer (SonoSite Inc., Micromaxx, Bothell, WA) and recorded onto a digital video disc or saved as printed images for review. After the examination, the ultrasonographer recorded whether or not there was a fluid collection, the size if present, and the anatomic location. A sonographic fluid collection suggestive of abscess

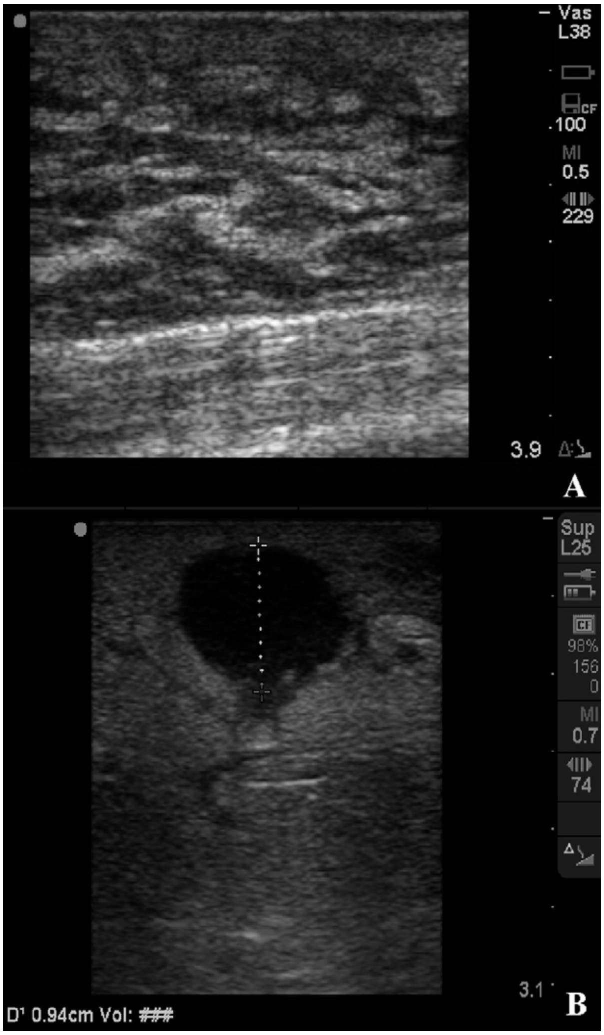

Figure 1. (A) Typical ultrasound appearance of cellulitis. Fluid surrounding fat globules creates a "cobblestone" appearance. (B) Typical ultrasound appearance of an abscess; a subcutaneous round or ovoid hypoechoic lesion.

(Figure 1) included a subcutaneous spherical or elliptical-shaped hypoechoic area (5,6). The study images and findings were then revealed and explained to the treating physician. A post-test questionnaire recorded the treating physician's management changes based on the results of the ultrasound examination. Treating physicians were then asked via Likert scale (range 0–5) whether they found the examination helpful or not. Patients were either followed-up by telephone call after 1 week, or returned for ED wound check visit within the following week to determine if further medical management had been required. If they were unable to be contacted, the electronic medical records were checked for a return visit. Demographic, laboratory studies, consultant notes, and radiologic reports were retrieved from the electronic medical records.

Outcome Measures

The primary outcome measure was how often the management plan changed after investigation by bedside ultrasonography. We hypothesized that the additional information provided by bedside ultrasonography would alter the initial clinical management plan. The secondary outcome was the comparative sensitivity and specificities of the clinician's initial management plan vs. the ultrasonographic diagnosis of SSTI. When these disagreed, a positive drainage procedure was used as the gold standard for the diagnoses of an abscess, and an unsuccessful drainage procedure or uneventful outpatient follow-up was considered evidence of no abscess.

Data Analysis

Data analysis included sensitivities and specificities of the clinical and ultrasound examinations. The results for these proportions are reported with 95% confidence intervals (CI). Descriptive analysis for patient and fluid collection characteristics were calculated using percentages or means and standard deviations. The Student's *t*-test was used to compare variables between the patient groups where management changed or stayed the same. Data calculations were performed using SAS version 9.1.3 (SAS Institute, Cary, NC), and Microsoft Excel 2007 for Windows (Microsoft Corporation, Redmond, WA).

RESULTS

Fifty-six children were screened for inclusion into the study. Six were excluded; 2 patients each for incomplete consent forms, incomplete data forms, or unable to complete examination. Fifty children were included for analysis (Figure 2). Twenty-nine patients were male, mean age was 9.5 years (SD ± 6.5 years; range 3 months–17.9 years). Sites of involvement included 21 on the upper body and 29 on the lower body. The most common areas of involvement were the thigh (n = 8), buttock (n = 7), abdomen (n = 6), and lower leg (n = 6).

Based on the pretest questionnaire given to the treating clinician, 30 children (60%) were assigned to require medical management. The mean likelihood (based on 0–5 Likert scale) of a fluid collection as assessed by the treating clinician in these patients was 1.7 (SD ± 0.9; range 0–3). Management changed in 5 patients (17%), with 4 requiring a drainage procedure. All four of these lesions produced purulent drainage, with the mean size of the collection measuring 1.4 mL (SD ± 1 mL; range

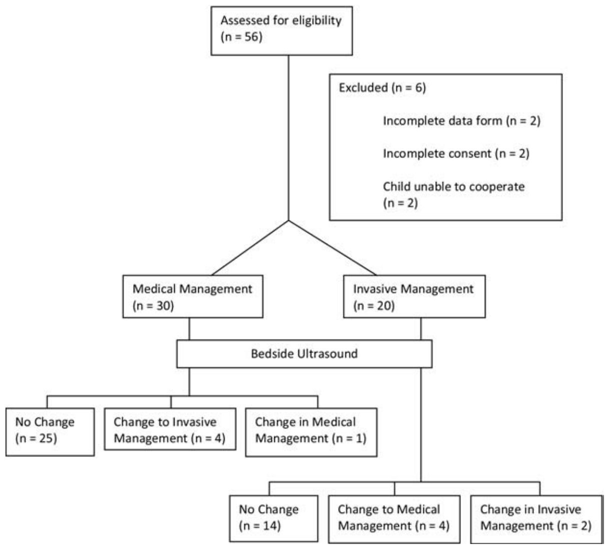

Figure 2. Patient flow.

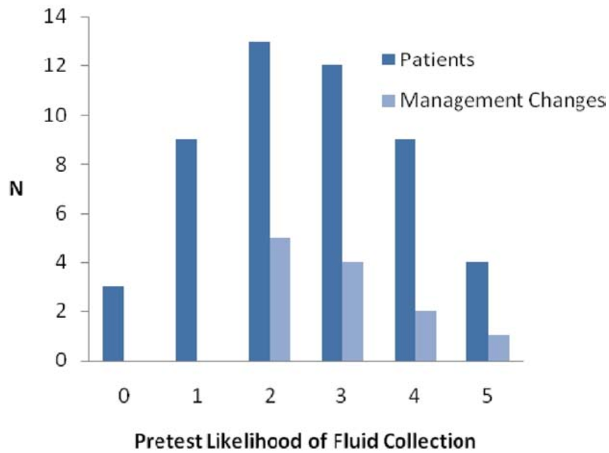

Figure 4. Management changes as per physician pretest likelihood of fluid collection.

0.3–2.5 mL) by ultrasound. The mean size of fluid collections that otherwise underwent a procedure was 1.9 mL (SD $\pm$ 1.45 mL; range 0.1–4.3 mL). This difference between these groups was not significant ($p = 0.46$). The remaining patient was determined not to have a cellulitis after ultrasound and was discharged home uneventfully without antibiotics.

Eight patients in the medical group had small (< 0.3 mL) fluid collections noted (Figure 3), which were not drained, and did well with outpatient treatment.

There were 2 patients where no collection was found by ultrasound and a negative procedure ensued. Both were classified by the treating physician as having a low likelihood of fluid and requiring medical management. One patient had a Radiology Department ultrasound examination suggestive of a superficial abscess, with no pus found on the resulting incision and drainage. The other came in after a dog bite to the hand the day prior, and a negative incision and drainage procedure was performed by a consultant unaware of the BUS findings.

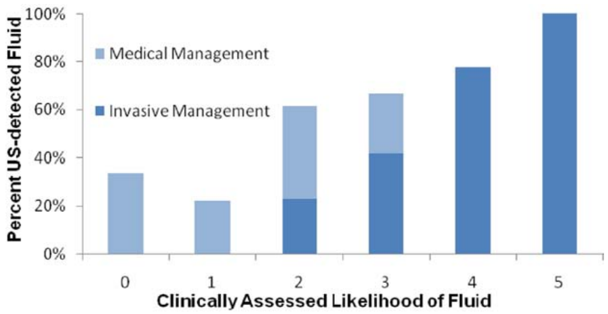

Figure 3. Percentage of patients in whom ultrasound discovered fluid as a function of clinically assessed likelihood of fluid and ultimate clinical outcome.

Twenty children (40%) were assigned to require invasive management by the treating clinician. The mean likelihood of a fluid collection in these patients was 3.75 (SD $\pm$ 0.9; range 2–5). Soft-tissue ultrasound examination of these lesions identified a fluid collection(s) in 17/20 (85%), with a mean volume of 1.4 mL (SD $\pm$ 1.2 mL; range 0.1–4.3 L). Management changed in 6/20 (30%), with 4 patients changing to medical management. One of these 4 patients returned 5 days after presentation and underwent incision and drainage after oral antibiotic failure. Of the 2 patients where management changed without switching to medical therapy, one received additional surgical consultation and the other had a change of invasive procedure.

Of the 5 patients with fluid collections > 0.3 mL that did not receive drainage, 3 had formal Radiology ultrasound examinations with findings similar to the bedside study of a disorganized fluid collection. One additional patient did not have a procedure due to parental refusal and underwent a prolonged parenteral and subsequent outpatient antibiotic course. The last patient had a perirectal abscess that the surgeons did not operate on. There is evidence that non-operative care in this setting results in reduced fistula formation (14).

Management changes occurred through a pretest likelihood range of 2–5 (Figure 4), and 36% of patients within the "equivocal" pretest probability range of 2–3 had management changes. Treating clinician's mean rating of BUS soft-tissue evaluation helpfulness was 3.8 (SD $\pm$ 1).

Methicillin-resistant *Staphylococcus aureus* (MRSA) was the most commonly isolated organism, seen in 55%

of available cultures. Methicillin-sensitive *S. aureus* was seen in only 15%.

Upon image and video review by the senior study ultrasonographers, there was complete inter-rater agreement on the findings of all reviewed studies, with the exception of one printed still image that was of limited quality on a patient with a low likelihood of a drainable fluid collection.

When BUS was compared to clinical suspicion for detecting fluid collections that eventually required drainage, bedside soft-tissue ultrasonography had a sensitivity of 90% (95% CI 77–100%) and specificity of 83% (95% CI 70–97%). Clinical suspicion had a sensitivity of 75% (95% CI 56–94%) and specificity of 80% (95% CI 66–94%).

DISCUSSION

Our results show that BUS changed clinical management of pediatric SSTI in 22% of cases. This falls within previous findings in adults from Tayal et al. and Squire et al., who noted management changes after BUS in 56% and 17% of patients, respectively (7,8). Additionally, our results suggest that bedside ultrasonography may have improved sensitivity and specificity compared to clinical examination alone in the detection of fluid collections eventually requiring drainage in children.

In our study, clinicians performed well in clinically predicting the presence or absence of drainable fluid collections in patients with high (4–5) and low (0–1) pretest probabilities. In Tayal et al., clinicians had an error rate of 30–50% throughout the range of pretest probabilities of subcutaneous fluid, and there remained a high rate of management change ($>$ 70%) even among the high-probability groups (7). Those authors included changes in needle placement, depth, incision, and location as management changes. We did not include these parameters because they are highly subjective, while recognizing that knowledge of cavity depth and extent of abscess loculations may be beneficial to the clinician about to perform an incision-and-drainage procedure. Thus, we may have underestimated the additional benefit of bedside soft-tissue ultrasound in children to this high-probability population. However, in the "equivocal" pretest probability groups 2–3, 36% of our study population had management changes. This group may more accurately reflect the specific pediatric population that would benefit from the additional information provided by BUS.

Due to the heterogeneous ages and body sizes in our study, we cannot comment on a threshold-sized collection that requires drainage. Tayal et al. noted that several fluid collections under 1 cm did well with outpatient management (7). In our study, no collection smaller than 0.3 mL failed outpatient therapy.

One of the false-negative patients had what appeared to be extensive and deep cellulitic changes on soft-tissue ultrasound. An abscess is a known complication of cellulitis, and it has been noted that soft-tissue abscesses may appear hypo-, iso-, or hyperechoic as they develop, sometimes appearing isoechoic with the surrounding cellulitic tissue (3,5). Although only indurated at study inclusion, this patient's lesion was noted to be fluctuant at the time of surgery the next day, likely representative of evolving consolidation and liquefaction. We did not require formal Radiology Department ultrasounds in this study and thus, it is unclear if a defined collection was missed or if this represented ongoing evolution of the inflammatory process.

BUS has been shown to be a useful tool in a variety of clinical and procedural scenarios for the emergency physician (9,15). The utility of BUS for SSTI evaluation has added importance with recent literature demonstrating the high prevalence of community-acquired MRSA as the etiology of SSTIs, as well as the increased ED visits for SSTI evaluations (16–21). Whereas outpatient management is acceptable for simple infections such as impetigo, simple cellulitis, and folliculitis, soft-tissue abscesses require incision and drainage as definitive treatment. As with previous studies showing the superior accuracy of ultrasound vs. landmark methods for central-line placement, our study adds to emergency medicine literature revealing the limitations of the physical examination for procedures (22–27).

In the ED, patients present with the expectation that an accurate diagnosis will be made in a timely fashion. In pediatrics, there is the expectation that this can be done with minimal discomfort and distress to the child. An incision-and-drainage procedure on a young child may require not only pain management, but also conscious sedation, delaying patient disposition and throughput. Safely performing conscious sedation requires adequate NPO (nothing by mouth) time, a monitored setting, i.v. placement, and undertaking the risks of sedation (28,29). Therefore, confirming the presence or absence of a drainable fluid collection and noting the extent of the collection would expedite management as well as potentially avoiding sedation for what might be a minimal yield or negative procedure. Conversely, discovering and draining a clinically unrecognized collection may prevent further visits to the pediatrician or emergency physician for the patient and caregiver.

Limitations

There are several limitations to this study. Because only a few emergency physicians staffing the pediatric ED had training in emergency ultrasound, this was a convenience sample with a small sample size. Currently, there is a paucity of ultrasound-trained clinicians within pediatric emergency medicine (30). Furthermore, adult emergency medicine BUS studies often utilize emergency medicine residents for enrolling patients, as BUS is part of the model of clinical practice of emergency medicine and part of core residency training (31,32). Pediatric EDs staffed by non-emergency medicine residents do not have this option. However, with continued pediatric emergency medicine interest in bedside ultrasonography, and appropriate training in soft-tissue applications, a larger pediatric study would be able to capture a greater number of patients for evaluation.

There was also variable involvement between the study ultrasonographer and the patient. In 15 cases the study ultrasonographer was also the treating clinician. Given the variable staffing during different hours in the pediatric ED, and the small number of available trained clinicians, uniform involvement was not possible. A future study would benefit by having all available clinicians experienced enough to enroll patients consecutively.

Although our minimum requirements to enroll patients essentially consisted of completion of an emergency ultrasound elective with 50 proctored ultrasounds plus five soft-tissue examinations, it is unknown how many examinations it takes to become proficient in soft-tissue ultrasound. Although both our enrolling institutions had the benefit of access to ultrasound fellowship-trained emergency physicians, a recent review of soft-tissue ultrasound applications in the pediatric emergency medicine literature describes it as an easily learned examination (33). In Squire et al., training consisted of a 30-min didactic plus a hands-on session with residents obtaining the study images (8). Tayal et al. used a group of five experienced ultrasonographers who were trained in soft-tissue examinations by the ultrasound director and had five additional hands-on sessions (7). The most recent American College of Emergency Physicians policy statement recommendation calls for a range of at least 25–50 documented and reviewed scans per core application, while also noting that procedural applications may require as few as 10 cases (9). This policy statement also includes pathways for ultrasound training for those who did not gain proficiency during residency or fellowship.

We also could not determine whether the effect of our BUS was merely from the presence of a second clinician evaluating the patient, or truly the information gleaned from the results of the ultrasound. Nor did we attempt to look at return visits for all eligible patients not enrolled in the study to determine if emergency physician BUS had an overall effect on patient outcome. A larger prospective randomized trial would help to clarify this.

There may be limited external validity in centers where emergency physicians have 24-h formal Radiology ultrasound available, do not routinely perform incision and drainage procedures, or in areas with a different MRSA prevalence rate. Our patients' culture results had a 55% MRSA recovery rate, which is consistent with the 59% rate found in a recent study looking at patients presenting with SSTI from 11 EDs across the United States (16).

CONCLUSION

In conclusion, bedside ultrasonography by emergency physicians may be a useful clinical adjunct in the evaluation of pediatric superficial soft-tissue infections.

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ARTICLE SUMMARY

1. Why is this topic important?

Emergency physicians are seeing and treating more cases of staphylococcal soft-tissue infections and subsequent abscesses. Bedside soft-tissue ultrasonography by emergency physicians in this setting has been shown to be useful in an adult population, but has not been studied in children.

2. What does this study attempt to show?

This study attempts to show that soft-tissue ultrasound by emergency physicians has an effect on the management of pediatric superficial soft-tissue infections.

3. What are the key findings?

Management changes were seen in 22% of patients after undergoing a bedside soft-tissue ultrasound. Bedside ultrasound is more sensitive and specific in the detection of subcutaneous fluid collections than clinical examination alone.

4. How is patient care impacted?

The use of bedside ultrasound avoided unnecessary invasive procedures, as well as accurately identified occult abscesses in children.