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Original Contribution

The effect of bedside ultrasound on diagnosis and management of soft tissue infections in a pediatric ED☆,☆☆

Katrina Iverson MD[a,*], Demetris Haritos MD[b], Ronald Thomas PhD[c], Nirupama Kannikeswaran MD[d]

[a]*Pediatric Emergency Medicine, Division of Emergency Medicine, Carman and Ann Adams Department of Pediatrics, Children's Hospital of Michigan, Wayne State University, Detroit MI 48201, USA*
[b]*Division of Emergency Medicine, Pediatric Emergency Medicine Ultrasound, Carman and Ann Adams Department of Pediatrics, Children's Hospital of Michigan, Wayne State University, Detroit MI 48201, USA*
[c]*Department of Pediatrics, Wayne State University School of Medicine, Detroit MI 48201, USA*
[d]*Division of Emergency Medicine, Carman and Ann Adams Department of Pediatrics, Children's Hospital of Michigan, Wayne State University, Detroit MI 48201, USA*

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Abstract

Background: Presentation of skin and soft tissue infections (SSTIs) to the pediatric emergency department (PED) has increased. Physical examination alone can be inadequate in differentiating cellulitis from an abscess. The purposes of this study were to determine the effect of bedside ultrasound (US) in improving diagnostic accuracy for SSTIs in the PED and to evaluate its effect on the management of patients with SSTIs.

Methods: We conducted a prospective study of a convenience sample of children who presented to an inner-city PED with signs and symptoms of SSTI. The treating physician's pretest opinions regarding the need for incision and drainage and procedural sedation were collected. A bedside US was performed by trained PED physicians to evaluate for cellulitis vs abscess. The treating physician was made aware of the US findings, and the effect on management was recorded.

Results: Sixty-five patients were enrolled, of whom 47 had US-proven abscess and 18 had cellulitis. The sensitivity of US for detection of abscess was 97.5% (95% confidence interval [CI], 90.1%-99.5%), and the specificity was 69.2% (95% CI, 57.8-72.4%). In comparison, the sensitivity for physical examination alone for detection of abscess was 78.7% (95% CI, 71.4%-84.4%), and the specificity was 66.7% (95% CI, 47.6-81.6%). Ultrasound disagreed with clinical examination and changed management in 9 (13.8%) of 65 patients.

Conclusions: Emergency department bedside US improves accuracy in diagnosis of SSTIs. Bedside US changes management in a small but significant number of patients with SSTIs.

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* Corresponding author. Denver, CO 80220, USA.
E-mail address: skierelise@hotmail.com (K. Iverson).

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1. Introduction

Skin and soft tissue infections (SSTIs) are a common complaint of children presenting to the pediatric emergency department (PED). Since the emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) as a widespread cause of community-acquired skin infections in the late 1990s, emergency department (ED) visits for SSTIs have more than doubled [1-3].

Differentiating the presence of cellulitis vs an abscess by history and physical examination alone can be challenging for even the most seasoned physician. This differentiation may be particularly difficult in children secondary to patient's lack of cooperation and pain hindering examination. The distinction between a cellulitis and an abscess, however, is crucial because definitive treatment of an abscess requires incision and drainage (I and D), which often requires sedation in the pediatric population. Misdiagnosis may lead either to unnecessary sedation or failure to treat adequately. Such treatment failures may lead to increased return visits to the PED.

Previous studies have described the use of ultrasound (US) in addition to physical examination by the ED physician to guide diagnosis and management of SSTIs in adults [4,5]. In their study on adult patients, Tayal et al [4] evaluated the impact of bedside US on the management of SSTIs and concluded that US changed physician management in approximately half of patients with clinical cellulitis in the ED . They further noted that US may improve management of SSTIs by detection of occult abscess, prevention of unnecessary invasive procedures, and guidance for further imaging or consultation. However, there is a paucity of studies from the PED evaluating the impact of US in the diagnosis and management of SSTIs.

The primary objective of our study was to determine whether the use of bedside US by pediatric emergency physicians would improve the diagnostic accuracy for differentiating cellulitis from subcutaneous abscess when compared with physical examination alone. The secondary objective was to evaluate the effect of bedside US on the management of SSTIs in a PED. We hypothesized that beside soft tissue US would increase diagnostic accuracy of SSTIs when compared with physician examination alone and thereby affect a change in the management and provide appropriate care for patients with SSTIs.

2. Methods

2.1. Study design and consent

This was a prospective study of a convenience sample of patients 6 months to 18 years of age who presented to an inner-city, tertiary care, level 1 PED with clinical symptoms and signs suggestive of SSTI.

This study was approved by the institution's Human Investigations Committee. Written informed consent was obtained from parents/caregivers of study participants before enrollment. In addition, oral assent was obtained from patients 7 to 12 years old, and written assent was obtained from patients 13 to 18 years old.

2.2. Study setting and population

This study was conducted at an inner city, tertiary care, level 1 trauma PED with an annual census of approximately 92 000 visits. Approximately 1400 patients are diagnosed with SSTIs annually. Of those diagnosed with SSTIs, 37% receive I and D, and of those, 17% require procedural sedation.

2.3. Selection of participants

Inclusion criteria include (1) being age 6 months to 18 years old and (2) having clinical symptoms and signs of SSTI (erythema, warmth, induration, or fluctuance). Exclusion criteria include (1) head and neck SSTI, (2) abscesses that are already open and draining, (3) abscess determined by the PED physician as requiring drainage in the operating room, and (4) refusal of consent by parent/caregiver for participation in the study.

All patients 6 months to 18 years old presenting with symptoms and signs of SSTIs were eligible for participation depending on availability of study team and willingness of participation. The study team consisted of all pediatric emergency medicine fellows as well as a core group of PED attending physicians who were trained specifically for this study. All ED physicians had previously received basic US education regarding typical US use in the PED. In addition, study-specific training consisted of 2 specific 60-minute didactic and hands-on training in soft tissue US by a PED physician with US certification before the study start date. These trainings were repeated quarterly during the study duration. In addition, interrater reliability was performed on US examinations throughout the study period.

2.4. Data collection and processing

Data was collected on patient demographics, presenting signs and symptoms, and physical examination findings (location, size, presence/absence of erythema, induration, and fluctuance) and attending physician's diagnosis (cellulitis vs and abscess). After the initial physical examination, the clinician caring for the patient answered a pre-US questionnaire that recorded their opinion regarding (1) presence of subcutaneous fluid, (2) need for I and D, and (3) need for procedural sedation. Need for I and D and sedation were recorded as a yes/no answer.

A soft tissue US was performed by one of the study team members using a Siemen Sonoline G60S (Siemen Medical Solutions USA, Inc. Mountain View, CA) machine and using a linear array transducer. On some occasions, the treating clinician was also the study team member performing the US. For the purpose of this study, an abscess was defined

sonographically as a hypoechoic or an anechoic collection with variation in septation and debris. All abscesses were evaluated for size, extent, and comparison with surrounding normal or cellulitic tissue. Cellulitis was defined sonographically as diffuse thickening of the skin and subcutaneous tissue with variable appearance of cobblestoning (hyperechoic fat lobules surrounded by edema) [6-8]. After US findings were recorded, the treating physician was made aware of the US findings, and the effect on the change in management plan was recorded. This was recorded as no change, new I and D, discontinuation of I and D, new sedation procedure, discontinuation of sedation, subspecialty consult, further imaging study, or other.

All US examinations were recorded using video clips and still images that were reviewed and confirmed by a single, independent pediatric emergency medicine (PEM) physician who is the director of US in our division. The reviewer has completed an American College of Emergency Physicians accredited bedside ultrasonography course and has performed and reviewed more than 1000 pediatric bedside US studies. The PEM US director's opinion regarding the presence or absence of an abscess was compared with the findings reported by the study physician performing the US and analyzed for discrepancies.

2.5. Outcome measures

The primary outcome measure was the effect of bedside US on diagnosis of SSTIs when compared with physical examination alone. We hypothesized that the application of US in combination with a physical examination will improve the accuracy of diagnosis of SSTI when compared with physical examination alone. Secondary outcome measure was the effect of US on management of SSTI.

2.6. Data analysis

All study variables were systematically coded, and the entire data entry was performed by the principal investigator to maintain consistency. Data analysis included sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of US examination and physical examination. Results for these proportions are reported with 95% confidence intervals (CI). To further examine the proportional difference between groups on how often US application changed management and on additional variables that are categorically scaled, Fisher exact χ^2 test was performed. To examine mean differences on continuously scaled variables, where applicable, a nonparametric Mann-Whitney U test was performed. Data calculations were performed using SPSS version 18.0 (IBM, Chicago, IL).

3. Results

A total of 66 patients with signs and symptoms of SSTIs were enrolled. One patient was excluded from the analysis secondary to an incomplete data form, leaving 65 patients for analysis. The mean age of the study sample was 5.2 years (SD, ±5.8 years). Of the study subjects, 21% (n = 14) were younger than 1 year, 44% (n = 29) were 1 to 4 years, 13.6% (n = 9) were 5 to 12 years, and 21% (n = 14) were older than 13 years. Of study subjects, 63.6% (42/67) were female. The 3 most common sites of SSTI were the buttock (n = 24, or 36.4%), leg (n = 12, or 18.5%), and others (n = 8, or 12.1%). Table 1 shows the signs and symptoms of SSTI.

Table 1 Clinical features of SSTIs

Clinical feature	Total no.	Cellulitis (n = 18)	Abscess (n = 47)
Fever	24 (36.9%)	5 (27.8%)	19 (40.4%)
Erythema	62 (95.4%)	18 (100%)	44 (93.6%)
Induration	58 (89.2%)	16 (88.9%)	42 (89.4%)
Fluctuance	28 (43.1%)	4 (22.2%)	24 (51%)

The sensitivity, specificity, PPV, and NPV of physical examination and US for the diagnosis of abscess are shown in Tables 2 and 3.

Fig. 1 shows the impact of US on the diagnosis and management of SSTIs in children. Forty-three children (66%) were initially assigned to require I and D based on physical examination. Ultrasound changed diagnosis for 6 (14%) of 43 patients in this group and elicited a change in management in 5 (11.6%) of 43 patients. All of these 5 patients who were US negative for an abscess were reassigned to receive medical management. One patient with no abscess detected on US still received I and D based on the treating physician's discretion, and pus was obtained. There were also 2 patients who had a US positive for abscess but had no I and D performed because the size of the abscess was deemed to be too small (average transverse measurement of 3.6 mm [SD, ±2.3 mm]) to require I and D by the treating physician.

There were 22 patients (34%) assigned to the pretest group that was believed not to require I and D based on physical examination findings. Ultrasound changed diagnosis in 10 (45.4%) of 22 patients and changed management for 4 (18.2%) patients in this group. Four patients underwent I and D that was not initially planned, and purulent material was obtained from all patients. There were 6 patients initially assigned to not require I and D that were US positive for abscess but I and D were not performed based on the treating physician's discretion. The size of abscess on US showed an average transverse measurement of 10.2 mm (SD, ±7 mm) and an average longitudinal measurement of 7.68 mm (SD, ±6 mm).

Table 2 Diagnostic accuracy of physical examination

Sensitivity	78.7% (95% CI, 71.4%-84.4%)
Specificity	66.7% (95% CI, 47.6%-81.6%)
PPV	86% (95% CI, 78.1%-92.3%)
NPV	54.5% (95% CI, 39%-66.8%)

Table 3 Diagnostic accuracy of bedside ultrasonography

Sensitivity	97.5% (95% CI, 90.1%-99.5%)
Specificity	69.2% (95% CI, 57.8%-72.4%)
PPV	83% (95% CI, 76.7%-84.7%)
NPV	94.7% (95% CI, 79.1%-99%)

Of the 43 patients who were initially assigned to require I and D, 23 were also assigned to require sedation for the procedure. Ultrasound changed management for 1 (4.3%) of 23 patients initially assigned to receive sedation because they were reassigned to receive medical management. Of the 22 patients initially assigned to require medical management, 2 (9%) had sedation added to their management along with a new I and D procedure.

The interrater reliability between the study sonologist and the expert sonographer on the findings of all studies that were reviewed was 0.96 (95% CI, 0.87-1). There were 9 studies that were unable to be reviewed by the expert sonographer either because of missing images or poor image quality.

4. Discussion

Our results show that the use of bedside US not only improved the diagnostic accuracy of SSTIs in children but also changed overall management in 13.8% of patients. Such enhanced diagnostic accuracy could result in improvement of care of patients with SSTIs by appropriately identifying those who require and do not require I and D. This is critical in the pediatric population because younger children who undergo I and D often require procedural sedation and analgesia.

Ultrasound had a high sensitivity for detecting subcutaneous abscess when compared with physical examination in our study similar to that reported by Squire et al [5] and Sivitz et al [9]. The specificity of US in our study was, however, lower than that reported in these 2 studies. The reason for this is unclear, although it could be secondary to the fact that not all patients with abscess detected on US had I and D performed. Although the treating physician was made aware of the US findings, the management decision of whether to perform I and D was left to the discretion of the treating physician. We did not collect the treating physician's rationale for not performing I and D although an abscess was detected on the US. The small size of the abscess was cited as a reason for not performing I and D, although there is no literature to support this management. Use of bedside US in our ED has been increasing over the past several years but is not routinely used by all physicians for diagnosis of abscess. Most of the patients with US positive for abscess but no I and D performed were initially assigned to not need I and D based on physical examination findings alone. Similarly, 1 patient who was assigned to the "not needing I and D" by US underwent I and D based on the treating physician's initial physical examination findings. It is possible that lack of familiarity with US for detection of SSTIs led many physicians to choose to follow their own initial clinical judgment rather than change their management based on US findings.

Abscesses often begin as cellulites, and the 2 conditions can frequently coexist with overlap of clinical examination findings. Although fever was noted in a higher percentage of patients with abscess, erythema and induration were found in most of the patients with either cellulitis or abscess. Fluctuance, which is often considered a criterion standard for presence of an abscess, was present in only 51% of patients with an abscess. It has been shown in adult literature that fluctuance on physical examination may be absent in 25% of patients, and absence of fluctuance does not rule out abscess [10,11].

Bedside US changed diagnosis in 24.6% of pediatric patients who presented with an SSTI by detecting subclinical abscess and changed management in 13.8% of pediatric patients by avoiding unnecessary invasive procedures. Two adult studies [4,5] and 1 pediatric study [9] have demonstrated comparable effect on change in management in patients presenting with SSTI.

Marin et al [12] evaluated a training protocol for pediatric emergency physicians learning bedside US for the evaluation of SSTIs. They concluded that, after a brief training program, these physicians were able to perform technically successful bedside US examinations of SSTIs with excellent agreement with an expert sonologist. Our study also used a brief training program for bedside US evaluation of SSTIs and on review of recorded US examinations had excellent interrater agreement with the findings of the director of PEM US who reviewed all the studies.

Given its high sensitivity over physical examination in the diagnosis of abscess, ease of learning, and being a noninvasive and painless procedure, we believe that bedside US has a definite role in the diagnosis and management of SSTIs in a PED.

4.1. Limitations

We studied a convenience sample of patients. Our study was also limited by a small sample size because of the limited availability of clinicians trained in soft tissue US.

There were 9 US studies that had poor resolution and could not be reviewed by the physician with US training. This could have impacted the results of diagnostic accuracy of US. However, the same sonographers had performed multiple other studies that were reviewed and were in complete agreement with the reviewing physician's findings.

Decision to perform I and D was left to the discretion of the treating physician. There were 8 patients who had a US positive for abscess; however, no I and D was performed. Six patients had a pretest assignment of not needing I and D. Two patients had a pretest assignment of needing I and D, but the procedure was discontinued after US showed an average transverse measurement of

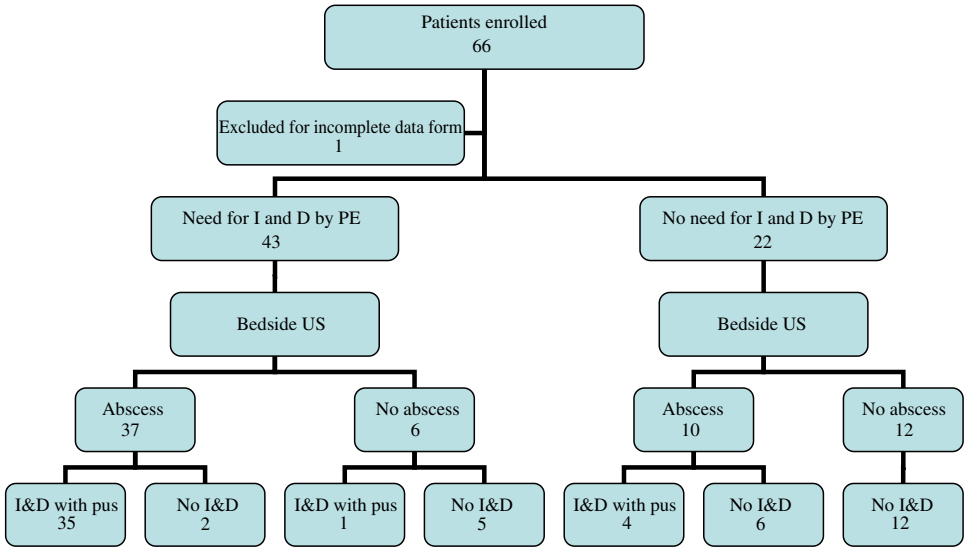

Fig. 1 Impact of US on management of children with SSTI.

3.6 mm (SD, ±2.3 mm). We did not contact patients for follow-up nor did we look at return visits. Thus, it is unknown if patients with small fluid collections did well with outpatient therapy or if patients without evidence of abscess on US returned for further intervention.

5. Conclusions

Emergency department bedside US improves accuracy in diagnosis of pediatric SSTIs. Bedside US changes management in a small but significant number of pediatric patients with SSTIs.

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