ABSCESS: Applied Bedside Sonography for Convenient Evaluation of Superficial Soft Tissue Infections

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Abstract

Objectives: Soft tissue infections are a common presenting complaint in the emergency department (ED). The authors sought to determine the utility of ED bedside ultrasonography (US) in detecting subcutaneous abscesses. **Methods:** Between August 2003 and November 2004, a prospective, convenience sample of adult patients with a chief complaint suggestive of cellulitis and/or abscess was enrolled. US was performed by attending physicians or residents who had attended a 30-minute training session in soft tissue US. The treating physician recorded a yes/no assessment of whether he or she believed an abscess was present before and after the US examination. Incision and drainage (I + D) was the criterion standard when performed, while resolution on seven-day follow-up was the criterion standard when I + D was not performed. **Results:** Sixty-four of 107 patients had I + D–proven abscess, 17 of 107 had negative I + D, and 26 of 107 improved with antibiotic therapy alone. The sensitivity of clinical examination for abscesses was 86% (95% confidence interval [CI] = 76% to 93%), and the specificity was 70% (95% CI = 55% to 82%). The positive predictive value was 81% (95% CI = 70% to 90%), and the negative predictive value was 77% (95% CI = 62% to 88%). The sensitivity of US for abscess was 98% (95% CI = 93% to 100%), and the specificity was 88% (95% CI = 76% to 96%). The positive predictive value was 93% (95% CI = 84% to 97%), and the negative predictive value was 97% (95% CI = 88% to 100%). Of 18 cases in which US disagreed with the clinical examination, US was correct in 17 (94% of cases with disagreement, $\chi^2 = 14.2$, $p = 0.0002$). **Conclusions:** ED bedside US improves accuracy in detection of superficial abscesses. **Key words:** emergency department; ultrasound; soft tissue infection. ACADEMIC EMERGENCY MEDICINE 2005; 12:601–606.

Superficial soft tissue infections are a common presenting complaint in the emergency department (ED). Differentiating a soft tissue abscess from cellulitis is important because each disorder requires a different treatment. Whereas cellulitis responds to systemic antibiotics, an abscess must be drained surgically. Diagnosis is traditionally based on the appearance of the lesion, with the criterion standard being demonstration of pus by needle aspiration or surgical drainage. Diagnosis is complicated by the fact that abscesses often begin as cellulitis and therefore the two conditions frequently coexist, leading to missed abscesses and unnecessary invasive procedures. Failure to make the correct diagnosis leads to inappropriate or delayed therapy, which can lead to medical complications, extra ED or clinic visits, and increased cost.

Previous case reports and retrospective analyses have described ultrasonography (US) findings in cellulitis and abscess[1–13] and have suggested a role for sonographic-guided aspiration of abscesses[10,14–18]; however, our literature search did not uncover any published prospective study of the use of US to assist in the diagnosis of soft tissue infections.

The purpose of our study was to determine whether the addition of emergency physician–performed bedside US to physical examination would increase the diagnostic accuracy for detecting superficial abscesses.

METHODS

Study Design. This was a prospective clinical trial that sought to compare the accuracy of US plus physical examination versus physical examination alone. The study was granted approval by our human subjects institutional review board.

Study Setting and Population. This study was performed at a university-affiliated, teaching ED with an annual census of 48,000 patient visits. The hospital supports a three-year emergency medicine residency program. The study lasted from August 2003 to November 2004. All adult patients presenting to the ED with a chief complaint suggesting cellulitis or superficial abscess were eligible for inclusion in the study. Presumed infections involving any areas of the body normally covered with keratinizing squamous

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epithelium met inclusion criteria (e.g., intraoral abscesses were not included). Patients younger than 18 years of age were excluded from the study.

Study Protocol. A convenience sample of eligible patients was recruited by the attending physicians and residents working in the ED. After informed consent was obtained from the patient, the treating physician completed a questionnaire recording demographic factors, the patient's signs and symptoms, physical examination findings, and a yes/no assessment of whether a subcutaneous abscess was present (Table 1). The physician then performed bedside US and recorded the findings along with the revised clinical impression on a second questionnaire. All patients with a pre-US assessment of abscess were treated with needle aspiration or incision and drainage (I + D) regardless of the US findings. The remainder of the patients were treated with needle or surgical drainage and/or antibiotics at the discretion of the treating physician. Patients who did not receive a drainage procedure were called after seven days to see if their skin infection had resolved. Demonstration of pus was considered the criterion standard for abscess in patients who underwent a drainage procedure. For patients who did not undergo drainage, resolution of symptoms at the follow-up telephone call was considered a criterion standard for absence of abscess (Figure 1).

All physicians (residents and faculty) completed 30 minutes of didactic and hands-on training before enrolling patients in the study. Residents at all levels (program-year 1, 2, 3) enrolled patients in the study.

Ultrasonography was performed and interpreted at the bedside by the physician enrolling the patient in the study. Examinations were performed using either a B-K Hawk 2102 US machine (Copenhagen, Denmark) using an 8.0-MHz linear array transducer or a Sonosite Titan (Bothell, WA) using a 10.0-Hz linear array transducer.

TABLE 1. Likelihood Ratios for Abscess by Risk Factors

Risk Factor (*n*)	No Abscess*	Abscess†	Likelihood Ratio (95% CI)
IVDU (40)	11	29	PLR, 1.77 (1.00, 3.15)
No IVDU (67)	32	35	NLR, 0.73 (0.58, 0.93)
Diabetes (17)	10	7	PLR, 0.47 (0.19, 1.14)
No diabetes (90)	33	57	NLR, 1.16 (1.05, 1.28)
Temperature ≥38°C (9)	6	3	PLR, 0.34 (0.09, 1.27)
Temperature <38°C (98)	37	61	NLR, 1.11 (1.04, 1.18)

*Negative incision and drainage or clinical resolution at one week.
†Positive incision and drainage.
IVDU = history of intravenous drug use; PLR = positive likelihood ratio; NLR = negative likelihood ratio.

Outcome Measures. The primary outcome variable was the true abscess status that comprised a composite of obtaining pus on I + D and a failure to resolve symptoms if the lesion was not drained. A secondary outcome was an analysis of how often US changed the diagnosis to the correct one. At the time of patient enrollment, demographic and clinical variables were recorded on the data questionnaire by a member of the study team.

Data Analysis. Analysis of the data on clinical and US diagnosis included sensitivities, specificities, positive predictive values (PPVs), and negative predictive values (NPVs). The results for these proportions are reported with 95% confidence intervals (CIs) calculated using the mid-P method.[19] Exact two-tailed p-values for two-by-two tables were calculated using the mid-P method. The relationships of risk factors to abscess are reported using the positive likelihood ratios and negative likelihood ratios. The 95% CIs for these ratios were calculated using an asymptotic method for the ratio of two proportions.[20] The statistical analysis was performed using EpiInfo version 3.2.2 (Centers for Disease Control and Prevention, Atlanta, GA) and Excel for Macintosh (version 10; Microsoft Corp., Redmond, WA).

RESULTS

A total of 135 adults with signs of soft tissue infection were enrolled between August 2003 and November 2004; however, 27 patients were lost to follow-up. Of the patients lost to follow-up, 25 who did not have I + D could not be reached by telephone and two had I + D but no record of the results could be located. Additionally, one patient did not improve after one week of treatment with antibiotics and did not return to the ED; therefore, no definitive diagnosis was made. A total of 107 patients had a definitive diagnosis and were included in the final analysis. Of those 107 patients, 74 (69%) were male and 33 (31%) were female. Forty patients (37%) had a history of intravenous drug abuse, and 17 patients (16%) were diabetic. The mean age of the patients was 39 years (range, 18–76 years). Sixty-four patients (60%) had I + D–proven abscesses, 17 had negative I + D, and 26 improved with antibiotic therapy alone. Of the five instances in which US provided a false-positive finding for abscess, three proved to be hematomas on I + D and two I + Ds yielded no fluid. Of the 64 patients with I + D–proven abscesses, nine patients (14%) had real-time US-guided drainage of the abscess (see Figure 1).

The sensitivity of clinical examination alone for subcutaneous abscess was 86% (95% CI = 76% to 93%), and the specificity was 70% (95% CI = 55% to 82%). The PPV was 81% (95% CI = 70% to 90%), and the NPV was 77% (95% CI = 62% to 88%). The sensitivity of US in addition to clinical examination for

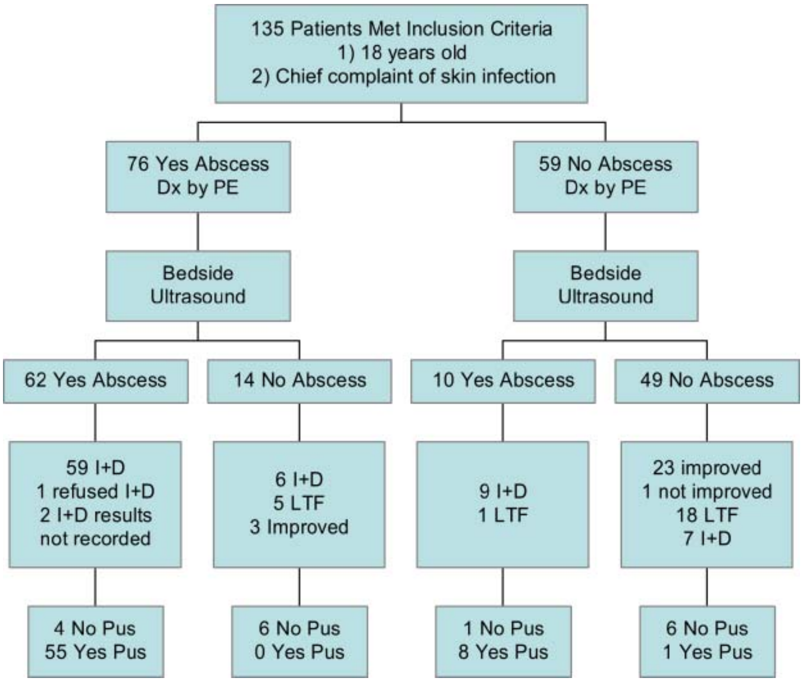

Figure 1. Patient flow diagram. PE = physical examination; I + D = incision and drainage; LTF = lost to follow-up.

subcutaneous abscess was 98% (95% CI = 93% to 100%), and the specificity was 88% (95% CI = 76% to 96%). The PPV was 93% (95% CI = 84% to 97%), and the NPV was 97% (95% CI = 88% to 100%) (see Tables 2 and 3).

The use of US changed the clinical impression in 18 cases (17%). Of these, US provided the correct diagnosis in 17 (94%; $\chi^2 = 14.2$; p = 0.0002). The clinical impression was changed from negative (no abscess) to positive (I + D–proven abscess) in nine cases (23% of negative clinical examinations) and from positive to negative in nine cases (13% of positive clinical examinations).

Tables 4 and 5 show the sensitivity and specificity of clinical examination and US examination evaluated by training level of the physician. Compared with clinical examinations by all other physicians, clinical examinations by first-year emergency medicine residents had a lower specificity (p = 0.03) and a similar sensitivity (p = 0.31). When compared with all other physicians, US evaluation by first-year emergency medicine residents had a lower specificity (p = 0.004).

DISCUSSION

The diagnosis of subcutaneous abscesses is traditionally a clinical one, with confirmation made by presence of pus at either needle aspiration or scalpel incision. Differentiation of abscess from simple cellulitis is clinically relevant, because the treatment for the two entities is different.

Although typically no imaging studies are done for soft tissue infections, the advantages of bedside US in the ED include portability, immediate availability, low cost, and increased patient comfort. The soft tissue US examination is technically uncomplicated and can be performed in less than 1 minute. In our study, clinicians were able to accurately identify abscesses with only 30 minutes of training. The didactic training consisted of a series of still images and video clips demonstrating the spectrum from early cellulitis to mature abscesses. The hands-on component demonstrated scanning technique using healthy volunteers.

Subcutaneous abscesses by definition are superficially located and therefore amenable to interrogation

TABLE 2. Diagnostic Accuracy of Clinical Examination

Sensitivity	86% (95% CI = 76%, 93%)
Specificity	70% (95% CI = 55%, 82%)
Positive predictive value	81% (95% CI = 70%, 90%)
Negative predictive value	77% (95% CI = 62%, 88%)

TABLE 3. Diagnostic Accuracy of Clinical Examination Plus Ultrasonography

Sensitivity	98% (95% CI = 93%, 100%)
Specificity	88% (95% CI = 76%, 96%)
Positive predictive value	93% (95% CI = 84%, 97%)
Negative predictive value	97% (95% CI = 88%, 100%)

TABLE 4. Sensitivity and Specificity of Clinical Examination by Level of Training

Training Level (No. of Subjects Enrolled)	Sensitivity (95% CI)	Specificity (95% CI)
EM1 (25)	80% (55%, 95%)	40% (14%, 71%)
EM2 (39)	91% (73%, 98%)	76% (53%, 92%)
EM3 (25)	88% (64%, 98%)	78% (44%, 96%)
Faculty (18)	82% (52%, 97%)	86% (47%, 99%)

EM1 = first-year emergency medicine resident; EM2 = second-year emergency medicine resident; EM3 = third-year emergency medicine resident.

using the highest frequency setting on the linear probe.[21] This results in high-resolution images unaffected by body habitus. Although we did not specifically study the interrater reliability of the US examination, we suggest that the superficial nature of these infections leads to less operator dependency when compared with US assessment of deeper structures.

The technique of soft tissue US is straightforward. The clinician places the transducer on the skin at the region of erythema or swelling. The gray-scale appearance of an abscess is a heterogeneic, anechoic, or hypoechoic mass containing a variable amount of internal echoes.[1,2,22–25] Abscesses are generally spherical in shape with poorly defined borders[3] (Figure 2). Compression of the mass with the transducer may demonstrate movement or "swirling" of pus.[26] In cellulitis, however, US shows thickening and diffuse hyperechogenicity of the subcutaneous fat with obliteration of the interface between the echogenic fat and the dermis.[9,27,28] This is commonly referred to as "cobblestoning" (Figure 3).

While color and power Doppler can help differentiate soft tissue infections by demonstrating diffuse hypervascularity in areas of inflammation, we did not use Doppler in this study.[29–31] The physicians were taught to make their assessment based on gray-scale findings only. We believe that this approach requires less time to learn and less actual time to scan the patient.

This study demonstrated that the use of US improves both the sensitivity and the specificity for detection of subcutaneous abscesses. Improving the sensitivity favorably impacts patient care by finding more abscesses that require a surgical intervention. Of equal importance, improving the specificity prevents unnecessary painful and potentially risky needle aspirations or incisional drainage.

TABLE 5. Sensitivity and Specificity of Ultrasonography by Level of Training

Training Level (No. of Subjects Enrolled)	Sensitivity (95% CI)	Specificity (95% CI)
EM1 (25)	93% (71%, 100%)	60% (29%, 86%)
EM2 (39)	100% (90%, 100%)	100% (87%, 100%)
EM3 (25)	100% (87%, 100%)	89% (56%, 99%)
Faculty (18)	100% (81%, 100%)	100% (72%, 100%)

An unexpected finding during this study was the discovery of large vessels in close proximity to an abscess. This finding changed management in some cases, even though the abscess could be diagnosed clinically without the aid of US. The true frequency of finding vessels was not determined because the study was not designed to capture these events. However, the value of sonography in identifying structures such as vessels and nerves before biopsy and in guidance of needle biopsies is well described in the literature.[10,32]

Of the five patients who had false-positive findings on US, three of them turned out to have hematomas. The echogenicity of blood contained within a hematoma is variable and depends largely on time of stasis. Initially blood appears anechoic, but over several hours as the blood begins to coagulate, it appears more and more echogenic.[9,33–36] Pus also appears echogenic but is differentiated from congealed blood by its heterogeneity. Clotted blood appears uniformly echogenic, while pus has a variable echogenic pattern.[37]

One patient initially believed to have a groin abscess was found to have a pseudoaneurysm on US. This patient was sent directly to surgery from the ED and had a favorable outcome. A bedside I + D procedure in this situation would have been potentially catastrophic. Aneurysms are easily identified by their sonographic features, including lack of echoes, connection to an artery, and pulsatile motion during systole.[6,7,9]

Bedside US is useful for answering a yes/no question that is not sufficiently resolved on clinical grounds alone. Our study showed that the addition of bedside US findings to the clinical examination increased diagnostic accuracy for detecting subcutaneous soft tissue abscesses. This contributes to the mounting evidence that using this portable noninvasive technology can reduce errors in management, thereby improving patient care.

LIMITATIONS

There were 25 patients who did not undergo any drainage procedure and could not be reached for telephone follow-up. Therefore, in these patients, no criterion standard was available and they were excluded from the final analysis. It is possible that this subset of patients may represent false-negative findings and could therefore reduce the sensitivity and NPV of the study.

Due to ethical concerns, it was not possible to achieve the criterion standard of needle aspiration in patients in which both clinical and US examinations were negative. Furthermore, due to the large indigent population served by our department, many patients did not have a telephone number at which they could be reached, thus impairing follow-up.

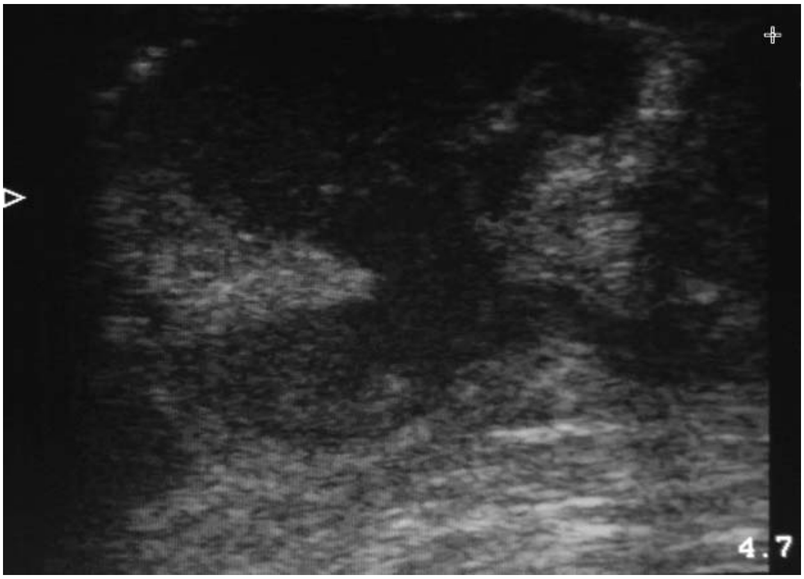

Figure 2. Ultrasound image (8.0-MHz linear probe) of abscess demonstrating hypoechoic (dark) tracts.

Because resolution of symptoms at one week was used as the criterion standard in patients who did not undergo a drainage procedure, it is possible that some of these patients had abscesses that resolved with antibiotic therapy. Because the utility of sonographic evaluation of soft tissue infections is defined by the ability to detect an abscess requiring drainage, we suggest that any nonrecognized abscesses that resolved without a drainage procedure may not be "clinically significant."

Conversely, some of the abscesses detected by US were quite small (one as small as 0.5 mL). It is not clear to us what the clinical course of these abscesses would have been without drainage. Further outcomes research is warranted to determine an algorithm to decide which abscesses should be treated without a drainage procedure.

CONCLUSIONS

Ultrasonography is a useful adjunct in evaluating soft tissue infections for the presence of subcutaneous abscesses. Routine sonographic evaluation of soft tissue infections can lead to increased diagnostic accuracy, therefore changing treatment decisions.

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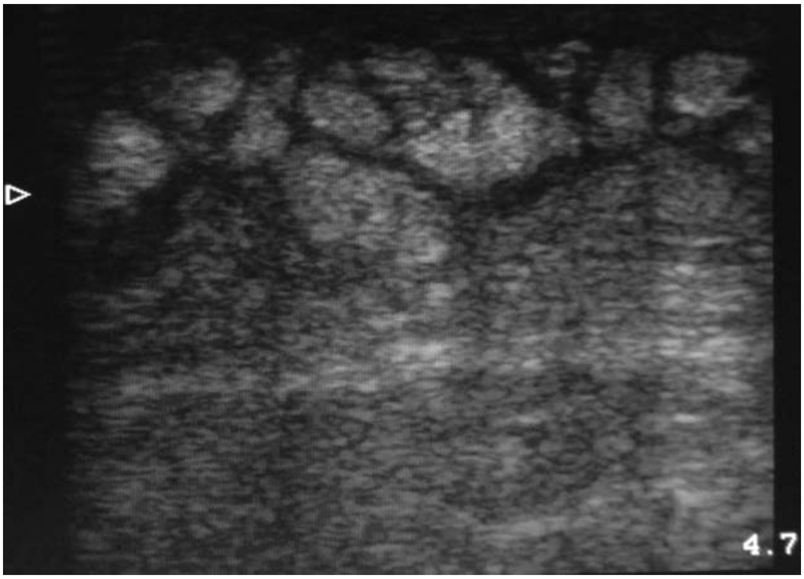

Figure 3. Ultrasound image (8.0-MHz linear probe) of cellulitis showing ``cobblestoning.''

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