

STRUCTURED EVIDENCE-BASED MEDICINE REVIEW

Point-of-care Ultrasound for Diagnosis of Abscess in Skin and Soft Tissue Infections

Sathyaseelan Subramaniam, MD, Jacqueline Bober, MD, Jennifer Chao, MD, and Shahriar Zehtabchi, MD

Abstract

Background: Traditionally, emergency department (ED) physicians rely on their clinical examination to differentiate between cellulitis and abscess when evaluating skin and soft tissue infections (SSTI). Management of an abscess requires incision and drainage, whereas cellulitis generally requires a course of antibiotics. Misdiagnosis often results in unnecessary invasive procedures, sedations (for incision and drainage in pediatric patients), or a return ED visit for failed antibiotic therapy.

Objective: The objective was to describe the operating characteristics of point-of-care ultrasound (POCUS) compared to clinical examination in identifying abscesses in ED patients with SSTI.

Methods: We systematically searched Medline, Web of Science, EMBASE, CINAHL, and Cochrane Library databases from inception until May 2015. Trials comparing POCUS with clinical examination to identify abscesses when evaluating SSTI in the ED were included. Trials that included intraoral abscesses or abscess drainage in the operating room were excluded. The presence of an abscess was defined by drainage of pus. The absence of an abscess was defined as no pus drainage upon incision and drainage or resolution of SSTI without pus drainage at follow-up. Quality of trials was assessed using the QUADAS-2 tool. Operating characteristics were reported as sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR-), with their respective 95% confidence intervals (CI). Summary measures were calculated by generating a hierarchical summary receiver operating characteristic (HSROC) model.

Results: Of 3,203 references identified, six observational studies (four pediatric trials and two adult trials) with a total of 800 patients were included. Two trials compared clinical examination with clinical examination plus POCUS. The other four trials directly compared clinical examination to POCUS. The POCUS HSROC revealed a sensitivity of 97% (95% CI = 94% to 98%), specificity of 83% (95% CI = 75% to 88%), LR+ of 5.5 (95% CI = 3.7 to 8.2), and LR- of 0.04 (95% CI = 0.02 to 0.08).

Conclusion: Existing evidence indicates that POCUS is useful in identifying abscess in ED patients with SSTI. In cases where physical examination is equivocal, POCUS can assist physicians to distinguish abscess from cellulitis.

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Skin and soft tissue infections (SSTI) include cellulitis and abscess of skin and its superficial fascia. Patient visits to emergency departments (ED) for SSTI evaluation have continued to rise, with 3.55 million visits documented in 2007 increasing to 4.21 million visits in 2010.¹ The use of incision and drainage has similarly risen from 736,000 to 1.48 million over the same years.¹

Traditionally, the diagnosis of abscess or cellulitis is made after obtaining a medical history and performing a physical examination.² However, physical examination has been shown to be associated with a fair to poor inter-rater reliability in identifying abscess and its severity.³⁻⁵ Therefore, physical examination alone might not be reliable enough to rule out presence of abscess, especially for smaller or deeper collections.

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Supervising Editor: Christopher R. Carpenter, MD, MSc.

Address for correspondence and reprints: Sathyaseelan Subramaniam, MD; e-mail: Subramaniam.sathyaseelan@gmail.com.

Cellulitis is commonly managed noninvasively with a course of antibiotics. Soft tissue abscess commonly requires invasive management with an incision and drainage in the ED.⁶ This procedure often causes discomfort and anxiety to the patient and caregivers of pediatric patients. It also frequently requires procedural sedation in the pediatric population.⁷

Misdiagnosing abscess as cellulitis often results in an unplanned revisit to a health care professional due to the failure of resolution with a course of antibiotics and worsening of the disease process. Misdiagnosing cellulitis as an abscess results in an unnecessary incision and drainage, along with the associated discomfort, anxiety, and potential need for procedural sedation.⁸ Point-of-care ultrasound (POCUS) has been studied for its use in differentiating abscess from cellulitis in ED patients with SSTI, both in adult and in pediatric populations.⁹ POCUS, when performed prior to incision and drainage, can prevent invasive procedures over vascular or neoplastic lesions that mimic abscess on clinical examination.¹⁰ The objective of this systematic review is to examine the operating characteristics of POCUS for abscess identification in SSTI, compared to clinical examination, in patients of all ages presenting to the ED.

METHODS

A systematic review protocol was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was agreed upon by all co-investigators a priori.¹¹ With the aid of experienced health science librarians, a thorough and systematic literature search of articles in any language was conducted from the inception of each database through May 21, 2015. The databases included were MEDLINE, Web of Science, CINAHL, EMBASE, and Cochrane Libraries. For the search, we selected medical subject headings (MeSH) and keywords to capture the concepts of ultrasonography, abscess, cellulitis, and SSTIs. The results were combined and exported to the EndNote bibliographic management tool and duplicate citations were removed. In addition, we searched studies listed in ClinicalTrials.gov. On January 1, 2016, we performed a limited review through EBSCO discovery tool (Elton Bryson Stephens Company discovery tool is an electronic resource that accesses several medical research databases with a comprehensive search tool and customization options)¹² and Google Scholar. Complete details of the search strategies including search terms are provided (Data Supplement S1, available as supporting information in the online version of this paper). Initially, all article titles and/or abstracts were independently screened for possible inclusion by two trained reviewers (SS and JB), with a third reviewer (JC) involved in disputes for inclusion or exclusion. Prior to review, all reviewers agreed to err on the side of inclusion. All articles selected initially by either reviewer had the full text ordered for further review.

Gray literature was searched by contacting experts in the field to solicit unpublished trials, hand searching all references of full text articles reviewed, and searching

abstracts from major emergency and ultrasound conferences (American Institute of Ultrasound Medicine, World Interactive Network Focused on Critical Care Ultrasound, Society for Academic Emergency Medicine, American College of Emergency Physicians) over the past 2 years. When additional information was required regarding a trial design or results, we contacted the authors directly to obtain the data.

Inclusion and Exclusion Criteria

Trials that compared clinical examination and ultrasound for detection of abscess in patients of any age in the ED were included. Trials were only included if the criterion standard for abscess diagnosis was pus drainage either on incision or at follow-up. Lack of an abscess was defined as no pus drainage on incision or resolution of SSTI at follow-up. Trials were excluded if they were not conducted in the ED or by emergency physicians. Trials were also excluded if they included intraoral abscesses or abscesses that required drainage in the operating room.

Quality Assessment

Two reviewers (SS and SZ) independently assessed the quality of the articles using the QUADAS-2 tool.¹³ Accordingly, all trials were rated for quality based on limitations known to study design.

Data Analysis

Two authors (SS and JB) abstracted data from the included trials. Abstracted data included the year, location and design of study, age and size of sample population, inclusion and exclusion criteria, outcomes measured, method and time of follow-up, and experience and training of study sonologists. Operating characteristics of POCUS in identifying abscess obtained from the included trials were reported as sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR-).

We tested the heterogeneity among the trials using DerSimonian and Laird's Q test. The calculations were based on the diagnostic odds ratios (ORs) for each test, using log scale.

We constructed a hierarchical summary receiver operator characteristic (HSROC) model to report the summary diagnostic accuracy of POCUS. The model allows both fixed and random effects (for threshold and accuracy). The HSROC model was used to obtain pooled sensitivity, specificity, LR+, LR-, and diagnostic ORs. All pooled statistics are reported with their respective 95% confidence intervals (CIs). Statistical analyses were performed using SAS (Version 9.4, SAS Institute) and Stata (Version 14, StataCorp).

RESULTS

The systematic search strategy identified 4,155 articles. We removed 952 duplicate articles and excluded an additional 3,178 articles based on title and/or abstract alone (see Figure 1). Twenty-five articles were included for full-text review. An additional trial's full text was included after an updated search on January 1, 2016.¹⁴ Ultimately, six trials met the inclusion criteria, providing

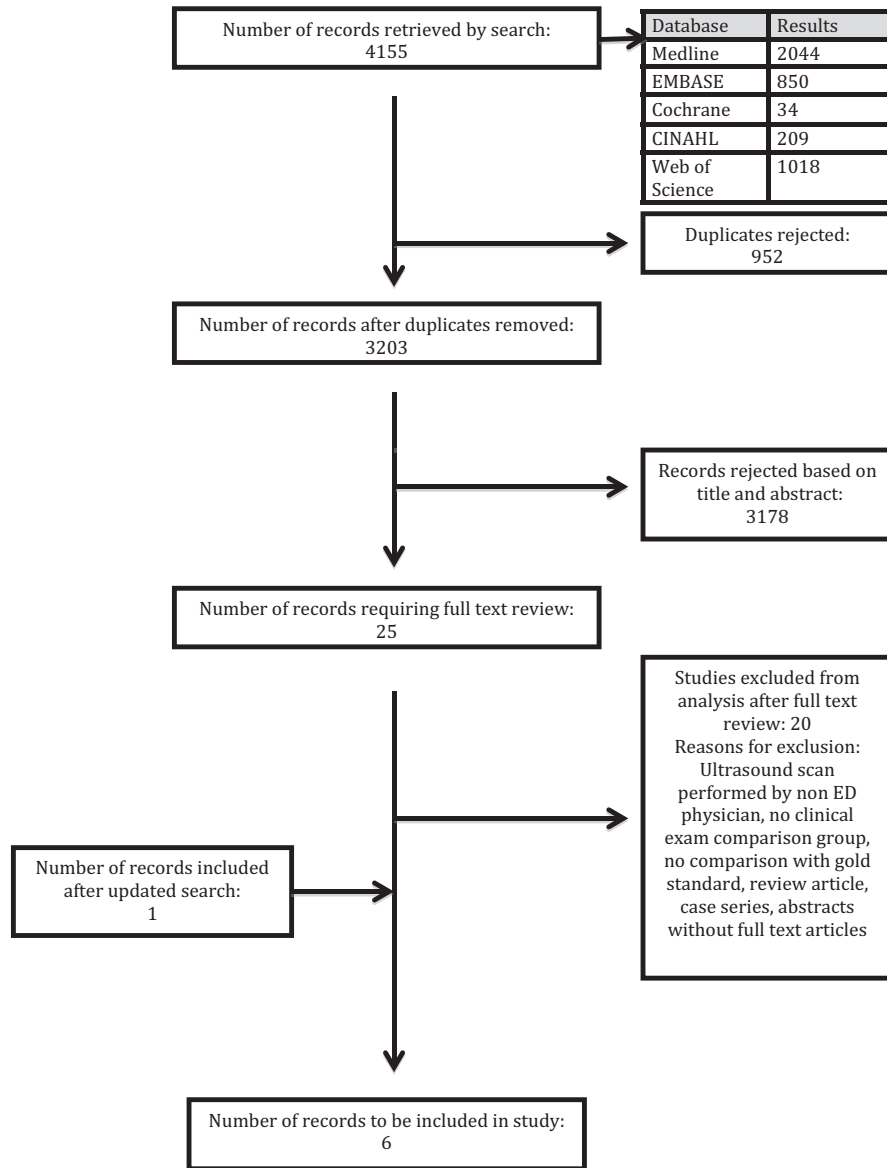


Figure 1. Flow diagram representing the process of selecting the trials.

a total of 800 patients in aggregate.¹⁴⁻¹⁹ All trials were prospective, observational studies conducted in the ED and compared POCUS with clinical examination in diagnosing abscess, with pus drainage as criterion standard, when evaluating SSTI. Four trials were on pediatric patients, and two were on adult patients (Table 1). Two studies had study physicians perform a combined clinical examination and POCUS prior to diagnosis.^{17,19} The remaining trials sought to have study physicians blinded from the clinical examination, by only performing POCUS prior to diagnosis.^{14-16,18} Two trials had specific operating characteristics of POCUS with or without clinical examination compared to clinical examination alone for a subgroup of clinically nonevident or equivocal SSTI lesions.^{14,19}

Follow-up of patients who did not undergo incision and drainage varied between 2 to 7 days. The method of follow-up was via phone call, return visit, and ED

chart review. One trial's follow-up timing and method was clarified after contacting the author.¹⁸

Methodologic Quality of the Included Trials

Quality assessments of the six trials based on the QUADAS-2 tool are displayed in Table 2. Overall, the agreement of two raters in evaluating the studies was good (kappa 0.76). With regard to outcomes being assessed by a blinded assessor, it is inherently not possible in any of the included trials. This is because the treating physician is responsible for incision and drainage of the patient and therefore cannot be blinded from the outcome of pus drainage. However, in cases of assessing outcome of follow-up of patients, two trials (Adams et al.¹⁴ and Marin et al.¹⁹) employed nurses and research coordinators. Although they were likely blinded to events in the ED, in an effort to be conservative on the quality, the nonblinded assessors that

Table 1
Characteristics of the Included Trials

Author	Year	Location	n	Age	Inclusion	Exclusion	Reference Standard (Abscess)	Outcome Measured	Follow-up	Study Design
Adams et al. ¹⁴	2015	United States	151	3 mo–21 y	Area with clinical features of SSTI	Previous imaging, immunocompromised, face, genital, perirectal abscess, paronychia, catheter or tube infections	Pus drainage vs. no pus drainage/ resolution on medical therapy	Sn & Sp of CE vs. POCUS for diagnosis	2–5 days	Prospective observational study
Marin et al. ¹⁹	2013	United States	387	12 mo–19 y	SSTI requiring systemic antibiotics	Non-English-speaking, previous imaging, immunocompromised, face, genital, perirectal abscess, paronychia, catheter or tube infections	Pus drainage vs. no pus drainage/ resolution on medical therapy	Sn & Sp of CE vs. CE + POCUS for diagnosis	2 days	Prospective observational study
Berger et al. ¹⁵	2012	United States	40	≥18 y	Clinical suspicion of abscess and plan to incise and drain	Spontaneous drainage, perineal, perianal, intraoral abscess	Pus drainage vs. no pus drainage on incision	Sn & Sp of CE vs. POCUS diagnosis	Not applicable, all patients had incision and drainage	Prospective observational study
Iverson et al. ¹⁸	2012	United States	65	6 mo–18 y	Clinical features of SSTI (erythema, warmth, fluctuance)	Draining abscess, abscess requiring OR, head and neck SSTI	Pus drainage vs. no pus drainage/ resolution on medical therapy	Sn & Sp of CE vs. POCUS diagnosis	3 days	Prospective observational study
Sivitz et al. ¹⁶	2010	United States	50	≤17 y	Clinical features of SSTI (erythema, warmth, tenderness)	Obvious abscess (e.g., draining abscess, palpable fluctuance)	Pus drainage vs. no pus drainage/ resolution on medical therapy	Sn & Sp of CE vs. POCUS diagnosis	7 days	Prospective observational study
Squire et al. ¹⁷	2005	United States	107	≥18 y	Presumed infection involving any area covered with keratinizing squamous epithelium	Intraoral abscess	Pus drainage vs. no pus drainage/ resolution on medical therapy	Sn & Sp of CE vs. POCUS diagnosis	7 days	Prospective observational study

CE = clinical examination; POCUS = point-of-care ultrasound; Sn = sensitivity; Sp = specificity; SSTI = skin and soft tissue infections.

Table 2
Quality Assessment of the Included Trials Using the QUADAS-2 Tool

Study	Sample	Avoided Inappropriate Exclusions?	Patients and Settings Match Study Question?	Blinded Interpretation of Index Test?	Acceptable Index Test Application?	Acceptable Reference (Criterion) Standard?	Outcomes Assessed by Blinded Assessor?	Assessed Outcomes Pertinent?	Appropriate Interval Between Test and Reference Standard?	Same Reference (Criterion) Standard for All Patients?	All Patients Analyzed?
Adams et al. 2015 ¹⁴	Convenient	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No
Marin et al. 2013 ¹⁹	Convenient	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
Berger et al. 2012 ¹⁵	Convenient	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Iverson et al. 2010 ¹⁸	Convenient	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No
Sivitz et al. 2010	Convenient	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No
Squire et al. 2013 ¹⁷	Convenient	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No

assessed outcomes (i.e., treating physicians performing incision and drainage in the ED) committed the entire group of assessors to become nonblinded assessors.

Diagnostic Performance of POCUS

The sensitivity of POCUS ranged from 90% to 98% and the specificity ranged from 67% to 88% in the included trials. The sensitivity of clinical examination ranged from 75% to 95% and the specificity ranged from 60% to 84% (Table 3). The operating characteristics of POCUS compared to clinical examination of two trials that analyzed clinically nonevident/equivocal lesions are presented in Table 4.

In the study conducted by Marin et al.,¹⁹ there was no pooled sensitivity and specificity for all 387 lesions. Therefore, we have presented the trial's operating characteristics for clinically evident lesions in Table 3 and the operating characteristics for clinically nonevident lesions in Table 4, as presented by the original study.

Test of heterogeneity for all trials together showed significant heterogeneity in the six studies ($\chi^2[5] = 33.11, p < 0.0001$). Because of the major differences in study design by Marin et al.¹⁹ compared to the others, we decided to test the heterogeneity among the remaining five trials, without the trial by Marin et al. After the trial by Marin et al.¹⁹ was removed, the test of heterogeneity was not statistically significant ($\chi^2[4] = 3.34, p = 0.50$).

Overall pooled sensitivity and specificity for POCUS (using data from all trials except for Marin et al.¹⁹) were 97% (95% CI = 94% to 98%) and 83% (95% CI = 75% to 88%) respectively, as seen in the HSROC model (Figure 2). LR+ was 5.5 (95% CI = 3.7 to 8.2), and LR- was 0.04 (95% CI = 0.02 to 0.08). The HSROC model in Figure 2 excludes the trial by Marin et al.

Although the description of POCUS training provided to study physicians for SSTI evaluation prior to trial enrollment was explained in each trial, background experience in POCUS among study physicians was not routinely described (Table 5). Marin et al.¹⁹ described all but one of their study physicians as novices, Berger et al.¹⁵ considered all study physicians as novices, while Adams et al.¹⁴ described all of their sonographers as POCUS credentialed physicians. Sivitz et al.¹⁶ had a mix of experience levels in his study physicians, while the remaining two trials did not provide any information on the background POCUS experience of their study physicians.^{17,18}

DISCUSSION

This systematic review assesses the diagnostic utility of POCUS in differentiating abscess from cellulitis in patients suspected of SSTI. The operating characteristics of POCUS are compared to those of physical examination. Physical examination is associated with a fair to poor inter-rater reliability in identifying abscess.^{4,5} In recent years, POCUS has emerged as a valuable tool in the ED due to its versatility, portability, lack of ionizing radiation, and tolerability by patients. Our systematic review reveals that in both adults and children, POCUS use for abscess diagnosis is more accurate than clinical examination alone. Two studies, Adams et al.¹⁴ and Marin et al.,¹⁹ examined a subgroup of clinically

Table 3
Operating Characteristics of the Six Included Prospective Observational Trials

Study	Intervention	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR- (95% CI)
Adams et al. 2015 ¹⁴	CE	84 (75–90)	60 (44–73)	2.1 (1.5–3.0)	0.3 (0.2–0.5)
	POCUS	96 (90–99)	87 (74–95)	7.5 (3.6–15.9)	0.04 (0.02–0.1)
Marin et al. 2013 ¹⁹	CE	95 (90–98)	84 (74–91)	6.0 (3.6–10.1)	0.06 (0.03–0.1)
	CE + POCUS	93 (87–96)	81 (70–89)	5.0 (3.1–8.2)	0.09 (0.05–0.2)
Berger et al. 2012 ¹⁵	CE	77 (58–89)	83 (37–99)	4.6 (0.8–28)	0.3 (0.1–0.6)
	POCUS	97 (83–100)	67 (24–94)	2.9 (0.9–9.0)	0.04 (0.005–0.4)
Iverson et al. 2012 ¹⁸	CE	90 (75–97)	72 (50–87)	3.2 (1.7–6.1)	0.1 (0.05–0.4)
	POCUS	98 (85–100)	68 (46–84)	3.0 (1.7–5.4)	0.04 (0.005–0.3)
Sivitz et al. 2010 ¹⁶	CE	75 (51–90)	80 (61–92)	3.8 (1.7–8.0)	0.3 (0.1–0.7)
	POCUS	90(68–99)	83 (65–94)	5.4 (2.4–12)	0.12 (0.03–0.5)
Squire et al. 2005 ¹⁷	CE	86 (74–93)	70 (54–82)	2.8 (1.8–4.5)	0.2 (0.1–0.4)
	CE + POCUS	98 (90–100)	88 (74–96)	8.5 (3.7–19)	0.02 (0.003–0.1)

CE = clinical examination; LR+ = positive likelihood ratio; LR- = negative likelihood ratio; POCUS = point-of-care ultrasound.

Table 4
Operating Characteristics of the Two Trials With Subgroup Analysis of Clinically Nonevident/Equivocal Lesions

Study	Intervention	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR- (95% CI)
Adams et al. 2015 ¹⁴	CE	83 (72–91)	30 (13–53)	1.2 (0.9–1.6)	0.6 (0.2–1.2)
	POCUS	95 (87–99)	78 (56–92)	4.4 (2.0–9.6)	0.06 (0.02–0.2)
Marin et al. 2013 ¹⁹	CE	54 (37–71)	46 (30–63)	1.0 (0.7–1.5)	1.0 (0.6–1.3)
	CE + POCUS	78 (58–90)	61 (46–71)	2.0 (1.4–2.8)	0.4 (0.2–0.6)

CE = clinical examination; LR+ = positive likelihood ratio; LR- = negative likelihood ratio; POCUS = point-of-care ultrasound.

nonevident/equivocal lesions and found POCUS markedly outperformed clinical examination alone.

The use of POCUS in differentiating abscess from simple cellulitis is of particular interest for the pediatric ED population since it can prevent unnecessary sedations if abscess is accurately ruled out. The use of procedural sedation for pediatric abscess incision and drainage varies across hospitals, with rates ranging from 2% to as high as 94%.^{7,20} Hospitals that more commonly employ procedural sedation for abscess management stand to benefit from accurate diagnosis. In addition, accurate ruling out of an abscess can help prevent a painful and anxiety-provoking procedure and continue to maintain good disposition timing.

The level of training needed for accurate POCUS use in SSTI evaluation appears to be low given that study physicians had varied but short periods of training in the included trials. The most rigorous training, by Adams et al.,¹⁴ included a 1- or 2-day course followed by 25 SSTI POCUS examinations with review by an emergency ultrasound director for accuracy.¹⁴ In the trial by Squire et al.,¹⁷ study physicians had minimal training, with only 30 minutes of combined didactic and hands-on training. Sensitivity of POCUS among all trials, regardless of differing background experience and POCUS training for SSTI evaluation, were similar for diagnosis of abscess. However, when comparing clinically nonevident lesions, novice sonographers in the trial by Marin et al.¹⁹ had lower values for operating characteristics of POCUS compared to credentialed sonographers in the trial by Adams et al.¹⁴ The study physicians in the study by Marin et al. also received less

rigorous dedicated POCUS training for SSTI evaluation compared to the study physicians in the study by Adams et al.^{14,19} This may indicate that experienced sonographers with more rigorous training in POCUS for SSTI evaluation are more accurate in the diagnosis of clinically nonevident/equivocal SSTI lesions using POCUS.

Fortunately, POCUS for SSTI evaluation is known to be technically straightforward and easy to learn.²¹ The American College of Emergency Physicians currently recommends that an emergency physician perform any particular emergency ultrasonography application for at least 25 to 50 times before being considered competent.²² All emergency medicine residents are required by the Accreditation Council for Graduate Medical Education to learn POCUS for SSTI evaluation during training. Pediatric emergency medicine fellowships have yet to adopt these recommendations. The results of this systematic review highlight the need for emergency physicians and trainees to incorporate POCUS as the standard of care for routine assessment of SSTI.

During the preparation of this article, we identified a systematic review on this topic, published online on October 19, 2015.²³ This systematic review by Alsaawi et al.²³ does not include two trials (Adams et al.¹⁴ and Iverson et al.¹⁸) in its search results and data analysis. Furthermore, this systematic review pools the two groups of clinically evident and nonevident lesions in the trial by Marin et al. based on the assumption that all “uncertain” lesions are abscesses.^{19,23} We believe that this approach misrepresents the reported data for operating characteristics of clinical examination compared

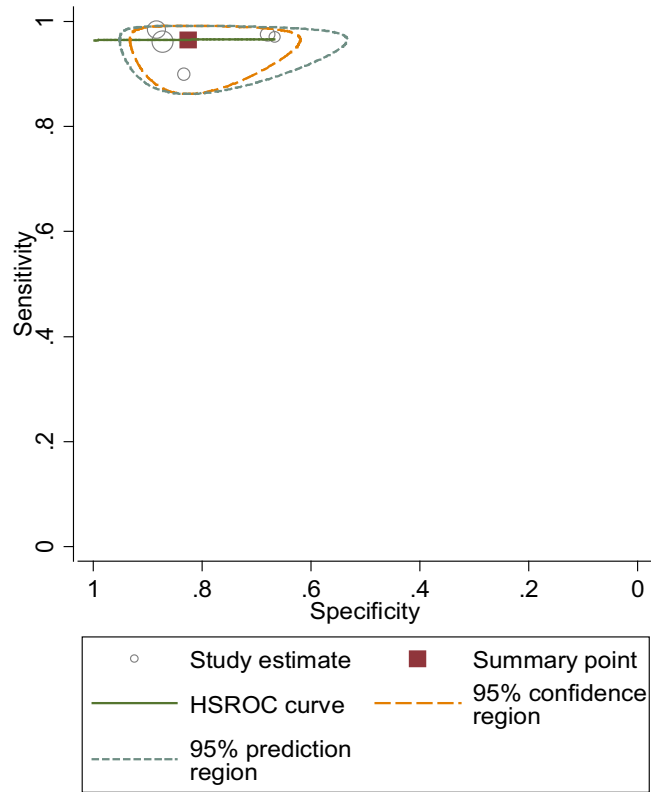


Figure 2. HSROC model generated from pooling five trials assessing the operating characteristic of POCUS in identifying abscess in ED patients with SSTI. The summary point represents the summary sensitivity and specificity. The 95% confidence region represents the 95% CIs of the summary sensitivity and specificity and the 95% prediction region represents the 95% CI of sensitivity and specificity of each individual study included in the analysis. The plot also includes study estimates indicating the sensitivity and specificity estimated using the data from each study separately. The size of the marker is scaled according to the total number in each study. HSROC = hierarchical summary receiver operating characteristic; POCUS = point-of-care ultrasound; SSTI = skin and soft tissue infections.

to clinical examination with POCUS. Our systematic review chose to report the data of Marin et al. as originally published.¹⁹

Although POCUS is currently the preferred method of imaging for SSTI in the ED, other imaging modalities such as computed tomography (CT) have been used as a diagnostic modality as well. Gaspari et al.²⁴ compared POCUS to CT in 65 patients and concluded that POCUS was more sensitive but less specific than CT. POCUS also provided more image detail for skin abscess. Unfortunately, ultrasound has its limitations with certain skin infections. Necrotizing fasciitis is a particular type of infection where magnetic resonance imaging is recognized as the imaging modality of choice because the presence of air within the superficial fascia decreases the quality of ultrasound images.²⁵

Future trials assessing the accuracy of POCUS in identifying abscess in SSTI evaluation will benefit from larger sample sizes to ensure a wider spectrum of disease severity (smaller collections vs. larger abscesses). Consecutive sampling, when possible, will also reduce

Table 5
POCUS Training for SSTI Evaluation and Background POCUS Experience of Study Physicians in Each Trial

Trial	Dedicated POCUS Training for SSTI Evaluation Provided to Physicians, Prior to Enrolling Patients	Background POCUS Experience of Study Sonographers
Adams et al. 2015 ¹⁴	1- or 2-day course and 25 accurate POCUS SSTI examinations, all reviewed for quality by POCUS director.	Eight POCUS credentialed PEM physicians and two POCUS credentialed PEM fellows.
Marin et al. 2013 ¹⁹	6 hours of lectures and hands-on training. Physicians supervised at bedside by an experienced sonologists and performed 5 proctored POCUS examinations, 80% had to be high quality.	One physician with POCUS training in accordance with ACEP recommendations and seven other physicians were POCUS novices.
Berger et al. 2012 ¹⁵	2-day POCUS course taught by a fellowship-trained physician and a 15-minute didactic session.	Study physicians were POCUS novices.
Iverson et al. 2012 ¹⁸	Two specific 60-minute didactic and hands-on training by a PEM physician with POCUS certification. Quarterly training provided during study duration.	Study physicians prior experience in POCUS not explained in trial methodology.
Sivitz et al. 2010 ¹⁶	30-minute didactic from a POCUS fellowship-trained physician and 50 POCUS examinations with 5 SSTI examinations.	Two POCUS-trained emergency physicians. Prior experience in POCUS not explained for two PEM fellows.
Squire et al. 2005 ¹⁷	30-minute didactic and hands-on training.	Study physicians prior experience in POCUS not explained in trial methodology.

PEM = pediatric emergency medicine; POCUS = point-of-care ultrasound; SSTI = skin and soft tissue infections.

the risk of selection bias. Such trials could also better delineate the sizes of collections and more accurately define abscess formation. Finally, a randomized controlled design would allow clinicians to assess the impact of preincision and drainage POCUS on patient-oriented outcomes. Based on criteria proposed by Lord et al.,²⁶ a randomized controlled trial would be necessary when considering the test accuracy of POCUS for skin and superficial abscess diagnosis. Lord and colleagues²⁶ explain that when a new test is more sensitive than an old test, it leads to detection of extra cases. However, treatment of cases detected by the old test may not apply to these extra cases. In such instances, decisions to use the test will be based on whether the trials could prove that treatment improves patient outcomes in the cases detected by the new and more sensitive test. Therefore, the test accuracy is linked with evidence of treatment efficacy. In the case of POCUS, it is possible that this test detects new cases (mostly small

abscesses) that are otherwise missed by physical examination alone. It is unclear if these small abscesses require incision and drainage or antibiotics alone for resolution of disease. Future trials can randomize patients to either clinical examination or POCUS prior to treatment and investigate patient-focused outcomes such as the number of incision and drainage procedures avoided, recurrent visits, or treatment complications.

Clinical Implications of the Systematic Review

Despite the limitations of the included trials, this systematic review indicates that POCUS is helpful in differentiating abscess from cellulitis in ED patients with SSTI. The low cost, absence of adverse effects or harms, and availability of the test in most EDs justify the liberal use of POCUS before making the decision to incise and drain an abscess. Emergency medicine educators (including POCUS trainers) should consider promoting the inclusion of this test in the assessment of patients suspected of an abscess. This approach could not only reduce the risk of unnecessary invasive procedures (incision and drainage, conscious sedation, etc.), but could also potentially facilitate drainage of abscess (if indicated) by providing information about the anatomical characteristics of the abscess.

LIMITATIONS

Skin and soft tissue infections represent a spectrum of disease from cellulitis to abscess that inherently causes problems with proper classification of diagnosis and has an impact on operating characteristics of both POCUS and clinical examination. For example, a lesion diagnosed as cellulitis at one point in time has the potential to evolve into an abscess hours or days later. This can result in a true positive diagnosis of cellulitis being reclassified as a false positive when there is a report of purulent discharge at follow-up, days later. Further complicating the classification of lesions is the volume of an abscess deemed by the physician as requiring a drainage procedure. All six studies reported pus drainage in the ED or at follow-up as the criterion standard for an abscess. However, POCUS is able to visualize collections less than 1 cm in volume. Although these lesions can be drained, some physicians may consider them small enough to be suitable for medical management without drainage. It is unclear from the included trials how study physicians chose to classify these small collections.

Except for Berger et al.,¹⁵ the remaining five trials had two reference standards, incision and drainage in the ED or follow-up (to assess resolution of symptoms or incision and drainage requirement). As explained by Kohn et al.,²⁷ having two forms of reference standard introduces differential verification bias. Also known as double criterion standard bias; it is the major limitation of these trials. In these five trials, it is more likely that patients with a positive index test (POCUS) received an incision and drainage while a negative index test led to clinical follow-up to assess for disease progression or resolution. Differential verification bias could have occurred in the subgroup of very small abscesses that produced pus on drainage (indicating a true positive), but also could

possibly have resolved on their own by the time of follow-up (indicating a true negative). In this situation, the reference standard applied to similar lesions can produce different outcomes. Ultimately, this form of bias skews the five trials toward an artificially elevated sensitivity and specificity. Performing incision and drainage on all patients would have eliminated this differential verification bias. However, employing this reference standard for all patients would not have been ethical or feasible, especially in patients with low suspicion for abscess. Follow-up of cases not undergoing incision and drainage seems to be the only viable alternative option. In addition, all six trials were observational trials and future higher-quality trials might confirm or refute our findings.

CONCLUSION

This systematic review evaluates six prospective observational trials comparing point-of-care ultrasound with clinical examination for identifying abscess in ED patients with skin and soft tissue infections. The existing evidence derived from these six trials indicates that point-of-care ultrasound is useful in identifying abscess in ED patients with skin and soft tissue infections. Considering the ease of performance and absence of any harm associated with this diagnostic modality, ED physicians should consider using point-of-care ultrasound liberally before performing incision and drainage, especially when physical examination is equivocal.

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Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. PubMed search strategy.



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