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REVIEW ARTICLE

Point-Of-Care Ultrasonography for Identification of Skin and Soft Tissue Abscess in Adult and Pediatric Patients; a Systematic Review and Meta-Analysis

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Abstract: **Introduction:** Differentiating the soft tissue abscess from other types of skin and soft tissue infections (SSTIs) poses a particular challenge because they have similar physical evaluation findings, but each disease has a different course, outcome, and treatment. This meta-analysis aimed to investigate the diagnostic accuracy of point-of-care ultrasonography for diagnosis of soft tissue abscess in the emergency departments. **Methods:** A comprehensive literature search of MEDLINE, Scopus, Web of Science, Embase, and Google Scholar, from inception to January 2023, was conducted to identify relevant studies investigating the diagnostic performance of point-of-care ultrasonography for identification of abscess. Methodological quality of the included studies was assessed using a revised tool for the quality assessment of diagnostic accuracy studies (QUADAS-2). **Results:** The pooled estimates of diagnostic parameters of ultrasonography for diagnosis of abscess were as follows: sensitivity, 0.93 (95% CI: 0.92–0.94); specificity, 0.87 (95% CI: 0.85–0.89), and the area under the summary receiver-operating characteristic (SROC), 0.95. The pooled sensitivity, specificity, and area under the SROC of studies in adult patients were 0.98 (95% CI: 0.92–1), 0.92 (95% CI: 0.86–0.95), and 0.99, respectively. The pooled sensitivity, specificity, and area under the SROC of studies in pediatric patients were 0.9 (95% CI: 0.87–0.92), 0.78 (95% CI: 0.73–0.82), and 0.91, respectively. **Conclusion:** Our meta-analysis demonstrated that the point-of-care ultrasonography has excellent diagnostic value for the abscess in the emergency department. Furthermore, we found that the diagnostic performance of point-of-care ultrasonography for diagnosis of abscess was higher for adult cases than for pediatric patients.

Keywords: Abscess; cellulitis; diagnostic imaging; meta-analysis; ultrasonography

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1. Introduction

Skin and soft tissue infections (SSTIs) are a highly prevalent presenting complaint in the ambulatory setting and also emergency department (1, 2). Recent investigations have shown that although the rise of methicillin-resistant Staphylococcus aureus can lead to significant increase in admission rates, duration of hospitalizations, and ambulatory and emergency department visits, most patients with suspected abscess are treated in emergency departments using incision and drainage as the gold standard of care (3, 4). Differentiating the soft tissue abscess from other types of SSTIs pose a particular challenge because they have similar physical evaluation findings, but each disease has a different course, outcome, and treatment. Indeed, cases with abscess are managed using drainage, whereas patients with cellulitis are commonly treated using systematic antibiotics (1). This misclassification can lead to unnecessary invasive interventions, exposure to sedation-related adverse events, and inappropriate management in patients with cellulitis (5). It has been shown that point-of-care ultrasonography as an adjunct to physical evaluations can improve the accuracy of diagnosis of skin abscess in cases with SSTIs and result in change in the decision to perform incision and drainage (6). A number of studies have in fact shown that point-of-care ultrasonography is superior to physical evaluation alone for diagnosis of abscess, but there is limited evidence supporting its efficacy in the emergency departments (7-9). Furthermore, conflicting findings have been reported in the literature regarding the accuracy of point-of-care ultrasonography for evaluation of SSTIs in the emergency departments (10, 11). In addition, previous investigations of point-of-care ultrasonography for diagnosis of abscess in pediatrics showed less consistency in comparison with data from investigations in adults, emphasizing the importance of further diagnostic studies (8, 11-13). Although majority of previous studies suggest the point-of-care ultrasonography for evaluation of SSTIs in the emergency department, systematic reviews and meta-analyses are required to determine the exact diagnostic accuracy of this imaging modality. Therefore, this systematic review and meta-analysis aimed to investigate the diagnostic accuracy of point-of-care ultrasonography for diagnosis of soft tissue abscess in the emergency departments and also the subgroup of pediatric patients.

2. Methods

2.1. Search strategy

This systematic review and meta-analysis of diagnostic studies was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses for Diagnostic Test Accuracy (PRISMA-DTA) guidelines. A comprehensive literature search of MEDLINE, Scopus, Web of Science, Embase, and Google Scholar, from inception to January 2023, was conducted to identify relevant studies investigating the

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diagnostic performance of point-of-care ultrasonography for diagnosis of abscess. Our searches were limited to peer-reviewed published papers and abstracts in English. Moreover, the references of the relevant papers were manually screened for the potential studies. The systematic search was performed using Medical Subject Heading (MeSH) terms, keywords, and Boolean operators: "Ultrasound" OR "Ultrasonography" OR "Sonography" OR "Sono" OR "Ultrasonic" OR "Sonogram" AND "Skin and soft tissue infections" OR "SSTI" OR "SSTIs" OR "Soft tissue infections" OR "Skin Diseases, Infectious" OR "Staphylococcal Skin Infections" OR "Soft Tissue Injuries" OR "Suppuration" OR "Suppurate" OR "pus" OR "abscess" OR "Cellulitis" OR "Gram positive infection" OR "Bacterial infection".

2.2. Study selection and eligibility criteria

Results from the electronic database search were assessed by two independent authors (MF and RAB) based on the keywords included in title and abstract for relevance and evaluated for inclusion criteria based on full text. Since screening process was managed using EndNote software, any duplicate studies were initially removed from the results. Any discrepancies and disagreements regarding studies evaluated for possible eligibility based on title and abstract or inclusion based on full text were resolved by discussion and consultation with a third author. The papers were included in the study if they evaluated the diagnostic accuracy of point-of-care ultrasonography for diagnosis of abscess, reported a 2 × 2 table containing true positive (TP), false positive (FP), true negative (TN), and false negative (FN), reported an original study or a case series with more than 10 cases, and published in English. We excluded systematic reviews and meta-analyses, case reports, case series with less than 10 patients, editorials, studies without extractable data to provide a 2 × 2 table, and papers published in languages other than English.

2.3. Data extraction

Two independent authors (AM and MF) extracted data from each included study using a standardized data extraction sheet. Data extracted from each study included first author, publication year, sample size, country, study location, mean age, sex, study design, prevalence of abscess, study population, diagnostic performance of point-of-care ultrasonography (TP, TN, FP, FN, sensitivity, and specificity), and gold standard. Any disagreements throughout data extraction were resolved through discussion with a third author.

2.4. Methodological quality assessment

Two independent authors (MF and RAB) separately assessed the methodological quality of the included studies using a revised tool for the quality assessment of diagnostic accuracy studies (QUADAS-2) tool. Any discrepancies about the results of this tool were resolved through consultation with a third author.

2.5. Statistical analysis

Statistical analysis was conducted using meta-Disc software version 1.4 (Ramona Cajal Hospital, Madrid, Spain) and Stata statistical software package (Stata Corp., College Station, TX, USA) (version 17.0). We used Cochrane Q-test and I2 to evaluate the heterogeneity among the included studies. A P-value less than 0.05 for Q-test or I2 higher than 50% indicate a significant heterogeneity among the included studies and a random-effects model was used. On the other hand, if P-value of Q-test was higher than 0.05 and I2 was less than 50%, a fixed-effects model was used for estimation of diagnostic parameters. Publication bias was investigated using Funnel plot and Begg's test. We calculated Spearman's rank correlation coefficient to assess the threshold effects.

3. Results

3.1. Search results

Initial search of the electronic databases yielded a total of 2564 studies, after which 917 duplicate papers were excluded. From the 1647 nonduplicate studies, 1602 studies were excluded after title and abstract screening. Forty-five studies were chosen for full-text evaluation. Afterwards, 30 studies were excluded due to having poor quality, non-extractable data, and being irrelevant. As a result, 15 studies met all eligibility criteria and were included in this meta-analysis. Figure 1 shows the PRISMA flowchart of inclusion and exclusion of the studies.

3.2. Characteristics of the included studies

The included studies encompassed 2615 patients, ranging from a minimum of 23 to a maximum of 1216. These studies were published between 1997 and 2020. Thirteen of the included studies were performed in USA, one in Ireland, and one in Lebanon. The reported mean age and the percentage of females ranged from 1.95 to 42 years and 31% to 64%, respectively. Fourteen studies had prospective observational design and one study was a clinical trial. Table 1 summarizes the main characteristics of the 15 included studies.

3.3. Methodological quality of the included studies

Table 2 presents our evaluation of the risk of bias and applicability domains of the 15 included studies in this meta-analysis using QUADAS-2 tool. Overall, the majority of the studies were considered to have low risk of bias and applicability concerns.

3.4. Screening performance characteristics of ultrasonography

Spearman's correlation coefficient for ultrasonography was 0.11 with a P value of 0.7, demonstrating that there is no threshold effect. There was a significant between-study heterogeneity for sensitivity (I2=74.4% and P<0.01), specificity (I2=81% and P<0.01), positive likelihood ratio (PLR) (I2=83.8% and P<0.01), negative likelihood ratio (NLR) (I2=79% and P<0.01), and diagnostic odds ratio (DOR) (I2=80.6% and P<0.01). The pooled estimates of diagnostic parameters of ultrasonography for diagnosis of abscess were as follows: sensitivity, 0.93 (95% CI: 0.92–0.94); specificity, 0.87 (95% CI: 0.85–0.89); positive likelihood ratio, 6.23 (95% CI: 3.91–9.92); negative likelihood ratio, 0.09 (95% CI: 0.05–0.15); and diagnostic odds ratio, 95.66 (95% CI: 40.46–226.18) (Figures 2-6). The area under the SROC curve for the accuracy of ultrasonography to diagnose abscess in the emergency settings was 0.95 (Fig. 7).

3.5. Subgroup analysis

The pooled sensitivity, specificity, PLR, NLR, and area under SROC of studies (n=4) in adult patients were 0.98 (95% CI: 0.92–1), 0.92 (95% CI: 0.86–0.95), 9.02 (95% CI: 4.31-18.87), 0.03 (95% CI: 0.01-0.08), and 0.99, respectively. The pooled sensitivity, specificity, PLR, NLR, and area under SROC of studies (n=7) in pediatric patients were 0.9 (95% CI: 0.87–0.92), 0.78 (95% CI: 0.73–0.82), 4.08 (95% CI: 3.11-5.37), 0.14 (95% CI: 0.08-0.25), and 0.91, respectively.

3.6. Publication bias

Results of Begg's test (P=0.58) and Egger's test (P=0.30) revealed that there was no significant publication bias in the included studies. Similarly, the funnel plot of the studies showed no significant publication bias (Fig. 8).

4. Discussion

In this systematic review and meta-analysis, we investigated the diagnostic accuracy of point-of-care ultrasonography for diagnosis of abscess in the emergency department and also the subgroups of pediatric and adult patients. The overall sensitivity, specificity, and accuracy of point-of-care ultrasonography for diagnosis of abscess were 0.93, 0.87, and 0.96, respectively. The sensitivity, specificity, and accuracy of point-of-care ultrasonography for diagnosis of abscess in adult patients were 0.98, 0.92, and 0.99, respectively. The meta-analysis of studies on pediatric cases found that the pooled sensitivity, specificity, and accuracy of point-of-care ultrasonography for diagnosis of abscess are 0.9, 0.78, and 0.91, respectively. These findings show that overall diagnostic performance of point-of-care ultrasonography for diagnosis of abscess is acceptable. However, the pooled estimates of diagnostic parameters revealed that sensitivity, specificity, and accuracy of point-of-care ultrasonography for diagnosis of abscess in pediatric patients is lower than those of adult cases. This may in part be clarified by differences between adult and pediatric cases with respect to the body habitus, as larger body sizes of adult patients may increase accuracy of point-of-care ultrasonography for detection of drainable abscesses. Moreover, final diagnosis of abscess is confirmed by incision and drainage and this procedure may require not only pain control, but also conscious sedation. Consequently, collaboration of the patients or their parents for further evaluations can be affected, which may reduce the accuracy of point-of-care ultrasonography for diagnosis of abscess.

In a randomized clinical trial by Gaspari et al. (14), 125 cases presenting to emergency department with soft tissue abscess were randomized to incision and drainage with physical examination or incision and drainage with point-of-care ultrasonography. The main assessed outcome in this study was failure of treatment at 10 days. The results of this study showed that point-of-care ultrasonography in addition to diagnosis of abscess, can reduce the rate of failure or need for repeated incision and drainage in patients with soft tissue abscess. However, since the vast majority of the included studies in our meta-analysis did not investigate the effect of point-of-care ultrasonography on the rate of treatment failure, we were not able to predict the pooled value of this outcome.

In a similar systematic review and meta-analysis by Subramaniam et al. (15), several electronic databases including Embase, Web of Science, CINAHL, Cochran, and MEDLINE were systematically searched from inception to 2015 to find studies evaluating the diagnostic performance of point-of-care ultrasonography for identification of abscess in emergency departments. They included four studies on adult patients and two studies on pediatric patients with a total number of 800 cases. They reported that sensitivity and specificity of point-of-care ultrasonography for diagnosis of abscess were 0.97 and 0.83, respectively. These parameters were higher than those calculated in our meta-analysis. One possible explanation for this inconsistency could be the difference between our meta-analysis and their study with respect to the number of included studies and the total number of assessed cases. Moreover, since they only reported the overall sensitivity and specificity of point-of-care ultrasonography for diagnosis of abscess, their findings may not be generalizable to pediatric population. Indeed, we found that the sensitivity and specificity of point-of-care ultrasonography for diagnosis of abscess are lower in pediatric cases compared to adult patients; therefore, we believe that this approach of Subramanian et al. misrepresents the reported results for diagnostic performance of this imaging modality. The role of point-of-care ultrasonography in diagnosis of abscess is particularly crucial for the pediatric cases because they may not tolerate sedation and incision and drainage. Since we found that point-of-care ultrasonography has acceptable diagnostic characteristics for diagnosis of abscess in pediatric cases, its use may reduce the rate of unnecessary painful and anxiety-provoking treatment (16, 17).

Similar to the study of Subramaniam et al., in another systematic review and meta-analysis by Alsaawi et al. (18) the data of only four studies were pooled to estimate the diagnostic characteristics of point-of-care ultrasonography for diagnosis of abscess. However, this study described the range of diagnostic characteristics of point-of-care ultrasonography and the overall pooled estimates of these variables were not reported.

5. Limitations

We acknowledge some limitations in our systematic review and meta-analysis of the studies investigating the diagnostic characteristics of point-of-care ultrasonography for diagnosis of abscess. First, we found significant heterogeneity among the included studies.

Although this was in part addressed by conducting subgroup analysis on pediatric and adult's patients, other factors such as lack of a common follow-up and difference in the use of index test may also contribute to heterogeneity. Second, some of the included studies were rated as unclear or high risk of bias on the patient selection and flow and timing domains. Third, the vast majority of the included studies had small sample sizes and the data of two studies were not extractable for meta-analysis. Therefore, further original studies with improved methods of patient selection and higher sample sizes are required to establish the results of this meta-analysis.

6. Conclusion

Our meta-analysis demonstrated that point-of-care ultrasonography has excellent diagnostic value for abscess diagnosis in emergency departments. Furthermore, we found that the diagnostic performance of point-of-care ultrasonography in diagnosis of abscess was higher for adult cases than for pediatric patients. However, since the conclusion of this meta-analysis was based on a limited number of studies with small sample sizes, further investigations are required to establish point-of-care ultrasonography for diagnosis of abscess in all age groups.

7. Declarations

7.1. Acknowledgments

The authors thank all those who contributed to this study.

7.2. Conflict of interest

None.

7.3. Funding and support

None.

7.4. Authors' contribution

All authors contributed to study design, data collection, and writing the draft of the study. All authors read and approved the final version of manuscript.

7.5. Data Availability

Not applicable.

7.6. Using artificial intelligence chatbots

None.

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Table 1: The main characteristics of the studies included in the meta-analysis

Authors	Year#	Country	Type	Location	Population	Age (year)	Female %	Prevalence of abscess	Reference standard
Knaysi et al. (3)	2020	Lebanon	Obs	ED	Adults	46 *	46.8	42	I&D or Follow-up
Gaspari et al. (14)	2019	USA	CT	ED	Adults	32.5	43	NR	I&D or Follow-up
Mower et al. (19)	2019	USA	Obs	ED	Adults and Pediatrics	36	52	68	I&D or Follow-up
Levine et al. (11)	2019	USA	Obs	PED	Pediatrics	5.3	37%	30	Radiology Department Imaging
Lam et al. (13)	2018	USA	Obs	ED	Pediatrics	NR	NR	58	I&D or Follow-up
Greenlund et al. (20)	2017	USA	Obs	Clinic	NR	NR	NR	NR	NR
Adams et al. (12)	2016	USA	Obs	PED	Pediatrics	7*	54%	68	I&D or Follow-up
Marin et al. (8)	2013	USA	Obs	PED	Pediatrics	7*	57%	62	I&D
Berger et al. (21)	2012	USA	Obs	ED	Adults	NR	NR	85	I&D
Iverson et al. (22)	2012	USA	Obs	PED	Pediatrics	5.2	64%	62	I&D
Sivitz et al. (23)	2010	USA	Obs	PED	Pediatrics	9.5	42%	44	I&D or Follow-up
Tayal et al. (9)	2006	USA	Obs	ED	Adults	42	47	43	I&D or Follow-up
Squire et al. (24)	2005	USA	Obs	ED	Adults	39	31%	60	I&D or Follow-up
Page-Wills et al. (25)	2000	USA	Obs	ED	NR	NR	NR	71	I&D
Quraishi et al. (10)	1997	Ireland	Obs	PED	Pediatrics	1.95	56%	74	I&D or Follow-up

All included studies had prospective design; Age is presented as mean except in studies marked with "*" which is presented as median. #: year of publication; ED: emergency department; PED: pediatric ED; CT: clinical trial; Obs: observational; I&D: Incision and drainage; NR: Not reported; USA: United States of America.

Table 2: Quality assessment of the included studies using QUADAS-2 tool

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Knaysi et al.	☹	☺	☺	☹	☺	☺	☺
Gaspari et al.	?	☺	☺	?	☺	☺	☺
Mower et al.	☺	☺	☺	?	☺	☺	☺
Levine et al.	?	☺	☺	☺	?	☺	☺
Lam et al.	?	☺	☺	?	☺	☺	☺
Greenlund et al.	☺	☺	?	?	☺	☺	?
Adams et al.	?	☺	☺	?	☺	☺	☺
Marin et al.	?	☺	☺	?	☺	☺	☺
Berger et al.	?	☺	☺	☺	☺	☺	☺
Iverson et al.	?	☺	☹	☹	☺	☺	☺
Sivitz et al.	?	☺	☺	?	☺	☺	☺
Tayal et al.	?	☺	☺	?	☺	☺	☺
Squire et al.	?	☺	☺	?	☺	☺	☺
Page-Wills et al.	?	☺	☹	?	☺	☺	☺
Quraishi et al.	?	☺	☺	?	☺	☺	☺

☺: Low Risk; ☹: High Risk; ?: Unclear Risk.

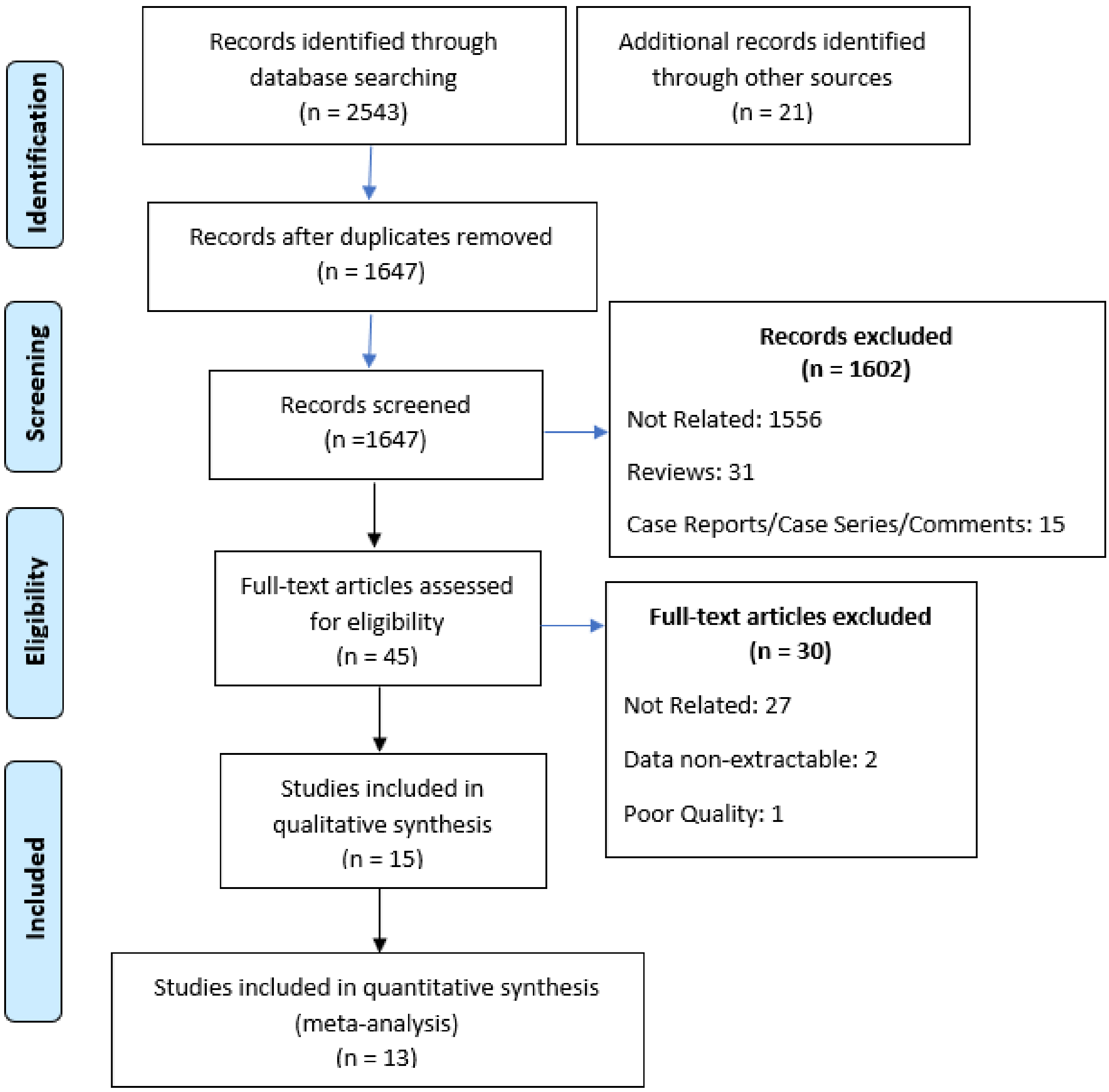

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart of the literature search and selection of studies that reported accuracy of point-of-care ultrasonography for diagnosis of abscess.

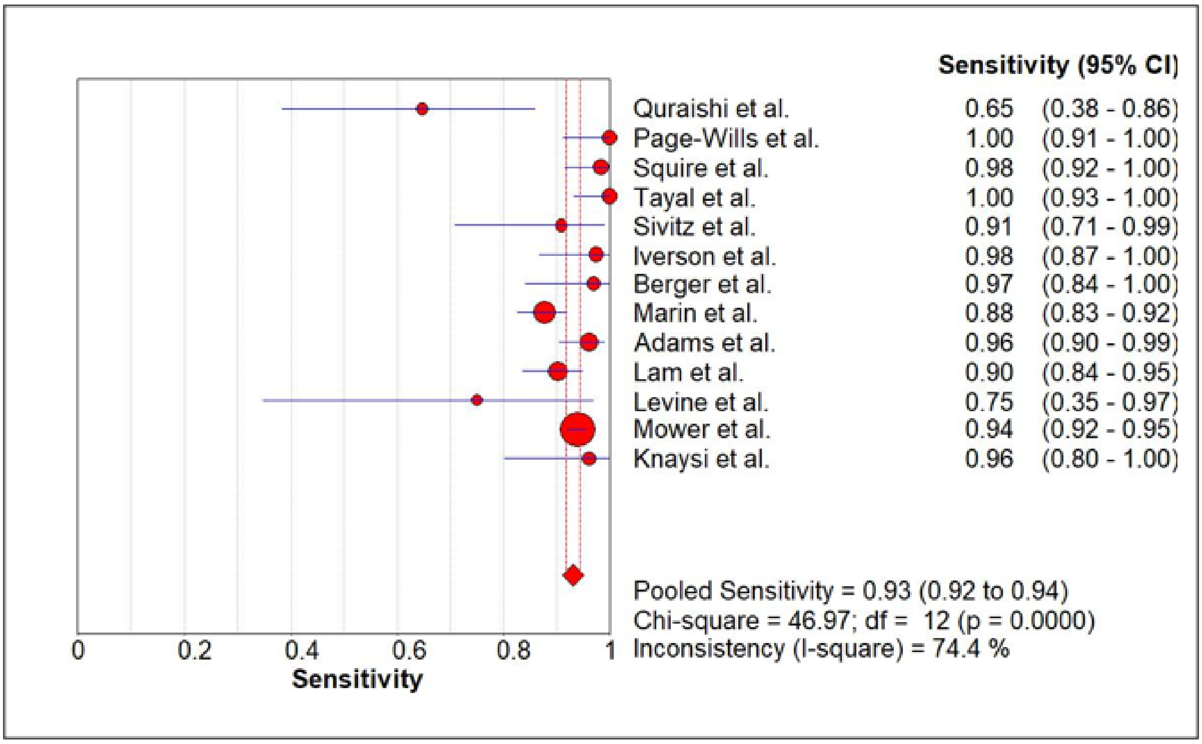

Figure 2: Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart of the literature search and selection of studies that reported accuracy of point-of-care ultrasonography for diagnosis of abscess.

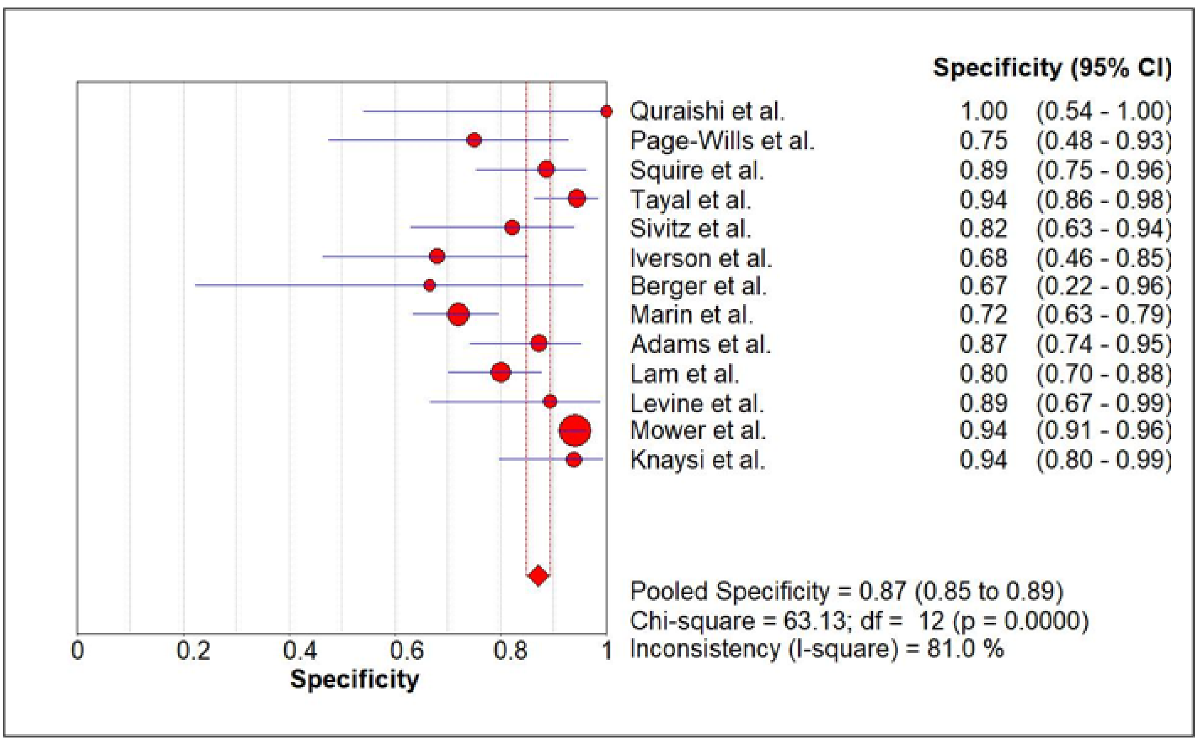

Figure 3: Forest plot of the pooled specificity of point-of-care ultrasonography for diagnosis of abscess. CI: confidence interval.

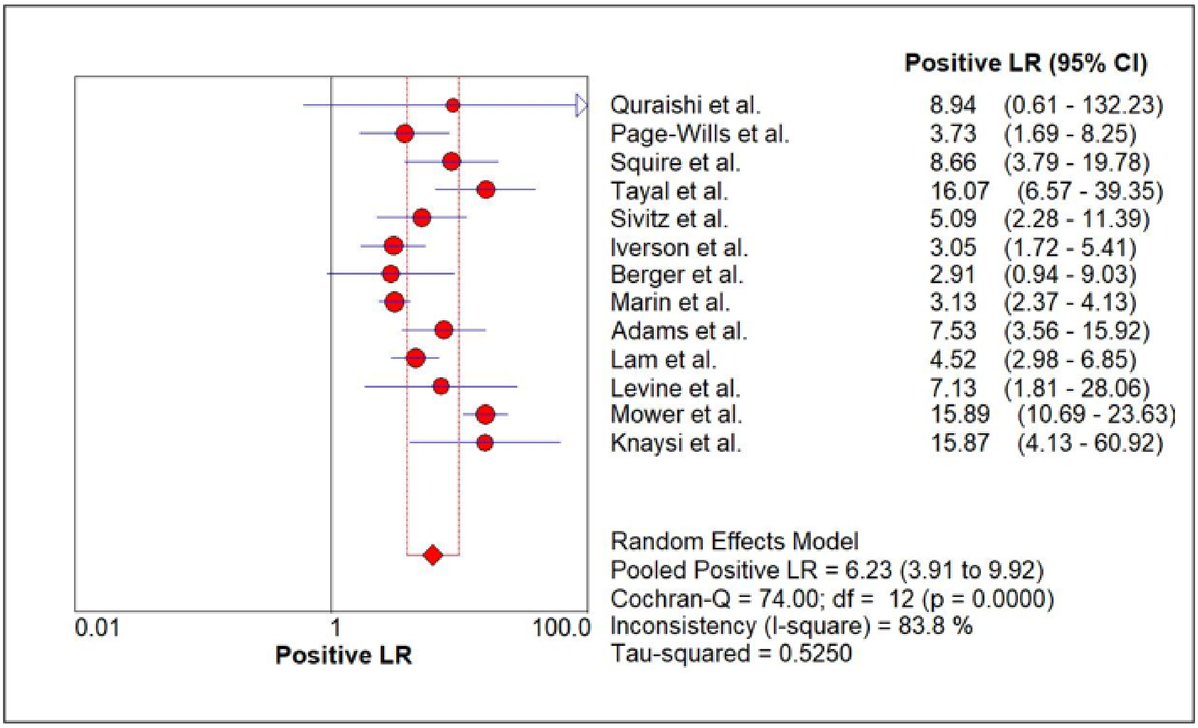

Figure 4: Forest plot of the pooled positive likelihood ratio (LR) of point-of-care ultrasonography for diagnosis of abscess. CI: confidence interval.

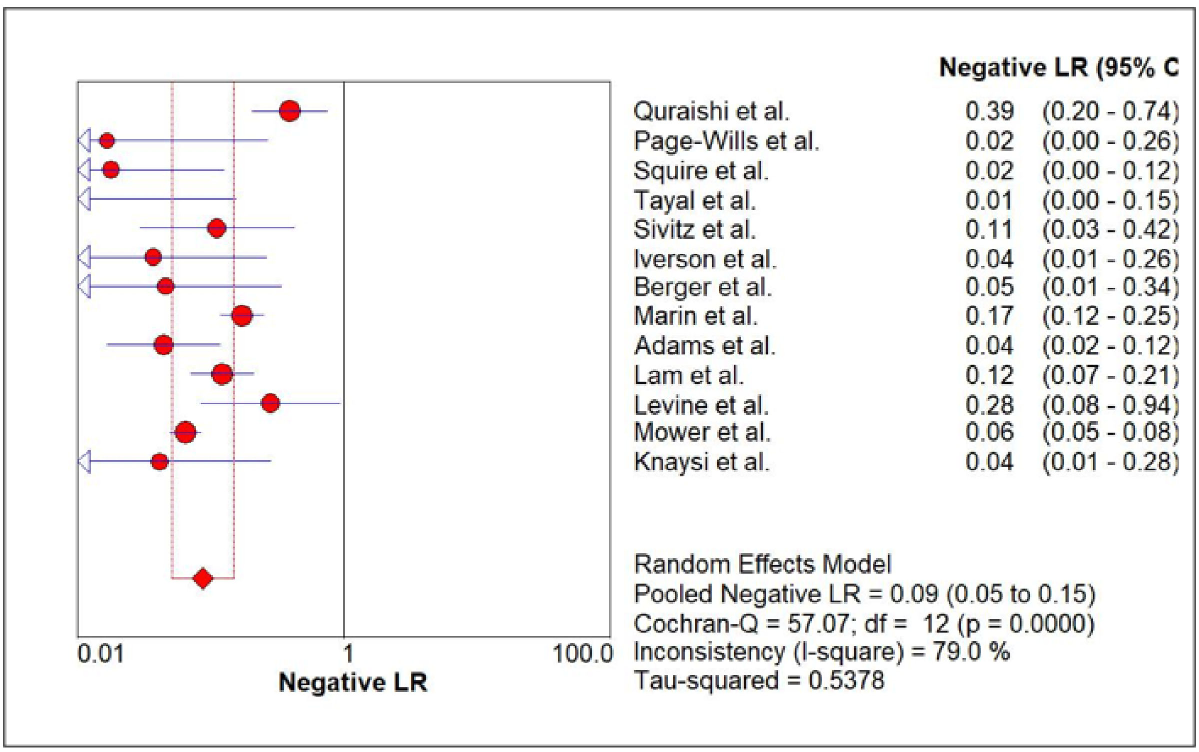

Figure 5: Forest plot of the pooled negative likelihood ratio (LR) of point-of-care ultrasonography for diagnosis of abscess. CI: confidence interval.

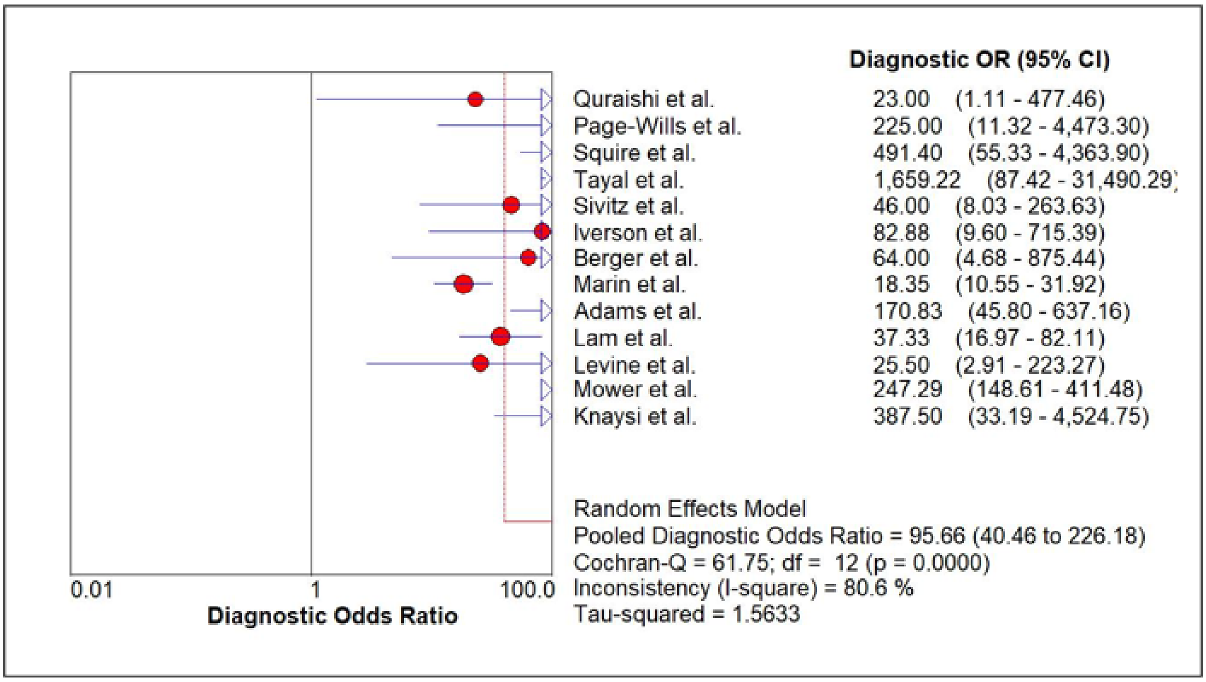

Figure 6: Forest plot of the diagnostic odds ratio (OR) of point-of-care ultrasonography for diagnosis of abscess. CI: confidence interval.

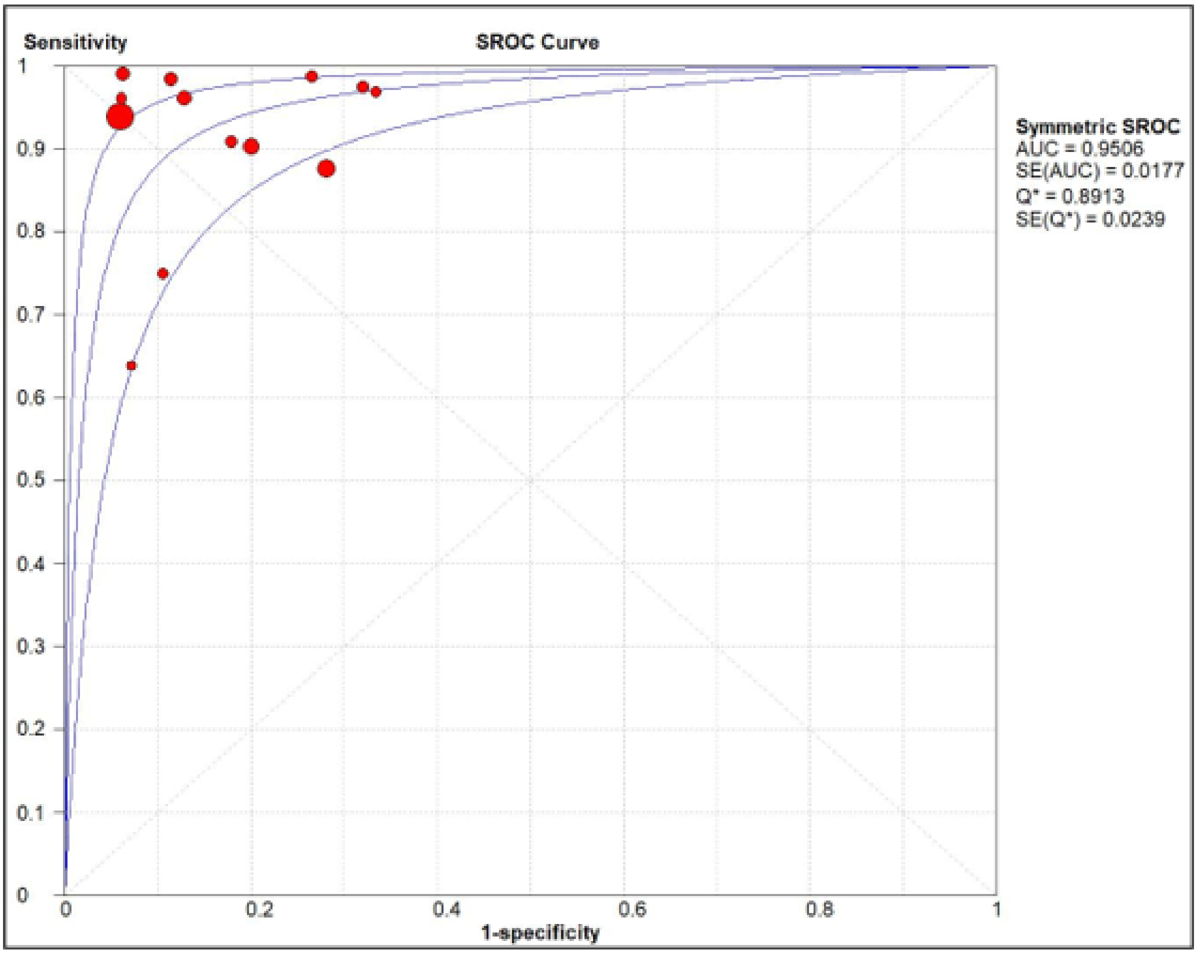

Figure 7: Summary receiver-operating characteristic (SROC) curve of point-of-care ultrasonography for diagnosis of abscess. AUC: area under the curve. SE: standard error.

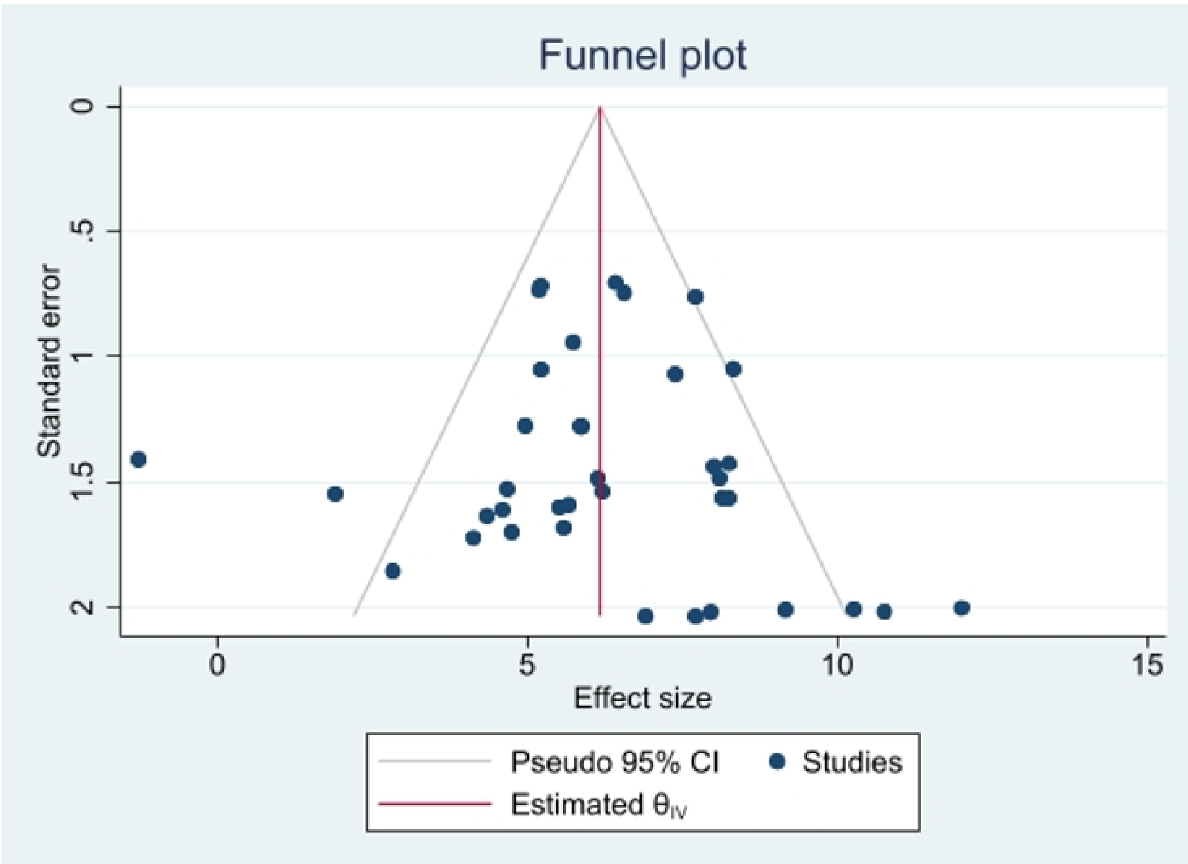

Figure 8: Funnel plot of publication bias on the pooled diagnostic odds ratio of point-of-care ultrasonography for diagnosis of abscess. CI: confidence interval.