Emergency Physician Ultrasonography for Evaluating Patients at Risk for Ectopic Pregnancy: A Meta-Analysis

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Study objective: Ectopic pregnancy is a common concern in emergency departments (EDs) and remains the leading cause of first-trimester mortality. Pelvic ultrasonography by emergency physicians has been investigated as a diagnostic test for ectopic pregnancy. We present a meta-analysis of the use of emergency physician ultrasonography in the evaluation of patients at risk of ectopic pregnancy.

Methods: A structured search was performed of both MEDLINE and EMBASE. Inclusion criteria were that (1) the study reported original research on ED patients at risk for ectopic pregnancy; (2) an emergency physician performed and interpreted the initial pelvic ultrasonography; and (3) follow-up was conducted on all patients. Sensitivity was defined as the proportion of patients with ectopic pregnancy for which ED ultrasonography demonstrated no intrauterine pregnancy. A random-effects model was used to obtain summary test characteristics.

Results: The initial search showed 576 publications, abstract review yielded 60 with potential relevance, and 10 studies were included. There was a total of 2,057 patients, of whom 152 (7.5%) had ectopic pregnancy. The pooled sensitivity estimate was 99.3% (95% confidence interval [CI] 96.6% to 100%), negative predictive value was 99.96% (95% CI 99.6% to 100%), and negative likelihood ratio was 0.08 (95% CI 0.025 to 0.25), all without significant heterogeneity.

Conclusion: The results of this meta-analysis suggest that in a wide variety of clinical settings, the use of bedside ultrasonography performed by emergency physicians as a diagnostic test for ectopic pregnancy provides excellent sensitivity and negative predictive value. Visualization of an intrauterine pregnancy by an emergency physician is generally sufficient to rule out ectopic pregnancy. [Ann Emerg Med. 2010;56:674-683.]

Please see page 675 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background and Importance

Ectopic pregnancy is a common, life-threatening condition, with approximately 100,000 cases per year in the United States.[1,2] It is the leading cause of first-trimester maternal death and is associated with an estimated $1.1 billion cost annually.[3-5] Early, accurate detection of ectopic pregnancy is critical to decrease morbidity and mortality and reduces costs associated with repeated emergency department (ED) visits, hospitalization, emergency and radical surgery, and future infertility evaluation and treatment.[6-8] Research and clinical practice have demonstrated a clear role for pelvic ultrasonography examination for patients at risk for ectopic pregnancy. For patients presenting to the ED, these examinations have traditionally been performed by radiology or gynecology consultants. However, consultant imaging may require significant time, patient transport, and availability of a medical sonographer and radiologist to perform and interpret the examination.

Throughout the last 2 decades, in an attempt to increase efficiency and decrease cost, emergency physicians have begun to perform and interpret limited pelvic ultrasonography studies for their patients at risk of ectopic pregnancy.[9] The real value of this approach is to identify an intrauterine pregnancy and thus eliminate the possibility of ectopic pregnancy (because heterotopic pregnancy is estimated to be rare, approximately 1 in 4,000 natural pregnancies).[2] Because ultrasonographic training and experience are limited compared with that for radiology or gynecology, several original research studies have investigated the accuracy of pelvic ultrasonography performed

Editor's Capsule Summary

What is already known on this topic

The Accreditation Council for Graduate Medical Education requires bedside ultrasonography as a core competency for emergency physician training. In addition, a recent systematic review reported that emergency department (ED) ultrasonography is 98% specific and 90% sensitive for detecting intrauterine pregnancies.

What question this study addressed

How sensitive is emergency physician–performed ultrasonography to rule out ectopic pregnancy?

What this study adds to our knowledge

This meta-analysis pooled 2,057 patients from 10 studies and found that emergency department ultrasonography was 99% sensitive for ectopic pregnancy.

How this is relevant to clinical practice

The studies that compose this meta-analysis demonstrate that emergency physicians can accurately perform limited pelvic ultrasonography to rule out ectopic pregnancy and do not need to wait for formal radiologic confirmation by a specialist.

by emergency physicians. These studies have generally shown both high sensitivity and negative predictive value as a screening test for ruling out ectopic pregnancy. Pelvic ultrasonography by emergency physicians has also been shown to be cost-effective and to decrease the time patients spend in the ED.[10,11] However, the studies have all been relatively small and many have used only selected physicians or a convenience sample of patients. Thus, the appropriate role of pelvic ultrasonography by emergency physicians in the initial evaluation of suspected ectopic pregnancy remains uncertain.

Goals of This Investigation

The purpose of this systematic review and meta-analysis is to critically evaluate the current body of literature on the use of pelvic ultrasonography by emergency physicians in the evaluation of ectopic pregnancy. The primary outcomes of interest are the sensitivity and negative predictive value of this test when performed by emergency physicians to better assess its appropriateness as a screening examination for ectopic pregnancy.

MATERIALS AND METHODS
Study Design

The design and results of this systematic review conform to the recommendations from the Meta-analysis of Observational Studies in Epidemiology statement.[12] This study was approved as exempt by the institutional review board at the University of California, San Francisco.

A comprehensive librarian-assisted literature search was performed of MEDLINE and EMBASE. The literature search retrieved citations from January 1966 to August 2009 in all languages and limited to human subjects. The search terms (including truncation) were "ectopic pregnancy," "ultrasound or ultrasonography or sonography," and "emergency." Additionally, we conducted online bibliographic searches of abstract submissions to *Annals of Emergency Medicine* and *Academic Emergency Medicine* from 1990 through August 2009. The bibliographies of articles identified through electronic searches were further reviewed for additional studies not previously recognized, and we conducted personal communication with investigators knowledgeable in the field to pursue unpublished studies.

Two authors (J.C.S., R.W.) performed independent reviews of all potentially relevant abstracts. Any abstract assessed by either reviewer to be potentially relevant was eligible for further review with the full article. These authors then independently reviewed these articles for inclusion criteria. Articles were included in the final analysis when both authors agreed, and discrepancies were discussed and resolved by consensus of 3 authors (J.C.S., R.W., M.A.K.). M.A.K. served as tiebreaker and reviewed only those articles in which there were discrepancies.

The following inclusion criteria were used to select articles for this review: (1) the study was original and evaluated a population of ED patients at risk for ectopic pregnancy, (2) an emergency physician performed and interpreted the initial bedside pelvic ultrasonography (transabdominal, transvaginal, or both), (3) a single or combination criterion standard (formal radiology ultrasonography, gynecology ultrasonography, radiology overread of ED ultrasonography, or clinical record review) was used for following all patients in the study, whether there was blinding or not.

Independently, 2 authors (J.C.S., R.W.) abstracted data from the included studies. Information abstracted included ED setting (university/county/community), study inclusion criteria, patient sampling (convenience/consecutive/random), prevalence of disease, and study results. The terms "false negative," "true positive," and "sensitivity/specificity" are used differently in various studies discussing ED pelvic ultrasonography in patients at risk for ectopic pregnancy. We standardized our definitions and vocabulary a priori such that we could make standardized contingency tables (Table 1). We defined the "disease" as ectopic pregnancy and "no disease" as no ectopic pregnancy. A positive ED ultrasonographic study result was defined as the absence of a definite intrauterine pregnancy. A negative ED study result was defined as a visible intrauterine pregnancy. A false-negative study result thus was one that was interpreted by an emergency physician as showing an intrauterine pregnancy

Table 1. Study contingency table with definitions.

Test Result (ED Physician)	Disease	
	Ectopic Pregnancy	No Ectopic Pregnancy
No IUP	TP	FP
IUP	FN	TN

IUP, Intrauterine pregnancy; *TP*, true positive (a study interpreted as no IUP by the ED physician that was an ectopic pregnancy); *FP*, false positive (study interpreted as no IUP by the ED physician that was not an ectopic pregnancy); *FN*, false negative (a study interpreted as IUP by the ED physician that was an ectopic pregnancy); *TN*, true negative (a study interpreted as IUP by the ED physician that was not an ectopic pregnancy).

when the patient was ultimately determined to have an ectopic pregnancy. The sensitivity of the screening pelvic ultrasonographic examination is the proportion of true-positive ED pelvic ultrasonographic examination results in those patients with ectopic pregnancy. Discrepancies were discussed and resolved by consensus of 3 authors (J.C.S., R.W., M.A.K.).

The quality characteristics of the selected studies were reviewed with the Quality Assessment of Diagnostic Accuracy Studies statement.[13,14] This 14-item checklist systematically analyzes the quality of reporting the results of tests of diagnostic accuracy. For this review, we judged the following issues as crucial to the validity of the studies: whether subjects reflect the spectrum of patients in actual clinical practice, and whether the whole patient sample or a random sample received the same reference standard regardless of the index test result. We planned a priori to evaluate sensitivity and specificity in a subgroup of studies that used an appropriate spectrum of patients, defined as using a consecutive sample of patients. We also planned to evaluate the subgroup of studies that performed a consultant ultrasonographic examination (radiologist or gynecologist) on the whole sample or random sample of the subjects.

Primary Data Analysis

Agreement between reviewers was assessed by Cohen's κ. We calculated heterogeneity and pooled test characteristics (sensitivity, specificity, positive and negative predictive value, and likelihood ratios) for pelvic ultrasonography performed by emergency physicians, using a random-effects meta-analysis model. A recent methodological development known as summary receiver operating curve analysis allows for simultaneous investigation of sensitivity and specificity characteristics with a hierarchic logistic regression model.[15-18] This approach may be complementary to the traditional analysis of isolating sensitivity and specificity because of the correlation between these test characteristics. We used the Metandi package in Stata for this comparison analysis.[19] We did not assess for publication bias because of the questionable validity of this approach when assessing diagnostic test meta-analyses.[20,21] All analyses were performed with Stata statistical software (version 10; StataCorp, College Station, TX).
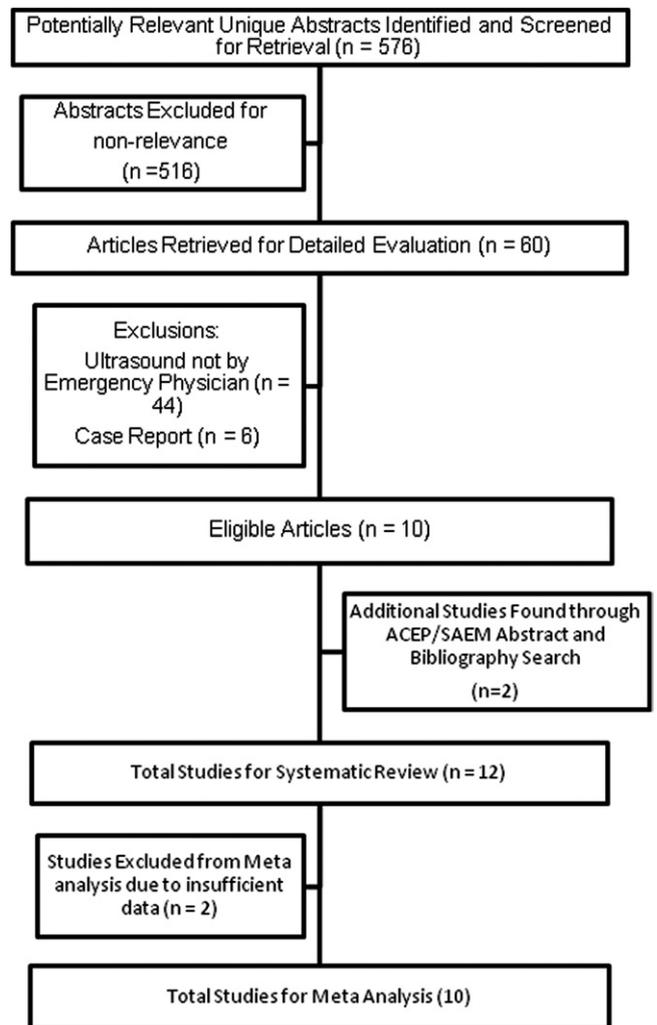

Figure 1. Flow diagram for study selection.

RESULTS

The initial MEDLINE and EMBASE search strategy yielded 576 nonduplicate publications (Figure 1). Title and abstract review yielded 60 articles with potential relevance, as assessed by at least 1 of the reviewers. There were no foreign language abstracts that did not also have an English translation, and none met criteria for relevance. The full articles for these 60 potentially relevant studies were reviewed, and after independent application of our criteria, final inclusion yielded 10 articles suitable for systematic review (99% agreement; κ=0.95; 95% confidence interval [CI] 0.84 to 1.0). Bibliographic search and research abstract submission search revealed 2 additional abstracts that met our inclusion criteria, for a total of 12 studies. Of these 12 studies, 3 did not provide sufficient information to derive 2×2 contingency tables for test characteristics. These study authors were contacted, and one replied with the necessary data,[22] which were included in the final analysis. Thus, we included 10 studies, with a total of 2,057 patients (152 patients with ectopic pregnancy) in our analysis.

Table 2. Study characteristics.

Study, First Author	Study Design	Prevalence of Ectopic Pregnancy, %	ED Setting	Participating Physicians	Training	Type of Ultrasonography	Reference Standard	QUADAS Limitations*
Burgher, 1998[44]	Retrospective	11 (5/46)	Naval teaching	Possibly all	3-Day course and 5 proctored examinations	TV	C, P	2, 4, 6, 11
Davis, 2005[22]	Prospective convenience	4 (3/70)	Urban university teaching	Possibly all	Lecture, slides, and practical—unknown time.	TA or TV	R	1, 2, 10, 11
Durham, 1997[23]	Prospective consecutive	8 (10/125)	Urban county teaching	Selected	24 h of didactic and hands-on experience	TA and TV	E, O	1, 6, 10, 11
Durston, 2000[10]	Retrospective	3 (25/790)	Kaiser HMO community	All	24 h of didactics and hands-on experience	TA or TV	C	6, 10, 11
Jehle, 1989[45]	Retrospective	3 (1/40)	Urban county teaching	Possibly all	Course to achieve "moderate level of expertise"	TA	C, O, R	1, 6, 7, 11
Mateer, 1996[29]	Prospective convenience	13 (40/300)	Urban university teaching	Selected	12 h of didactic and 10–12 proctored examinations	TV	C	1, 6, 10, 11
Moore, 2007[24]	Prospective consecutive	12 (28/242)	Urban university teaching	All	3 h of didactic and ongoing didactics and practicals	TA	C, P	6, 11
Shih, 1997[11]	Prospective convenience	8 (6/74)	Kaiser HMO community	Selected	24 h of didactic and hands-on plus 10 proctored examinations	TA or TV	C	1, 6, 10, 11
Stein, 2009[28]	Prospective consecutive	9 (20/227)	Urban university teaching	All	American College of Emergency Physicians Guidelines	TA and TV	C, R	6, 10, 11
Wong, 1998[25]	Prospective consecutive	3 (5/143)	Urban teaching	All	On-the-job training	TA	G	6, 11

QUADAS, Quality Assessment of Diagnostic Accuracy Studies; *TV*, transvaginal sonography; *C*, clinical record follow-up; *P*, telephone follow-up; *TA*, transabdominal sonography; *R*, radiology ultrasonography; *E*, emergency physician overread; *O*, radiology overread; *HMO*, health maintenance organization; *G*, gynecology ultrasonography.

*Numbers are from the QUADAS tool.[13,14] 1=Sample possibly not representative of all ED patients, 2=selection criteria not clearly described, 6=patients did not all receive same reference standard, 7=reference standard potentially not independent of the index test, 10=index test not clearly blinded to reference result, 11=reference result not clearly blinded to index test.

Characteristics of Study Subjects

The prevalence of ectopic pregnancy in these 10 studies ranged from 3% to 13%, with a median prevalence of 8.1% (95% CI 3.8% to 11.6%). A variety of study designs were used (Table 2). The majority (7) were prospective in nature, and 4 of these used consecutive patient design. The studies were conducted in a broad range of practice settings, including mostly academic medical centers (58% of patients) but also 2 community hospitals (42% of patients). A variety of educational processes were used to train emergency physicians in performing and interpreting the ultrasonographic results. Training typically consisted of a brief didactic course, followed by a variable number of hands-on cases or proctored examinations. The majority of studies used all or nearly all the emergency physicians in the department in their studies. The majority of the studies reported the use of transvaginal ultrasonography, but 3 used exclusively transabdominal sonography.

Of the 10 included studies, 7 demonstrated reported sensitivities and negative predictive values of 100%. In each of the studies by Durham et al,[23] Moore et al,[24] and Wong et al,[25] there was 1 patient whose emergency physician interpreted a definite intrauterine pregnancy when the patient ultimately was diagnosed with ectopic pregnancy (in the case of Moore et al,[24] it was a heterotopic pregnancy). With a random-effects model, sensitivity (Figure 2) demonstrated excellent homogeneity (I^2=0.0%; P=.96) and revealed a pooled estimate of 99.3% (95% CI 96.6% to 100%). The negative predictive value (Figure 3) also demonstrated excellent homogeneity (I^2=0.0%;

P=.996), with overall estimate of 99.96% (95% CI 99.6% to 100%). The negative likelihood ratio was 0.08 (95% CI 0.025 to 0.25).

There was significant heterogeneity in both the specificity analysis (I^2=94.9%; P<.001) and the positive predictive value analysis (I^2=63.6%; P=.003). Because this implies that the studies are dissimilar for these particular test characteristics, summary statistics are not presented (Figures 4 and 5). Overall, emergency physicians were able to rule out ectopic pregnancy in between 38% and 74% of cases that were screened. But there was heterogeneity within these results as well (I^2=94.9%; P<.001), and thus no further pooled estimate is presented.

When we reanalyzed the data with the summary receiver operating curve analysis, our results were similar (Figure 6). The sensitivity was 97% (95% CI 92% to 99%), and the specificity was 71% (95% CI 60% to 80%). The pooled diagnostic odds ratio was 116 (95% CI 27 to 497).[26,27] The diagnostic odds ratio represents the odds of a positive test result in patients with ectopic pregnancy relative to the odds of a positive test result in patients without ectopic pregnancy. It combines the strengths of sensitivity and specificity to yield the overall accuracy. Our high diagnostic odds ratio indicates overall excellent accuracy, but there is significant width in the CI, likely because of the heterogeneity in the specificity. In our case, because the importance of the test lies in reducing false negative results (a bedside ultrasonography diagnosis of intrauterine pregnancy that is truly an ectopic pregnancy), the sensitivity, negative
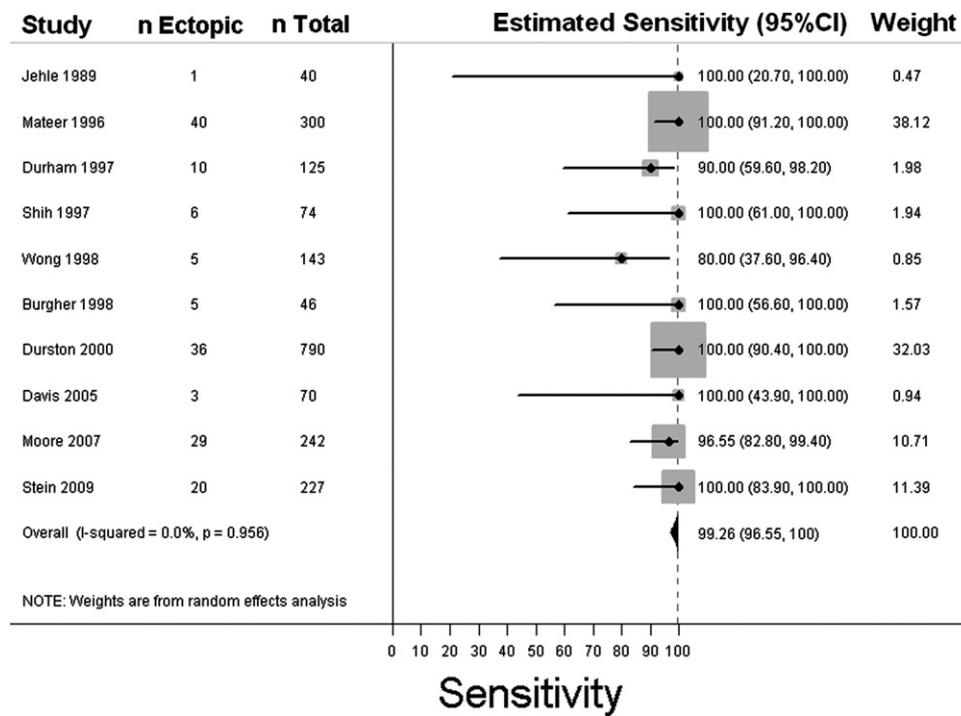
Figure 2. Sensitivity.

Figure 3. Negative predictive value.

predictive value, and negative likelihood ratio are more important indicators of test performance.

Our first subgroup analysis focused on the issue of the appropriate spectrum of patients. We chose the subgroup of studies that attempted to prospectively enroll consecutive patients (ie, pertinent to the first Quality Assessment of Diagnostic Accuracy Studies limitation) to best approximate true clinical conditions.[23-25,28] A pooled analysis of 737 patients in the 4 studies that did not have this Quality Assessment of Diagnostic Accuracy Studies limitation revealed no meaningful

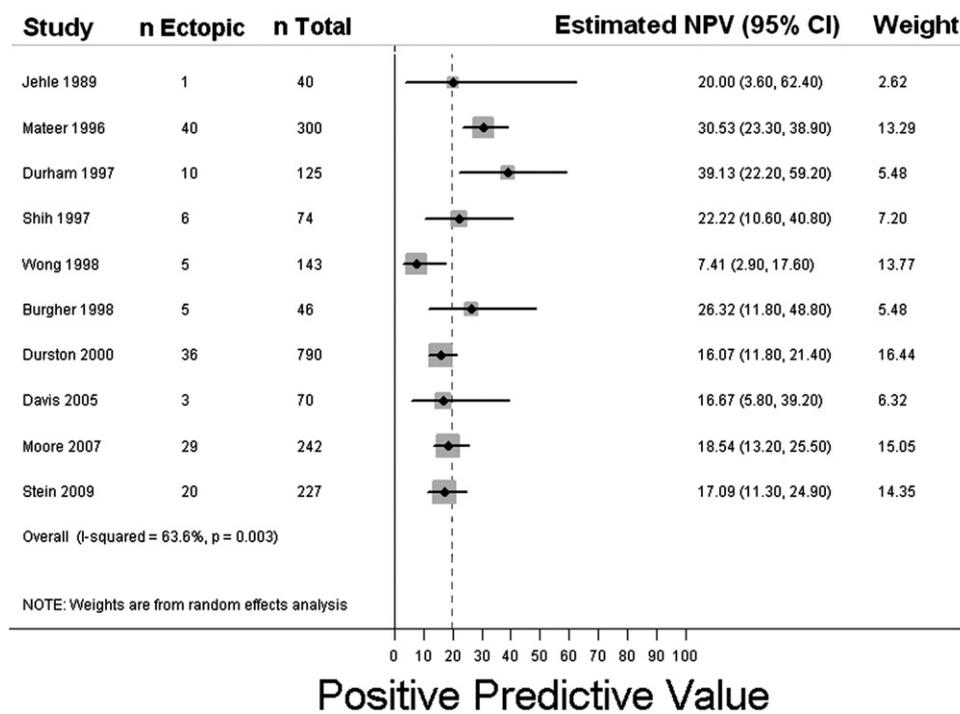| Study	n Ectopic	n Total	Estimated Specificity (95% CI)	Weight
Jehle 1989	1	40	89.74 (76.40, 95.90)	9.70
Mateer 1996	40	300	65.00 (59.00, 70.50)	10.48
Durham 1997	10	125	87.83 (80.60, 92.60)	10.44
Shih 1997	6	74	69.12 (57.40, 78.80)	9.48
Wong 1998	5	143	63.77 (55.50, 71.30)	10.09
Burgher 1998	5	46	65.85 (50.50, 78.40)	8.66
Durston 2000	36	790	75.07 (71.90, 78.00)	10.81
Davis 2005	3	70	77.61 (66.30, 85.90)	9.69
Moore 2007	29	242	42.25 (35.80, 49.00)	10.34
Stein 2009	20	227	53.14 (46.30, 59.80)	10.31
Overall (I-squared = 94.4%, p = 0.000)				

NOTE: Weights are from random effects analysis

0 10 20 30 40 50 60 70 80 90 100

Specificity

Figure 4. Specificity.

Study	n Ectopic	n Total	Estimated NPV (95% CI)	Weight
Jehle 1989	1	40	20.00 (3.60, 62.40)	2.62
Mateer 1996	40	300	30.53 (23.30, 38.90)	13.29
Durham 1997	10	125	39.13 (22.20, 59.20)	5.48
Shih 1997	6	74	22.22 (10.60, 40.80)	7.20
Wong 1998	5	143	7.41 (2.90, 17.60)	13.77
Burgher 1998	5	46	26.32 (11.80, 48.80)	5.48
Durston 2000	36	790	16.07 (11.80, 21.40)	16.44
Davis 2005	3	70	16.67 (5.80, 39.20)	6.32
Moore 2007	29	242	18.54 (13.20, 25.50)	15.05
Stein 2009	20	227	17.09 (11.30, 24.90)	14.35
Overall (I-squared = 63.6%, p = 0.003)				

NOTE: Weights are from random effects analysis

0 10 20 30 40 50 60 70 80 90 100

Positive Predictive Value

Figure 5. Positive predictive value.

difference from the overall result (other than the expected wider CIs). Sensitivity showed no significant heterogeneity ($I^2=0.0\%$; $P=.51$) and showed an estimate of 97.0% (95% CI 91.6% to 100%). Negative predictive value also showed no significant heterogeneity ($I^2=0.0\%$; $P=.85$) and showed an estimate of 99.4% (95% CI 98.3% to 100%). Specificity and positive predictive value continued to reveal heterogeneity.

Our second planned subgroup analysis was to be done on those studies that performed the same reference standard (radiology ultrasonography) on all subjects regardless of the
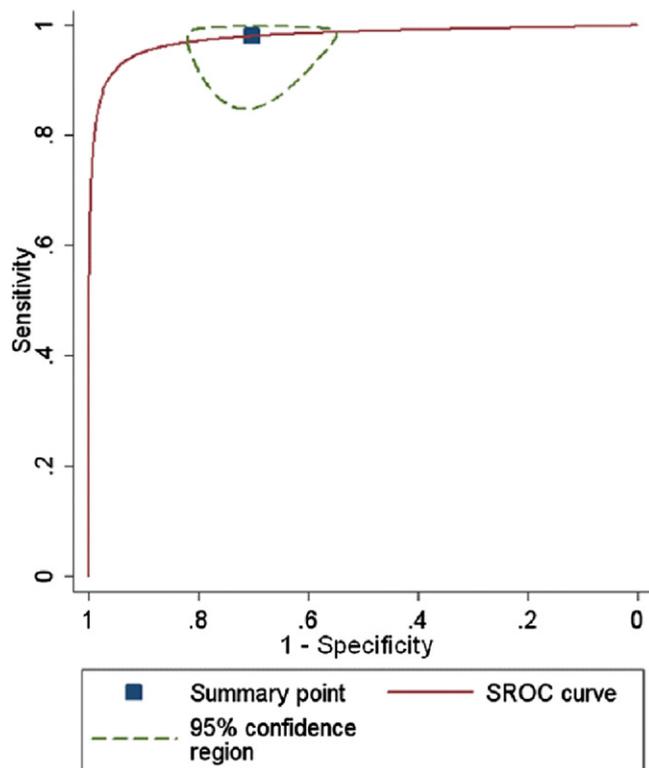
Figure 6. Summary receiver operating characteristic plot. The figure shows the summary curve, along with the point estimate and the 95% confidence region.

results of the index test. We were able to find only 1 study that clearly met this requirement,[22] and thus we were unable to summarize further.

Sequential exclusion of each study from the analysis resulted in only minor changes in the pooled test characteristics, including exclusion of the study with the most influence, Mateer et al,[29] which resulted in a sensitivity of 98.8% (95% CI 95.4% to 100%), without evidence of heterogeneity (I^2=0.0%; P=.93).

LIMITATIONS

Although meta-analysis allows for the combination of several underpowered studies to increase sample size and subsequently the confidence of the summary findings, the results of a meta-analysis must be viewed with caution. Summary statistics incorporate the biases of the individual trials and potentially create new sources of bias through study selection and study heterogeneity. As a result, up to 35% of meta-analyses prove to be flawed after large clinical trials are performed.[30]

Although we performed a comprehensive literature search, our analysis may still contain publication bias. In an attempt to minimize publication bias, we included both research abstracts and published studies. Nonetheless, it is likely that smaller studies exist that have been performed, but not published or presented at scientific meetings. It is unclear whether the exclusion of these data would lead us to under- or overestimate

the sensitivity or negative predictive value of ultrasonography for excluding ectopic pregnancy. We did not pursue statistical analysis of publication bias because the validity of this approach when assessing diagnostic test meta-analyses is questionable.[20,21]

The studies themselves have significant limitations that might affect the results of our analysis. Most important, only 1 of the studies in this analysis applied a consistent reference standard independent of the emergency physician ultrasonography. In most studies, patients with an initial pelvic ultrasonography result showing an intrauterine pregnancy had clinical follow-up, whereas patients without an initial intrauterine pregnancy often had immediate radiology ultrasonography or obstetrics/gynecology consultation. It is likely that this leads to a form of verification bias sometimes referred to as double criterion standard bias.[31] This can artificially increase the sensitivity of the screening test.

DISCUSSION

To our knowledge, this is the first meta-analysis of the test performance characteristics of emergency physician ultrasonography as a diagnostic test for ectopic pregnancy. Because screening tests rely on the ability of the test to exclude disease, sensitivity, negative predictive value, and negative likelihood ratio are the most important test characteristics to consider. The results of this analysis suggest excellent sensitivity, negative predictive value, and negative likelihood ratio values across a wide variety of practice environments.

Previous individual studies investigating the use of emergency physician–performed ultrasonography in the evaluation of ectopic pregnancy have demonstrated excellent test performance but were limited by their single-center nature and their sample size. There have been 2 previous systematic reviews on this topic. The first effort was by the Canadian Coordinating Office for Health Technology Assessment in 2006,[32] which assessed portable ultrasonographic technology used by emergency physicians in 3 settings: abdominal trauma, ectopic pregnancy, and abdominal aortic aneurysm. They reviewed 5 of the studies that we included[10,11,23,25,29] and reported average test characteristics (negative predictive value 98.3, 95% CI 96.3 to 99.2; and negative likelihood ratio 0.08, 95% CI 0.04 to 0.17) but did not perform formal meta-analysis of their results, and thus we cannot assess for heterogeneity. Nevertheless, their findings were similar to ours. The second attempt to summarize these data was conducted by McRae et al[33] and published in 2009. The analysis included 3 of the studies in our review[23,25,29] and was unable to generate summary statistics because of heterogeneity. It defined disease as intrauterine pregnancy and a true-positive test result as a definite intrauterine pregnancy and thus did not evaluate pelvic ultrasonography by emergency physicians as a traditional screening test for ectopic pregnancy.

Our study, in contrast, assesses the evidence for using emergency physician–performed ultrasonography as a screening test for ruling out ectopic pregnancy. By standardizing testing vocabulary such that a negative study result for ectopic

pregnancy was one in which an intrauterine pregnancy was clearly identified by the emergency physician, the sensitivity, negative predictive value, and negative likelihood ratio for ruling out ectopic pregnancy can be evaluated and summary statistics generated. Across the 10 studies that met our inclusion criteria, the prevalence of disease ranged from 3% to 13%, with a mean prevalence of 7.5% (95% CI 6.4% to 8.8%). As a result, using our pooled negative likelihood ratio of 0.08 and our prevalence of 7.5%, the identification of an intrauterine pregnancy by an emergency physician in this clinical setting would yield a posttest probability of ectopic pregnancy of 0.6%. Even if one were to consider a population with an overall prevalence of 15%, greater than that observed in any of these ED-based studies, then the posttest probability of ectopic pregnancy after identification of an intrauterine pregnancy would be 1.3%. This level of certainty is likely to meet the needs of the majority of emergency physicians and approximates the sensitivity, negative predictive value, and negative likelihood ratio reported by radiologists and gynecologists.[2]

Although screening tests largely rely on high sensitivity and negative predictive value, the specificity is important to consider. In this case, the specificity refers to the probability that a woman without an ectopic pregnancy will have an ED ultrasonographic result that demonstrates an intrauterine pregnancy. Patients without ectopic pregnancy can have normal or abnormal intrauterine pregnancy (ie, spontaneous abortion) or molar pregnancies. One explanation for the heterogeneity in specificity may have been because the mix of these entities in the non–ectopic pregnancy populations varied from study to study. It is also possible that different study designs were biased in one direction or another in terms of specificity. For example, studies that used only selected emergency physicians with high level of training (Registered Diagnostic Medical Sonographer) may be more likely to have higher specificity.

Because of the range of practices and training methods represented in the current analysis, it is likely that our results are generalizable. A previous meta-analysis of ultrasonography by emergency physicians in the setting of evaluating patients at risk of deep venous thrombosis found that a significant limitation of their data was that it was collected only at academic medical centers in which ultrasonographic skill of the provider is likely higher than that of most community emergency physicians.[34] As can be seen in Table 2, in our analysis, many studies were performed at academic medical centers, but 2 were conducted at community health maintenance organization settings, and these accounted for 42% of the patient cases analyzed. Despite these practice variations, we were unable to find any significant heterogeneity of sensitivity or negative predictive value. The concern about nongeneralizable skill of ultrasonographic providers was also the reason for identifying a subgroup of studies that enrolled consecutive patients, which generally requires the entire physician staff to perform the ultrasonographic studies; this avoids the situation in which only the most interested, most highly trained emergency physicians

are the ones performing the examinations. Our findings here showed 4 studies, and the results again appear to be robust because the pooled estimates are nearly identical.

Diagnostic ultrasonography has increasingly been used in the emergency diagnosis and management of a wide variety of conditions during the past 2 decades, findings that led the American College of Emergency Physicians to issue resolutions calling for 24-hour availability of ultrasonography for ED patients.[35,36] Yet survey data during subsequent years suggest that emergency access to radiology department ultrasonography continues to be unreliable, particularly outside of regular business hours.[35-43] Emergency physicians have recognized a need for improving access to ultrasonographic technology and have been investigating its use at the bedside.[9] As a result, it is a mandate of the Accreditation Council for Graduate Medical Education that emergency medicine residency programs include bedside ultrasonographic education as a part of training, and pelvic ultrasonography is a standard part of the ultrasonographic curriculum in most emergency medicine residency programs. Outside of academic centers, national estimates show that approximately 19% of community EDs in the United States have an ultrasonographic machine available for bedside use.[37] What remains at this point is to provide evidence that this practice is safe across a wide range of practice environments and that it improves (or does not worsen) patient outcomes. Our study attempts to systematically review the use of ultrasonography by emergency physicians as a screening test for ectopic pregnancy to further the goal of providing evidence that the test performance is not only robust across a wide variety of study populations and physician groups but also of an acceptable range for use in clinical practice. Although our results appear promising, there remains a need for properly designed comparative studies that include prospective consecutive enrollment in multiple centers, with appropriate patient follow-up to assess clinically important outcomes such as morbidity (rates of rupture and rates of unexpected return visits to health care settings) and mortality. We hope that the widespread use of this technology in academic medical centers does not preclude such a study.

This systematic review demonstrates that the use of bedside ultrasonography performed by emergency physicians consistently exhibits excellent test characteristics for ruling out ectopic pregnancy in a wide variety of clinical settings. These findings support the appropriate use of pelvic ultrasonography by emergency physicians in clinical practice.

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