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ORIGINAL ARTICLE

The use of additional imaging studies after biliary point-of-care ultrasound in the emergency department

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Abstract

Purpose We sought to determine the test characteristics of biliary point-of-care ultrasound (POCUS) and to assess the usefulness of obtaining radiology ultrasound (RUS) or cholescintigraphy (HIDA) after biliary POCUS.

Methods We conducted a retrospective review of emergency department patients who underwent biliary POCUS between May 4, 2018 and November 28, 2021. To be included, patients had to have at least one of the following confirmatory evaluations (considered in this order): surgery, HIDA, RUS, or abdominal CT scan. When a discrepancy existed between the POCUS and the RUS or HIDA, they were compared to a higher criterion standard (if available).

Results Using 348 patients who had a confirmatory evaluation after biliary POCUS, we found the sensitivity and specificity of biliary POCUS for gallstones to be 97.0% (95% CI 92.6 to 99.2%) and 99.5% (95% CI 97.3 to 100%), respectively. For cholecystitis, the sensitivity and specificity were 83.8% (95% CI 72.9 to 91.6%) and 98.6% (95% CI 96.4 to 99.6%), respectively. RUS and POCUS were concordant in 72 (81.8%) of 88 cases in which the patient had both studies while HIDA and POCUS were concordant in 24 (70.6%) of 34 cases. POCUS was deemed correct in at least 50% of discrepant cases with RUS and at least 30% of discrepant cases with HIDA.

Conclusion Biliary POCUS has excellent sensitivity and specificity for cholelithiasis; it has lower sensitivity for cholecystitis, but the specificity remains high. Performing a confirmatory RUS or cholescintigraphy after a positive biliary POCUS adds little value, but additional imaging may be useful when POCUS is negative for cholecystitis.

Keywords Cholecystitis · Gallstones · Point-of-care ultrasound · HIDA · Sensitivity · Specificity

Introduction

Cholelithiasis is a common condition in the emergency department (ED) and affects more than 20 million Americans each year [1]. Emergency physicians frequently assess patients with epigastric or right upper quadrant abdominal pain, and they must determine if the patients' pain is from cholelithiasis, cholecystitis, or other pathology. Cholescintigraphy (also known as a hepatobiliary iminodiacetic acid [HIDA] scan) has been reported to be the most accurate imaging modality for acute cholecystitis [2], with one meta-analysis reporting a sensitivity of 96% and a specificity of 90% [3]. However, ultrasound is less expensive and less invasive, so emergency medicine, radiology, and surgical societies recommend that ultrasound be used as the first-line imaging investigation for acute cholecystitis [4–6].

While traditionally, ultrasound has been performed by the radiology department, a number of studies have found that emergency physician-performed point-of-care ultrasound (POCUS) for biliary disease achieves a sensitivity and specificity that is similar to that of radiology ultrasound (RUS) [7–12]. In particular, one systematic review reported a sensitivity of 89.8% and a specificity of 88.0% of emergency physician–performed biliary POCUS for cholelithiasis [11]. However, a Canadian study found a sensitivity of only 67.1% of biliary POCUS for cholecystitis [13], which raises concerns that biliary POCUS may have inadequate sensitivity to rule out cholecystitis. As such, there may be

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a role for additional advanced imaging tests after a biliary POCUS that does not show cholecystitis, but the role of those tests in that situation is unclear. Additionally, ultrasound is highly user-dependent, so, in some cases, surgeons may feel uncomfortable using the results of emergency physician–performed POCUS to decide when to perform a cholecystectomy [14]. Consequently, they may request a RUS or a different imaging study after a POCUS even when the POCUS is consistent with cholecystitis.

We thus performed a retrospective study to assess the accuracy of biliary POCUS for gallstones and cholecystitis in our hospital system. Secondarily, we sought to determine the utility of performing additional advanced imaging studies after a biliary POCUS.

Materials and methods

Study design and setting

This was a retrospective chart review of ED patients on whom a biliary POCUS was performed at our hospital or one of its two associated freestanding emergency departments. Our hospital is a community teaching hospital located in xxx; it has an annual ED volume of approximately 57,000 visits, an emergency medicine residency program, and an emergency ultrasound fellowship that started in July 2021. This study was approved with an expedited review by our hospital's institutional review board.

Data collection

In our hospital system, since May 4, 2018, images from POCUS studies have been stored in Qpath (Telexy Healthcare, Maple Ridge, BC, Canada) and our hospital's picture archiving and communication system (PACS) such that they are visible to all physicians and nonphysician providers in our hospital system. Additionally, since that date, reports with the emergency physician's interpretations of all POCUS studies have been visible in our electronic medical record system — Epic (Madison, WI). A specialist in information technology searched Epic for patients on whom a biliary POCUS was performed from May 4, 2018 until November 28, 2021.

During the study period, biliary POCUS scans were performed using the C60xp 5-2 MHz probe and the Sonosite X-Porte machine. All biliary POCUS scans were performed by emergency medicine staff and residents. Their level of training ranged from novice 1st year emergency medicine residents to attendings with fellowship training in advanced emergency ultrasound. All diagnostic POCUS studies are cosigned by an emergency physician attending that has privileges to perform biliary POCUS in our ED. Our resident POCUS training curriculum and POCUS credentialing and privileging policies are in accordance with the American College of Emergency Physicians' Ultrasound Guidelines Policy Statement from 2016 [15].

We included all patients in our analysis who had a biliary POCUS and a confirmatory evaluation within 30 days to use as a criterion standard (as described below). We excluded patients who had a cholecystectomy prior to the biliary POCUS or in whom the biliary POCUS was performed after the criterion standard test.

The medical records for each patient who had a biliary POCUS performed were reviewed by a single research assistant who was trained by the principal investigator. For each patient, the following data were collected for the visit during which the biliary POCUS was performed: level of training of the sonographer (emergency medicine resident, emergency ultrasound fellow, emergency medicine attending, or ultrasound-fellowship-trained attending), patient age, patient race/ethnicity, gender, body mass index (BMI), ED disposition, biliary POCUS results, results of other abdominal imaging tests done within 30 days of the POCUS, pathological findings specified in the operative report for the cholecystectomy (if applicable), and results of any other abdominal imaging tests done within 30 days. For each imaging test result, the research assistant categorized the results as "yes" or "no" for gallstones and yes or no for cholecystitis. Interpretations that indicated "possible cholecystitis," "concerning for cholecystitis," or something else along those lines were recorded as yes for cholecystitis. When reviewing operative reports, we specifically searched to see if gallstones were noted and whether gallbladder inflammation was noted (indicative of cholecystitis).

Previous work defined cholecystitis on biliary POCUS as gallstones plus any one of the following: wall thickening greater than 3 mm, pericholecystic fluid, or a sonographic Murphy's sign [12]. We did not require the POCUS meet these criteria, but more simply, we considered the POCUS to demonstrate cholecystitis if the person who interpreted the POCUS indicated in the medical record that they thought the POCUS showed cholecystitis.

As mentioned above, confirmatory evaluations were used if they were performed within 30 days of the biliary POCUS. This means some of them were performed on a subsequent visit to the hospital. To search for return visits to the ED and imaging tests performed after discharge, we searched Epic's Care Everywhere which allowed us to search for records outside our hospital system. We chose a relatively long follow up period of 30 days to increase the number of patients who had confirmatory evaluations.

To confirm the accuracy of the data abstraction and allow for calculation of an interrater reliability, 10% of patients were also reviewed by a physician investigator. In comparing the data collected by the research assistant to that collected

by the physician investigator, there were no discrepancies with regard to the presence or absence of gallstones on the biliary POCUS (free marginal kappa = 1.0). There was one case in which the research assistant and physician investigator disagreed on whether the biliary POCUS report indicated cholecystitis (free marginal kappa = 0.97). This case was adjudicated as positive for cholecystitis.

Study goals

The primary goal of this study was to determine the sensitivity and specificity of emergency physician–performed biliary POCUS in our hospital system. Secondarily, we sought to assess the value of performing a RUS or HIDA scan after a biliary POCUS.

Data analysis

To assess the accuracy of biliary POCUS for gallstones, we followed the algorithm shown in Fig. 1. In particular, we used the following as confirmatory evaluations: gallstone(s) noted at the time of surgery (on the operative note), gallstone(s) noted on the radiology attending's interpretation of a RUS, or gallstones(s) noted on the radiology attending's interpretation of a CT scan. These confirmatory evaluations had to be performed within 30 days of the biliary POCUS and were valued in the order that they are listed. Since ultrasound may identify gallstones not visible on CT scan [15], if the biliary POCUS was interpreted as showing gallstones but no gallstones were seen on CT scan, two ultrasound-fellowship trained faculty members acted as adjudicators. They both reviewed the biliary POCUS images while blinded to the original POCUS interpretation and the radiologist's CT scan report. If they both visualized gallstone(s) on the POCUS, it was deemed to be a true positive study. If one or neither of the reviewing faculty members identified gallstones on the POCUS images, it was deemed a false positive.

To assess the accuracy of biliary POCUS for cholecystitis, we followed the algorithm shown in Fig. 2. In particular, we used one of the following confirmatory evaluations as the criterion standard: gallbladder inflammation noted at the time of surgery (on the operative note), cystic duct obstruction noted on the radiology attending's interpretation of a HIDA scan, cholecystitis as interpreted by a radiology attending of a RUS, or cholecystitis noted on the radiology attending's interpretation of a CT scan. Again, these confirmatory evaluations had to be performed within

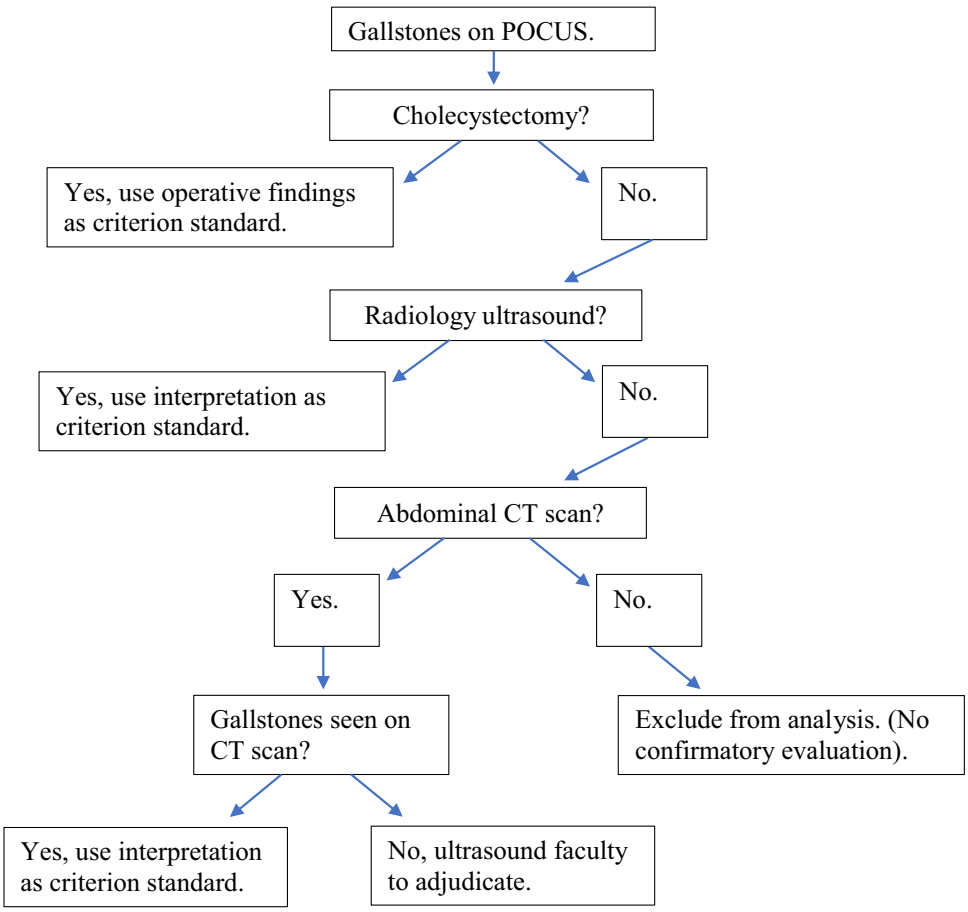

Fig. 1 Algorithm for how confirmatory evaluations were used as the criterion standard for gallstones

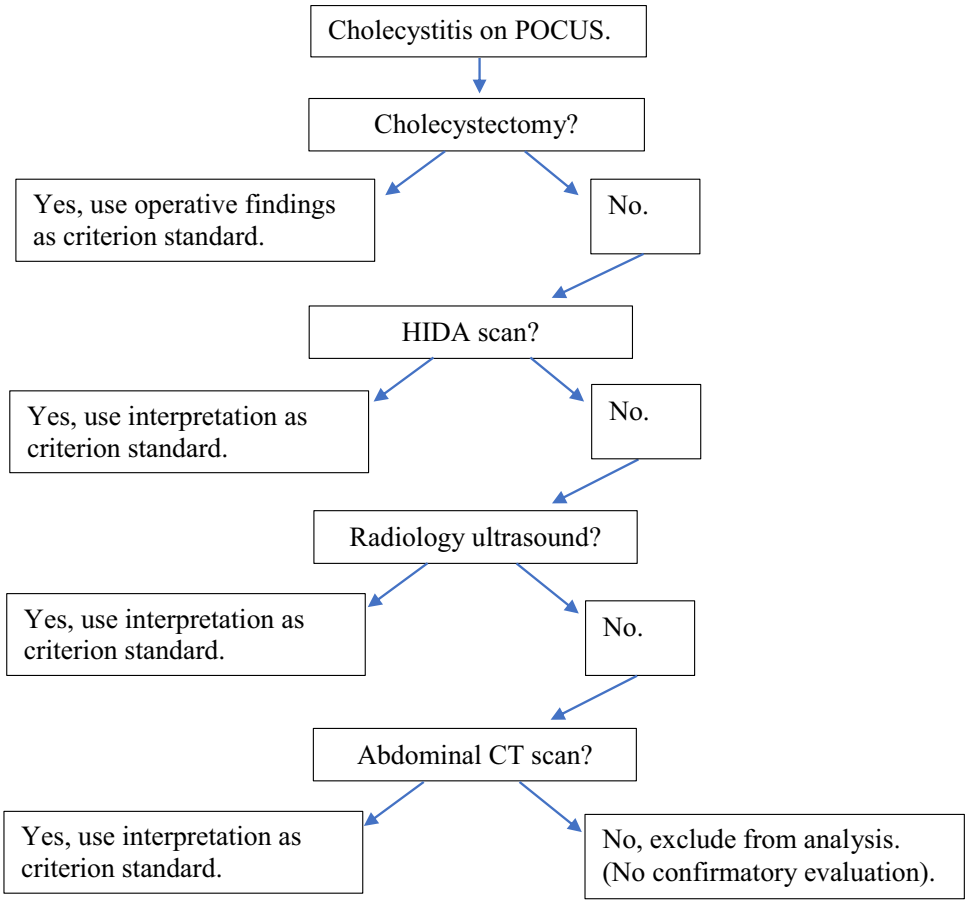

Fig. 2 Algorithm for how confirmatory evaluations were used as the criterion standard for cholecystitis

30 days of the biliary POCUS and were valued in the order that they are listed.

Finally, we individually evaluated cases in which a patient had a biliary POCUS and then had a RUS or HIDA scan to determine how often the additional imaging test correctly resulted in a change in the diagnosis. Previous studies about biliary POCUS have utilized RUS as a gold standard [7–10], and previous publications have reported HIDA scan to be the most accurate test for cholecystitis [2, 3]. However, with improving ultrasound technology and advancing technical skill among emergency physician sonographers, it is possible that POCUS is more accurate than RUS or HIDA scan. Therefore, we calculated the test characteristics for RUS and HIDA scan by comparing their results to a higher criterion standard (HIDA scan or operative report for RUS and operative report for HIDA scan). Also, for cases in which there was a discrepancy between the POCUS and the RUS or HIDA scan, we were able to adjudicate which test was correct by comparing to a higher criterion standard.

Data were aggregated in Excel (version 16.60, Microsoft, Redmond, WA) and analyzed in a statistical program called R Studio (version 2022.02.2). The sensitivity and specificity of biliary POCUS were calculated with 95% confidence intervals in the standard fashion by comparing biliary POCUS results to the highest available criterion standard.

Results

Study population and characteristics

Between May 4, 2018 and November 28, 2021, emergency medicine providers performed and documented 664 biliary POCUS exams in our medical record system (Table 1). Of the 664 patients who had a biliary POCUS, 255 (38.4%) had no confirmatory evaluation within 30 days of the POCUS, 60 (9.0%) had an additional abdominal imaging study before the POCUS, and 1 (0.2%) had already had a cholecystectomy at the time of the POCUS. These patients were excluded, leaving 348 (52.4%) of the original 664 for analysis. Notably, although we allowed for the confirmatory evaluations to have occurred up to 30 days after the POCUS, all but two of the confirmatory evaluations were done within 2 weeks of the POCUS.

A comparison of all patients who had a biliary POCUS and those who had a biliary POCUS along with a subsequent confirmatory evaluation within 30 days is shown in Table 1.

Table 1 Baseline and demographic characteristics of the patients who underwent biliary POCUS

Characteristic	Underwent biliary POCUS ($n=664$)	Underwent confirmatory evaluation[b] ($n=348$)
Median age (IQR) — yr	43 (30–57)	48 (34–60)
Male sex — no. (%)	242 (36.4)	138 (40.0)
Race — no. (%)		
White	458 (69.0)	234 (67.2)
Multiracial	84 (12.6)	44 (12.6)
Black	66 (9.9)	33 (9.5)
Other	30 (4.5)	20 (5.7)
Unknown/refused	19 (2.9)	13 (3.7)
Asian	7 (1.1)	4 (1.1)
Ethnicity —no. (%)		
Hispanic	412 (62.0)	229 (65.8)
Median body mass index (IQR)[a]	26.6 (23.5–30.5)	27.5 (24.3–32.0)
Sonographer level of		
training	411 (61.9)	215 (61.8)
Emergency medicine resident	194 (29.2)	96 (27.5)
Ultrasound attending	48 (7.2)	28 (8.0)
Emergency medicine attending	9 (1.4)	7 (2.0)
Ultrasound fellow	2 (0.3)	2 (0.6)
Physician assistant		

[a]Not documented for 52 patients

[b]HIDA scan, radiology ultrasound, CT scan, or surgical findings within 30 days of the POCUS

Overall, the POCUS studies were performed by 70 different sonographers, with the majority being performed by emergency medicine residents. Patients ranged in age from 11 to 95 years old. Notably, patients who had a confirmatory evaluation after their biliary POCUS were older, more likely to be male, and had a higher median BMI.

Test characteristics for biliary POCUS

To assess the accuracy of biliary POCUS for the presence or absence of gallstones, the following were used as criterion standard tests: 201 abdominal CT scans, 89 cholecystectomies, and 48 RUS. In 8 cases, the biliary POCUS was read as having gallstones while the CT scan was not, and no higher criterion standard test was performed. The POCUS images from each of these cases were reviewed by two ultrasound-fellowship-trained emergency physicians, and in all 8 cases, both of those physicians agreed that there were, in fact, gallstones on the POCUS. These 8 cases were thus adjudicated as being true positive studies. Accounting for these cases, POCUS had a sensitivity of 97.0% (95% CI 92.6 to 99.2%) and a specificity 99.5% (95% CI 97.3 to 100%) (Table 2). This corresponds to a positive likelihood ratio of 197 (95% CI: 28 to 1392) and a negative likelihood ratio of 0.03 (95% CI 0.01 to 0.08).

To assess the accuracy of biliary POCUS for cholecystitis, we used the following as criterion standard tests: 201 abdominal CT scans, 94 cholecystectomies, 47 RUS, and 6 HIDA scans. Overall, biliary POCUS had a sensitivity of 83.8% (95% CI 72.9 to 91.6%) and a specificity of 98.6%

Table 2 Shows the performance of biliary POCUS for gallstones (a) and cholecystitis (b)

(a)

	Gallstones on criterion standard	No gallstones on criterion standard	
Gallstones on POCUS	131	1	Sensitivity = 97.0%
No gallstones on POCUS	4	202	Specificity = 99.5%

(b)

	Cholecystitis on criterion standard	No cholecystitis on criterion standard	
Cholecystitis on POCUS	57	4	Sensitivity = 83.8%
No cholecystitis on POCUS	11	276	Specificity = 98.6%

(95% CI 96.4 to 99.6%). This corresponds to a positive likelihood ratio 59 (95% CI 22 to 156) and a negative likelihood ratio of 0.16 (95% CI 0.10 to 0.28).

Radiology ultrasound after biliary POCUS

In total, 88 patients had a RUS following a biliary POCUS. The two ultrasounds were concordant for both the presence/absence of gallstones and the presence/absence of cholecystitis in 72 of 88 cases (81.8%). For the presence/absence of gallstones alone, they were concordant in 83 of 88 (94.3%). For the presence/absence of cholecystitis alone, they were concordant in 77/88 (87.5%).

Each of the 16 cases in which there was a discrepancy between the RUS and POCUS were reviewed in detail. We considered pathologic findings from an operative report or a HIDA scan to be higher criterion standard studies, and so we used those findings (if available) to adjudicate the discrepancy between the two types of ultrasounds. In 7 of the 16 cases, no higher criterion standard evaluation was performed, so we could not make any judgment as to which ultrasound was correct. In 8 cases, patients with a discrepancy between the RUS and POCUS ended up having a cholecystectomy, and in 7 of those, the pathologic findings on the operative report were consistent with the POCUS (rather than the RUS). In one discrepant case, both the POCUS and the RUS identified gallstones, but the POCUS was read as cholecystitis while the RUS was not. This patient had a HIDA scan which was consistent with cholecystitis. This patient refused cholecystectomy. As such, overall, in 8 of 9 cases in which there was a discrepancy between the RUS and the POCUS and a higher criterion standard was available, the POCUS was deemed to be correct.

We calculated the test characteristics of RUS for cholecystitis by considering operative findings or HIDA scan results to be higher criterion standards. In doing so, we identified 20 true positives, 15 true negatives, 9 false negatives, and 3 false positives. Thus, in our sample, the sensitivity and specificity of RUS for cholecystitis were 69.0% (95% CI 49.2 to 84.7%) and 83.3% (95% CI 58.6 to 96.4%), respectively.

HIDA Scan after Biliary POCUS

In total, 34 patients had a HIDA scan after a biliary POCUS. In 24 (70.6%) of those cases, the biliary POCUS and the HIDA scan results agreed with regard to whether or not the patient had cholecystitis. In 10 cases (29.4%), there was discordance. Each of these 10 cases was reviewed in detail. In 5 of the discordant cases, the patient did not have a cholecystectomy within 30 days to allow us to determine if the POCUS or HIDA scan was, in fact, correct. However, in 5 of the discrepant cases, the patient had a cholecystectomy. In three of these cases, the patient's biliary POCUS was interpreted as showing gallstones and cholecystitis, but the HIDA scan was read as being negative for cholecystitis. In each of these three cases, gallbladder inflammation consistent with cholecystitis was noted on the operative report. In two cases, the patient's biliary POCUS was interpreted as gallstones without cholecystitis. The patient continued having pain, so a HIDA scan was performed, and it was consistent with cholecystitis. The operative reports for these two patients indicated gallbladder inflammation indicative of cholecystitis. As such, overall, in the 5 cases where a cholecystectomy was performed after a discrepancy between the biliary POCUS and the HIDA scan, the biliary POCUS was deemed to ultimately be correct in 3 of 5 (60%).

Overall, in the 34 cases in which a HIDA scan was performed, 14 (41.1%) were interpreted by the attending radiologist as being consistent with cholecystitis, and 21 (61.8%) had a cholecystectomy within 30 days of the POCUS. Using the pathologic findings on the operative report for the cholecystectomy, we found the HIDA scan to be accurate for the diagnosis of cholecystitis in 18 (85.7%) of 21 cases — 13 true positives, 3 false negatives, 5 true negatives, and 0 false positives. Using these data, we calculated the sensitivity and specificity to be 81.3% (95% CI 54.4 to 96.0%) and 100% (95% CI 47.8 to 100%), respectively.

Discussion

Our study assessed the accuracy of emergency physician–performed biliary POCUS in a community hospital system with a large number of operators of various levels of training, and it confirmed prior work that these studies are highly sensitive and specific for determining the presence or absence of gallstones [10, 11]. Similarly, our findings support prior work in that biliary POCUS is less sensitive for cholecystitis but still quite specific for the diagnosis and for the need for cholecystecomy [13, 17]. What makes our study novel was the assessment of the use of RUS and HIDA scan after biliary POCUS, and this analysis produced several interesting findings.

First, we found that emergency physician–performed POCUS was as accurate as if not more accurate than RUS of the gallbladder. Only one prospective study has compared biliary POCUS to RUS using surgical findings as a gold standard, and in that study, just as in our study, RUS was not more accurate than POCUS [12]. Most prior studies assessing the accuracy of biliary POCUS have used RUS as the criterion standard [7–10], but our data suggest that this should not be done in the future. With the increased focus on competency in the use of POCUS in emergency medicine residency programs [18] and with improved ultrasound technology, POCUS may be just as accurate as RUS in assessing for gallstones and cholecystitis. Moreover, the emergency

physician's more detailed knowledge of the patient's clinical presentation may give them an advantage in their assessment of cholecystitis versus cholelithiasis over a radiologist. At the same time, these data highlight the importance of emergency physicians providing accurate and pertinent clinical information to the radiologist reading the RUS.

The data above do not mean that there is no role for RUS of the gallbladder after a POCUS. Biliary POCUS studies are meant to determine two things: if the patient has gallstones and if they have cholecystitis. RUS of the gallbladder is a more complete assessment designed to detect a broader range of pathology. Moreover, in some cases, the physician performing the POCUS may not obtain adequate images to assess for cholecystitis, in which case proceeding with RUS would be appropriate. However, in our real-world sample of patients, the use of RUS after a biliary POCUS was at least as likely to result in a change to the incorrect diagnosis as it was to result in a change to the correct diagnosis.

Next, our study found that HIDA scans are sometimes falsely negative for cholecystitis. As such, it may be dangerous to conclude that a patient does not have cholecystitis based solely on a HIDA scan if the biliary POCUS was suggestive of cholecystitis. Prior data have suggested that short of pathological findings from surgery, HIDA scan is the most accurate test for cholecystitis [2, 19, 20]. However, these data are greater than 10 years old, and in modern day, the initiation of antibiotics at the time of POCUS diagnosis could lead to a HIDA scan that does not show cystic duct obstruction (but would have if done earlier).

Since POCUS is quite specific for cholecystitis, performing a HIDA scan after a biliary POCUS that demonstrated cholecystitis is unlikely to be helpful. A more mathematically sound strategy would be to utilize a HIDA scan if an ultrasound shows cholelithiasis (and not cholecystitis), but some features of the clinical presentation suggest possible cholecystitis. This strategy has been previously suggested in the surgical literature [20]. Another strategy would be to use CT scan after a biliary POCUS to confirm cholecystitis and to rule out other pathology. Although not the first-line test for cholecystitis, CT scan may be as sensitive [21] or more sensitive than ultrasound for cholecystitis [22, 23], especially complicated cholecystitis [24]. Also, while not evaluated in this study, it is important to mention that magnetic resonance (MR) imaging is a fairly accurate test for cholecystitis, perhaps as accurate as ultrasound [3, 21]. However, MR is more expensive and less available than ultrasound, so it is not a first-line test. MR cholangiopancreatography (MRCP) is known to be a useful and highly accurate test in evaluating choledocholithiasis or biliary obstruction [25], but the value of MR following a biliary POCUS when the concern is for cholecystitis is unclear.

We understand the hesitance that surgeons may have to take patients to perform surgery on patients based on a POCUS performed by a physician outside the radiology department since, in many places, it is still not the norm to do so. As a solution, we recommend that surgeons learn to perform their own biliary POCUS exams, as suggested the European Society of Trauma and Emergency Surgery [6], so that they need not trust another physician's ultrasound but can confirm their findings independently if they so choose.

When interpreting the results of this study, there are some limitations to consider. First of all, our calculations of the test characteristics for biliary POCUS, RUS, and HIDA scan were likely influenced by sampling bias. Most notably, since we calculated the test characteristics of RUS and HIDA scan only using a sample of patients who first had a POCUS, it is likely that the group of patients on whom these tests were performed was more complicated, which may have resulted in an underestimation of their accuracy. Additionally, CT scan was used as a criterion standard test, but CT scan is insensitive for gallstones (which are often not radio-opaque) [16, 21]. However, since we utilized direct image review of POCUS studies and included criterion standard imaging studies performed within 30 days (allowing for the possibility that some patients with missed pathology might return), we suspect that including CT scan as a criterion standard test had a minimal impact on our test characteristic estimates.

Another limitation is that more than a third of patients who had a biliary POCUS during the dates analyzed did not have a confirmatory evaluation within 30 days to use as a criterion standard, resulting in their exclusion. It is unclear how the inclusion of these patients in our analysis would have affected the results. However, given that the patients who had confirmatory evaluations were older and had higher BMIs, we would expect that patients who had confirmatory evaluations were actually more complicated and more difficult to ultrasound which might suggest the accuracy of biliary POCUS was underestimated. On the other hand, some patients may not have had a biliary POCUS at all because the sonographer felt it would be too technically difficult. Thus, as compared to a study that protocolized a biliary POCUS on all patients with suspected biliary disease, our test characteristics may overestimate the accuracy of biliary POCUS. With all that being said, our numbers represent an estimate of the test characteristics on a real-world sample of patients — those on whom the EM physicians decided to perform a biliary POCUS and document the results in the medical record.

In conclusion, our study confirms prior data in that emergency physician–performed biliary POCUS has excellent sensitivity and specificity for gallstones. Biliary POCUS is less sensitive for cholecystitis but is still very specific. Performing RUS of the gallbladder or a HIDA scan after a biliary POCUS that was interpreted as cholecystitis does not seem necessary for confirming the diagnosis. However, additional imaging may be useful in the evaluation for cholecystitis when biliary POCUS is non-diagnostic or negative.

Declarations

Competing interests The authors declare that they have no conflict of interest.

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