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Evaluation of point-of-care ultrasound use in the diagnostic approach for right upper quadrant abdominal pain management in the emergency department: a prospective study

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Abstract

Point-of-care ultrasound (PoCUS) is commonly used at the bedside in the emergency department (ED) as part of clinical examinations. Studies frequently investigate PoCUS diagnostic accuracy, although its contribution to the overall diagnostic approach is less often evaluated. The primary objective of this prospective, multicenter, cohort study was to assess the contribution of PoCUS to the overall diagnostic approach of patients with right upper quadrant abdominal pain. Two independent members of an adjudication committee, who were blind to the intervention, independently evaluated the diagnostic approaches before and after PoCUS for the same patient. The study included 62 patients admitted to the ED with non-traumatic right upper quadrant abdominal pain from September 1, 2022, to March 6, 2023. The contribution of PoCUS to the diagnostic approach was evaluated using a proportion test assuming that 75% of diagnostic approaches would be better or comparable with PoCUS. Wilcoxon signed-rank tests evaluated the impact of PoCUS on the mean number of differential diagnoses, planned treatments, and complementary diagnostic tests. Overall, 60 (97%) diagnostic approaches were comparable or better with PoCUS ($\chi^2 = 15.9$, $p < 0.01$). With PoCUS, the mean number of differential diagnoses significantly decreased by 2.3 (95% CI – 2.7 to – 1.5) ($p < 0.01$), proposed treatments by 1.3 (95% CI – 1.8 to – 0.9) ($p < 0.01$), and complementary diagnostic tests by 1.3 (95% CI – 1.7 to – 1.0) ($p < 0.01$). These findings show that PoCUS positively impacts the diagnostic approach and significantly decreases the mean number of differential diagnoses, treatments, and complementary tests.

Keywords Point of care ultrasound · Abdominal pain · Diagnostic approach · Abdominal ultrasound

Introduction

Many medical specialties and paramedical fields are increasingly using point-of-care ultrasound (PoCUS) [1–3]. As a pillar of clinical evaluation along with inspection, palpation, percussion, and auscultation [4, 5], PoCUS has now become essential in daily clinical practice [6–8]. In a position statement published in 2015, the American Academy of Emergency Medicine followed by the European Federation of Societies for Ultrasound in

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Medicine and Biology in 2016 recommended the inclusion of PoCUS in the curricula of medical schools to improve the learning of core concepts and enhance students' understanding of physical examinations [4, 5]. The integration of PoCUS into clinical examination thus raises the question of PoCUS accuracy to improve the diagnostic approach.

In daily practice, abdominal pain accounts for 7% to 10% of emergency department (ED) consultations [9], while the mean reported prevalence of abdominal pain in family physician consultations is 2.8% according to a recent systematic review [10]. In the case of abdominal pain, right upper quadrant pain evokes a large differential diagnosis. PoCUS can be a valuable tool to investigate this symptom as it can orientate the investigator toward the presence of free fluid [11], lung involvement [11–13], aortic aneurysm [14], gallbladder involvement [15, 16], hydronephrosis [17], or small bowel obstruction [18]. PoCUS can therefore be used diversely in abdominal physical examinations. Most scientific societies encourage its use to address a specific clinical question rather than to provide a diagnosis, which is usually confirmed by a comprehensive ultrasound in radiology [5, 19, 20]. For this additional reason, it is necessary to evaluate PoCUS accuracy to improve the overall diagnostic approach in addition to assessing PoCUS diagnostic accuracy itself.

The primary objective of this study is to evaluate the contribution of PoCUS to the overall diagnostic approach of patients presenting to the ED with right upper quadrant abdominal pain. The overall diagnostic approach is an entity that includes the differential diagnosis, complementary diagnostic tests, and planned treatments.

Methods

Study design

This prospective, interventional, multicenter cohort study was conducted in five EDs in Belgium (two tertiary university centers and three secondary-level hospitals) from September 1, 2022, to March 6, 2023.

This study was approved by the ethical committees of all participating centers and registered under the number B4032022000058. The interventional rather than observational nature of the study was motivated by the lack of clear guidelines in Belgium regarding the integration of PoCUS into the standard of care contrary to other countries in Europe and North America [8, 19, 21]. The manuscript was written according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [22]. The ClinicalTrials.gov identifier of this study is NCT05438654.

Study setting

Adult patients aged 18 years and older presenting to the ED with non-traumatic right upper quadrant abdominal pain were screened for inclusion. Patients suffering from pain for less than 11 days who had not undergone any complementary diagnostic tests were eligible for inclusion. Patients were not included if they failed to provide signed consent, if any reason prevented the use of ultrasound, if they were in palliative care, which jeopardized the required 1-month follow-up, or if they were pregnant. Data collection and management as well as the 1-month follow-up by telephone and with patient files were performed by trained research associates using dedicated secure software (REDCap© 12.5.72023 Vanderbilt University).

Clinical procedure

All 12 investigators were emergency physicians who were familiar with PoCUS. They underwent a 2-h refresher course on the PoCUS protocol used for this study involving the evaluation of the right lung base, Morrison pouch, aorta, right kidney, gallbladder, and bowel (Supplement Information 1). After triage and obtaining the signed consent, one investigator performed a clinical evaluation to obtain the patient's medical history and conduct a clinical examination without PoCUS. At this stage, the investigator reported bedside on a first case report form the differential diagnosis, scheduled complementary diagnostic tests and planned treatment, based on a pre-determined list of items with the possibility of adding other items if necessary; each item was associated with a certainty coefficient (0%, 20%, 40%, 60%, 80%, and 100%). The investigator also reported a certainty coefficient for the overall diagnostic approach. After sealing the first case report form in an envelope, the same investigator immediately performed PoCUS bedside according to the dedicated protocol. A second case report form identical to the first was then completed and sealed in a second envelope along with the PoCUS findings. At this point, the investigator could enlarge the PoCUS protocol to any region susceptible to contribute to the diagnostic approach. Patient demographic data were also recorded as well as the discharge diagnosis and orientation after the ED consultation.

After 1-month follow-up with patients, an initial adjudication committee comprised of two emergency physicians, who did not have access to the other study data, had to confirm or determine the final diagnosis to explain the right upper quadrant pain. In case of discrepancies, a third member was called on. Patients lost to follow-up were secondarily excluded from the study.

Evaluation procedure

After anonymizing the data, a second adjudication committee comprised of two members independent of the study evaluated the diagnostic approaches made before and after PoCUS for the same patient in light of the final diagnosis established by the initial adjudication committee. A third member was required in case of discrepancies. For this adjudication, the diagnostic approaches used for the same patient were initially randomized in two columns, one representing the diagnostic approach before PoCUS and the other after PoCUS, along with the physicians' certainty coefficients. The second adjudication committee had to determine which column reported the better diagnostic approach without knowing which one represented the diagnostic approach before or after PoCUS, meaning that the committee was blind to the intervention. The second adjudication thus evaluated the impact of PoCUS on the overall diagnostic approach, which is the primary outcome of this study. In advance, the better diagnostic approach was defined as the one with a differential diagnosis list, treatment plan, and choice of complementary diagnostic tests deemed to be more consistent with the final diagnosis given the physicians' certainty coefficients. It was also possible to consider the two diagnostic approaches to be comparable. Figure 1 depicts the study timeline. Figure 2 depicts an example of the second adjudication process.

Sample size

A sample of 59 patients was needed to show a 18% improvement in the diagnostic approach with a power of 0.9 and an alpha value of 0.05. Considering an attrition rate of 10%, the sample size needed to perform this study was 65 patients. The 18% improvement in the diagnostic process from 57 to 75% was chosen based on previous publications, which showed a 57% correct diagnosis rate based on medical history and clinical examination without PoCUS in the case of non-traumatic abdominal pain and an improvement in the diagnostic accuracy or diagnostic process from 8 to 24% with PoCUS depending on the study [23–25]. To be clinically relevant, it was assumed that 75% of diagnostic approaches would be comparable or better after PoCUS.

Statistical analysis

The software JMP Pro 16.2.0 (SAS Institute Inc.) was used to analyze the data. Patients lost to follow-up were excluded from the analysis. Continuous variables describing the study population were detailed using medians and interquartile ranges (IQR). Categorical variables were reported by category as numbers and percentages. The χ^2 test of independence was used to compare categorical variables. The Wilcoxon-Mann–Whitney test was used to compare groups for continuous variables. The significance level corresponds to a p-value of ≤ 0.05. Finally, 95% confidence intervals were calculated.

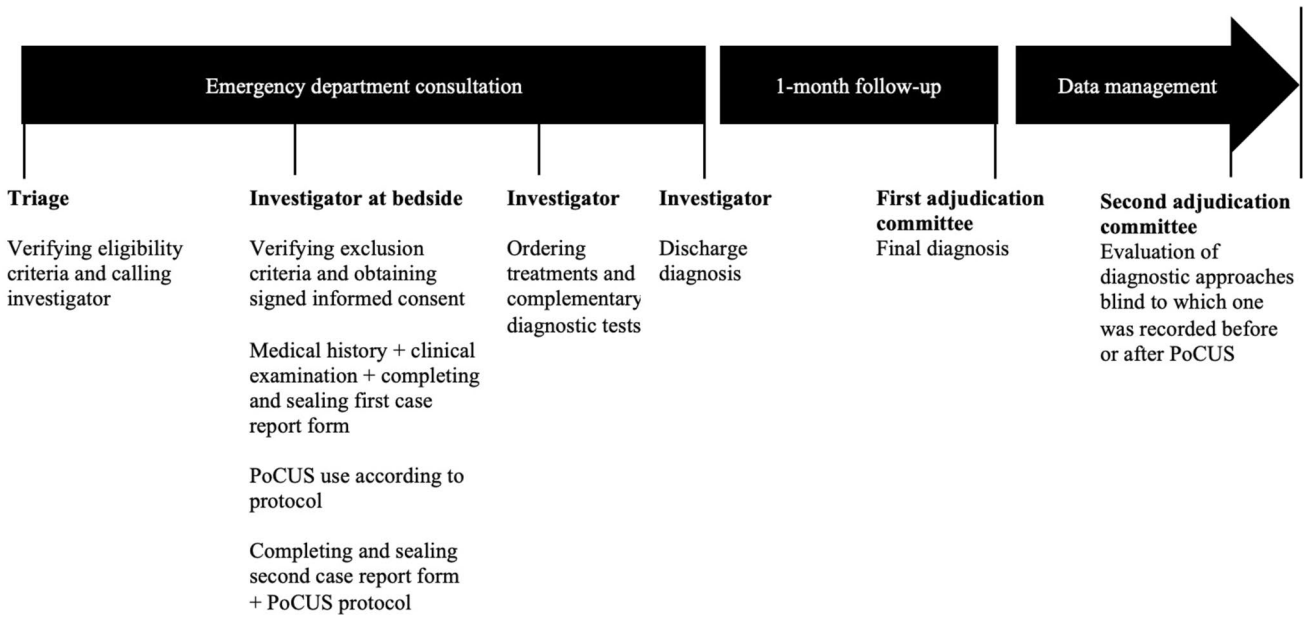

Fig. 1 Study timeline

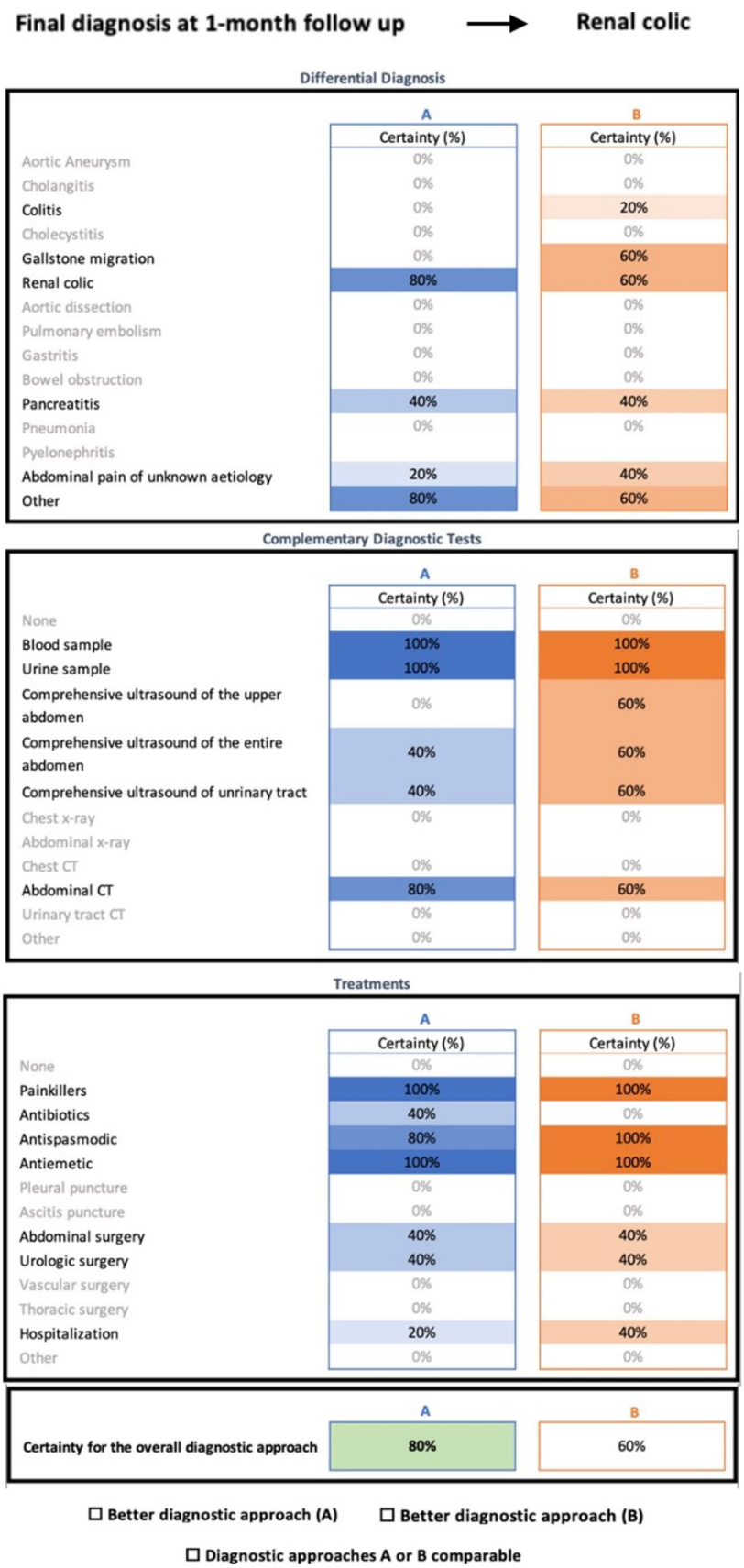

Fig. 2 Example of the second adjudication process evaluating the impact of PoCUS on the overall diagnostic approach. For each included patient, column A represents one randomized overall diagnostic approach, and column B the other. The independent members of the adjudication committee were blind to which overall diagnostic approach was performed before or after PoCUS

Primary outcome criterion

The contribution of PoCUS to the diagnostic approach as part of the clinical examination of patients presenting to the ED with right upper quadrant abdominal pain was evaluated using a proportion test. This proportion test was performed according to the hypothesis that the expected percentage of diagnostic approaches considered comparable and better after PoCUS would reach 75%.

Secondary outcome criteria

A proportion test was used to evaluate the influence of patients' baseline characteristics (body mass index, numerical pain rating scale, triage level, orientation after discharge) and the influence of PoCUS use (echogenicity, utility) and findings (pleural effusion, lung interstitial syndrome, aortic aneurysm, free abdominal fluid, gallstone, cholecystitis, hydronephrosis, bowel obstruction) on the primary outcome. The influence of the final diagnosis on the primary outcome was also evaluated. A χ^2 test was used to compare the subgroups.

A Wilcoxon test was used to evaluate the impact of PoCUS use on the physicians' certainty coefficients regarding both the overall diagnostic approach and the final diagnosis when the latter was included in the differential diagnosis list. A Wilcoxon signed-rank test was used to evaluate the impact of PoCUS use on the mean number of differential diagnoses, planned treatments, and complementary diagnostic tests.

Results

In the five centers, a convenience sample of 66 patients met the inclusion criteria, with four being lost to follow-up. Overall, 62 patients were included in the final analysis (Fig. 3).

Median (IQR) age of patients was 45 years (33–56), and 37 (60%) were women. Median (IQR) body mass index was 27 (24–30). At discharge, 41 (66%) patients went home, although one (2%) returned to the ED for the same complaint of right upper quadrant abdominal pain before the end of the 1-month follow-up. Table 1 details the patient characteristics at baseline.

Considering the final diagnosis established by the first adjudication committee (Table 2), the second adjudication committee considered that after PoCUS, 51 (82%) diagnostic approaches were better and 9 (15%) were comparable, resulting in a primary outcome of 97% ($n = 60$) ($\chi^2 = 15.9$) ($p < 0.01$). In two (3%) cases where the diagnostic approaches were better without PoCUS, the final

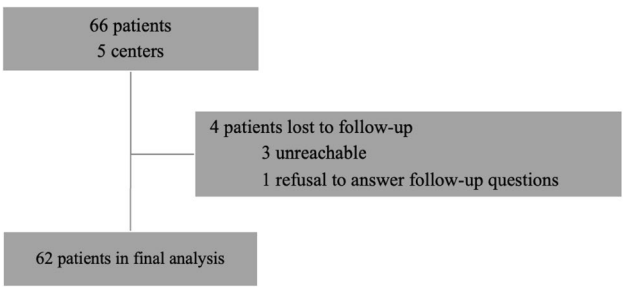

Fig. 3 Flow chart

Table 1 Baseline characteristics of the cohort patients

Variables	Number of patients (%), $N = 62$ (100%)
Sex	
Women	37 (60)
Age, median (IQR)	45 (33–56)
Body mass index, median (IQR)	27 (24–30)
Numerical pain rating scale	
0–5	27 (44)
6–7	12 (19)
8–10	23 (37)
Triage	
1	0 (0)
2	16 (26)
3	31 (50)
4	11 (18)
5	4 (6.5)
Destination at discharge	
Home	41 (66)
Hospitalization	21 (34)
Echogenicity	
Poor	5 (8.1)
Satisfying	13 (21)
Good	44 (71)
PoCUS utility	
Not useful	1 (1.6)
Slightly useful	5 (8.1)
Moderately useful	16 (2.6)
Useful	25 (40)
Very useful	15 (24)
Positive PoCUS findings	
Lung	0 (0)
Peritoneal free fluid	0 (0)
Aorta	0 (0)
Gallbladder	20 (32)
Kidney	7 (11)
Bowel	4 (6.4)

IQR interquartile range, *PoCUS* point-of-care ultrasound

Table 2 Final diagnosis distribution

Final diagnosis	*N* (%), 62 (100)
Symptomatic cholelithiasis	14 (23)
Abdominal pain of unknown etiology	9 (15)
Renal colic	8 (13)
Gastritis	6 (9.7)
Acute cholecystitis	5 (8.1)
Pyelonephritis	4 (6.5)
Bowel obstruction	3 (4.8)
Appendicitis	2 (3.2)
Parietal pain	2 (3.2)
Post-surgery abdominal abscess	1 (1.6)
Colitis	1 (1.6)
Constipation	1 (1.6)
Diverticulitis	1 (1.6)
Enteritis	1 (1.6)
Pancreatitis	1 (1.6)
Partial obstruction with fecal impaction	1 (1.6)
Pneumonia	1 (1.6)
Pulmonary embolism with pulmonary infarction	1 (1.6)

diagnoses were abdominal pain of unknown etiology and symptomatic cholelithiasis.

The investigators considered that 56 (90%) PoCUS were moderately to very useful. The pre-established PoCUS protocol was enlarged to other regions in 14 (23%) cases. Triage level significantly influenced the primary outcome ($\chi^2 = 15.0$) ($p = 0.02$). By contrast, the primary outcome was not significantly influenced by PoCUS characteristics (utility, echogenicity) and findings or by the final diagnosis.

Regarding the certainty coefficient, a mean difference of 20 (95% CI 16–24) was found for the overall diagnostic approach ($p < 0.01$). The final diagnosis was included in the differential diagnosis list in 54 (87%) cases and was present both before and after PoCUS in 50 (81%) cases. After PoCUS, the certainty coefficient for the final diagnosis increased in 32 (55%) cases. Among the 54 (87%) cases for which the final diagnosis was included in the differential diagnosis list, a mean difference of 17 (95% CI 11.6–22.5) was found for the certainty coefficient for the final diagnosis ($p < 0.01$) (Fig. 4). Among the 62 patients included in the final analysis, the mean number of differential diagnoses before (5.9) and after (3.6) PoCUS decreased significantly (mean difference -2.3 (95% CI – 2.7 to – 1.5), $p < 0.01$), as did the number of planned treatments before (5.2) and after (3.9) PoCUS (mean difference – 1.3 (95% CI – 1.8 to – 0.9), $p < 0.01$), and the number of scheduled complementary diagnostic tests before (5.2) and after (3.9) PoCUS (mean difference -1.3 (95% CI – 1.7 to – 1), $p < 0.01$).

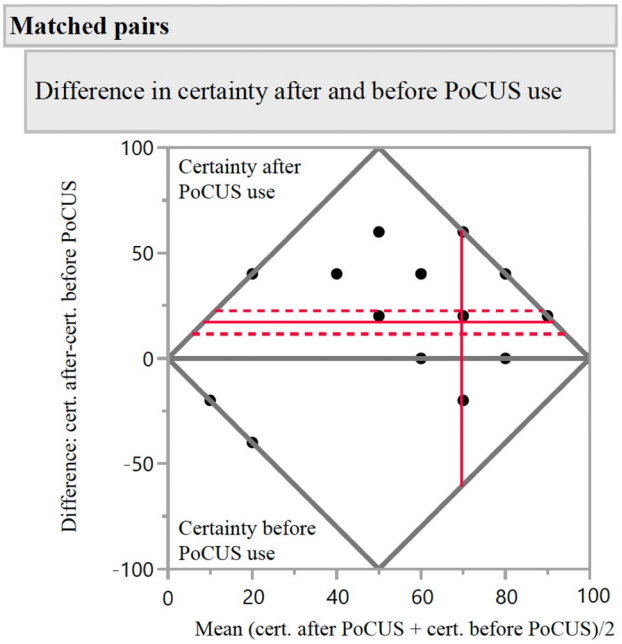

Fig. 4 Matched pairs of certainty coefficients for the final diagnoses found in the differential diagnosis list before and/or after PoCUS. Horizontal red line difference in certainty coefficient before and after PoCUS. Vertical red line overall mean certainty coefficient. The difference in certainty coefficient is in favor of PoCUS

Discussion

This study demonstrates that PoCUS is a valuable tool to enhance the bedside overall diagnostic approaches for patients suffering from right upper quadrant abdominal pain, as 60 (97%) of the adjudicated diagnostic approaches were comparable or better with PoCUS. Compared with the hypothesized proportion of 75%, this result is statistically significant. The study of Lindelius et al. reported that PoCUS was misleading in 10% of cases and did not contribute to the diagnosis in 40% compared with 3% and 15%, respectively, in our study [25]. This could be explained by the fact our study focuses on the right upper quadrant of the abdomen.

One strength of our study was the adjudication process of the diagnostic approaches, namely the differential diagnoses, planned treatments, and complementary diagnostic tests, as the independent members of the adjudication committee were blind to the diagnostic approaches made before and after PoCUS. Several studies separately evaluate as the primary outcome the diagnostic accuracy [16, 26–29], the number of differential diagnoses [30–32], or the physician's certainty coefficients [31, 33–35] before and after PoCUS rather than evaluating the overall diagnostic approach using PoCUS by taking into account all these factors. As part of clinical examination, PoCUS influences the overall diagnostic approach in terms of the differential diagnosis, treatment choice, and complementary diagnostic examinations simultaneously [11,

30–41]. For this reason, in this study, the better diagnostic approach was defined as the one with a differential diagnosis list, treatment plan, and choice of complementary diagnostic tests deemed to be more consistent with the final diagnosis given the physicians' certainty coefficients. Although investigating PoCUS diagnostic accuracy is important to understand the impact of false negative or false positive PoCUS results on the clinical approach, it is undeniably crucial to evaluate the impact of PoCUS use on the overall diagnostic approach given the clinical integration of PoCUS at the bedside usually before other complementary diagnostic results are planned or known [39, 42]. This assessment allows for the evaluation of PoCUS based on its real use in clinical practice, which is another strength of this study.

The demographic characteristics of patients at baseline and the characteristics of PoCUS had no significant impact on the primary outcome, with the exception of triage level. This is possibly because the two cases favoring the overall diagnostic approach before PoCUS had the same level of triage [4]. Although PoCUS is known for its good sensitivity and specificity for gallbladder assessments, the subgroup analysis by diagnosis or PoCUS findings had no influence on the primary outcome, even though the most frequently encountered diagnosis in our study was symptomatic cholelithiasis [15]. This could be due to the low number of patients in this subgroup or because the diagnostic approach is, surprisingly, not influenced by cholelithiasis findings.

The certainty coefficients regarding the overall diagnostic approach favored PoCUS use. This is in accordance with other studies, although they did not evaluate PoCUS use in patients suffering from right upper quadrant pain [31, 34, 43, 44]. Although Houzé-Cerfont et al. support using six levels of confidence, each separated by 20%, as a good modality to quantitatively evaluate certainty, the significant mean difference of 20 represents only one category of certainty level [45]. This result may have been less than 20 if the investigators had been free to choose any level of confidence between 0 and 100%. The quantitative assessment of certainty is nevertheless subject to a selection bias due to its qualitative nature and intrinsic subjectivity.

Jang et al. demonstrated a 45% improvement in the differential diagnosis with PoCUS in patients suffering from abdominal pain compared with 55% in our study [41]. Our somewhat better result is perhaps due to our decision to only include patients suffering from right upper quadrant abdominal pain, as ultrasound is the modality of choice to investigate this specific region of the abdomen [46]. In the study of Bektas et al., which focused exclusively on the right upper quadrant as opposed to the entire abdomen, the improvement attributed to PoCUS was nevertheless rather poor and mainly related to a 16% improvement in physicians' confidence about their decision to conduct complementary diagnostic tests rather than an improvement in the diagnostic approach itself [24].

The significant decrease in the number of differential diagnoses established before and after PoCUS (mean difference -2.3 (95% CI – 2.7 to – 1.5) ($p < 0.01$)) is in line with the results of previous studies. The 2018 study of Buhumaid et al. on chest pain and shortness of breath showed that integrating PoCUS into the clinical examination reduced the differential diagnoses from five to three ($p < 0.01$), while the 2018 study of Durgun et al. showed a reduction from four to two differential diagnoses ($p < 0.01$) for patients suffering from abdominal pain [30, 31, 47]. These results are encouraging for the systematic integration of PoCUS into clinical examinations of the thorax and abdomen. The lower number of planned treatments and complementary diagnostic tests with PoCUS was probably related to the decrease in the number of differential diagnoses. The fact that the overall diagnostic approach was considered to be better after PoCUS in 51 (82%) patients in this study strengthens the assumption that this quantitative decrease in treatments and complementary diagnostic tests also reflects a qualitative improvement.

PoCUS nevertheless resulted in misleading diagnostic approaches in two cases (3%), one of which had symptomatic cholelithiasis as the final diagnosis. As cholelithiasis is accessible to PoCUS, this suggests that PoCUS negatively impacted the differential diagnosis. This illustrates the importance of performing a complementary comprehensive ultrasound in radiology in addition to PoCUS, which also highlights the need to study PoCUS diagnostic accuracy compared with comprehensive ultrasound. Overall, studying the impact of PoCUS on the diagnostic approach should be combined with its diagnostic accuracy in order to better support its clinical integration.

These findings are subject to biases due to the small number of investigators, which may not be representative of the emergency physician population using PoCUS, as well as the convenience sample. The investigators were nevertheless in charge of the included patients and used PoCUS in the clinical setting of the ED, which reflects the reality of PoCUS use in clinical practice. PoCUS is indeed intended to be used and its results integrated into the clinical context [48].

Another limitation of this study is that despite the quantitative evaluation of the primary outcome, this analysis was based on the assessment of an adjudication committee that considered the entire diagnostic approach before and after PoCUS in light of the final diagnosis. This was nevertheless the only way to consider the entire diagnostic approach as a single entity. Prior to the study, it was not realistic to define an ideal differential diagnosis list, treatments, and complementary diagnostic tests for each type of pathology. The adjudication committee, which was blind to the intervention, was comprised of physicians in charge of teaching medical semiology and diagnostic approaches to medical students. This strengthens our belief that they accurately chose the best diagnostic approach.

The fact that PoCUS was used after taking the medical history and clinical examination could be seen as a bias. The time spent performing the ultrasound could have allowed the investigator to obtain supplementary information about the patient's medical history, which could have biased the effect of PoCUS on the overall diagnostic approach. This is nevertheless representative of how PoCUS is used in clinical practice.

This prospective, interventional, multicenter cohort study supports the contribution of PoCUS to the overall diagnostic approach at the bedside. Using PoCUS significantly and favorably impacts the number of differential diagnoses, planned treatments, and complementary diagnostic tests. This is in accordance with the use of PoCUS as a pillar of clinical examination for patients suffering from right upper quadrant pain in the ED.

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Data availability Data are available on resonnable request.

Declarations

Conflict of interest The authors declare they have no relevant financial or non-financial interest to disclose. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish Patients signed informed consent regarding the publication of their data.

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