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Point-of-care ultrasonography: Downstream utilization of and diagnostic (dis)agreements with additional cross-sectional imaging

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ABSTRACT

Objectives: Point-of-care ultrasonography (POCUS), defined as ultrasonography (US) performed and interpreted by the clinician, is increasingly performed. This study aimed to determine the frequency of and reasons why clinicians of the emergency department request cross-sectional imaging after POCUS and how often radiologists experience diagnostic (dis)agreements.

Methods: This retrospective study included a consecutive series of 503 patients who underwent POCUS at the emergency department of a tertiary care center.

Results: Downstream cross-sectional imaging was performed in 77 (15.3%) of 503 POCUS examinations. Reasons for additional cross-sectional imaging were, in order of decreasing frequency: suspicion of pathology that was not assessed with POCUS in 46 cases (59.7%), confirmation of conclusive POCUS findings in 21 cases (27.3%), inconclusive POCUS (i.e. insufficient visualization of the structure of interest to make a diagnosis, despite an attempt of the POCUS operator) in 7 cases (9.6%), a combination of inconclusive POCUS and suspicion of pathology that was not assessed with POCUS in 2 cases (2.6%), and clarification of incidental findings on POCUS in 1 case (1.3%). In the 21 cases that underwent additional cross-sectional imaging to confirm POCUS findings, POCUS agreed with additional cross-sectional imaging in 19 (90.5%) and disagreed in 2 (9.5%) cases.

Conclusions: The use of POCUS appears to not cause any considerable downstream overutilization of cross-sectional imaging. In addition, radiologists experience few diagnostic disagreements when asked to perform second opinion cross-sectional imaging. Future studies with more homogeneous datasets in terms of POCUS operators are required to confirm our results.

1. Introduction

Ultrasonography (US) was introduced in clinical practice at the end of the 1960s [1]. Thanks to technological developments, the image quality of US has increased tremendously over the past few decades, along with the number of clinical applications [1]. Although US has traditionally been in the realm of radiology in many countries, several applications such as cardiac, obstetric, and gynecologic US, have historically been performed and interpreted by non-radiologists in most clinics [1]. The proportion of US examinations performed by non-radiologists is growing rapidly. This is due to the increasing availability of less expensive and portable US devices [2], and increasing awareness among clinicians that a US examination after history taking and physical examination may expedite diagnosis and potentially improve outcome in the appropriate clinical setting [3–4]. The latter is also referred to as point-of-care US (POCUS), which has been defined as US performed and interpreted by the clinician at the bedside [3–4].

The line between what can be considered a US examination that should be performed by a radiologist, and what can be considered a POCUS examination that can be performed by a clinician is blurred. In fact, several publications about POCUS mention applications such as abdominal aortic aneurysm screening, deep venous thrombosis, rotator cuff tears, appendicitis, biliary colic, focused assessment with sonography for trauma (FAST), renal colic, and scrotal pain [3,5], which may be considered the domain of radiologists in many countries. In our tertiary care center, POCUS (which we consider to equal US performed by

Abbreviations: CT, computed tomography; FAST, focused assessment with sonography for trauma; POCUS, point-of-care ultrasonography; US, ultrasonography.

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clinicians in the remainder of this manuscript) is increasingly performed by internal medicine and emergency medicine physicians in the emergency room. There is no official working agreement between the radiology department and the emergency department as to which US examinations should be performed by whom, and radiologists do not provide any US training to clinicians in our institution.

POCUS may potentially benefit patients because a clinician can directly correlate his or her history taking and clinical examination with imaging findings to establish a diagnosis. Clinicians who have a US device directly at their disposal can also more rapidly start performing the US examination than a radiologist, which reduces diagnostic delay. However, a problem arises when the POCUS operator is not sufficiently confident or diagnostically accurate, due to lack of skill and/or inexperience. This may lead to imaging overutilization when clinicians request too many additional cross-sectional imaging examinations to confirm their US interpretations [6]. Although there is some literature on the downstream utilization of imaging after POCUS and on the volumes of US examinations in a radiology department after introduction of POCUS [7–8], there are currently no data on why clinicians request subsequent cross-sectional imaging after POCUS and how often radiologists face diagnostic discrepancies. This information is important to support the value of POCUS, and to identify potential areas for improvement and further research.

The purpose of this study was therefore to determine the frequency of and reasons why clinicians request subsequent cross-sectional imaging after POCUS and how often radiologists experience diagnostic (dis) agreements.

2. Materials and methods

2.1. Study design

This study was approved by the local institutional review board (IRB number: 202000824) and the requirement for informed consent was waived. A total of 1,001 consecutive POCUS examinations performed at the emergency department of a tertiary care center (University Medical Center Groningen, the Netherlands) between 11th June and 17th November 2020 were potentially eligible for inclusion in this study. A POCUS examination was excluded when a corresponding report of the performing clinician with a description and interpretation of imaging findings was lacking in the electronic patient file system, when the POCUS itself did not serve direct diagnostic purposes (e.g. US guidance for invasive procedures), when it concerned an examination of a phantom, when the corresponding report of the performing clinician only mentioned that the region of interest could not be visualized, or when POCUS was performed directly after associated cross-sectional imaging by the radiology department.

2.2. Data collection

For each POCUS examination, the following variables were extracted: patient age, patient sex, date and time of the POCUS study, the recorded clinical indication for which the POCUS was done (grouped according to the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10)), specialty of the person performing the POCUS (internal vs. emergency medicine), body region (chest, abdomen, extremities, or other), and findings of the POCUS examination (also grouped according to the ICD-10). Note that clinical indication of the POCUS study according to ICD-10 does not always indicate the anatomic area of interest (e.g. ICD-10 chapters E (endocrine, nutritional and metabolic diseases) and R (symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified)), hence "body region" of the POCUS study was collected as a variable. Also note that although the ICD-10 group of the clinical indication of the POCUS study may be the same as the ICD-10 group of the findings of the POCUS study, they may still contain different diagnoses (e.g. both cholecystitis and cholecystolithiasis are categorized in ICD-10 chapter K). Nevertheless, ICD-10 groups were used for both clinical indication and findings of the POCUS study to provide a global picture of the diagnostic categories that were encountered. Finally, for each cross-sectional imaging examination (US, computed tomography (CT), magnetic resonance imaging) that was performed by the radiology department in relationship to and within 4 weeks after the POCUS examination, the imaging modality, date and time when it was performed, and the reason for additional cross-sectional imaging was recorded. Reasons for additional cross-sectional imaging were categorized into the following 4 groups:

1. Confirmation of conclusive POCUS findings (i.e. POCUS showed either a certain pathology or excluded a certain pathology, but additional cross-sectional imaging was nevertheless requested to confirm this presence or absence of pathology)
2. Clarification of incidental findings on POCUS (i.e. POCUS incidentally showed an abnormal finding not related to the patient's symptoms)
3. Inconclusive POCUS (i.e. POCUS could neither identify nor exclude a certain pathology because of insufficient visualization of the structure of interest, despite an attempt of the POCUS operator)
4. Suspicion of pathology that was not assessed with POCUS (i.e. the reason for the additional cross-sectional imaging request is dissimilar to that of POCUS).

2.3. Data analysis

The percentage of POCUS examinations that was followed by cross-sectional imaging performed by the radiology department was calculated. The percentages of cross-sectional imaging examinations that fell into each of the aforementioned 4 categories as reasons for additional cross-sectional imaging were also calculated. For all cases in the category "confirmation of POCUS findings", the number of true positive, false positive, true negative, and false negative POCUS examinations were calculated, using additional cross-sectional imaging as reference standard. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) (version 23, IBM).

3. Results

3.1. POCUS and patient characteristics

A total of 1,001 consecutive POCUS examinations were potentially eligible for inclusion. Eventually, 503 POCUS examinations were included (Fig. 1). These 503 POCUS examinations were performed in 278 male and 225 female patients, who had a mean age ± SD of 61.7 ± 16.7 years (range: 14–96 years). Most POCUS examinations were performed by the internal medicine specialty (62.4%). Recorded clinical indications for POCUS were one for 299 (59.4%) examinations, two for 85 (16.9%) examinations, three for 39 (7.8%) examinations, and four or more for 18 (3.6%) examinations. For the remaining 62 POCUS examinations (12.3%), the indication was unknown. Top-three clinical indications for POCUS comprised ICD-10 chapters I (diseases of the circulatory system; 22.2%), R (symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified; 22.2%), and N (diseases of the genitourinary system; 19.7%). The abdomen was the most frequently evaluated body region, by 332 (53.5%) POCUS examinations (Fig. 2). Top-three findings of POCUS were no pathology (48.1%), followed by ICD-10 chapters J (diseases of the respiratory system; 11.3%) and R (symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified; 8.2%). Table 1 shows more detailed information on patient and POCUS characteristics.

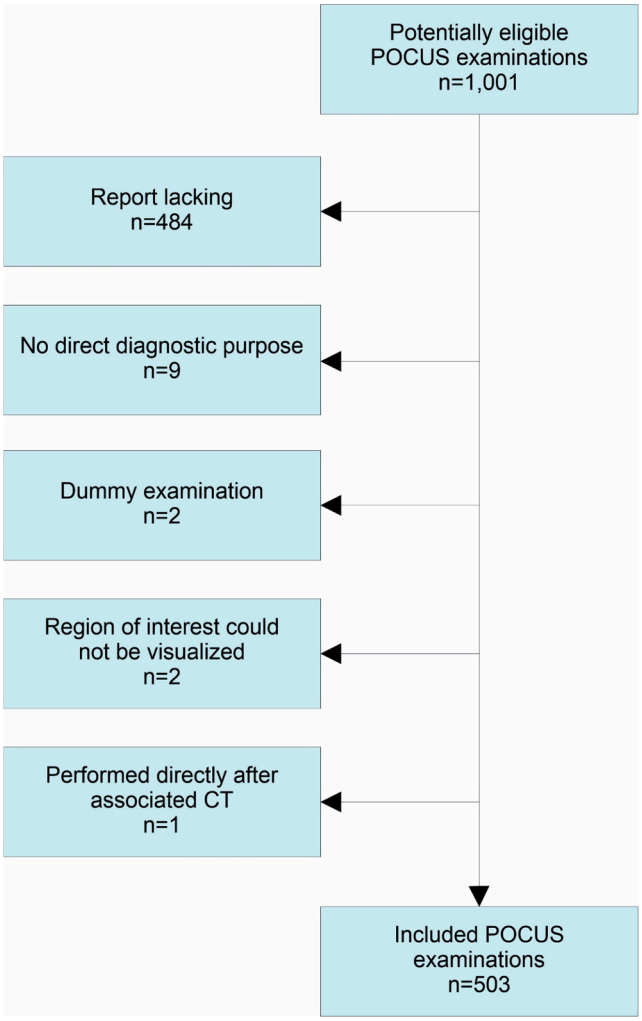

Fig. 1. Flowchart showing the selection of POCUS examinations for this study.

Table 1
Patient and POCUS characteristics (n = 503).

Variable	n (%)
Sex	
Female	225 (44.7)
Male	278 (55.3)
Clinical indication for POCUS (according to ICD 10)*	
I – Diseases of the circulatory system	148 (22.2)
R – Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	148 (22.2)
N – Diseases of the genitourinary system	131 (19.7)
J – Diseases of the respiratory system	81 (12.2)
E – Endocrine, nutritional and metabolic diseases	37 (5.6)
K – Diseases of the digestive system	22 (3.3)
Unknown	62 (9.3)
Diverse†	20 (3.0)
Other‡	17 (2.6)
Specialty of POCUS provider	
Internal medicine	314 (62.4)
Emergency medicine	189 (37.6)
Findings of POCUS (grouped according to ICD 10)*	
No pathology	263 (48.1)
J – Diseases of the respiratory system	62 (11.3)
R – Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	45 (8.2)
I – Diseases of the circulatory system	44 (8.0)
Indeterminate pathological finding	38 (6.9)
E – Endocrine, nutritional and metabolic diseases	34 (6.2)
N – Diseases of the genitourinary system	33 (6.0)
Other‡	28 (5.1)

* As some POCUS examinations had several clinical indications or evaluated more than one body region, the numbers of clinical indications and findings for POCUS are higher than the number of POCUS examinations included in this study.
† Four or more clinical indications.
‡ Indications/Findings that could be classified according to ICD-10, of which each chapter comprised less than 20 cases.

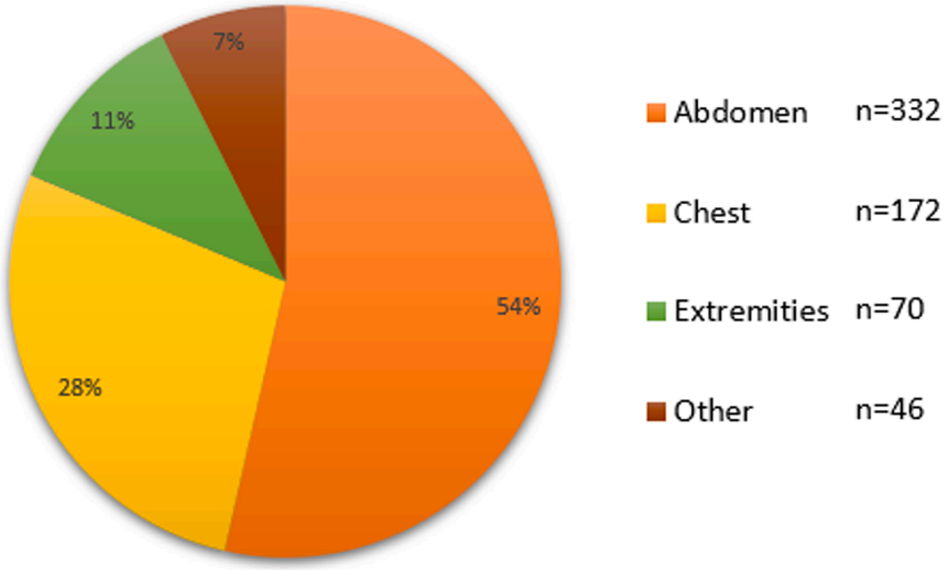

Fig. 2. Frequencies of body regions investigated with POCUS.

3.2. Frequency of and reasons for additional cross-sectional imaging after POCUS

Downstream cross-sectional imaging was performed in 77 (15.3%) of 503 POCUS examinations. Median time between POCUS and additional cross-sectional imaging was 1 day (range: 0–12 days). Additional cross-sectional imaging concerned US in 39 cases and CT in 38 cases. Reasons for additional cross-sectional imaging were, in order of decreasing frequency: suspicion of pathology that was not assessed with POCUS in 46 cases (59.7%) (Fig. 3), confirmation of conclusive POCUS findings in 21 cases (27.3%), inconclusive POCUS in 7 cases (9.6%), a combination of inconclusive POCUS and suspicion of pathology that was not assessed with POCUS in 2 cases (2.6%), and clarification of incidental findings on POCUS in 1 case (1.3%) (Table 2). Note that additional cross-sectional imaging for pathology that was not assessed by POCUS concerned CT in 32 cases and US in 14 cases. Most of these additional CT examinations concerned the abdomen (n = 15, 46.9%), followed by the chest (n = 14, 43.8%), chest and abdomen (n = 2, 6.2%), and brain and cervical spinal column (n = 1, 3.1%). All additionally requested US examinations concerned the abdomen (n = 14, 100%).

Table 2
Reasons for additional cross-sectional imaging after POCUS.

Reason for additional cross-sectional imaging after POCUS	No. (%)	US	CT
Suspicion of pathology that was not assessed with POCUS	46 (59.7%)	Abdomen (n = 14)	Abdomen (n = 16)Chest (n = 14)Chest and abdomen (n = 2)
Confirmation of conclusive POCUS findings	21 (27.3%)	Abdomen (n = 11)Extremities (n = 7)	Abdomen (n = 2)Chest (n = 1)
Inconclusive POCUS	7 (9.6%)	Abdomen (n = 3)Extremities (n = 2)	Chest (n = 2)
Combination of inconclusive POCUS and suspicion of pathology that was not assessed with POCUS	2 (2.6%)	Abdomen (n = 1)	Abdomen (n = 1)
Clarification of incidental findings on POCUS	1 (1.3%)	Abdomen (n = 1)	

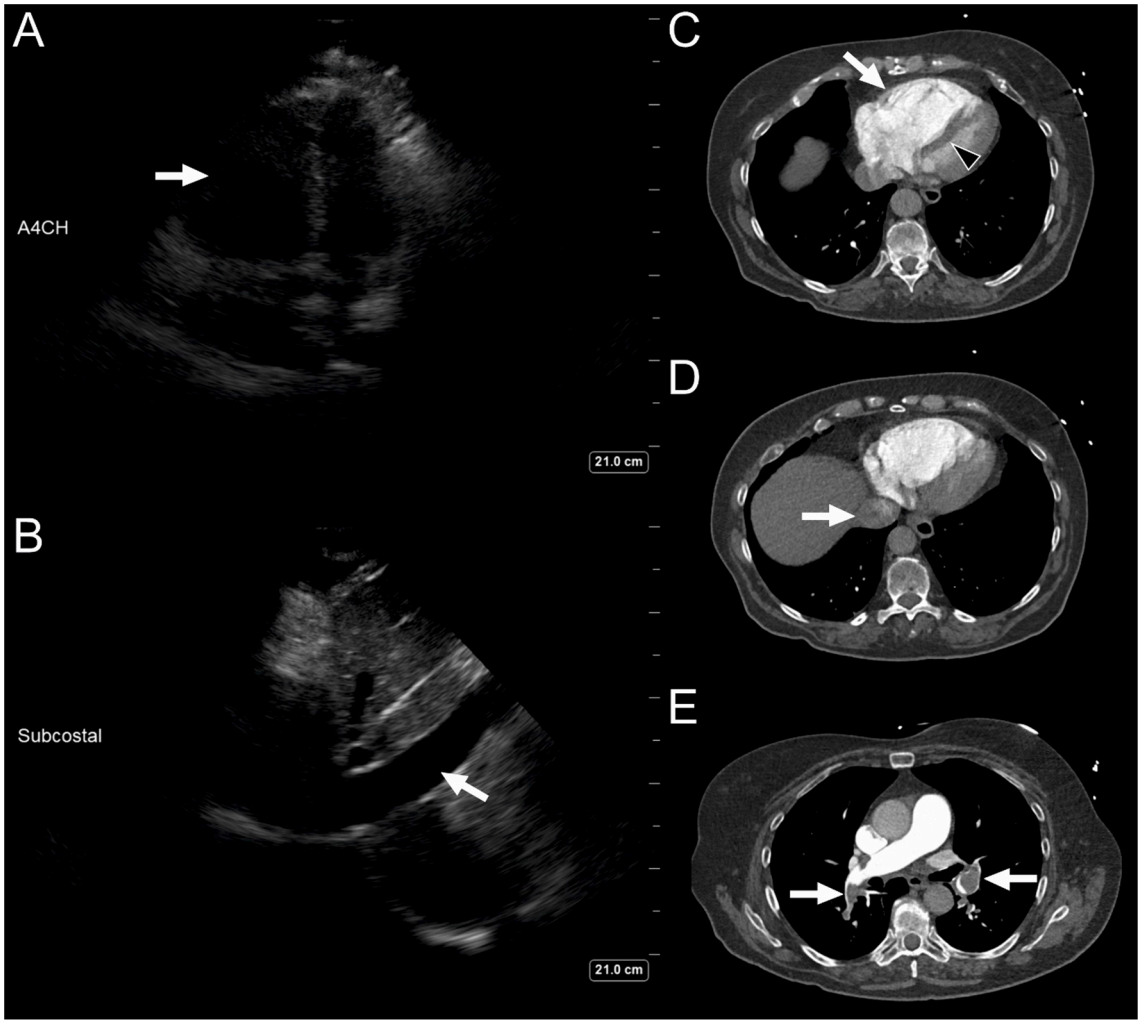

Fig. 3. A 69-year-old woman was admitted with acute severe dyspnea after collapse. POCUS showed a dilated right ventricle (A, arrow) and a dilated inferior vena cava without inspiratory collapse (B, arrow), leading to the suspicion of pulmonary embolism and a request for CT. Subsequent CT also showed a dilated right ventricle (C, arrow) along with interventricular septal deviation (C, arrowhead), and a dilated inferior vena cava (D, arrow), and confirmed the suspected diagnosis by demonstrating emboli in the left and right pulmonary arteries (E, arrows).

Table 3
Diagnostic outcome of POCUS examinations for which additional cross-sectional imaging was requested to confirm conclusive POCUS findings, using additional cross-sectional imaging as reference standard.

Diagnostic outcome POCUS	POCUS finding
True positive (n = 8)	Deep venous leg thrombosis (n = 3) Abdominal aortic aneurysm (n = 1) Appendicitis (n = 1) Cholecystolithiasis (n = 1) Hydronephrosis, pleural effusion, and ascites (n = 1) Ascites (n = 1)
False positive (n = 1)	Ascites (n = 1)
True negative (n = 11)	No deep venous leg thrombosis (n = 4) No hydronephrosis (n = 3) No abdominal abscess (n = 1) No ascites (n = 1) No cholecystolithiasis (n = 1) No thoracic aortic aneurysm (n = 1)
False negative (n = 1)	No cholecystolithiasis (n = 1)

3.3. Diagnostic (dis)agreements between POCUS and additional cross-sectional imaging

In the 21 cases that underwent additional cross-sectional imaging to confirm conclusive POCUS findings, POCUS agreed with additional cross-sectional imaging in 19 (90.5%) and disagreed in 2 (9.5%) cases. There were 8 true positive, 1 false positive, 11 true negative, and 1 false negative POCUS findings (Table 3). Most true positives concerned deep venous leg thrombosis (n = 3), and most true negatives also concerned deep venous leg thrombosis (n = 4) followed by hydronephrosis (n = 3). The single false positive concerned a case in which POCUS suggested a small amount of ascites, which was not confirmed with additional radiological US. The single false negative concerned a case in which POCUS suggested no cholecystolithiasis, but additional radiological US disproved this finding.

4. Discussion

The results of this study show that a minority (approximately 15%) of POCUS examinations in patients presenting at a tertiary care emergency department are followed by additional radiological cross-sectional imaging. The main reason for additional cross-sectional imaging was suspicion of pathology that was not assessed with POCUS (59.7%), followed by confirmation of conclusive POCUS findings (27.3%), and inconclusive POCUS (9.6%). All cross-sectional imaging examinations that were requested to search for pathology that was either not assessed with POCUS or that could not reliably be evaluated with POCUS, would probably have been performed anyway, regardless of whether or not POCUS was done. However, this does not necessarily apply to the additional cross-sectional imaging examinations that were requested as second opinions to confirm positive or negative POCUS findings. Insecurity and/or inexperience of the POCUS operator are the most likely causes of these second opinion requests. This may potentially be reduced with feedback and teaching. Nevertheless, it should be noted that these second opinion requests comprised only 4% of all POCUS examinations. Interestingly, there were very few diagnostic discrepancies between POCUS and the 21 additional cross-sectional imaging examinations that were requested as second opinions, with only one false positive POCUS suggesting a small amount of ascites and one false negative POCUS suggesting no cholecystolithiasis (both without any clinical consequences). Requests for additional cross-sectional imaging to clarify incidental findings on POCUS were relatively rare, with only 1 case in which serendipitously visualized liver lesions proved to be simple liver cysts on subsequent radiological US. Our findings can be considered reassuring, because they suggest that the use of POCUS does not cause any considerable downstream overutilization of cross-sectional imaging. In addition, POCUS findings appear to be mostly accurate. Importantly, however, the latter only applies to the limited number of heterogeneous cases that was forwarded to the radiology department for a second opinion consultation.

Previous studies on the utilization of additional cross-sectional imaging after POCUS in the emergency department are rather limited. A study by Allen et al. [7] investigated the use of imaging downstream to US studies interpreted by radiologists vs. non-radiologists in the emergency department in the United States between 2009 and 2014. Their data demonstrated that most of this additional imaging occurred during the first 7 days after the emergency department visit [7], which roughly corresponds to what was found in the present study. They also found that when radiologists interpreted the initial US examination, subsequent use of imaging resources was significantly less than when the initial emergency department US examination was interpreted by non-radiologists [7]. This difference was approximately 34% at 7 and 14 days and 31% at 30 days [7]. Allen et al. [7] acknowledged that the causes of this observed difference remain unclear, because they did not actually investigate the reasons why additional imaging was requested after POCUS. They speculated that the higher use of limited US examinations by non-radiologists or a lack of confidence in the interpretations of non-radiologists may potentially explain this increase in follow-up imaging examinations [7]. Our results support the speculations of Allen et al. [7]. Another study by Kaplan et al. [8] investigated if and how volumes of radiology US examinations ordered by emergency medicine changed as POCUS grew at their pediatric hospital in the United States between 2011 and 2017. They reported that emergency medicine POCUS growth was accompanied by steady or increasing volumes of emergency medicine ordered radiology US examinations [8]. They also reported that skin and soft tissue infection US, an examination performed diagnostically by both radiology and emergency medicine, showed stable or increased volumes of radiology US examinations during growth in POCUS [8]. Kaplan et al. [8] concluded that radiology US and POCUS are complementary rather than competing practices, and that POCUS has not replaced radiology US in an area of overlapping service. It was outside the scope of the present study to assess whether POCUS has affected the US volumes that are performed by our radiology department. However, we agree with their statement that POCUS and radiology US can be considered complementary without any need for turf battles. This complementarity may be optimized by cooperation and concertation between radiologists and clinicians who perform POCUS (in terms of training and credentialling, imaging standards, workflow, quality assurance, and billing), which has been shown feasible in a study by Zwank et al. [9].

The present study had several limitations. First, the results are only applicable to patients who undergo POCUS by internal medicine or emergency medicine physicians at the emergency department of a tertiary care center. The results may be different when POCUS is applied in other settings. In addition, only a small number of FAST examinations was included as POCUS (performed by emergency physicians) in this study, because the vast majority of these examinations are performed by the radiology department at our institution. Second, almost half of cases (484 of 1,001) were excluded because an official report of the POCUS examination was missing in the electronic patient file system. A post-hoc analysis on available data for these excluded cases showed a similar frequency of subsequent cross-sectional imaging within 4 weeks after the POCUS examination (Supplemental Table 1) compared to the included cases, namely 16.2% vs. 15.3%, respectively. This suggests that these excluded cases were generally not different from those that were included in terms of subsequent imaging utilization. Nevertheless, reporting bias in this setting cannot be excluded with absolute certainty. Third, there is currently no official working agreement between radiologists and clinicians who perform POCUS as to by whom, when, and how the various US examinations in the emergency department should be performed. Different types of US examinations have different levels of complexity, and POCUS operators have different levels of experience and expertise [10]. These factors undoubtedly affect subsequent

imaging utilization and the degree of diagnostic errors. Fourth, only in those cases in which additional US or CT was requested to confirm POCUS findings, the diagnostic (dis)agreements between POCUS and additional cross-sectional imaging could be determined. This is due to the fact that in all other situations in which additional cross-sectional imaging is requested (i.e. clarification of incidental POCUS findings, inconclusive POCUS, suspicion of pathology that was not assessed with POCUS), the number of true positive, false positive, true negative, and false negative cases cannot be assessed. This also applies to all other POCUS examinations for which no additional cross-sectional imaging was requested.

In conclusion, the use of POCUS appears to not cause any considerable downstream overutilization of cross-sectional imaging. In addition, radiologists experience few diagnostic disagreements when asked to perform second opinion cross-sectional imaging. Future studies with more homogeneous datasets in terms of POCUS operators are required to confirm our results.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejrad.2022.110344.

References

[1] ESR Executive Council 2009, European Society of Radiology, ESR position paper on ultrasound, Insights Imaging 1 (1) (2010) 27–29.
[2] European Society of Radiology (ESR), ESR statement on portable ultrasound devices, Insights Imaging 10 (1) (2019) 89.
[3] C.L. Moore, J.A. Copel, Point-of-care ultrasonography, N. Engl. J. Med. 364 (8) (2011) 749–757.
[4] J.R. Ingelfinger, J.L. Díaz-Gómez, P.H. Mayo, S.J. Koenig, Point-of-care ultrasonography, N. Engl. J. Med. 385 (17) (2021) 1593–1602.
[5] M.J. Arnold, C.E. Jonas, R.E. Carter, Point-of-Care Ultrasonography, Am. Fam. Physician 101 (5) (2020) 275–285.
[6] W.R. Hendee, G.J. Becker, J.P. Borgstede, J. Bosma, W.J. Casarella, B.A. Erickson, C.D. Maynard, J.H. Thrall, P.E. Wallner, Addressing Overutilization in Medical Imaging, Radiology 257 (1) (2010) 240–245.
[7] B. Allen Jr, L.V. Carrol, D.R. Hughes, J. Hemingway, R. Duszak Jr, A. B. Rosenkrantz, Downstream imaging utilization after emergency department ultrasound interpreted by radiologists versus nonradiologists: a Medicare claims-based study, J. Am. Coll. Radiol. 14 (4) (2017) 475–481.
[8] S.L. Kaplan, A.E. Chen, R.G. Rempell, N. Brown, M.C. Velez-Florez, A. Khwaja, Impact of emergency medicine point-of-care ultrasound on radiology ultrasound volumes in a single pediatric emergency department, J. Am. Coll. Radiol. 17 (12) (2020) 1555–1562.
[9] M.D. Zwank, B.D. Gordon, S.M. Truman, Refining the wild wild west of point-of-care ultrasound at an academic community hospital, J. Am. Coll. Radiol. 14 (12) (2017) 1574–1577.e3.
[10] J.L. Jacoby, D. Kasarda, S. Melanson, J. Patterson, M. Heller, Short- and long-term effects of emergency medicine sonography on formal sonography use: a decade of experience, Ultrasound Med. 25 (2) (2006) 233–236.