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Evaluating the Diagnostic Accuracy of Point of Care Ultrasound for Paediatric Appendicitis: A UK Multicentre Observational Study

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Competing interests:

None declared for all authors

Abstract

Objective:

To evaluate the diagnostic accuracy of Point of Care Ultrasound performed by Paediatric Emergency Medicine clinicians for suspected paediatric appendicitis.

Design:

Prospective observational study.

Setting:

Two Paediatric Emergency Departments in the UK.

Patients:

1-16 years presenting with abdominal pain and right lower quadrant tenderness on examination.

Primary outcome measures:

Sensitivity, specificity, positive predictive value and negative predictive value of Point of Care Ultrasound.

Secondary outcome measure:

Comparison to radiology performed ultrasound in terms of agreement of findings.

Results

226 patients were included in our study of which 130 (58%) were male. The mean age of patients was 9.7 years. 28 patients had appendicitis confirmed on histological examination, giving a prevalence of 12.4%. Compared to our reference standard Point of Care Ultrasound demonstrated a sensitivity of 0.89 (0.71 – 0.97), specificity 0.96 (0.92 – 0.98) positive predictive value 0.76 (0.57 – 0.88) and negative predictive value 0.98 (0.95 – 1.00). The appendix was visualised in 82/226 patients (36%). There was a very high degree of agreement between Point of Care Ultrasound and radiology performed ultrasound with a Cohen's kappa (k) of 0.87 [95% CI 0.70 – 1.00].

Conclusion

Point of Care Ultrasound performed by PEM clinicians has a high degree of accuracy in detecting paediatric appendicitis. There was a high level of agreement between Point of Care Ultrasound and radiology performed ultrasound.

- **What is already known on this topic** – Accurate diagnosis of paediatric appendicitis remains challenging with high rates of negative appendicectomies.
- **What this study adds** – PEM performed POCUS was very accurate in identifying paediatric appendicitis. A high level of agreement was found between POCUS and formal radiology ultrasound.
- **How this study might affect research, practice or policy** – POCUS may be an effective utility to deliver improvements needed in the care of paediatric appendicitis.

Introduction

Despite being a very common paediatric presentation, appendicitis remains a challenging condition to diagnose. Use of ultrasound has been shown to reduce the number of negative appendicectomies, which was found to be 10% in the UK[1]. The national Getting It Right First Time (GIRFT) Pathway recommends ultrasound as the first-line imaging strategy in paediatric appendicitis where diagnostic uncertainty exists[2]. Whilst ultrasonography is advocated as the most appropriate imaging investigation owing to it being non-irradiating and well tolerated by patients, there is a paucity of trained paediatric radiologists in the UK[3]and in other parts of the world[4]. Accordingly, GIRFT recognises that training the existing workforce including sonographers and other non-radiologist clinicians is a "key lever" in improving the care of children with appendicitis. Several studies have evaluated the performance of Point of Care Ultrasound (POCUS) in diagnosing paediatric appendicitis with encouraging results. We wanted to examine the potential POCUS has in delivering the improvements needed in the care of paediatric patients with suspected appendicitis.

Objective

To evaluate the diagnostic accuracy of POCUS in identifying appendicitis in patients presenting to the Paediatric Emergency Department (PED).

Methods

This was a prospective observational study conducted at two dedicated PED's in the UK. One large district general hospital with approximately 33,000 paediatric attendances annually and one tertiary paediatric hospital with approximately 75,000 attendances annually. We collected data for 226 patients on a convenience sampling basis during a pre-determined 18-month period from January 2024 to July 2025, which was dependent upon a clinician with expertise in POCUS being available to perform the scan.

The NHS Health Research Authority decision tool classified this study as a service evaluation concluding that it related to routinely collected patient data. Written approval was provided by the NHS Clinical Governance Department at each study site prior to commencement.

Inclusion criteria:

Data were collected for patients if they were between 1 and 16 years of age, attended with a complaint of abdominal pain and were felt by the assessing clinician to have tenderness in the right lower quadrant on examination and where appendicitis was one of the differential diagnoses.

We did not include children who had previously undergone appendicectomy. All POCUS scans were conducted by three senior physicians in Paediatric Emergency Medicine (PEM) with over 10 years of paediatric experience. Each hold postgraduate qualifications within paediatric POCUS and serve as faculty on the SUNUS training course[5]. Each had undertaken over 30 supervised abdominal scans prior to study commencement. All scans were conducted according to the established departmental protocol (Web appendix 1).

Web Appendix 1: Scanning technique for suspected appendicitis as adapted from Sunderland Royal Hospital Paediatric Emergency Department Clinical Guideline: Point of Care Ultrasound for suspected appendicitis.

Technique:

Abdominal views:

Select the curvilinear probe 5-2MHz probe.

Scan the right upper quadrant, left upper quadrant and pelvis in the transverse and longitudinal planes in order to assess for the presence of free fluid. (Description shortened)

Right lower quadrant views:

Select the high frequency linear probe 12-5MHz probe. If the patient is able to point to the area of maximal tenderness, use this as your starting point for the scan. Place the probe over gently in this area. Apply steady pressure to displace bowel gas. Identify the psoas muscle and the iliac vessels. Interrogate for the appendix, which is typically found anterior (superficial) to the psoas muscle and iliac vessels. Interrogate this region carefully and systematically in both the longitudinal and transverse planes; the appendix is identified as a blind-ending tubular structure, which is non-compressible and is non-peristalsing. Measure the maximal diameter of the appendix from outer wall to outer wall. Interrogate the right lower quadrant region for secondary signs of appendicitis.

As outlined in the guideline and consistent with other published studies[6-10], features indicative of appendicitis were one or more of the following:

- Appendix visualised with a diameter >0.6cm associated with sonographic tenderness in this region.
- Appendix visualised with a single wall thickness ≥0.3cm with enhanced vascular pattern on colour flow Doppler and sonographic tenderness in this region.

It is recognised that appendicitis can be correctly sonographically classified even when the appendix has not been visualised based on the appearance of a number of secondary signs[11-13]. Thus, we included the following indicators of an abnormal scan in our study which were taken in clinical context:

- Inflamed echogenic regional fat in the right iliac fossa with sonographic tenderness
- Localised free fluid in the right lower quadrant with sonographic tenderness

A scan was considered normal if either the appendix was visualised and was measured to be <0.6cm in diameter, or if it was not visualised and none of the other above secondary signs were present. Scans in which multiple enlarged lymph nodes were identified were not deemed to be consistent with appendicitis unless there were any other specific features that prompted the clinician undertaking the scan to conclude otherwise.

Descriptive reports were documented within the patient's electronic medical record in real-time before being entered into the study database. We classified findings into one of four categories based on the impression of the clinician conducting the scan:

1. Normal with appendix visualised - measurements recorded
2. Normal with appendix not visualised
3. Abnormal with appendix visualised - measurements recorded
4. Abnormal with appendix not visualised with a description of why the scan was considered to be consistent with appendicitis such as evidence of localised free fluid or significant hyper inflammatory fat wrapping in right lower quadrant obscuring the appendix.

Information was collected on the patient's gender, age, duration of symptoms, white cell count, neutrophil count, and a C-reactive protein (CRP). We calculated a Paediatric Appendicitis Score (PAS)[14] for every patient. We also recorded whether the patient underwent a radiology performed ultrasound and what this demonstrated, as well as the disposal outcome for each child: discharged, admitted for observation, went to theatre. For those who ultimately went to theatre we recorded the findings as documented in the operative note and the results of the histology. Finally, we documented whether child re-attended within 30 days of initially being seen.

Our reference standards for the diagnosis of appendicitis were a positive result from the patient's appendix histology sample taken at the time of surgery, and findings documented in the operative notes. For those concluded not to have appendicitis, a lack of re-attendance within 30 days of initial presentation to our hospital or the neighbouring surgical centre was used.

As a secondary analysis we compared the agreement of POCUS to RADUS when this had been conducted.

Data Analysis

Data were entered into MS Excel (Microsoft, Redmond, WA) and analysed using JASP (an open-source and widely used alternative to SPSS) Version 0.19.3, with an alpha level of .05 throughout. Variables are described as mean (standard deviation) or number (percentage) as appropriate with differences between scale values evaluated using the Welch corrected t-test and categorical variables using the chi-square test. Sensitivity, specificity and positive and negative predictive values are given with 95% confidence intervals. Inter-rater reliability was measured using Cohen's kappa. Using an estimated prevalence of appendicitis of 15% in this population the sample size we required for 90-95% power was 218.

Results

226 patients were included in our study of which 130 (58%) were male. The mean age of patients was 9.7 years. 28 patients had appendicitis confirmed on histological examination, giving a prevalence of 12.4%. (See Table 1 for demographics).

Compared to our reference standard POCUS demonstrated a sensitivity of 0.89 (0.71 – 0.97), specificity 0.96 (0.92 – 0.98) positive predictive value 0.76 (0.57 – 0.88) and negative predictive value 0.98 (0.95 – 1.00).

Out of 226 patients we had three false negative POCUS scans along with eight false positive POCUS scans (See Table 2). There were six cases where POCUS correctly classified patients as not having appendicitis who went on to have a negative appendicectomy. For two of these cases RADUS was also carried out. One concluded “could represent early appendicitis” and another demonstrated “a very small amount of free fluid of unknown significance”.

We visualised the appendix in 82/226 patients (36%), including 60 cases where the appendix was normal. The mean (SD) appendix diameter was 0.38 (1.12) cm for normal and 0.86 (0.19) cm for abnormal.

The largest appendix diameter was 1.3cm. Perforation had occurred in eight cases in our study; POCUS correctly classified all cases. There were two cases of retrocaecal appendicitis. POCUS correctly classified both, one in which the appendix was visualised and one where perforation had occurred with free fluid and significant inflammatory fat wrapping seen. POCUS identified one normal retrocaecal appendix where the findings at surgery were “injected” but the histology was normal.

In our study cohort of 226 patients, POCUS identified 22 cases of other abdominal pathology that was likely the cause of the patient’s symptoms while excluding appendicitis: one right sided moderate-sized ovarian cyst, one haemorrhagic ovarian cyst, one large uterine fibroid, one cholelithiasis and 18 cases of mesenteric adenitis. There were two cases of free fluid without any other obvious cause, neither went on to have any significant pathology. Only two CT scans were performed in our study cohort. One case where POCUS correctly excluded appendicitis and the patient was found to have pyelonephritis on CT. One case where both POCUS and RADUS demonstrated features of possible appendicitis but CT did not conclusively and the patient did not go to theatre.

Our secondary outcome measure was to evaluate the agreement between POCUS and RADUS. 33 RADUS scans were conducted. We showed a significant association between POCUS and RADUS ratings $\chi2(1) = 25.16$, $p<.001$ which equates to a Cohen's kappa (k) of 0.87 [95% CI 0.70 – 1.00].

There were no recorded instances of difficulty completing any POCUS scans due to patient discomfort in this study.

Discussion

This large, prospective study has demonstrated that PEM-performed POCUS can accurately detect paediatric appendicitis. A 2025 systematic review and meta-analysis, including eight studies and 993 patients, examined the accuracy of POCUS for detecting paediatric appendicitis. It demonstrated a high specificity of 90.2% (95% CI 86.5% - 93.0%) and a moderately high sensitivity of 85.6% (95% CI 68.9% - 94.1%) concluding that POCUS is effective for diagnosing appendicitis in paediatric patients [15].

Our high sensitivity supports the role of POCUS as a diagnostic tool for safely ruling-out appendicitis if POCUS findings are negative. Only three POCUS scans were falsely negative within our study. One ten-year-old boy with an initial PAS of 2/10 had a non-visualised appendix on POCUS with no sonographic tenderness. He was brought back for planned surgical review then operated on 72 hours after his initial presentation and was found to have “mild appendicitis with a healthy base” with a positive histology. One 15-year-old boy had a 0.58cm appendix but with no apparent secondary signs on POCUS and was noted to have “tip appendicitis” in theatre and a positive histology. For the remaining false negative case the patient’s appendix was not visualised on POCUS following symptoms for <24 hours but went on to have appendicitis when taken to theatre one day later. It is possible that POCUS may be negative early in the course of the illness and such cases warrant strict safety netting or observation. Although it was only one case in our study, where the appendix diameter approaches the 0.6cm cutoff then close repeated scanning may be appropriate.

In six cases, POCUS correctly classified patients as not having appendicitis who could have avoided a negative appendicectomy. Our data highlight the utility of POCUS as a tool for ruling-out appendicitis when the findings are negative.

We also demonstrated an excellent specificity with only eight false positives in our large study cohort. In three out of eight cases the patient had clinically significant surgical pathology in the right lower quadrant requiring operative intervention including: Meckel’s diverticulitis, omental infarction and omental cyst. One case had an appendicolith noted at surgery but with normal histology. The remaining four false positives cases did not go to theatre after repeated surgical review. In six out of the eight false positive cases, RADUS was conducted which also concluded either “acute appendicitis” or “cannot exclude appendicitis”. Our very high specificity highlights the utility that a positive POCUS finding may have in ruling-in appendicitis.

GIRFT highlight the negative appendicectomy rate (the proportion of children who have a normal appendix removed) as an important quality indicator for the care of paediatric appendicitis patients. This was found to be 10% on average in the UK, however large cohort studies have demonstrated rates as high as 46% [16]. Many studies have demonstrated the positive impact that pre-operative ultrasound has had in terms of reducing this figure [17,18]. In our study our negative predictive value was extremely high meaning that a negative POCUS can provide reassurance to the clinician that appendicitis is very unlikely.

The PAS was developed as a clinical decision tool to predict the likelihood of appendicitis in children between 3 – 18 years old presenting with acute abdominal pain localised to the right lower quadrant [14]. It includes findings from history, clinical examination and laboratory results to create a score from 0–10 stratifying patients into low risk (≤ 3), equivocal (4 – 6) or high risk (≥ 7) for appendicitis. PAS has been validated in several multicentre studies with a range of sensitivities from 73 – 100% and specificities from 50 – 95% dependent on the cut-off value used [19-23].

GIRFT recommend that ultrasound is most useful in the following scenarios: an intermediate PAS, a high PAS alongside diagnostic uncertainty and a low PAS where symptoms are not resolving. In our cohort with PAS >7 the sensitivity of POCUS was 100%, suggesting that even for patients where diagnostic uncertainty exists a negative POCUS alongside a high PAS can be used to rule-out appendicitis with a high degree of reliability. For those with a low PAS, the proportion of appendicitis in our study was also low meaning further study is needed to determine the relationship between PAS and POCUS (See Tables 3-5).

Studies evaluating the diagnostic accuracy of RADUS for paediatric appendicitis showed a sensitivity ranging from 74-96.2% and specificity ranging from 92-97% [24,25] with a recent meta-analysis reporting a pooled sensitivity and specificity of 93% and 89% [26]. Studies comparing the diagnostic accuracy of RADUS against POCUS for appendicitis report a range of sensitivities and specificities with some finding RADUS to be clearly better (53% and 82%

for POCUS, 92% and 92% for RADUS[27] and others finding the two to perform similarly (93.8% and 87.5% for POCUS, 81.25% and 100% for RADUS [9]. In our study the accuracy of POCUS was identical to that of RADUS with full agreement in findings for 31/33 RADUS scans. For the remaining two cases, POCUS correctly ruled-out appendicitis with RADUS concluding a false-positive result and for another, POCUS incorrectly ruled-in appendicitis with RADUS concluding a true-negative.

As a secondary outcome measure, we demonstrated a very high degree of agreement between POCUS and RADUS. This has exceeded other published studies in which concordance has been shown to be very good ranging from k = 0.74-0.83 [28,9] and adds a degree of robustness to our findings. Other studies have been similarly encouraging when examining the ability of POCUS-users to correctly classify positive and negative findings with a strong inter-rater reliability between users[29].

For six patients in our study, POCUS showed evidence of appendicitis but the child was not taken to theatre. In five of the six cases RADUS also concluded "possible /probable appendicitis". Two cases underwent conservative treatment with antibiotics but the surgical and radiology opinion was that of appendicitis. The remaining four cases were classified as false positives. Non-operative management of appendicitis is recognised as an acceptable management strategy in select cases. Various randomised controlled trials have been conducted in order to establish the success, safety and cost-effectiveness of a non-operative treatment pathway compared with appendicectomy in children with uncomplicated appendicitis, showing that non-operative treatment was safe and effective [30,31,32]. One systematic review and meta-analysis showed complications and length of hospital stay was no different among patients treated with antibiotics compared with those who underwent appendicectomy [33] with another demonstrating reduced complication rates but longer length of stay in the conservative group[34].

Although it was not a stated outcome measure there were no recorded instances of being unable to complete POCUS scans within our cohort, confirming that POCUS for appendicitis appears to be well-tolerated in paediatric patients including very young children.

A retrospective review within one of the study sites revealed that the number of RADUS requests for suspected appendicitis in the same timeframe was significantly lower (less than half) the number POCUS scans being conducted. This demonstrates the impact POCUS could have in terms of reducing the need for formal RADUS being requested in the PED. This has obvious cost benefits and may reflect recently published data from other hospital settings which concluded that the use of POCUS leads to fewer radiology requests, rather than more[35].

This is of particular relevance when radiology services may not be available in non-specialist centres out of hours, as highlighted by GIRFT, leading to variation in care and delays in diagnosis. As such, we believe the value of POCUS may be most significant in settings where access to specialist imaging services is limited, which has been identified to be a significant issue in a previous UK survey[36].

The large number of scans conducted for patients with abdominal pain and right lower quadrant tenderness, many referred to the PED from primary care or urgent treatment centres as “?appendicitis” indicates that there are sufficient opportunities for clinicians to achieve the required experience and develop their skills in POCUS for suspected appendicitis. This will, in time, improve access to ultrasound for children with acute abdominal pain as advocated by the GIRFT pathway.

Our recommendation in-line with GIRFT is that POCUS training be cascaded to clinicians assessing patients with suspected appendicitis including PEM clinicians and paediatric surgeons. Studies have concluded that competence in scanning for paediatric appendicitis can be achieved after short periods of focused training and is feasible outside the context of POCUS fellowship training [37]. Lack of training opportunities and supervision has been highlighted in the past as a significant barrier to achieving and maintaining competency in POCUS [38,39]. However provision of PEM-specific training courses[5] and fellowships are now becoming more widely available, including in the UK[40].

Strengths of this study include its large size, the fact that it was conducted across two dedicated PED's across the UK and that all scans were carried out by experienced and accredited POCUS practitioners and according to an established protocol.

Limitations for this study include our convenience sampling method which was dependent upon the availability of a clinician trained in POCUS being able to perform the scans, meaning that not all potential patients were included. However, as all potential patients were included when the POCUS clinicians were on shift across an 18-month period there is no reason to suspect that the included population is not representative. We were unable to blind the clinicians conducting the scans to the patient's clinical appearance. POCUS is considered as an extension of clinical assessment with patient interaction forming a fundamental part of the overall process therefore this should not be considered a limitation. Clinicians undertaking the scans were not aware of the eventual outcome of the patient at the time of documenting their POCUS findings.

Conclusion

This large, multicentre, prospective study has demonstrated that POCUS performed by PEM clinicians has a high degree of accuracy in detecting paediatric appendicitis. There was a high level of agreement between POCUS and RADUS. Abdominal POCUS is well tolerated by patients in the PED. Further prospective studies are recommended to corroborate our findings, in particular, whether POCUS can enhance the utility of clinical decision rules such as PAS.

Table 1. Differences in measured variables between those with / without appendicitis

	Not Appendicitis	**Appendicitis**	**p**	**d [95% CI]**
Number	198 (87.6%)	28 (12.4%)		
Age (years)	9.52 (3.59)	11.25 (3.72)	.027*	0.47 [0.06 – 0.88]
Gender (M,%)	M 109/198 (55.1%)	M 21/28 (75.0%)	.046*	
Duration of Pain (days)	2.90 (3.59)	2.79 (2.23)	.81	
PAS	3.63 (1.71)	6.79 (1.79)	<.001*	1.81 [1.22 – 2.38]
WCC (n=127)	9.98 (5.18)	16.66 (9.39)	.001*	0.88 [0.40 – 1.34]
Neu (n=127)	6.95 (5.10)	11.65 (5.74)	<.001*	0.87 [0.40 – 1.32]
CRP (n=129)	18.60 (32.54)	69.39 (53.63)	<.001*	1.14 [0.64 – 1.64]
POCUS (N,%)	+ve 8/198 (4.0%)	+ve 25/28 (89.3%)	<.001*	

Table 2: Table showing false positive cases on POCUS

Gender F/M	Age	Duration of symptoms	CRP	WBC	Neu	PAS	POCUS findings	Diagnosis
M	14	1 day	1.2	25	22	6	Free fluid, echogenic fat, appendix not seen, enhanced colour doppler	Meckel's diverticulitis
M	12	1 day	2	7	2.8	6	Echogenic fat, free fluid, appendix not seen	Omental infarction
M	11	1 day	6	21	20	6	0.62cm appendix with ?appendicolith	Appendicolith, histology negative
M	6	4 days	55	9.2	4.4	6	0.67cm tubular structure ?appendix	Omental cystic lesion
M	7	2 days	<1	10.4	7.7	8	0.74cm tubular structure, free fluid	Did not go to theatre RADUS findings: "Borderline appendix, prominent lymph nodes, cannot exclude appendicitis" Final diagnosis: ? Mesenteric adenitis
M	15	1 day	22	16	14.3	7	0.78cm blind-ending tubular structure, ?appendix	Did not go to theatre RADUS not performed Final diagnosis: Unclear
M	11	1 days	6	10.5	6.8	6	0.9cm ?appendix with surrounding echogenic inflammatory fat	Did not go to theatre RADUS not performed Final diagnosis: Unclear
M	15	3 days	<1	6.9	3.2	5	0.78cm appendix	Did not go to theatre RADUS findings "prominent appendix with tenderness and periportal oedema, early appendicitis cannot be excluded" Final diagnosis: Unclear. Felt initially to be appendicitis but improved clinically without antibiotics, discharged 2 days later.

Table 3: Performance measures of POCUS as a diagnostic test for appendicitis for PAS low (1-4)

	Not Appendicitis	Appendicitis	Total	
-ve POCUS	137 (136)	1 (2.0)	138	
+vePOCUS	1 (2.0)	1 (0.03)	2	
Total	198	2	140	
			Value	**95% CI**
Sensitivity			0.50	0.03 – 0.97
Specificity			0.99	0.95 – 0.97
Positive predictive value			0.50	0.03 – 0.97
Negative predictive value			0.99	0.95 – 1.00

Table 4: Performance measures of POCUS as a diagnostic test for appendicitis for PAS intermediate (5 - 6)

	Not Appendicitis	Appendicitis	Total	
-ve POCUS	42 (35.7)	2 (8.3)	44	
+vePOCUS	5 (11.3)	9 (2.7)	14	
Total	47	11	140	
			Value	**95% CI**
Sensitivity			0.82	0.48 – 0.97
Specificity			0.89	0.76 – 0.96
Positive predictive value			0.64	0.36 – 0.86
Negative predictive value			0.95	0.83 – 0.99

Table 5: Performance measures of POCUS as a diagnostic test for appendicitis for PAS high (7-10)

	Not Appendicitis	Appendicitis	Total	
-ve POCUS	8 (3.2)	0 (4.8)	8	
+vePOCUS	2 (16.8)	15 (10.2)	17	
Total	10	15	25	
			Value	**95% CI**
Sensitivity			1.00	0.75 – 1.00
Specificity			0.80	0.44 – 0.96
Positive predictive value			0.88	0.62 – 0.98
Negative predictive value			1.00	0.60 – 1.00

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