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Ultrasound in Emergency Medicine

PEDIATRIC EMERGENCY MEDICINE POINT-OF-CARE ULTRASOUND FOR THE DIAGNOSIS OF INTUSSUSCEPTION

Theodore E. Trigylidas, MD,* Mary A. Hegenbarth, MD,* Lina Patel, MD,* Christopher Kennedy, MD,* Kevin O'Rourke, MD,† and James C. Kelly, MD, RDMS*

*Department of Pediatrics, University of Missouri–Kansas City School of Medicine and Division of Emergency Medicine, Children's Mercy Hospital, Kansas City, Missouri and †Department of Emergency Medicine, University of Missouri–Kansas City School of Medicine, Truman Medical Center, Kansas City, Missouri

Corresponding Address: Theodore E. Trigylidas, MD, Division of Emergency Medicine, Children's National Medical Center, The George Washington University School of Medicine and Health Sciences, 111 Michigan Ave. NW, Washington, DC 20010

☐ **Abstract—Background: Delayed diagnosis of intussusception can lead to air enema failure and increased morbidity. There are limited studies reporting the accuracy of pediatric emergency medicine (PEM) physician point-of-care ultrasound (POCUS) in diagnosing intussusception. Objectives: The primary objective was to evaluate the accuracy of PEM POCUS in identifying ileocolic intussusception. The secondary objective was to identify factors associated with air enema failure. Methods: This was a retrospective study of children who underwent POCUS for suspected intussusception in a pediatric emergency department between January 2001 and December 2015. Patients were included if a pediatric radiologist confirmed the POCUS examination interpretation by image review, radiology department ultrasound, or air enema. Age, symptom duration, recurrent intussusception, and location of intussusception were examined as factors for air enema failure. Results: One hundred and two POCUS examinations were completed on 101 patients who met the inclusion criteria. The mean age of patients was 22 months. Of 75 patients with intussusception, 72 were detected with POCUS. PEM POCUS had a sensitivity of 96.0% (95% confidence interval [CI] 91.6–100.0%), specificity of 92.6% (95% CI 82.7–100.0%), positive predictive value of 97.3% (95% CI 93.6–100.0%), and negative predictive value of 89.3% (95% CI 77.8–100.0%). Air enema failure was associated with intussusception distal to the splenic flexure (odds ratio = 10.00 [95% CI 2.81–35.61]; $p < 0.01$) and age <6 months (OR = 6.83 [95% CI 1.94–24.09]; $p < 0.01$). Conclusion: PEM POCUS identifies intussusception with high sensitivity and specificity. Patients <6 months old or with intussusception distal to the splenic flexure had a higher risk of air enema failure.**

☐ **Keywords—air enema; intussusception; pediatric emergency medicine; POCUS; point-of-care ultrasound**

Reprints are not available from the authors.

INTRODUCTION

Early recognition of ileocolic intussusception in children is important for successful reduction with air enema and the prevention of complications, such as ischemia, necrosis, and perforation (1–4). Intussusception typically affects children 6–36 months of age, with children outside this age range often having an identifiable pathological lead point (5–7). Ultrasound has gradually replaced contrast enema as the criterion standard for diagnosis because it is more rapid, less invasive, and has excellent accuracy (sensitivity and specificity both ≥98%) (8–11).

In recent years, emergency physician point-of-care ultrasound (POCUS) has become a widely used tool for

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rapidly answering focused clinical questions. The expanding role of POCUS in the general emergency department (ED) setting has stimulated interest in pediatric POCUS. Pediatric emergency medicine (PEM) fellowships increasingly include POCUS in their curricula (9). Ultrasound offers particular advantages in pediatrics because it is noninvasive, eliminates the risk of ionizing radiation, and is generally well-received by patients and families at the bedside (9,12). However, many centers do not have 24-hour access to radiology department sonography. This lack of access may result in diagnostic delays of time-sensitive conditions, such as intussusception.

Several studies suggest that POCUS performed by PEM physicians can be useful for diagnosing intussusception (1,3,8,9,13). In 2012, a prospective study of PEM physicians with no previous ultrasound experience in identifying intussusception who underwent a 1-hour POCUS training session was reported. Of 13 patients described in the study, POCUS had a sensitivity and specificity of 85% and 97%, respectively, when compared with radiology department ultrasound (3). Other retrospective reviews have found sensitivities and specificities ranging from 79–100% and 88–97%, respectively (13,14). Although these studies are encouraging, a recent consortium of ultrasound-trained PEM physicians determined that further validation in different emergency settings would be helpful to further characterize the utility of POCUS in identifying intussusception (12).

Predictors of air enema failure have long been studied and recognized to help reduce morbidity. Older age (≥3 years), longer symptom duration (>24 h), and identifiable lead points have all been linked to poorer outcomes with air enema and requirement for operative repair (4,5,15–17). More recently, patients requiring operative repair were found more likely to have intussusception located more distally in the colon (4). There have not been ultrasound studies to date linking distal intussusception and likelihood of successful air enema.

The primary objective of this study was to evaluate the accuracy of PEM POCUS in identifying ileocolic intussusception. A secondary objective was to identify factors associated with air enema failure.

METHODS

Study and Design

This was a retrospective study of patients who presented to a pediatric ED (PED) with suspected ileocolic intussusception between January 2001 and December 2015. The study was conducted at an urban, tertiary care PED with an annual census of approximately 70,000. The study received approval by the local institutional review board.

Patient Selection

This study was comprised of a convenience sample of patients who presented to the PED during the study period and had POCUS performed for suspected ileocolic intussusception by 1 of 2 PEM physicians. These study physicians were on staff throughout the study duration, were experienced in the use of POCUS, had received training in the use of ultrasound for diagnosis of intussusception as outlined below, and were early adopters of their POCUS training in their day-to-day practice. POCUS findings were confirmed by ≥ 1 of the following methods: 1) concurrent POCUS image review by a radiologist; 2) radiology department ultrasound; or 3) air contrast enema. Patients were excluded if they did not have a confirmatory study or if POCUS was completed by other PEM physicians who did not routinely use POCUS in their practice, resulting in small numbers of examinations (3 total). Patients were also excluded if they had small-bowel intussusception, had POCUS performed for an indication other than uncomplicated intussusception, or had equivocal POCUS images without a radiology department ultrasound.

POCUS Training

In collaboration with the radiology department, a PEM POCUS program was developed at our institution in 2001. This program closely followed national guidelines established by the American College of Emergency Physicians (18). Initial ultrasound training involving both didactic and hands-on experience was undertaken by most of the PEM attendings and fellows. This education initially focused on common indications such as Focused Assessment with Sonography for Trauma. Subsequently, PEM physicians were encouraged by the radiology department to attempt to identify ileocolic intussusception in order to enable more rapid diagnosis and therapeutic enema. A brief educational module was developed covering basic techniques for visualizing ileocolic intussusception, pertinent articles, and review of numerous positive ultrasound images of intussusception. Physicians who attended these training sessions were then encouraged to practice POCUS techniques on their own and gain experience through self-directed learning and radiology department oversight via image review. If the POCUS examination was felt to show intussusception, a pediatric radiologist was consulted and either confirmed POCUS results by image review or requested a radiology department ultrasound. Depending on the radiologist, some patients with POCUS positive for intussusception went directly for therapeutic enema without a radiology department ultrasound; others had radiology department ultrasound performed regardless of POCUS findings.

POCUS examinations that did not show a typical ileocolic intussusception were confirmed either by image review, a radiology department ultrasound, or both. Those that did not receive a radiology department ultrasound either had resolution of symptoms or an alternate diagnosis established. If POCUS examinations were deemed equivocal, a radiology department ultrasound was obtained.

POCUS images that were reviewed with a radiologist were either done in real-time during daytime hours with printed images or were submitted for review several days later via a quality assessment (QA) meeting. If real-time image review was not available, a radiology ultrasound was obtained when clinical concern for intussusception remained.

Data Collection

Most patients had a standard QA form filled out after POCUS completion. POCUS examinations were performed using a Sonosite 180 (2001–2009) and SonoSite M-Turbo ultrasound system (2009 to present; SonoSite, Bothell, Washington). Images were printed (Figure 1) or uploaded to a hard drive and then archived. Printed images contained patient identifiers and the sonographer's initials. The abdominal quadrant where the image was captured was either labeled on the image or written on the QA form. QA forms were then completed and submitted to radiology for review along with the printed images. The QA forms and POCUS images were archived and kept by the PEM ultrasound director. A log sheet of POCUS examinations performed by each physician for suspected intussusception was kept in the archive.

Additional chart reviews were conducted to capture instances where a POCUS examination may have been performed but not logged or placed on a QA form. Charts of patients seen by the 2 PEM physicians during the study period were queried by searching for the *International Classification of Diseases, 9th revision* (560.0) and *International Classification of Diseases, 10th revision* (K56.1) codes for intussusception; additional patients identified by this search were included in the study if there was documentation in the provider note of a POCUS examination performed on the date of visit and a confirmatory study was completed.

Data collection was completed using Research Electronic Data Capture hosted at Children's Mercy Hospital (19). Data included patient demographics (age, gender, and ethnicity), symptom duration, PEM physician POCUS interpretation, location of intussusception, air enema results, previous history of intussusception, if surgery was required, and whether the patient was referred from an outside facility. Intussusceptions found in the right lower quadrant or right upper quadrant were defined a priori to be proximal to splenic flexure; those found in the left upper quadrant or left lower quadrant (LLQ) were defined a priori to be distal to splenic flexure.

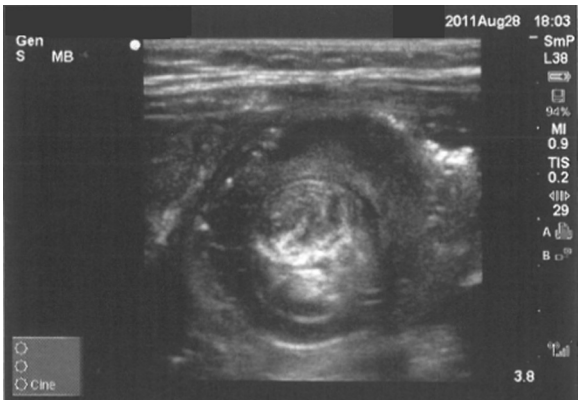

Figure 1. Point-of-care ultrasound image of ileocolic intussusception identified in the left lower quadrant. This was a 2-month-old male who would later go on to fail air enema and require operative repair.

We chose to study patient age (<6 months vs. 6–36 months, ≥36 months vs. 6–36 months), symptom duration (<24 h vs. ≥24 h), history of recurrent intussusception, and location of intussusception (proximal vs. distal to splenic flexure) as predictors of air enema failure because these have been linked to air enema failure in previous studies (4,5,15–17). Other symptoms (e.g., lethargy and bloody diarrhea) were not analyzed because they were not consistently documented. Age ranges were chosen to examine whether patients falling out of the classic intussusception age range were more likely to fail air enema.

Statistics

The primary objective was addressed by examining sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio of PEM physician POCUS when compared with radiology department confirmatory studies. The secondary objective was addressed by reporting descriptive statistics for each independent variable and the outcome variable. The Fisher exact test was used to determine the relationship for each independent variable and the outcome measure. We reported odds ratios (ORs) with 95% confidence intervals (CIs). Two-sided $p < 0.05$ was considered statistically significant. The data analyses for this paper were generated using SAS software (version 9.4; SAS Institute Inc., Cary, NC).

RESULTS

During the study period, 508 patients in our ED were found to have intussusception. A total of 112 patients

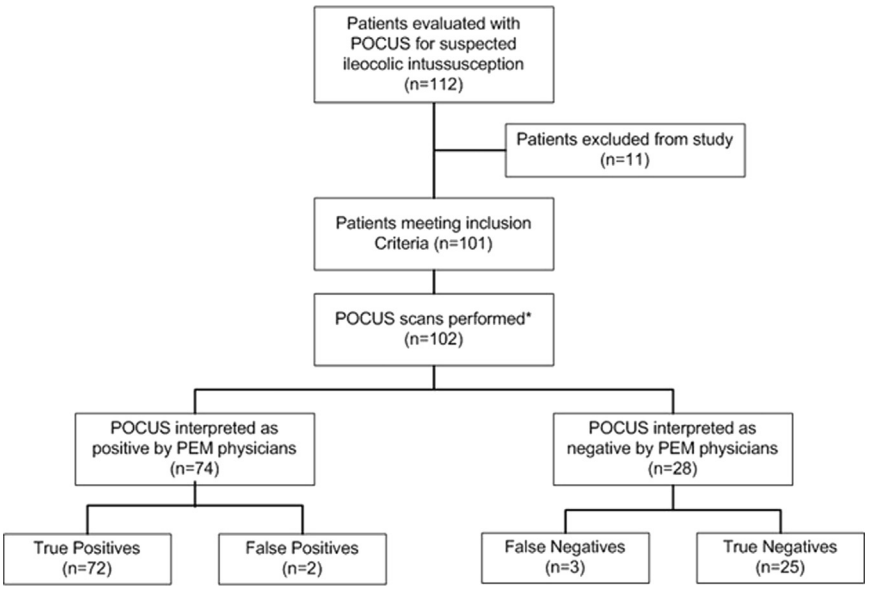

Figure 2. Flow diagram for total patients included in the study. POCUS = point-of-care ultrasound; PEM = pediatric emergency medicine.

underwent POCUS evaluation by PEM physicians for suspected ileocolic intussusception (Figure 2). Eleven patients were excluded: 7 had small-bowel intussusception, 2 had negative POCUS examination with no confirmatory radiology study, and 2 had indeterminate results. The 2 patients with no confirmatory studies had low clinical suspicion for intussusception before POCUS examination and ultimately went on to have a benign clinical course. For the 2 indeterminate cases, 1 had poor quality POCUS images that were difficult to interpret by a radiologist and had no confirmatory radiology department ultrasound performed. The second had computed tomography performed at an outside hospital that demonstrated an intra-abdominal mass thought to be intussusception vs. thickened bowel loops; POCUS evaluation was suspicious for intussusception but was not over-read by a radiologist, and a subsequent radiology department ultrasound was negative. Neither of these children had recurrence of symptoms suggestive of intussusception.

Included for analysis were 102 POCUS examinations performed on 101 patients. One patient had 2 POCUS examinations; the first was positive for ileocolic intussusception, which was successfully reduced with air enema. Symptoms recurred during the same visit, prompting a repeat evaluation, which was negative for intussusception both by POCUS and by radiology department ultrasound. Ninety-five patients were identified via QA forms; 6 were identified via chart query.

Of the 102 POCUS examinations analyzed, 70 were performed by 1 study physician and 32 by another. Seventy-five patients (74%) had ileocolic intussusception. Seventy-two of 75 cases of intussusception were detected by POCUS; 33 were confirmed by both radiologist interpretation of POCUS image and radiology department ultrasound, 25 by radiologist interpretation of POCUS images alone, and 14 by radiology department ultrasound alone. Three patients with false negative POCUS examinations were found on radiology department ultrasound to have intussusception; all were later successfully reduced with air enema. The false negative examinations were performed earlier in the study period when the sonographers were less experienced. Twenty-five of 27 patients without confirmed intussusception had true negative POCUS examinations, with 2 false positive POCUS examinations. Among all true negative POCUS examinations, 22 were confirmed with radiology ultrasound and 3 were confirmed by POCUS image review alone. Those 3 patients went on to have benign clinical courses with no further clinical concern for intussusception. Demographic factors between patients with and without intussusception were similar (Table 1). POCUS had a sensitivity of 96.0% (95% CI 91.6–100.0%), specificity of 92.6% (95% CI 82.7–100.0%), positive predictive value of 97.3% (95% CI 93.6–100.0%), negative

Table 1. Patient Characteristics (N = 101)

	No Intussusception Found (n = 26)	Confirmed Intussusception (n = 75)
Mean age, months (range)	28 (3–88)	20 (2–73)
Male, n (%)	16 (62%)	51 (68)
Ethnicity, n (%)		
White	16 (62)	42 (56)
African American	5 (19)	18 (24)
Hispanic	4 (15)	12 (16)
Other	1 (4)	3 (4)

Table 2. Test Characteristics of Point-Of-Care Ultrasound

Characteristic	Value (95% CI)
Sensitivity	96.0% (91.6–100.0)
Specificity	92.6% (82.7–100.0)
Positive predictive value	97.3% (93.6–100.0)
Negative predictive value	89.3% (77.8–100.0)
Positive likelihood ratio	12.96 (3.41–49.22)
Negative likelihood ratio	0.04 (0.01–0.13)

CI = confidence interval.

predictive value of 89.3% (95% CI 77.8–100.0%), positive likelihood ratio of 12.96 (95% CI 3.41–49.22), and negative likelihood ratio of 0.04 (95% CI 0.01–0.13) in identifying ileocolic intussusception (Table 2).

Fourteen patients (19%) with confirmed intussusception were <6 months of age, 50 (67%) were 6–36 months of age, and 11 (15%) were ≥36 months of age. Table 3 outlines further characteristics of patients with confirmed intussusception. Nineteen patients (25%) had symptom duration longer than 24 h. Six patients (8%) had a history of intussusception, ranging from several hours to 1 year earlier. Fifteen patients (20%) had lesions located distal to the splenic flexure. Thirty-eight of 75 patients (51%) were referred to our tertiary care facility from an outside facility. Eleven of these patients were reported to have positive ultrasounds at the referring facility, and 2 had intussusception found on CT.

Seventy-two patients (96%) had air enema performed. Three patients with confirmed intussusception were found to have spontaneous reduction on radiology department ultrasound and did not undergo enema. An additional 7 patients were found to have spontaneous reduction during the air enema procedure. Twenty patients (27%) failed air enema reduction and required operative repair. Eight of these patients were <6 months of age, 10 were 6–36 months of age, and 2 were ≥36 months of age (Figure 3). Pathological lead points were found in 3 patients who required surgery, including 2 patients who were 5 months of age with Meckel's diverticulum and 1 patient who was 3 months of age with intestinal malrotation.

To further identify factors associated with air enema failure, we analyzed 4 patient characteristics (Table 3). Patients <6 months of age were more likely to require operative repair compared with patients in the classic 6–36 month age range (OR = 6.83 [95% CI 1.94–24.09]; $p < 0.01$). Patients with intussusception located distal to the splenic flexure were also more likely to require operative repair (OR = 10.00 [95% CI 2.81–35.61]; $p < 0.01$). Age ≥36 months, symptom duration ≥24 h, and history of recurrent intussusception were not found to significantly correlate with need for surgery.

DISCUSSION

In this retrospective study, PEM physicians with limited ultrasound training in the diagnosis of intussusception were able to use POCUS to accurately diagnose ileocolic intussusception with high sensitivity and specificity. Furthermore, this is the first POCUS study to confirm surgical reports that intussusception located more distally in the colon is more likely to fail air enema and require operative repair.

Our study shows that POCUS performs with a high positive likelihood ratio, emphasizing that patients found to have intussusception are likely to have the disease. POCUS also showed high sensitivity and specificity with few false negative and false positive results. Similar performance characteristics were found in a retrospective study of 44 patients with suspected intussusception who had POCUS performed by emergency physicians who received a 1-hour minimum instruction (13). Another prospective study found a lower sensitivity (85%) and higher specificity (97%) compared with our study, suggesting that POCUS may be less effective as a screening test but an excellent rule-in test (3). Previous studies have demonstrated that junior radiology residents often perform as well as their supervising attending physicians when performing ultrasound for intussusception (20,21). Further prospective study in different settings and with physicians of varying levels of expertise would be helpful in determining whether PEM physician-performed POCUS is accurate enough to rule out intussusception.

Our results emphasize the importance of specifying anatomic location when identifying intussusception, potentially offering prognostic information to the radiologist and surgeon providing subsequent care. In our patient population, having intussusception located distal to the splenic flexure had a risk increase of 35% for requiring operative repair. Although other studies have commented on this association, this is the first using POCUS that identified patients likely to fail air enema (4,15). This finding also emphasizes the importance of thorough 4-quadrant abdominal scanning when performing POCUS to identify intussusception. Anecdotally, we found our false negative examinations decreased as we gained more experience and began routinely examining the entire colon, including the LLQ.

We also found that when compared with patients 6–36 months of age, patients <6 months of age were more likely to require operative repair (OR = 6.83; $p < 0.01$), while patients ≥36 months of age were not (OR = 1.14; $p = 0.88$). This finding is in contrast to other studies, where older children were more likely to fail air enema and have a higher incidence of an identifiable lead point (5–7). It is unclear why our results contradict previous

Table 3. Relationship Between Intussusception Patient Characteristics and Requirement for Operative Repair (n = 75)

	n (%)	OR	*p* Value	95% CI
Air enema performed*	72 (96)	—	—	—
Spontaneous reduction†	10 (13)	—	—	—
Age and need for operative repair				
<6 vs. 6–36 months	8/14 (57)	6.83	<0.01	1.94–24.09
6–36 vs. 6–36 months	10/50 (20)	—	—	—
≥36 vs. 6–36 months	2/11 (18)	1.14	0.88	0.21–6.29
Symptom duration >24 h	19 (25)	1.02	0.97	0.32–3.33
History of recurrent intussusception	6 (8)	0.26	0.20	0.26–1.41
Intussusception distal to splenic flexure	15 (20)	10.00	<0.01	2.81–35.61

CI = confidence interval; OR = odds ratio.
* Three cases were found to have spontaneous reduction of intussusception on radiology department ultrasound and did not receive air enema.
† Discovered either after radiology department ultrasound or during air enema.

reports, although it is possible that the PEM physicians chose not to perform POCUS in older children they suspected of having a lead point. Although other studies have found conflicting results regarding longer symptom duration (i.e., ≥24 h) as a predictor of air enema failure, we did not find this association in our population (22–24).

In our study, 7 patients were excluded from study analysis because they were found to have small-bowel intussusception rather than ileocolic intussusception. Four of these patients had findings on POCUS examination that were interpreted by the PEM physician as showing intussusception; however, radiology confirmatory studies

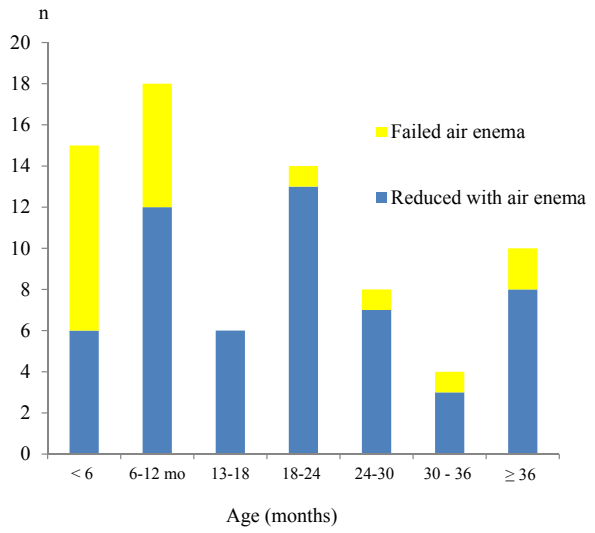

Figure 3. Age distribution of patients with confirmed intussusception and outcome after air enema (n = 75).

identified small-bowel intussusception. Two patients were correctly identified by the study physician as having small-bowel intussusception with POCUS, and 1 patient was identified as having small bowel intussusception but did not have radiology over-read. Correct determination of small-bowel vs. colonic intussusception is important, because small-bowel intussusception does not require therapeutic enema reduction, seldom requires surgery, and usually spontaneously resolves. Small-bowel intussusception is typically smaller (<2 cm diameter involving <2.3 cm bowel segment) and located in the umbilical or left-sided abdomen (25). If the sonographer is unsure whether intussusception found on POCUS is large vs. small bowel, further evaluation by radiology department ultrasound is warranted.

Limitations

There are several limitations to our study. The retrospective design of our study makes it vulnerable to omissions (missed POCUS examinations), as well as selection bias in which children underwent POCUS examination. Despite our efforts to record all POCUS examinations performed over the study period, it is likely that some were not documented. These omissions seem most likely in patients with negative POCUS examination whose symptoms resolved, thereby not undergoing further confirmatory study because intussusception was no longer clinically suspected. In addition, PEM physicians were not blinded to results of outside imaging studies, which may bias results towards improved POCUS accuracy. We chose to study the performance of 2 PEM physicians who completed more POCUS examinations for suspected intussusception. Two other PEM physicians who identified intussusception using POCUS during the study period were not included because of the small number of examinations (1–2 examinations each, 3 total). Therefore, our results cannot be generalized to more inexperienced, novice sonographers. Anecdotally, false negative examinations tended to occur early in the examiner's experience when the need to examine the entire colon (including the LLQ) was not appreciated.

This study focused on classic ileocolic intussusception requiring reduction, and therefore we chose to exclude patients ultimately found to have small-bowel intussusception. However, some of these patients had abnormal ultrasound findings documented that suggested the study physicians may have suspected it to varying degrees. We did not include these cases in our primary analysis because of the subjective nature of these interpretations. Anecdotally, as the study physicians became more experienced, they were better able to differentiate between ileocolic and possible small-bowel intussusception, but this was never the focus of our POCUS examinations

for intussusception. These unexpected findings may bias our results, potentially artificially improving our specificity. We also excluded 2 indeterminate cases that were difficult to include in the primary analysis because of their ambiguous (or unclear) interpretations and may have affected our overall accuracy.

CONCLUSIONS

Our study shows that PEM physicians can accurately diagnose ileocolic intussusception using POCUS. Further prospective study would be helpful to better define how much experience is needed and whether POCUS is accurate enough to rule out intussusception (12). Finally, it would be beneficial to determine whether POCUS can significantly shorten time to air enema reduction or decrease the overall length of stay in the ED.

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ARTICLE SUMMARY

1. Why is this topic important?

Intussusception is a common abdominal emergency in children that has potential for high morbidity with delayed diagnosis. Point-of-care ultrasound (POCUS) is an emerging diagnostic tool in pediatric emergencies with limited data on its accuracy in diagnosing intussusception.

2. What does this study attempt to show?

This study attempts to validate previous studies in demonstrating that pediatric emergency medicine (PEM) physician POCUS is accurate in diagnosing ileocolic intussusception. We also attempt to identify prognostic factors for air enema failure.

3. What are the key findings?

PEM physician POCUS is an accurate tool in diagnosing ileocolic intussusception. Age <6 months and intussusception lesions located distal to the splenic flexure were associated with air enema failure ($p < 0.01$).

4. How is patient care impacted?

Our study supports the use of POCUS by PEM physicians to help diagnose intussusception. Our data also identify high-risk features in patients who may go on to require operative repair.