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Point-of-care ultrasound as the first imaging strategy in young infants aged under 90 days presenting with gastrointestinal manifestations at the emergency department

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Abstract

This study compared the emergency department (ED) flow of young infants under 90 days old presenting with gastrointestinal symptoms who underwent point-of-care ultrasound (POCUS) versus X-ray (XR) as their primary imaging test. The study retrospectively enrolled infants under 90 days old with gastrointestinal (GI) symptoms who visited a tertiary university-affiliated hospital ED from January 2019 to September 2022. The patients were divided into 2 groups based on whether they received XR or POCUS as their first imaging test. Out of 440 patients, 352 (80%) were enrolled in the XR-first group and 88 (20%) in the POCUS-first group. No significant differences exist in demographics, clinical characteristics, or the prevalence of surgical abdomen between the groups. The time-to-disposition and ED length of stay (EDLOS) were significantly shorter in the POCUS-first group as compared to those in the XR-first group (86 min vs 127 min, $P = .013$; 121 min vs 157 min, $P = .049$; respectively). In the POCUS-first group, only 30.7% of the cases required an additional XR. The performance of POCUS in screening for surgical abdomen showed a sensitivity and specificity of 95.8% and 95.3%, respectively. In young infants under 90 days presenting with GI symptoms at the ED, using POCUS as the first imaging test instead of XR can shorten time-to-disposition and EDLOS, improving ED flow with acceptable screening performance for surgical emergencies.

Abbreviations: CT = computed tomography, ED = emergency department, EDLOS = emergency department length of stay, GI = gastrointestinal, HPS = hypertrophic pyloric stenosis, IRB = institutional review board, MRI = magnetic resonance imaging, PED = pediatric emergency department, POCUS = point-of-care ultrasound, RADUS = radiology-performed ultrasound, US = ultrasound, XR = x-ray.

Keywords: emergency service, infant, length of stay, point-of-care systems, ultrasonography

1. Introduction

Gastrointestinal (GI) symptoms (i.e., feeding difficulties, vomiting, and diarrhea) are common reasons for emergency department (ED) visits in young infants under 90 days.[1,2] While most cases are self-limiting conditions (e.g., gastroesophageal reflux), serious conditions [e.g., intussusception, hypertrophic pyloric stenosis (HPS), and midgut volvulus] must be differentiated; these surgical emergencies can rapidly worsen a patient's condition.[3,4] However, symptoms can be vague; among young infants, physical examination and history-taking may be limited due to patient cooperation, making it challenging to differentiate from a surgical abdomen.[4,5] Therefore, additional imaging tests may be required occasionally. The primary choice would be X-ray (XR) due to its simplicity and promptness in progress; ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) are the following: However, XR involves radiation exposure, which is of particular concern to young infants due to their higher probability of cancer risk and longer expected lifespan as compared to that in older children or adults.[6,7] Additionally, the accuracy of XR screening for the surgical abdomen is limited; further imaging (i.e., US, CT, or MRI) is often needed in cases of suspected surgical abdomen.[8]

According to several reports, point-of-care US (POCUS) performed by ED physicians is known to effectively screen for common surgical conditions in young infants, such as HPS, midgut volvulus, and intussusception.[9–11] As compared

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to those in XR, POCUS has the advantages of no radiation exposure and higher screening capability.[8] However, its accuracy when performed by ED physicians may be insufficient as compared to that of radiology-performed ultrasound (RADUS) and thus can vary due to other factors (i.e., artifacts of bowel gas, patient cooperation, and the physician's proficiency).[12,13] Additionally, it is important to consider that excessive POCUS can delay and negatively impact the ED process, consume the time of ED physicians, and harbor the possibility of not being critical to the clinical decision.[12,14] Nonetheless, there are only a few studies analyzing the impact of POCUS on ED flow and screening for surgical abdomen in young infants presenting with GI symptoms.[9]

In this study, the authors compared the ED flow between young infants with GI symptoms who visited the emergency room and underwent XR as their primary screening test versus those who underwent POCUS. Furthermore, the performance of POCUS in screening for surgical abdomen was analyzed.

2. Materials and methods

2.1. Population and study design

We retrospectively enrolled patients under 90 days old with GI symptoms (i.e., vomiting, diarrhea, constipation, hematochezia, and abdominal distension) who visited a tertiary university-affiliated hospital ED from January 2019 to September 2022. Patients diagnosed with a surgical abdomen outside and those with previous abdominal surgery were excluded. Patients with mild or without symptoms suggesting surgical abdomen (i.e., bloody stools, projectile vomiting, or bilious vomiting) and those with no remarkable findings upon examination were not subjected to imaging and excluded from the study. The Institutional Review Board of the Asan Medical Center approved this study (IRB No. 2022-1442) and waived the requirement for informed consent.

2.2. Group designation and clinical process of diagnostic imaging

After history-taking and examination, and if further imaging was needed, XR was conducted primarily due to its simplicity and promptness in progress. In cases where XR facilities were occupied by other exams, thus making immediate imaging impossible, POCUS was then performed primarily. Patients were categorized into XR- and POCUS-first groups according to the primary choice of test. Following the primary test, additional imaging, including XR, POCUS, or RADUS, was conducted as needed.

In the XR-first group, if there is any sign suggesting surgical abdomen, a subsequent POCUS or RADUS was performed when the following parameters were fulfilled: hematochezia, bilious vomiting, or projectile vomiting on history; high-pitched bowel sounds or a palpable mass on physical examination; or overdistended stomach, asymmetric bowel gas, mass-like radio-opacity, absent distal bowel gas, or the double-bubble sign on XR.[4,8] Subsequent RADUS was performed if it was immediately available. In the POCUS-first group, if the surgical abdomen was completely ruled out after POCUS, patients were discharged without further testing. However, if the study was incomplete or if there was a need to exclude serious bacterial infection due to accompanying lethargy and fever, additional chest and abdominal XRs were performed. Furthermore, if a surgical abdomen was suggested on POCUS, a chest and abdominal XR was conducted for pre-anesthesia assessment.

In both groups, RADUS was used to confirm the surgical abdomen; additional CT scans before surgery were generally not performed. All discharged patients were scheduled for outpatient follow-up, with instructions to revisit the ED in case of acute symptom worsening before their outpatient appointment. A total of 92.7% of patients were followed up in the ED or outpatient settings, wherein their final diagnoses were then confirmed.

2.3. POCUS protocol

POCUS for GI symptoms in young infants was primarily conducted to exclude conditions such as HPS, intussusception, intestinal malrotation with or without midgut volvulus, and other mechanical obstructions. This involved checking the antropyloric canal, the structure of the ileocecal valve, the interposition of the superior mesenteric artery/vein, the whirlpool sign of the mesentery, and any obstructive sign of the bowel.[15,16] The POCUS was performed using an EPIQ5 (Philips Ultrasound, Bothell, WA) device with either a 5- to 12-MHz or a 4- to 18-MHz linear transducer. Pediatric ED (PED) physicians participating in this study included 7 attendings and 3 fellows with a median POCUS experience of 5 years (range, 1–12 years). All PED physicians completed the annual professional pediatric emergency US course, which included a 1-day, hands-on session. All POCUS images of the patients were saved and reviewed regularly by the chief ED physician, who has 13-year POCUS experience, to verify the diagnosis and provide feedback to the other ED physicians.

2.4. Data collection and analysis

The collected data included the patients' clinical features (age, sex, body weight, gestational age, and clinical presentation), procedures (enema, intravenous medication), diagnostic testings (XR, POCUS, RADUS, and laboratory test), ED patient flow (time-to-disposition and EDLOS), and clinical course (final diagnosis, disposition, and revisits). The screening performance of POCUS was analyzed, and the ED patient flow was compared between the XR- and POCUS-first groups.

For comparison between the groups, the Mann–Whitney *U* test and Student *t* test were used for continuous variables, particularly when appropriately considering their distribution. In contrast, the χ^2, or Fisher exact test, was used appropriately for categorical variables. These analyses were performed using SPSS

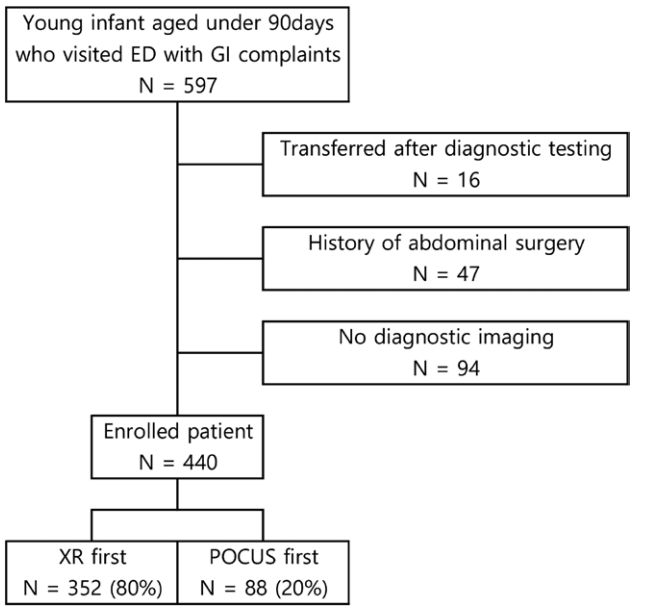

Figure 1. Flowchart of the study patients. ED = emergency department, GI = gastrointestinal, POCUS = point-of-care ultrasound, XR = X-ray.

Statistics for Windows, version 21.0. (IBM Corp., New York); a $P < .05$ was considered statistically significant.

3. Results

During the study period, a total of 597 young infants aged under 90 days old with GI manifestations visited the ED (Fig. 1). After excluding 16 who were diagnosed and transferred from another facility, 47 with a history of abdominal surgery, and 94 who were sent home without any tests due to mild symptoms, 440 patients were finally enrolled. Of these, 352 (80%) were in the XR-first group, while 88 (20%) were in the POCUS-first group. During the study period, a total of 208 POCUS examinations were performed. When categorized by level of experience (fellows with 2 years or less, junior attendings with 3 to 5 years, and senior attendings with 6 years or more) there was no significant difference in the POCUS performance rates among the groups ($P = .079$). Over the study period, the proportion of POCUS-first patients increased from the first 2 years to the last 2 years (14% to 25.3%, $P = .001$), with a notable rise in cases where POCUS was performed as a standalone procedure (5.7% to 13.1%, $P < .001$) (Table S1, Supplemental Digital Content, http://links.lww.com/MD/O245).

The demographic and clinical characteristics between the 2 groups are summarized in Table 1, showing no significant differences among gender, age, prematurity, or body weight. The POCUS-first group had a higher frequency of hematochezia as compared to that of the XR-first group (21.6% vs 11.1%, $P = .009$). Intussusception was more common in the POCUS-first group (4.5% vs 0.3%, $P = .001$); there was no difference in the frequency of the other surgical abdomens between the groups. The use of intravenous hydration and glycerin enema was similar in both groups, with no difference in disposition.

In the XR-first group, 186 (52.8%) patients underwent XR alone, 120 (34.1%) had subsequent POCUS, and 46 (13.1%) had subsequent RADUS (Fig. 2). In the POCUS-first group, 42 (47.7%) patients had POCUS alone, 44 (50%) had subsequent XR, and 2 (2.3%) had subsequent RADUS. Among the 44 patients with subsequent XR, 17 (19.3%) underwent XR due to mandatory clinical processes after being diagnosed with surgical abdomen by POCUS (Table S2, Supplemental Digital Content, http://links.lww.com/MD/O245) as follows: 15 (17%) for pre-anesthesiologic assessment and the other 2 (2.3%) for evaluating procedure-associated complications following air-enema reduction of intussusception. The other 27 (30.7%) patients required supplemental XR due to inconclusive POCUS findings as follows: 14 (15.9%) due to bowel gas artifact, 6 (6.8%) with poor cooperation, and 5 (5.7%) with additional chest and abdominal XR for differentiating serious bacterial infections.

The POCUS-first group had significantly shorter time-to-disposition and EDLOS as compared to those of the XR-first group (86 min vs 127 min, $P = .013$; 121 min vs 157 min, $P = .049$; Table 2). For those with nonsurgical abdomen, the POCUS-first group had significantly shorter time-to-disposition and EDLOS as compared to those of the XR-first group (68 min vs 110 min, $P < .001$; 97 min vs 133 min, $P = .001$); there was no significant difference among the patients with surgical

Table 1

Demographic and clinical characteristics of the study patient.

	XR-first	POCUS-first	
	N = 352	N = 88	*P*-value
Sex, male	190 (54)	46 (52.3)	.774
Age, d	39 (23–65)	50 (26.3–65)	.705
Prematurity	28 (8)	9 (10.2)	.492
Body weight, kg	4.4 (3.7–5.3)	4.5 (3.5–5.4)	.991
Chief complaints			
Vomiting	271 (77)	62 (70.5)	.201
Hematochezia	39 (11.1)	19 (21.6)	.009
Diarrhea	21 (6)	5 (5.7)	.919
Constipation	13 (3.7)	2 (2.3)	.745
Abdominal distension	8 (2.3)	–	.185
Diagnosis			
Surgical abdomen	58 (16.5)	20 (22.7)	.170
Infantile hypertrophic pyloric stenosis	49 (13.9)	15 (17)	.457
Midgut volvulus	8 (2.3)	–	.367
Intussusception	1 (0.3)	4 (4.5)	.001
Duplication cyst	-	1 (1.1)	.200
Acute gastroenteritis	87 (24.7)	15 (17)	.127
Nonspecific vomiting	75 (21.3)	16 (18.2)	.517
Constipation	54 (15.3)	8 (9.1)	.132
Gastroesophageal reflux	43 (12.2)	17 (19.3)	.082
Allergic colitis	17 (4.8)	11 (12.5)	.008
Infectious condition*	9 (2.6)	1 (1.1)	–
Others†	9 (2.6)	–	–
RADUS	63 (17.9)	14 (15.9)	.660
IV hydration or medication	134 (38.1)	30 (34.1)	.490
Glycerin enema	96 (27.3)	17 (19.3)	.127
Disposition			
Discharge	273 (77.6)	71 (80.7)	.526
Admission	71 (20.2)	14 (15.9)	.365
Transfer	8 (2.3)	3 (3.4)	.541
Mortality	–	–	–

Values are represented as a number (%) or median (interquartile range). –

Abbreviations: POCUS = point-of-care ultrasound, RADUS = radiology-performed ultrasound, XR = X-ray.

*Infectious conditions include urinary tract infection, pneumonia, hepatitis, and omphalitis.

†Others include heart failure, adrenal insufficiency, and intra-abdominal cancer.

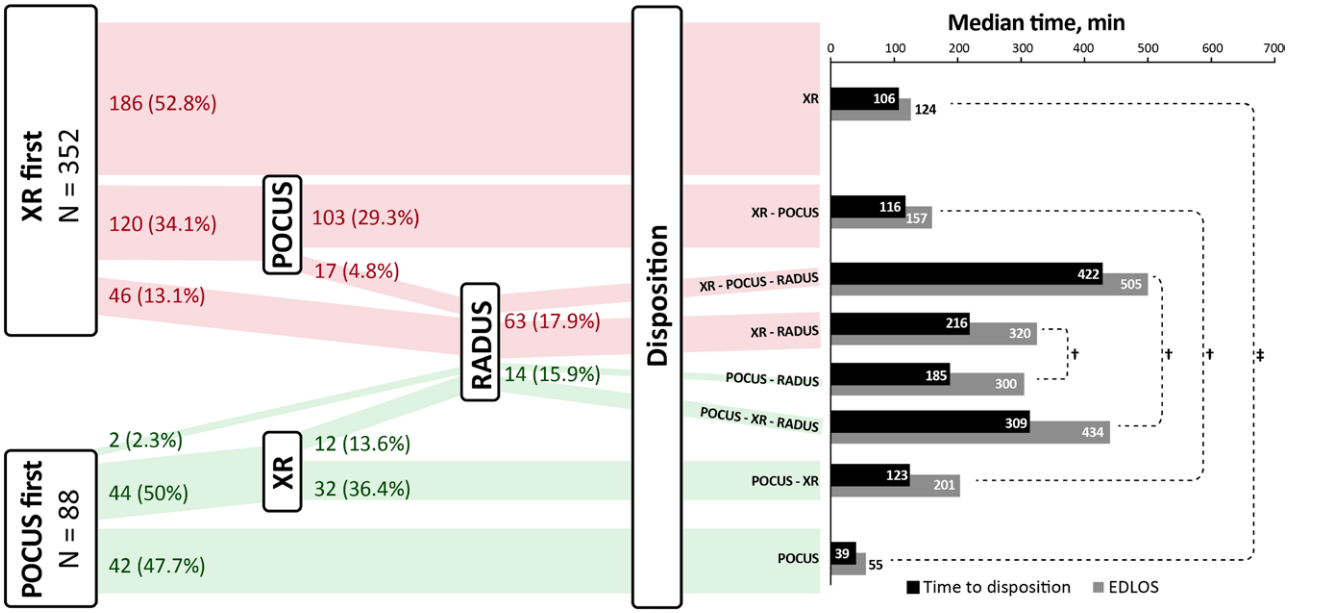

Figure 2. Patients' diagnostic imaging flow and median time of the ED process. ED = emergency department, POCUS = point-of-care ultrasound, RADUS = radiologist-performed ultrasound, XR = X-ray. †Both *P* values ≥0.05, ‡both *P* values <0.001.

abdomen. Furthermore, there was no significant difference in the frequency of revisits or missed surgical abdomen at the first visit between the 2 groups. Individual ED flow of the subgroups according to combined imaging tests is illustrated in Figure 2. The POCUS- and XR-only groups showed significant differences in both time-to-disposition and EDLOS (39 min vs 106 min; 55 min vs 124 min; respectively; both $P < .001$) among the comparisons between the counterpart groups. The subgroup analysis of these 2 groups revealed no significant difference in demographics; however, the POCUS-only group had a higher frequency of hematochezia and allergic colitis (19% vs 6.5%, $P = .009$; 19% vs 2.7%, $P = .001$; respectively) and noted fewer instances of observed feeding during the ED stay (7.1% vs 28.5%, $P = .003$) as compared to those the XR-only group (Table S3, Supplemental Digital Content, http://links.lww.com/MD/O245).

In the study cohort, POCUS was performed on 208 (47.3%) patients, thus demonstrating its screening performance for surgical abdomen with a sensitivity of 95.8%, specificity of 95.3%, accuracy of 95.5%, positive predictive value of 88.5%, and a negative predictive value of 98.4%. (Table 3). Two cases of false negatives on POCUS were observed: 1 was a 38-day-old male with vomiting, diagnosed with HPS at an outpatient visit with worsening of symptoms after discharge from ED; the other was a 10-day-old male with fever and vomiting, later diagnosed with midgut volvulus by RADUS after being missed in the initial POCUS and XR, thereby leading to emergency surgery.

4. Discussion

According to the study, for young infants under aged 90 days with GI manifestations visiting the ED, a POCUS-first approach showed improved ED flow compared to an XR-first approach. The POCUS-first group had shorter time-to-disposition and ED length of stay (EDLOS) without an increase in revisit rates or missed cases of surgical abdomen, and only 30.7% required supplemental XR excluding the mandatories. Overall, POCUS demonstrated acceptable performance in screening for surgical abdomen within the entire cohort.

Similarly to the results, the use of POCUS in specific fields and for certain conditions is known to improve ED flow.[9,17,18] Improvements in time-to-disposition and EDLOS can directly affect ED crowding, which in turn, impacts clinical outcomes for patients.[19,20] Reducing unnecessary EDLOS benefits other patients by allowing for quicker administration of medications and other critical clinical processes.[21,22] Although the POCUS-first group did not have significantly reduced revisit rates, missed surgical abdomen cases, or the frequency of RADUS compared to the XR-first group, the reduction in time-to-disposition and EDLOS suggests that this approach is worth further validation through well-designed, large-sized studies.

The improved ED flow in the POCUS-first group compared to the XR-first group can be inferred from comparing the POCUS-only and XR-only subgroups, which constituted about half of each group (47.7%, 52.8%, respectively). Despite similar times from arrival to initial test, significant differences were noted in time-to-disposition and EDLOS. The XR-only group observed for symptom recurrence post-feeding frequently, potentially delaying ED flow. Despite there are several specific findings on XR the surgical abdomen has, it can be nonspecific in during the early stages, thus requiring additional clues derived from clinical observation. In contrast, POCUS allows for direct visualization of structures such as the pylorus, ileocecal valve, and interposition of the superior mesenteric artery/vein, thereby omitting the need for additional clinical clues and enabling faster screening for surgical abdomen and decision-making regarding disposition.[6] Such capability might have contributed to the quick ED process in the POCUS-first group without the need for additional ED stays for observation.

The POCUS-first approach also offered the significant benefit of reducing radiation exposure for individual patients. Children and adolescents are more sensitive to radiation than adults, with young infants at an even higher risk for developing malignancy and having a longer life expectancy; therefore, careful consideration of radiation hazards is needed.[6,7] In this study, only 30.7% of patients in the POCUS-first group needed additional XR, excluding mandatories; this highlighted the notion that POCUS was a preferable option over XR to minimize radiation exposure, particularly in settings with limited RADUS availability.

While the POCUS-first approach has been shown to improve ED flow and reduce radiation exposure, caution is still warranted. Variability in its impact on ED flow and RADUS needs across different settings may warn against generalizing our study results.[13,23] Moreover, despite the acceptable screening

Table 2

Patients' ED flow and revisit rates.

	XR-first N = 352	POCUS-first N = 88	*P*-value
Time-to disposition, min			
Surgical abdomen	241 (146–393)	392 (285–574)	.447
Nonsurgical abdomen	110 (67–193)	68 (35–139)	<.001
Overall	127 (70–221)	86 (39–218)	.013
EDLOS, min			
Surgical abdomen	296 (143–508)	394 (250–598)	.823
Nonsurgical abdomen	133 (81–224)	97 (48–160)	.001
Overall	157 (91–303)	121 (54–290)	.049
Revisit within a day	5 (1.4)	3 (3.4)	.202
Revisit within a week	18 (5.1)	5 (5.7)	.830
Missed surgical abdomen at the first visit	6 (1.7)	–	.605

Values are represented as a number (%) or median (interquartile range). –

Abbreviations: ED = emergency department, EDLOS = ED length of stay, POCUS = point-of-care ultrasound, XR = X-ray.

Table 3

Performance of POCUS when screening for the surgical abdomen.

Sensitivity	95.8%
Specificity	95.3%
Accuracy	95.5%
Positive predictive value	88.5%
Negative predictive value	98.4%

performance of POCUS and with only 2 false negatives, which were saved after subsequent RADUS and outpatient follow-up, the diagnostic capability of POCUS by ED physicians may not be sufficient as compared to that of RADUS; reliability and variability in operator proficiency may be of primary concerns.[9,12] Therefore, caution may still be needed when exclusively relying on POCUS for ruling out surgical abdomen in young infants, thus emphasizing the importance of appropriate follow-up and not hesitating to request RADUS if any uncertainties persist.[9,12,13]

Ultrasound is a highly valuable diagnostic modality with no radiation hazard; however, it requires significant material and human medical resources. Therefore, in settings where US machines are readily available and human resources are sufficient, the active use of POCUS is highly recommended for young infant with GI manifestation. In contrast, in resource-limited settings, it is necessary to maximize the use of clinical findings and X-rays while applying POCUS more selectively.

This study had several limitations. The retrospective and single-institution nature of the small sample size necessitate caution when generalizing the results. The non-randomized allocation based on XR facility occupancy might have introduced selection bias. Although there was no significant difference in POCUS usage based on experience level, and efforts were made to ensure a relatively uniform and high level of POCUS performance among physicians, The lack of standardized indications for imaging tests and reliance on clinical decisions by individual physicians could lead to variability in the clinical process within each group. Despite these limitations, the clear advantages of the POCUS-first approach in terms of ED flow and reducing radiation exposure could make our study results worth validating through further well-designed and large-scale studies.

5. Conclusions

In young infants aged under 90 days presenting with GI symptoms at the ED, using POCUS as the first imaging test instead of XR can shorten time-to-disposition and EDLOS, improving ED flow with acceptable screening performance for surgical emergencies.

Author contributions

Conceptualization: Jun Sung Park.
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Writing – original draft: Jun Sung Park.
Writing – review & editing: Jun Sung Park.

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