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Feasibility of Point-of-Care Ultrasound for Diagnosing Hypertrophic Pyloric Stenosis in the Emergency Department

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Objectives: This study aimed to investigate the feasibility of point-of-care ultrasound (POCUS) for diagnosing hypertrophic pyloric stenosis (HPS) in the emergency department (ED).

Methods: A retrospective study was conducted in infants aged younger than 90 days who were brought to the ED due to vomiting between January 2015 and December 2019. Of these, infants who were clinically suspected of having HPS and underwent ultrasound were included and categorized into 3 groups: POCUS only, POCUS followed by radiologist-performed ultrasound (RADUS), and RADUS only. All confirmative diagnoses of HPS were made by RADUS. The diagnostic performance of POCUS was analyzed, and the ED patient flow was compared between the POCUS-performed (POCUS only or POCUS followed by RADUS) and RADUS-only groups.

Results: Overall, 171 patients with a median age of 34 days were included. Of these, 79 patients (46.2%) underwent POCUS only, and none had HPS; 50 patients (29.2%) underwent POCUS followed by RADUS; and 42 patients (24.5%) underwent RADUS only. Overall, 41 patients (24.0%) were diagnosed with HPS, and POCUS showed a sensitivity of 96.6% and specificity of 94.0%. In the total cohort, length of stay in the ED (EDLOS) was shorter in the POCUS-performed group than in the RADUS-only group (2.6 vs 3.8 hours, $P = 0.015$). Among non-HPS patients, time to disposition (1.8 vs 2.7 hours, $P = 0.005$) and EDLOS (2.0 vs 3.0 hours, $P = 0.004$) were shorter in the POCUS-performed group than in the RADUS-only group. Performing POCUS followed by RADUS did not significantly delay the treatment among HPS patients.

Conclusions: Point-of-care ultrasound is accurate and useful for diagnosing HPS and improved the ED patient flow by reducing EDLOS and door-to-disposition time in non-HPS patients.

Key Words: diagnostic imaging, point-of-care system, pyloric stenosis, sensitivity, specificity, ultrasonography

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Vomiting is a common complaint for which young infants are brought to the emergency department (ED).[1] Almost 50% of infants aged younger than 90 days vomit more than once a day; however, most of these episodes are related to gastroesophageal reflux and often resolve spontaneously.[2,3] Hypertrophic pyloric stenosis (HPS) is a rare cause of vomiting diagnosed in this age group with a prevalence of 2 per 1000 live births. Hypertrophic pyloric stenosis can lead to dehydration with worsening of vomiting until surgical pyloromyotomy is performed.[4–6] Hence, rapid and accurate diagnosis of HPS is crucial for timely treatment in addition to differentiating HPS from other benign causes of vomiting.[5]

The classic presentation of HPS is progressive projectile nonbilious vomiting with a palpable olive-like mass in the right upper quadrant of the abdomen.[7] Nevertheless, these clinical findings are often subjective and even unreliable, especially in the early stage of HPS.[8] Radiologist-performed ultrasound (RADUS) for diagnosing HPS has been widely used as a confirmatory imaging modality[9]; however, the varying availability of radiology may increase the overall length of stay in the ED (EDLOS). Recently, several studies have reported on the diagnostic yield of point-of-care ultrasound (POCUS) performed by emergency physicians for various pediatric conditions,[10–13] and a pilot study in which 10 cases of HPS among 67 patients were diagnosed by pediatric emergency physicians performing POCUS showed promising results, with 100% sensitivity and 100% specificity.[14] These results suggest that POCUS may be a useful tool for the diagnosis of HPS in the ED; however, larger scale studies are needed.

This study aimed to investigate the feasibility of POCUS for diagnosing HPS in the ED, the diagnostic performance of POCUS, and its effect on ED patient flow as compared with patients undergoing RADUS.

METHODS

Study Design and Population

We conducted a retrospective study in infants younger than 90 days who were brought to a tertiary care, university-affiliated hospital ED due to vomiting between January 2015 and December 2019. The overall number of pediatric patients evaluated annually in our ED is approximately 35,000. Among the 515 patients initially considered for inclusion in the study, we excluded 344 patients in whom a diagnostic ultrasound was not performed, those who were transferred from another hospital after the diagnosis of HPS, those with bilious vomiting or underlying surgical problems, or those who had inadequate medical records. Among the excluded patients, diagnostic ultrasound was not performed in 281 patients who presented with minor regurgitation or infrequent episodes of nonprojectile vomiting without recurrence after oral feeding during the ED stay, of which 267 patients (95.0%) did not have HPS according to their medical records during the outpatient follow-up. For our study group, we included 171 patients who were clinically suspected of having HPS and underwent diagnostic ultrasound (POCUS and/or RADUS). The Institutional Review Board of the Asan Medical Center approved this study (IRB no. 2020-0502) and waived the requirement for informed consent.

Ultrasound Protocol and Group Designation

Patients were categorized into a POCUS-performed group (POCUS only or POCUS followed by RADUS) and a RADUS-only group. In our hospital, the duty hours of radiologists are divided

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into regular work hours and on-call hours (weekday between 5:00 P.M. and 9:00 A.M., weekends, or national holidays). Patients who visited the ED during the radiologists' regular work hours when there was the possibility of performing RADUS immediately were transferred to a dedicated room located outside the ED and underwent RADUS. Otherwise, POCUS was initially performed in all eligible patients by the pediatric emergency physicians in the ED. Additional RADUS was mainly performed to confirm the diagnosis of HPS when the result of POCUS was positive but was occasionally performed even when the result of POCUS was negative if the patient had persistent vomiting during the ED stay. The diagnosis of HPS was excluded only when the result of POCUS was negative, and oral feeding was well tolerated in the ED; these patients were discharged without undergoing RADUS. Considering the progressive course of HPS, all discharged patients were advised to follow up in the outpatient clinic, and the parents were counseled to revisit the ED for persistent or worsening vomiting.

Pediatric emergency physicians participating in this study included 6 attendings and 3 fellows with approximately 4 years (range, 1–10 years) of experience in performing POCUS. All pediatric emergency physicians completed the annual professional pediatric emergency ultrasound course, which included a 4-hour hands-on session including evaluation for HPS. All POCUS images of patients were saved and reviewed regularly by the chief ED physician with 10-year POCUS experience to verify the diagnosis and provide feedback to the other ED physicians. Point-of-care ultrasound was performed using the iE33 (Philips Ultrasound, Bothell, WA) with a 3- to 11-MHz linear or a 5- to 8-MHz curvilinear transducer, and RADUS was performed using the EPIQ5 (Philips Ultrasound, Bothell, WA) with a 5- to 12-MHz linear transducer. The linear transducer was mainly used for the evaluation of the pylorus, and the curvilinear transducer was occasionally used for a general evaluation of the abdomen. Ultrasound was performed regardless of the patient's fasting state, and oral feeding of glucose water was sometimes required to visualize the antropyloric canal more clearly.[15] The hypoechoic muscle was measured on a longitudinal view of the midline of the pylorus, and the length of the pylorus was measured.[16] The diagnostic criteria of HPS were a pyloric muscle thickness (PMT) >3 mm, pyloric muscle length (PL) >15 mm, and/or pyloric diameter >10 mm on ultrasound.[17–19] All confirmative diagnoses of HPS were based on RADUS findings.

Data Collection and Analysis

Data collected included the clinical features (age, sex, current weight, gestational age, birth weight, ED visiting time, and duration of illness), ED patient flow (door-to-disposition time, door-to-contact-the-surgeon time, door-to-surgery time, and EDLOS), and the results of ultrasounds (POCUS and/or RADUS). The diagnostic performance of POCUS was analyzed, and the ED patient flow was compared between the POCUS-performed group and the RADUS-only group in the overall cohort and in those with the presence and absence of HPS.

The diagnostic performance of POCUS was analyzed using the MedCalc Version 19.6.3 (MedCalc Software Ltd, Ostend, Belgium). For comparison between the groups, the Mann-Whitney U test or Student t test was used for continuous variables, and the χ^2 test was used for categorical variables. These analyses were performed using PASW Statistics for Windows Version 18.0 (SPSS Inc, Chicago, IL). $P < 0.05$ was considered statistically significant.

RESULTS

Characteristics of Study Population

Overall, 171 patients were included in the analysis; 79 patients (46.2%) underwent POCUS only, 50 patients (29.2%)

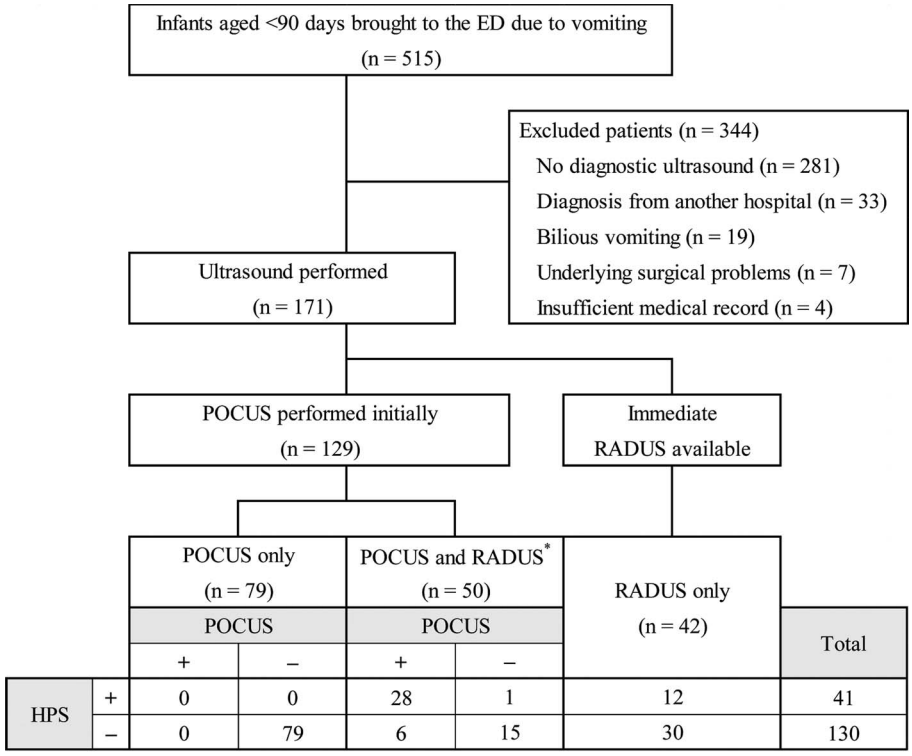

FIGURE 1. Flowchart of the study population. RADUS was used to confirm the diagnosis of HPS even when the result of POCUS was negative if the patient showed persistent vomiting during the ED stay (asterisk). RADUS indicates radiologist-performed ultrasound.

TABLE 1. Clinical Features of the Study Population

Variables	HPS (n = 41)	Non-HPS (n = 130)	Overall (n = 171)	*P*
Sex, male	35 (85.4)	74 (56.9)	109 (63.7)	0.001
Age, d*	33 (28–44)	34 (24–52)	34 (25–50)	0.955
Current weight, kg	4.3 (4.1–4.6)	4.6 (4.4–4.8)	4.6 (2.6–6.5)	0.206
Preterm birth†	3 (9.7)	27 (24.1)	30 (21.0)	0.068
Birth weight, kg	3.3 (3.1–3.4)	3.2 (3.1–3.3)	3.2 (2.1–4.3)	0.477
Visit during radiologists' on-call hours	25 (61.0)	89 (68.5)	114 (66.7)	0.448
Duration of illness, h*	168 (84–240)	24 (12–120)	48 (24–168)	<0.001

Variables are presented as number (%), mean (±2SD), or median (interquartile range).

*Median (interquartile range) used due to nonnormal distribution.

†Percentages are calculated out of patients without missing values.

underwent POCUS followed by RADUS, and 42 patients (24.5%) underwent RADUS only (Fig. 1). The clinical features of the patients are presented in Table 1. The median age was 34 days, and 114 patients (66.7%) visited the ED during the radiologists' on-call hours when RADUS could not be performed immediately.

Finally, 41 patients (24.0%) were diagnosed with HPS, whereas 130 patients (76.0%) did not have HPS. The probable diagnoses of non-HPS patients in the ED included gastroesophageal reflux, gastroenteritis, ileus, or sepsis. Compared with the non-HPS patients, HPS patients had a male predominance (85.4% vs 56.9%, $P = 0.001$) and relatively longer duration of illness (168 vs 24 hours, $P < 0.001$); however, other variables were not significantly different between those with and without HPS.

Diagnostic Performance of POCUS

Point-of-care ultrasound was performed in 129 patients (POCUS only in 79 patients and POCUS followed by RADUS in 50 patients), and 29 patients were diagnosed with HPS. All 79 patients who were discharged after undergoing only POCUS were considered as having no HPS. Among them, 77 patients (97.5%) visited the outpatient clinic, and none of them were diagnosed with HPS. Fifty patients underwent POCUS followed by RADUS; among these, there were 6 false-positives of the 34 patients diagnosed with HPS on POCUS, and there was 1 false-negative of the 16 patients diagnosed with non-HPS on POCUS. The diagnostic performance of POCUS is presented in Table 2. The sensitivity, specificity, positive predictive value, and negative predictive value of POCUS were 96.6%, 94%, 82.4%, and 98.9%, respectively. The diagnostic accuracy of POCUS was 94.6% (89.1%–97.8%).

The false-negative patient showed PMT of 2.8 mm and PL of 7 mm on the initial POCUS and was discharged with an outpatient follow-up appointment. After a day of worsening vomiting, the patient revisited the ED and was diagnosed with HPS using RADUS based on PMT of 7 mm and PL of 23 mm. Six false-positive patients showed median (interquartile range) PMT and PL of 4.3 mm (4.0–4.9 mm) and 14.5 mm (14.0–15.8 mm), respectively. The subsequent RADUS showed median (interquartile range) PMT and PL of 2.2 mm (1.8–2.7 mm) and 11 mm (10–12.8 mm), respectively. Among them, 2 patients were diagnosed with pyloric spasm showing transient thickening of the pylorus without prolonged obstruction on RADUS, and 1 patient was too irritable and complete evaluation of the pylorus could not be fully completed. Upon retrospective review, we found that 3 patients' PMT were overestimated because the measurement included the mucosa and serosa layer.

ED Patient Flow With the Use of POCUS

The ED patient flow was compared between 129 patients in the POCUS-performed group and 42 patients in the RADUS-only group (Table 3). Analysis was performed for all 171 patients, and subanalysis was performed in the 130 non-HPS patients and the 41 HPS patients. In the total cohort, EDLOS was shorter in the POCUS-performed group than in the RADUS-only group (2.6 vs 3.8 hours, $P = 0.015$). Among non-HPS patients, time to disposition (1.8 vs 2.7 hours, $P = 0.005$) and EDLOS (2.0 vs 3.0 hours, $P = 0.004$) were shorter in the POCUS-performed group than in the RADUS-only group. Differences in the ED patient flow such as time to disposition, time to contact the surgeon, time to surgery, and EDLOS were not significant between the POCUS-performed group and the RADUS-only group among HPS patients ($P = 0.083$, 0.078, 0.073, and 0.767, respectively). This indicates that treatment of HPS patients is not significantly delayed irrespective of whether POCUS is performed.

DISCUSSION

This study shows the accuracy of POCUS for diagnosing HPS by trained pediatric emergency physicians as well as its usefulness in improving the ED patient flow by reducing the EDLOS and door-to-disposition time. We included a relatively large number of patients and demonstrate the feasibility of performing POCUS for diagnosing HPS in the ED, similar to previous studies.[14,20]

Performing POCUS significantly reduced the overall EDLOS (2.6 vs 3.8 hours, $P = 0.015$), especially among the non-HPS patients (2.0 vs 3.0 hours, $P = 0.004$). Prior studies have similarly reported that POCUS reduced EDLOS in certain conditions such as intussusception or acute appendicitis.[21,22] Performing POCUS for the diagnosis of HPS in the present study contributed to a decrease in the overall EDLOS and improved

TABLE 2. Diagnostic Performance of POCUS

Indicator	Value (95% CI)
Sensitivity	96.6% (82.2%–99.9%)
Specificity	94.0% (87.4%–97.8%)
Accuracy	94.6% (89.1%–97.8%)
Positive predictive value	82.4% (68.2%–91.0%)
Negative predictive value	98.9% (93.2%–99.8%)
Positive likelihood ratio	16.092 (7.385–35.063)
Negative likelihood ratio	0.037 (0.005–0.252)

TABLE 3. Comparison of the ED Patient Flow Between the POCUS-Performed and RADUS-Only Groups

Variables	POCUS-Performed Group	RADUS-Only Group	Total	*P*
Overall patients, n (%)	129 (75.4)	42 (24.6)	171 (100)	—
Door-to-disposition time, h	2.3 (1.0–4.3)	2.8 (2.0–4.2)	2.4 (1.2–4.2)	0.070
EDLOS, h	2.6 (1.2–5.2)	3.8 (2.5–6.3)	3.0 (1.4–5.4)	0.015
Non-HPS patients, n (%)	100 (76.9)	30 (23.1)	130 (100)	—
Door-to-disposition time, h	1.8 (0.8–3.4)	2.7 (1.8–4.2)	2.0 (1.0–3.6)	0.005
EDLOS, h	2.0 (1.0–3.4)	3.0 (2.3–4.1)	2.4 (1.2–3.8)	0.004
HPS patients, n (%)	29 (70.7)	12 (29.3)	41 (100)	—
Door-to-disposition time, h	5.1 (2.5–6.3)	3.2 (2.1–4.3)	4.3 (2.3–5.5)	0.083
Door-to-contact-surgeon time, h	5.0 (2.9–6.3)	3.2 (2.2–4.3)	4.3 (2.8–5.8)	0.078
Door-to-surgery time, h	25.3 (13.2–35.8)	22.6 (18.7–40.6)	23.7 (16.3–35.8)	0.730
EDLOS, h	6.0 (4.3–10.0)	6.3 (4.1–7.6)	6.2 (4.3–8.4)	0.767

Variables are presented as number (%) or median (interquartile range).
EDLOS indicates length of stay in the emergency department.

the patient flow in the ED. This advantage of POCUS was a strength in this study because a majority of patients (66.7%) visited the ED during the radiologists' on-call hours when RADUS could not be performed immediately. Although additional RADUS had to be performed primarily for HPS patients, preemptive POCUS did not significantly delay the treatment. Considering the higher likelihood of the absence of HPS,[3,4] performing POCUS could reduce crowding in the ED and eventually improve the quality of care and reduce overall health care costs.[23]

Our results demonstrate the highly accurate diagnostic performance of POCUS, with 96.6% sensitivity, 94.0% specificity, 82.4% positive predictive value, and 98.9% negative predictive value. There were 6 false-positives in this study; however, no patient underwent unnecessary surgery because additional RADUS was performed in all patients in whom HPS was suspected on POCUS. Considering that HPS can be confused with pyloric spasm on ultrasound and 2 patients with pyloric spasm in our study were misdiagnosed with HPS initially with POCUS, it may be necessary to observe the pylorus for a longer time or confirm the finding using RADUS.[10,24] Additional RADUS was performed in 16 patients who showed no HPS on POCUS but had persistent vomiting during the ED stay. Only 1 false-negative was observed, and the patient was managed appropriately. Despite the high accuracy of POCUS, a misdiagnosis could lead to unnecessary surgery or worsening dehydration with metabolic derangement; thus, pediatric emergency physicians should be aware of the risk of inaccurate diagnosis using POCUS. In this study, serious consequences due to misdiagnosis on POCUS were prevented by careful consideration of clinical symptoms during the ED stay and by performing RADUS. Moreover, patients with no HPS on POCUS were advised to follow up in the outpatient clinic after discharge.

This study has a few limitations. First, complete follow-up data of all patients were not available, although the proportion of the missed patients was not large. Although there was a shared consensus of performing ultrasound by the clinical criteria described earlier, each physician could have adjusted the criteria depending on the clinical situation. These limitations of a retrospective study can cause selection bias; therefore, future well-designed prospective studies should be conducted. Second, the results of this single-center study may not be generalizable because the setting and resources of other EDs may be different from those of our ED. In particular, considering the relatively higher proportion of HPS patients (42/171, 24.6%) compared with that in a previous prospective study (10/67, 14.9%),[14] cautious interpretation of the results is needed for institutions with different clinical criteria for performing ultrasound. Finally, although all the POCUS images were regularly reviewed by the chief ED physician, real-time validation by an expert was not performed, which can cause interrater variability and reduce both the validity and reliability of diagnostic performance.

In conclusion, POCUS for diagnosing HPS is accurate and useful in improving ED patient flow by reducing EDLOS and door-to-disposition time in non-HPS patients without delaying the treatment of HPS patients. Therefore, performing POCUS by trained pediatric emergency physicians might be recommended for young infants in whom HPS is clinically suspected.

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