Evaluation of Hypertrophic Pyloric Stenosis by Pediatric Emergency Physician Sonography

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Abstract

Objectives: The objective was to evaluate the accuracy of pediatric emergency physician (EP) sonography for infants with suspected hypertrophic pyloric stenosis (HPS).

Methods: This was a prospective observational pilot study in an urban academic pediatric emergency department (PED). Patients were selected if the treating physician ordered an ultrasound (US) in the department of radiology for the evaluation of suspected HPS.

Results: Sixty-seven patients were enrolled from August 2009 through April 2012. When identifying the pylorus, pediatric EPs correctly identified all 10 positive cases, with a sensitivity of 100% (95% confidence interval [CI] = 62% to 100%) and specificity of 100% (95% CI = 92% to 100%). There was no statistical difference between the measurements obtained by pediatric EPs and radiology staff for pyloric muscle width or length (p = 0.5 and p = 0.79, respectively).

Conclusions: Trained pediatric EPs can accurately assess the pylorus with US in the evaluation of HPS with good specificity.

Infants may present to the pediatric emergency department (PED) with symptoms of vomiting or spitting-up. Although the majority of these complaints are minor, a surgical cause for vomiting remains in the differential diagnosis. Hypertrophic pyloric stenosis (HPS) is the most common surgical cause of nonbilious vomiting in infants under 6 months of age, affecting two to five per 1,000 live births. While the typical history of progressive nonbilious projectile vomiting has not changed over the years, the classical physical examination findings of a palpable midline abdominal mass or “olive” and laboratory findings of a hypokalemic hypochloremic metabolic alkalosis are seen less frequently.

Radiologists have been using ultrasound (US) to investigate HPS since 1977, and it is the reference standard for diagnosis. Whereas department of radiology services are not always available at all hours, emergency physicians (EPs) are able to perform focused sonography at all times. Bedside point-of-care US by EPs has been growing over the past 20 years. There are core indications and credentialing requirements for EP sonography for a variety of diagnostic, procedural, and monitoring purposes. Pediatric EPs are increasingly utilizing point-of-care emergency US. However, to our knowledge, there has been only one case report to date of EP sonography for HPS. Proficiency in visualization of the pylorus would be a valuable addition to bedside US screening applications currently in use by EPs. Infants brought in with gastrointestinal complaints are often difficult to assess and may receive testing and imaging to make up for a lack of signs or symptoms on physical examination. The ability to accurately assess for the most common surgical cause of nonbilious vomiting could help patient triage and facilitate improved throughput by reducing unnecessary testing or imaging. To our knowledge, no study to date has prospectively assessed the accuracy of pediatric EP bedside sonography for HPS. We hypothesized that pediatric EPs, with a basic knowl-
edge of bedside US, can accurately identify cases of HPS at our center.

**METHODS**

**Study Design**
This was a prospective observational pilot study approved by the institutional review board. Written informed consent was obtained from the parent or guardian of each participant.

**Study Setting and Population**
The study was conducted in the PED of an urban teaching hospital with a pediatric emergency medicine (PEM) fellowship program. Diagnostic radiology US is available from 8 a.m. to 10 p.m. weekdays, 8 a.m. to 5 p.m. on weekends, and on call after hours. The annual PED census is approximately 30,000 visits per year. The study took place between August 2009 and April 2012.

**Study Protocol**
Infants with suspected HPS were included if the treating physician ordered a formal radiology department US and a PEM study sonographer was available. Laboratory investigation or other imaging studies were performed at the discretion of the treating clinician, who may have also been the study sonographer in some cases. In cases where US was not done immediately, so as not to delay routine care, study imaging commenced upon patient return to the ED. The study sonographers in these cases remained blinded to any radiologic findings.

Infants were excluded if they were transferred from another institution with definitive imaging for HPS, if there was a history of prior abdominal surgery, if the patient required critical care while in the ED, or if study images were not available for review.

Study sonographers (six PEM fellows, one pediatric EP attending physician) received a 45-minute didactic lecture from the lead study sonographer (attending) reviewing the relevant findings and technique for pyloric imaging using still images and video clips, as well as hands-on practice sessions imaging the pylorus. No study sonographer had completed more than 25 pyloric examinations at the outset of the investigation. PEM fellows had no prior experience as sonographers during their pediatric residencies. US training within the PEM fellowship consists of an initial 2-week elective during the first year, followed by regular clinical usage that is primarily procedural or pregnancy-related.

**Ultrasound Protocol.** Studies were performed using a Sonosite MTurbo (Bothell, WA) with a 13- to 8-MHz linear transducer. Study sonographers were instructed to begin in the subxyphoid area with the transducer in a transverse orientation. After identifying the anterior gastric wall and liver edge, the gastric wall was traced laterally to the patient’s right side and caudad until indentifying the pylorus in its long axis. Study sonographers could, at their discretion, feed the child glucose-water solution or roll the child into a decubitus position to visualize the pylorus. While no specified length of time was required for the examination, sonographers were encouraged to spend time watching for visualization of passage of gastric contents through the pyloric channel. After identifying the pylorus, the sonographer measured the diameter of the pyloric muscle wall and the length of the pyloric channel. It is recognized that older infants may have larger pyloric masses than younger infants presenting with HPS, but that the minimum abnormal muscle wall measurement is 3 mm. There is a range in the radiology literature for pyloric channel length criteria from 15 to 19 mm. A muscle width of >3 mm and channel length of >17 mm was considered positive for this study, and width < 3 mm and length < 17 mm, considered negative (Figure 1). Preference was given to the width measurement in case of mixed finding between length and width. Any visualized active passage of gastric contents through a dilated, relaxed pylorus was also considered a negative study. While multiple measurements could be made, the measurement recorded on the data sheet was used for analysis. The radiology measurement recorded on the final report was used for analysis. This report was found using an electronic log of all pyloric US studies done by the department of radiology on PED patients and was used to determine cases that were missed for study enrollment.

The study sonographic findings were blinded from the radiologists and the treating pediatric EP. If the treating clinician was also the study sonographer, clinical decisions were made using only the radiology imaging findings. Images and/or video clips were saved for review. A pediatric radiologist reviewed study images for quality.

**Measures**
The primary outcome of interest was the accuracy of pediatric EP sonography for pyloric stenosis. The radiology US findings were used as the criterion standard, with confirmation of positive cases from surgical operative notes. With HPS being a progressive condition, patients with normal US by radiology who went on to develop HPS days later were not considered false-negative cases.

**Data Analysis**
Data on patient demographics, pertinent history, physical examination findings, laboratory results, and radiographic studies were collected on a standardized data collection sheet along with the relevant study US findings. Data were recorded in Excel (Microsoft Corp., Redmond, WA) and analyzed using Minitab 16 (Minitab Inc., State College, PA). Descriptive statistics with 95% confidence intervals (CIs) were calculated. Student’s t-tests were used for continuous variables and Fisher’s exact tests for nominal data. Paired student’s t-tests and Bland-Altman plots were used to assess the agreement between the study and radiology measurement of pyloric muscle length and width. Normality for continuous variables was evaluated by visual inspection of histograms and the log of normal probability plots.

**Sample Size.** Based on historical data from our institution, we found that the prevalence of positive US for
HPS in vomiting infants going for US was 15%. To account for the novelty of this modality in our study sonographers, we used the lower end of accuracy seen in early radiology literature for HPS21 and determined that a sample size of 67 was required for a desired sensitivity of 0.8 and specificity of 0.9 (95% CI = 0.75 to 1).

RESULTS

A total of 117 patients were eligible for enrollment during the study period. Seventy-five parents were approached for enrollment, three parents refused enrollment, and five had no imaging or data sheet to review. During the study period, 67 patients were enrolled, of whom 60% (n = 40) were male. The mean (±SD) age at presentation was 46 (±29) days, with a mean (±SD) duration of symptoms of 102 (±100) hours. Patients presented with projectile vomiting in 81% (n = 46), documented weight loss in 14% (n = 8), and decreased urine output in 23% (n = 13). Only one patient presented with a palpable “olive” on physical examination. Clinical characteristics of the HPS-positive and HPS-negative cases are summarized in Table 1.

Compared to the patients who received pyloric US by radiology but were not enrolled, there were no statistical differences in sex, laboratory utilization, laboratory abnormalities, age at presentation, or percentage with HPS. Unenrolled cases did have a longer mean duration of symptoms (p = 0.03), were less likely to report decreased urine (p = 0.002), and presented less frequently with projectile vomiting (p = 0.001). Ten patients (15%) in the enrolled population had HPS determined by study US. There were no false-positive or false-negative studies. The overall sensitivity for the study sonographers when identifying the pylorus was 100% (95% CI = 66% to 100%), with a specificity of 100% (95% CI = 92% to 100%).

Our protocol prioritized the functional assessment over measurements and our data set included illustrative cases that demonstrated the ability of an EP sonographer to correctly recognize discrepant findings. In one HPS patient the measurements of the muscle wall ranged from 2.9 to 3.6 mm, with a channel length of 19 mm, but with visualized passage of gastric fluid through a nonrelaxing canal. In 20 minutes of viewing, the channel never dilated or shortened. In another, muscle diameter measurements initially ranged from 2.5 to 3 mm before the pylorus relaxed, dilated, and narrowed to 1.5 mm with noted passage of fluid in a true normal.

Comparing EP sonography measurements to radiology measurements, the mean differences were for width –0.05 mm (95% CI = –0.19 to 0.1 mm, p = 0.5) and for length 0.8 mm (95% CI = –5.5 to 7.2 mm, p = 0.77). Bland-Altman plots show acceptable agreement between the pediatric EP and radiology measurements on muscle length and width (Figure 2). In three studies

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographics (N = 67)</th>
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<tbody>
<tr>
<td>Variable</td>
<td>HPS+ (n = 10)</td>
</tr>
<tr>
<td>Mean (range) age, days</td>
<td>37.4 (14–83)</td>
</tr>
<tr>
<td>Mean (range) symptoms, hours</td>
<td>134 (20–504)</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>70</td>
</tr>
<tr>
<td>History of weight loss (%)</td>
<td>40</td>
</tr>
<tr>
<td>Projectile vomiting (%)</td>
<td>90</td>
</tr>
<tr>
<td>Decreased urination (%)</td>
<td>30</td>
</tr>
</tbody>
</table>

HPS = hypertrophic pyloric stenosis; + = positive; – = negative
there were more than ±2 SD differences in muscle width. When the images were reviewed, these measurements were determined to be accurate. On two HPS-positive studies, the length measurements were outside the 2 SD threshold. In one, the pyloric mass was large enough that the difference was not clinically significant. In the other, the measured length of 14 mm was a foreshortened measurement on an otherwise positive study.

There were five patients where gas or overdistended stomachs prevented direct visualization of the pylorus by the study sonographer. Two of these five could also not be visualized by radiology department US. When reviewed with radiology and the senior sonographer, an additional six studies had suboptimal visualization or measurements of the pylorus. These cases were analyzed in the categories of HPS-positive or HPS-negative in which they were assigned by the study sonographer.

The lead sonographer performed the majority of the studies (Table 2), and the imaging quality of the fellows was significantly different compared with that of the senior sonographer. More non- or suboptimal visualization or measurements were done by fellows in 10 studies versus one study by the attending (p = 0.002). None of the patients with missing data sheets or imaging had HPS.

**DISCUSSION**

This study demonstrates that trained pediatric EPs can be accurate in the evaluation of HPS using bedside sonography. The high specificity and narrow CI make it acceptable as a “rule-in” test. These results are important, as indicated by the low prevalence of HPS in patients going for US, because clinical suspicion based on the patient’s medical history alone is not an accurate predictor of disease. More than half (n = 36, 63%) of the normal patients presented with complaints of projectile vomiting. Furthermore, with only a single patient presenting with a pathognomonic palpable olive-shaped mass, the classic physical examination finding is also rare.

The results of our Bland-Altman plots show that pediatric EP sonographers’ measurements agree with those obtained by radiology. While the primary objective was just the determination of positive and negative cases, it would be concerning if there were large differences in the means between the EP and radiology measurements. Some variability in measurements may be expected in normal patients where the pylorus is undergoing regular contraction and relaxation. Length measurements, which are recognized in the literature to be more variable, also showed good agreement between radiology and pediatric EP sonographers. Radiology literature notes that measurements may change during the course of an examination and that the overall morphology of the channel is also a significant component of the examination.

Emergency physicians frequently use bedside US, and the American College of Emergency Physicians’ most recent emergency US policy statement called for more research in pediatric abdominal applications. Recent publications describe both EPs’ and surgeons’ ability to accurately diagnose primarily positive HPS cases in a small case series and observational studies. The prevalence of HPS in the patient

<table>
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<tr>
<th>Pediatric EP Sonographer</th>
<th>Enrolled/Positive HPS Cases</th>
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<tbody>
<tr>
<td>Attending</td>
<td>40/3</td>
</tr>
<tr>
<td>Fellow 1</td>
<td>14/1</td>
</tr>
<tr>
<td>Fellow 2</td>
<td>7/3</td>
</tr>
<tr>
<td>Fellow 3</td>
<td>2/1</td>
</tr>
<tr>
<td>Fellow 4</td>
<td>2/0</td>
</tr>
<tr>
<td>Fellow 5</td>
<td>1/1</td>
</tr>
<tr>
<td>Fellow 6</td>
<td>1/1</td>
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</table>

**Table 2**

Studies by EP Sonographers

HPS = hypertrophic pyloric stenosis.
population evaluated in a surgical clinic was above 90%, much greater than typically encountered in the emergency setting,18,22 and thus limits the generalization of their results in our setting.

Many EPs obtain lab testing or imaging on infants to screen for HPS. An ED with an active and robust bedside US practice including this modality could help to prioritize patient management. This could also allow for more expeditious transfer of infants to a facility with pediatric surgical capabilities. Existing applications taught to EM residents and PEM fellows, such as the focused assessment with sonography in trauma and hepatobiliary sonography, already evaluate relevant adjacent anatomic structures. Additional training to recognize the pylorus would build on these core foundations. Training in pyloric sonography should be considered for those who will evaluate infants with nonbilious vomiting, such as EPs, pediatric EPs, and surgeons.

LIMITATIONS

There are several limitations to this study. First, this was a convenience sampling of patients with a small number of positive cases at a single institution. US is highly operator-dependent and the results at other institutions with different sonographic experience may vary. The lower confidence limit for sensitivity of 62% is not an acceptable statistic for a screening test. The attending sonographer performed 60% of the studies. On sensitivity analysis, the lower confidence limit for sensitivity was similar, but low, for both the attending and the fellow sonographers (56 and 52%).

We could not determine how many studies are required for competence in this modality, as none of the participating fellow sonographers accrued more than the 25 studies generally considered to be the lower limit for competency for an application in emergency sonography. However, all but two of 10 suboptimal studies occurred during a fellow’s initial five studies. Upon review, either gastric air shadowing or inadequate depth settings were the primary reasons for difficulties with visualization. The results from the novices are consistent with those of many other emergency US applications, where greater than 25 studies are required for adequate accuracy in image acquisition and interpretation.20–28 When describing the learning curve for the sonographic evaluation of HPS, even radiologists reported errors at the 15th, 29th, and 35th cases studied.18

There was no measure for recording the confidence of the study sonographers in their findings, and we did not examine the potential bias of having the treating clinician as the sonographer. There are no published clinical scoring models to place infants presenting with vomiting into high- and low-risk categories. The greatest possible clinical bias was in finding an “olive,” which was documented in only a single patient during the study period in either the enrolled or the unenrolled population. We did not record the time it took to perform the study. This was not considered feasible, as many of the study US were also used as a platform for teaching to fellows, rotating residents, and medical students about the relevant anatomy and sonographic findings. Part of the scanning technique also included the infant’s ability to calm down after placing gel and a probe on the abdomen, sometimes requiring a pacifier, glucose water solutions, or parental contact. This period of patience is not unlike intermittently waiting to listen to the breath sounds or for a heart murmur in a crying child, but complicates the determination of a “start” time for the examination.

These findings should not suggest that radiology US is only for ruling in or out HPS in vomiting infants, as other possible diagnoses may benefit from additional imaging. We did not attempt to evaluate for malrotation, volvulus, or other surgical etiologies that may be apparent on US, although none was present as an alternate diagnosis in our study population.

CONCLUSIONS

In this pilot study, we demonstrated the feasibility of accurate identification and measurement of the pylorus by pediatric emergency physicians in the evaluation for hypertrophic pyloric stenosis. While good specificity was demonstrated, a larger study is needed to determine both the learning curve for emergency sonographers and the test accuracy in other ED settings.

The authors acknowledge Dr. Aridaman Jain for his statistical support.

References

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