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Use of Ultrasound Measurements to Direct Laparoscopic Pyloromyotomy in Infants

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ABSTRACT

Background: Laparoscopic pyloromyotomy is associated with an increased risk of incomplete myotomy compared with open myotomy. We hypothesized that utilizing ultrasound measured length to direct laparoscopic pyloromyotomy would reduce the risk of incomplete pyloromyotomy without a concomitant increase in the risk of mucosal perforation.

Methods: Infants (n=43) with hypertrophic pyloric stenosis diagnosed by ultrasound and subsequent laparoscopic pyloromyotomy over a 2-year period (December 2006 through December 2008) were studied. Pyloromyotomy length was guided by preoperative ultrasound measurements. Pyloromyotomy was considered complete if the measured length was ≥ the ultrasound measurement. Infants were followed prospectively for time to full feeding, time to discharge, and complications.

Results: The cohort included 38 male and 5 female infants (age, 37±13 days; range, 17 to 72 days) who underwent ultrasound (length 1.9±0.2cm; thickness 4.4±0.9mm) and laparoscopic pyloromyotomy. Infants achieved full feeding 28±16 hours postoperatively and were discharged 34±18 hours postoperatively. No infant required reoperation for incomplete myotomy. One infant sustained mucosal perforation (2%). No patient suffered other complications.

Conclusion: Preoperative ultrasound measurement of pyloric length to determine the length of laparoscopic pyloromyotomy, rather than visual cues alone, appears to minimize the risk of incomplete pyloromyotomy.

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INTRODUCTION

Pyloric stenosis is the leading cause of congenital narrowing of the gastric outlet, resulting from hypertrophy of the longitudinal and circular layers of the pylorus. The cause remains unknown with a sporadic hereditary pattern and evidence to suggest that the failure of muscle relaxation may be due to inadequate innervation, nitric oxide synthetase, resistance to vasoactive intestinal peptide, or a combination of these. Regardless of these insights, reliable nonoperative therapies have not been identified, and pyloric stenosis remains the leading indication for abdominal surgery in infants.

Historically, the treatment of pyloric stenosis has been longitudinal division of the pyloric muscles via a right upper quadrant laparotomy incision. Described by Ramstedt in 1912, the division of the pyloric muscle temporarily alleviates the gastric outlet obstruction while the hypertrophied pyloric muscle regresses over the first 6 months of life.[1] Due to the high success rate (>95%) and low complication rate (<10%) of open pyloromyotomy, the Ramstedt pyloromyotomy has become the "gold standard" by which to compare all alternative approaches.

The advent of minimally invasive surgery in infants and children appeared ideally suited for the treatment of hypertrophic pyloric stenosis. Refinements in instrumentation, as well as the availability of 3-mm instruments and 4-mm cameras allowed the completion of a traditional Ramstedt pyloromyotomy by laparoscopic techniques. Traditional "open" pyloromyotomy is associated with a 1% to 5% risk of mucosal perforation and a 1% to 3% risk of incomplete pyloromyotomy.[2] In contrast, the reported rate of incomplete pyloromyotomy requiring reoperation varies among series but appears higher with the laparoscopic technique.[2] The higher rate of incomplete pyloromyotomy may represent the learning curve associated with a new procedure and/or limitations in technique imposed by the approach.[3–5] With respect to technique, Yagmurlu et al[6] at reoperation for incomplete laparo-

scopic pyloromyotomy found that in 2 patients the pyloromyotomy failed to extend to the antrum, and in 2 patients the prior myotomy had fused closed, suggesting that incomplete laparoscopic pyloromyotomy results from inadequate length or insufficient separation of the divided muscle fibers, or both combined.

Today, ultrasound is most often utilized for the diagnosis of hypertrophic pyloric stenosis if suspected. Sensitivity and specificity of ultrasound in this setting are often reported to be >85%.[7,8] While the ultrasound criteria for diagnosis are well established, the length of pyloromyotomy needed to alleviate the obstruction remains less clear. Ostlie et al[9] found by ultrasound that the mean length of the pyloric channel in infants with pyloric stenosis is 1.95cm. They further suggest that completion of a laparoscopic pyloromyotomy of >2.0cm eliminates the risk of incomplete pyloromyotomy. We hypothesized that laparoscopic pyloromyotomy directed by ultrasound pyloric length with intraoperative confirmation of this ultrasound length would reduce the risk of incomplete pyloromyotomy. In addition, utilizing the ultrasound measurement of muscle diameter would permit deployment of the arthrotomy knife blade to a depth less than the wall thickness, which should avoid inadvertent mucosal perforation during the seromuscular incision.

METHODS

In a children's hospital, all infants (n=43) with hypertrophic pyloric stenosis diagnosed by ultrasound over a 2-year period (December 2006 through December 2008) were offered laparoscopic pyloromyotomy. All ultrasounds were reviewed by a board-certified, fellowship-trained pediatric radiologist preoperatively. Once diagnosed, infants were resuscitated and electrolytes were corrected with IV fluids. Surgery was considered once the infant had >1mL/kg/hour of urine output and serum bicarbonate level ≤30mmol/L. Laparoscopic pyloromyotomy length was guided by the preoperative ultrasound measurements of channel length and wall thickness. Laparoscopic pyloromyotomy was considered complete if (1) separation of the mid portion of the pyloromyotomy was 1.5cm as indicated by full deployment of the laparoscopic pyloric spreader **(Figure 1)**; and (2) the estimated operative length, as determined by the relationship of the metal portion of a laparoscopic grasper (2.0cm), equaled or exceeded the preoperative ultrasound measurement of the pylorus in the long axis **(Figure 2)**. With institutional board approval, infants were followed prospectively for time to full feeding, time to discharge, and complications.

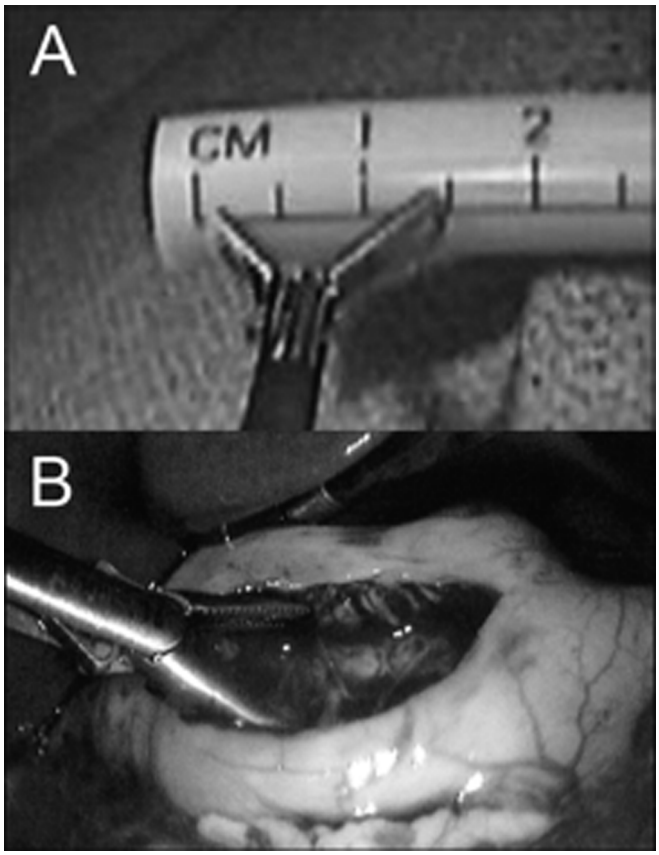

Figure 1. (A) Image of pyloric spreader fully deployed measuring 1.5cm at maximal separation. (B) Operative image demonstrating maximal separation of pyloric spreader in the mid portion of the completed pyloromyotomy, indicating a separation of 1.5cm.

Data were accrued for 24 months, and analysis was performed at 26 months. All patients were available for review and postoperative follow-up at ≤1 month was completed. Data are reported as the mean ± standard deviation. Comparisons were made using the unpaired Student *t* test. Differences were accepted as significant at $P<0.05$.

RESULTS

During the study interval, 43 infants (38 male, 5 female) age 37±13 days (range 17 to 72) underwent ultrasound and laparoscopic pyloromyotomy. By ultrasound, measurements of pyloric channel length (1.94±0.25cm) and wall thickness (4.4±0.9mm) were abnormal and consistent with the diagnosis of hypertrophic pyloric stenosis. Laparoscopic pyloromyotomy (38.7±8.1 minutes) was performed after rehydration and correction of electrolyte

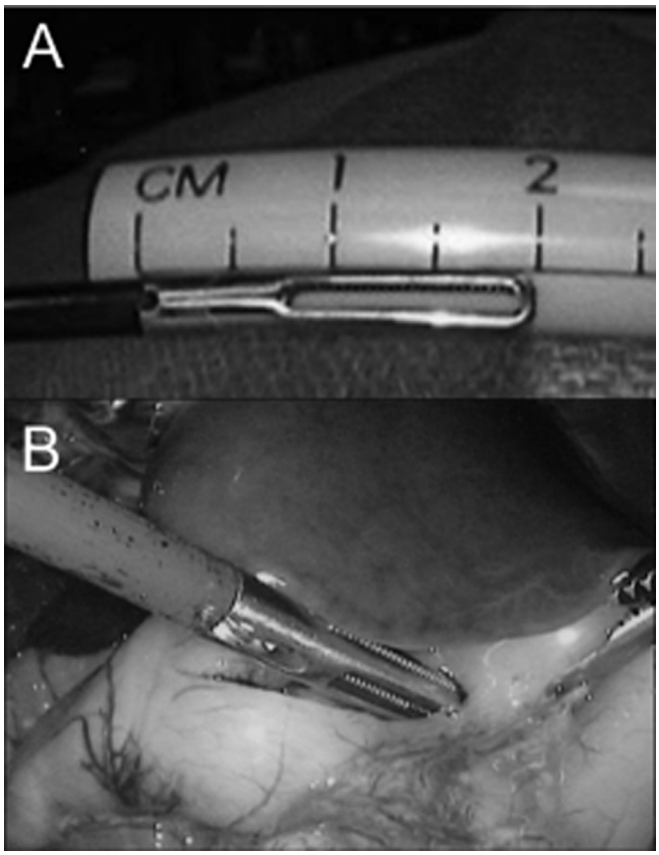

Figure 2. (A) Image of the metal portion of a laparoscopic grasper measuring 2.0cm. (B) Operative image of the metal portion of the laparoscopic grasper placed within the long axis of the completed pyloromyotomy, indicating an estimated pyloromyotomy length of 2.0cm.

disturbances. The pyloromyotomy was performed guided by the preoperative ultrasound measurements. Separation of the mid point of the pylorus was confirmed by full deployment of the laparoscopic pyloromyotomy spreader (1.5cm) within the pyloromyotomy **(Figure 1)**. The pyloromyotomy was considered adequate once the estimated operative length equaled or exceeded the ultrasound measurement **(Figure 2)**. Formula or breast milk feedings were initiated 4 hours postoperatively and advanced per schedule. Infants achieved full feeding 28±16 hours postoperatively. Postoperative emesis averaged 1.0±1.5 episodes per patient, but there was a wide degree of variability (0=19, 1=13, 2=5, 3=3, >3=1). Infants were discharged 34±18 hours postoperatively (range, 15 to 116). No infant required reoperation for incomplete myotomy. One infant sustained mucosal perforation during laparoscopic pyloromyotomy (2%), recognized intraoperatively, and completed open. During hospitalization, one infant with neurologic impairment demonstrated persistent nonbilious emesis. Upper gastrointestinal contrast study did not suggest incomplete pyloromyotomy but rather identified significant gastroesophageal reflux. The infant failed medical management and subsequently underwent laparoscopic Nissen fundoplication and gastrostomy button placement during the same hospitalization. Postoperatively, the infant achieved full enteral feeding without further difficulty. Both infants were excluded from analysis of postoperative emesis, time to full feeding, and length of stay. No patient required readmission or suffered other complications.

DISCUSSION

We found that the utilization of preoperative ultrasound measurements to guide laparoscopic pyloromyotomy length resulted in zero incomplete pyloromyotomies over a 2-year period. One mucosal perforation occurred (2%) during the spreading of the pyloromyotomy near the antral junction and required conversion to open. While there may be utility in the muscle wall thickness measurement to guide deployment of the arthrotomy knife blade to avoid mucosal perforation during the seromuscular incision, it does not appear beneficial in reducing the risk of mucosal perforation that occurs during spreading of the muscle.

Some have suggested that the frequency and duration of postoperative emesis may indicate an inadequate pyloromyotomy that may not require reoperation but can lead to prolonged postoperative emesis and hospitalization.[10,11] Campbell et al,[10] when examining the results of open and laparoscopic pyloromyotomy at multiple institutions, found that while mean costs were the same, there was a significant skewness of distribution in the cost of the laparoscopic group, suggesting that several infants may have suffered complications and prolonged length of stay due to the laparoscopic procedure. There is a wide range of reported rates of postoperative emesis following pyloromyotomy whether done open or laparoscopically.[11–14] Moreover, we could not find a relationship between postoperative emesis and age at presentation, serum bicarbonate at presentation, ultrasound measurement of pyloric channel length or thickness, all of which have been suggested as potential factors in the frequency of postoperative emesis. Together these findings suggest that postoperative emesis is likely multi-factorial, and the method of pyloromyotomy as the primary determinant of postoperative emesis is unlikely.

Ramstedt pyloromyotomy has consistently demonstrated a high success rate, minimal complications, and

nearly 100% survival. Although the frequency of mucosal perforation or incomplete pyloromyotomy remains low, failure to recognize mucosal perforation can be life threatening. Failure to achieve a complete myotomy often results in a second operation or prolonged hospital stay, or both. As a result, we as well as others have been interested in ways to eliminate or minimize these complications associated with laparoscopic pyloromyotomy.[12–14] With respect to the learning curve associated with laparoscopic pyloromyotomy, we found in a teaching institution that the learning curve rapidly declined, primarily characterized by a reduction in operative time and need for conversion to open.[15] Similarly, Vegunta et al[16] reported in a consecutive series of 185 infants undergoing laparoscopic pyloromyotomy that with experience operative times and hospitals stays were shortened, but most importantly complications were nearly eliminated. When examining complications in open (4.4%) or laparoscopic pyloromyotomy (5.6%), Yagmurlu et al[6] found that the rates of complications were not different, but the incidence of mucosal perforation was higher in the open group while incomplete pyloromyotomy occurred more often in the laparoscopic group. This same trend is observed in a meta-analysis performed by Hall et al[2] examining 3 prospective studies and one prospective randomized trial. No statistically significant differences between approaches could be identified, but they speculated that trends in differences might simply reflect the learning curve associated with these earlier studies.

Ultrasound is most frequently utilized for the diagnosis of hypertrophic pyloric stenosis due to the excellent sensitivity and specificity reported by experienced ultrasonographers, and the ease of obtaining the noninvasive study. Potentially, the ultrasound can be further utilized to direct the extent of laparoscopic pyloromyotomy. In the open procedure, the pylorus can be palpated to help define the extent of the pyloromyotomy. Since this is not possible during the laparoscopic approach, we have tended to rely on visual cues to ensure an adequate pyloromyotomy length. By utilizing the preoperative ultrasound measurement of channel length to guide the extent of laparoscopic pyloromyotomy, and confirmation with repeated measurement at the completion of the pyloromyotomy, we found that no patient suffered incomplete pyloromyotomy. Arguably, not only are the ultrasound measurements imprecise, but also the technique we described is an estimate rather than an absolute measurement of the pyloromyotomy length, both of which are somewhat dependent on the experience and expertise of the ultrasonographer and surgeon, respectively **(Figure 2)**. However, like those of Ostlie et al,[9] our findings suggest that ultrasound may indeed be useful in ensuring a complete laparoscopic pyloromyotomy. While the measured length of the pyloric channel (1.94±0.25cm) we observed is nearly the same as that reported by Ostlie et al (1.95±0.28cm), 30% of infants (13/43) had a pyloric channel length >2.0cm and had the pyloromyotomy length been limited to 2cm, as suggested by Ostlie et al, nearly a third of infants would have remained at risk for incomplete pyloromyotomy or inadequate pyloromyotomy. Furthermore, 7/43 infants had a pyloric length <1.7cm, which is one standard deviation below the average of 1.94cm. In this group, a pyloromyotomy of 2.0cm could have resulted in a greater number of mucosal perforations due to the unnecessary extension onto either margin of the pyloromyotomy where perforations are most likely to occur during the spreading of the divided pylorus.[6]

CONCLUSION

The use of preoperative ultrasound measurement of pyloric channel length to guide the length of laparoscopic pyloromyotomy rather than visual cues alone appears to minimize the risk of incomplete pyloromyotomy without an increased risk of mucosal perforation in infants. Although the frequency and duration of postoperative emesis following pyloromyotomy is likely multi-factorial, the low incidence of significant postoperative emesis utilizing our approach supports the concept that achieving adequate pyloromyotomy length is an important factor among the possible determinants of postoperative recovery and complications.

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