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ORIGINAL ARTICLE

Single-site umbilical laparoscopic pyloromyotomy in neonates less than 21-day old

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Abstract
Purpose Single-site umbilical laparoscopic pyloromyotomy for hypertrophic pyloric stenosis in neonates <3-week old has rarely been reported in the literature. This article reports our initial experience with this procedure.
Methods Overall, 13 cases of hypertrophic pyloric stenosis occurred in neonates <3-week old from January 2010 to April 2013 in our hospital. All neonates were treated by a single-site laparoscopic procedure. A 5-mm trocar and endoscope were introduced through an incision in the center of the umbilicus, and two 3-mm working instruments were inserted directly into the abdomen via separate lateral fascial stab incisions in the umbilical fold, and a single-site umbilical laparoscopic pyloromyotomy was then performed.
Results The procedure was performed in 13 infants (12 male) with mean age of 17.3 days. The average length of the operation was 26 min. The mean postoperative hospital stay was 4.5 days. All patients were discharged home on full feeds. Follow-up examinations were scheduled 2 to 6 weeks after discharge, and no postoperative complications were noted in any of the patients.
Conclusion These cases had shorter and thinner pylori than their older counterparts. However, the laparoscopic procedure was safe and feasible, with good postoperative results and excellent cosmesis. Surgeons should have a firm foundation of advanced minimal access surgical skills prior to attempting the procedure.

Keywords Single-site laparoscopic surgery · Neonate · Hypertrophic pyloric stenosis

Introduction

Infantile hypertrophic pyloric stenosis (HPS) occurs in approximately three of every 1000 live births [1], making it the most common indication for surgical intervention in infancy. The typical presentation is projectile, non-bilious vomiting occurring between 3 weeks and 3 months of age. Failure to diagnose the condition often results in weight loss, dehydration and metabolic abnormalities. The sonographic diagnostic criteria include a pyloric muscle thickness (PMT) of at least 3–4 mm and a pyloric muscle length (PML) of at least 14–17 mm [2].

Laparoscopic pyloromyotomy was first reported by Alain and colleagues [3] in 20 infants in 1991, and gained popularity because of its various advantages, such as a shorter operation, a faster time to full feeding and fewer complications. Single-site laparoscopic surgery has been increasingly used in the clinical setting [4, 5]. By taking advantage of the umbilicus as the sole access site, the procedure leaves almost no visible postoperative scar. Single-site laparoscopic pyloromyotomy has been introduced in some centers, and was shown to be an effective and safe procedure. With the recent advent of single-site laparoscopic surgery techniques, our group undertook

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single-site laparoscopic pyloromyotomy in 13 neonates when they were <3-week old. The sonographic diagnostic measurements showed that the infants had shorter and thinner pylori than their older counterparts. However, despite these smaller features, our early experience suggested that the outcomes of the procedure were excellent.

Materials and methods

Overall, 13 cases of hypertrophic pyloric stenosis occurred in infants <3-week old from January 2010 to April 2013 in our hospital. Single-site umbilical laparoscopic pyloromyotomy was performed for all of these infants. A retrospective analysis was undertaken, and the data collected included the demographic information, clinical manifestations, ultrasonographic and upper gastrointestinal series findings, associated anomalies, perioperative complications, the duration of hospital stay, etc.

Diagnostic criteria

The diagnosis of HPS is ascertained after obtaining an appropriate history and by the palpation for a pyloric olive. The diagnosis may be established by ultrasonography of the pylorus. The precise diagnostic criteria for HPS in neonates 3-week old or younger remain incompletely defined. In our group, the criteria used for a diagnosis were the presence of projectile, non-bilious vomiting, a pyloric muscle thickness >3.0 mm, a pyloric muscle length >14 mm and a pyloric stenosis index (double the pyloric muscle thickness divided by the diameter of the pyloric canal) >0.5.

Surgical technique

Once an infant with a clinical and sonographic diagnosis of hypertrophic pyloric stenosis was admitted, he or she was intravenously hydrated, and the electrolytes and acid–base status were normal, the laparoscopic approach was discussed with the patient's parents, and formal consent was obtained for single-site laparoscopic pyloromyotomy under general anesthesia.

The patient was placed supine on the table. A 5-mm port was placed at the center of the umbilicus through a longitudinal midline umbilical incision, which allowed for CO_2 insufflation and the use of an endoscope. Two 3-mm working instruments were inserted directly into the abdomen via separate lateral fascial stab incisions at the 10 and 2 o'clock positions, respectively, in the umbilical fold (Fig. 1). A 3-mm grasper was then passed through the left umbilical stab incision to grasp the antrum of the stomach proximal to the pylorus by the assistant. By exerting

Fig. 1 Instruments within the umbilical ring during a pyloromyotomy. 118 × 113 mm (96 × 96 DPI)

traction to the patient's left and somewhat down, the pylorus was nicely exposed and positioned at a diagonal [6]. A 3-mm pyloromyotomy knife was introduced into the abdominal cavity to make a seromuscular incision from the antrum to the pyloroduodenal junction. The paddle tip of a pyloric spreader was used to push into the center of the myotomy, and was twisted to help initiate breaking apart the muscle, and then a second 3-mm grasper was inserted through the right umbilical stab incision and used to enlarge the myotomy site carefully, as is accomplished with conventional laparoscopic pyloromyotomy (Fig. 2). After completion of the pyloromyotomy, 40–50 ml of air could be insufflated into the stomach to inspect the submucosa for perforation. After completion of the procedure, the 5-mm cannula site in the umbilicus was closed with a 3–0 absorbable suture, and then the skin incision at the umbilical fold was closed with glue (Fig. 3).

Results

Overall, 13 infants with hypertrophic pyloric stenosis that were <3-week old underwent single-site umbilical laparoscopic pyloromyotomy from January 2010 to April 2013 in our hospital. Twelve of the patients were male and one was female, with a mean age of 17.3 days, a mean birth weight of 3.3 kg and a mean gestational age of 37.6 weeks. The pyloric olive was palpated in three (23.08 %) of the patients (Table 1). One neonate (7.69 %) had a family history of HPS in a first-degree relative (the neonate's father).

The mean pyloric muscle thickness was 3.6 ± 0.35 mm, and the mean pyloric muscle length was 15.8 ± 2.8 mm. In the four cases where the pyloric muscle thickness was

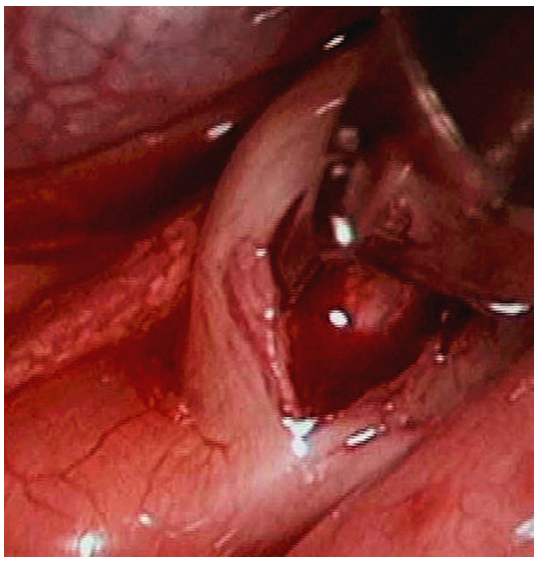

Fig. 2 The pyloric muscle was bluntly separated by single-site laparoscopic procedure. 118 × 123 mm (96 × 96 DPI)

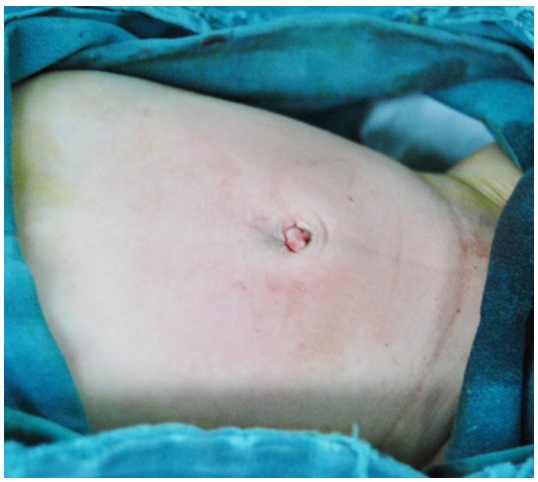

Fig. 3 Postoperatively, there is virtually no discernible incision. 153 × 136 mm (96 × 96 DPI)

between 3.0 and 3.5 mm, pyloric obstruction was shown by an upper gastrointestinal series. Two 7-day-old patients were admitted because of projectile non-bilious vomiting. The pyloric muscle thickness in both cases was 3 mm. Antireflux medications were used, but there was no effect in either case. Repeated ultrasound was performed 1 week later and showed that the pyloric muscle thickness was 3.8 in one case and 4.0 mm in the other. The pyloric stenosis index in all the cases was more than 0.5.

All procedures were completed by single-site umbilical laparoscopic pyloromyotomy. The length of the operation ranged from 15 to 30 min (mean 26 min), with no cases converted to open surgery or standard laparoscopy. The postoperative hospital stay ranged from 3 to 6 days (mean

Table 1 The demographic and clinical data of the IHPS patients diagnosed before they were 3-week old

	Age of diagnosis ≤3 weeks, $n = 13$
Sex (male/female)	12/1
Positive family history	1 (7.69 %)
Mean gestational age at birth (weeks)	38.4
Mean weight (kg)	3.3
Mean age of diagnosis (days)	17.3
Mean birth weight (kg)	3.3
Palpable olive mass	3 (23.08 %)
Jaundice	3 (23.07 %)
Diagnosed by ultrasound	100 % (13/13)
Diagnosed by barium meal study	4 (30.8 %)
Average length of operation	26 min
Intraoperative complications	0
Postoperative complications	0
Time to start oral feeding (days)	1
Mean postoperative hospital stay (days)	4.5

4.5 days), and all patients were discharged home on full feeds without emesis and were demonstrating good weight gain. Three cases were lost follow-up, but the other 10 cases were followed up for 3 to 24 months (mean 16.5 months) after discharge, and no postoperative complications were noted in any of the patients.

An 11-day-old neonate was complicated with an acute intussusception that developed the day after admission, and air enema reduction was unsuccessful. Emergency laparoscopic hydrostatic enema reduction was success under general anesthesia, and saline was discharged from the colon; the single-site umbilical laparoscopic pyloromyotomy was performed at the same time while the patient was under general anesthesia.

Discussion

In most instances, pyloric muscle hypertrophy is not present during the neonatal period. Thus, vomiting usually starts after 3 weeks of age. However, pyloric stenosis does exist in younger infants, and it has been reported as early as the first week of life [7], and even reported in utero [8]. Although the diagnosis and treatment of hypertrophic pyloric stenosis (HPS) have been well established for many years, the presentation in patients younger than 3-week old and in preterm infants is often atypical, leading to a delayed diagnosis [9]. The need for surgical intervention in a vomiting neonate may be clear, but many families and

pediatricians may require stronger diagnostic criteria that delineate the necessity of surgical treatment [10]. However, ultrasonographic diagnostic criteria for these patients remain to be established.

Huang et al. [11] reported that a total of 8.41 % (18/214) of the patients were diagnosed before 3 weeks of age in their study, confirming that neonatal disease is rare, but does exist. Demian et al. [12] reported that the ultrasound measurements of the pyloric muscle thickness (PMT) were influenced by the age, size or prematurity of infants, because younger and smaller patients presented with a smaller pylorus than their older counterparts; she suggested that a sonographic triad of a longitudinal muscle thickness $\geq$2.5 mm, a muscle length $\geq$14 mm and gastric outlet obstruction, can provide a prompt and accurate diagnosis. Lamki et al. [13] found that the PMT was significantly smaller in children <30-day old, but there was no difference in the PML, so they suggested using a diagnostic PMT value of 3 mm in children <1 month of age. Haider et al. [14] found that a decreased PMT was strongly correlated with weight, but not age. Forster et al. [15] recommended using the same criteria (PMT $\geq$3 mm and PML $\geq$17 mm) for all patients. Leaphart et al. [10] described that the PMT was significantly smaller in the "younger" patients than in their older counterparts, and suggested that 3.5 mm may be a useful cut-off value for the diagnosis of HPS in younger patients. In our group, the mean PMT was 3.6 $\pm$ 0.35 mm, and the mean PML was 15.8 $\pm$ 2.8 mm. In four of the cases, the PMT was between 3 and 3.5 mm, and the diagnosis was confirmed by an upper gastrointestinal series. A barium meal study is often used initially to determine whether gastroesophageal reflux or other causes of gastrointestinal obstruction are present [11].

A high index of suspicion is required for neonates presenting with gastric outlet obstruction. Compared with older infants with HPS, the pyloric olive was palpated less often in the patients younger than 21 days. Ultrasound and contrast studies provide additional information, but a definitive diagnosis may only be made intraoperatively in some cases. Upper endoscopy may show a distended stomach with an inconspicuous pylorus that did not open during the endoscopic examination [16]; laparoscopy generally shows a grossly distended stomach without an obviously thickened pyloric wall, which is in contrast to the findings in their older counterparts.

Patients younger than 3-week old with pyloric stenosis and the use of single-site umbilical laparoscopic pyloromyotomy in this age group have rarely been reported in the literature. Based on our experience, the procedure appears to be reasonable and feasible for the treatment of pyloric stenosis, but it had some disadvantages.

The lack of separation of the camera and instruments leads to limited maneuverability in the single-site procedure [4, 5]. Keeping the camera and the two operating forceps parallel in the abdominal cavity could help to avoid collision of the instruments. Furthermore, it was thought that having the camera in line with the instruments could compromise the intracorporeal visualization of the operating field, so a 30° camera was introduced. Using an endoscope longer than the other instruments takes the assistant's hands out of the working space of the surgeon, and the angulation of the optical axis of at least 30° provides an offset, rather than inline, view of the pylorus [5]. The use of a transabdominal suspension suture around the round ligament was sometimes useful for providing a good workspace.

The pyloromyotomy knife was easy to use for the seromuscular incision, and a pyloric spreader was then used to initiate spreading of the pyloric muscle. As the thickness of the pyloric muscle was thinner than that of the older patients, the depth of the seromuscular incision could not be more than 3 mm. The correct "feel" of incising and spreading the muscle requires the accumulation of experience by the surgeon.

To prevent duodenal perforation, surgeons should grasp the antrum of the stomach, rather than grasping the vulnerable duodenum distal to the pylorus. A serosal incision could be made from the antrum to the pyloroduodenal junction, but care is needed to avoid the pyloroduodenal junction. Because the neonates with EPS present with a smaller pylorus than older infants, the seromuscular incision must be made shallower than in older patients. The mucosa must also be carefully inspected to rule out any perforation.

Tajiri et al. [17] described 14 neonates who underwent surgery using the transumbilical approach by a half circumumbilical incision, and no intra- or post-operative complications were encountered. In fact, the transumbilical approach for neonates with hypertrophic pyloric stenosis is easier to perform than that for older infants with the same disease. If mucosal perforation is encountered that requires conversion, the operation can be accomplished by standard laparoscopic surgery or by the transumbilical approach.

There were no intra- or post-operative complications in our patients. To assess the true complication rate of single-site pyloromyotomy, more experience with larger numbers of patients is required. The lengths of the operation for the neonates were similar to the mean conventional laparoscopic times of 20–31 min reported in recent studies [18]. No special equipment was needed for the single-site laparoscopic pyloromyotomy, and the expenses were equal to those of standard laparoscopy. The procedure was safe and feasible, with good postoperative results and excellent cosmesis. Surgeons should have a firm foundation of advanced minimal access surgical skills, and a cautious, graduated approach should be used when attempting the procedure.

Conflict of interest Bing Li and co-authors have no conflicts of interest.

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