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Trends and surgical outcomes of laparoscopic versus open pyloromyotomy

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Abstract

Background—Hypertrophic pyloric stenosis (HPS) is one of the most common pediatric illnesses necessitating surgical intervention. Controversy remains over the optimal surgical approach between laparoscopic pyloromyotomy (LP) and open pyloromyotomy (OP). LP has gained acceptance for management of HPS in an era of expanding minimal access surgical approaches to pediatric conditions. Several studies suggest advantages of LP over OP; however, selection bias and small sample sizes remain a concern. This study compares the outcomes of LP versus OP using propensity score methods.

Methods—The 2013–2015 ACS NSQIP Pediatric PUF was queried for all infants undergoing pyloromyotomy. The trend in the proportion of infants undergoing LP was described and perioperative outcomes between the OP and LP cohorts were compared using propensity score weighted regression models.

Results—4847 infants were identified to have undergone surgical pyloromyotomy. The proportion of LP performed increased significantly from 59% in 2013 to 65.5% in 2015 ($p < 0.001$). LP was associated with lower overall complications (1.4% vs 2.9%) (OR_{adj} 0.52, 95% CI 0.34–0.80), surgical site-related complications (1.1% vs 2.1%) (OR_{adj} 0.52, 95% CI 0.32–0.84), and post-operative length of stay (1.5 days vs 1.9 days) (OR_{adj} 0.89, 95% CI 0.81–0.98) without significant differences in related re-operation (0.9% vs 0.9%) (OR_{adj} 1.01, 95% CI 0.52–1.93) or readmissions (1.4% vs 2.1%) (OR_{adj} 0.73, 95% CI 0.46–1.17).

Conclusions—Our study demonstrates that LP is increasingly utilized for management of hypertrophic pyloric stenosis and is associated with shorter length of stay, and lower odds of surgical site-specific and overall complications without differences in related re-operations. This study supports LP as a safe and effective method for management of HPS.

Keywords

Minimally invasive surgery; Pyloromyotomy; Pyloric stenosis; NSQIP

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In the first year of life, hypertrophic pyloric stenosis (HPS) is the most common infantile condition requiring surgical intervention, with an estimated incidence of 1.7 per 1000 person-years. HPS occurs most frequently in first-born males with significant familial aggregation and heritability [1, 2]. The condition can be fatal if left untreated due to malnutrition and dehydration that results from hypertrophy of the smooth circular muscle within the pylorus. Pyloromyotomy for the treatment of pyloric stenosis was first described by Ramstedt in 1912 and, in 1991, Alain et al. described the laparoscopic approach [3, 4].

Several meta-analyses and large retrospective analyses have evaluated comparative outcomes of each approach with varying conclusions [5–8]. Generally, these analyses conclude that open versus laparoscopic approaches have similar safety and effectiveness profiles. Two of the analyses favored laparoscopic approach due to reduced length of stay, time to full enteral feeds, and lower rates of total and wound-related complications. Hall et al. reported a large retrospective analysis of 2830 infants undergoing pyloromyotomy from 2007 to 2010 and they concluded that laparoscopic pyloromyotomy was associated with increased rates of incomplete myotomy (0.29% vs 1.16%). The other analyses did not make recommendations for either approach, concluding that approach be dictated by surgeon discretion owing to lack of differences in clinically meaningful outcomes.

In addition, the procedures have been compared in several randomized controlled trials. Leclair et al. performed a single-institution, randomized, controlled trial of 102 infants with pyloric stenosis from 1999 to 2003 [9]. They found a significant difference in operating and anesthesia time favoring open pyloromyotomy; however, the authors concluded that this may have been related to lack of surgeon experience with laparoscopic approach. In this series, they also reported a 6% rate of incomplete pyloromyotomy which is significantly higher than expected. Furthermore, Hall et al. reported a multicenter, international, double-blind, randomized controlled trial of 180 infants undergoing either open or laparoscopic pyloromyotomy from 2003 until 2007 [10]. They found a reduction in time to achievement of full enteral feeds and post-operative length of stay in infants undergoing laparoscopic approach. St. Peter et al. performed a single-institution, prospective, randomized trial of 200 infants undergoing either open or laparoscopic pyloromyotomy from 2003 to 2006 [11]. They found no significant difference in operative time, length of stay, or wound infection between approaches; however, they did note decreased doses of analgesia and reduced emesis post-operatively with laparoscopic approach.

Although the laparoscopic pyloromyotomy is accepted, inconsistency of reported outcomes has resulted in variability in the utilization of laparoscopic versus open approaches worldwide [12, 13]. We aim to further evaluate the most recent outcomes of laparoscopic versus open approaches to pyloromyotomy using the American College of Surgeons National Surgical Quality Improvement Program Pediatric database.

Materials and methods

The Stanford University Research Compliance Office determined that this study did not meet the definition of human subject research as defined in federal regulations 45 CFR 46.102; therefore, an IRB submission was not required.

Patient selection criteria

The 2013–2015 American College of Surgeons National Surgical Quality Improvement Program pediatric participant user data file (ACS NSQIP Pediatric PUF) was queried for all infants undergoing laparoscopic pyloromyotomy (LP) or open pyloromyotomy (OP) without exclusion. The query was performed by first selecting CPT 43520 and utilizing the surgical approach variable to stratify patients. The 2012 ACS NSQIP Pediatric PUF was excluded from analysis because cases were not distinguished by approach.

Estimating propensity scores

Estimation of treatment effects from observational data is difficult because exposure to treatment is non-random and often confounded with patient and contextual characteristics. To adjust for these factors, the differences in outcomes between laparoscopic and open pyloromyotomy were estimated using propensity scores as regression weights. A propensity score is defined as the probability of treatment exposure (laparoscopic vs open pyloromyotomy) conditional on pre-treatment covariates. Each infant's propensity score was estimated using boosted regression, which is a non-parametric procedure that iteratively adds regression trees of limited depth until the optimal balance between groups is achieved in terms of pre-treatment covariates. Boosted regression has been shown to produce models with less prediction error than other common methods [14–16].

The model to estimate propensity scores included 29 pre-operative variables, including sex, age in days, weight at time of surgery, gestational age at birth, ventilator dependence, current pneumonia, history of asthma, chronic lung disease, oxygen support, structural pulmonary abnormalities, esophagogastrintestinal disease, pancreaticohepatobiliary disease, presence and severity of cardiac risk factors, history of cardiac surgery, developmental delay, seizure disorder, structural CNS abnormality, neuromuscular disorder, steroid use within 30 days, failure to thrive, receipt of nutritional support, bleeding disorder, hematologic disorder, inotropic support, CPR within 7 days, congenital malformation, blood transfusions within 48 h prior to surgery, case status, and ASA classification. Characteristics of the laparoscopic and open pyloromyotomy samples, both before and after propensity score weighting, are presented in Table 1. The Kolmogorov–Smirnov (KS) statistic tests group differences in each variable, and its sum is minimized to find the optimal covariate balance across variables.

Estimating average treatment effects

Propensity score weighted logistic regression models were used to estimate the odds ratios (95% CIs) associated with laparoscopic versus open pyloromyotomy for the occurrence of a surgical site complication, systemic complication, any complication, related readmission, and related re-operation. Surgical site complications were derived from the following variables: bleeding, superficial and deep wound disruption, and organ space, deep, and superficial surgical site infections. Systemic complications were derived of the following variables: pneumonia, urinary tract infection, catheter-associated blood stream infection, sepsis, septic shock, venous thrombus, pulmonary embolus, cardiac arrest, seizures, stroke, acute renal failure, progressive renal insufficiency, and unplanned intubation.

Propensity score weighted Poisson regression models were used to estimate the odds ratios (95% CIs) associated with laparoscopic versus open pyloromyotomy for number of days between operation and discharge, and for total length of stay. Propensity score weighted linear regression models were used to calculate beta effect estimates for anesthesia time and operative time. Mortality rates could not be analyzed due to insufficient numbers.

Secondary analysis of related re-operations

Descriptive statistics were performed to provide additional insight on relatively rare indications for related re-operation. This was completed by tabulating and categorizing the reason for related re-operation by designated CPT and ICD-9 code assignments.

Results

As presented in Table 1, the laparoscopic ($N = 3035$) and open ($N = 1812$) pyloromyotomy samples were similar on most pre-operative covariates, and small differences were further reduced by the propensity score weighting. Overall, excellent balance was achieved on all pre-operative clinical and treatment history variables, with no significant KS statistics.

The proportion of LP performed increased significantly from 59% in 2013 to 65.5% in 2015 ($p < 0.001$), as shown in Fig. 1. 33 infants in the laparoscopic cohort suffered only one surgical site complication and 39 infants in the open cohort suffered 42 surgical site complications. 11 infants in the laparoscopic cohort suffered 14 systemic complications and 16 infants in the open cohort suffered 19 systemic complications. The breakdown of surgical site and systemic complications are further outlined in Table 2. In propensity score weighted logistic regressions, the odds ratios (95% CIs) associated with laparoscopic pyloromyotomy were 0.52 (0.32–0.84) for surgical site complications, 0.52 (0.23–1.17) for systemic complications, 0.52 (0.34–0.80) for all complications, 0.73 (0.46–1.17) for related readmissions, and 1.01 (0.52–1.93) for related re-operation. The beta effect sizes from propensity score weighted linear regression models for duration of anesthesia and total operative time were -5.2 (-6.1 to -1.2) and -5.5 (-6.8 to -4.2), respectively. In addition, the odds ratios (95% CIs) from propensity score weighted Poisson regression models were 0.89 (0.81–0.98) for days between operation and discharge, and 0.87 (0.77–0.99) for total length of stay, as shown in Table 3.

Table 4 outlines reasons for related re-operations ($N = 43$) occurring a mean 6.9 (SD = 8.3) and 7.9 (SD = 9) days after index operation for laparoscopic versus open pyloromyotomy ($p = 0.71$), respectively.

Discussion

Our study confirms that laparoscopic approach to management of HPS is associated with lower odds of overall and surgical site-specific complications. The relative infrequency of complications from the surgical management of pyloric stenosis requires large cohorts to identify difference in outcomes. For this reason, the ACS NSQIP Pediatric PUF is particularly suited for addressing the controversy that exists in approach for surgical management of HPS.

Leclair et al. and Hall et al. reported increased rates of incomplete myotomy for infants undergoing laparoscopic pyloromyotomy; however, this has been demonstrated to improve significantly with increased surgeon experience [17]. In our series, after propensity score weighted logistic regression, there was no difference in the rate of related re-operation between either approach (0.9% vs 0.9%). Furthermore, although we are unable to conclude with statistical certainty, given rarity of re-operative complications, rates of incomplete pyloromyotomy requiring re-operation was higher for infants initially undergoing an open surgical approach. These observations do not support evidence that laparoscopic approach may be associated with increased rates of incomplete pyloromyotomy requiring re-operation.

Several studies have demonstrated reduction in time to achievement of full enteral feeds and post-operative length of stay. Although the ACS NSQIP Pediatric PUF database does not collect data on time to full enteral feeding and institutional protocols for feeding are highly variable, our study demonstrates a benefit from laparoscopic approach in the days between operation and discharge and total length of stay. Given that tolerance of enteral feeds is the most significant factor in the discharge of children with hypertrophic pyloric stenosis who are typically otherwise healthy, it is reasonable to conclude that time to tolerance of enteral feeds was shorter in the LP cohort in our study.

Economic, cosmetic, and less tangible benefits of laparoscopy must be considered. Value and cost-effectiveness of healthcare delivery has become an increasingly important focus in the United States. Carrington et al. performed a cost-effectiveness analysis of reported clinical outcomes from a multicenter, international, double-blind randomized, controlled trial [18]. Overall, laparoscopic pyloromyotomy was found to be cost-effective over an open approach with similar operative costs and overall savings of \$1263 ($p = 0.005$), most of which was due to reduced length of stay. Our study similarly demonstrated significant difference in days between operation and discharge which excludes any variation in pre-operative resuscitation performed among participating hospitals. In addition, St. Peter et al. performed a follow-on study objectively evaluating parental perception of laparoscopic versus open pyloromyotomy scars [19]. They demonstrated cosmetic superiority of the laparoscopic approach. Evidence also suggests that adhesion-related complications occur less frequently after laparoscopic versus open procedures, an important consideration, especially for infants and children [20]. Our study demonstrates statistically significant reduction in duration of anesthesia and operative time for infants undergoing laparoscopic pyloromyotomy. Arguably, this reduction in duration of anesthesia and operative time is not clinically meaningful; however, it does not support the criticism of longer operative times for laparoscopy. The importance of minimizing the duration of anesthesia in infants is being recently recognized and FDA guidance has called for reduction in duration and occurrences of exposure [21].

This study has several limitations. First, we used the ACS NSQIP Pediatric PUF and so known limitations of this dataset must be considered. The ACS NSQIP Pediatric PUF has an Inter-Rater Reliability (IRR) of approximately 2% for all assessed program variables, includes 30-day follow-up only, and is representative of only a sample of cases performed at participating sites [22]. Due to the relative infrequency of complications observed for infants

undergoing pyloromyotomy, sampling error could impact our findings. The lack of facility identifiers in the NSQIP dataset makes it impossible to estimate hospital and surgeon volume effect on HPS outcomes. Although anonymity of participating sites prevents analysis on the generalizability of the dataset, the costs and resources required to participate in the ACS NSQIP Pediatric program make it likely that only practice patterns of larger pediatric institutions are represented. In addition, the rates of post-operative complications may be underestimated due to reporting bias. Propensity score analysis can only account for observed covariates and so unobserved covariates such as pre-operative antibiotic use or surgeon experience may contribute to differences in outcomes described [23].

In conclusion, laparoscopic pyloromyotomy is associated with lower odds of surgical site-specific complications, lower odds of overall complications, and shorter length of stay. In addition, there is no statistically significant difference in rates of related readmission or re-operation, indicating that rates of gastrointestinal injury and incomplete myotomy are likely not different. Laparoscopic pyloromyotomy is increasingly utilized for management of hypertrophic pyloric stenosis and is safe and effective in centers capable of minimally invasive surgery.

References

1. Krogh C, Fischer TK, Skotte L, Biggar RJ, Øyen N, Skytthe A, Goertz S, Christensen K, Wohlfahrt J, Melbye M (2010) Familial aggregation and heritability of pyloric stenosis. *J Am Med Assoc* 303:2393–2399. 10.1001/jama.2010.784
2. Chung E (2008) Infantile hypertrophic pyloric stenosis: genes and environment. *Arch Dis Child* 93:1003–1004. 10.1136/adc.2008.141499 [PubMed: 19028966]
3. Ramstedt C (1912) Zur operation der angeborenen pylorus-sten-ose. *Med klin*
4. Alain JL, Grousseau D, Terrier G (1991) Extramucosal pyloromyotomy by laparoscopy. *Surg Endosc* 5:174–175 [PubMed: 1839574]
5. Sathya C, Wayne C, Gotsch A, Vincent J, Sullivan KJ, Nasr A (2017) Laparoscopic versus open pyloromyotomy in infants: a systematic review and meta-analysis. *Pediatr Surg Int* 33:325–333. 10.1007/s00383-016-4030-y [PubMed: 27942806]
6. Oomen MWN, Hoekstra LT, Bakx R, Ubbink DT, Heij HA (2012) Open versus laparoscopic pyloromyotomy for hypertrophic pyloric stenosis: a systematic review and meta-analysis focusing on major complications. *Surg Endosc* 26:2104–2110. 10.1007/s00464-012-2174-y [PubMed: 22350232]
7. Sola JE, Neville HL (2009) Laparoscopic vs open pyloromyotomy: a systematic review and meta-analysis. *J Pediatr Surg* 44:1631–1637. 10.1016/j.jpedsurg.2009.04.001 [PubMed: 19635317]
8. Jia W-Q, Tian J-H, Yang K-H, Ma B, Liu Y-L, Zhang P, Li R-J, Jia R-H (2011) Open versus laparoscopic pyloromyotomy for pyloric stenosis: a meta-analysis of randomized controlled trials. *Eur J Pediatr Surg* 21:77–81. 10.1055/s-0030-1261926 [PubMed: 20957601]
9. Leclair M-D, Plattner V, Mirallie E, Lejus C, Nguyen J-M, Podevin G, Heloury Y (2007) Laparoscopic pyloromyotomy for hypertrophic pyloric stenosis: a prospective, randomized controlled trial. *J Pediatr Surg* 42:692–698. 10.1016/j.jpedsurg.2006.12.016 [PubMed: 17448768]
10. Hall NJ, Pacilli M, Eaton S, Reblock K, Gaines BA, Pastor A, Langer JC, Koivusalo AI, Pakarinen MP, Stroedter L, Beyerlein S, Haddad M, Clarke S, Ford H, Pierro A (2009) Recovery after open versus laparoscopic pyloromyotomy for pyloric stenosis: a double-blind multicentre randomised controlled trial. *Lancet* 373:390–398. 10.1016/S0140-6736(09)60006-4 [PubMed: 19155060]
11. St Peter SD, Holcomb GW, Calkins CM, Murphy JP, Andrews WS, Sharp RJ, Snyder CL, Ostlie DJ (2006) Open versus laparoscopic pyloromyotomy for pyloric stenosis: a prospective, randomized trial. *Ann Surg* 244:363–370. 10.1097/01.sla.0000234647.03466.27 [PubMed: 16926562]

12. Ednie AC, Amram O, Schuurman N, Yanchar NL (2017) Comparing pyloromyotomy outcomes across Canada. *J Pediatr Surg* 52:739–743. 10.1016/j.jpedsurg.2017.01.021 [PubMed: 28238307]
13. Ceccanti S, Mele E, Frediani S, Morgante D, Iaconelli R, Almenrader N, Passariello M, Cozzi DA (2013) Moving toward laparoscopic pyloromyotomy: an initial Italian experience and national survey. *Am Surg* 79:955–958 [PubMed: 24069999]
14. Friedman J (2001) Greedy function approximation: a gradient boosting machine. *Ann Stat*
15. Efron B, Hastie T, Johnstone I (2004) Least angle regression. *Ann Stat*
16. McCaffrey D, Ridgeway G, Morral A (2004) Propensity score estimation with boosted regression for evaluating causal effects in observational studies. *Psychol Methods*
17. van der Bilt JDW, Kramer WLM, van der Zee DC, Bax NMA (2004) Laparoscopic pyloromyotomy for hypertrophic pyloric stenosis: impact of experience on the results in 182 cases. *Surg Endosc* 18:907–909. 10.1007/s00464-003-9075-z [PubMed: 15108114]
18. Carrington EV, Hall NJ, Pacilli M, Drake DP, Curry JI, Kiely EM, De Coppi P, Pierro A, Eaton S (2012) Cost-effectiveness of laparoscopic versus open pyloromyotomy. *J Surg Res* 178:315–320. 10.1016/j.jss.2012.01.031 [PubMed: 22480835]
19. St. Peter SD, Acher CW, Shah SR, Sharp SW, Ostlie DJ (2016) Parental and volunteer perception of pyloromyotomy scars: comparing laparoscopic, open, and nonsurgical volunteers. *J Laparoendosc Adv Surg Tech* 26:305–308. 10.1089/lap.2015.0566
20. Anderson SA, Beierle EA, Chen MK (2014) Role of laparoscopy in the prevention and in the treatment of adhesions. *Semin Pediatr Surg* 23:353–356. 10.1053/j.sempedsurg.2014.06.007 [PubMed: 25459441]
21. Research C DE and Drug Safety and Availability - FDA Drug Safety Communication: FDA review results in new warnings about using general anesthetics and sedation drugs in young children and pregnant women>
22. American College of Surgeons (2016) User guide for the 2015 ACS NSQIP Pediatric procedure targeted participant use data file (PUF) American College of Surgeons National Surgical Quality Improvement Program-Pediatric
23. Rubin DB (1997) Estimating causal effects from large data sets using propensity scores. *Ann Intern Med* 127:757 10.7326/0003-4819-127-8_Part_2-199710151-00064 [PubMed: 9382394]

Fig. 1.
Trends in adoption of laparoscopic pyloromyotomy ($p < 0.001$)

Table 1

Characteristics of laparoscopic and open pyloromyotomy samples before and after propensity score weighting

Characteristic	Laparo scopic (<i>n</i> = 3035)	Open unbalanced (<i>n</i> = 1812)	Open balanced (<i>n</i> = 1812)	KS <i>p</i> value
Female (%)	510 (16.8)	272 (15)	286 (15.8)	0.404
Age (days)	44.1	45.9	46.5	0.998
Weight (kgs)	3.98	4.05	3.99	1.000
> 36 week gestation (%)	2735 (90.1)	1627 (89.8)	1634 (90.2)	0.920
Ventilator dependent (%)	12 (0.4)	7 (0.4)	5 (0.3)	0.564
Asthma (%)	3 (0.1)	2 (0.1)	2 (0.1)	0.940
Chronic lung disease (%)	18 (0.6)	16 (0.9)	11 (0.6)	0.896
Oxygen support (%)	30 (1.0)	20 (1.1)	14 (0.8)	0.504
Pulmonary abnormalities (%)	12 (0.4)	16 (0.9)	11 (0.6)	0.462
Esophagogastrintestinal disease (%)	2270 (74.8)	1151 (63.5)	1335 (73.7)	0.390
Pancreaticobiliary disease (%)	6 (0.2)	7 (0.4)	4 (0.2)	0.774
No cardiac risk factors (%)	2929 (96.5)	1729 (95.4)	1743 (96.2)	0.598
Previous cardiac surgery (%)	12 (0.4)	14 (0.8)	9 (0.5)	0.598
Developmental delay (%)	9 (0.3)	11 (0.6)	7 (0.4)	0.518
Seizure disorder (%)	3 (0.1)	4 (0.2)	4 (0.2)	0.522
Structural CNS abnormality (%)	15 (0.5)	14 (0.8)	11 (0.6)	0.754
Neuromuscular disorder (%)	3 (0.1)	4 (0.2)	2 (0.1)	0.916
Steroid use within 30 days (%)	9 (0.3)	4 (0.2)	4 (0.2)	0.738
Failure to thrive (%)	82 (2.7)	45 (2.5)	47 (2.6)	0.804
Nutritional support (%)	52 (1.7)	42 (2.3)	33 (1.8)	0.874
No bleeding disorder (%)	2431 (80.1)	1506 (83.1)	1470 (81.1)	0.420
Hematologic disorder (%)	15 (0.5)	11 (0.6)	9 (0.5)	0.708
Previous CPR within 7 days (%)	0 (0.0)	2 (0.1)	0 (0.0)	0.332
No congenital malformation (%)	2832 (93.3)	1689 (93.2)	1692 (93.4)	0.874
Blood transfusion within 48 h of surgery (%)	0 (0.0)	2 (0.1)	2 (0.1)	0.522
Elective case (%)	762 (25.1)	439 (24.2)	437 (24.1)	0.416
Emergent case (%)	980 (32.3)	620 (34.2)	603 (33.3)	0.446

Characteristic	Laparo scopic (<i>n</i> = 3035)	Open unbalanced (<i>n</i> = 1812)	Open balanced (<i>n</i> = 1812)	KS <i>p</i> value
Urgent case (%)	1296 (42.7)	754 (41.6)	772 (42.6)	0.972
ASA class I (%)	659 (21.7)	442 (24.4)	402 (22.2)	0.726
ASA class II (%)	1936 (63.8)	1109 (61.2)	1154 (63.7)	0.918
ASA class III (%)	431 (14.2)	246 (13.6)	248 (13.7)	0.632
ASA class IV (%)	6 (0.2)	13 (0.7)	7 (0.4)	0.244

Table 2

Breakdown of unadjusted surgical site and systemic complication rates between laparoscopic versus open pyloromyotomy

Outcome ^a	Laparoscopic	Open
All surgical site complications ^a	<i>N</i> = 33	<i>N</i> = 42
Bleeding complication (%)	2 (6.1)	4 (9.5)
Superficial wound dehiscence (%)	2 (6.1)	7 (16.7)
Deep wound dehiscence (%)	11 (33.3)	9 (21.4)
Organ space SSI (%)	0 (0)	2 (4.8)
Deep incisional SSI (%)	1 (3)	4 (9.5)
Superficial SSI (%)	17 (51.5)	16 (38.1)
All systemic complications	<i>N</i> = 14	<i>N</i> = 19
Pneumonia (%)	1 (7.1)	2 (10.5)
Urinary tract infection (%)	4 (28.6)	6 (31.6)
Sepsis (%)	1 (7.1)	4 (21.1)
Cardiac arrest (%)	1 (7.1)	1 (5.3)
Seizures (%)	1 (7.1)	0 (0)
Ischemic or hemorrhagic stroke (%)	1 (7.1)	0 (0)
Unplanned intubation (%)	5 (35.7)	6 (31.5)

^a Outcome variables that were included in the analysis but that did not occur are excluded from this table

Table 3
Unadjusted outcomes and adjusted odds ratios comparing laparoscopic versus open pyloromyotomy

Outcome	Laparoscopic	Open	Effect sizes (95% CI)	Sig
Surgical site complications (%)	33 (1.1)	39 (2.1)	OR 0.52 (0.32–0.84)	$p = 0.007$
Systemic complications (%)	11 (0.4)	16 (0.9)	OR 0.52(0.23–1.17)	NS
All complications (%)	43 (1.4)	53 (2.9)	OR 0.52 (0.34–0.80)	$p = 0.007$
Related readmissions (%)	42 (1.4)	38 (2.1)	OR 0.73 (0.46–1.17)	NS
Related re-operation (%)	26 (0.9)	17 (0.9)	OR 1.01 (0.52–1.93)	NS
Mean (SD) duration of anesthesia (min)	77.9 (42.4)	83.4 (67.1)	$b = -5.2 (-6.1 \text{ to} -1.2)$	$p = 0.003$
Mean (SD) total operative time (min)	27.2 (19.2)	32.7 (24.1)	$b = -5.5 (-6.8 \text{ to} -4.2)$	$p < 0.001$
Mean (SD) days between operation and discharge	1.5 (3.0)	1.9 (4.2)	OR 0.89 (0.81–0.98)	$p = 0.021$
Mean (SD) total length of stay (days)	2.6 (4.4)	3.2 (8.4)	OR 0.87 (0.77–0.99)	$p = 0.034$

Table 4

Reasons for related re-operation after pyloromyotomy

Reason	Laparoscopic (<i>n</i> = 26)	Open (<i>n</i> = 17)
Gastrointestinal injury (%)	2 (7.7)	1 (5.9)
Incomplete pyloromyotomy (%)	4 (15.4)	5 (29.4)
Surgical site complication (%)	11 (42.3)	7 (41.2)
Unrelated (%)	2 (7.7)	1 (5.9)
Unknown (%)	7 (26.9)	3 (17.6)