Predictors of Morbidity Following Enterostomy Closure in Infants: An American College of Surgeons Pediatric National Surgical Quality Improvement Program Database Analysis

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Abstract

Optimal timing of enterostomy closure in infants is poorly defined, and clinical practice is based mainly on surgeon preference. This study aims to determine the predictors of morbidity in infants < 365 days old undergoing enterostomy reversal. A retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program Pediatric (ACS-NSQIP Peds) database was conducted from 2012–2017, including all laparoscopic and open enterostomy reversals in patients < 365 days old. Predictors of overall morbidity were analyzed by bivariate and multivariate logistic regression analysis with statistical significance at P < .05. We identified 2415 cases with an overall morbidity rate of 30.5%. Bivariate analysis identified that younger age, lower weight, prematurity, pulmonary disease, previous cardiac surgery, preoperative nutritional support, preoperative steroids, and preoperative transfusion were associated with overall morbidity for enterostomy closure. On multivariate analysis, prematurity < 30 weeks at birth (odds ratio [OR], 1.49; 95% confidence interval [CI]; 1.07-2.08), pulmonary disease (OR, 1.31; 95% CI, 1.01-1.71), and preoperative nutritional support (OR, 2.46; 95% CI 1.99-3.05) were independently associated with overall morbidity. Age and weight at the time of enterostomy closure were not independently associated with overall morbidity on multivariate analysis. Prematurity < 30 weeks at birth, presence of pulmonary disease, and preoperative need for nutritional support were independent predictors of overall morbidity in patients < 365 days old undergoing enterostomy reversal. Given the high rate of overall morbidity in this population, further research into the matter is warranted.

Keywords

pediatric, neonate, infant, enterostomy, enterostomy reversal

Abbreviations and Acronyms

ACS-NSQIP = American College of Surgeons National Surgical Quality Improvement Program
ACS-NSQIP Peds = American College of Surgeons National Surgical Quality Improvement Program Pediatric
CPT = current procedural terminology

Introduction

Enterostomy formation is often necessary for the treatment of several acute life-threatening conditions in the infant population.[1–3] These conditions include necrotizing enterocolitis, spontaneous intestinal perforation, and meconium obstruction, which may be fatal without surgical intervention.[1,4] Despite optimal management, enterostomy formation is a source of long-term morbidity in the infant population and may result in complications such as stoma prolapse, intestinal obstruction, stoma retraction, stoma ischemia, fluid and electrolyte losses, and poor weight gain in up to 41% of patients.[1,5–7]

Optimal timing of closure of enterostomy is controversial and conflicting evidence exists on best practice. Several studies have suggested using specific weight cut-offs to identify patients who are safe for enterostomy closure.[1,8,9] However, patients who have failure to thrive due to a nutritionally restrictive enterostomy may find it difficult to attain these specific weight goals. Other authors have suggested waiting a certain amount of time from enterostomy creation until reversal to ensure safe closure.[10–13] Advocates of late closure report fewer adhesions and reduced inflammation as a benefit to delaying stoma closure. Regardless, good nutritional status and a stable medical condition are preferable for ostomy reversal.[4] Due to this conflicting data and lack of prospective randomized controlled trials on this topic, closure timing is often left up to the surgeon's experience and preference.

To date, there is no large data series reporting on the timing of enterostomy closure and factors associated with morbidity and mortality. It would be useful to determine a set of predictors that could guide the timing of enterostomy takedown in infants. This study aims to determine risk factors associated with morbidity and mortality for the takedown of enterostomy in the infant population.

Materials and Methods

Data Collection

Data were collected from the American College of Surgeons National Surgical Quality Improvement Program Pediatric (ACS-NSQIP Peds) Registry. ACS-NSQIP Peds collects 94 data points from children less than 18 years who undergo major surgical procedures. Outcome data is collected for 30 days postoperatively. Institutional Review Board approval was not obtained as the NSQIP registry is a publicly available and de-identified data set.

Cohort Selection

A retrospective review of the ACS-NSQIP Peds database was performed from 2012 to 2017 to evaluate variables associated with morbidity in pediatric patients undergoing ostomy reversal. We included all patients under 365 days old undergoing laparoscopic and open enterostomy reversal. Included were all patients with current procedural terminology (CPT) codes 44227, 44620, 44625, and 44626.

Cohort Characteristics

Patient characteristics and outcomes were collected as part of the ACS-NSQIP Peds database. Patient characteristics included age, weight, prematurity, neurologic disorder, major cardiac risk factor, previous cardiac surgery, structural pulmonary abnormality, pulmonary disease, need for pulmonary support, preoperative nutritional support, preoperative transfusion (<72 hours before surgery), and preoperative steroids. Age was further divided into 3 separate categories: 0–30 days, 1–3 months, and 3–12 months. Prematurity was further divided into groups of <30 weeks, 31–36 weeks, and >36 weeks (term). Similarly, weight was divided into 3 separate categories: <2 kg, 2–4 kg, and >4 kg.

Outcomes

The primary outcome of this study was defined as 30-day morbidity as a result of enterostomy closure. Morbidity was defined by the presence of at least 1 of the following postoperative complications: death, pulmonary complication, renal complication, cerebrovascular accident, intraventricular hemorrhage, seizure, cardiac arrest, pneumonia, reintubation, hemorrhage, renal failure or insufficiency, deep vein thrombosis, sepsis, urinary tract infection, central line-associated bloodstream infection, dehiscence, surgical site infection, reoperation, and readmission.

Statistical Analysis

Bivariate analysis of predictors of morbidity was performed using Chi-square test or *t*-test of proportions as appropriate. Multivariate analysis of predictors of morbidity was performed by multiple logistic regression resulting in risk-adjusted odds ratios for the outcome of interest given each risk factor. Statistical significance was assigned to a $P<.05$. Statistical analysis was performed with R version 3.5.1.

ACS-NSQIP Disclosure Statement

The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS-NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

Results

From 2012 to 2017, a total of 2415 open or laparoscopic enterostomy reversals were performed on infants <365 days old. Sixty-two percent of these patients were male, and the average age at time of enterostomy takedown was 152 days old (±87 days). We were not able to extract data on time from enterostomy formation until takedown. The average weight at enterostomy takedown was 5.10 kg (±2.38 kg).

In total, 30.5% of patients in our study population had any morbidity (Table 1). The most frequent morbidities encountered were bleeding, infection, and the need for reoperation. We found that children at younger ages at enterostomy reversal had higher rates of morbidity. This finding was significant on bivariate analysis; however, this relationship was not maintained on multivariate analysis. Additionally, there was a higher rate of morbidity in patients when enterostomy closure occurred at lower weights.

Similarly, this relationship was significant on bivariate analysis but was not significant on multivariate analysis. Compared to children born at term, premature infants had significantly higher morbidity rates at ostomy reversal on bivariate analysis. However, only prematurity <30 weeks was significantly associated with morbidity (Table 2). These data suggest that reversing enterostomies at a lower weight may not confer increased morbidity.

On bivariate analysis, underlying neurologic disorder (35%; $P<.05$), major or severe cardiac risk factor (34.9%; $P=.02$), previous cardiac surgery (42.8%; $P<.05$), pulmonary disease (47.2%; $P<.05$), respiratory support (51.1%; $P<.05$), preoperative nutritional support (46.9%; $P<.05$), preoperative transfusion within 72 hours of surgery (42.4%; $P<.05$), and preoperative steroid use (53.1%, $P<.05$) were significantly associated with any morbidity. On multivariate analysis, however, only prior pulmonary disease (odds ratio [OR], 1.31; 95% confidence interval [CI], 1.01-1.71) and the need for preoperative nutritional support (OR, 2.46; 95% CI 1.99-3.05) were found to be significantly associated with morbidity (Table 2).

Discussion

Our study sought to identify predictors of morbidity and mortality in pediatric patients <365 days old undergoing enterostomy closure. Our findings from multivariate analysis indicated that prematurity <30 weeks, presence of pulmonary disease, and the need for perioperative nutrition were significantly associated with increased morbidity and mortality. Interestingly, age and weight at time of reversal were not significantly associated with increased morbidity on multivariate analysis.

There have been several studies assessing individual risk factors associated with enterostomy closure in the pediatric patient. To our knowledge, this is the first large data series that examines variables associated with morbidity in infants <365 days old undergoing enterostomy reversal. Currently, there is poor evidence to direct ostomy closure in the pediatric population.[11] Often, a weight of 2.0–2.5 kg is used as a threshold to direct timing for enterostomy closure.[1,4] This practice, however, has recently come into question.

Several retrospective studies have established the safety of ostomy reversal at weights <2.0 kg without increasing morbidity or mortality.[6,9,14] Talbot et al examined a cohort of 89 patients

Table 1. Bivariate Analysis of Demographic Features and Preoperative Risk Factors Versus Morbidity In Children < 365 Days Old

Variables	Total	No Morbidity n (%)	Any Morbidity n (%)	*P* value
All Patients	2415	1679 (69.5)	736 (30.5)	--
Age				
3–12 months	1198	948 (79.1)	250 (20.9)	<.05
1–3 months	267	192 (72.0)	75 (28.0)	
Neonate (0–30 days)	949	539 (56.8)	410 (43.2)	
Weight				
>4 kg	1405	1103 (78.5)	302 (21.5)	<.05
2–4 kg	889	516 (58.0)	373 (42.0)	
<2 kg	121	60 (50.0)	61 (50.0)	
Birth type				
Term (>36 weeks)	979	749 (81.1)	185 (18.9)	<.05
Premature (31–36 weeks)	555	397 (71.5)	158 (28.5)	
Premature (<30 weeks)	881	488 (55.4)	393 (44.6)	
Preoperative risk factors				
Neurologic disorder	535	344 (64.3)	191 (35.7)	<.05
Major/severe cardiac risk factor	473	308 (65.1)	165 (34.9)	.02
Previous cardiac surgery	276	158 (57.2)	118 (42.8)	<.05
Structural pulmonary abnormality	124	78 (62.9)	46 (37.1)	.10
Pulmonary disease				
(including asthma)	631	333 (52.8)	298 (47.2)	<.05
Ventilator, trachea, or O2 support	401	196 (48.9)	205 (51.1)	<.05
Preoperative nutritional support	979	520 (53.1)	459 (46.9)	<.05
Preoperative transfusion				
(<72 hours)	217	125 (57.6)	92 (42.4)	<.05
Preoperative steroids	96	45 (46.9)	51 (53.1)	<.05

<6 months of age who underwent ostomy reversal. Patients were divided into four groups based on weight at reversal (<2 kg, 2.01–2.5 kg, 2.51–3.5 kg, and >3.5 kg). They found no significant difference in postoperative morbidity associated with ostomy reversal at lower weights compared to higher weights.[9] Lucas et al examined the NSQIP-Pediatric database from 2012 to 2015 to determine risk factors for adverse outcomes. Similar to our findings, they determined that closure at <2 kg was not associated with an increased risk of 30-day mortality after enterostomy closure.[14]

Our findings demonstrate that closure of enterostomy at lower weights is feasible and is not associated with increased morbidity. Prematurity <30 weeks, existing pulmonary disease, and the need for perioperative nutritional support were the only factors associated with increased morbidity on enterostomy reversal. These findings should prompt surgeons to avoid using an arbitrary weight cut-off in determining appropriateness for enterostomy reversal. Instead, modifiable factors such as nutritional optimization and resolution of pulmonary disease should dictate the timing of reversal.

This study is limited by its retrospective database design; thus, the causality of risk factors affecting outcomes cannot be concluded. Individual factors of patients were unable to be ascertained or investigated further. The indication for ostomy and the type of ostomy formed was not able to be determined during data collection. We were limited by the variables collected in the NSQIP database, and all outcomes and morbidities were only available within 30 days of surgery. In addition, determining whether ostomy takedown was performed electively versus urgently for an ostomy-related complication could improve our analysis. Future investigation into specific risk factors resulting in common complications could better equip surgeons in the preoperative evaluation of an infant's preparedness for enterostomy reversal.

In conclusion, we have identified several risk factors that are associated with morbidity in children <365 days old undergoing enterostomy reversal. Our findings suggest that an arbitrary weight or age cut-off may not be associated with operative morbidity in this population. The decision on the timing of enterostomy takedown will likely continue to be based on sur-

Table 2. Multivariate Analysis of Predictors of Morbidity In Children < 365 Days Old			
Variables	**OR**	**95% CI**	***P* value**
Age			
3–12 months	Reference	--	
1–3 months	1.28	0.91-1.80	.15
Neonate (0–30 days)	1.31	0.97-1.77	.08
Weight			
>4 kg	Reference	--	
2–4 kg	1.04	0.78-1.39	.77
<2 kg	1.25	0.78-2.01	.34
Birth type			
Term (>36 weeks)	Reference	--	
Premature (31–36 weeks)	1.25	0.93-1.68	.13
Premature (<30 weeks)	1.49	1.07-2.08	.02
Preoperative risk factors			
Neurologic disorder	1.21	0.97-1.51	.08
Major/severe cardiac risk factor	0.96	0.76-1.21	.07
Previous cardiac surgery	1.12	0.84-1.49	.44
Structural pulmonary abnormality	1.16	0.76-1.74	.48
Pulmonary disease			
(including asthma)	1.31	1.01-1.71	.05
Ventilator, trachea, or O2 support	1.20	0.90-1.59	.21
Preoperative nutritional support	2.46	1.99-3.05	<.05
Preoperative transfusion			
(<72 hours)	0.92	0.67-1.25	.60
Preoperative steroids	1.14	0.73-1.77	.57

Abbreviations: CI, confidence interval; OR, odds ratio.

geon preference and experience; however, this study describes additional factors to consider before proceeding to surgery.

Conflict of Interest

None of the authors identify a conflict of interest.

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References

1. Lee J, Kang MJ, Kim HS, et al. Enterostomy closure timing for minimizing postoperative complications in premature infants. *Pediatr Neonatol*. 2014;55(5):363-368. doi:10.1016/j.pedneo.2014.01.001
2. Chong C, van Druten J, Briars G, et al. Neonates living with enterostomy following necrotising enterocolitis are at high risk of becoming severely underweight. *Eur J Pediatr*. 2019;178(12):1875-1881. doi:10.1007/s00431-019-03440-6
3. Christian VJ, Polzin E, Welak S. Nutrition management of necrotizing enterocolitis. *Nutr Clin Pract*. 2018;33(4):476-482. doi:10.1002/ncp.10115
4. Yang YJ. The optimal timing of enterostomy closure in preterm infants. *Pediatr Neonatol*. 2014;55(5):333-334. doi:10.1016/j.pedneo.2014.06.001
5. Bethell G, Kenny S, Corbett H. Enterostomy-related complications and growth following reversal in infants. *Arch Dis Child Fetal Neonatal Ed*. 2017;102(3):F230-F234. doi:10.1136/archdischild-2016-311126
6. Kargl S, Wagner O, Pumberger W. Ileostomy complications in infants less than 1500 grams – frequent but manageable. *J Neonatal Surg*. 2016;6(1):4. doi:10.21699/jns.v6i1.451
7. Rothstein FC, Halpin TC, Kliegman RJ, Izant RJ. Importance of early ileostomy closure to prevent chronic salt and water losses after necrotizing enterocolitis. *Pediatrics*. 1982;70(2):249-253.
8. Yang HB, Han JW, Youn JK, Oh C, Kim HY, Jung SE. The optimal timing of enterostomy closure in extremely low birth weight patients for acute abdomen. *Sci Rep*. 2018;8(1):2-11. doi:10.1038/s41598-018-33351-9
9. Talbot LJ, Sinyard RD, Rialon KL, et al. Influence of weight at enterostomy reversal on surgical outcomes in infants after emergent neonatal stoma creation. *J Pediatr Surg*. 2017;52(1):35-39. doi:10.1016/j.jpedsurg.2016.10.015
10. Banerjee DB, Vithana H, Sharma S, Tsang TTM. Outcome of stoma closure in babies with necrotising enterocolitis: early vs late closure. *Pediatr Surg Int*. 2017;33(7):783-786. doi:10.1007/s00383-017-4084-5
11. Struijs MC, Sloots CEJ, Hop WCJ, Tibboel D, Wijnen RMH. The timing of ostomy closure in infants with necrotizing enterocolitis: A systematic review. *Pediatr Surg Int*. 2012;28(7):667-672. doi:10.1007/s00383-012-3091-9
12. Struijs MC, Poley MJ, Meeussen CJHM, Madern GC, Tibboel D, Keijzer R. Late vs early ostomy closure for necrotizing enterocolitis: Analysis of adhesion formation, resource consumption, and costs. *J Pediatr Surg*. 2012;47(4):658-664. doi:10.1016/j.jpedsurg.2011.10.076
13. Al-Hudhaif J, Phillips S, Gholum S, Puligandla PP, Flageole H. The timing of enterostomy reversal after necrotizing enterocolitis. *J Pediatr Surg*. 2009;44(5):924-927. doi:10.1016/j.jpedsurg.2009.01.028
14. Lucas DJ, Gosain A. Association of Comorbidities with Adverse Outcomes After Enterostomy Closure in Premature Neonates. *JAMA Surg*. 2018;153(8):776-778. doi:10.1001/jamasurg.2018.0874