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Laparoscopic Nissen fundoplication in infants with hypoplastic left heart syndrome☆,☆☆

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ABSTRACT

Background/Purpose: Patients with hypoplastic left heart syndrome (HLHS) experience a higher risk for complications from gastroesophageal reflux, prompting frequent need for fundoplication. Patients between stage I and II palliation ("interstage") are at particularly high operative risk because of the parallel nature of their pulmonary and systemic blood flow. Laparoscopic approach for fundoplication is common for pediatric patients. However, its safety in interstage HLHS is relatively unknown. We examined the perioperative physiologic burden of a laparoscopic fundoplication in HLHS patients.

Methods: All patients who underwent open or laparoscopic fundoplication during the interstage period at our institution since 2006 were reviewed. Perioperative physiologic data, echocardiographic findings, survival, and complications were collected from the anesthetic record and patient chart.

Results: Nineteen patients with HLHS had laparoscopic fundoplication, 13 (68%) during the interstage period, compared to 64 performed by the open approach. Ten (77%) of 13 interstage patients had perioperative hemodynamic instability. Incidence of instability between open and laparoscopic groups was not different. One laparoscopic patient required ECMO support for shunt thrombosis.

Conclusions: Despite a high incidence of hemodynamic instability, overall outcomes are consistent with those reported in the literature for this high-risk patient population. Laparoscopic approach for fundoplication during the interstage period appears to be a relatively safe option for these patients.

Hypoplastic left heart syndrome (HLHS) is a congenital heart defect that consists of a variably underdeveloped left ventricle, aortic valve and ascending aorta, resulting in single ventricle physiology with systemic blood flow that is dependent upon a patent foramen ovale and ductus arteriosus [1]. Newborns with HLHS undergo the first of three palliative cardiac surgical procedures, the Norwood procedure, usually within the first one to two weeks of life. The operation relieves obstruction to systemic outflow by anastomosing the trunk of the main pulmonary artery to the aortic arch, and establishes appropriate pulmonary blood flow by either a systemic arterial-to-pulmonary artery shunt (Blalock–Taussig shunt, BTS) or by a right ventricular-to-pulmonary artery shunt (Sano modification, RV–PA). After this procedure, the systemic and pulmonary vascular systems exist in parallel with flow to each depending on the ratio of systemic vascular resistance (SVR) to pulmonary vascular resistance (PVR) [2,3]. The relative blood flow to each system can vary rapidly when extrinsic stressors arise, potentially leading to rapid, profound hypoxemia, myocardial ischemia, cardiovascular collapse and even death. The second stage of palliation involves a superior vena cava-to-pulmonary artery anastomosis (bidirectional Glenn) and takedown of the shunt, and usually occurs between 3 and 6 months of age. After this, the systemic and pulmonary circulations are now in series and no longer directly competing with each other for cardiac output.

Patients with HLHS experience poor growth between the first and second stages of palliation and often require supplemental nutrition by either nasoenteric tube or gastrostomy [4–7]. In addition, these patients often have vocal cord dysfunction and dysphagia and are at high risk for aspiration [8], which can rapidly progress to increased PVR, hypoxemia and cardiovascular collapse. Therefore, surgical antireflux procedures, such as Nissen fundoplication, are commonly performed in this patient population [8]. However, a major concern exists with the

Abbreviations: HLHS, hypoplastic left heart syndrome; BTS, Blalock–Taussig shunt; RV–PA, right ventricle-to-pulmonary artery shunt (Sano shunt); SVR, systemic vascular resistance; PVR, pulmonary vascular resistance; RV, right ventricular; ECMO, extracorporeal membrane oxygenation; IAP, intraabdominal pressure; TEE, transesophageal echocardiography; ASA, American Society of Anesthesiology; OR, operating room.

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trade-off in risk between perioperative complications and that of poor growth and aspiration from reflux disease, both of which can be life threatening. Several case series have reported on outcomes and complications after gastrostomy and fundoplication in children with HLHS [4,9–11]. Overall, it appears that these procedures can be performed safely in this high-risk group so long as a highly specialized team of anesthesiologists, pediatric surgeons and intensivists provides the perioperative care.

We previously reported on the intraoperative hemodynamics and postoperative course of 36 interstage HLHS patients who underwent an open approach for fundoplication [11]. Since the time of that analysis, there have been several reports suggesting that laparoscopy can be safely performed in this high-risk patient cohort [8,12–15]. However, data on perioperative hemodynamics in this patient population remain scant, and are much needed to help determine whether or not increases in abdominal pressure and carbon dioxide absorption from insufflation may precipitate adverse events in the fragile cardiovascular systems of the interstage HLHS patients, especially during longer, more complex laparoscopic procedures such as fundoplication. Here we report our experience with laparoscopic Nissen fundoplication in interstage HLHS patients to better understand the incidence of perioperative physiologic dysfunction and overall outcomes in this particularly high-risk group of patients.

1. Methods

After the approval from the Institutional Review Board (VUIRB#: 101469), we reviewed all patients at our institution from the Society for Thoracic Surgeons database with procedure code 33619 (Norwood operation) who also underwent fundoplication between April 2006 and April 2014. The patients' medical records were reviewed to determine whether the procedure was performed open or laparoscopically, and the remaining preoperative, perioperative and postoperative data points were collected from the chart and anesthetic records of each patient. Inclusion criteria were all patients who underwent open or laparoscopic fundoplication after Norwood operation during the study period. There were no exclusion criteria.

The following definitions were used in the collection of data from the patient chart and anesthetic records [11]. Preoperative echocardiographic findings were extracted from the last echocardiogram prior to the general surgical operation. Right ventricular (RV) dysfunction, ventricular outflow tract obstruction, neoaortic valve insufficiency and tricuspid insufficiency were defined as those stated as abnormal on the summary of the echocardiogram report and were classified as mild, moderate or severe. Outflow tract obstruction included neoaortic valve stenosis, residual aortic arch gradient or residual coarctation. Intraoperative hemodynamic instability was defined by any of the following: (1) measured systolic blood pressure < 75% of baseline systolic blood pressure for >10 min or that required support with vasoactive medications by infusion or two or more doses or fluid bolus >20 ml/kg; (2) systolic blood pressure >25% above baseline for >10 min; (3) heart rate <120 or >200 for >10 min; (4) any significant rhythm change; and (5) arterial saturation <70% or >20% below intraoperative baseline. Surgical times were defined as follows: *operative time* was time from incision to skin closure, *induction* was the time from operating room (OR) entry to incision, *maintenance* was the time from incision to skin closure, *emergence* was the time from skin closure to OR exit and *recovery* was the time from OR exit to recovery room discharge or the first hour after return to the intensive care unit if the patient was admitted direct from the OR.

Evidence of postoperative instability was evaluated from patient care records for the first 24 h after operation. Escalation of respiratory care was defined as an increase in supplemental oxygen, reintubation or initiation of positive pressure ventilation. Escalation of hemodynamic care was defined as the need for initiation or escalation of vasoactive and inotropic infusions, agents to decrease afterload, antihypertensive agents or antiarrhythmics. Evidence of decreased perfusion was defined as the need for inotropic or vasoactive medications, postoperative lactate >2.2, base deficit >2, pH <7.25 or postoperative chest radiograph consistent with pulmonary edema, new opacification or new effusion.

2. Results

We identified 183 patients who underwent Norwood operation during the study period. One hundred of these patients underwent fundoplication or gastrostomy (54.6%) and gastrostomy alone was only performed in nine patients (4.9%). Seventy-seven of the 91 patients who underwent Nissen fundoplication had the operation during the interstage period; this group is the focus of our report. Thirteen of these operations were performed laparoscopically (16.9%). Study population demographics and characteristics are shown in Table 1.

Perioperative events are shown in Table 2. Ten (77%) of 13 laparoscopic interstage patients and 47 (73%) of 64 open patients experienced perioperative hemodynamic instability, demonstrating that in our series there was no difference in overall incidence of instability. Mean operative time was not different between the two groups. Each segment of the perioperative period – induction, maintenance, emergence, recovery and the first 24 h after the operation – was individually compared. No statistically significant differences were found with the exception of a higher incidence of 24 h escalation of hemodynamic care in the laparoscopic group (31% vs. 4%, $p < 0.05$). One laparoscopic patient (8%) required extracorporeal membrane oxygenation (ECMO) support because of intraoperative thrombosis of his BTS and he remained on ECMO for three days postoperatively. Two patients in the open group required ECMO, as we have previously reported [11].

We further evaluated the last preoperative echocardiogram to identify predictors of perioperative instability. Four echocardiographic findings (right ventricular dysfunction, ventricular outflow tract obstruction, neo-aortic valve insufficiency and tricuspid insufficiency) that are commonly used in the routine assessment of post-Norwood patients were assessed in all patients (Table 1). The presence and severity of each finding are listed for each individual in the laparoscopic group (Table 3). None of these findings were able to accurately predict the subsequent incidence of instability.

Five (38.4%) patients in the laparoscopic interstage group had died at the time of our analysis. Median time elapsed since fundoplication at the

Table 1
Study population and demographics.

	N (%)
Male	69 (69)
Female	31 (31)
Norwood operation	
Age at operation (median)	5 d
Shunt type	
Blalock–Taussig	64 (64)
RV-to-PA	36 (36)
Progress to stage 2	85 (85)
Mortality	26 (26)
Gastric operation	
Interstage	82 (82)
Age at operation (median)	50 d
Time after Norwood (median)	44 d
G tube only	5 (6)
Nissen only	1 (1)
Nissen + G tube	76 (93)
Post-stage 2	18 (18)
Age at operation (median)	200 d
Time after Norwood (median)	198 d
G tube only	4 (22)
Nissen only	0 (0)
Nissen + G tube	14 (78)
Preop echo findings (interstage only)	
RV dysfunction	29 (36)
Outflow tract obstruction	10 (13)
Neoaortic valve insufficiency	30 (37)
Tricuspid valve insufficiency	78 (95)

RV right ventricle, *PA* pulmonary artery.