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Outcomes of laparoscopic and open surgery in children with and without congenital heart disease

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Abstract

Background—Children with congenital heart disease (CHD) often require non-cardiac surgery.

We compared outcomes following open and laparoscopic intra-abdominal surgery among children with and without CHD.

Methods—We performed a retrospective cohort study using the 2013–2015 National Surgical Quality Improvement Project-Pediatrics. We matched 45,012 children <18 years old who underwent laparoscopic surgery to 45,012 children who underwent open surgery. We determined

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Level-of-Evidence:

Level III - Treatment Study

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the associations between laparoscopic (versus open) surgery and 30-day mortality, in-hospital mortality, 30-day morbidity, and postoperative length-of-stay.

Results—Among children with minor CHD, laparoscopic surgery was associated with lower 30-day mortality (Odds Ratio [OR] 0.34 [95% Confidence Interval 0.15–0.79]), inhospital mortality (OR 0.42 [0.22–0.81]) and 30-day morbidity (OR 0.61 [0.50–0.73]). As CHD severity increased, this benefit of laparoscopic surgery decreased for 30-day morbidity (ptrend=0.01) and in-hospital mortality (ptrend=0.05), but not for 30-day mortality (ptrend=0.27). Length-of-stay was shorter for laparoscopic approaches for children at cost of higher readmissions. On subgroup analysis, laparoscopy was associated with lower odds of postoperative blood transfusion in all children.

Conclusions—Intra-abdominal laparoscopic surgery compared to open surgery is associated with decreased morbidity in patients with no CHD and lower morbidity and mortality in patients with minor CHD, but not in those with more severe CHD.

Keywords

NSQIP; pediatric surgery; mortality; morbidity; laparoscopic surgery; congenital heart disease

1. Introduction

Congenital heart disease (CHD) affects approximately 10 per 1,000 live births in the United States [1]. As these children survive longer due to improvements in diagnosis and treatment, nearly half are expected to need additional non-cardiac surgeries by age 5 years [2, 3]. CHD is associated with an increased risk of mortality and morbidity following non-cardiac surgery [4–6]. However, less is known about the impact of laparoscopic or open approaches on postoperative outcomes in this particularly vulnerable and increasingly more prevalent patient population.

Numerous intra-abdominal operations in children can be performed either open or laparoscopically [7]. Meta-analyses for specific procedures such as laparoscopic appendectomy among healthy children results in less postoperative pain and shorter hospitalization compared to open [8, 9]. However, these studies have typically excluded children with CHD, who may be more vulnerable to the deleterious effects of pneumoperitoneum on cardiopulmonary physiology [10–13]. Recent studies that reported laparoscopic surgery is safe in children with CHD have been limited to either highly select patient populations, such as infants or single procedures, or single-institution non-comparative series [14–18]. Therefore, a more generalizable comparison of outcomes of laparoscopic versus open surgery for children with CHD is lacking.

In this cohort study, we compared outcomes of open and laparoscopic intra-abdominal surgery among children of all ages with different severities of CHD using data collected in the American College of Surgeons National Surgical Quality Improvement Program-Pediatrics (NSQIP-P). We hypothesized that any mortality and morbidity advantage of laparoscopic over open surgery is attenuated by greater severity of CHD.

2. Methods

2.1. Design and Data Source

This is a retrospective cohort study using data collected in NSQIP-P from 2013 to 2015. Because the dataset is completely de-identified, this study was determined to be non-human subjects research and deemed exempt from review by our institutional review board.

The NSQIP-P dataset contains information on children <18 years of age undergoing non-cardiac surgery at participating hospitals throughout the United States. The number of participating hospitals increased from 56 in 2013, to 64 in 2014, to 80 in 2015, and include freestanding general acute care children's hospitals, children's hospitals within a larger hospital, specialty children's hospitals, and general acute care hospitals with a pediatric wing. NSQIP-P contains detailed information on demographic characteristics such as age, sex, and race, perioperative characteristics such as case urgency and procedure code, and postoperative complications such as unplanned readmissions, reintubation, and mortality. Data were collected up to 30-days after surgery, although discharge and death data were available if patients were still hospitalized past the 30-day window. Each participating hospital has a full-time, trained and certified surgical clinical reviewer who conducts data entry and routine audits to ensure accuracy, completeness, and precision. NSQIP-P has an overall inter-rater reliability of 98% [19]. A systematic sampling strategy is employed by each surgical clinical reviewer to reduce selection bias within and between hospitals. Hospitals which had an inter-rater reliability disagreement rate >5% and/or 30-day follow-up rate <80% were excluded per NSQIP-P criteria [19].

2.2. Participants

Children ages 0 to 17 years old who underwent any intra-abdominal operation in 2013, 2014, and 2015 were included. Those who were missing an indicator variable indicating laparoscopic or open surgery were excluded.

2.3. Exposures

The primary exposure was laparoscopic surgery, which was ascertained using an indicator variable defined by NSQIP-P beginning in 2013. This indicator variable stratified cases into laparoscopic only, combination open/laparoscopic, and open only surgeries. For our primary analysis, laparoscopic and combination open/laparoscopic cases were combined into "laparoscopic surgery". Procedures were identified using Common Procedural Terminology (CPT) codes. Regardless of whether procedures had separate laparoscopic CPT codes or none, the indicator variable was used to stratify laparoscopic from open surgery. To control for potential effects of pneumoperitoneum on outcomes, our analysis was restricted to intra-abdominal procedures, leaving 46 total surgical procedures (Appendix Table A.1.).

2.4. Outcomes

The primary outcome was 30-day mortality. This was chosen for two reasons: first, mortality is a highly pertinent outcome after surgery in high-risk patients; and second, 30-day mortality may more accurately reflect episodes of care and depends less on inter-hospital differences than in-hospital mortality [20]. Secondary outcomes included in-hospital

postoperative mortality, defined as any in-hospital death occurring during the same hospitalization after surgery regardless of whether it occurred within the 30-day postoperative window; 30-day postoperative morbidity; and postoperative length of stay (LOS).

30-day morbidity was a composite outcome comprising any 30-day postoperative complication, excluding mortality. These included: surgical site infection (SSI), pneumonia, urinary tract infection, central line-associated blood stream infection, unplanned reintubation, renal insufficiency, venous thrombotic events, neurologic sequelae (coma, seizure, stroke, nerve injuries), myocardial infarction (MI), sepsis, transfusion (defined as packed or whole red blood cell transfusions from start of surgery to 72 hours post-operatively), unplanned readmission, or unplanned reoperation. This composite measure of morbidity, as defined in previous NSQIP-P studies, was chosen because of the expected overall low incidence of individual adverse events [6, 21]. Morbidity outcome events were based on the number of patients experiencing any complication, rather than number of complications per patient. Postoperative LOS was calculated as days of hospitalization from operation until discharge or death.

2.5. Covariates

CHD severity was classified as none (absent), minor, major, and severe (Appendix Table A. 2.). These definitions, defined by NSQIP-P, classified CHD severity based on repair status and residual hemodynamic abnormality and have been utilized in other studies of postoperative outcomes in children with CHD [4, 6, 16].

The following pre-specified clinical characteristics were ascertained and included in the multivariate matching to balance cohorts (described below): age at surgery (continuous), sex, race (non-Hispanic white, non-Hispanic black, and other), year of operation, American Society of Anesthesiologists (ASA) physical status class (1, 2, 3, 4, 5), preoperative ventilator-dependence, preoperative inotrope-dependence, case urgency (elective versus non-elective), weight at surgery (continuous), gestational age at birth (>36 weeks, 31–36 weeks, 25–30 weeks, <25 weeks, unknown), history of chronic lung disease or bronchopulmonary dysplasia, and number of concurrent procedures (1, 2, >2).

Operative time was not included as a covariate given its role as an intermediate variable on the causal pathway between our exposure of interest and outcomes, which may induce bias. [22] As part of the hospital agreements with NSQIP-P, no data that could potentially identify individual hospital were included in the released databases; therefore, no hospital-level information was available for analysis.

2.6. Statistical Analysis

2.6.1. Matching Algorithm—Within each stratum of CHD severity, a patient who underwent laparoscopic surgery was matched 1:1 with a patient who underwent the same operation but via open approach. Each pair was exactly matched on the type of operation and also matched on the pre-specified covariates, which was done by minimizing the Mahalanobis distance between laparoscopic and open patients using a caliper of 0.1 standard

deviations [23]. Matching was done with replacement of patients who underwent open surgery to ensure best matches and maximize analysis of laparoscopic cases [24]. All matches were performed before viewing outcomes [25]. The five most frequently matched operations within each stratum of CHD are shown in Appendix Table A.3.

Chi-square and Wilcoxon rank-sum tests compared categorical and continuous variables, respectively. Differences in clinical characteristics between patients who had laparoscopic and open surgery before and after matching were assessed using standardized mean differences (SMD), with values <0.2 deemed acceptable [26, 27].

2.6.2. Outcome Comparison—The associations between laparoscopic surgery and dichotomous outcomes were estimated using three separate conditional logistic regression models for each stratum of CHD severity. Due to the limited number of outcome events and because cohorts were balanced across covariates after matching, surgical approach was the only independent variable in the models. Tests for trend across strata of CHD severity were performed using likelihood ratio tests of interaction terms for CHD severity and surgical approach.

For postoperative LOS, which is a nonparametric continuous variable, we used generalized estimating equations with clustering on each matched pair and the sandwich robust covariance estimator [28]. Because of missing and negative LOS values, postoperative LOS analyses were performed using complete case analysis in those patients with a postoperative LOS greater than or equal to 0 (signifying outpatient procedure). This smaller cohort constituted 98% of the original matched cohort.

In exploratory analyses, we examined subgroups of postoperative morbidity hypothesized *a priori* to differ between laparoscopic and open procedures: unplanned readmissions, transfusions, reintubations, MI, and SSI. We also restricted our mortality and morbidity analyses to infants 1-year-old, as this group may be the most vulnerable to adverse outcomes [14, 16], and to the most common procedure, initial gastrostomy. As a sensitivity analysis, we restricted analysis to patients undergoing only a single procedure without concurrent procedures, in case of residual confounding or selection bias from the additional procedures. Second, we recoded combination open/laparoscopic cases (which includes laparoscopic surgeries that were converted to open) as open surgeries, which constituted 2–6% of cases within CHD groups, as this may indicate a sudden adverse intraoperative episode such as acute bleeding and lead to worse postoperative outcomes.

All analyses were performed in Stata (v.14, StataCorp LP, College Station, TX) with a two-tailed alpha of 0.05.

3. Results

Within the 2013–2015 NSQIP-P datasets, 70,133 children met eligibility criteria and were included in the analyses. Of these, 25,045 (35.7%) and 45,088 (64.3%) children underwent open and laparoscopic intra-abdominal surgery, respectively (Table 1). By CHD severity, 704 (1.0%), 3,697 (5.3%), 4,102 (5.8%), and 61,630 (87.9%) children had severe, major, minor, and no CHD, respectively. Before matching, significant differences in covariates

including age, weight at surgery, ASA class, and baseline ventilator-dependence were noted between open and laparoscopic operations, with laparoscopic surgery performed more often in older, heavier, and healthier children without ventilator-dependence.

After matching, 45,012 pairs were analyzed, of which 355, 1,579, 1,843, and 41,235 matched pairs were in the severe, major, minor, and no CHD groups, respectively (Table 2). Excellent balance was observed across all strata of CHD severity (Table 2). The frequencies of individual outcomes from the matched cohorts are shown in Appendix Table A.4.

The results of the primary and secondary outcome analyses are shown in Tables 3 and 4. Among children without CHD, laparoscopic surgery was not associated with mortality, but was associated with lower 30-day morbidity (Odds Ratio [OR] 0.88 [95% Confidence Interval (CI) 0.83–0.93]). Among children with minor CHD, laparoscopic surgery was associated with lower odds of 30-day mortality (OR 0.34 [95% CI 0.15–0.79]), in-hospital mortality (OR 0.42 [95% CI 0.22–0.81]), and 30-day morbidity (OR 0.61 [95% CI 0.50–0.73]) than open surgery. As CHD severity increased to major and severe CHD strata, this relative benefit of laparoscopic surgery decreased for 30-day morbidity (ptrend=0.01) and in-hospital mortality (ptrend=0.05) but not for 30-day mortality (ptrend=0.27). Postoperative LOS was shorter following laparoscopic compared to open surgery across all CHD groups (Table 4). Larger differences in LOS were seen across increasing CHD severity groups, although the difference was not statistically significant for the minor CHD group.

For the subgroup analysis, the magnitude of the association between laparoscopic surgery and higher unplanned readmissions increased across worsening CHD severity groups (ptrend=0.02; Table 5). Laparoscopic surgery was associated with lower odds of transfusion and SSI in nearly all CHD groups, with no significant trends across CHD severity groups. No trends across CHD groups were observed between laparoscopic surgery and either reintubation or MI, though lower odds of reintubation were associated with laparoscopic surgery in children without CHD. Infants 1-year-old constituted 15, 60, 73, and 75% of the none, mild, major, and severe CHD groups, respectively. The mortality and morbidity results did not change substantially when assessing only infants (Table 5), only gastrostomy patients (Appendix Table A.5.), or only single procedures (Appendix Table A.6.). When converted cases were reclassified as open instead of laparoscopic, point estimates of odds ratios for morbidity and mortality were similar to our primary analysis, but trends across CHD severity groups were no longer significant (Appendix Table A.7.).

4. Discussion

In this cohort study of 45,012 matched pairs of children undergoing intra-abdominal surgery, we found that severity of CHD is an important determinant of postoperative mortality and morbidity following laparoscopic or open surgery. Laparoscopic surgery was associated with lower 30-day mortality, in-hospital mortality, and 30-day morbidity in children with minor CHD. These benefits were attenuated or absent among children with major or severe CHD. In none of the primary analyses was laparoscopic surgery associated with worse outcomes than open surgery. Rather, these results indicate that although some of the benefits of laparoscopic surgery are lost among children with increasing CHD severity, other specific

advantages are maintained. These findings have important implications for joint decision-making and optimizing the safety of children with CHD who require intra-abdominal surgery.

Our study has several strengths that differentiate it from prior studies that examined the association between laparoscopic surgery and clinical outcomes. First, we included children of all ages who underwent surgery at hospitals throughout the United States. One previous study that found fewer complications and lower LOS with comparable 30-day mortality for laparoscopic versus open surgery included only infants <1 year of age; the relative effects are unknown in older children [16]. Second, we assessed a large, contemporary cohort undergoing 46 different operations with different severity of CHD. Several other small case series analyzed their single-institution records to show the safety of laparoscopic surgery, but these were limited by low sample size, specific type of CHD (*e.g.*, hypoplastic left heart syndrome), or analysis of a single procedure (*e.g.*, laparoscopic fundoplication) [14, 15, 17, 18]. By considering multiple intra-abdominal operations simultaneously, we could assess the safety of laparoscopic surgery in a broader context. Third, we used multivariate matching to adjust for multiple potential measured confounders and therefore provide a less biased estimate of the association between laparoscopic surgery and post-operative mortality and morbidity. Fourth, we performed several subgroup and sensitivity analyses to assess the robustness of our findings.

A possible explanation for our primary findings is the different physiologic stress that open surgery and laparoscopic surgery have on children with CHD [29, 30]. Though the stress from laparoscopic surgery is likely less compared to open surgery, the pneumoperitoneum required for intra-abdominal laparoscopic surgery may mitigate the benefit achieved from smaller incisions among children with CHD. Among healthy children, this increased intra-abdominal pressure (10–20mmHg) has been shown to reduce cardiac output, increase peripheral vascular resistance, increase peak airway pressures required for proper ventilation, and decrease end-tidal lung volumes for given pressures needed for ventilation [10–13]. Among healthy children, these physiologic changes are reversed once the abdomen is desufflated. However, for children with CHD, the severity and duration of physiologic effects from pneumoperitoneum remain unknown. In our study, the mortality risk difference between laparoscopic and open surgery was driven more by increases in mortality in the laparoscopy group rather than decreases in mortality in the open group. Thirty-day mortality rates across minor, major, and severe CHD groups rose from 1.4 to 1.7 to 2.8% for open surgery, whereas they rose from 0.7% to 1.3% to 2.3%, respectively, for laparoscopic surgery. These results suggest that a patient's severity of CHD may be related to his or her vulnerability to changes induced by laparoscopy. However, because hemodynamic and pulmonary measures during and after surgery are not recorded in NSQIP-P, this hypothesis remains speculative and warrants prospective study. It is possible that severe CHD simply becomes the driver of postoperative mortality, regardless of surgical approach.

We also demonstrated, as expected, that LOS increased as CHD severity increased, suggesting that the underlying heart disease influences duration of hospitalization after surgery. Within each CHD severity group, even the severe CHD group, we found that laparoscopic surgery was associated with shorter LOS compared to open surgery. However,

an association was also found between laparoscopic surgery and more unplanned readmissions, which increased significantly across CHD severity groups (Table 5). This finding emphasizes the tension between LOS and readmissions as quality metrics seen in surgery [31] and impacts patient counseling. Second, laparoscopic surgery was associated with lower odds of blood transfusion within 72 hours of the procedure compared to open surgery for all children. This lower risk of transfusion has implications on patient outcomes, as transfusion is independently associated with an increased incidence of 30-day mortality and postoperative infections in children undergoing non-cardiac surgery [32]. Since transfusion is innately tied to intraoperative blood loss, laparoscopy should be considered to be associated with less blood loss, although this was not directly measured in NSQIP-P. Third, there was weak evidence that laparoscopic surgery was associated with lower odds of SSI compared to open surgery, especially in the major, minor, and no CHD categories. This is noteworthy given that published risk calculators for SSI using NSQIP-P do not currently incorporate laparoscopic versus open approach [33]. Taken altogether, along with our primary findings, laparoscopic surgery has advantages over open surgery in some, but not all, clinically meaningful surgical outcomes, which importantly appear to be modified by underlying heart disease.

Our study must be interpreted in light of certain limitations. First, as with all observational studies, unmeasured confounding, misclassification of covariates, and bias are possible. One specific example is lack of information on whether a patient had a prior ostomy creation, which could direct whether a procedure is started open or laparoscopic. However, we used multivariate matching to balance the cohorts and performed several subgroup and sensitivity analyses with similar general findings. NSQIP-P also has stringent data measurement and collection to increase validity and reliability. Second, NSQIP-P lacks hospital- and surgeon-level information, which precludes assessment and comparison of hospital and surgeon quality indicators that have been strongly associated with outcomes, including surgical volume [34, 35], surgical subspecialization [36], and nursing quality [37]. Individual surgeon experience with a certain approach is also important to surgical outcomes. Additionally, inter-hospital variation in quality of care is known to influence mortality outcomes [38]. However, the goal of this study was not to identify variation among hospitals or providers nor the processes that might contribute to inter-hospital differences. Third, the laparoscopic indicator variable could not distinguish between pure laparoscopic versus robotic-assisted laparoscopic operations. However, the physiologic effects and anatomic approach are the same. Fourth, concurrent procedures may vary broadly in severity and complexity, which may affect outcomes. However, the results from sensitivity analysis restricted to single procedures were similar to those of our primary analyses. Lastly, as we restricted our analysis to intra-abdominal procedures, our results may not be generalizable to other procedures that can be done by open or laparoscopic means, such as lobectomy. However, including only intra-abdominal procedures increased the internal validity of our study. Additionally, given the heterogeneity of patients in our study, our results are likely broadly applicable.

5. Conclusions

Intra-abdominal laparoscopic surgery may be the safer approach in children with minor CHD, but appears comparable to open surgery in those with more severe disease. Benefits in specific outcomes such as transfusion and LOS following laparoscopy must be balanced against disadvantages such as readmissions. Future prospective studies are warranted to validate these findings and elucidate more detailed cardiopulmonary changes associated with laparoscopic surgery to ensure the optimal care of these children.

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Abbreviations

ASA	American Society of Anesthesiologists
CHD	congenital heart disease
CI	confidence interval
CPT	common procedural terminology
LOS	length of stay
MI	myocardial infarction
NHB	non-Hispanic Black
NHW	non-Hispanic White
NSQIP-P	National Surgical Quality Improvement Program – Pediatrics
OR	odds ratio
SMD	standardized mean difference
SSI	surgical site infection

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Appendix A

Table A.1

Common Procedural Terminology codes for included and matched surgical procedures.

Lap CPT	Laparoscopic procedure	Open CPT	Open procedure
43653	Lap gastrostomy	43830	Gastrostomy

Lap CPT	Laparoscopic procedure	Open CPT	Open procedure
		43832	
43279	Lap fundoplasty	43325	Fundoplasty
43280		43327	
		43328	
44970	Lap appendectomy	44950	Appendectomy
		44960	
54692	Lap orchiopexy	54650	Orchiopexy (intra-abdominal)
47562	Lap cholecystectomy	47600	Cholecystectomy
47563		47605	
47564		47610	
		47612	
		47620	
50947	Lap ureteroneocystostomy	50780	Ureteroneocystostomy
50948		50782	
		50783	
44186	Lap ileostomy/jejunostomy	44310	Ileostomy/jejunostomy
44187			
44180	Lap enterolysis	44005	Enterolysis
44188	Lap colostomy	44320	Colostomy
45395	Lap proctectomy	45112	Proctectomy
45397		45119	
		45120	
50544	Lap pyeloplasty	50400	Pyeloplasty
		50405	
45400	Lap proctopexy	45540	Proctopexy
45402		45541	
		45550	
58661	Lap salpingo-oophorectomy	58720	Salpingo-oophorectomy
		58940	
		58943	
		58950	
		58952	
38120	Lap splenectomy	38100	Splenectomy
		38101	
43281	Lap repair of paraesophageal hernia without mesh	43332	Repair of paraesophageal hernia without mesh
		43334	
		43336	
43282	Lap repair of paraesophageal hernia with mesh	43333	Repair of paraesophageal hernia with mesh
		43335	

Lap CPT	Laparoscopic procedure	Open CPT	Open procedure
		43337	
50543	Lap partial nephrectomy	50240	Partial nephrectomy
50545	Lap nephrectomy	50220	Nephrectomy
50546		50225	
50548		50230	
		50234	
		50236	
44204	Lap partial colectomy	44140	Partial colectomy
44205		44141	
44206		44143	
44207		44144	
44208		44145	
		44147	
		44160	
44202	Lap enterectomy	44120	Enterectomy
		44121	
		44125	
		44126	
		44128	
		44130	
44210	Lap total colectomy	44155	Total colectomy
44211		44156	
44212		44157	
		44158	
49324	Lap insertion of intraperitoneal catheter	49421	Insertion of peritoneal dialysis catheter
55550	Lap varicocelectomy	55530	Varicocelectomy
43644	Lap gastric bypass	43845	Gastric bypass
43645		43846	
43770	Lap gastric band	43842	Gastric band
43771			
43773			
58541	Lap hysterectomy	58150	Hysterectomy
58542		58180	
38570	Lap RPLND	38564	RPLND
38572		38747	
		38765	
		38770	
		38780	
44227	Lap closure of enterostomy	44620	Closure of enterostomy

Lap CPT	Laparoscopic procedure	Open CPT	Open procedure
		44625	
		44626	
		62225	
		62230	Replacement CSF shunt
		62223	Creation VP shunt
		62220	Creation VA shunt
		62258	Removal of CSF shunt
		43520	Pyloromyotomy
		50760	Ureteroureterostomy
		50830	Urinary undiversion
		39503	Neonatal diaphragmatic hernia repair
		39541	Diaphragmatic hernia repair (non-neonatal)
		44050	Reduction of volvulus, intussusception, internal hernia
		51500	Excision of urachal remnant
		44346	Revision of colostomy with repair of para-colostomy hernia
		44660	Closure of enterovesical fistula without GI/bladder resection
		44661	Closure of enterovesical fistula with GI/bladder resection
		44650	Closure of enteroenteric or enterocolic fistula
		44615	Intestinal stricturoplasty
		44300	Enterostomy/cecostomy tube placement
		51960	Enterocystoplasty

CPT = common procedural terminology; lap = laparoscopic; RPLND = retroperitoneal lymph node dissection; VA = ventriculoatrial; VP = ventriculoperitoneal; CSF = cerebrospinal fluid

Table A.2

NSQIP-P definition and classification of CHD severity.

Classification	Definition and Criteria
Minor CHD	<ul style="list-style-type: none"> Cardiac condition with or without medication and maintenance (eg, atrial septal defect, small-to-moderate ventricular septal defect with no symptoms) Repair of congenital heart defect with normal cardiovascular function and no medication
Major CHD	<ul style="list-style-type: none"> Repair of congenital heart defect with residual hemodynamic abnormality with or without medications (eg, Tetralogy of Fallot with wide open pulmonary insufficiency, hypoplastic left heart syndrome including stage 1 repair)
Severe CHD	<ul style="list-style-type: none"> Uncorrected cyanotic heart disease Patients with any documented pulmonary hypertension Patients with ventricular dysfunction requiring medications Listed for heart transplant

NSQIP-P = National Surgical Quality Improvement Program Pediatrics version; CHD = congenital heart disease

Table A.3

Most common surgical procedures and frequencies after matching, by CHD severity.

Procedure	No.
<i>Severe CHD (355 matched pairs)</i>	
Gastrostomy	360
Fundoplication	202
Appendectomy	44
Intra-abdominal orchiopexy	32
Cholecystectomy	28
<i>Major CHD (1579 matched pairs)</i>	
Gastrostomy	1414
Fundoplication	766
Appendectomy	172
Intra-abdominal orchiopexy	134
Neonatal diaphragmatic hernia repair	116
<i>Minor CHD (1843 matched pairs)</i>	
Gastrostomy	1506
Fundoplication	752
Appendectomy	348
Pyloromyotomy	168
Cholecystectomy	142
<i>No CHD (41235 matched pairs)</i>	
Appendectomy	46134
Cholecystectomy	8272
Pyloromyotomy	6028
Gastrostomy	5494
Fundoplication	2648

CHD = congenital heart disease

Table A.4

Frequencies of outcomes in matched cohort, stratified by CHD severity.

Variable	No CHD	Minor CHD	Major CHD	Severe CHD
Total No. (%)	82470 (91.6)	3686 (4.1)	3158 (3.5)	710 (0.8)
30-day mortality	69 (0.1)	37 (1.0)	47 (1.5)	18 (2.5)
In-hospital mortality	112 (0.1)	57 (1.6)	70 (2.2)	23 (3.2)
30-day morbidity	7033 (8.5)	825 (22.4)	817 (25.9)	227 (32.0)
Reintubation	195 (0.2)	80 (2.2)	123 (3.9)	50 (7.0)
MI	31 (0.04)	22 (0.6)	39 (1.2)	17 (2.4)
Transfusion	669 (0.8)	175 (4.8)	200 (6.3)	82 (11.6)
SSI	2686 (3.3)	147 (4.0)	170 (5.4)	26 (3.7)

Variable	No CHD	Minor CHD	Major CHD	Severe CHD
UTI	268 (0.3)	28 (0.8)	29 (0.9)	2 (0.3)
CLABSI	43 (0.1)	11 (0.3)	18 (0.6)	4 (0.6)
Pneumonia	206 (0.3)	84 (2.3)	95 (3.0)	9 (1.3)
Sepsis	409 (0.5)	45 (1.2)	68 (2.2)	11 (1.6)
VTE	48 (0.1)	5 (0.1)	8 (0.3)	8 (1.1)
Neurologic sequelae	59 (0.1)	24 (0.7)	24 (0.8)	5 (0.7)
Unplanned reoperation	1511 (1.8)	176 (4.8)	188 (6.0)	57 (8.0)
Unplanned readmission	3841 (4.7)	343 (9.3)	269 (8.5)	86 (12.1)

Numbers are no. (%). CHD = congenital heart disease; MI = myocardial infarction; SSI = surgical site infection; UTI = urinary tract infection; CLABSI = central-line-associated bloodstream infection; VTE = venothrombotic event

Table A.5

Procedure-specific (gastrostomy) subgroup analysis across CHD severity, stratified by outcome.

Outcome	Lap	Open	OR	95% CI	p for trend*
30-day mortality					0.67
Severe CHD	4 (2.2)	8 (4.4)	0.38	0.09–1.57	
Major CHD	11 (1.6)	13 (1.8)	0.80	0.32–2.02	
Minor CHD	6 (0.8)	9 (1.2)	0.58	0.17–1.93	
No CHD	14 (0.5)	13 (0.5)	1.09	0.48–2.50	
In-hospital mortality					0.07
Severe CHD	5 (2.8)	8 (4.4)	0.53	0.14–1.95	
Major CHD	18 (2.6)	14 (2.0)	1.36	0.63–2.96	
Minor CHD	7 (0.9)	16 (2.1)	0.31	0.11–0.90	
No CHD	23 (0.8)	17 (0.6)	1.44	0.72–2.88	
30-day morbidity					0.01
Severe CHD	55 (30.6)	52 (28.9)	1.11	0.66–1.84	
Major CHD	165 (23.3)	176 (24.9)	0.90	0.68–1.18	
Minor CHD	119 (15.8)	178 (23.6)	0.51	0.38–0.70	
No CHD	399 (14.5)	442 (16.1)	0.85	0.72–1.01	

CHD = congenital heart disease; CI = confidence interval; lap = laparoscopic

* p for trend from likelihood ratio test across patients with CHD (minor, major, severe).

Table A.6

Sensitivity analysis across CHD severity restricted to single procedures without concurrent procedures, stratified by outcome.

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
30-day mortality					0.003
Severe CHD	4 (1.9)	1 (0.5)	4.00	0.45–35.79	

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
Major CHD	14 (1.6)	19 (2.1)	0.67	0.30–1.48	
Minor CHD	3 (0.3)	15 (1.3)	0.08	0.02–0.37	
No CHD	22 (0.1)	33 (0.1)	0.60	0.33–1.10	
In-hospital mortality					<0.001
Severe CHD	8 (3.9)	1 (0.5)	8.00	1.00–63.96	
Major CHD	23 (2.6)	22 (2.5)	1.06	0.54–2.11	
Minor CHD	6 (0.5)	21 (1.8)	0.16	0.05–0.48	
No CHD	36 (0.1)	56 (0.2)	0.55	0.34–0.90	
30-day morbidity					0.007
Severe CHD	60 (29.1)	45 (21.8)	1.55	0.96–2.50	
Major CHD	210 (23.5)	213 (23.8)	0.98	0.76–1.25	
Minor CHD	188 (16.3)	236 (20.4)	0.69	0.54–0.88	
No CHD	2619 (7.3)	2788 (7.8)	0.91	0.86–0.97	

CHD = congenital heart disease; CI = confidence interval; lap = laparoscopic

* p for trend from likelihood ratio test across patients with CHD (minor, major, severe).

Table A.7

Sensitivity analysis across CHD severity where laparoscopic converted to open procedures were reclassified as open, stratified by outcome.

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
30-day mortality					0.56
Severe CHD	8 (2.5)	10 (3.2)	0.75	0.26–2.16	
Major CHD	17 (1.2)	24 (1.7)	0.67	0.34–1.31	
Minor CHD	10 (0.6)	19 (1.1)	0.38	0.15–0.98	
No CHD	26 (0.1)	28 (0.1)	0.92	0.51–1.64	
In-hospital mortality					0.30
Severe CHD	12 (3.8)	10 (3.2)	1.26	0.49–3.25	
Major CHD	29 (2.1)	31 (2.2)	0.92	0.53–1.60	
Minor CHD	17 (1.0)	27 (1.6)	0.54	0.26–1.09	
No CHD	46 (0.1)	41 (0.1)	1.15	0.72–1.82	
30-day morbidity					0.39
Severe CHD	95 (30.1)	115 (36.4)	0.68	0.47–1.01	
Major CHD	323 (23.4)	363 (26.3)	0.83	0.68–1.00	
Minor CHD	304 (18.3)	378 (22.8)	0.69	0.57–0.84	
No CHD	3006 (7.7)	3397 (8.7)	0.84	0.79–0.89	

CHD = congenital heart disease; CI = confidence interval; lap = laparoscopic

* p for trend from likelihood ratio test across patients with CHD (minor, major, severe).

Table 1

Baseline cohort characteristics (unmatched).

Variable	Laparoscopic	Open	p	SMD
Overall, No. (%)	45088 (64.3)	25045 (35.7)		
Severe CHD, No. (%)	368 (52.3)	336 (47.7)		
Age, median (IQR), yr	0.4 (0.1–1.5)	0.3 (0.1–0.7)	<0.001	0.26
Male	209 (56.8)	194 (57.7)	0.80	0.02
Race			0.10	0.002
NHW	204 (55.4)	195 (58.0)		
NHB	57 (15.5)	34 (10.1)		
Other	107 (29.1)	107 (31.9)		
Year of surgery			0.76	0.05
2013	109 (29.6)	103 (30.7)		
2014	110 (29.9)	106 (31.6)		
2015	149 (40.5)	127 (37.8)		
ASA			<0.001	0.18
1	0 (0.0)	4 (1.2)		
2	22 (6.0)	19 (5.7)		
3	207 (56.3)	143 (42.6)		
4	138 (37.5)	167 (49.7)		
5	1 (0.3)	3 (0.9)		
Elective surgery	326 (88.6)	256 (76.2)	<0.001	0.33
Weight at surgery, median (IQR), kg	5.5 (3.7–9.8)	4.4 (3.4–7.1)	<0.001	0.22
Prematurity (<37wks)			0.01	0.13
None	302 (82.1)	243 (72.3)		
31–36wks	47 (12.8)	70 (20.8)		
25–30wks	8 (2.2)	15 (4.5)		
<25wks	1 (0.3)	3 (0.9)		
Unknown	10 (2.7)	5 (1.5)		
Inotrope-dependence	15 (4.1)	27 (8.0)	0.03	0.17
Chronic lung disease	42 (11.4)	44 (13.1)	0.50	0.05
Vent-dependence	40 (10.9)	81 (24.1)	<0.001	0.35
No. of simult. procs			0.16	0.05
1	229 (62.2)	196 (58.3)		
2	129 (35.1)	136 (40.5)		
3+	10 (2.7)	4 (1.2)		
Major CHD, No. (%)	1614 (43.7)	2083 (56.3)		
Age, median (IQR), yr	0.5 (0.2–1.4)	0.2 (0.03–0.6)	<0.001	0.33
Male	837 (51.9)	1192 (57.2)	0.001	0.11
Race			0.002	0.12

Variable	Laparoscopic	Open	p	SMD
NHW	871 (54.0)	1004 (48.2)		
NHB	278 (17.2)	385 (18.5)		
Other	465 (28.8)	694 (33.3)		
Year of surgery			0.59	0.03
2013	395 (24.5)	522 (25.1)		
2014	479 (29.7)	641 (30.8)		
2015	740 (45.9)	920 (44.2)		
ASA			<0.001	0.32
1	12 (0.7)	18 (0.9)		
2	200 (12.4)	196 (9.4)		
3	1052 (65.2)	1090 (52.3)		
4	348 (21.6)	722 (34.7)		
5	2 (0.1)	57 (2.7)		
Elective surgery	1382 (85.6)	1412 (67.8)	<0.001	0.43
Weight at surgery, median (IQR), kg	5.4 (3.8–9.7)	3.6 (2.6–6.5)	<0.001	0.35
Prematurity (<37wks)			<0.001	0.11
None	966 (59.9)	1078 (51.8)		
31–36wks	304 (18.8)	409 (19.6)		
25–30wks	194 (12.0)	414 (19.9)		
<25wks	88 (5.5)	160 (7.7)		
Unknown	62 (3.8)	22 (1.1)		
Inotrope-dependence	34 (2.1)	226 (10.9)	<0.001	0.36
Chronic lung disease	407 (25.2)	533 (25.6)	0.80	0.01
Vent-dependence	263 (16.3)	755 (36.3)	<0.001	0.47
No. of simult. procs			0.10	0.04
1	923 (57.2)	1216 (58.4)		
2	623 (38.6)	806 (38.7)		
3+	68 (4.2)	61 (2.9)		
Minor CHD, No. (%)	1860 (45.3)	2242 (54.7)		
Age, median (IQR), yr	0.6 (0.2–4.5)	0.4 (0.1–1.4)	<0.001	0.34
Male	1056 (56.8)	1331 (59.4)	0.09	0.05
Race			0.45	0.04
NHW	1010 (54.3)	1174 (52.4)		
NHB	342 (18.4)	423 (18.9)		
Other	508 (27.3)	645 (28.8)		
Year of surgery			0.001	0.12
2013	463 (24.9)	660 (29.4)		
2014	545 (29.3)	670 (29.9)		
2015	852 (45.8)	912 (40.7)		

Variable	Laparoscopic	Open	p	SMD
ASA			<0.001	0.22
1	53 (2.9)	62 (2.8)		
2	491 (26.4)	440 (19.6)		
3	1139 (61.2)	1366 (60.9)		
4	174 (9.4)	352 (15.7)		
5	3 (0.2)	22 (1.0)		
Elective surgery	1499 (80.6)	1608 (71.7)	<0.001	0.21
Weight at surgery, median (IQR), kg	6.4 (4.0–15.3)	4.8 (2.9–9.5)	<0.001	0.37
Prematurity (<37wks)			<0.001	0.18
None	1027 (55.2)	1009 (45.0)		
31–36wks	322 (17.3)	424 (18.9)		
25–30wks	321 (17.3)	506 (22.6)		
<25wks	122 (6.6)	258 (11.5)		
Unknown	68 (3.7)	45 (2.0)		
Inotrope-dependence	12 (0.7)	90 (4.0)	<0.001	0.23
Chronic lung disease	488 (26.2)	613 (27.3)	0.43	0.03
Vent-dependence	179 (9.6)	399 (17.8)	<0.001	0.24
No. of simult. procs			<0.001	0.08
1	1171 (63.0)	1294 (57.7)		
2	627 (33.7)	888 (39.6)		
3+	62 (3.3)	60 (2.7)		
No CHD, No. (%)	41246 (66.9)	20384 (33.1)		
Age, median (IQR), yr	10.2 (4.8–14.1)	3.9 (0.4–10.4)	<0.001	0.64
Male	23640 (57.3)	11586 (56.8)	0.26	0.01
Race			0.08	0.01
NHW	23938 (58.0)	11686 (57.3)		
NHB	4580 (11.1)	2378 (11.7)		
Other	12728 (30.9)	6320 (31.0)		
Year of surgery			<0.001	0.15
2013	11865 (28.8)	6950 (34.1)		
2014	12494 (30.3)	6493 (31.9)		
2015	16887 (40.9)	6941 (34.1)		
ASA			<0.001	0.43
1	14519 (35.2)	4353 (21.4)		
2	19846 (48.1)	9568 (46.9)		
3	6513 (15.8)	5591 (27.4)		
4	363 (0.9)	796 (3.9)		
5	5 (0.01)	76 (0.4)		
Elective surgery	16791 (40.7)	11948 (58.6)	<0.001	0.36

Variable	Laparoscopic	Open	p	SMD
Weight at surgery, median (IQR), kg	35.6 (17.7–56.5)	15.9 (6.7–34.8)	<0.001	0.61
Prematurity (<37wks)			<0.001	0.21
None	31209 (75.7)	15827 (77.6)		
31–36wks	2075 (5.0)	1918 (9.4)		
25–30wks	590 (1.4)	905 (4.4)		
<25wks	113 (0.3)	220 (1.1)		
Unknown	7259 (17.6)	1514 (7.4)		
Inotrope-dependence	57 (0.1)	190 (0.9)	<0.001	0.11
Chronic lung disease	584 (1.4)	647 (3.2)	<0.001	0.12
Vent-dependence	331 (0.8)	723 (3.6)	<0.001	0.19
No. of simult. procs			<0.001	0.44
1	35945 (87.2)	14083 (69.1)		
2	5112 (12.4)	6083 (29.8)		
3+	189 (0.5)	218 (1.1)		

Values are No. (%) unless otherwise specified.

ASA = American Society of Anesthesiologists physical status; CHD = congenital heart disease; NHW = non-Hispanic whites; NHB = non-Hispanic blacks; SMD = standardized mean difference.

Table 2

Matched cohort characteristics.

Variable	Laparoscopic	Open	p	SMD
Overall, No. (%)	45012	45012		
Severe CHD, No. (%)	355 (50)	355 (50)		
Age, median (IQR), yr	0.4 (0.1–1.4)	0.3 (0.2–0.7)	0.40	0.10
Male	200 (56.3)	187 (52.7)	0.33	0.07
Race			0.02	0.06
NHW	194 (54.7)	215 (60.6)		
NHB	57 (16.1)	33 (9.3)		
Other	104 (29.3)	107 (30.1)		
Year of surgery			0.85	0.003
2013	105 (29.6)	102 (28.7)		
2014	104 (29.3)	111 (31.3)		
2015	146 (41.1)	142 (40.0)		
ASA			0.99	0.01
1	0 (0.0)	0 (0.0)		
2	22 (6.2)	21 (5.9)		
3	196 (55.2)	196 (55.2)		
4	136 (38.3)	138 (38.9)		
5	1 (0.3)	0 (0.0)		
Elective surgery	316 (89.0)	310 (87.3)	0.49	0.05
Weight at surgery, median (IQR), kg	5.4 (3.7–9.7)	4.5 (3.6–7.5)	0.09	0.10
Prematurity (<37wks)			0.06	0.19
None	290 (81.7)	305 (85.9)		
31–36wks	46 (13.0)	44 (12.4)		
25–30wks	8 (2.3)	3 (0.9)		
<25wks	1 (0.3)	1 (0.3)		
Unknown	10 (2.8)	2 (0.6)		
Inotrope-dependence	15 (4.2)	14 (3.9)	0.85	0.01
Chronic lung disease	41 (11.6)	27 (7.6)	0.07	0.13
Vent-dependence	39 (11.0)	41 (11.6)	0.81	0.02
No. of simult. procs			0.08	0.02
1	222 (62.5)	212 (59.7)		
2	123 (34.7)	140 (39.4)		
3+	10 (2.8)	3 (0.9)		
Major CHD, No. (%)	1579 (50)	1579 (50)		
Age, median (IQR), yr	0.5 (0.2–1.3)	0.4 (0.2–0.9)	0.001	0.13
Male	823 (52.1)	848 (53.7)	0.37	0.03
Race				0.01

Variable	Laparoscopic	Open	p	SMD
NHW	848 (53.7)	859 (54.4)		
NHB	273 (17.3)	236 (15.0)		
Other	458 (29.0)	484 (30.7)		
Year of surgery			0.05	0.04
2013	382 (24.2)	334 (21.2)		
2014	473 (30.0)	524 (33.2)		
2015	724 (45.9)	721 (45.7)		
ASA			0.22	0.003
1	11 (0.7)	3 (0.2)		
2	191 (12.1)	193 (12.2)		
3	1034 (65.5)	1056 (66.9)		
4	341 (21.6)	326 (20.7)		
5	2 (0.1)	1 (0.1)		
Elective surgery	1348 (85.4)	1338 (84.7)	0.62	0.02
Weight at surgery, median (IQR), kg	5.3 (3.7–9.3)	5.1 (3.6–7.8)	0.004	0.13
Prematurity (<37wks)			0.11	0.08
None	942 (59.7)	1004 (63.6)		
31–36wks	302 (19.1)	274 (17.4)		
25–30wks	192 (12.2)	181 (11.5)		
<25wks	87 (5.5)	83 (5.3)		
Unknown	56 (3.6)	37 (2.3)		
Inotrope-dependence	34 (2.2)	25 (1.6)	0.24	0.04
Chronic lung disease	405 (25.7)	392 (24.8)	0.59	0.02
Vent-dependence	261 (16.5)	257 (16.3)	0.85	0.01
No. of simult. procs			0.60	0.03
1	901 (57.1)	929 (58.8)		
2	611 (38.7)	586 (37.1)		
3+	67 (4.2)	64 (4.1)		
Minor CHD, No. (%)	1843 (50)	1843 (50)		
Age, median (IQR), yr	0.6 (0.2–4.3)	0.5 (0.2–2.4)	0.01	0.15
Male	1046 (56.8)	1097 (59.5)	0.09	0.06
Race			0.001	0.06
NHW	1001 (54.3)	1089 (59.1)		
NHB	339 (18.4)	264 (14.3)		
Other	503 (27.3)	490 (26.6)		
Year of surgery			0.66	0.03
2013	460 (25.0)	484 (26.3)		
2014	539 (29.3)	531 (28.8)		
2015	844 (45.8)	828 (44.9)		

Variable	Laparoscopic	Open	p	SMD
ASA			0.003	0.07
1	53 (2.9)	47 (2.6)		
2	484 (26.3)	397 (21.5)		
3	1131 (61.4)	1243 (67.4)		
4	172 (9.3)	153 (8.3)		
5	3 (0.2)	3 (0.2)		
Elective surgery	1484 (80.5)	1463 (79.4)	0.39	0.03
Weight at surgery, median (IQR), kg	6.3 (4.0–15.0)	5.6 (3.9–11.4)	0.003	0.19
Prematurity (<37wks)			<0.001	0.13
None	1014 (55.0)	1108 (60.1)		
31–36wks	321 (17.4)	311 (16.9)		
25–30wks	320 (17.4)	285 (15.5)		
<25wks	121 (6.6)	111 (6.0)		
Unknown	67 (3.6)	28 (1.5)		
Inotrope-dependence	11 (0.6)	7 (0.4)	0.48	0.03
Chronic lung disease	488 (26.5)	457 (24.8)	0.24	0.04
Vent-dependence	176 (9.6)	156 (8.5)	0.25	0.04
No. of simult. procs			0.93	0.01
1	1163 (63.1)	1172 (63.6)		
2	618 (33.5)	612 (33.2)		
3+	62 (3.4)	59 (3.2)		
No CHD, No. (%)	41235 (50)	41235 (50)		
Age, median (IQR), yr	10.2 (4.8–14.1)	9.9 (4.4–13.8)	<0.001	0.05
Male	23636 (57.3)	24000 (58.2)	0.01	0.02
Race			0.12	0.003
NHW	23933 (58.0)	24073 (58.4)		
NHB	4577 (11.1)	4393 (10.7)		
Other	12725 (30.9)	12769 (31.0)		
Year of surgery			0.64	0.01
2013	11862 (28.8)	11963 (29.0)		
2014	12489 (30.3)	12512 (30.3)		
2015	16884 (41.0)	16760 (40.7)		
ASA			0.36	0.01
1	14519 (35.2)	14267 (34.6)		
2	19839 (48.1)	20036 (48.6)		
3	6509 (15.8)	6586 (16.0)		
4	363 (0.9)	341 (0.8)		
5	5 (0.01)	5 (0.01)		
Elective surgery	16780 (40.7)	16361 (39.7)	0.003	0.02

Variable	Laparoscopic	Open	p	SMD
Weight at surgery, median (IQR), kg	35.6 (17.7–56.5)	33.9 (16.6–55.3)	<0.001	0.06
Prematurity (<37wks)			0.03	0.02
None	31204 (75.7)	31602 (76.6)		
31–36wks	2072 (5.0)	2018 (4.9)		
25–30wks	589 (1.4)	559 (1.4)		
<25wks	113 (0.3)	102 (0.3)		
Unknown	7257 (17.6)	6954 (16.9)		
Inotrope-dependence	57 (0.1)	47 (0.1)	0.33	0.01
Chronic lung disease	583 (1.4)	525 (1.3)	0.08	0.01
Vent-dependence	330 (0.8)	294 (0.7)	0.15	0.01
No. of simult. procs			0.29	0.01
1	35936 (87.2)	36086 (87.5)		
2	5110 (12.4)	4969 (12.1)		
3+	189 (0.5)	180 (0.4)		

Values are No. (%) unless otherwise specified.

ASA = American Society of Anesthesiologists physical status; CHD = congenital heart disease; NHW = non-Hispanic whites; NHB = non-Hispanic blacks; SMD = standardized mean difference.

Table 3

Mortality and morbidity across CHD severity, stratified by outcome.

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
30-day mortality					0.27
Severe CHD	8 (2.3)	10 (2.8)	0.75	0.26–2.16	
Major CHD	21 (1.3)	26 (1.7)	0.77	0.41–1.45	
Minor CHD	12 (0.7)	25 (1.4)	0.34	0.15–0.79	
No CHD	34 (0.1)	35 (0.1)	0.97	0.58–1.62	
In-hospital mortality					0.05
Severe CHD	13 (3.7)	10 (2.8)	1.39	0.55–3.51	
Major CHD	35 (2.2)	35 (2.2)	1.00	0.59–1.68	
Minor CHD	20 (1.1)	37 (2.0)	0.42	0.22–0.81	
No CHD	57 (0.1)	55 (0.1)	1.04	0.69–1.57	
30-day morbidity					0.01
Severe CHD	108 (30.4)	119 (33.5)	0.82	0.57–1.19	
Major CHD	398 (25.2)	419 (26.5)	0.91	0.76–1.10	
Minor CHD	355 (19.3)	470 (25.5)	0.61	0.50–0.73	
No CHD	3359 (8.2)	3674 (8.9)	0.88	0.83–0.93	

CHD = congenital heart disease; CI = confidence interval; lap = laparoscopic

* p for trend from likelihood ratio test across patients with CHD (minor, major, severe).

Table 4

Postoperative length-of-stay, stratified by CHD severity.

Outcome	Lap	Open	Beta-coefficient (lap vs open)	95% CI	p
Severe CHD (n=621, 87%)					
LOS, median (IQR), days	5 (2–11)	7 (3–15)	–3.6	–6.0–(–1.2)	0.004
Major CHD (n=2679, 84%)					
LOS, median (IQR), days	5 (2–12)	6 (3–16)	–2.0	–3.0–(–1.0)	<0.001
Minor CHD (n=3252, 88%)					
LOS, median (IQR), days	3 (1–8)	4 (1–9)	–0.8	–1.5–0.01	0.05
No CHD (n=81929, 99%)					
LOS, median (IQR), days	1 (1–3)	1 (1–3)	–0.4	–0.5–(–0.3)	<0.001

CHD = congenital heart disease; CI = confidence interval; IQR = interquartile range; lap = laparoscopic; LOS = length of stay

Table 5

Subgroup analyses across CHD severity, stratified by outcome.

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
Readmission					0.02
Severe CHD	49 (13.8)	37 (10.4)	1.45	0.89–2.38	
Major CHD	169 (10.7)	100 (6.3)	2.00	1.50–2.67	
Minor CHD	181 (9.8)	162 (8.8)	1.17	0.91–1.50	
No CHD	1955 (4.7)	1886 (4.6)	1.05	0.98–1.13	
Transfusion					0.37
Severe CHD	29 (8.2)	53 (14.9)	0.34	0.19–0.64	
Major CHD	78 (4.9)	122 (7.7)	0.54	0.38–0.75	
Minor CHD	64 (3.5)	111 (6.0)	0.41	0.28–0.61	
No CHD	64 (3.5)	111 (6.0)	0.55	0.46–0.66	
Reintubation					0.47
Severe CHD	23 (6.5)	27 (7.6)	0.80	0.41–1.55	
Major CHD	63 (4.0)	60 (3.8)	1.07	0.72–1.57	
Minor CHD	35 (1.9)	45 (2.4)	0.73	0.45–1.20	
No CHD	35 (1.9)	45 (2.4)	0.49	0.35–0.69	
MI					0.81
Severe CHD	10 (2.8)	7 (2.0)	1.53	0.53–4.40	
Major CHD	20 (1.3)	19 (1.2)	1.06	0.54–2.09	
Minor CHD	11 (0.6)	11 (0.6)	1.00	0.40–2.52	
No CHD	13 (0.03)	18 (0.04)	0.67	0.31–1.48	
SSI					0.09
Severe CHD	10 (2.8)	16 (4.5)	0.53	0.21–1.33	
Major CHD	50 (3.2)	120 (7.6)	0.28	0.19–0.42	
Minor CHD	56 (3.0)	91 (4.9)	0.51	0.34–0.76	
No CHD	1244 (3.0)	1442 (3.5)	0.82	0.75–0.89	
INFANTS[†]					

Outcome	Lap events No. (%)	Open events No. (%)	Odds Ratio (lap vs open)	95% CI	p for trend*
30-day mortality					0.50
Severe CHD	8 (3.2)	10 (3.5)	0.85	0.29–2.48	
Major CHD	20 (1.8)	26 (2.1)	0.71	0.35–1.43	
Minor CHD	11 (1.0)	20 (1.8)	0.39	0.14–1.03	
No CHD	19 (0.3)	22 (0.4)	1.10	0.50–2.39	
In-hospital mortality					0.13
Severe CHD	13 (5.2)	10 (3.5)	1.33	0.49–3.61	
Major CHD	33 (3.0)	34 (2.8)	1.10	0.62–1.96	
Minor CHD	17 (1.6)	32 (2.8)	0.47	0.22–0.99	
No CHD	28 (0.5)	36 (0.6)	0.76	0.39–1.45	
30-day morbidity					0.08
Severe CHD	97 (38.8)	110 (38.3)	0.97	0.63–1.51	
Major CHD	315 (28.4)	347 (28.6)	0.92	0.74–1.14	
Minor CHD	232 (21.3)	318 (28.2)	0.64	0.50–0.83	
No CHD	560 (9.3)	661 (10.4)	0.96	0.82–1.12	

CHD = congenital heart disease; CI = confidence interval; lap = laparoscopic; MI = myocardial infarction; SSI = surgical site infection

* p for trend from likelihood ratio test across patients with CHD (minor, major, severe).

¶ Infants 1-year-old constituted 15, 60, 73, and 75% of the non-, mild, major, and severe CHD groups, respectively.