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Mortality and morbidity after laparoscopic surgery in children with and without congenital heart disease

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Abstract

Objectives—To determine the risk of morbidity and mortality after laparoscopic surgery among children with congenital heart disease (CHD).

Study design—Cohort study using the 2013–2014 National Surgical Quality Improvement Program-Pediatrics, which prospectively collected data at 56 and 64 hospitals in 2013 and 2014, respectively. Primary exposure was CHD. Primary outcome was overall in-hospital postoperative mortality. Secondary outcomes included 30-day mortality and 30-day morbidity (any non-death adverse event). Among 34,543 children who underwent laparoscopic surgery, 1349, 1106, and 266 had minor, major, and severe CHD, respectively. After propensity score matching within each

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stratum of CHD severity, morbidity and mortality were compared between children with and without CHD.

Results—Children with severe CHD had higher overall mortality and 30-day morbidity (Odds Ratio [OR] 12.31, 95% confidence interval [CI] 1.59 to 95.01; OR 2.51, 95% CI 1.57 to 4.01, respectively), compared with matched controls. Overall mortality and 30-day morbidity were also higher among children with major CHD compared with children without CHD (OR 3.46, 95% CI 1.49 to 8.06; OR 2.07, 95% CI 1.65 to 2.61, respectively). Children with minor CHD had similar mortality outcomes, but had higher 30-day morbidity compared with children without CHD (OR 1.71, 95% CI 1.37 to 2.13).

Conclusions—Children with major or severe CHD have higher morbidity and mortality after laparoscopic surgery. Clinicians should consider the increased risks of laparoscopic surgery for these children during medical decision-making.

Keywords

NSQIP; outcomes; laparoscopy; minimally-invasive surgery; pediatric

The prevalence of congenital heart disease (CHD) in the United States is ~10 per 1,000 live births,¹ but the prevalence continues to grow due to increased survival in children with CHD from advances in diagnosis, treatment, and technology.² Nearly half of children with CHD may require additional non-cardiac surgeries over their lifetime.³ Children with CHD have a higher risk of postoperative mortality and morbidity following non-cardiac surgery when compared with children without CHD.⁴ However, outcomes of children with CHD who undergo laparoscopic surgery, which is a minimally invasive approach, have not been well characterized.

Laparoscopic surgery, which uses 3–12mm incisions rather than larger incisions used in open surgery, has increased in clinical practice and is now a common surgical approach.^{5, 6} Numerous disciplines including pediatric general surgery^{5, 6} and pediatric urology⁷ utilize laparoscopic approaches in both minor and major operations, which decreases postoperative pain and hospital stays in otherwise healthy children.⁸ Laparoscopy requires insufflation of the surgical field with carbon dioxide to allow for visualization of the operative site. The insufflation pressure required (10–20 mmHg) can 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 in healthy subjects.^{9–13} These adverse physiologic effects of insufflation may thus potentially counteract any advantages conferred by the less-invasive approach in children with CHD, although the balance remains unclear.

We conducted a cohort study to compare postoperative mortality and morbidity following laparoscopic surgery among children with and without CHD. We hypothesized that children with more severe CHD will have greater adverse outcomes than children without CHD but no difference will be seen with mild CHD.

Methods

This is a cohort study using prospectively collected data in NSQIP-P from 2013 to 2014. 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 general, urologic, and other sub-specialty surgeries except cardiac surgery at participating hospitals throughout the United States. Participating hospitals increased from 56 in 2013 to 64 in 2014, and include freestanding general acute care children's hospitals, children's hospitals within a larger hospital, specialty children's hospitals, or general acute care hospitals with a pediatric wing. NSQIP-P contains detailed information on baseline characteristics such as age and race, perioperative characteristics such as case urgency and surgical complexity, postoperative complications, and mortality. Data were collected up to 30-days after surgery, although discharge and death date 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 abstracts and audits the data to ensure high accuracy, completeness, and precision, with an overall inter-rater reliability of 98%. A systematic sampling strategy is employed by every 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 criteria.

Children ages 0 to 17 years old of all races who underwent any laparoscopic surgery in 2013 and 2014 were included. These surgeries included any procedures that required insufflation of a body cavity – such as the mediastinum or peritoneum – with carbon dioxide gas to create a working space. For example, laparoscopic appendectomy or laparoscopic pyeloplasty were common procedures within pediatric general surgery and pediatric urology, respectively. Laparoscopic surgery was ascertained within NSQIP-P using an indicator variable that NSQIP-P began recording in 2013. Laparoscopic cases that were converted to open were included. Children who underwent open-only surgery or who were missing an indicator for laparoscopic surgery were excluded.

The primary exposure was diagnosis of CHD, which was ascertained using an indicator variable defined by NSQIP-P. CHD was classified as minor, major, and severe. These definitions defined by NSQIP-P prospectively classify CHD severity based on repair status and residual hemodynamic abnormality and have been validated in other studies of postoperative outcomes in children with CHD.^{4, 14} As an example, NSQIP-P defines a minor CHD as an atrial septal defect that does not have symptoms of congestive heart failure or a patient who had a repair of a CHD with normal cardiovascular function. This is in contrast to the definition of a severe CHD, which could be an uncorrected cyanotic heart disease, a patient with pulmonary hypertension, or ventricular dysfunction.

The primary outcome was overall mortality. Overall mortality was defined as any in-hospital death occurring during the same hospitalization after surgery, regardless of whether it occurred within the 30-day postoperative window.

Secondary outcomes were 30-day postoperative mortality and 30-day morbidity, which are standardly measured in surgical research and clinical care. 30-day morbidity was a composite measure comprising of any 30-day postoperative complication, excluding mortality, measured by NSQIP-P. These included: surgical site infection (SSI), pneumonia, urinary tract infection (UTI), central line-associated blood stream infection (CLABSI), reintubation, readmission, renal insufficiency, venous thrombotic events, neurologic sequelae (coma, seizure, stroke, nerve injuries), graft failure, cardiac arrest, sepsis, transfusion, unplanned readmission, or unplanned reoperation. This composite measure of morbidity was chosen because of the expected overall low incidence of individual adverse events and it has been used in previous analyses of NSQIP-P outcomes.¹⁵ Morbidity outcome events were based on the number of patients experiencing any complication, rather than number of complications per patient.

Propensity scores were used to balance characteristics associated with CHD between the cohorts (with and without CHD). Clinical characteristics chosen *a priori* to be incorporated in the propensity scores included: age at surgery (<6mos, 6–12mos, 1–6yrs, 6–12yrs, >12yrs), sex, race (non-Hispanic white, non-Hispanic black, and other), year of operation, case urgency (elective versus non-elective), American Society of Anesthesiologists (ASA) class (1–2, >2), and procedural complexity. Procedural complexity was defined as a continuous variable using work relative value units based on the Centers for Medicare and Medicaid Services Resource Based Relative Value Scale.¹⁶ Including surgical complexity, which has been associated with postoperative mortality, mitigates potential confounding by indication.¹⁷ Race was included because it has been previously shown to be associated with postoperative complications.¹⁵ 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 or characteristics were available for analysis. Variables that may mediate the effect of CHD on post-operative mortality, such as length of surgery, were not included as covariates because inclusion of mediators may adjust away any true associations between the exposures and outcomes of interest.¹⁸

Statistical Analyses

Power calculations for the primary outcome, overall mortality, were performed for matched pairs with power=80% and alpha=0.017 (Bonferroni correction = 0.05/3 for three outcome models). Assuming an overall mortality rate of 1% in the unexposed children without CHD following surgery,⁴ the sample sizes available within NSQIP-P would allow detection of odds ratios (OR) of 6.60, 2.88, and 2.65, in the severe, major, and minor CHD groups, respectively.

Chi-square tests (or Fisher exact tests if frequency <10 in a cell) and Wilcoxon rank-sum tests were used to compare categorical and continuous variables, respectively, for each stratum of CHD severity against children without CHD as the comparator in the unmatched cohorts. Propensity scores were used to balance the distribution of characteristics associated with the exposure of interest (CHD) between each paired comparison,^{4, 19, 20} for instance, between children with severe CHD and children without any CHD. Within each strata of CHD severity, logistic regression models were used to estimate the probability of having

CHD, using the covariates chosen a priori as the independent variables. Next, children with and without CHD were matched on their propensity scores using nearest neighbor matching with a caliper of 0.1. This procedure produced 1:1 matched cohorts of children with and without CHD within each stratum of CHD severity. Covariate balance between the matched children with and without CHD was assessed using both univariate (chi-square and Wilcoxon rank-sum) tests and standardized mean differences, where values ≤ 0.1 reflect minimal differences between groups.²⁰ Next, the associations between CHD and outcomes were estimated using conditional logistic regression models for each stratum of CHD severity. Due to the few events, CHD was the only independent variable in the outcome models.

One subgroup analysis and several sensitivity analyses were performed. First, we assessed specific subgroups of 30-day overall morbidity to determine what adverse outcome events occurred – reintubation, myocardial infarction, infection-related (SSI, UTI, CLABSI, pneumonia, sepsis), and readmissions. For sensitivity analyses, we restricted our analyses to infants <1 year old, as this group may be the most vulnerable to adverse outcomes and has been previously studied.^{14, 21} We also excluded patients who underwent laparoscopic surgery that was converted to open, as this may indicate a sudden adverse intraoperative episode such as acute bleeding or indicate risk factors such as complex anatomy that may bias towards worse postoperative outcomes. Third, we limited our analyses to those laparoscopic surgeries within pediatric general surgery and pediatric urology, as these most often involve intra-abdominal procedures that require pneumoperitoneum, and excluded all other subspecialties in case of errors in coding for the laparoscopy indicator variable.

All analyses were performed in Stata (v14, StataCorp LP, College Station, TX) with a Bonferroni-corrected two-tailed alpha of 0.017 given the three outcome models.

Results

A total of 34,543 children underwent laparoscopic surgery at 56 and 64 participating hospitals participating in NSQIP-P in 2013 and 2014, respectively. Of these children, 31,822 had no CHD, 1,349 had minor CHD, 1,106 had major CHD, and 266 had severe CHD (Table I and II). Children with CHD tended to be younger, of races other than non-Hispanic white, and had higher ASA class, compared with children without CHD. Frequencies of outcomes, including specific complications, are shown in Table III (available at www.jpeds.com).

After propensity-score matching within each stratum of CHD severity, patients with and without CHD who underwent laparoscopic surgery were similar, with all characteristics having standardized mean differences <0.1 (Table IV; available at www.jpeds.com). A stepwise association between increasing severity of CHD and higher mortality and morbidity was found (Table V). Compared with children without CHD, but similar with respect to age, surgical complexity, case urgency, and ASA classification, children with severe CHD had significantly higher overall mortality (OR 12.31, 95% confidence interval (CI) 1.59 to 95.01) and 30-day overall morbidity (OR 2.51, 95% CI 1.57 to 4.01). Similarly, children with major CHD had significantly higher overall mortality (OR 3.46, 95% CI 1.49 to 8.06) and 30-day overall morbidity (OR 2.07, 95% CI 1.65 to 2.61) than matched children

without CHD. Children with minor CHD had similar mortality outcomes but significantly higher 30-day overall morbidity (OR 1.71, 95% CI 1.37 to 2.13), compared with matched children without CHD.

In the analysis of morbidity subgroups, a stepwise association was found between CHD severity and odds of postoperative reintubation (Table VI). Children with minor CHD had 3-fold increased need for reintubation (OR 3.09, 95% CI 1.48–6.47), but this rose to a 15-fold increased need for reintubation for children with severe CHD (OR 15.81, 95% CI 2.03–123.11) compared with children without CHD.

Regression coefficients for sensitivity analyses were similar to the primary analyses. However, statistical significance was not reached for all outcomes among children with compared with children without CHD due to the smaller sample size (see Tables VII–IX; available at www.jpeds.com).

Discussion

Although our findings may seem unsurprising, few studies have thoroughly examined postoperative outcomes in children with CHD undergoing non-cardiac surgery. One study explored overall postoperative mortality and complications in children with and without CHD.⁴ This study utilized the 2012 version of NSQIP-P – which lacks information on laparoscopic surgery – and compared children with and without CHD undergoing non-cardiac surgery. The authors showed significantly elevated mortality and morbidity among children with CHD compared with their counterparts, but no conclusions could be drawn with regard to laparoscopic surgery specifically. Of note, their point estimates of mortality and morbidity were lower than our results. This may be due to the inclusion of open surgery in their analysis. Our study population consisted of children who underwent only laparoscopic surgery and covered two years of NSQIP-P data.

We found that children with major or severe CHD had significantly higher mortality and morbidity than children without CHD. Even among children with minor CHD, 30-day postoperative complications were significantly higher than children without CHD. This dose-response relationship between CHD severity and worse outcomes indicates that children with severe CHD are more vulnerable to poor outcomes than children with mild CHD due to one of three possibilities: the stress of surgery; the effects of laparoscopic surgery in particular; or the underlying pathophysiology of their CHD. Though our results cannot clearly narrow the etiology for the worse outcomes, we hypothesize that all three contribute.

It is important to note the known effects of pneumoperitoneum on cardiovascular and pulmonary physiology. A previous study showed that among 12 healthy (ASA class I) infants, aortic blood flow and cardiac stroke volume significantly decreased and systemic resistance significantly increased after just 5 minutes of insufflation to 10 mmHg.¹⁰ Similarly, cardiac index was decreased¹² and left ventricular regional wall motion abnormalities were noted¹³ using transesophageal echocardiography among healthy (ASA class I) children undergoing laparoscopic herniorrhaphy. Additionally, peak inspiratory

pressures increased, expiratory tidal volumes decreased, and elimination of carbon dioxide gas was elevated after pneumoperitoneum was established in healthy children, suggesting increased reabsorption of insufflation gas.^{11, 22, 23} Although these prior studies in healthy children showed reversal of the pathophysiology once the pneumoperitoneum was released, our findings of a stepwise increase in odds of reintubation after surgery, which was significant for children with minor as well as severe CHD, support the idea that physiologic reserve may be more limited in children with CHD. This finding also argues in favor of prolonged effects of insufflation on cardiopulmonary physiology as a primary reason for the associations we detected. However, short of intraoperative physiologic measurements, this potential biological mechanism remains hypothesis.

Also noteworthy is that the majority of deaths occurred among infants <1 year of age. This particular subgroup analysis was pre-specified because of the concern for increased vulnerability among younger patients.^{14, 21}

Implications of our findings include the need for careful joint informed decision-making to justify and perform laparoscopic surgery for children with CHD and also caution in caring for these children, beginning with extubation. Multi-disciplinary input and consideration from surgeons, cardiologists, and anesthesiologists are essential in ultimately electing, preparing for, and caring following laparoscopic surgery in children with CHD. Given our findings, the risks of laparoscopic surgery must be weighed carefully.

Of note, our study did not compare laparoscopic with open approaches for children with CHD. Open surgery, though it avoids gas insufflation, carries its own risks compared with laparoscopic surgery with more postoperative pain from a larger incision and potential for greater blood loss with subsequent intravascular fluid shifts. In many situations, there is a laparoscopic approach for a given open surgery. In other clinical scenarios, however, such as for nonpalpable intra-abdominal testes, diagnostic laparoscopy and laparoscopic orchiopexy are nearly universally performed over open intra-abdominal orchiopexy.

Our results must be interpreted in light of their limitations. First, the primary exposure of CHD severity was pre-defined by NSQIP-P and cannot be analyzed by specific types of CHD, such as atrial septal defect, or degree of severity of risk factors, such as degree of pulmonary hypertension. However, we noted a step-wise increase in odds ratios of all outcomes and sensitivity analyses across the three categories of increasing CHD severity, giving face validity to the NSQIP-P subgrouping. Secondly, propensity-score matching limited our sample size and decreased power by excluding many unexposed patients without CHD. However, we detected statistically significant associations between CHD and postoperative mortality and morbidity despite conservative adjustment with the Bonferroni correction for multiple comparisons. Additionally, propensity-score matching is considered more robust and less biased compared with other propensity-score methods.¹⁹ Third, despite the use of methods to control for measured confounders, all observational studies may have unmeasured confounders. Additionally, our sensitivity analyses all support the robustness of our results and their generalizability to patients with CHD. Fourth, as an observational study, our study is subject to selection and misclassification bias. However, NSQIP-P's stringent internal quality indicators, standardized sampling scheme, and certified

surgical clinical reviewers minimize these possibilities. Furthermore, misclassification of exposures and outcomes would likely be non-differential between the groups and thus bias towards the null. Fifth, our study cannot delineate the exact causal mechanisms through which children with more severe CHD have worse outcomes. This remains an area of needed research and warrants future comparisons of laparoscopic versus open surgery to determine the optimal approach of least risk. A further limitation is the inability, as stipulated by NSQIP-P, to stratify results by center or account for clustering at the center level, which could adjust for variations in practice patterns, volume of laparoscopic procedures, experience of providers in caring for children with CHD, and hospital quality. Lastly, our results may not be generalizable to the national population as NSQIP-P is not a representative sample of the population. However, with expansion from 56 participating hospitals in 2013 to 64 in 2014 and the heterogeneous make-up of participating hospitals, our results are likely applicable to most children with or without CHD undergoing laparoscopic surgery.

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Abbreviations

ASA	American Society of Anesthesiologists
CHD	congenital heart disease
CI	confidence interval
CLABSI	central line-associated bloodstream infection
NSQIP-P	National Surgical Quality Improvement Program – Pediatrics
OR	odds ratio
SSI	surgical site infection
UTI	urinary tract infection

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Table 1

Unmatched cohort characteristics, stratified by CHD severity.

Variable	No CHD	Minor CHD	* p	Major CHD	* p	Severe CHD	* p
Total n	31822	1349		1106		266	
Age							
<6mos	3745 (11.8)	558 (41.4)	<0.001	543 (49.1)	<0.001	125 (47.0)	<0.001
6–12mos	1261 (4.0)	160 (11.9)		175 (15.8)		37 (13.9)	
1–6yrs	5476 (17.2)	257 (19.1)		205 (18.5)		60 (22.6)	
6–12yrs	9859 (31.0)	172 (12.8)		84 (7.6)		22 (8.3)	
>12yrs	11480 (36.1)	202 (15.0)		99 (9.0)		22 (8.3)	
Male	18467 (58.0)	767 (56.9)	0.39	579 (52.4)	<0.001	156 (58.7)	0.84
Race							
NHW	18843 (59.2)	758 (56.2)	<0.001	616 (55.7)	<0.001	152 (57.1)	0.006
NHB	3680 (11.6)	243 (18.0)		193 (17.5)		47 (17.7)	
Other	9298 (29.2)	348 (25.8)		297 (26.9)		67 (2.2)	
Year of surgery							
2013			0.09		0.003		0.69
2014	14917 (46.9)	601 (44.6)		469 (42.4)		128 (48.1)	
	16904 (53.1)	748 (55.4)		637 (57.8)		138 (51.9)	
ASA							
1–2	26309 (82.7)	437 (32.4)	<0.001	157 (14.2)	<0.001	20 (7.5)	<0.001
>2	5512 (17.3)	912 (67.6)		949 (85.8)		246 (92.5)	
Elective	14597 (45.9)	1060 (78.6)	<0.001	931 (84.2)	<0.001	234 (88.0)	<0.001
Operative complexity	9.45 (9.45–11.29)	10.05 (8.48–18.10)	0.15	11.29 (8.48–18.10)	<0.001	8.48 (8.48–18.10)	0.015

Numbers are n (%) or median (interquartile range).

* p-values compare children without CHD to each CHD category of severity.

ASA = American Society of Anesthesiologists; CHD = congenital heart disease; NHW = non-Hispanic white; NHB = non-Hispanic black

Table 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

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

Table 3

Frequency of outcomes in unmatched cohort, stratified by CHD severity.

Variable	No CHD	Minor CHD	* p	Major CHD	* p	Severe CHD	* p
Total n	31822	1349		1106		266	
Overall mortality	54 (0.2)	19 (1.4)	<0.001	24 (2.2)	<0.001	14 (5.3)	<0.001
30-day mortality	35 (0.1)	13 (1.0)	<0.001	16 (1.5)	<0.001	9 (3.4)	<0.001
30-day morbidity	2619 (8.2)	272 (20.2)	<0.001	286 (25.9)	<0.001	77 (29.0)	<0.001
Reintubation	57 (0.2)	31 (2.3)	<0.001	34 (3.1)	<0.001	14 (5.3)	<0.001
MI	11 (0.03)	9 (0.7)	<0.001	12 (1.1)	<0.001	3 (1.1)	<0.001
Transfusion	302 (1.0)	58 (4.3)	<0.001	63 (5.7)	<0.001	18 (6.8)	<0.001
SSI	844 (2.7)	39 (2.9)	0.59	30 (2.7)	0.90	12 (4.5)	0.06
UTI	95 (0.3)	10 (0.7)	0.01	10 (0.9)	0.003	2 (0.8)	0.19
CLABSI	10 (0.03)	3 (0.2)	0.01	1 (0.09)	0.31	1 (0.4)	0.09
Pneumonia	90 (0.3)	22 (1.6)	<0.001	23 (2.1)	<0.001	3 (1.1)	0.04
Sepsis	149 (0.5)	20 (1.5)	<0.001	15 (1.4)	<0.001	7 (2.6)	<0.001
VTE	21 (0.07)	4 (0.3)	0.02	4 (0.4)	0.01	2 (0.8)	0.02
Neurologic sequelae	29 (0.1)	13 (1.0)	<0.001	6 (0.5)	0.001	1 (0.4)	0.22
Graft failure	1 (<0.01)	0	1.00	0	1.00	0	1.00
Unplanned reoperation	615 (1.9)	72 (5.3)	<0.001	73 (6.6)	<0.001	20 (7.5)	<0.001
Unplanned readmission	1484 (4.7)	136 (10.1)	<0.001	123 (11.1)	<0.001	37 (13.9)	<0.001

Numbers are n (%) or median (interquartile range).

* p-values compare children without CHD to each CHD category of severity. 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 4

Matched characteristics within strata of CHD severity.

Variable	No CHD	CHD	p	SMD
<i>Severe CHD</i>	N=266	N=266		
Age			0.94	
<6mos	123 (46.2)	125 (47.0)		0.015
6–12mos	36 (13.5)	37 (13.9)		0.011
1–6yrs	61 (22.9)	60 (22.6)		0.009
6–12yrs	27 (10.2)	22 (8.3)		0.065
>12yrs	19 (7.1)	22 (8.3)		0.042
Male	156 (58.7)	156 (58.7)	1.00	<0.001
Race			0.82	
NHW	159 (59.8)	152 (57.1)		0.053
NHB	43 (16.2)	47 (17.7)		0.040
Other	64 (24.1)	67 (25.2)		0.026
Year of surgery			0.54	0.053
2013	135 (50.8)	128 (48.1)		
2014	131 (49.3)	138 (51.9)		
ASA			0.44	0.067
1–2	25 (9.4)	20 (7.5)		
>2	241 (90.6)	246 (92.5)		
Elective	233 (87.6)	234 (88.0)	0.90	0.011
Operative complexity	8.48 (8.48–18.10)	8.48 (8.48–18.10)	0.88	0.043
<i>Major CHD</i>	N=1106	N=1106		
Age			0.99	
<6mos	550 (49.7)	543 (49.1)		0.013
6–12mos	175 (15.8)	175 (15.8)		<0.001
1–6yrs	202 (18.3)	205 (18.5)		0.007
6–12yrs	79 (7.1)	84 (7.6)		0.017
>12yrs	100 (9.0)	99 (9.0)		0.003
Male	588 (53.2)	579 (52.4)	0.70	0.016
Race			0.97	
NHW	620 (56.1)	616 (55.7)		0.007
NHB	194 (17.5)	193 (17.5)		0.002
Other	292 (26.4)	297 (26.9)		0.010

Variable	No CHD	CHD	p	SMD
Year of surgery			0.73	0.015
2013	461 (41.7)	469 (42.4)		
2014	645 (58.3)	637 (57.6)		
ASA			0.76	0.013
1–2	162 (14.7)	157 (14.2)		
>2	944 (85.4)	949 (85.8)		
Elective	934 (84.5)	931 (84.2)	0.86	0.007
Operative complexity	11.29 (8.48–18.10)	11.29 (8.48–18.10)	0.84	0.002
Minor CHD	N=1349	N=1349		
Age			1.00	
<6mos	559 (41.4)	558 (41.4)		0.002
6–12mos	160 (11.9)	160 (11.9)		<0.001
1–6yrs	254 (18.8)	257 (19.1)		0.006
6–12yrs	172 (12.8)	172 (12.8)		<0.001
>12yrs	204 (15.1)	202 (15.0)		0.004
Male	766 (56.8)	767 (56.9)	0.97	0.001
Race			0.72	
NHW	778 (57.7)	758 (56.2)		0.030
NHB	239 (17.7)	243 (18.0)		0.008
Other	332 (24.6)	348 (25.8)		0.027
Year of surgery			0.94	0.003
2013	603 (44.7)	601 (44.6)		
2014	746 (55.3)	748 (55.4)		
ASA			0.93	0.003
1–2	435 (32.3)	437 (32.4)		
>2	914 (67.7)	912 (67.6)		
Elective	1057 (78.4)	1060 (78.6)	0.89	0.005
Operative complexity	9.45 (8.48–18.10)	10.05 (8.48–18.10)	0.45	0.031

Numbers are n (%) or median (interquartile range).

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

Table 5

Conditional logistic regression models within propensity-score matched cohorts, stratified by CHD severity.

Outcome	# events	Odds Ratio	95% CI	* p
Severe CHD (n=266)				
Any mortality	17	12.31	1.59–95.01	0.016
30-day mortality	12	7.00	0.86–56.89	0.07
30-day morbidity	118	2.51	1.57–4.01	<0.001
Major CHD (n=1106)				
Any mortality	31	3.46	1.49–8.06	0.004
30-day mortality	22	2.68	1.05–6.86	0.04
30-day morbidity	459	2.07	1.65–2.61	<0.001
Minor CHD (n=1349)				
Any mortality	33	1.46	0.68–3.14	0.34
30-day mortality	22	1.58	0.61–4.12	0.35
30-day morbidity	455	1.71	1.37–2.13	<0.001

CHD = congenital heart disease; CI = confidence interval

*
p<0.017 considered statistically significant.

Table 6

Conditional logistic regression models for complications by subgroup within propensity-score matched cohorts, stratified by CHD severity.

Outcome	# events	Odds Ratio	95% CI	p [*]
Severe CHD (n=266)				
Reintubation	15	15.81	2.03–123.11	0.008
Myocardial infarction [^]	3	–	–	–
Infection-related	31	2.31	1.03–5.16	0.04
Readmissions	63	1.53	0.88–2.64	0.13
Major CHD (n=1,028)				
Reintubation	38	8.99	3.16–25.55	<0.001
Myocardial infarction [^]	12	–	–	–
Infection-related	120	1.60	1.08–2.38	0.02
Readmissions	199	1.80	1.31–2.48	<0.001
Minor CHD (n=1,349)				
Reintubation	43	3.09	1.48–6.47	0.003
Myocardial infarction [^]	9	–	–	–
Infection-related	126	1.44	0.96–2.16	0.08
Readmissions	220	1.69	1.24–2.32	0.001

CHD = congenital heart disease; CI = confidence interval

* p<0.017 considered statistically significant.

[^] myocardial infarction had too few events for convergence of conditional logistic regression.

Table 7

Sensitivity analyses of outcome models with restriction to infants <1 year old.

Outcome	# events	Odds Ratio	95% CI	p [*]
Severe CHD (n=162)				
Any mortality	17	11.30	1.45–88.00	0.02
30-day mortality	12	6.00	0.72–49.84	0.10
30-day morbidity	84	5.72	2.83–11.59	<0.001
Major CHD (n=718)				
Any mortality	28	4.46	1.68–11.81	0.003
30-day mortality	20	2.81	1.01–7.83	0.047
30-day morbidity	339	2.40	1.80–3.18	<0.001
Minor CHD (n=718)				
Any mortality	25	1.12	0.44–2.87	0.81
30-day mortality	19	1.17	0.39–3.54	0.78
30-day morbidity	274	1.91	1.43–2.56	<0.001

CHD = congenital heart disease; CI = confidence interval

* p<0.017 considered statistically significant.

Table 8

Sensitivity analyses of outcome models with restriction to laparoscopic-only procedures.

Outcome	# events	Odds Ratio	95% CI	p [*]
Severe CHD (n=238)				
Any mortality	15	8.27	1.02–66.73	0.047
30-day mortality	11	4.00	0.45–35.79	0.22
30-day morbidity	99	2.48	1.46–4.21	0.001
Major CHD (n=933)				
Any mortality	26	2.92	1.14–7.52	0.03
30-day mortality	17	2.02	0.67–6.09	0.21
30-day morbidity	353	2.16	1.64–2.85	<0.001
Minor CHD (n=1,159)				
Any mortality	31	1.44	0.63–3.28	0.38
30-day mortality	20	1.59	0.55–4.62	0.40
30-day morbidity	378	1.72	1.33–2.22	<0.001

CHD = congenital heart disease; CI = confidence interval

*
p<0.017 considered statistically significant.

Table 9

Sensitivity analyses of outcome models with restriction to pediatric surgery or pediatric urology cases.

Outcome	# events	Odds Ratio	95% CI	p [*]
Severe CHD (n=253)				
Any mortality	16	11.30	1.45–88.00	0.02
30-day mortality	12	7.00	0.86–56.89	0.07
30-day morbidity	115	2.51	1.54–4.10	<0.001
Major CHD (n=1,028)				
Any mortality	31	3.59	1.44–8.93	0.006
30-day mortality	22	2.84	1.02–7.91	0.045
30-day morbidity	422	2.17	1.70–2.78	<0.001
Minor CHD (n=1,235)				
Any mortality	28	1.22	0.51–2.97	0.65
30-day mortality	19	1.62	0.52–5.00	0.40
30-day morbidity	409	1.75	1.38–2.22	<0.001

CHD = congenital heart disease; CI = confidence interval

* p<0.017 considered statistically significant.