



Gastrointestinal complications associated with the surgical treatment of heart disease in children



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ARTICLE INFO

Article history:

Received 27 April 2016

Received in revised form 14 October 2016

Accepted 16 October 2016

Key words:

Congenital heart disease

Pediatric

Surgery

Heart

Gastrointestinal tract

ABSTRACT

Background/purpose: The gastrointestinal system is prone to complications following heart surgery. We sought to determine the incidence and factors associated with gastrointestinal complication after cardiac surgery in children. **Methods:** A retrospective review of patients aged < 16 years that underwent cardiac surgery between 2009 and 2013. Primary outcome was occurrence of gastrointestinal complication within 30 days. Multivariable logistic regression was performed to identify variables related to occurrence of gastrointestinal complication. Patients with gastrointestinal complication were matched with controls and postoperative lengths of stay compared.

Results: Eight hundred eighty-one children underwent 1120 cardiac surgical procedures. At time of operation, 18% were neonates and 39% were infants. Cardiopulmonary bypass was used in 79%. Of 1120 procedures, 31 (2.8% [95% CI 2.0–3.9%]) had gastrointestinal complication. Necrotizing enterocolitis accounted for 61% of complications. Of patients with gastrointestinal complication, 87% survived to hospital discharge. Gastrointestinal complication was associated with preoperative co-morbidity (OR 2.2 [95% CI 1.02–4.8]) and univentricular disease (OR 2.5 [95% CI 1.1–5.5]). Neonates had the highest risk of gastrointestinal complication. Patients with gastrointestinal complications had longer hospital stays than controls (median difference, 13 days [95% CI 3–43]).

Conclusions: Serious gastrointestinal complications are uncommon but associated with longer hospital stay. Neonates with univentricular disease and preoperative comorbidity are at highest risk.

Type of study: Prognosis study.

Level of evidence: II.

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Six out of every 1000 babies have some form of significant congenital heart disease and many will require corrective or palliative cardiac surgery during infancy or childhood [1]. In the United Kingdom (UK), around 4500 pediatric cardiac surgical procedures are undertaken each year [2].

The gastrointestinal system is prone to complications after cardiac surgery because of the interactions between the gastrointestinal (GI) and cardiovascular systems. Complications are largely the result of perfusion abnormalities of the splanchnic circulation that lead to ischemia–reperfusion injury [3]. Potential abdominal complications include necrotizing enterocolitis, GI bleeding, colitis, enteric ischemia, intestinal perforation, and pancreatitis. Despite the associated risks of significant morbidity and mortality, they are the least studied complication of pediatric cardiac surgery.

Our aim was to determine the incidence of GI complications following heart surgery in children aged < 16 years. In addition, we sought to determine the factors associated with GI complications and whether

such complications impact on survival and postoperative length of stay. We hypothesized that children with GI complications would have longer postoperative hospital stay compared to matched controls that underwent the same procedure but did not develop GI complications.

1. Methods

1.1. Study population

Our institution provides care for infants and children with all forms of congenital and acquired heart disease including hypoplastic left heart syndrome. Around 350 patients undergo cardiac surgery each year. Our unit is one of two centers in the UK that undertakes pediatric heart transplantation and ventricular assist device (VAD) implantation. After favorable opinion from the NHS Research Ethics Committee, all patients aged < 16 years who underwent cardiac surgical procedure at our institution between January 2009 and December 2013 were retrospectively identified from our submission to the national Central Cardiac Audit Database. *Cardiac surgical procedure* was defined as any cardiac or intrathoracic great vessel procedure. The prospectively collected

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data included details about patient diagnoses, co-morbidities, and the operation performed. It is subject to external quality assurance with annual inspection to confirm that every cardiac surgical procedure undertaken at the institution has been entered in the database. In addition, a random sample of medical records is compared to the database entries to assess data quality [4].

We excluded patients with corrected gestational age <42 weeks undergoing isolated arterial duct ligation. These patients receive postoperative care at the regional neonatal intensive care units and are not followed up at our institution. Patients undergoing VAD implantation were excluded to allow estimation of incidence of GI complication relevant to non-VAD centers.

1.2. Study design

The operative data was linked using medical record number to the institution's pediatric critical care audit database. This database is prospectively maintained and collects demographics, diagnosis, admission physiology, complication data and individual patient outcome. All complications that occur prior to hospital discharge are collected prospectively. The database feeds into the national Pediatric Intensive Care Audit Network (PICANet) audit and is externally validated annually by PICANet. The medical records of patients undergoing cardiac surgery that were not admitted to the pediatric critical care unit were reviewed to ensure a complete dataset for all procedures (<3% of total).

The following data was recorded for each cardiac surgical procedure: patient demographics (age, weight, gestational age, gender), co-morbidities, operative procedure (bypass or non-bypass), and postoperative factors (length of stay, length of ventilation, use of renal replacement therapy and extracorporeal membrane oxygenation (ECMO), and GI complication). Operative procedure was categorized using the risk adjusted classification for congenital heart surgery (RACHS-1) [5]. This method classifies surgical procedures for congenital heart disease into six categories of increasing predicted operative risk: category 1 was low risk, and category 6 the highest risk. Age was classified into three groups: neonate (<30 days), infant (30 days to 1 year), and child/adolescent (>1 year). Preoperative co-morbidity data is collected as part of the Central Cardiac Audit Database dataset and defined by the International Pediatric and Congenital Cardiac Code (IPCCC) [6]. IPCCC defines comorbid conditions and groups into 4 categories: premature (gestational age <37 weeks); Down syndrome; congenital non-Down syndrome co-morbidity (all genetic syndromes, congenital structural defects of organs other than the heart); and acquired co-morbidity (including preoperative comorbidities, e.g. neurologic impairment, renal failure) [6].

Conditions listed in Table 1 were considered GI complications and were defined using the definitions of abdominal complications published by the Multi-Societal Database Committee for Pediatric and Congenital Heart Disease [7]. These definitions provide comprehensive standardized nomenclature for perioperative gastrointestinal complications in the pediatric cardiac surgical population. *Necrotizing enterocolitis* (NEC) was defined as “an acute reduction in the supply of oxygenated blood to the small intestine or large intestine, typically resulting in acidosis, abdominal distention, pneumatosis, and/or intestinal perforation, that prompts initiation of antibiotics or exploratory laparotomy” [7]. NEC was

diagnosed by the attending pediatric surgeon and radiology reviewed by the attending radiologist. Infants with NEC were staged using Bell's criteria [8]. *Gastrointestinal bleeding* was defined as bleeding from the upper or lower gastrointestinal tract requiring blood transfusion. Patients with GI bleeding secondary to NEC were classified as NEC alone. *Enteritis* was defined as “inflammation of the small bowel with abdominal pain with fever, ileus and possibly peritoneal signs” [7].

1.3. Enteral feeding practice

Initiation of enteral nutrition usually begins within 6 h of admission to the pediatric intensive care unit unless the patient is hemodynamically unstable as defined by high vasopressor requirement or has low cardiac output state, or extubation is anticipated within the next 6 h. An initial trophic feed rate of 20 mL/kg/day is used and human milk is preferred in infants. Feeds are advanced when tolerated and intermittent feeds used when possible. Patients aged >28 days and expected to be ventilated >48 h receive selective digestive tract decontamination (nystatin, colistin and neomycin; neonates receive nystatin only). Probiotics are not used.

1.4. Outcome measures and statistical analysis

The primary outcome measure was occurrence of a GI complication within 30 days after cardiac surgery. Patients with preoperative gastrointestinal disease listed in Table 1 and present during the index hospital admission were excluded from outcome analysis. When GI complication occurred in a patient who underwent surgical re-intervention within 30 days of the first operation, the complication was assigned to the last procedure only. Surgical operation more than 30 days after the first procedure was treated as independent within the analysis.

Variables are presented as counts (percentages) or median with interquartile range [IQR]. The proportions of categorical variables were compared with chi-square test or Fisher's exact test when any expected frequency was <5. Non-normally distributed continuous data were compared between groups using Mann-Whitney test. Multivariable analysis was performed to identify variables related to occurrence of GI complication using logistic regression. The following variables were defined a priori: pre-operative (age group, gender, comorbidity, functionally univentricular or biventricular heart disease [9]; operative (bypass versus non-bypass), and post-operative factors (extracorporeal membrane oxygenation, renal replacement therapy). The odds ratio (OR) and the 95% confidence interval (95% CI) were calculated for tested variables.

The effect of GI complication on postoperative hospital stay was determined by matching each case with a GI complication to a control patient from the same age group who underwent the same surgical procedure but did not have a postoperative GI complication. SPSS V22 (IBM, Chicago IL, USA) was used to undertake the exact matching on all of the following criteria: age group, surgical procedure, alive at 30 days and presence of preoperative comorbidity. Cases with GI complication that could not be matched on all of the criteria with a control patient were not analyzed further. Baseline characteristics of matched pairs were compared with McNemar exact test for categorical data and Wilcoxon matched pairs test for continuous data. Postoperative length of stay in paired cases and controls was compared with the Wilcoxon matched pairs test and 95% confidence interval for the median difference calculated using Hodges-Lehmann estimator. A *p* value <0.05 was considered statistically significant.

2. Results

2.1. Patient characteristics

Between 2009 and 2013, 1030 patients aged <16 years underwent 1369 cardiac surgical procedures. Of these, 249 (18%) procedures met

Table 1
Qualifying gastrointestinal conditions [7].

Complication requiring laparotomy
Necrotizing enterocolitis
Pancreatitis
Gastrointestinal bleeding requiring transfusion
Ileus
Ischemic bowel
Enteritis
Colitis

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