Five-year experience with congenital cardiac surgery at National University Heart Centre, Singapore

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ABSTRACT

Introduction: Surgical procedures performed for congenital heart disease are usually complex and variable. The aims of this paper were to analyse patient demographics in a centre that caters to congenital cardiac surgery, compare departmental standards to international centres, and investigate the relationship between patient volume and clinical outcome.

Methods: A total of 163 patients who presented to the Cardiac, Thoracic and Vascular Surgery Department of the National University Hospital, Singapore between 2002 and 2006 were identified and studied retrospectively. Patient demographics were analysed. The mortality rates and patient volume were compared with those observed at international centres.

Results: The mean annual patient volume was 32.6 cases. The mean age of the patients was 15.7 years, with the oldest patient being 73 years old. 57.1 percent of the patients were Chinese, 23.3 percent were Malay and 19.6 percent were Indian and other races. Foreigners made up nearly half of the patient cohort (45.4 percent). Atrial septal defect was found to be the most common diagnosis (n is 64), with the secundum being most commonly involved (76.9 percent). The commonest postoperative morbidities encountered were arrhythmias and pleural effusions. Patient volume was not found to be a significant factor affecting clinical outcomes.

Conclusion: With a growing population of adults with congenital heart disease and a significant number of foreign patients, improvements to our resources and infrastructure need to be considered in order to cope with the increasing demands. Despite having a low patient volume, the centre is still able to provide congenital heart surgery with good clinical outcomes that are comparable to those of international centres with similar or higher patient volumes.

Keywords: clinical outcomes, congenital cardiac surgery, congenital heart disease, patient volume

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INTRODUCTION

Congenital heart disease (CHD) is the leading non-infective cause of death among newborn infants and affects nearly one in 100 in this age category.[1-3] More specifically, the incidence of moderate and severe forms of CHD runs up to six per 1,000 live births, with the incidence rate at up to 19 per 1,000 when bicuspid aortic values are included. Overall, a third of those affected require some form of surgical or catheter-based intervention within the first year of life. In the United States, there are more than 35,000 new CHD cases diagnosed each year and over one million survivors of CHD in the community.[4] It has been estimated that more than 80% of children with CHD survive into adulthood.[5] CHD can occur in adults as well. This group of patients would include those previously operated on during infancy or childhood, or those with lesions that are unrecognised until later in life. In the current era, there is an increasing population of adults with congenital malformed hearts. Yet, the prevalence in the adult population is not known, and the unavailability of the exact numbers affected has hampered further planning and research.[6] However, the most important point to note is that most deaths from CHD now occur in adults.[7] The lack of trained medical and surgical staff and clinical units to manage this specialised field of medicine is the most pressing issue that requires further investigation. Furthermore, these figures represent a significant economic and social burden, and hence drive

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Table I. Patient characteristics (n = 163).

Characteristic	No. (%)
Age (yrs)	
< 12	94 (57.7)
≥ 12	69 (42.3)
Gender	
Male	74 (45.4)
Female	89 (54.6)
Race	
Chinese	93 (57.1)
Malay	38 (23.3)
Indian	16 (9.8)
Others	16 (9.8)
Nationality	
Singaporeans	89 (54.6)
Foreigners	74 (45.4)
Surgery Status	
Elective	146 (89.6)
Emergency	17 (10.4)

the need for intensive research into causation and risk assessment.

CHD can present in different ways. In the majority of cases (70%), it arises sporadically or in an isolated form. In the remaining 30% of cases,[8] CHD is usually associated with either a syndrome (Down syndrome) or rarely, a dominantly inherited form of disease. The pathogenesis is likely to be a result of multiple gene defects and/or interactions between defective genes and the foetal environment. Surgery is usually required as a final measure when other forms of therapy either cannot maintain adequate circulation for development or quality of life, or the structural defect requires correction to prevent further damage to the heart or other organs.

Till today, impaired cardiac function remains the principal cause of morbidity and mortality following paediatric cardiac surgery. Within 6–18 hours of major procedures involving cardiopulmonary bypass and myocardial ischaemia, cardiac performance has been predicted to decline significantly.[9] Contributing factors include haemodilution during surgery, the development of a systemic inflammatory response to surgical trauma, and leakages in capillaries that result in the accumulation of fluid and proteins within the interstitial space.[10]

Over the years, there have been significant developments and progress in improving the outcomes for patients with CHD who undergo surgery. Indeed, the advent of new techniques, modifications and medications has led to a significant reduction in mortality rates for these patients.[11,12] At the same time, studies have found other factors that greatly modify clinical outcomes, such as the volume of cases handled by an institution or a person.[13] A recent review of 72 studies revealed that centres with a higher volume of cases have a better clinical outcome.[14] Numerous studies have also documented an inverse relationship between the hospital volume of clinical procedures and clinical outcomes.[15,16] However, due to the complexity and variability of surgical procedures conducted for CHD, not much has been done to investigate this particular relationship.

Currently, there are two public hospitals in Singapore that are equipped to provide surgery for the treatment of CHD: the National University Heart Centre (NUHC) and KK Women's and Children's Hospital. Patients who seek surgical therapy for CHD in these hospitals include a spectrum of both locals and foreigners. With regard to the inverse relationship between patient volume and clinical outcomes, there has also been little examination of this aspect in the context of these two hospitals. A retrospective review of the Department of Cardiac, Thoracic and Vascular Surgery (CVTS) at the NUHC, Singapore was therefore carried out to: analyse the demographics of patients undergoing congenital cardiac surgery; obtain a benchmark comparison of department standards to that of international centres for CHD surgery; and determine the existence of a significant inverse relationship between patient volume and clinical outcomes within the department.

METHODS

The study group consisted of patients who had previously undergone palliative or reparative congenital heart surgery in the CVTS department, NUHC, Singapore between January 1, 2002 and December 31, 2006. The patients' demographic data was obtained from the departmental database file, and further information was retrieved from individual operation notes, discharge summaries and perfusionist records. The data of foreign hospitals was obtained from relevant, established medical journal articles and health department databases reviewing a similar area of interest.

The main demographic variables examined included patient age, gender, race, status and type of surgery, surgeon volume, patient diagnoses, cyanotic status, preoperative left ventricular ejection fraction (LVEF), pre-morbid conditions, duration of surgery, cardiopulmonary bypass status and time, cross clamp time, postoperative ventilation status, length of hospital stay and postoperative morbidities. The main

Table II. Surgery demographics (n = 163).

Parameter	No. (%)
Cyanotic status	
Acyanotic	127 (77.9)
Cyanotic	36 (22.1)
Preoperative LVEF	
> 60%	123 (75.5)
< 60%	40 (24.5)
Duration of surgery	
< 3 hrs	127 (77.9)
≥ 3 hrs	36 (22.1)
Cardiopulmonary bypass status	
On	127 (77.9)
Off	36 (22.1)
Cardiopulmonary bypass time	
< 80 mins	74 (58.3)
≥ 80 mins	53 (41.7)
Cross clamp time	
< 40 mins	63 (49.6)
≥ 40 mins	64 (50.4)
Postoperative ventilation status	
Ventilated	143 (87.7)
< 96 hrs	130 (90.9)
> 96 hrs	13 (7.98)
Non-ventilated	20 (12.3)
Length of hospital stay	
< 3 weeks	124 (76.1)
≥ 3 weeks	39 (23.9)

LVEF: left ventricular ejection fraction

Table III. The basic patient diagnoses (n = 163).

Diagnosis	No.
Atrial septal defect	64
Ventricular septal defect	35
Patent ductus arteriosus	21
Pulmonary valve anomaly	15
Tetralogy of fallot	15
Single ventricle	12
AVSD	7
Transposition of great arteries	5
Tricuspid regurgitation	5
Coarctation of the aorta	5
Double outlet right ventricle	4
Cleft mitral value	3
Cor triatrium	3
Coronary AVF	2
Atrial myxoma	2
Congenital heart block	1
Hypoplastic right heart syndrome	1
TAPVD	1
Aortic regurgitation	1

AVF: arteriovenous fistula; TAPVD: total anomalous pulmonary venous drainage; AVSD: atrioventricular septal defect

areas of interest that were compared with data from foreign hospitals were department patient volume and mortality rates from January 2002 to December 2006. For the purpose of analysis, the mean annual hospital/department volumes of surgical procedures for CHD were categorised into the "low-volume" and "high-volume" groups. The cut-off point for each category was < 100 and ≥ 100, respectively. Mortality was defined as "death occurring within 30 days of surgery or within the same hospital admission".[17] The analysis was then expanded to include observed mortality rates corresponding to patient volumes in NUHC and likewise, in other foreign hospitals. The significance of the relationship between mortality rates and patient volumes in NUHC when compared to data from international centres was determined using chi-square (χ^2) testing.

RESULTS

During the period of the study, 163 patients underwent surgery for CHD. This was 5.85% of a total of 2,785 cardiac surgeries performed in NUHC during that period. On average, there was a mean annual volume of 32.6 patients undergoing surgery for CHD. There was a higher number of paediatric patients undergoing surgery, but there were also a significant number of adult patients. The mean age of the patients was 15.7 years (Table I). 46 (28.2%) patients were less than one year old, and the oldest patient was 73 years old. Women comprised 54.6% of the patients. The majority of patients were Chinese (57.1%), followed by Malay (23.3%), Indian (9.8%) and other races (9.8%). The department had a fairly equal volume of local and overseas patients. In terms of surgery status, most of the procedures (89.6%) were elective procedures, followed by emergency procedures (10.4%) (Table I).

The preoperative demographics are presented in Table II. Three-quarter of the patients were acyanotic and had LVEF of more than 60% prior to the surgery. The basic diagnoses of the patients are shown in Table III. The most common diagnosis was atrial septal defect (ASD) (n = 64, 39.3%), followed by ventricular septal defect (VSD) (n = 35, 21.5%). Of the diagnoses of ASD, five involved the primum (7.69%), 50 involved the secundum (76.9%), eight involved the patent foramen ovale (12.3%) and two involved the sinus venosus (3.08%). Of the diagnoses of VSD, 20 were perimembranous (71.4%) and eight were subarterial (28.6%). In this study, some patients also had more than one diagnosis made. The preoperative morbidity rates are presented in Table IV. Among the eight mortalities reported in the department, congestive cardiac failure

Table IV. Preoperative morbidities.

Morbidity	No.
Encephalitis	1
Cerebrovascular accident	1
Diaphragmatic hernia	2
Gut anomaly	2
Sepsis	1
Diabetes mellitus	2
Hypertension	10
Arrhythmia	6
Cardiac failure	9
Pulmonary hypertension	7
Dysmorphism	12
Chronic lung disease	10
Prematurity	9

Table VI. Postoperative morbidities (n = 26).

Morbidity	No.
Recurrent laryngeal nerve palsy	1
Chylothorax	1
Pneumothorax	1
Pneumonia	1
Acute renal failure	2
Bleeding requiring re-opening	3
Cerebrovascular accident	3
Arrhythmia	7
Pleural effusion	4
Deep wound infection	3

Table V. Main surgical procedures.

Surgical procedure	No. of patients	No. of mortalities	Cause of death
Atrial septal defect repair	64	0	
Ventricular septal defect repair	35	0	
Permanent pacemaker insertion	1	0	
Fontan	1	0	
Coronary AVF ligation	2	0	
Pulmonary vulvotomy	1	1	Cardiac failure
TAPVD repair	1	0	
Main pulmonary artery ligation	3	0	
Aortic valve repair	1	0	
Tricuspid valve repair	6	0	
Mitral valve repair	4	0	
Myxoma excision	2	0	
Cor triatrium resection	3	0	
Atrial septectomy	5	0	
Blalock-Taussig shunt	14	2	Cardiac failure
Homograft repair	8	0	
Arterial switch	1	1	Cardiac failure
RVOT plasty	8	1	Cardiac failure
Tetralogy of fallot repair	7	1	Cardiac failure
Patent ductus arteriosus ligation	25	1	Respiratory failure secondary to chronic lung disease
Coarctation repair	5	1	Disseminated intravascular coagulation
AVSD closure	4	0	

AVF: arteriovenous fistula; TAPVD: total anomalous pulmonary venous drainage; RVOT: right ventricular outflow tract; AVSD: atrioventricular septal defect

(two patients, 25%) was the most common cause of preoperative morbidity. Other preoperative morbidities included sepsis (one patient, 12.5%), prematurity (one patient, 12.5%), malrotation of the small bowel, bronchopulmonary dysplasia and pulmonary hypertension (one patient, 12.5%).

The surgical variables are documented in Table II. In terms of surgeon volume, surgeon A was involved in the majority of the surgeries (n = 99, 60.7%) followed by surgeon B (n = 22, 13.5%), surgeon C (n = 16, 9.82%) and other surgeons (n = 26, 16.0%). The majority of the surgeries lasted < 3 hours. The mean duration of surgery was 2.93 hours. During surgery, more than three-quarter of the patients required a cardiopulmonary bypass. For those who did, the mean cardiopulmonary bypass time was 81.3 minutes, while the median cross clamp time was 40 minutes. The main surgical procedures performed are listed in Table V. Repair of ASD was carried out by pericardial patch (n = 38), Dacron patch (n = 13) or direct suture (n = 13). Repair of VSD was carried out by Dacron patch (n = 32) or direct suture (n = 3). Patients diagnosed with tetralogy of fallot were managed in the theatre using either homograft replacement (n = 5) or transposition of the great arteries (n = 3).

A large proportion of patients were ventilated postoperatively in the intensive care unit (n = 143). Ventilation times ranged from < 96 hours (n = 130, 90.9%) to ≥ 96 hours (n = 13, 9.1%). Three-quarter of the patients were hospitalised for less than three weeks. The median duration of hospitalisation was one week. Major postoperative morbidities/complications were reported in 26 (16.0%) patients (Table VI). Overall, eight hospital deaths (4.91%) were reported and 155 patients were discharged (95.1%). Out of the patients discharged, 14.8% (n = 23) had significant morbidity postoperatively. Emergency procedures had

Table VII. Observed mortality rates for hospital volumes.

	No. of cases	Mean annual volume	Hospital volume	Deaths	OMR (%)	p-value
NUHC	163	32.6	Low	8	4.91	
Montefiore Moses[17]	170	42.5	Low	6	3.53	0.531
NYU Hospitals Centre[17]	326	81.5	Low	15	4.60	0.880
North Shore University Hospital[17]	41	10.3	Low	2	4.88	0.994
University Hospital UpState[17]	345	86.3	Low	18	5.22	0.883
Westchester Medical[17]	238	59.5	Low	15	6.30	0.555
Columbia Presbyterian[17]	1807	451.8	High	74	4.10	0.619
LIJ Medical Centre[17]	670	167.5	High	31	4.63	0.879
Mount Sinai Hospital[17]	550	137.5	High	23	4.18	0.690
Strong Memorial Hospital[17]	533	133.3	High	24	4.50	0.829
Italian Multicentre Study[18]	856	171.2	High	27	3.15	0.260

OMR: observed mortality rate

a higher mortality rate (17.6%) as compared to elective procedures (3.42%). The causes of the eight hospital deaths (4.91%) are documented in Table V.

Table VII presents a comparison of patients undergoing surgery for CHD in NUHC with patients undergoing these procedures in hospitals with annual CHD surgery volumes of < 100 and ≥ 100 surgeries.[17,18] The comparisons include the mean annual volume of cases, observed mortality rates (OMR) and statistical significance. The mean OMR of low patient volume centres[17] was similar to that observed in NUHC at 4.91%, whereas for high patient volume centres,[17,18] the mean OMR (4.11%) was lower than that in NUHC. As indicated, the OMR ranged from 3.15% for patients undergoing surgery in hospitals with annual volumes of ≥ 100 surgeries to 6.30% for patients undergoing surgery in hospitals with annual volumes of < 100 surgeries. However, statistical analysis of the comparison of outcomes between NUHC and the presented centres showed that the difference was not statistically significant. This confirmed the theory that an inverse relationship between patient volume and clinical outcome does not exist in the CVTS department at NUHC.

DISCUSSION

One of the primary purposes of this study was to analyse the demographics of patients attending the department for CHD surgery. A total of 163 patients were seen at the CVTS department, NUHC for CHD surgery during the five-year period between 2002 and 2006, with a mean of 32.6 cases per annum. The race distribution analysis revealed that more than half of the patients (57.0%) were Chinese, while Malays made up the next biggest proportion of patients (23.4%), followed by Indians and other races (19.6%). Foreigners made up nearly half of the patients (45.4%). These numbers are a good reflection of the hospital's growing role as an international centre that provides world-class healthcare with a simultaneous emphasis on safety and on pushing the boundaries of excellence.

Despite the fact that there was a good mix of both local and international patients, there remains a marked difference with respect to the complexity of cases between those handled in the department and in the hospitals in the New York State Report.[17] The majority of cases in our study were simple ASD and VSD repairs, with a very small number of complex congenital cases (Table III), as compared to a larger number of complex congenital cases that were managed in international centres.[17] This difference could have contributed to a bias in the results. The mean age of CHD patients in our series was 15.7 years. It is important to note that there was a large number of adult patients (42.3%) who underwent surgery in our study, with the oldest patient being 73 years of age, while the New York State Report was based mainly on a paediatric population.[17] This is an important limitation of our study, which suggests that a longer duration of study period and more intensive recruitment of paediatric patients are required in future similar studies. This study is also limited by the fact that the majority of surgeries in this department were carried out by surgeon A (n = 99, 60.7%). This raises the issue of training more cardiothoracic surgeons in the field of congenital cardiac surgery.

As mentioned earlier, there is a definite increase in the population of adults with congenitally malformed hearts. However, we are limited in terms of our medical and surgical expertise to cope with the special needs of these patients.[19] Some of the challenges that the CVTS department will face in the near future, in terms of dealing with adult congenital cardiac disease, include the inappropriate surveillance of adult patients with CHD, weak infrastructure, family planning and the

management of pregnant patients with CHD.[19,20]

Patients with adult congenital cardiac disease may not receive appropriate long-term surveillance for several reasons. These include loss to follow-up by specialists, inadequate patient education and insufficient education of the medical fraternity regarding the complexity of an adult with a congenitally malformed heart. Clinics catering to adults with CHD are highly dependent on multidisciplinary collaborations with other specialties in order to operate successfully. This may seem like an insurmountable task in Singapore. However, in Canada, the United Kingdom, the Netherlands and Switzerland, specialised clinics for adult patients with congenitally malformed hearts have now existed for a generation or more. When these countries first started such clinics, they were also faced with similar problems with their infrastructure. With the growing number of adults with CHD, there is now an ever increasing number of pregnant women with this disease. Similarly, there are limited services for helping these women through their pregnancies. Hence, as we progress and mature in our capabilities, the care of adult patients with CHD in our department should become more secure.

The statistical analysis of clinical outcomes in comparison with other international centres showed that the standards of clinical outcomes in our department are comparable to those of international centres, despite the fact that it has a smaller patient volume. The findings of this study have served to confirm that the inverse hospital volume-mortality relationship does not exist within the department. Some modifying factors that may have contributed to this better outcome are better associated services such as intensive care facilities, the ability to attract and retain skilled staff and clinical research excellence, which have maintained the hospital as a leader at the cutting edge of medical technology and expertise. At the same time, it is also important not to extrapolate beyond the available data, as further increases to case volumes in larger centres may lead to poorer outcomes, should there be a decline in the communication system within the hospital. In the CVTS department at NUHC, clinical data is readily available, and with the gradual decline in mortality rates in congenital cardiac surgery, there will be a shift in focus to the quality of surgical outcomes. Hence, future initiatives could include attempts to assess the provider quality of congenital cardiac surgery through the calculation of provider-specific risk-adjusted mortality rates. At the same time, an evaluation of other important but more complex measures of quality, such as the medical vs. surgical treatment of patients, timing and the choice of procedures, could also be performed.

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