Surgical palliation in patients with a single ventricle and dextrocardia

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Background: Dextrocardia is found in a significant proportion of patients undergoing a single-ventricle repair. Surgical outcomes in this cohort are unclear.

Methods: The records of 41 consecutive patients with single-ventricle physiology and dextrocardia presenting in a single institution from 1990 to 2008 were reviewed. Of this cohort, 19 patients had heterotaxy syndrome. Twenty-five of the 41 patients had atrioventricular valve regurgitation (AVVR) on presentation (mild, 13; moderate, 9; severe, 3).

Results: One patient died before intervention. Initial surgical palliation was performed in 31 patients. Four patients died postoperatively and 4 interim deaths occurred between initial palliation and bidirectional cavopulmonary shunt (BCPS). Thirty of the surviving 32 patients underwent BCPS, with 2 perioperative deaths. There were 4 additional deaths before Fontan surgery. Twenty-two of the surviving 25 patients underwent a Fontan procedure. There was 1 postoperative mortality. Survival to the age of 15 years was 56% (95% confidence interval [CI], 39%-70%). Patients with moderate or severe regurgitation had higher mortality if they were managed conservatively rather than by surgery (5 of 6 vs 2 of 6; $P = .24$). Patients with bilateral BCPS had better operative outcomes and survival compared with peers with unilateral anastomosis (odds ratio, 27; $P = .005$; 95% CI, 2.7-269). The side of the systemic venous pathway did not seem to influence outcomes.

Conclusions: Surgical outcomes of single-ventricle palliation seem poor in patients with dextrocardia. Aggressive management of congenital AVVR might improve the long-term prognosis. (*J Thorac Cardiovasc Surg* 2014;148:1475-80)

Dextrocardia, defined as cardiac positioning with a rightward base-apex axis, is a rare cardiac anomaly with an estimated incidence of 1 in 10,000 to 12,000 births.^{1,2} Albeit sparse in the general population, a recent review of 212 patients who underwent a univentricular repair in our institution revealed a high incidence of dextrocardia at 11.3%.¹ The prevalence of univentricular anatomy in patients with dextrocardia has been reported to be 16% to 25%.²⁻⁴ Currently, there are no reports describing the impact of dextrocardia in patients undergoing univentricular repair. After the Fontan procedure, the bulk

of the ventricular mass on the right side may cause obstruction to the systemic venous pathway draining the inferior vena cava. It is unclear whether a right-sided atrial tunnel or extracardiac conduit should be avoided in this instance.

In addition, there is a known high incidence of heterotaxia in patients with dextrocardia.⁴ The associated variations in both systemic venous and pulmonary drainage pose some operative challenges. The aim of this study was to investigate the outcomes of patients with dextrocardia undergoing single-ventricle palliation with a particular focus on the impact of the side of the routing of the systemic venous pathway.

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PATIENTS AND METHODS

The study protocol was approved by our institutional Human Research Ethics Committee. Between 1990 and 2008, 543 consecutive patients with a functionally single ventricle were admitted to the Royal Children's Hospital, Melbourne, Australia. The records of 41 patients (7.6%) diagnosed with dextrocardia were reviewed. Their most current follow-up data were gathered from the hospital database and referring cardiologists.

Dextrocardia status, along with all other visceral and vascular parameters were identified from echocardiography, and further verified against intraoperative reports to ensure accuracy. The anatomic details of the patients are described in [Tables 1 and 2](#).

Fifteen of the 41 patients (37%) had a common atrioventricular (AV) valve. A common AV valve was present more frequently in patients with heterotaxy (13 of 19, 68% vs 2 of 22, 9.1%). Twenty-five patients had AV valve regurgitation at diagnosis. AV valve regurgitation (AVVR) was

Abbreviations and Acronyms

AV	= atrioventricular
AVVR	= atrioventricular valve regurgitation
BCPS	= bidirectional cavopulmonary shunt
CI	= confidence interval
HR	= hazard ratio

more common in patients with heterotaxy (16 of 19, 84% vs 9 of 22, 41%; $P = .009$). The morphology of the regurgitant valve of these 25 patients was as follows: common AV valve (12), tricuspid (10), both mitral and tricuspid (2), and mitral (1).

Statistical Analysis

All continuous data were expressed as the median (interquartile range). Categorical data were expressed as the frequency (percentage). Proportions were evaluated with χ^2 analysis. Risk factors for mortality were examined by univariate Cox regression and overall survival of the patient population from birth was illustrated via Kaplan-Meier analysis. The small sample size precluded use of a multivariate analysis to separate the effects of different risk factors on mortality. Logistic regression was used to compare the impact of having a bilateral bidirectional cavopulmonary shunt (BCPS) rather than a unilateral one on mortality and/or postoperative complications after BCPS.

RESULTS

The list of surgical interventions is shown in [Figure 1](#). One patient with associated cerebral lesions died before surgery took place.

There were 4 in-hospital deaths after the initial neonatal surgery related to myocardial dysfunction. An additional 4 patients died in the interim period between initial palliation and subsequent BCPS procedure. Autopsy was performed in all 4 patients and the following causes of death were identified: aspiration pneumonia (1), respiratory failure (1), unknown (2).

Thirty patients underwent BCPS at a median age of 1.4 years (0.5-5.9 years). Fourteen patients had single BCPS, 10 received bilateral BCPS, and the remaining 6 patients had Kawashima procedures. The cavopulmonary shunts were placed in the left, right, and bilaterally in 7, 9, and 14 patients, respectively.

Two patients died postoperatively. Both patients had difficult postoperative courses with low output syndrome requiring extracorporeal membrane oxygenation. Five patients had the following postoperative complications: arrhythmia (4), thromboembolism (1), heart failure (1), and reoperation for take-down of the BCPS to a Blalock-Taussig shunt (1). There were 4 deaths between hospital discharge after BCPS and Fontan surgery or last follow-up, all sudden unexpected deaths.

Fontan Procedure

Of the 25 surviving patients, 22 underwent a Fontan procedure at a median age of 5.4 years (1.7-17.2 years). An

extracardiac Fontan operation was performed in 17 patients and a lateral tunnel Fontan operation was done in 5 patients. Fourteen of the Fontan conduits were fenestrated. The extracardiac conduits coursed along the left side of the heart in 11 patients and the right side in 6. Thirteen of the 17 patients who underwent an extracardiac conduit had their conduit on the ipsilateral side of an existing BCPS anastomosis. One patient died after Fontan secondary to low output syndrome. Eleven patients had pleural effusions persisting for more than 2 weeks after surgery. Postoperative recovery course was complicated in 13 patients by arrhythmia (3), bleeding (1), and reoperation for 2 patients for management of postoperative bleeding and mediastinitis.

AVVR

Twenty-five of the 41 patients (61%) had AVVR diagnosed on initial presentation: mild (13), moderate (9), and severe (3). Six of the 12 patients with moderate or severe regurgitation and 2 with mild regurgitation underwent valve repairs. The AV valve repair was performed shortly after the initial palliation surgery (2), during BCPS (4), after BCPS (1), and during Fontan (1). Two patients required further mechanical valve replacement during the same hospital stay. Later reoperation was necessary in 2 additional patients for further progression of the AVVR.

A total of 10 of the 25 patients with AVVR died. Of the remaining 15 patients, progression in severity from mild to moderate was only noted in 1 patient who was managed conservatively. Amongst the 12 patients with moderate or severe regurgitation, 4 of the 6 who were conservatively managed died and 1 of the 6 who underwent surgery died.

Late Follow-up and Survival Analysis

There were no further deaths after Fontan completion. Four patients were lost to follow-up. After a median follow-up of 11.2 years (range, 1.2-19.2 years), 20 patients were still alive. Overall survival to 15 years of age was 56% (95% confidence interval [CI], 39%-70%) ([Figure 2](#)). Survivors were in New York Heart Association class I (13), II (4), and III (3). By univariate analysis, transposition of great arteries (hazard ratio [HR], 3.4, $P = .057$; 95% CI, 0.97-11.72) and dominant right ventricle (HR, 2.6; $P = .059$; 95% CI, 0.96-7.08) were associated with poorer postoperative outcomes, but failed to achieve statistical significance ([Table 3](#)).

Side of Anastomosis and Outcomes

Analysis of the relationship between the side of anastomosis and postoperative outcomes failed to reveal a significant relationship for both BCPS and Fontan patients. Two of 9 patients (22.2%) with right BCPS anastomoses and 4 out of 7 patients (57.1%) with left BCPS anastomosis experienced either a postoperative complication or death. Four of 6 patients (66.7%) and 7 of 11 patients (63.6%) with

TABLE 1. Morphologic characteristics of the patient cohort

Characteristic	Total, n (%)	With heterotaxy, n (%)	Without heterotaxy, n (%)
Number of patients	41	19 (46.3)	22 (53.7)
Gender			
Male	24 (58.5)	13 (68.4)	11 (50.0)
Female	17 (41.5)	6 (31.6)	11 (50.0)
Dominant ventricle			
Left	10 (24.4)	2 (10.5)	8 (36.4)
Right	20 (48.8)	10 (52.6)	10 (45.5)
Biventricular	8 (19.5)	4 (21.1)	4 (18.2)
Unknown	3 (7.3)	3 (15.8)	0 (0)
Atrioventricular discordance	7 (17.1)	1 (5.3)	6 (27.3)
Common atrioventricular valve	15 (36.6)	13 (68.4)	2 (9.1)
Septal defects			
Ventricular septal defect	22 (53.7)	6 (31.6)	16 (72.7)
Complete atrioventricular septal defect	17 (41.5)	14 (73.7)	3 (13.6)
Aorta			
Right arch	20 (48.8)	9 (47.4)	11 (50.0)
Hypoplastic ascending aorta	4 (9.8)	1 (5.3)	3 (13.6)
Aortic stenosis	3 (7.3)	0 (0)	3 (13.6)
Aortic atresia	3 (7.3)	1 (5.26)	2 (9.1)
Pulmonary veins			
Anomalous pulmonary venous drainage	9 (22.0)	9 (47.4)	0 (0)
Pulmonary valve			
Pulmonary stenosis	22 (53.7)	10 (52.6)	12 (54.5)
Pulmonary atresia	11 (26.8)	8 (42.1)	3 (13.6)
Superior vena cava			
Right-sided	14 (34.1)	3 (15.8)	11 (50.0)
Left-sided	5 (12.2)	2 (10.5)	3 (13.6)
Bilateral	22 (53.7)	14 (73.7)	8 (36.4)
Inferior vena cava			
Right-sided	30 (73.2)	13 (68.4)	17 (77.3)
Middle	3 (7.3)	0 (0)	3 (13.6)
Left-sided	8 (19.5)	6 (31.6)	2 (9.1)
Interrupted	11 (26.8)	9 (47.4)	2 (9.1)
Visceral situs			
Solitus	17 (41.5)		
Inversus	5 (12.2)		
Ambiguous (heterotaxy)	19 (46.3)		
Spleen			
Single	25 (61.0)	3 (15.8)	22 (100)
Asplenia	12 (29.3)	12 (63.2)	0
Polysplenia	6 (14.6)	6 (31.6)	0
Hepatic veins			
Right-sided	29 (70.7)	12 (63.2)	17 (77.3)
Left-sided	12 (29.3)	7 (36.8)	5 (22.7)
Drain into inferior vena cava	30 (73.2)	11 (57.9)	19 (86.4)
Drain directly into atrium	11 (26.8)	8 (42.1)	3 (13.6)
Intestinal malrotation	13 (31.7)	12 (63.2)	1 (4.5)

right and left Fontan anastomoses, respectively, had postoperative complications. One-third of the patients (2 of 6) with ipsilateral Fontan anastomoses were free of complications,

TABLE 2. Dominant diagnosis of total patient cohort

Diagnoses	No. of cases (N = 41)
Double-outlet right ventricle	13
Tricuspid atresia	6
Complete atrioventricular septal defect	6
Hypoplastic left ventricle	2
Hypoplastic right ventricle	1
Transposition of great arteries	3
Pulmonary atresia	3
Pulmonary stenosis	2
Aortic atresia	1
Mitral atresia	1
Double-outlet left ventricle	1
Double-inlet right ventricle	1
Ebstein anomaly	1

whereas half of the patients with anastomoses between the contralateral inferior vena cava and pulmonary arteries (4 of 8) were complication free.

A review of the effect of the side of BCPS anastomosis on subsequent surgical outcomes was performed. Logistic regression revealed that patients receiving bilateral BCPS anastomosis had less risk of death or complications than those having a unilateral anastomosis (odds ratio = 27; $P = .005$; 95% CI, 2.7-269).

DISCUSSION

Dextrocardia, although rare in the general population, is found in a significant proportion of patients with a single ventricle.¹ Although this anatomic variant has no clinical implications on cardiac function in isolation, it is commonly accompanied by multiple cardiac and extracardiac malformations.^{1,4} Our series is marked by the striking predominance of some morphologic features. Half of our patients had heterotaxy and most of those had a common AV valve. Half had bilateral superior vena cava. Most patients had pulmonary stenosis (54%) or atresia (28%). At the time of the initial diagnosis, 60% of the patients had AVVR.

The outcomes of single-ventricle palliation seem to be worse in patients with dextrocardia compared with those with levocardia. Only 56% of the patients were still alive at the age of 15 years. Our expectation of survival at the age of 15 years for patients offered single-ventricle palliation would be 71%.¹ The fact that half of the patients had prolonged effusion after Fontan surgery confirms that dextrocardia correlates to the severity of the condition in single-ventricle physiology. Dextrocardia has not been singled out in the past as a predictor of an adverse outcome after single-ventricle palliation, likely because of the rarity of the condition. It is unclear whether the observed unfavorable outcomes were related to the main or associated cardiac conditions or to the technical difficulties linked to the

FIGURE 1. Surgical progression of the patient cohort. *BCPS*, Bidirectional cavopulmonary shunt; *BT*, Blalock-Taussig; *PA*, pulmonary artery; *PDA*, patent ductus arteriosus.

position of the heart in the right chest. It has been clearly demonstrated that heterotaxia adversely affects outcomes after single-ventricle palliation.^{5,6} Like others, we have recently shown that patients born with a single ventricle had worse outcomes if they had AVVR.⁷⁻⁹ In the current series, the incidence of heterotaxy, common AV valve, and AV regurgitation at first presentation were 46%,

36%, and 60%, respectively; in a recent study of our patients with a single ventricle, these incidences were estimated to be 12%, 14%, and 13% only.¹ There is no doubt that the difficulty of performing AV valve repair is increased by dextrocardia. Notwithstanding these difficulties, it is likely that these patients would benefit from early intervention; considerable mortality occurred in our

FIGURE 2. Kaplan-Meier survival of the patient cohort.

patients with moderate or severe regurgitation who were managed conservatively.

We tried to determine whether laying the systemic venous pathway on the right side of the chest behind the ventricular mass was associated with adverse outcomes. We similarly investigated the diverse configurations of the Fontan circuit between the inferior vena cava and the pulmonary artery. In this small number of patients, neither the side of the extracardiac conduit nor placing it on the same or the opposite side of the BCPS seemed to influence outcome. Similar findings were demonstrated by Sakurai and colleagues¹⁰ in their retrospective review of 56 patients with a malpositioned heart and apicocaval juxtaposition. It therefore seems that the surgeon should evaluate the best course of the conduit in each individual patient, and that the passage of an extracardiac conduit behind the ventricular mass should not be precluded. The location of the inferior vena cava or the hepatic veins, the size of the pulmonary

vessels, the size of the ventricular and atrial masses, and the requirement to achieve bilateral distribution of the hepatic venous flow, should all influence the decision on the type of Fontan technique used and its side.

In our analysis, the presence of bilateral BCPS was linked to improved outcomes. This finding is in contrast to previous studies showing the detrimental effect of the presence of bilateral vena cava on outcomes after cavopulmonary anastomosis.¹¹ The detrimental impact of bilateral BCPS has sometimes been attributed to the risk of developing thrombi between the 2 anastomosis in the area of the pulmonary artery where blood flow is limited. It is possible that, in patients with dextrocardia necessitating complex channeling at the time of the Fontan surgery, having bilateral BCPS confers an advantage in providing a better flow distribution to both lungs.

Because adverse outcomes in these patients with dextrocardia seem to be more related to its association with adverse morphologic features than technical considerations related to the construction of the systemic venous pathway of the Fontan circuit, it is unlikely that these outcomes will improve significantly. Families and practitioners should be aware of these grim outcomes.

This study is limited by its retrospective nature and the rarity of the condition. In addition, patients in this historical review were operated on at a later age than occurs today.

In conclusion, surgical outcomes after single-ventricle palliation seem poor in patients with dextrocardia, likely because of their frequent association with heterotaxy, a common AV valve, and AVVR. Aggressive management of the AVVR might improve the long-term prognosis.

TABLE 3. Cox regression analysis summary of mortality predictive factors

Factor	Present		Not present		P value	Cox regression	
	Total no. of patients	Died (%)	Total no. of patients	Died (%)		95(%) confidence interval	Hazard ratio
Transposition of great arteries	26	14 (54)	15	3 (20)	.057	0.97-11.72	3.36
Dominant right ventricle	20	11 (55)	21	6 (29)	.059	0.96-7.08	2.61
Situs inversus/ambiguous	24	13 (54)	17	4 (24)	.1	0.83-7.83	2.55
Heterotaxy syndrome	19	11 (58)	22	6 (27)	.12	0.81-5.94	2.19
Asplenia/polysplenia	17	10 (59)	24	7 (29)	.16	0.76-5.28	2.01
Atrioventricular discordance	7	1 (14)	34	16 (47)	.18	0.03-1.91	0.25
Noncardiac malformation	18	9 (50)	21	6 (29)	.26	0.64-5.08	1.8
Anomalous hepatic drainage	11	3 (27)	30	14 (47)	.26	0.14-1.70	0.49
Right hepatic vein	29	13 (45)	12	4 (33)	.44	0.50-4.78	1.55
Interrupted inferior vena cava	11	6 (55)	30	11 (37)	.51	0.52-3.79	1.4
Abnormal pulmonary venous drainage	9	5 (56)	32	12 (38)	.54	0.49-3.94	1.39
Congenital/secondary atrioventricular regurgitation	35	14 (40)	6	3 (50)	.55	0.20-2.39	0.69
Atrioventricular septal defect	22	9 (41)	19	8 (42)	.64	0.31-2.06	0.79
Bilateral superior vena cava	22	9 (41)	19	8 (42)	.74	0.33-2.22	0.85
Congenital atrioventricular regurgitation	25	11 (44)	16	6 (38)	.79	0.42-3.09	1.14
Common atrioventricular valve	16	7 (44)	25	10 (40)	.81	0.34-2.33	2.33
Ventricular septal defect	22	7 (32)	19	10 (53)	.2	0.20-1.39	1.39
Right aortic arch	20	8 (40)	21	9 (43)	.9	0.36-2.44	0.94

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