Congenital Heart Surgery Outcomes in Down Syndrome: Analysis of a National Clinical Database

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KEY WORDS
Down syndrome, congenital heart defects

ABBREVIATIONS
STS—Society of Thoracic Surgeons
IQR—interquartile range

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WHAT'S KNOWN ON THIS SUBJECT: Contemporary data regarding outcomes for patients with Down syndrome who undergo congenital heart disease surgery are limited.

WHAT THIS STUDY ADDS: The authors describe outcomes for a large, multicenter cohort of patients with Down syndrome who underwent congenital heart disease surgery.

abstract

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OBJECTIVE: We describe patient characteristics and postoperative morbidity and mortality rates for patients with Down syndrome undergoing congenital heart disease surgery.

METHODS: This retrospective cohort study used the Society of Thoracic Surgeons Congenital Heart Surgery Database to compare patient characteristics and postoperative outcomes for patients (0–18 years) with or without Down syndrome who underwent surgery in 2000–2008.

RESULTS: A total of 45 579 patients (4350 patients with Down syndrome and 41 229 without Down syndrome) were included (median age: 7 months [interquartile range [IQR]: 47 days to 4 years]; 56% male). Patients with Down syndrome were younger at surgery, with the exception of those undergoing tetralogy of Fallot repair or atrioventricular septal defect repair. Mortality rates for patients with or without Down syndrome did not differ significantly. Lengths of stay were prolonged for patients with Down syndrome undergoing atrial septal defect closure (median: 4 days [IQR: 3–5 days] vs 3 days [IQR: 2–4 days]; $P < .0001$), ventricular septal defect closure (median: 5 days [IQR: 4–8 days] vs 4 days [IQR: 3–6 days]; $P < .0001$), or tetralogy of Fallot repair (7 days [IQR: 5–10 days] vs 6 days [IQR: 5–9 days]; $P < .001$) and were associated with postoperative respiratory and infectious complications. Patients with Down syndrome undergoing ventricular septal defect closure had a higher rate of heart block requiring pacemaker placement (2.9% vs 0.8%; $P < .0001$).

CONCLUSION: In this large, contemporary cohort, Down syndrome did not confer a significant mortality risk for the most common operations; however, postoperative morbidity remained common. *Pediatrics* 2010; 126:315–322

Down syndrome is the most commonly occurring chromosomal abnormality, and recently reported data suggest that the prevalence in the United States has increased by nearly one-third in the past 2 decades.[1] Congenital heart disease is reported to occur in 40% to 60% of patients with Down syndrome, with complete atrioventricular septal defect being the most common defect.[2,3] Other frequently occurring lesions include atrial and ventricular septal defects and tetralogy of Fallot. Previous studies that evaluated outcomes after congenital heart disease surgery for patients with Down syndrome showed conflicting results. Some reported increased mortality rates, lengths of stay, and morbidities such as duration of ventilation and infection rates, whereas others suggested similar or improved outcomes for patients with Down syndrome who underwent atrioventricular septal defect repair.[2–5] Studies reported to date were limited by small sample size and focused primarily on patients undergoing atrioventricular septal defect repair.

The purpose of this study was to describe postoperative morbidity and mortality rates for a large, multicenter, contemporary cohort of patients with Down syndrome undergoing congenital heart disease surgery. The primary analysis focused on the most common operations performed for patients with Down syndrome. Because of the infrequency of patients with Down syndrome undergoing staged palliation for a functionally univentricular heart at any single center, we also evaluated outcomes in this subgroup of rarer cases in a secondary analysis.

METHODS

Data Source

This retrospective cohort study used the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database. As described previously, the STS Congenital Heart Surgery Database collects operative and perioperative data for all patients undergoing surgery for congenital heart anomalies at participating centers.[6] It is estimated that STS centers currently represent nearly two-thirds of all centers performing congenital heart disease surgery in the United States.[7] Data collected include demographic information, cardiac diagnoses, noncardiac and genetic abnormalities, preoperative factors, intraoperative details, surgical procedures performed, postoperative complications, and in-hospital deaths. The Duke Clinical Research Institute serves as the data warehouse and analysis center for all of the STS national databases. This study was approved by the Duke University institutional review board and by the Access and Publications Committee of the STS Workforce for National Databases.

Patient Population

To maximize data integrity, analysis was restricted to 63 STS centers with >90% complete data for all study variables. From these centers, ≤18-year-old patients who underwent congenital heart disease surgery between January 1, 2000, and June 30, 2008, were included. Only the first operation of each hospitalization was analyzed. We excluded 15 290 patients with a genetic abnormality other than Down syndrome and 867 patients with missing or invalid data on gender, weight, or type of procedure. This left a final study population of 45 579 patients from 63 centers.

Data Collection

Data collection included demographic information, Down syndrome status, preoperative risk factors (defined in the database as preoperative acidosis, shock, arrhythmia, atrioventricular block, pulmonary hypertension, mechanical ventilatory support, endocarditis, sepsis, neurologic deficit, or seizure), cardiac diagnosis, and surgical procedure performed. Operative data included duration of cardiopulmonary bypass, cross clamp, and circulatory arrest (if applicable). Outcome data included in-hospital death, total postoperative length of stay, and postoperative complications. Postoperative complications were classified as delayed sternal closure, unplanned reoperation during the hospitalization, renal failure requiring temporary or permanent dialysis, neurologic deficit (transient or permanent deficit or seizures), infection (sepsis, wound infection or dehiscence, mediastinitis, or endocarditis), pulmonary complication (phrenic or recurrent laryngeal nerve injury, pneumothorax, pleural effusion requiring drainage, mechanical ventilatory support for >7 days, reintubation, or tracheostomy), arrhythmia, atrioventricular block requiring permanent pacemaker placement, cardiac arrest, extracorporeal membrane oxygenation treatment, or pulmonary hypertension. Of note, pulmonary hypertension is defined currently in the database as pulmonary artery pressure greater than or equal to systemic arterial pressure, as estimated through echocardiography or cardiac catheterization.

Analysis

Patient characteristics and outcomes were summarized for patients with Down syndrome and patients without Down syndrome by using frequencies and proportions for categorical variables and medians and interquartile ranges (IQRs) for continuous variables. Patient weights were plotted on standard growth curves and converted to *z* scores.[8] Standard growth curves were used for both patients with Down syndrome and patients without Down syndrome, because the

goal was to facilitate comparison of weights between patients with Down syndrome and patients without Down syndrome with normalization for age at surgery, rather than comparison with the respective normative populations.

The 10 most common surgical procedures were determined for the Down syndrome and non–Down syndrome groups. Five of the most common procedures for patients with Down syndrome, including atrial septal defect closure (any type), ventricular septal defect closure (any type), complete atrioventricular septal defect repair, mitral valve repair/replacement, and tetralogy of Fallot repair (including operations involving a transannular patch, nontransannular patch, or right ventricle-to-pulmonary artery conduit), were then evaluated further. For these procedures, patient characteristics, operative data, and outcomes, including in-hospital mortality rates and postoperative lengths of stay, were compared for patients with Down syndrome and patients without Down syndrome by using the Pearson χ^2 test for categorical variables and the Wilcoxon rank-sum test for continuous variables. Postoperative complications (as noted above) were evaluated similarly. Finally, in-hospital mortality rates and postoperative lengths of stay were evaluated for the subgroup of patients with Down syndrome with a functionally univentricular heart who underwent staged palliation, including stage 1 palliation (Norwood operation or Damus-Kaye-Stansel operation), cavopulmonary anastamosis (bidirectional Glenn or hemi-Fontan operation), and Fontan completion (lateral tunnel or extracardiac tunnel).

Missing data were rare (<0.5% for all variables). Patients with missing data were excluded from analyses involving the missing variable. *P* values were reported without adjustment for multiple comparisons. In light of the number of end points evaluated, a highly stringent criterion ($P < .001$) was used for interpretation of statistical significance.

TABLE 1 Patient Characteristics

	With Down Syndrome ($N = 4350$)	Without Down Syndrome ($N = 41\,229$)
Male, *n* (%)	2013 (46.3)	23 297 (56.5)
Age at surgery, median (IQR), mo	5.2 (3.4–10.7)	8 (1.1–51.6)
Length, median (IQR), cm	61 (56–69)	68 (53–102)
Weight, median (IQR), kg	5.3 (4.3–7.6)	7.3 (3.8–16.3)
Weight *z* score, median (IQR)	−2.1 (−2.9 to −1.2)	−0.9 (−1.9 to 0.1)

RESULTS

Preoperative and Operative Characteristics

A total of 45 579 patients were evaluated, including 4350 patients with Down syndrome and 41 229 patients without Down syndrome. Patient characteristics are presented in Table 1. The Down syndrome group included fewer male patients and was younger at the time of surgery. As expected, patients with Down syndrome also weighed less at the time of surgery, even after normalization for age. The 10 most common procedures performed for patients with Down syndrome and patients without Down syndrome are presented in Table 2. Complete atrioventricular septal defect repair was the most common procedure (33%) performed for patients with Down syndrome, whereas ventricular septal defect repair was the most common procedure (8%) performed for patients without Down syndrome.

Five of the most common procedures performed for patients with Down syndrome (atrial septal defect closure, ventricular septal defect closure, complete atrioventricular septal defect repair, mitral valve repair/replacement, and tetralogy of Fallot repair) were investigated further (Table 3). Patients with Down syndrome were younger at the time of surgery, with the exception of those undergoing tetralogy of Fallot repair or complete atrioventricular septal defect repair, who were similar in age to patients without Down syndrome. Weight *z* scores at the time of surgery were lower for patients with Down syndrome, compared with patients without Down syndrome, for all procedures.

TABLE 2 Most Common Surgical Procedures

Procedure	*n* (%)
Patients with Down syndrome	
Complete AVSD repair	1430 (33)
VSD closure	832 (19)
Mitral valve repair/replacement	320 (7)
Partial AVSD repair	273 (6)
PDA ligation	184 (4)
Tetralogy of Fallot repair	178 (4)
ASD closure	178 (4)
Coarctation/arch repair	103 (2)
Tricuspid valve repair/replacement	80 (2)
Tetralogy of Fallot-AVSD repair	62 (1)
Patients without Down syndrome	
VSD closure	3416 (8)
ASD closure	2773 (7)
Coarctation/arch repair	2636 (6)
PDA ligation	2548 (6)
Tetralogy of Fallot repair	2274 (6)
Cavopulmonary anastamosis	2194 (5)
Fontan operation	1952 (5)
Norwood procedure	1615 (4)
Systemic-pulmonary shunt	1461 (4)
Arterial switch operation	1240 (3)

ASD indicates atrial septal defect; VSD, ventricular septal defect; AVSD, atrioventricular septal defect; PDA, patent ductus arteriosus.

Patients with Down syndrome, compared with patients without Down syndrome, who were undergoing atrial septal defect closure (21% vs 7%; $P < .0001$) or ventricular septal defect closure (22% vs 12%; $P < .0001$) were more likely to have preoperative risk factors. There was no difference in the frequency of preoperative risk factors among patients with Down syndrome

TABLE 3 Patient Preoperative Characteristics for Selected Procedures

Procedure	With Down Syndrome	Without Down Syndrome	*P*
ASD closure			
Male, *n* (%)	76 (43)	1180 (43)	.9
Age at surgery, median (IQR), mo	14.4 (6.6–36.0)	49.2 (26.4–91.2)	<.0001
Length, median (IQR), cm	73 (63–86)	102 (87–125)	<.0001
Weight, median (IQR), kg	8.5 (6.0–12.2)	16.0 (11.8–24.9)	<.0001
Weight *z* score, median (IQR)	−1.9 (−2.7 to −1.1)	−0.4 (−1.3 to 0.5)	<.0001
Preoperative risk factor, *n* (%)	38 (21)	199 (7)	<.0001
VSD closure			
Male, *n* (%)	392 (47)	1730 (51)	.07
Age at surgery, median (IQR), mo	4.8 (3.2–7.1)	7.4 (3.8–25.2)	<.0001
Length, median (IQR), cm	60 (56–65)	67 (59–87)	<.0001
Weight, median (IQR), kg	5.1 (4.2–6.1)	6.6 (4.8–11.6)	<.0001
Weight *z* score, median (IQR)	−2.4 (−3.2 to −1.6)	−1.6 (−2.5 to −0.5)	<.0001
Preoperative risk factor, *n* (%)	179 (22)	419 (12)	<.0001
Complete AVSD repair			
Male, *n* (%)	621 (43)	158 (44)	.9
Age at surgery, median (IQR), mo	4.4 (3.4–5.8)	4.6 (3.1–8.5)	.01
Length, median (IQR), cm	59 (56–62)	61 (56–67)	<.0001
Weight, median (IQR), kg	4.9 (4.3–5.6)	5.1 (4.2–6.8)	.0004
Weight *z* score, median (IQR)	−2.4 (−3.1 to −1.7)	−2.1 (−2.8 to −1.4)	<.0001
Preoperative risk factor, *n* (%)	256 (18)	61 (17)	.7
Mitral valve repair/replacement			
Male, *n* (%)	141 (44)	466 (48)	.2
Age at surgery, median (IQR), mo	32.4 (8.1–74.4)	55.2 (16.8–126.0)	<.0001
Length, median (IQR), cm	82 (64–104)	105 (76–138)	<.0001
Weight, median (IQR), kg	11.6 (6.2–17.9)	16.8 (9.2–32)	<.0001
Weight *z* score, median (IQR)	−1.9 (−2.7 to −0.7)	−0.8 (−2.0 to 0.2)	<.0001
Preoperative risk factor, *n* (%)	63 (20)	195 (20)	0.8
Tetralogy of Fallot repair			
Male, *n* (%)	109 (61)	1288 (59)	.5
Age at surgery, median (IQR), mo	5.5 (3.6–7.5)	5.2 (3.2–8.2)	.01
Length, median (IQR), cm	62 (58–66)	63 (58–69)	.01
Weight, median (IQR), kg	6.1 (4.9–7.1)	6.4 (5.3–7.9)	.002
Weight *z* score, median (IQR)	−1.7 (−2.6 to −0.9)	−0.9 (−1.9 to −0.1)	<.0001
Preoperative risk factor, *n* (%)	27 (15)	274 (12)	.3

ASD indicates atrial septal defect; VSD, ventricular septal defect; AVSD, atrioventricular septal defect.

who were undergoing other procedures. For patients with atrial septal defects, there were significant differences between patients with Down syndrome and patients without Down syndrome with respect to preoperative pulmonary hypertension rates (6.2% vs 0.2%; $P < .0001$) and preoperative neurologic deficit or seizure rates (2.8% vs 0.9%; $P = .01$ for trend). No significant difference in preoperative infection rates (sepsis or endocarditis, 0% vs 0.1%; $P = .7$) or preoperative mechanical ventilation rates (2.3% vs 1.4%; $P = .4$) was found. For patients with ventricular septal defects, significant differences in preoperative pulmonary hypertension rates (8.4% vs 2.0%; $P < .0001$) and preoperative neurologic deficit or seizure rates (1.3% vs 0.5%; $P = .008$ for trend) were found. No difference in preoperative infection rates (0.4% vs 0.6%; $P = .4$) or preoperative mechanical ventilation rates (1.9% vs 1.8%; $P = .8$) was seen. Of note, there was no significant difference in preoperative pulmonary hypertension rates among patients undergoing atrioventricular septal defect repair (4.1% vs 4.7%; $P = .6$).

Operative data are presented in Table 4. Patients with Down syndrome who were undergoing ventricular septal defect closure had longer duration of cardiopulmonary bypass, compared with patients without Down syndrome. No statistically significant difference in the duration of cardiopulmonary bypass was seen for the other procedures evaluated.

Outcomes

Outcome data for patients who underwent the most common types of surgery performed for patients with Down syndrome are presented in Table 5. No statistically significant differences in in-hospital mortality rates were seen for patients with Down syndrome, compared with patients without Down

TABLE 4 Operative Characteristics

Procedure	Duration, Median (IQR), min		*P*
	With Down Syndrome	Without Down Syndrome	
ASD closure			
CPB	42 (30–59)	45 (34–63)	.03
Cross-clamp	19 (12–29)	22 (14–32)	.007
VSD closure			
CPB	77 (60–95)	72 (55–92)	<.0001
Cross-clamp	46 (35–59)	41 (30–56)	<.0001
Complete AVSD repair			
CPB	122 (98–156)	123 (98–152)	.9
Cross-clamp	88 (68–113)	86 (63–111)	.06
Mitral valve repair/replacement			
CPB	94 (70–133)	105 (73–139)	.02
Cross-clamp	57 (41–84)	63 (43–90)	.03
Tetralogy of Fallot repair			
CPB	109 (89–135)	108 (84–138)	.5
Cross-clamp	66 (50–86)	65 (48–84)	.2

ASD indicates atrial septal defect; VSD, ventricular septal defect; AVSD, atrioventricular septal defect; CPB, cardiopulmonary bypass.

TABLE 5 Postoperative Outcomes

Procedure	With Down Syndrome	Without Down Syndrome	*P*
ASD closure			
Length of stay, median (IQR), d	4 (3–5)	3 (2–4)	<.0001
In-hospital death, *n* (%)	1 (0.6)	3 (0.1)	.1
VSD closure			
Length of stay, median (IQR), d	5 (4–8)	4 (3–6)	<.0001
In-hospital death, *n* (%)	5 (0.6)	17 (0.5)	.7
Complete AVSD repair			
Length of stay, median (IQR), d	7 (5–11)	7 (5–14)	.9
In-hospital death, *n* (%)	27 (1.9)	14 (3.9)	.02
Mitral valve repair/replacement			
Length of stay, median (IQR), d	5 (4–8)	5 (4–8)	.6
In-hospital death, *n* (%)	1 (0.3)	19 (2.0)	.04
Tetralogy of Fallot repair			
Length of stay, median (IQR), d	7 (5–10)	6 (5–9)	.0004
In-hospital death, *n* (%)	4 (2.3)	14 (0.6)	.02

ASD indicates atrial septal defect; VSD, ventricular septal defect; AVSD, atrioventricular septal defect.

syndrome. There were trends toward increased mortality rates for patients with Down syndrome undergoing tetralogy of Fallot repair and decreased mortality rates for patients with Down syndrome undergoing complete atrioventricular septal defect repair or mitral valve repair/replacement, which did not reach statistical significance. Postoperative lengths of stay were similar for patients undergoing complete atrioventricular septal defect repair and mitral valve repair/replacement. Patients with Down syndrome undergoing atrial septal defect closure, ventricular septal defect closure, or tetralogy of Fallot repair had significantly prolonged lengths of stay, compared with patients without Down syndrome.

Evaluation of the groups with longer lengths of stay demonstrated similar postoperative complications across groups. Compared with patients without Down syndrome, larger proportions of patients with Down syndrome undergoing ventricular septal defect closure experienced postoperative infections (3.4% vs 1.1%; $P < .0001$), respiratory complications (11.3% vs 5.2%; $P < .0001$), and pulmonary hypertension (2.2% vs 0.7%; $P = .0001$). In addition, a larger proportion of patients with Down syndrome undergoing ventricular septal defect closure had atrioventricular block requiring permanent pacemaker placement (2.9% vs 0.8%; $P < .0001$). These complications were also seen for patients with Down syndrome undergoing atrial septal defect closure (with the exception of pacemaker placement), including postoperative infections (1.7% vs 0.5%; $P = .04$ for trend), respiratory complications (5.1% vs 1.9%; $P = .005$ for trend), and pulmonary hypertension (1.7% vs 0.2%; $P = .0002$). Finally, a larger proportion of patients with Down syndrome undergoing tetralogy of Fallot repair had respiratory complications (18.0% vs 11.5%; $P = .009$ for trend), but there was no significant difference in pulmonary hypertension or postoperative infection rates. No significant difference in these complication rates was found for patients with Down syndrome without prolonged lengths of stay, with the exception of a trend toward a greater respiratory complication rate for patients with Down syndrome undergoing mitral valve repair/replacement (12.5% vs 6.8%; $P = .001$). Finally, the complication of postoperative chylothorax requiring medical or surgical intervention was evaluated. With the exception of patients undergoing atrial septal defect repair, greater proportions of patients with Down syndrome, compared with patients without Down syndrome, had postoperative chylothorax (ventricular septal defect repair, 3.6% vs 0.6%; $P < .0001$; complete atrioventricular septal defect repair, 6.2% vs 1.7%; $P = .0006$; tetralogy of Fallot repair, 11.8% vs 2.8%; $P < .001$; mitral valve repair/replacement, 3.1% vs 0.6%; $P = .0005$).

Outcomes also were evaluated for the subgroup of patients with Down syndrome with a functionally univentricular heart undergoing staged palliation (stage 1 palliation, $n = 11$; cavopulmonary anastamosis, $n = 32$; Fontan operation, $n = 17$). Patients with Down syndrome undergoing these operations had greater in-hospital mortality rates, compared with patients without Down syndrome (stage 1 palliation, 72.7% vs 19.4%; $P < .0001$; cavopulmonary anastamosis, 18.8% vs 1.8%; $P < .0001$; Fontan operation, 23.5% vs 1.6%; $P < .0001$). The median lengths of stay for patients with Down syndrome, compared with patients without Down syndrome, were as follows: stage 1 palliation, 27 days (IQR: 1–32 days) vs 21 days (IQR: 12–36 days; $P = .6$); cavopulmonary anastamosis, 10 days (IQR: 6–22 days) vs 6 days (IQR: 4–9 days; $P = .0002$); Fontan operation, 9 days (IQR: 8–18 days) vs 9 days (IQR: 7–14 days; $P = .3$).

DISCUSSION

This study is the largest to date evaluating outcomes for patients with Down syndrome undergoing congenital heart disease surgery. Down syndrome did not confer a significant mortality risk for the most common operations performed in this population. However, patients undergoing atrial septal defect repair, ventricular septal defect repair, and tetralogy of Fallot repair had prolonged lengths of stay and higher rates of postoperative complications.

The approach to the care of patients with Down syndrome with congenital heart diseases has changed over time. In the past, surgical repair of cardiac defects often was not considered, because of the long-term natural history and reduced life expectancy and because of reports that suggested higher perioperative morbidity and mortality rates. Increased postoperative infection rates, prolonged ventilation, and longer lengths of stay were reported for patients with Down syndrome.[9] Increased mortality rates also were reported.[10]

In the past 3 decades, however, life expectancy and treatment for noncardiovascular morbidities in patients with Down syndrome, such as respiratory and neurodegenerative complications, have improved.[10] During this time, outcomes for patients undergoing congenital heart disease surgery also have improved, because of refinements in surgical techniques and improvements in perioperative care.[11] Surgical repair of congenital heart defects in patients with Down syndrome is now performed routinely. The distribution of cardiac surgical procedures performed for children with Down syndrome that was found in our study is similar to that reported by others, with complete atrioventricular septal defect repair and ventricular septal defect repair being the most common procedures.[9]

In evaluation of patient characteristics, we found that children with Down syndrome were younger at the time of surgery for all procedures evaluated except complete atrioventricular septal defect repair and tetralogy of Fallot repair. As expected, even after normalization with respect to age, weight at the time of surgery was lower for patients with Down syndrome for all procedures. This is likely related to both the decreased growth velocity and the problems with poor feeding known to affect patients with Down syndrome.[12–14] The decision to perform surgical repair earlier for patients with Down syndrome may be related to the upper airway and feeding/growth issues associated with Down syndrome, in addition to poor growth and respiratory symptoms associated with congestive heart failure. Alternatively, concern regarding the development of early pulmonary vascular disease in patients with Down syndrome with cardiac defects involving significant left-to-right shunts may play a role in earlier surgical intervention.[14] Irreversible pulmonary vascular occlusive disease was reported for patients with Down syndrome, <6 months of age, with complete atrioventricular septal defects.[15] Interestingly, we found that larger proportions of patients with Down syndrome undergoing atrial septal defect repair or ventricular septal defect repair were reported to have preoperative pulmonary hypertension but there was no difference in rates for patients undergoing atrioventricular septal defect repair.

Our findings regarding postoperative mortality rates in this large, multiinstitutional cohort support the results of single-institution studies that demonstrated similar or improved survival rates for patients with Down syndrome. A recent retrospective study by Simsic et al[16] noted no increase in hospital mortality rates for neonates with genetic abnormalities who were undergoing congenital heart disease surgery. Formigari et al[3] reported that patients with Down syndrome undergoing repair of complete atrioventricular septal defects had decreased mortality rates, in comparison with patients with a normal karyotype. It was speculated that the improved survival rates might be attributable to more-favorable cardiac anatomic features, with lower rates of left-sided atrioventricular valve abnormalities and left-sided obstructive lesions.[17–20] However, we did find a trend toward increased mortality rates for patients with Down syndrome undergoing tetralogy of Fallot repair. Although we did not find any difference in the proportions of patients with preoperative risk factors, compared with patients without Down syndrome, we did find that a larger proportion of patients with Down syndrome undergoing tetralogy of Fallot repair had postoperative respiratory complications. Whether this was related to the trend toward increased mortality rates is unclear. To our knowledge, no previous studies have evaluated contemporary outcomes for patients with Down syndrome undergoing isolated tetralogy of Fallot repair.

In our secondary analysis of data for the subgroup of patients with Down syndrome with a functionally univentricular heart undergoing staged palliation, we found significantly increased in-hospital mortality rates at all 3 stages. The small sample size, even in this multiinstitutional cohort, precluded detailed analysis of data for this population. It is known that factors such as pulmonary hypertension, which we and others have shown to be present in patients with Down syndrome, can be associated with a significant mortality risk in the single-ventricle population.[21]

In addition, we found that patients with Down syndrome undergoing atrial septal defect repair, ventricular septal defect repair, or tetralogy of Fallot repair had longer lengths of hospital stay, compared with patients without Down syndrome. These findings may be attributable to larger proportions of patients with Down syndrome with preoperative risk factors and postoperative complications in these groups. Postoperative complications consisted of respiratory and infectious complications and pulmonary hyper-

tension, similar to results of previous studies. Malec et al[9] reported higher rates of postoperative complications, including respiratory infections and sepsis, for patients with Down syndrome undergoing congenital heart disease surgery, which led to prolonged ventilation and longer ICU lengths of stay. Respiratory complications and infections are known to play significant roles in morbidity and death for patients with Down syndrome in general.[22] Chronic upper airway obstruction, increased secretions, and gastroesophageal reflux leading to chronic aspiration all may occur in patients with Down syndrome. Patients with Down syndrome also may be predisposed to frequent infections as a result of abnormalities in T lymphocyte maturation and function.[23] In addition, we found that larger proportions of patients with Down syndrome (with the exception of those undergoing atrial septal defect repair) had postoperative chylothorax. Abnormalities of the lymphatic system and congenital pulmonary lymphangiectasis have been reported for patients with Down syndrome and may play a role.[24]

Finally, we found that a larger proportion of patients with Down syndrome undergoing ventricular septal defect repair had postoperative complete heart block requiring permanent pacemaker placement. This finding also was reported by Tucker et al,[25] in an analysis of data in the Pediatric Cardiac Care Consortium database for 4432 patients who underwent surgical repair of a perimembranous ventricular septal defect. The presence of Down syndrome was the strongest predictor of postoperative atrioventricular block requiring pacemaker placement, independent of patient age or weight at surgery. The reason for this finding remains unclear. Although anomalies in the conduction system in patients with atrioventricular septal defects have been reported, abnormalities in the conduction system in patients with ventricular septal defects have not been described.[26]

The limitations of this study are related to the observational and voluntary nature of the database. In our description of patient characteristics and outcomes, we were limited by the variables collected in the STS Congenital Heart Surgery Database. There may be other factors that affect patient preoperative status or postoperative outcomes. Our analysis also may be limited by the definitions currently used in the database. For example, the definition of pulmonary hypertension currently requires systemic or suprasystemic right heart pressures. This might have resulted in smaller proportions of patients in our study being identified as having preoperative or postoperative pulmonary hypertension, in comparison with other studies.[14] We were unable to evaluate whether patients with pulmonary hypertension were treated with pulmonary vasodilator medications, because this information is currently not collected in the database. Finally, we were unable to evaluate long-term outcomes (such as atrioventricular valve surgery after complete atrioventricular septal defect repair), because these data are currently not collected. Plans to expand data collection to include long-term morbidity and mortality information would allow these types of analyses to be performed in the future.

CONCLUSIONS

In this contemporary, multiinstitutional cohort, patients with Down syndrome undergoing congenital heart disease surgery did not have a significant mortality risk, in comparison with patients without Down syndrome, for the most common congenital heart disease operations performed in this population. The subgroup of patients with Down syndrome with a functionally univentricular heart undergoing staged palliation did have significantly increased in-hospital mortality rates, compared with patients without Down syndrome. Patients undergoing atrial septal defect repair, ventricular septal defect repair, or tetralogy of Fallot repair appear to have prolonged lengths of stay, as well as more postoperative complications, including infections, respiratory complications, and pulmonary hypertension. A greater proportion of patients with Down syndrome undergoing ventricular septal defect repair also developed complete heart block requiring pacemaker placement. Anticipation and early implementation of prevention and treatment measures may help to reduce these postoperative morbidities in patients with Down syndrome undergoing congenital heart disease surgery.

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