

## Economic and Safety Implications of Introducing Fast Tracking in Congenital Heart Surgery

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**Background**—The feasibility of fast-tracking children undergoing congenital heart disease surgery has not been assessed adequately. Current knowledge is based on limited single-center experiences without contemporaneous control groups.

**Methods and Results**—We compared administrative data for atrial septal defect (ASD) and ventricular septal defect (VSD) surgeries in children 2 months to 19 years of age at the Mount Sinai Medical Center (MSMC) with data from comparable patients at 40 centers contributing to the Pediatric Health Information System. Three-year blocks, early in and after fast tracking had been implemented at the MSMC, were examined. Seventy-seven and 89 children at MSMC undergoing ASD and VSD closure, respectively, were compared with 3103 ASD and 4180 VSD patients nationally. With fast tracking fully implemented, median length of stay at the MSMC decreased by 1 day compared with the earlier era (length of stay, 1 and 3 days for ASD and VSD, respectively). Nationally, median length of stay remained unchanged (3 days for ASD and 4 days for VSD) in the observed time periods. Hospitalization costs fell by 33% and 35% at MSMC (ASD and VSD, respectively), whereas they rose by 16% to 17% nationally. When analyzed in multiple regression models, the decrease in both length of stay and cost remained significantly greater at MSMC compared with nationally ( $P < 0.0001$  for all). Hospital mortality and 2-week readmission rates were unchanged at MSMC between the 2 time periods and were not different from the national rates.

**Conclusion**—Shorter length of stay and cost savings compared with national data were observed after implementation of fast tracking. (*Circ Cardiovasc Qual Outcomes*. 2013;6:201-207.)

**Key Words:** cardiac anesthesia ■ mechanical ventilator ■ pediatric cardiac surgery ■ pediatric and congenital heart disease ■ pediatric intensive care unit

Fast tracking in cardiac surgery refers to early extubation, patient mobilization, and hospital discharge with the goal of reducing costs and perioperative morbidity.<sup>1</sup> Fast tracking was first introduced in adult cardiac surgery as a response to growing economic pressure after diagnosis-related groups were introduced into Medicare reimbursement in the United States in the early 1980s. Limiting costs through a more efficient use of medical resources while maintaining quality of care has become an essential concept for all health care institutions.

There are sufficient data demonstrating that fast tracking decreases costs without increasing complications for adult cardiac surgical patients,<sup>2</sup> leading to its almost universal adoption. In contrast, potential benefits of fast tracking in children undergoing surgery for congenital heart disease (CHD) remain largely unproven. Evidence to prove feasibility, safety, and costs associated with fast tracking in CHD surgery is mostly limited to single-center experiences.<sup>3-6</sup> No study to date has compared a cohort of infants and children undergoing surgery

for CHD using an integrated fast-tracking strategy with a contemporaneous control cohort.

In this article, we report our study comparing children undergoing repair of isolated atrial septal defects (ASDs) or ventricular septal defects (VSDs) at our hospital in 2 different time periods, during the early phase and after full implementation of a fast-tracking strategy, with cohorts of patients undergoing the same types of surgery at 40 centers throughout the United States during the same years. Our hypothesis was that surgical fast tracking for these 2 CHD surgical procedures is associated with reductions in length of stay (LOS) and costs without adverse effects on hospital mortality or readmission rates.

### Methods

#### Patient Selection

After obtaining institutional review board approval, we conducted a retrospective study of pediatric patients undergoing surgery for CHD at the Mount Sinai Medical Center (MSMC), New York, NY, from 2001 to

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### WHAT IS KNOWN

- Prior studies have found that fast-tracking in adult cardiac surgery reduces costs without increasing complication rates.
- The potential benefits of fast-tracking for children undergoing surgery for congenital heart disease are largely unproven and controversial.

### WHAT THE STUDY ADDS

- This is the first study comparing length of stay and costs at an institution with fast-tracking for congenital heart surgery with a contemporaneous nation-wide cohort.
- Implementing fast-tracking was associated with shorter hospital length of stay and lower costs for atrial and ventricular septal defect repairs in children.
- Fast-tracking for atrial and ventricular septal defect repairs was not associated with changes in hospital readmission rates or mortality.

2003 (T1) and 2007 to 2009 (T2), before and after full implementation of fast tracking, respectively. The earlier time period was dictated by the availability of control data (vide infra). Patients included were between 2 months and 19 years of age when they had surgery for isolated ASD or VSD (with or without ASD). The Enhanced Automated Graphical Logistics Environment database of the MSMC was queried for patient records containing *International Classification of Diseases*, ninth revision (ICD-9), codes for those lesions in T1 and T2. We excluded patients with diagnostic and procedural ICD-9 codes indicating more complex CHD surgery (eg, ASD closure as part of a more complex surgery) and hospital admission >1 day before the procedure date. Patients <2 months of age were excluded from the analyses because fast tracking was not applied to this age group through most of the early implementation phase. Patients who were admitted >1 day before surgery were excluded because this implied additional diagnoses such as acute exacerbation of congestive heart failure. Overall, only patients with simple ASD and VSD lesions were included in the analyses.

### Data Collection

For subjects identified in the Enhanced Automated Graphical Logistics Environment database, the following data were collected: age, sex, ZIP code, date of admission, date of hospital discharge, ICD-9 admission code, ICD-9 diagnostic codes, ICD-9 procedure codes, date of surgery, all procedure codes, and total hospital costs. In addition, Enhanced Automated Graphical Logistics Environment was queried for readmission within 14 days of hospital discharge as well as for in-hospital mortalities.

For our contemporaneous control groups, the Pediatric Health Information System (PHIS) database was searched using the same ICD-9 diagnostic codes for ASD and VSD and the same exclusion criteria that were used to identify patients at the MSMC. This administrative database was developed by the Child Health Corporation of America (Shawnee Mission, KS) and warehouses longitudinal, inpatient, emergency department, ambulatory surgery, and observational hospital discharge data from 40 not-for-profit, tertiary care pediatric hospitals in the United States. The PHIS database allows cross-hospital comparisons for the purpose of improving quality of care for children.<sup>7</sup> MSMC does not contribute data to PHIS.

To determine the economic impact of fast tracking, we determined the total hospital costs associated with hospitalization for ASD and VSD repair from Enhanced Automated Graphical Logistics Environment and from the PHIS database for all available cases. Because data were obtained from different years and diverse geographical areas, we adjusted for inflation using the consumer price index from the US Bureau for Labor Statistics and regional cost-of-living differences using the Center for Medicare and Medicaid Services wage index.

### Fast-Track Patient Management

Fast tracking at the MSMC included the following components, which were implemented during a period of several years: (1) day of admission surgery, (2) anesthetic management aiming for early endotracheal extubation either in the operating room or within a few hours after admission to the intensive care unit (ICU), (3) early mobilization, and (4) early ICU and hospital discharge. An inhalation-based anesthesia technique, supplemented with neuraxial opioid administration, was applied to all patients unless contraindications for such a technique applied (eg, systemic anticoagulation). Surgery, including the use of cardiopulmonary bypass, was performed using established surgical techniques and cardiopulmonary bypass protocols. Surgical access included midline sternotomy or a midaxillary approach.<sup>8</sup> The goal of the fast-track technique was to remove the endotracheal tube in the operating room at the end of surgery. Patients were discharged from the hospital using established criteria, including full mobilization, adequate pain control, removal of all invasive lines, and tolerance of a full diet.

### Statistical Methods

Separate analyses were performed for isolated ASD and VSD ( $\pm$ ASD) cases. For each diagnosis and each time period, MSMC and PHIS data are described by number (percent), medians, interquartiles, and ranges. For the purpose of this study, we refer to centers as the individual hospitals and site as MSMC versus PHIS. Data on length of hospital stay (LOS) were treated as count data and were analyzed with the generalized linear models with log link for Poisson regression. The cost data were treated as continuous data and were log transformed to resemble a normal distribution. Both models used a compound symmetry variance-covariance matrix to account for cluster data within centers (ie, assumed patients were equally correlated within a center) and were implemented with the SAS GENMOD and MIXED procedures. Factors considered included site, time period, and a term representing the interaction of site and time effects. This interaction term addresses the question of whether the change in LOS (or cost) from T1 to T2 at MSMC differed significantly from the corresponding change in the PHIS centers and is the focus of these analyses. For LOS analyses, the models further included sex and whether patients were <1 year old. Estimates for the effects of each factor were obtained by exponentiating the estimated coefficients from the Poisson model. For continuous factors, this represents the relative increase in LOS for each unit increase in the factor. For binary factors, it is the relative increase when the factor is present. Analyses were implemented with SAS version 9.2 and SPSS version 19.

### Results

Overall, 77 ASD patients (T1,  $n=41$ ; T2,  $n=36$ ) and 89 patients with VSD (T1,  $n=37$ ; T2,  $n=52$ ) who had undergone surgery at MSMC were identified and compared with 3103 ASD patients (T1,  $n=1685$ ; T2,  $n=1418$ ) and 4180 children with a VSD (T1,  $n=2106$ ; T2,  $n=2074$ ) from the PHIS database (Tables 1 and 2). Thirty-five PHIS centers contributed information for T1, and 40 centers contributed data for T2. The number of cases performed in the respective time periods at the PHIS centers varied (ASD: T1, 14–171; T2, 6–128; VSD: T1, 6–150; T2, 3–110). Details on the analyses are presented for each lesion separately.

### Atrial Septal Defects

#### Demographics

At the MSMC, patients in the later time period were significantly younger (median age, 3.1 years; interquartile range [IQR], 1.5–7.1 years) compared with the early MSMC era (median age, 6.3 years; IQR, 3.3–13.3 years;  $P=0.02$ ) and younger compared with the PHIS patients (median age, 4.2 years; IQR, 2.3–7.2 years;  $P=0.02$ ). Age at surgery for the PHIS patients did not change significantly between T1 (median age, 4.3 years; IQR, 2.3–8.0 years) and T2. Among all cohorts, there was a predominance of

**Table 1. ASD Patients' Demographics and Comparative Details for MSMC and PHIS Centers**

	MSMC T1	PHIS T1	<i>P</i> *	MSMC T2	PHIS T2	<i>P</i> *
Patients, n	41	1685 (41 [6–150])†		36	1418 (31.5 [1–110])†	
Centers, n	...	35		...	40	
Age, median (range)[IQR], y	6.3 (0.9–18.7) [3.3–13.3]	4.3 (0.1–18.7) [2.3–8.0]	0.021	3.1 (0.5–17.9) [1.5–7.1]	4.2 (0.1–18.9) [2.3–7.2]	0.256
Male sex, n (%)	19 (46)	662 (39)	0.358	12 (33)	572 (40)	0.429
Chromosomal defects, n (%)	2 (4.9)	109 (6.5)	0.889	2 (5.6)	96 (6.8)	0.992
Failure to thrive, n (%)	0	54 (3.2)	0.481	3 (8.3)	86 (6.1)	0.412
Respiratory disease, n (%)	0	1 (0.1)	0.116	0	7 (0.5)	0.525

ASD indicates atrial septal defect; IQR, interquartile range; MSMC, Mount Sinai Medical Center; PHIS, Pediatric Health Information System database; T1, early time period (2001–2003); and T2, late time period (2007–2009).

\**P* values were obtained either from Wilcoxon rank-sum test or from logistic regression (with Firth option for 0 cell count).

†Total number of patients and (median [range]) of patients at PHIS centers.

female over male patients (60:40), but there were no significant sex distribution differences between MSMC and PHIS or between time periods at either site. Details on other demographic data, for which there were no significant differences between the MSMC and PHIS ASD cohorts, can be found in Table 1.

### Length of Stay

In the earlier time period, the median LOS for an ASD procedure at the MSMC was 2 days compared with 3 days for the PHIS centers ( $P<0.0001$ ). Among the PHIS centers, there were 7 centers with a median LOS of 2 days, 21 with a median LOS of 3 days, and 7 with an LOS of 4 to 5.5 days.

After full implementation of fast tracking at the MSMC, LOS decreased significantly to a median of 1 day (MSMC T1 versus T2:  $P<0.0001$ ), which was also significantly shorter compared with the PHIS centers, where the median LOS at T2 remained at 3 days ( $P<0.0001$ ; Table 3). Furthermore, the median LOS for an ASD repair at the MSMC was shorter than any of the reported median LOSs from the PHIS centers (PHIS T2: 4 PHIS centers with a median LOS of 2 days, 25 with a median LOS of 3 days, and 11 with an LOS from 3.5–7 days). The decrease in LOS at MSMC was not attributable to changes in admission practices because all patients in both eras were admitted on the day of their procedure.

Multiple Poisson regression analysis was performed to test whether the observed change in LOS at the MSMC, which was seen after the implementation of fast tracking, differed significantly from the change in LOS during the same time period in PHIS with other factors accounted for. Factors included in the model were age, sex, time period, site (PHIS versus MSMC), and

the interaction of site with time period. The association between age and LOS was explored and found to have a cutoff at 1 year of age, so age <1 year was entered as the age factor in the model. This analysis found a significantly greater decrease in LOS in the observed time period (T1 to T2) for ASD patients at the MSMC compared with PHIS (the site by time period interaction term:  $P<0.0001$ ). The estimated ratios of the average LOS are 1.07 for female versus male ( $P=0.010$ ), 1.63 for age <1 year versus  $\geq 1$  year ( $P<0.001$ ), 1.39 for PHIS versus MSMC at T1 ( $P<0.001$ ), and 2.69 for PHIS versus MSMC at T2 ( $P<0.001$ ). Compared with T1, the average LOS was 42% shorter at T2 ( $P<0.001$ ) for MSMC, in contrast to 13% ( $P<0.001$ ) longer for PHIS. The results were virtually unchanged when the 5 centers with no information in the first period were excluded from the analysis. Table 4 shows LOS values obtained by applying the fitted model to combinations of age group, time period, and site for a female patient to illustrate the average effect of these factors. For example, the expected average LOS across the PHIS centers for a >1-year-old female patient undergoing surgery for ASD in the early time period was 3.3 days compared with 2.4 days at the MSMC and 3.8 and 1.4 days for the later time period, respectively.

Aside from overall LOS, early hospital discharge can be used as an indicator for changes in LOS patterns. We therefore looked at the percentage of patients who were discharged on or before postoperative day 2. At the PHIS centers, 30% of the patients were discharged early at T1. This was reduced to 17% at T2 ( $P<0.0001$ ). At the MSMC, the proportion with early discharge increased from 68% at T1 to 83% at T2, but this difference did not reach statistical significance ( $P=0.13$ ; Table 5).

**Table 2. VSD Patients' Demographics and Comparative Details for MSMC and PHIS Centers**

	MSMC T1	PHIS T1	<i>P</i> *	MSMC T2	PHIS T2	<i>P</i> *
Patients, n	37	2106 (52 [14–171])†		52	2074 (51 [6–263])†	
Centers, n	...	35		...	35	
Age, median (range) [IQR], y	0.7 (0.1–18.3) [0.4–5.8]	0.7 (0.1–18.9) [0.4–2.4]	0.288	0.8 (0.1–18.7) [0.4–3.3]	0.6 (0.1–18.6) [0.3–1.5]	0.117
Sex (male), n (%)	20 (54)	1077 (51)	0.735	28 (54)	1082 (52)	0.819
Chromosomal defects, n (%)	8 (22)	419 (20)	0.711	8 (15)	438 (21)	0.375
Failure to thrive, n (%)	7 (19)	449 (21)	0.814	10 (19)	624 (30)	0.114
Respiratory disease, n (%)	1 (2.7)	14 (0.7)	0.044	0	13 (0.6)	0.798

IQR indicates interquartile range; MSMC, Mount Sinai Medical Center; PHIS, Pediatric Health Information System database; T1, early time period (2001–2003); T2, late time period (2007–2009); and VSD, ventricular septal defect.

\**P* values were obtained either from Wilcoxon rank-sum test or from logistic regression (with Firth option for 0 cell count).

†Total number of patients and (median [range]) of patients at PHIS centers.



**Table 3. Observed LOS for Patients Undergoing Surgery for ASD and VSD at the MSMC and PHIS Centers**

	ASD		VSD	
	T1	T2*	T1	T2*
MSMC LOS, median (IQR), d	2.0 (2.0–3.0)	1.0 (1.0–2.0)	4.0 (3.0–7.0)	3.0 (2.0–4.0)
PHIS† LOS, median (IQR), d	3.0 (2.0–4.0)	3.0 (3.0–4.0)	4.0 (3.0–6.0)	4.0 (3.0–6.0)

ASD indicates atrial septal defect; IQR, interquartile range; LOS, length of stay; MSMC, Mount Sinai Medical Center; PHIS, Pediatric Health Information System database; T1, early time period (2001–2003); T2, late time period (2007–2009); and VSD, ventricular septal defect.

\*The changes in LOS from T1 to T2 at MSMC differed significantly (each  $P<0.0001$ ) from the corresponding change among the PHIS centers.

†All centers combined.

### Safety Considerations

Further analyses were performed to examine whether introducing a fast-tracking strategy was associated with a change in morbidity and mortality. There were no surgical mortalities in the ASD cohort at the MSMC or the PHIS centers in the observed time periods.

Hospital readmission rates (within 14 days of initial hospital discharge) were compared between the patient cohorts. Nationally, readmission rates after ASD repair were relatively constant at 5.0% (T1) and 6.1% (T2). At the MSMC, no ASD patient was readmitted in the early time period compared with 3 of 36 patients (8.3%) in the period after the introduction of fast tracking ( $P=0.10$ ).

### Costs

Cost data were available from 22 PHIS centers with complete or nearly complete (98%) information for both time periods. At the MSMC, the median adjusted total hospital costs for ASD repair hospitalization decreased by 33% between the earlier and later periods (\$11 561 [IQR, \$10 499–\$13 723] compared with \$7759 [IQR, \$6800–\$10 127], respectively;  $P<0.0001$ ). In contrast, the median cost for ASD repair at the PHIS centers increased by 15.6% during the same time periods (\$21 512 [IQR, \$16 796–\$26 348] compared with \$24 873 [IQR, \$20 024–\$30 441], respectively;  $P<0.0001$ ; Figure). There were decreases in median cost from T1 to T2

**Table 4. Expected LOS for ASD and VSD Female Patients Based on Model Fit by Regression, Clustering on Sites**

	ASD, d*				VSD, d†			
	T1		T2		T1		T2	
	MSMC	PHIS	MSMC	PHIS	MSMC	PHIS	MSMC	PHIS
Age, y								
<1	3.9	5.4	2.3	6.1	8.7	6.3	3.8	6.3
≥1	2.4	3.3	1.4	3.8	5.6	4.1	2.5	4.1

ASD indicates atrial septal defect; LOS, length of stay; MSMC, Mount Sinai Medical Center; PHIS, Pediatric Health Information System database; T1, early time period (2001–2003); T2, late time period (2007–2009); and VSD, ventricular septal defect.

These numbers are obtained by substitution in:

\* $LOS = \exp[0.81 + 0.065 \text{ (if female)} + 0.49 \text{ (if age } < 1 \text{ y)} + 0.33 \text{ (if PHIS)} - 0.54 \text{ (if T2)} + 0.66 \text{ (if PHIS and T2)}]$ .

† $LOS = \exp[1.69 + 0.027 \text{ (if female)} + 0.44 \text{ (if age } < 1 \text{ y)} - 0.31 \text{ (if PHIS)} - 0.81 \text{ (if T2)} + 0.81 \text{ (if PHIS and T2)}]$ .

in 7 of the PHIS centers; the decreases ranged from –3% to –29%, and none exceeded the 33% decrease at MSMC.

Multiple regression analysis was performed to compare the observed change in cost at the MSMC with the change in cost at the PHIS centers in the observed time period (T1 to T2). This analysis found that the change in cost between the 2 time periods at the MSMC differed significantly from PHIS (interaction term site by time period:  $P<0.0001$ ).

### Ventricular Septal Defects

#### Demographics

The above analyses were repeated for the VSD cohorts. The median age at VSD surgery did not change significantly during the observed time period and was similar between the MSMC and PHIS centers: T1 PHIS, 8.4 months (IQR, 4.5 months–2.4 years); T2 PHIS, 6.7 months (IQR, 4.1 months–1.5 years); T1 MSMC, 8.5 months (IQR, 4.5 months–5.8 years); and T2 MSMC, 9.3 months (IQR, 4.4 months–3.3 years). Among all patient cohorts, there was a slight predominance of male over female patients (52:48). The prevalence of respiratory disease was marginally higher in the MSMC VSD cohort ( $P=0.044$ ); however, this finding was based on a single patient. Details on other demographic data, for which there were no significant differences between the MSMC and PHIS VSD cohorts, can be found in Table 2.

#### Length of Stay

For the earlier time period, the median LOS for VSD surgery was the same at the MSMC and PHIS centers (4 days). After full implementation of fast tracking at the MSMC, the median LOS decreased to 3 days and was significantly shorter compared with the PHIS centers, where the median LOS remained unchanged ( $P<0.0001$ ; Table 3). In T1, there were 7 PHIS centers with a median LOS of 3 to 3.5 days, 15 with 4 to 4.5 days, and 13 with  $\geq 5$  days. In the later time period, only 3 PHIS centers reported a median LOS of 3 days (22 with 4–4.5 days, 15 with  $\geq 5$  days). At the PHIS centers, the proportion with early hospital discharge decreased from 10% at T1 to 4% at T2 ( $P<0.0001$ ) compared with an increase at MSMC from 14% at T1 to 48% at T2 ( $P<0.0007$ ; Table 5). The decrease in LOS at MSMC was not attributable to changes in admission practices because the median time from date of procedure to date of discharge was identical to LOS for T1, and the same was true for T2.

Multiple Poisson regression analysis was performed analogous to the ASD analysis and showed a significantly greater decrease in LOS in the observed time period (T1 to T2) for VSD patients at the MSMC compared with PHIS (the site by period interaction term,  $P<0.0001$ ). The average LOS ratios are 1.03 for female versus male ( $P=0.21$ ), 1.55 for age  $< 1$  year versus  $\geq 1$  year ( $P<0.001$ ), 0.74 for PHIS versus MSMC at T1 ( $P<0.001$ ), and 1.66 for PHIS versus MSMC at T2 ( $P<0.001$ ). Compared with T1, the estimated reduction in average LOS at T2 was 55% ( $P<0.001$ ) for MSMC, but no change (0.5%,  $P=0.881$ ) was seen for PHIS. The results were virtually unchanged when the 5 centers with no information in the first period were excluded from the analysis. Table 4 shows LOS values obtained by applying the fitted model to combinations of age, time period, and site to illustrate the average effect of these factors. For example, the expected average LOS across the PHIS centers for a female patient  $< 1$  year of age

**Table 5. Patients With Early Hospital Discharge, and Significance Tests Comparing T1 With T2 at the MSMC and at the PHIS Centers**

	ASD				VSD			
	MSMC		PHIS*		MSMC		PHIS*	
	n (N)	%	n (N)	%	n (N)	%	n (N)	%
T1	28 (41)	68.3	498 (1685)	29.6	5 (37)	13.5	203 (2106)	9.6%
T2	30 (36)	83.3	247 (1418)	17.4	25 (52)	48.1	80 (2074)	3.9%
<i>P</i>		0.13		<0.0001		0.0007		<0.0001

ASD indicates atrial septal defect; MSMC, Mount Sinai Medical Center; n, number of patients discharged early (on or before postoperative day 2); N, total number of patients per site and time period; PHIS, Pediatric Health Information System database; T1, early time period (2001–2003); T2, late time period (2007–2009); and VSD, ventricular septal defect.

\*All centers combined.

undergoing surgery for VSD in the early time period was 6.3 compared with 8.7 days at the MSMC and 6.3 compared with 3.8 days for the later time period, respectively.

### Safety Considerations

Among the PHIS centers, there were 9 hospital mortalities among the 2106 patients (0.4%) during the early time period and 1 of 2074 patients (0.05%) during the later period. At the MSMC, there were no hospital mortalities for children undergoing VSD closure in either era.

Readmission rates within 14 days of discharge at the PHIS centers after VSD repair were relatively constant (T1, 4.6%; T2, 5.7%). At the MSMC, there was no readmission in the early time period, and 1 of 52 patients (1.9%) were readmitted in T2.

### Costs

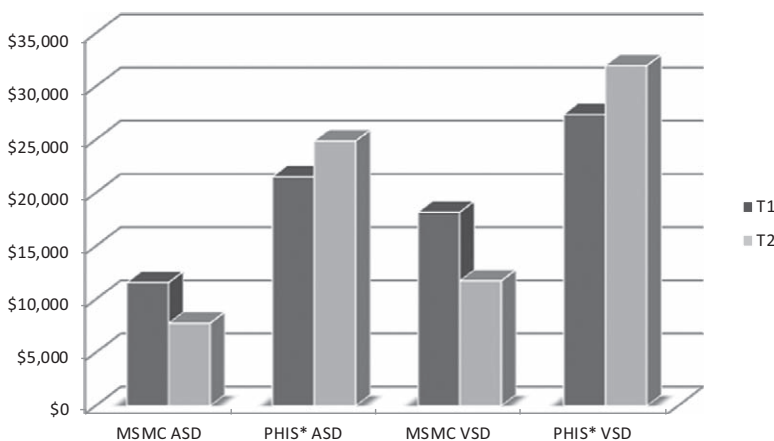
Similar to the ASD cohort, adequate cost data for the VSD patients were available only from 22 PHIS centers. At the MSMC, the median adjusted cost for VSD repair during the earlier period was \$18 185 (IQR, \$13 186–\$25 337), which decreased significantly to \$11 733 (IQR, \$9500–\$13 631;  $P<0.001$ ) in the later period after the implementation of fast tracking, a 35% reduction (the Figure). At the PHIS centers, the median adjusted cost for VSD repair during the earlier time period was \$27 366 (IQR, \$22 027–\$34 573), which increased by 16.7% ( $P<0.001$ ) to \$31 949 (IQR, \$25 842–\$39 951) in the later period. There were decreases in median cost from T1 to T2 in 10 PHIS centers, with decreases ranging from –0.5% to –34%; none exceeded the 35% decrease at the MSMC.

Multiple regression analysis found that the change in cost between the 2 time periods at the MSMC differed significantly from that at PHIS (interaction term site by time period,  $P<0.0001$ ).

### Discussion

Fast tracking in CHD surgery is not uniformly accepted, although it was introduced as early as the late 1970s.<sup>9–11</sup> Large multicenter, controlled studies confirming potential benefits have not been performed; thus, concerns about the safety of such an approach remain.<sup>12</sup> This is despite numerous reports about the feasibility of fast tracking in the pediatric cardiac surgery population.<sup>3–6,13</sup> In an era of increasing concerns about cost containment, dwindling reimbursement rates, and the introduction of bundled care plans, practitioners and administrators are on the look out for means of more efficient resource use and cost reduction. Leaving aside ethical issues, cost savings can be achieved only if fast tracking is not associated with an increase in morbidity, the economic consequences of adverse events and complications being far more costly than benefits gained.<sup>14–18</sup> Any analysis of the benefits (eg, reduced LOS) of introducing fast tracking into a surgical practice must therefore also address the safety of such an approach. Furthermore, when only the results from 2 eras at a single center are considered, it is not possible to separate the effect of introducing fast tracking from the effects of other changes in clinical practice over time.

To the best of our knowledge, this is the first study to examine the economic and safety implications of introducing fast tracking into pediatric cardiothoracic surgical practice by comparing the



**Figure.** Median costs for atrial septal defect (ASD) and ventricular septal defect (VSD) repair at the Mount Sinai Medical Center (MSMC) and Pediatric Health Information System (PHIS) centers. \*PHIS centers (n=22) with complete or nearly complete (98%) cost data. T1 indicates early time period (2001–2003); and T2, late time period (2007–2009).

detected changes with corresponding changes in a large number of contemporary programs in the United States. Concordant with fully implementing fast tracking, we observed significant reductions in hospital LOS and cost savings of >30%, which were not accompanied by increases in mortality or readmissions. Of note, the LOS for ASDs and VSDs nationwide during the same 2 time periods remained unchanged while costs increased.

These findings confirm and validate reports from single-center studies<sup>3</sup> and mirror similar reports from adult cardiac surgery. Morales et al,<sup>19</sup> for example, implemented early extubation as part of a fast-tracking approach during a 5-year period in children after Fontan surgery. Hospital and ICU costs for patients who were extubated in the operating room at the end of the procedure were 31% and 35% lower, respectively, compared with costs for children who were extubated later in the ICU. There was no difference in early morbidity or in survival rates with a follow-up of >12 months. Preisman et al<sup>20</sup> performed a prospective, randomized, observational study assigning children undergoing CHD surgery to extubation in the operating room versus ICU. Early extubation was associated with shorter ICU and hospital LOS, and no difference in complications such as radiographic findings and other pulmonary complications, need for reoperation, need for reintubation, sepsis, renal failure, or arrhythmias was seen. Several other studies have also reported shorter LOS and cost savings associated with fast tracking in CHD surgery.<sup>4,21</sup>

Lessons can also be learned from adult cardiac surgery in which fast tracking has become an established practice in patients undergoing routine cardiac surgery.<sup>22</sup> Chamchad et al<sup>23</sup> looked at the impact of early extubation in adult cardiac surgery patients on ICU and hospital LOS using a propensity score case-control approach. The Society of Thoracic Surgeons database was queried and 713 matched pairs were identified. Extubation in the operating room resulted in reductions in ICU and hospital LOS of almost 1 day each. The magnitude of reported cost reduction in adult cardiac surgery matches our findings. Cheng et al<sup>24</sup> published their results of a prospective, randomized trial in adult patients undergoing coronary artery bypass grafting >20 years ago. Early endotracheal extubation and fast tracking resulted in a 25% reduction of costs and a 15% increase in case volume while slightly decreasing complications.

There are good data including those from randomized, controlled studies showing that fast tracking in adults undergoing cardiac surgery is safe<sup>25</sup> and offers benefits that include cost savings.<sup>26-29</sup> Van Mastrigt et al<sup>30</sup> published a large meta-analysis including 27 studies on fast tracking in adult cardiac surgery and found that fast tracking in general and early extubation in particular resulted in significant shorter ICU and hospital stay without an increase in morbidity and mortality. A similar meta-analysis in CHD patients concluded that early extubation, which is a main component of fast tracking, seems to be safe and was actually associated with lower early mortality. There was a trend toward shorter ICU and hospital LOS, lower hospital costs, and less respiratory morbidity; however, on the basis of the studies included, the authors concluded that the evidence was insufficient to generally recommend this strategy for children undergoing CHD surgery.<sup>31</sup>

Any analysis on the impact of fast tracking in children undergoing CHD surgery is complicated by the complexity and wide variety of CHD cases, making comparisons between different centers difficult, and has resulted in criticism of the

validity of reports on cost savings of fast tracking in CHD surgery. Different practice standards and patterns further complicate the matter. We therefore limited our analyses to 2 simple lesions (ASD and VSD) with established morbidity and mortality rates. Including VSD patients allowed us to assess the feasibility and success of our fast-tracking approach in a substantially younger patient population. Fast tracking is a multidisciplinary, multimodality approach. To separate possible effects of fast tracking on economics and safety from other factors such as improvement in the surgical approach to these lesions over the observed time period, we aimed to compare our findings with a nationwide standard. Although the PHIS centers vary in their approach to CHD surgery, the large number of centers represented in this database provided a contemporary standard of CHD surgery in the United States.

### Limitations

Study limitations include the fact that the retrospective, observational study design does not allow conclusions on causality between implementation of fast tracking and the outcomes. Additionally, we had no access to information about whether any of the PHIS centers were implementing fast tracking in the study periods. Although LOS data for both time periods were available from 35 PHIS centers, many centers did not provide information about costs. To determine whether omitting the centers that did not have complete cost data introduced a bias into the cost comparisons, we repeated the LOS analyses using only the 22 centers that had provided complete or nearly complete cost data. The results gave no evidence of such a bias because there were no marked changes; in particular, the interaction term comparing the change at MSMC with the change in PHIS remained highly significant ( $P<0.0001$ ) for ASD and for VSD.

As noted in the Methods section, surgical access for ASD repair at the MSMC varied and included an axillary approach, particularly in the later time period. Comparable data on surgical access and technique are not available from the PHIS database; however, we expect that nearly all patients in PHIS centers had a midline sternotomy of some type. Of note, a comparison of small cohorts of patients with ASD repair at MSMC using midaxillary and midline sternotomy approaches revealed no difference in LOS.<sup>8</sup> Nonetheless, we could not separate the contributions of surgical approach or any other aspect of the MSMC fast-tracking practices to the aggregate differences in LOS and costs using these administrative data sets.

Another limitation is that costs might have been calculated differently at the various sites. Although that would invalidate comparisons of absolute costs between MSMC and the PHIS centers, it does not affect the change of cost assessments between time periods at MSMC or PHIS. In addition, the cost comparisons could have been affected by the presence of very long-term hospitalizations experienced by small number of the PHIS patients. To consider this possibility, we repeated the regression analyses for the cost comparisons after excluding 31 PHIS patients whose costs exceeded \$100 000 or the 76 PHIS patients whose LOS exceeded 15 days. In both cases, the significance level of the interaction term remained at  $P<0.0001$  for ASD and for VSD.

Another limitation is that we considered only patients with ASDs and VSDs, not those with more complex lesions. Using only simple, well-defined lesions allowed us to better control



for the larger variance in perioperative management seen with more complex CHD. Additionally, safety was assessed in terms of hospital mortality and readmission rate. More specific data on complications related to CHD surgery are difficult to obtain with a retrospective study unless complications were assessed and coded uniformly across all institutions. It is logical to assume, however, that patients with serious complications related to fast tracking would be hospitalized longer or would be readmitted after discharge. Because LOS was shorter at MSMC with fast tracking without an increase in readmissions, we conclude that fast tracking in CHD was accomplished safely. Additionally, administrative databases do not capture information on readmissions to hospitals other than the one at which the surgical repair originally took place. Because MSMC derives its patients almost exclusively from the New York City area, readmissions were highly likely to occur there. Because several of the PHIS centers draw patients regionally or even nationally, readmissions for those would be more likely to occur at a patient's local hospital. Thus, the available data would, if anything, tend to bias toward a higher readmission rate at MSMC compared with PHIS.

### Conclusions

In the present study, we compared hospital LOS and costs before and after implementation of fast tracking in a pediatric cardiothoracic surgical practice with contemporaneous nationwide cohorts. After the implantation of fast tracking, we observed a shorter LOS and reduced costs for children undergoing surgery for isolated ASDs and VSDs without an increase in mortality or readmission rates. From our analyses, we conclude that this observation supports the significant role that fast tracking may have played in the observed improved outcomes. Further work is required to determine whether similar advantages can be derived from applying fast tracking to surgery for more complex forms of CHD.

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### Disclosures

None.

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