Technical Performance Score Predicts Resource Utilization in Congenital Cardiac Procedures

The technical performance score (TPS), which measures technical adequacy of repair in congenital cardiac surgery, has been associated with early outcomes, such as mortality, adverse events, prolonged ventilation and hospital length of stay, and midterm outcomes such as post-discharge mortality, unplanned post-discharge reinterventions, and neurodevelopmental outcomes (1-3). In this study, we hypothesized that improved quality of care measured by TPS would also be associated with lower hospital cost of care.

We prospectively evaluated consecutive unique patients who underwent congenital cardiac surgery at our center between January 1, 2011, and March 31, 2013. Only the first index procedure was included in the analysis; readmissions for any reason, whether planned or unplanned, were excluded. Institutional Review Board approval was obtained for this study.

TPS was calculated as Class 1 (optimal, trivial or no residua), Class 2 (adequate, minor residua), or Class 3 (inadequate, major residua, or pre-discharge reintervention for major residua) based on echocardiographic and clinical findings at discharge. Hospital costs for each admission were calculated using cost-to-charge ratio standardized to 2013 U.S. dollars to account for inflation.

A generalized linear model assuming a gamma distribution with a log link was used to examine the relationship between technical performance score and total hospital costs, adjusting for baseline patient risk using RACHS-1 (Risk Adjustment in Congenital Heart Surgery) and PRECISE (Pediatric Resource Expenditure in Cardiac Specialty Encounters) methods of risk adjustment. Analyses were repeated summing hospital costs for the surgical admission plus all additional costs incurred during the 2 years post-discharge. SAS version 9.4 (SAS Institute, Cary, North Carolina) was utilized for statistical analysis.

There were a total of 1,730 consecutive unique patients meeting inclusion criteria in our cohort. The median total hospital costs for the index operation adjusted to the year 2013 costs across TPS classes as well as adjusted cost increases for hospital admission and 2-year follow-up are shown in Table 1.

After adjusting for baseline patient risk, inadequate TPS remained significantly associated with higher cost (increase by factor of 2.48, \( p < 0.001 \)) (Table 1). Inclusion of TPS increased \( R^2 \) from 40.9% to 50.8%, indicating that an additional 10% of the variability in cost was explained by the inclusion of TPS. Results were similar regardless of the method of risk adjustment. Looking at a combination of hospital admission costs and 2-year post-discharge costs adjusted to 2013 dollars, Class 3 TPS was again associated with higher costs (Table 1). \( R^2 \) increased from 41.5% to 48.4% with inclusion of TPS.

In our study TPS, which measures adequacy of repair, was strongly associated with greater hospital costs even after adjusting for well known risk factors. Inclusion of TPS increased the coefficient of determination for the model from 40.9% to 50.8%, indicating that TPS accounted for an additional 10% of the variability in costs.

Birkemeyer et al. (4) in an elegant study demonstrated that greater technical skill was associated with lower complication, reoperation, and readmission rates following bariatric surgery, confirming that technical adequacy of a repair may be a key factor in outcomes.

Pasquali et al. (5) have shown the existence of significant variability in hospital costs across centers, predominantly related to complications and length of stay. Prior work (1-3) has shown that Class 3 TPS is associated with higher complication rates and greater length of stay and perhaps some of the variability seen in Pasquali et al.’s study could be attributable to the adequacy of repair.

Our study confirms that TPS can serve as an important benchmark for resource use in congenital heart surgery. In our study, the per-patient risk adjusted differences of $8,668 from Class 1 to Class 2, $135,948 from Class 1 to Class 3, and $127,280 from Class 2 to Class 3 suggests substantial potential for cost savings within our institution. This translates into approximately $13.7 million over a year, if all
surgery is at optimal level and $10.9 million if quality is improved for all Class 3 to a level of Class 2. With an estimated 35,000 patients undergoing congenital cardiac surgery in the United States each year, our findings imply potential for large aggregate cost savings, but more importantly may result in a significant reduction in complications and length of stay.

Our study has some limitations. The data in this study represents a single institution’s experience. Currently TPS is measured at discharge, and perhaps intraoperative TPS determination and intervention could mitigate costs associated with postoperative interventions. TPS in its current form gives equal weight to all components, and further development is needed to determine which subprocedures carry more weight for any given congenital cardiac procedure. Although common pre-operative factors that may contribute to increased resource use have been included in our analysis, procedure-specific factors may need to be included in future analyses.

Patients with Class 3 TPS have a significantly higher total hospital cost after adjusting for other patient risk factors known to be associated with higher resource utilization. Maximizing technical adequacy of the repair may play a significant role in reducing health care costs. These findings have implications for cost containment and suggest that TPS can be a useful benchmark for resource utilization across centers.

### Table 1: Multivariable Analysis: Hospital Costs for Surgical Admission, Fiscal Year 2013

<table>
<thead>
<tr>
<th>Technical performance score</th>
<th>Percentage of Cohort</th>
<th>Coefficient (95% Confidence Interval)</th>
<th>p Value</th>
<th>Cost Increase by Factor of</th>
</tr>
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<tbody>
<tr>
<td>Class 1, optimal</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 2, adequate</td>
<td>31</td>
<td>0.07 (-0.02 to 0.15)</td>
<td>0.11</td>
<td>1.07</td>
</tr>
<tr>
<td>Class 3, inadequate</td>
<td>11</td>
<td>0.91 (0.72 to 1.10)</td>
<td>&lt;0.001</td>
<td>2.48</td>
</tr>
<tr>
<td>Not scorable</td>
<td>8</td>
<td>-0.18 (-0.44 to 0.09)</td>
<td>0.20</td>
<td>0.84</td>
</tr>
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<table>
<thead>
<tr>
<th>RACHS-1 risk category</th>
<th>Percentage of Cohort</th>
<th>Coefficient (95% Confidence Interval)</th>
<th>p Value</th>
<th>Cost Increase by Factor of</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>0.32 (0.23 to 0.41)</td>
<td>&lt;0.001</td>
<td>1.38</td>
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<tr>
<td>3</td>
<td>30</td>
<td>0.78 (0.67 to 0.88)</td>
<td>&lt;0.001</td>
<td>2.17</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>1.00 (0.84 to 1.16)</td>
<td>&lt;0.001</td>
<td>2.71</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>1.11 (0.91 to 1.31)</td>
<td>&lt;0.001</td>
<td>3.03</td>
</tr>
<tr>
<td>NA, &lt;18 yrs of age</td>
<td>20</td>
<td>1.52 (1.18 to 1.85)</td>
<td>&lt;0.001</td>
<td>4.56</td>
</tr>
<tr>
<td>Multiple procedures at index surgery</td>
<td>14</td>
<td>0.19 (0.07 to 0.31)</td>
<td>0.001</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Median hospital costs in year 2013 (25th and 75th percentile) for technical performance score classes are as follows: Class 1: $42,474 ($30,345–66,163); Class 2: $48,859 ($37,742–79,742); Class 3: $126,560 ($64,095–270,039); technical performance score not scorable: $28,299 ($11,458–56,073). Multivariable model, in addition to the variables shown in Table 1, included age, prematurity, extra-cardiac anomaly, genetic syndrome, and weekend admission. For surgical admission only: R² = 40.9% without technical performance score; R² = 50.8% when technical performance score is included. For surgical admission <2 years post-discharge (model not shown): R² = 41.5% without technical performance score; R² = 48.4% when technical performance score is included.

NA = not applicable; RACHS-1 = Risk Adjustment in Congenital Heart Surgery.

### References


Ischemia and Infarction in STEMI Patients With Multivessel Disease

Insights From the CvLPRIT Nuclear Substudy

The CvLPRIT (Complete versus Lesion-only PPrimary PCI Trial) trial was undertaken in 7 UK centers (1,2). Patients with ST-segment elevation myocardial infarction (STEMI) and multivessel coronary stenoses were randomized to primary percutaneous coronary intervention (PCI) to the infarct-related artery (IRA) only, or complete revascularization. At 12-month follow-up, the rate of the combined primary endpoint (all-cause mortality, recurrent MI, heart failure, ischemia-driven revascularization) was lower after complete revascularization. All surviving patients were asked to undergo myocardial perfusion scintigraphy (MPS) 6 to 8 weeks post-admission. It was expected that this a priori nuclear substudy would provide mechanistic insights into the outcome of the main trial, and help to define the clinical role of MPS in the PPCI era.

Stress-rest MPS was performed according to local departmental practice: technetium-99m-tetrofosmin 95%, 2-day protocol 84%, vasodilator stress 84%, glyceryl trinitrate at rest 59%. Blinded semiquantitative analysis was performed in a central core lab (A.D.K.), and summed scores were expressed as percentages of the left ventricular myocardium (%LV). Separate scores were calculated for IRA and non-IRA territories. Supervising physicians were blinded to the results of MPS unless inducible hypoperfusion exceeded 20%LV (no patient), or symptoms developed within 1 month such that another ischemia test would otherwise have been required (3 patients, all IRA only, no significant inducible hypoperfusion, no further revascularization).

Of 296 CvLPRIT trial patients, 205 (69%) underwent MPS as intended; they were broadly similar to those in the overall study cohort (1). The vast majority were asymptomatic and on optimal medical therapy at the time of MPS. IRA-only patients had more extensive resting defects (infarction) than complete revascularization patients (Table 1). This was associated with a nonsignificant trend toward more extensive infarction in the territory of the index IRA rather than that of a non-IRA. The extent of inducible hypoperfusion (ischemia) was small, and exceeded 10%LV in only 14 patients (7%). There was no difference between the IRA-only and complete revascularization groups (Table 1).

Sixteen patients experienced a late cardiac event following MPS. No scintigraphic variable was predictive of the combined primary endpoint. However, the extent of infarction was greater in patients experiencing death, MI, or heart failure than in those who had no event or a revascularization event: median 23.5 (interquartile range [IQR]: 19.1 to 35.3) versus 8.8 (IQR: 4.4 to 16.2) versus 7.4 (IQR: 2.9 to 10.3) %LV (p < 0.01), whereas resting LV ejection fraction was lower: 43 (IQR: 30 to 45) versus 57 (IQR: 51 to 62) versus 59 (IQR: 46 to 62) % (p = 0.01). The extent of inducible hypoperfusion was similar: 0 (IQR: 0 to 1.5) versus 1.5 (IQR: 0 to 4.4) versus 2.9 (IQR: 0 to 7.4) %LV (p = 0.26).

The reduction in infarct size after complete revascularization might represent early improvement in collateral perfusion from treated non-IRAs to the watershed of the IRA territory. “Hard” cardiac events (as opposed to revascularization) occurring after MPS

### Table 1: Characteristics of Patients in the CvLPRIT Nuclear Substudy

<table>
<thead>
<tr>
<th></th>
<th>IRA only (n = 101)</th>
<th>Complete (n = 104)</th>
<th>p Value</th>
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<tbody>
<tr>
<td>MPS variables</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stress defect, %LV</td>
<td>13.2 (7.4-19.1)</td>
<td>13.2 (7.4-16.2)</td>
<td>0.16</td>
</tr>
<tr>
<td>Rest defect, %LV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>10.3 (5.9-17.6)</td>
<td>8.8 (4.4-14.7)</td>
<td>0.049</td>
</tr>
<tr>
<td>IRA territory</td>
<td>8.8 (3.3-14.0)</td>
<td>5.9 (2.9-11.8)</td>
<td>0.09</td>
</tr>
<tr>
<td>Non-IRA territory</td>
<td>0 (0-4.4)</td>
<td>0 (0-4.0)</td>
<td>0.70</td>
</tr>
<tr>
<td>Inducible hypoperfusion, %LV</td>
<td>1.5 (0-4.4)</td>
<td>1.5 (0-5.9)</td>
<td>0.70</td>
</tr>
<tr>
<td>Resting ejection fraction, %</td>
<td>58 (49-62)</td>
<td>57 (50-64)</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Primary clinical endpoints

- Early events (pre-MPS or <6 weeks): 9 (9) vs 1 (1), p < 0.01
- Late events (post-MPS or >6 weeks)
  - All events: 12 (12) vs 4 (4), p = 0.04
  - Death: 1 (1) vs 0 (0)
  - Recurrent MI: 1 (1) vs 0 (0)
  - Heart failure: 2 (2) vs 1 (1)
  - Revascularization: 8 (8) vs 3 (3)

Values are n/N (%), median (interquartile range), or n (%).

9%LV = percentage of the left ventricular myocardium; CvLPRIT = Complete versus Lesion-only PPrimary PCI Trial; MI = myocardial infarction; MPS = myocardial perfusion scintigraphy.