Surgeon and Center Volume Influence on Outcomes After Arterial Switch Operation: Analysis of the STS Congenital Heart Surgery Database

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Background. The relative impact of center volume and of surgeon volume on early outcomes after the arterial switch operation (ASO) is incompletely understood.

Methods. Neonates in the Society of Thoracic Surgeons Congenital Heart Surgery Database (2005–2012) undergoing ASO for transposition of the great arteries were included in the analysis. Multivariable logistic regression with adjustment for patient factors and ventricular septal defect closure was used to evaluate relationships between annual center and surgeon volume and a composite end point (in-hospital mortality or major complications).

Results. The study included 2,357 patients (84 centers, 155 surgeons). Median annual ASO center volume was 4 (range, 1 to 18). Median annual surgeon volume was 2 (range, 0.1 to 11). In-hospital mortality was 3.4%; 14.7% had major morbidity and 15.5% met the composite end point. Analyzed individually, lower center and surgeon volumes were each associated with the composite end point (odds ratios for centers with 2 versus 10 cases/y, 1.92; 95% confidence interval, 1.23 to 2.99); odds ratios for surgeons with 1 versus 6 cases/y, 2.16; 95% confidence interval, 1.42 to 3.26). When analyzed together, the addition of surgeon volume to the center volume models attenuated but did not completely mitigate the association of center volume with outcome (relative attenuation of odds ratio = 31%). Addition of center volume to surgeon volume models attenuated the association of surgeon volume with outcome to a lesser degree (relative attenuation of odds ratio = 11%).

Conclusions. Center and surgeon volume each influence early outcomes after ASO; however, surgeon volume appears to play a more prominent role. Surgeon and center ASO volume should be considered in the context of initiatives to improve outcomes from ASO for transposition of the great arteries.


Much attention has been focused on evaluating the influence of surgeon and center volume on outcomes after a variety of surgical procedures, including complex congenital heart operations [1–11]. Although some studies have shown discordant results, the majority have found at least a modest relationship between center volume and outcomes, which become most apparent with increasing case complexity [1–8]. A recent analysis of infants undergoing the Norwood operation in the Society of Thoracic Surgeons Congenital Heart Surgery Database (STSCHSD), suggested that center and surgeon volume each played an important role and was significantly associated with outcome in this patient population [1].

However, the relationship of center and surgeon volume with outcome for patients undergoing other types of congenital heart surgery is less clear, and it is hypothesized that for some operations (such as the arterial switch operation [ASO]) surgeon volume may play a more important role, similar to the findings in adult cardiac surgery. That hypothesis is expressed by some in the suggestion that “[t]he results of the Norwood operation reflect the quality of the institution, while the results of the arterial switch operation reflect the quality of the surgeon.” Therefore, the purpose of this study was to evaluate the relationships between center volume and surgeon volume and early outcome after the ASO in a large multicenter cohort.

Material and Methods

Data Source
The STSCHSD was used for this study. As of January 2014, the database contains deidentified data on more than...
292,000 surgeries conducted since 2000 at 120 centers in North America, representing approximately 90% of all US centers performing congenital heart surgery and greater than 90% of all operations [12–15]. 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 STSCHSD Access and Publications Committee and the Duke University institutional review board and was not considered human subjects research by the Duke University Institutional Review Boards in accordance with the Common Rule (45 CFR 46.102(f)).

**Patient Population**

Neonates (≤30 days) undergoing ASO or ASO + ventricular septal defect (VSD) repair as an index operation in the STSCHSD between January 2005 and July 2012 were included. Patients with a diagnosis of double-outlet right ventricle were excluded. Patients undergoing concomitant surgical procedures were also excluded with the exception of atrial septal defect or patent foramen ovale repair, patent ductus arteriosus repair, and main or branch pulmonary artery reconstruction. To ensure data integrity, centers with greater than 15% missing data for preoperative risk factors, noncardiac or genetic abnormalities, or postoperative length of stay were excluded. Additionally, any center with greater than 15% missing data for complications, mortality, or preoperative length of stay were also excluded. The resultant population included 2,357 patients from 84 centers.

**Data Collection**

Data collection included demographic information, baseline characteristics, preoperative risk factors as defined in the STSCHSD, operative variables, and outcomes data. Surgeon and center characteristics were also collected, including average annualized surgeon and center ASO and total cardiopulmonary bypass case volume. Surgeon and center case volumes were calculated using only index cardiopulmonary bypass or non-cardiopulmonary bypass operations classifiable by the STS–European Association for Cardio-Thoracic Surgery mortality categories. Operations in patients older than 18 years and for isolated patent ductus arteriosus closure in patients weighing 2.5 kg or less were excluded. Annualized surgeon case volume was only calculated for surgeons participating in the database for at least 12 consecutive months.

**Outcomes**

The primary outcome was a composite end point, defined as in-hospital mortality (during the same hospital admission) after ASO ± VSD or the occurrence of one or more of six designated major complications as previously defined [15]. The six major complications included renal failure requiring temporary or permanent dialysis, neurologic deficit persisting at discharge, atrioventricular block or arrhythmia requiring a permanent pacemaker, postoperative mechanical circulatory support, phrenic nerve injury, or any unplanned reintervention before discharge [15]. For comparisons, isolated ASO included operations with the unique procedural code for ASO, whereas ASO + VSD included operations with a procedural code for combined ASO + VSD repair or operations with concomitant procedural codes for ASO and VSD repair.

**Analysis**

Patient characteristics and outcomes were summarized overall and stratified by hospital and surgeon volume categories using frequencies and proportions for categorical variables and medians and interquartile ranges for continuous variables. Missing data were rare; preoperative prematurity (n = 52; 2.6%), any noncardiac anomalies (n = 7; 0.3%), and any preoperative risk factor (n = 16; 0.7%) were the only variables with missing data. For these variables, missing was imputed to none. Center and surgeon average annual ASO ± VSD volumes were analyzed both as continuous and categorical variables. Volume was categorized for descriptive purposes based on the distribution of the data. Center volume was categorized as 0 to 5, 6 to 10, and more than 10 cases per year. Surgeon volume was categorized as 0 to 2, 3 to 6, and more than 6 cases per year. Note that the cut points for categories are lower than those used in the previously published Norwood analysis [1] because of the lower case volumes of ASO relative to Norwood procedures across centers and surgeons.

The overall distributions of surgeon and center volume were plotted. Patient characteristics overall and across center and surgeon volume groups were described. Multivariable logistic regression was used to evaluate the association of surgeon and center volume with the composite end point. First, separate models were fitted for hospital volume and surgeon volume. In both, volume was transformed using restricted cubic splines with one single knot at the median value. The choice of a single knot was based on the sample size. Generalized estimating equations with robust standard error estimates were used to account for the within-center correlation. Odds ratios (ORs) and 95% confidence intervals are presented.

To examine the relationship between center and surgeon volume, models were fitted including both volume variables and compared with the models including only center or surgeon volume alone. The relative attenuation of the OR for either center or surgeon volume (once the other volume variable was added into the model) was calculated using a previously described formula: \( \text{OR}_{V} = \frac{\text{OR}_{C} \times \text{OR}_{S}}{\text{OR}_{C} + \text{OR}_{S} - \text{OR}_{C} \times \text{OR}_{S}} \) where \( \text{OR}_{C} \) is the OR for mortality with a given center volume without consideration of surgeon volume, and \( \text{OR}_{S} \) is the OR for mortality with a given center volume after adjustment for surgeon volume [16, 17].

All models were adjusted for important patient characteristics including age at surgery, sex, weight-for-age-and-sex Z-score, any STS-defined preoperative risk factors, any genetic or noncardiac abnormalities, and whether a VSD repair was performed in conjunction with the ASO. All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC) and R version 2.15.2 (R Foundation for
Statistical Computing, Vienna, Austria). A probability value of less than 0.05 was considered statistically significant.

Results

Patient, Center, and Surgeon Characteristics

A total of 155 surgeons performed 2,357 ASO ± VSD operations at 84 centers. The median annual ASO ± VSD center volume was 4 (range, 1 to 18), and the median annual surgeon ASO ± VSD volume was 2 (range, 0.1 to 11). Overall, 54 (64%) of the 84 centers performed 0 to 5 ASO ± VSD per year, 21 (25%) performed 6 to 10 ASO ± VSD per year, and 9 (11%) performed greater than 10 cases per year (Fig 1). Regarding surgeon volume, 71 (46%) of the 155 surgeons performed 0 to 2 ASO ± VSD per year, 75 (48%) performed 3 to 6 ASO ± VSD cases per year, and 9 (6%) performed greater than 6 ASO ± VSD cases per year (Fig 2). Patient and center characteristics across center volume groups are shown in Table 1. Patient and surgeon characteristics across surgeon volume groups are shown in Table 2. At the patient level, surgeon and center volume were correlated (Pearson correlation = 0.61; \( p < 0.0001 \)), demonstrating that high-volume surgeons were concentrated at high-volume centers. Notably, high-volume surgeons had significantly shorter cardiopulmonary bypass times and aortic cross-clamp times compared with surgeons from medium- and low-volume groups, despite operating on patients with a higher prevalence of potential preoperative risk factors (including weight < 2.5 kg).

Relationship of Center and Surgeon Volume With Postoperative Outcome

Overall unadjusted in-hospital mortality was 3.4%; 14.7% had major morbidity and 15.5% met the composite end point for adverse outcome. After adjustment for patient risk factors (including age, sex, weight, any preoperative risk factors as coded by the STSCHSD, noncardiac anomalies, and concomitant VSD repair) but without adjustment for surgeon volume, lower center volume was significantly associated with higher odds of the composite end point: OR for centers with 2 cases per year versus 10 cases per year was 1.92 (95% confidence interval, 1.23 to 2.99; \( p = 0.001 \); Table 3). Similarly, lower surgeon volume (after adjustment for patient risk factors but without adjustment for center volume) was significantly associated with higher odds of the composite end point: ORs for surgeons with 1 case per year versus 6 cases per year was 2.16 (95% confidence interval, 1.42 to 3.26; \( p < 0.001 \); Table 3).

The results from the two models accounting for both center and surgeon volume are presented in Table 3. When both center and surgeon volumes were entered into the models together, the impact of center volume (with adjustment for surgeon volume) on the composite end point was lessened (relative attenuation of OR = 31% for 2 versus 10 cases/y) and the relationship between center volume and the composite end point was no longer statistically significant (Fig 3). Conversely, the impact of surgeon volume (with adjustment for center volume) on the composite end point was largely unchanged (relative attenuation of OR = 11% for 1 versus 6 cases/y), and surgeon volume remained significantly associated with the composite end point (Fig 4).

Comment

The present analysis demonstrates that surgeon and center volume are both associated with early outcomes
after ASO ± VSD procedure. However, surgeon volume appears to play a more prominent role. Studies in the adult cardiac surgery literature have described similar results with respect to other types of operative procedures [9–11], although analyses of the interaction between surgeon and center volume have been hampered because the majority of high-volume surgeons are clustered at high-volume centers. Hannan and colleagues [11] used New York’s clinical coronary artery bypass graft (CABG) surgery registry and found that survival after CABG was optimized by choosing a high-volume surgeon and a high-volume center. More importantly, they found that the adjusted OR for death was substantially reduced (1.30 versus 1.55) by selecting a high-volume surgeon and a high-volume center. More importantly, they found that the adjusted OR for death was substantially reduced (1.30 versus 1.55) by selecting a high-volume surgeon and a high-volume center. The positive volume-outcome relationship after CABG has been consistent across patient risk categories, suggesting that initiatives to divert patient care to high-volume surgeons and centers should not be restricted to high-risk subgroups [9–11].

Data from the congenital heart disease population have been mixed regarding the nature and importance of the volume–outcome relationship [1–8, 18], although there are relatively few studies that have included analyses based on both surgeon and institutional volume [1, 4]. Welke and colleagues [2] found, using the Nationwide Inpatient Sample, that volume alone was a marginal discriminator of mortality with a c statistic (area under the receiver operating characteristic curve) of 0.5. In agreement with these data, Pasquali and associates [7] showed among 53 centers contributing Norwood cases to the STSCHSD that institutional volume was modestly associated with in-hospital mortality and that it explained only 14% of the between-center mortality variation. Welke and colleagues [6] identified similar relationships between center volume and mortality among high-complexity or difficult operations (including Norwoods) using the STSCHSD. Adjusted mortality rate for these high-complexity procedures decreased from 14.8% at small programs to 8.4% at those programs performing more than 350 cases per year. Conversely, performance of small programs was nearly equivalent with larger programs for lower-complexity procedures. As noted previously by others, model discrimination improved significantly (from 0.53 to 0.84) after addition of patient risk factors and case mix to center volume alone.

Table 1. Patient Characteristics, Operative Characteristics, and Outcomes Stratified by Center Volume Tertiles

<table>
<thead>
<tr>
<th>Variable</th>
<th>0–2 Cases/y (n = 731)</th>
<th>5–10 Cases/y (n = 926)</th>
<th>&gt;10 Cases/y (n = 747)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (days)</td>
<td>7 (5–10)</td>
<td>6 (5–8)</td>
<td>6 (4–10)</td>
<td>0.097</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>3.4 (3.0–3.7)</td>
<td>3.4 (3.0–3.7)</td>
<td>3.4 (3.0–3.7)</td>
<td>0.455</td>
</tr>
<tr>
<td>Weight &lt; 2.5 kg</td>
<td>52 (7%)</td>
<td>45 (5%)</td>
<td>48 (6.4%)</td>
<td>0.137</td>
</tr>
<tr>
<td>Any preoperative risk factor</td>
<td>337 (46%)</td>
<td>473 (51%)</td>
<td>390 (52%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Operative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>178 (152–216)</td>
<td>166 (142–193)</td>
<td>141 (118–167)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cross-clamp time (min)</td>
<td>104 (82–127)</td>
<td>93 (79–117)</td>
<td>76 (61–95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>20 (14–28)</td>
<td>17 (13–23)</td>
<td>516 (12–23)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Discharge mortality</td>
<td>242 (5.7%)</td>
<td>473 (51%)</td>
<td>390 (52%)</td>
<td>0.137</td>
</tr>
<tr>
<td>Major complication</td>
<td>383 (46%)</td>
<td>461 (49%)</td>
<td>424 (56%)</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Values are median and interquartile range.

Table 2. Patient Characteristics, Operative Characteristics, and Outcomes Stratified by Surgeon Volume Tertiles

<table>
<thead>
<tr>
<th>Variable</th>
<th>0–2 Cases/y (n = 390)</th>
<th>3–6 Cases/y (n = 1514)</th>
<th>&gt;6 Cases/y (n = 453)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (days)</td>
<td>7 (5–10)</td>
<td>7 (4–9)</td>
<td>6 (4–8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>3.4 (3.0–3.7)</td>
<td>3.4 (3.0–3.7)</td>
<td>3.3 (2.9–3.6)</td>
<td>0.002</td>
</tr>
<tr>
<td>Weight &lt; 2.5 kg</td>
<td>28 (7%)</td>
<td>72 (5%)</td>
<td>43 (10%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Any preoperative risk factor</td>
<td>176 (45%)</td>
<td>777 (51%)</td>
<td>234 (52%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Operative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>182 (156–218)</td>
<td>162 (137–192)</td>
<td>146 (117–173)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cross-clamp time (min)</td>
<td>99 (80–123)</td>
<td>93 (77–118)</td>
<td>75 (57–89)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>19 (13–28)</td>
<td>18 (13–25)</td>
<td>5 (12–23)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Discharge mortality</td>
<td>26 (6.7%)</td>
<td>45 (3.0%)</td>
<td>8 (1.8%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Major complication</td>
<td>72 (18.5%)</td>
<td>223 (14.7%)</td>
<td>52 (11.5%)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Values are median and interquartile range.

CPB = cardiopulmonary bypass.
Interestingly, our results, as anticipated, were different from those reported by Hornik and coworkers [1] for the Norwood procedure. In the Norwood analysis, although both surgeon and center volume were important, center volume effects on outcome appeared to be greater relative to surgeon volume effects. Karamlou and colleagues [4] previously demonstrated that volume–outcome relationships can be disparate within different congenital heart disease subgroups in a Congenital Heart Surgeons’ Society (CHSS) study that included infants in four diagnostic or procedural subgroups (Norwood, interrupted aortic arch, pulmonary atresia with intact ventricular septum, and transposition of the great arteries [TGA]). Infants with TGA undergoing ASO were the only group in whom higher surgeon and institutional volume improved time-related survival.

### Table 3. Relationship of Surgeon Volume and Center Volume on Composite End Point

<table>
<thead>
<tr>
<th>Model Without Surgeon Volume</th>
<th>Model With Surgeon Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Center Volume</strong></td>
<td><strong>Adjusted Odds Ratio</strong></td>
</tr>
<tr>
<td>2 cases (versus 10 cases)</td>
<td>1.92 (1.23–2.99)</td>
</tr>
<tr>
<td>5 cases (versus 10 cases)</td>
<td>1.38 (1.12–1.70)</td>
</tr>
<tr>
<td>7 cases (versus 10 cases)</td>
<td>1.15 (1.05–1.27)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Without Center Volume</th>
<th>Model With Center Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Surgeon Volume</strong></td>
<td><strong>Adjusted Odds Ratio</strong></td>
</tr>
<tr>
<td>1 case (versus 6 cases)</td>
<td>2.16 (1.42–3.26)</td>
</tr>
<tr>
<td>3 cases (versus 6 cases)</td>
<td>1.50 (1.26–1.77)</td>
</tr>
<tr>
<td>5 cases (versus 6 cases)</td>
<td>1.11 (1.05–1.18)</td>
</tr>
</tbody>
</table>

*Relative attenuation is defined as \((\text{OR}_C – \text{OR}_{SC})/\text{OR}_C\) – 1, where \(\text{OR}_C\) is derived from the models with only center volume (left columns), and \(\text{OR}_{SC}\) is derived from the models with both surgeon and center volume (right columns).

CI = confidence interval.

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Fig 3. Predicted composite end point rates of a patient with population average risk for the hospital volume model including surgeon volume (blue line) and not including surgeon volume (red line); thinner lines indicate 95% confidence interval; both models are adjusted for patient risk factors. Note the modulating effect of surgeon volume on outcome.

Fig 4. Predicted composite end point rates of a patient with population average risk for the surgeon volume model including hospital volume (blue line) and not including hospital volume (red line); thinner lines indicate 95% confidence interval; both models are adjusted for patient risk factors. As compared with Figure 3, note that the predicted risk of achieving the composite end point is negligibly altered by the addition of hospital volume.
There are several reasons for lack of consensus regarding the relationship between volume and mortality in congenital heart surgery [1, 2, 6, 7, 18–22]. The use of clinical versus administrative datasets for investigation of this relationship has received increased attention [18–22]. Pasquali and associates [21] demonstrated that these types of data have discrepancies in case ascertainment that translated into important differences in mortality statistics. Heterogeneity in definitions (even with seemingly obvious metrics such as in-hospital mortality), limited statistical power, and dynamic interactions with other influential variables (ie, patient factors) are other potential sources of variable results. Other academic datasets that contain granular patient-level information and longitudinal follow-up, such as those maintained by the CHSS, are voluntary and costly to maintain. A recent study linking the STSCHSD and CHSS databases provided a denominator and therefore some insight into the generalizability of five of the active CHSS studies [22]. Patient enrollment in the CHSS studies, described as a proportion of patients identified as eligible using the STSCHSD, ranged from 34% to 40%. Furthermore, the CHSS cohorts may have limited comparability to our present study as the CHSS transposition cohort circumscribed a discrete change in surgical practice (ie, transition from the atrial switch to ASO) [4].

The results of our present study are important because they suggest that improving early outcomes after ASO might require unique initiatives from those designed to improve Norwood outcomes. Survival for palliated single-ventricle patients is likely to be more dependent on preoperative and postoperative management than survival after complete repair in a biventricular circulation. Larger centers may have access to resources unavailable in smaller centers, including 24/7 coverage in the intensive care unit, rapid deployment extracorporeal life support, home-monitoring programs, and so forth. Additionally, the Norwood operation can be applied in a heterogeneous anatomic population with variable patient risk, whereas the ASO is confined to a relatively homogeneous population. Ultimately, our findings suggest that initiatives designed to improve surgeon performance may be valuable in reducing ASO morbidity and mortality. Traditional methods such as maintenance of board certification and continuing medical education have limited ability to provide meaningful evaluation of surgical skill [23]. Recent focus on the utility of benchmarking and participation in clinical registries could provide important and timely feedback to surgeons and centers regarding their performance. Birkmeyer and colleagues [24] recently showed a clear relationship between surgical proficiency and improved outcomes among bariatric surgeons, and suggested that a peer rating system for assessment of individual surgeon skill might be a more effective strategy. Similar concepts prompted development of so-called technical performance scores for congenital heart operations that can be applied to evaluate the adequacy of surgical repair [8, 25]. These scores have been positively correlated with improved outcomes for both ASO ± VSD and the Norwood operation [8, 25]. Confidential, periodic review of identified underperformers combined with shared expertise and targeted mentorship may translate into a reduction in mortality and complications. Although regionalization of care for high-complexity lesions has been proposed previously [8], such strategies will undoubtedly limit access to care for some patients, impose socioeconomic hardships on families, and potentially lead to treatment delays. Furthermore, there are low-volume surgeons and hospitals that provide excellent care and, conversely, high-volume surgeons and centers that provide relatively poor care. It remains unclear, therefore, whether regionalization for congenital heart surgery based on volume alone is feasible or even desirable.

Limitations
The limitations of this study are primarily related to the nature of the STSCHSD. Although it is the largest pediatric heart surgery registry in North America, not all US centers participate. In addition, although data for standard core data fields are nearly complete, not all centers submit complete data for all variables captured by the database, and are thus not included in the analysis. Therefore, our results may not be generalizable to all US centers. In addition, we included patients with both isolated TGA and TGA with VSD; thus the center and surgeon volume numbers in our analysis will be slightly higher compared with analyses restricted to patients with isolated TGA. Because there was a lower mortality after ASO or ASO ± VSD compared with the Norwood analysis by Hornik and colleagues [1], a composite end point was selected as it was more clinically applicable and also increased statistical power. This may limit comparability with the study by Hornik and colleagues [1] and other studies focused on a volume–mortality relationship alone. Additionally, volume tertiles for surgeons were concentrated in the arguably low-volume end of the spectrum given the relatively large number of surgeons included. Although we were able to include many patient preoperative risk factors in our analysis of patient risk status, not all potential risk factors were collected in the database. The database does contain specific definitions for all variables, but cannot exclude variation in coding across centers. Finally, although the database does currently capture information regarding some process measures, information regarding personnel, or hospital structure or process measures were unavailable for this analysis; therefore, we are unable to evaluate the relationship of these factors to surgeon volume, center volume, or outcome.

Conclusions
Both center and surgeon volume influence early outcome after ASO; however, surgeon volume appears to be the more important factor. The importance of annual surgeon and center ASO volume should be considered in the context of any initiative to improve outcomes from management of patients with TGA.
CONGENITAL HEART SURGERY

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DISCUSSION

DR NAHIDH W. HASANIYA (Loma Linda, CA): Did you consider the experience of the surgeon because maybe the high-volume surgeons are more experienced surgeons? This is why all this versus the actual number. Thank you.

DR KARAMLOU: Thank you for your question. So, the experience of the respective surgeon is not something that we were able to capture with the STS (The Society of Thoracic Surgeons) dataset. It’s a very important question but I cannot answer it using the STS data. However, we looked at this question with a cohort of four diagnostic lesions or procedures as part of a CHSS (Congenital Heart Surgeons’ Society) study. One of these lesions was TGA (transposition of the great arteries), and so we investigated outcomes for the arterial switch based upon surgeon experience factors. Experience was defined by four total factors, some of which were the number of cases that a surgeon had done both since the inception of the study cohort, the number of cases per year, and the increase in their case velocity over time. The arterial switch was one of the operations (in contrast to the Norwood) in which all of the experience factors were significantly associated with improved time-related survival. I would infer, based upon this similarity, that experience would be equally important in the present study.

DR BOHDAN MARUSZEWSKI (Warsaw, Poland): Tara, did you differentiate between the arterial switch and the switch plus VSD (ventricular septal defect) closure? Because in both databases, STS and the AATS (American Association for Thoracic Surgery),

References

there are substantial differences in the outcomes between those two procedures.

DR KARAMLOU: Yes, there is a difference, and our data confirmed this to be true. However, in contrast to the Norwood operation where the number of centers was about 79, we had 84. The number of surgeons in the Norwood paper was about 90; we had 155.

So because of the limitations of statistical power, owing both to the increased number of surgeons and centers and to the decreased mortality rate of the switch as compared to the Norwood, we elected to combine both transposition and transposition with VSD.

DR MARUSZEWSKI: Thank you.

DR PRANAVA SINHA (Washington, DC): Excellent presentation. Two questions for you. Did you take into account how many of these cases were done by trainees? Does the STS database give you that data because I would assume it would go under the mentor surgeon’s name.

DR KARAMLOU: I’m sorry. I couldn’t hear the first part of your question.

DR SINHA: Did you take into account how many of these were done by trainees under some senior surgeon’s supervision? And secondly, based on this data, how do you propose that the current mentorship model needs to be modified?

DR KARAMLOU: So those are both very good and, unfortunately, the second is potentially lengthy to answer. Regarding the first question, in the STS database, there is a field where you can enter if there was a resident present, but there is no way to discern whether the resident was the primary surgeon or an assistant. Moreover, it is not possible to determine even if we knew the resident was the surgeon, whether he/she performed the critical portions of the procedure. I cannot, therefore, address your question with this dataset.

I can tell you that the range of surgeons that were operating at these institutions, there were 28 centers who had one surgeon doing all of the switches, and those, as you might expect, were the lower-volume centers. And then there was a couple of institutions that had many surgeons, one as many of six. It is likely that the larger centers had trainees whereas the smaller-volume centers did not have trainees.

In terms of how would we change our current paradigm for mentorship, I think that’s a much more difficult question to answer. Technical performance scores, which Dr Nathan will address, and feedback mechanisms that hopefully will come from that might be additional methods to improve mentorship. Additionally, the ACGME (Accreditation Council for Graduate Medical Education) -accredited fellowship in congenital cardiac surgery may also provide a better structured and validated experience for residents, but this is speculation.

DR JAMES S. TWEDDELL (Milwaukee, WI): That was a very nice presentation, so I’m just going to ask you the easy question. Why is institutional experience so important for the Norwood and more important than for the arterial switch operation?

DR KARAMLOU: So, again, these are speculative. I hypothesized in the manuscript that the heterogeneity of the population studied in the Norwood paper (ie, it was not restricted to HLHS [hypoplastic left heart syndrome]) may increase the number of confounders compared to a very homogeneous population studied in the present study.

Secondly, for neonates after the Norwood operation, systems and process issues such as 24/7 coverage in your ICU (intensive care unit), preoperative length of stay of, variability in management in the perioperative period, the presence of a rapid-deployment ECMO (extracorporeal membrane oxygenation) program probably have a greater impact in a single-ventricle patient than in a biventricular circulation such as after a switch operation. If this hypothesis is correct, then center issues may have a more important impact than surgeon-only factors.

DR DAVID M. OVERMAN (Minneapolis, MN): Tara, one last question. I noticed on the institutional volume slide, the hazard function started to rise in the higher-volume end of the graphic as opposed to the surgeon volume data, which was a continual decay of risk. Could you speculate as to why that might be?

DR KARAMLOU: Yes. I think that’s more a function of how volume was modeled in this paper. In our sensitivity analysis, we investigated volume using restricted cubic splines with different knots to determine how sensitive was the prediction based on how volumes are parameterized.

For the institutions, the outcome was more sensitive, and you may have been able to model it in a slightly different way. I can tell you that the relationship still held true, there was a decrement going from high to medium to low, but it wasn’t as strong as the one that you saw just for surgeon volume.

DR OVERMAN: Thank you.