The Society of Thoracic Surgeons Adult Cardiac Surgery Database: 2018 Update on Research: Outcomes Analysis, Quality Improvement, and Patient Safety

Vinay Badhwar, MD, J. Scott Rankin, MD, Vinod H. Thourani, MD, Richard S. D'Agostino, MD, Robert H. Habib, PhD, David M. Shahian, MD, and Jeffrey P. Jacobs, MD

Department of Cardiovascular and Thoracic Surgery, West Virginia University, Morgantown, West Virginia; Department of Cardiac Surgery, MedStar Heart and Vascular Institute and Georgetown University, Washington, DC; Division of Thoracic and Cardiovascular Surgery, Lahey Hospital and Medical Center, Burlington, Massachusetts; The Society of Thoracic Surgeons Research Center, Chicago, Illinois; Center for Quality and Safety, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts; and Division of Cardiovascular Surgery, Johns Hopkins University, Johns Hopkins All Children's Heart Institute, Johns Hopkins All Children's Hospital, Saint Petersburg, Florida

The Society of Thoracic Surgeons Adult Cardiac Database (ACSD) is an international voluntary registry that provides adult cardiac surgery programs with risk-adjusted outcome reports for quality improvement. With more than 6,300,000 procedural records in adult cardiac surgery, the ACSD has proven to be a leading instrument for clinical outcomes research. The ACSD generated numerous major original contributions that were either published or accepted for publication in 2017. These works significantly contributed to the practice of adult cardiac surgery through outcome measurement and quality improvement. This paper summarizes the recent ACSD contributions to the literature.

(Ann Thorac Surg 2018;106:8–13)

Since its inception in 1989, The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) has exceeded 6.3 million patient records to become one of the preeminent clinical data registries in the world. The STS, in cooperation with the Duke Clinical Research Institute as its data warehouse and analytic center, has leveraged the ACSD for more than 2 decades to provide leadership in the areas of statistical risk modeling, quality improvement, voluntary public reporting, and clinical research. The database currently includes 1,088 US participants, 31 international participants, and 3,108 surgeons. The ACSD represents more than 95% of all US cardiac operations performed annually, with yearly audits to certify data quality, accuracy, and completeness [1–4].

The ACSD has facilitated establishing several national trends in cardiac surgical practice. These have included data-driven decision making, observational outcomes research, and cost assessments. Analyses from the ACSD have been used for value-based reimbursement, best-practice protocols, voluntary public reporting, and clinical guideline development. Risk-adjusted quality metrics, developed by STS and endorsed by the National Quality Forum, provide comprehensive perspectives on cardiac surgical quality. Linkage of the ACSD to additional government health care registries now permit longer-term analysis of late results and readmissions [4]. This report summarizes the contributions of the ACSD in the areas of clinical outcome analyses and quality improvement that were either published or accepted for publication in 2017.

Clinical Outcome Analyses

Coronary Artery Bypass Graft Surgery

Two studies investigated contemporary topics in coronary artery bypass graft surgery (CABG) [5, 6]. Schwann and colleagues [5] highlighted contemporary 30-day or inhospital operative outcomes for multiarterial CABG stratified by the conduit type other than the left internal thoracic artery [5]. All patients received a left internal thoracic artery graft. There were 73,054 patients who received bilateral internal thoracic artery (BITA) multiarterial bypass grafts (MABG), 97,623 who received a radial artery (RA) MABG, and 1,334,511 whose additional grafts were saphenous vein (SABG). The groups showed distinctly different patient characteristics: SABG (73.8% men; median age, 66 years); BITA-MABG (85.1% men; median age, 59 years); and RA-MABG (82.5% men; median age, 61 years). Operative mortality for SABG was 1.91%, which was higher than for BITA-MABG (1.19%,

Address correspondence to Dr Badhwar, Department of Cardiovascular and Thoracic Surgery, West Virginia University, 1 Medical Center Dr, Morgantown, WV 26506; email: vinay.badhwar@wvumedicine.org.

Published by Elsevier Inc.

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2018.04.052

Abbreviations and Acronyms

ACSD	= Adult Cardiac Surgery Database
BITA	= bilateral internal thoracic arteries
CABG	= coronary artery bypass graft surgery
CI	= confidence interval
HR	= hazard ratio
MABG	= multiarterial bypass graft
MVRR	= mitral valve repair/replacement
O/E	= observed-to-expected ratio
ONCABG	= on-pump coronary artery bypass graft surgery
OPCABG	= off-pump coronary artery bypass graft surgery
OR	= odds ratio
RA	= radial artery
SABG	= saphenous vein bypass graft
SAVR	= surgical aortic valve replacement
STS	= The Society of Thoracic Surgeons
TAVR	= transcatheter aortic valve replacement
TVR	= tricuspid valve repair

$p < 0.001$) and RA-MABG (1.19%, $p < 0.001$). The incidence of deep sternal wound infection for SABG was 0.73%, lower than that associated with BITA-MABG (1.08%, $p < 0.001$) yet similar to that of RA-MABG (0.71%, $p = 0.55$). BITA-MABG showed a marginally and not clinically significant increased risk-adjusted operative mortality to SABG (odds ratio [OR] 1.14, 95% confidence interval [CI: 1.00 to 1.30) but a doubled risk for deep sternal wound infection (OR 2.09, 95% CI: 1.80 to 2.43). RA-MABG had operative mortality (OR 1.01, 95% CI: 0.89 to 1.15) and deep sternal wound infection risk (OR 0.97, 95% CI: 0.83 to 1.13) similar to that of SABG. The researchers conclude that MABG in the United States is associated with mortality risk comparable to that of SABG but an increased deep sternal wound infection risk exists with BITA-MABG. These short-term results should not in any way dissuade the use of MABG, given its well-established long-term survival advantage.

Keeling and colleagues [6] examined the outcomes of patients for planned off-pump CABG (OPCABG) in whom a conversion to an on-pump CABG (ONCABG) was required. A total of 196,576 patients undergoing planned OPCABG within the ACSD from July 2007 to June 2014 were evaluated. Patients were grouped according to the reason for intraoperative conversion to cardiopulmonary bypass: (1) planned conversion; (2) unplanned conversion for visualization; (3) unplanned conversion for hemodynamic instability; and (4) no conversion. The overall rate of OPCABG conversion to ONCABG was 5.5%, with 49.6% of the conversions being planned. Patients not undergoing conversion had an observed-to-expected ratio [O/E] 30-day mortality of 0.8. Patients undergoing conversion to ONCABG had worse outcomes regardless of etiology of conversion (planned conversion O/E 1.4, unplanned conversion for visualization O/E 1.6, and unplanned conversion for hemodynamic instability O/E 2.7). Similar

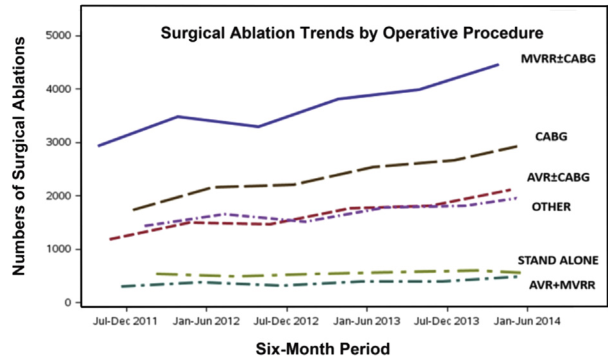

Fig 1. Trends of surgical ablation in the United States by operative procedure. (Reproduced from [7] with permission from The Society of Thoracic Surgeons.) (AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; MVRR = mitral valve repair/replacement.)

O/E ratios were observed for renal failure and prolonged ventilation after conversion. Logistic regression analysis showed advanced age, ejection fraction less than 35%, preoperative intraaortic balloon pump placement, increasing number of diseased coronary arteries, preoperative heart failure within 2 weeks, and urgent procedural status were all independent predictors for conversion to ONCABG ($p \leq 0.01$). The investigators concluded that intraoperative conversion from OPCABG to ONCABG remains a morbid event with a risk of mortality much higher than expected and that surgeons should instead consider elective ONCABG for cases with a high predictive risk for conversion.

Atrial Fibrillation

Two studies involved perioperative management of atrial fibrillation. The first examined the contemporary outcomes of surgical ablation in the United States [7]. This study of 86,941 patients with preoperative atrial fibrillation undergoing primary nonemergent operations from July 2011 to June 2014 revealed an increased application of surgical ablation across all operative categories (Fig 1). Overall, 48.3% (42,066 of 86,941) underwent surgical ablation, with the highest rate occurring with mitral valve repair or replacement (MVRR) operations at 68.4% (14,693 of 21,496) and the lowest with isolated CABG at 32.8% (9,156 of 27,924). After propensity matching of two groups of 28,739 patients with or without surgical ablation, it was found that adding an ablation resulted in a clear reduction of operative mortality and stroke (Table 1). This paper supports current guideline recommendations [8] for a wider application of surgical ablation for atrial fibrillation, when appropriate, as a method of increasing quality outcomes.

For patients with atrial fibrillation undergoing cardiac surgery, Friedman and colleagues [9] utilized the STS ACSD to analyze the impact of surgical left atrial appendage obliteration on longitudinal thromboembolism. The researchers examined 10,524 patients undergoing surgery with preoperative atrial fibrillation of whom 3,892 underwent surgical obliteration of the left

Table 1. Relative Risks of Performing Concomitant Surgical Ablation in Propensity Matched Patients With Atrial Fibrillation[a]

Outcome	Overall (n = 57,478)	No Ablation (n = 28,739)	Ablation (n = 28,739)	Relative Risk (95% CI)	*p* Value
Mortality	4.31 (2,480)	4.5 (1,292)	4.13 (1,118)	0.92 (0.85–1.00)	0.0422
Reoperation for bleeding	3.61 (2,075)	3.73 (1,073)	3.49 (1,002)	0.93 (0.86–1.02)	0.1195
Permanent stroke	1.96 (1,124)	2.13 (612)	1.78 (512)	0.84 (0.74–0.94)	0.0028
Transient ischemic attack	0.38 (218)	0.42 (121)	0.34 (97)	0.80 (0.61–1.05)	0.1064
Prolonged ventilation >48 hours	16.31 (9,373)	16.75 (4,813)	15.87 (4,560)	0.95 (0.90–0.99)	0.0224
Renal failure	4.62 (2,585)	4.35 (1,219)	4.88 (1,366)	1.12 (1.03–1.22)	0.0107
Pacemaker	6.87 (3,946)	5.89 (1,693)	7.84 (2,253)	1.33 (1.24–1.43)	<0.0001
Phrenic nerve injury	0.06 (33)	0.06 (16)	0.06 (17)	1.06 (0.53–2.14)	0.8655
Readmission 30 days	13.36 (7,347)	12.79 (3,511)	13.92 (3,836)	1.09 (1.03–1.15)	0.0011

[a] Reproduced from [7] with permission from The Society of Thoracic Surgeons.

Values are percentage (n).

CI = confidence interval.

atrial appendage. The STS data were linked to the Centers for Medicare and Medicaid Services registry to track readmissions for stroke. At a mean follow-up of 2.6 years, patients with surgical appendage obliteration versus no obliteration had lower rates of thromboembolism (4.2% versus 6.2%), all-cause mortality (17.3% versus 23.9%), and the composite endpoint of stroke and mortality (20.5% versus 28.7%), but no significant difference in rates of hemorrhagic stroke (0.9% versus 0.9%). After inverse probability weighted adjustment, surgical left atrial appendage occlusion was associated with a significantly lower rate of thromboembolism (hazard ratio [HR] 0.67) and all-cause mortality (HR 0.88) but not hemorrhagic stroke. These findings support the use of left atrial occlusion in patients with atrial fibrillation undergoing cardiac surgery and have relevance to ongoing randomized trials examining surgical or interventional occlusion.

Aortic Valve Replacement

The next two studies evaluated contemporary outcomes with surgical aortic valve replacement (SAVR) and transcatheter aortic valve replacement (TAVR).

Bavaria and colleagues [10] assessed all ACSD US surgeon-participants to determine surgeon-level involvement and performance during TAVR. Among the 487 surgeon respondents in the ACSD, 410 (84.2%) reported that TAVR was performed at their institutions. From the survey, 77.5% (313 of 404) noted TAVR was performed within the function of a heart team and 83.7% (339 of 405) noted that both cardiologists and surgeons were jointly responsible for TAVR referrals. Almost all sites documented surgeon involvement in the preoperative, intraoperative, and postoperative care of patients undergoing TAVR: 91.4% (370 of 405) participate in multidisciplinary meetings, 86.6% (266 of 307) manage TAVR postoperatively, and at least 50% regularly performed a majority of the technical aspects of the procedure. This paper, based on voluntary surgeon-respondents, noted that cardiac surgeons continue to play a critical part of TAVR operations and that the heart team model should be replicated for all other areas of structural heart disease.

Brennan and colleagues [11] performed a propensity matched analysis to determine the outcomes of SAVR versus TAVR in intermediate and high-risk patients. Data from the STS ACSD and the STS/American College of Cardiology Transcatheter Valve Therapy Registry were linked to Centers for Medicare and Medicaid Services administrative claims data for longitudinal follow-up. From the Centers for Medicare and Medicaid Services-linked cohorts, 9,464 propensity matched US patients who underwent commercial TAVR or SAVR were identified and analyzed. The median age was 82 years, with 48% women, and a median STS predicted risk of mortality score of 5.6%. Patients undergoing TAVR or SAVR had no difference in 1-year rates of death (17.3% versus 17.9%; HR 0.93, 95% CI: 0.83 to 1.04) and stroke (4.2% versus 3.3%; HR 1.18, 95% CI: 0.95 to 1.47). Similarly, no difference was observed in days alive and out of the hospital to 1 year (HR 1.00, 95% CI: 0.98 to 1.02). In this matched cohort, however, TAVR patients were more likely to be discharged home postoperatively (69.9% versus 41.2%; OR 3.19, 95% CI: 2.84 to 3.58). That illustrated relatively similar outcomes between SAVR and TAVR in an intermediate and high-risk population.

Aortic Arch Operations

The depth of hypothermia and the modality of cerebral perfusion during circulatory arrest–facilitated aortic arch operations remains an area of controversy. Englum and colleagues [12] examined 12,521 arch operations under circulatory arrest in the STS ACSD between 2011 and 2014 and divided these into deep hypothermia (20°C), low-moderate hypothermia (20.1° to 24°C), and high-moderate hypothermia (24.1° to 28°C). Furthermore, cerebral perfusion strategy was examined and included none, antegrade or retrograde, or both. After adjusting for potential confounders, strategies were compared using a composite endpoint (operative mortality or neurologic complication). Surprisingly, the three most common strategies utilized were straight deep hypothermia with no cerebral perfusion (25%), deep hypothermia with retrograde perfusion (16%), and deep hypothermia with antegrade perfusion (14%). Overall rates of the composite endpoint of operative mortality and stroke were 23%, 12%, and 8%, respectively. Among the most common strategies, not utilizing cerebral perfusion was associated with significantly higher risk of the composite endpoint of risk-adjusted operative mortality and stroke (OR 1.6, $p < 0.01$). There was no clearly superior strategy among remaining techniques or combinations, suggesting that as long as cerebral perfusion is utilized, similar outcomes may be expected until randomized trials provide more information.

Tricuspid Valve Repair During Mitral Surgery

An analysis of the STS ACSD was performed to evaluate the risk of concomitant tricuspid valve repair (TVR) in patients undergoing MVRR with or without CABG at incremental grades of preoperative tricuspid regurgitation [13]. Between July 2011 and June 2014, 88,473 MVRR patients (isolated MVRR, n = 62,118; MVRR plus CABG, n = 26,355) were examined. Outcomes with or without TVR were independently analyzed at three levels of tricuspid regurgitation: none-mild, moderate, and severe. Risk-adjusted mortality and major morbidity was compared between patients with or without TVR. Overall risk-adjusted occurrence of any morbidity associated with performance of TVR was increased in both MVRR (OR 1.36) and MVRR plus CABG (OR 1.33), but at all grades of tricuspid regurgitation, TVR was not associated with increased risk-adjusted mortality. This contemporary analysis reveals that concomitant TVR was not associated with a risk-adjusted increase in mortality, regardless of tricuspid regurgitation severity, and therefore, a more aggressive approach to concomitant TVR may be justified if medically appropriate.

Postoperative Care

Postoperative pneumonia rates are hypothesized to be related to preoperative comorbidity. Brescia and colleagues [14] examined 324,085 isolated CABG patients from 998 STS ACSD participants between 2011 and 2013 and applied multivariable analyses to determine whether other factors may be involved in the occurrence of postoperative pneumonia. Although 9,175 patients (2.83%) had pneumonia, there was wide variability in pneumonia rates between participants, with some hospitals having rates more than six times higher than others (10th to 90th percentile: 1.0% to 6.1%). After multiple regression models, only 2.05% of hospital variation in pneumonia rates was explained collectively by traditional patient comorbid risk factors, leaving 97.95% of variation unexplained. As patient risk profiles accounted only for a fraction of hospital variation in pneumonia rates, these findings suggest that improvement in processes of postoperative care may be required to reduce the majority of such nosocomial infections.

Quality Improvement

Coronary Artery Bypass Grafting

In an attempt to answer whether outcome differences exist when surgeons operate in more than one hospital, Shroyer and colleagues [15] examined 543,403 isolated CABG patients from the STS ACSD between 2011 and 2014 to compare risk-adjusted outcomes between single-center surgeons versus multicenter surgeons, and evaluate outcomes between the primary versus secondary hospital of multicenter surgeons. Of 2,676 cardiac surgeons, 668 (25%) operated at more than one center. The O/E mortality ratios were 1.06 (95% CI: 1.01 to 1.12) and 0.97 (95% CI: 0.94 to 1.00) for multicenter surgeons and single-center surgeons ($p < 0.001$). For multicenter surgeons, the O/E mortality ratios were 1.17 (95% CI: 1.09 to 1.27) versus 1.01 (95% CI: 0.96 to 1.07, $p < 0.001$), for their secondary versus primary facilities, respectively. Single-center surgeons had better outcomes than multicenter surgeons, and better outcomes for multicenter surgeons occurred at their home versus satellite hospital. The researchers conclude with a provocative call to scrutinize single-center versus multicenter surgeons in an attempt at quality improvement for CABG.

Overall Outcome Trends

D'Agostino and colleagues [4] recently updated the national outcomes and volume trends in adult cardiac surgery as summarized in the ACSD compared with prior years [4]. In this paper, the contemporary national aggregate outcomes and volume trends in cardiac surgery were documented. The most commonly performed operation continues to be CABG (Fig 2), and although baseline comorbid risk appears to be on the rise (Fig 3), so too are the volumes of aortic valve operations (Fig 4) and mitral valve operations (Fig 5).

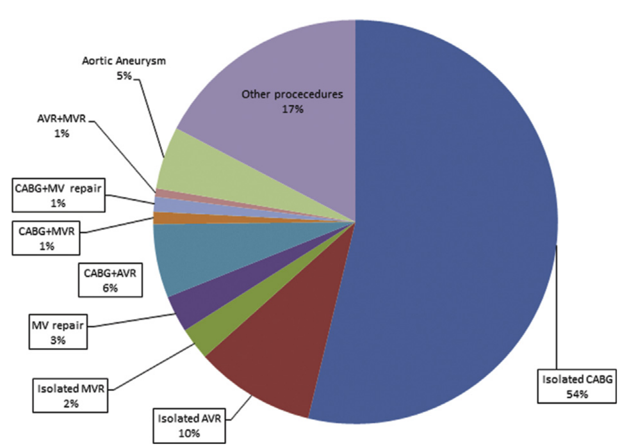

Fig 2. Proportions of cardiac surgical procedures performed in The Society of Thoracic Surgeons Adult Cardiac Surgery Database. (Reproduced from [4] with permission from The Society of Thoracic Surgeons.) (AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; MV = mitral valve; MVR = mitral valve replacement.)

Ann Thorac Surg
2018;106:8–13

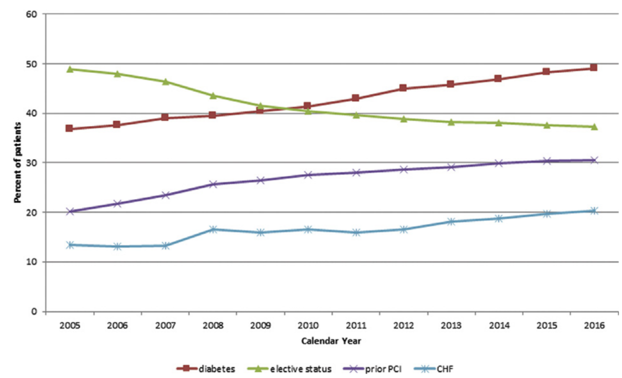

Fig 3. Trends in baseline comorbidity risk of cardiac operations. (Reproduced from [4] with permission from The Society of Thoracic Surgeons.) Red line indicates diabetes mellitus; green line, elective status; purple line, prior percutaneous coronary intervention (PCI); blue line, congestive heart failure (CHF).

Now with the ACSD in its 28th year, the researchers emphasize the value and importance of the ACSD in producing comprehensive, accurate, and highly detailed clinical data that, in turn, advances quality and safety in cardiac surgery. D'Agostino and associates [4] note that ongoing improvements to the ACSD will continue to position it at the forefront of clinical databases in health care and will ensure that our specialty remains a leader in providing the highest quality and value care available.

International STS Database Participation

The merits of the ACSD articulated by D'Agostino [4] provide encouragement to a growing number of international participants. Some countries are attempting to establish a "de novo" national clinical database, but several have noted that is not a straightforward endeavor. Shapira and colleagues [16, 17] from Jerusalem have been early participants in the STS ACSD and their experience has helped lead the way for many international sites

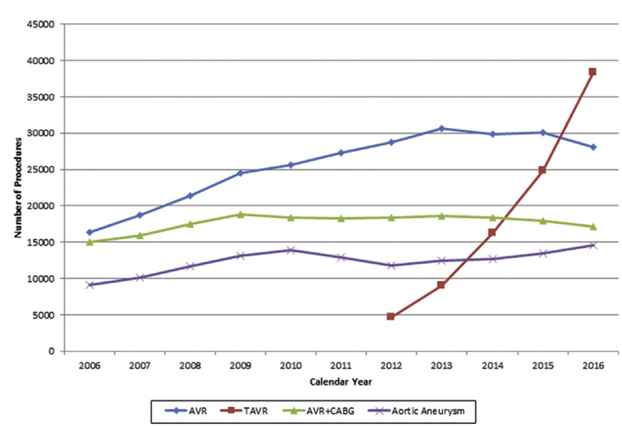

Fig 4. Aortic valve operations. (Reproduced from [4] with permission from The Society of Thoracic Surgeons.) Blue line indicates aortic valve replacement (AVR); red line, transcatheter aortic valve replacement (TAVR); green line, AVR plus coronary artery bypass graft surgery (CABG); purple line, aortic aneurysm.

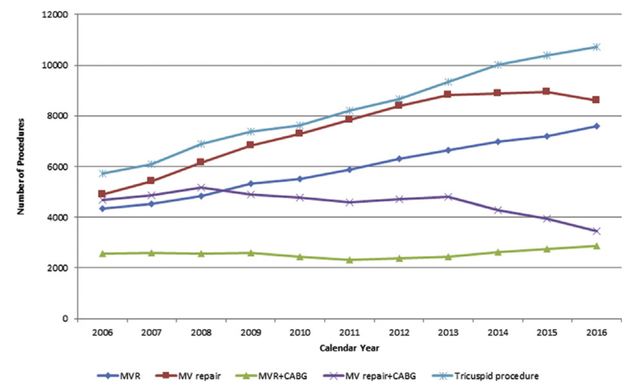

Fig 5. Trends in mitral and tricuspid operations. (Reproduced from [4] with permission from The Society of Thoracic Surgeons.) Dark blue line indicates mitral valve replacement (MVR); red line, mitral valve (MV) repair; green line, MVR plus coronary artery bypass graft surgery (CABG); purple line, MV repair plus CABG; light blue line, tricuspid procedure.

regarding the steps and methods of STS ACSD participation. They recently documented their journey from a single participant site to the use of the STS ACSD as a national database platform across all sites in Israel [17]. They outline five steps in their journey: (1) group decision; (2) funding; (3) contractual relationships among participating centers and the STS; (4) design and construction of infrastructure; and (5) final implementation. Through the creation of a multicenter member steering committee, they were able to execute the delivery of implementation that covered institutional and patient-level penetration, user feedback, performance improvement, and insurance and hospital provider integration. They found that with the implementation of the STS ACSD at a national level, they were afforded the opportunity to monitor and improve quality while facilitating comparative effectiveness to improve resource allocation. Based on their experience, the researchers firmly believe that efforts to encourage ongoing participation in the STS ACSD by other countries should continue as the ACSD realizes its potential to impact quality as "a global force for good."

Quality Measurement Development

The STS Quality Measurement Task Force developed a composite performance measure for MVRR with concomitant CABG [18]. Rankin and colleagues [19] analyzed 26,463 patients undergoing MVRR plus CABG operations between July 1, 2011, and June 30,2014. In 2016, the STS developed an isolated MVRR composite [19]. These established STS risk models were applied to include patients with concomitant closures of atrial septal defects and patent foramen ovale, surgical ablation for atrial fibrillation, and TVR. Participants with fewer than 10 eligible cases over 3 years were excluded from composite performance. The MVRR plus CABG composite consisted of two domains: risk-adjusted mortality, and the any-or-none occurrence of major morbidity (prolonged ventilation, deep sternal infection, permanent stroke, renal failure, and reoperation). Composite performance scores were calculated with the use of hierarchical regression models, and high-performing and low-performing outliers were determined with the use of 95% Bayesian credible intervals. Two percent of programs (14 of 703) were classified as one-star programs (lower than expected performance), 95% (666 of 703) were classified as two-star programs (as-expected performance), and 3% (23 of 703) were classified as three-star programs (higher than expected performance). A monotonic decline in both mortality and morbidity was observed as star rating scores increased. This measure, now endorsed by the National Quality Forum, may be used for future MVRR public reporting initiatives planned for 2019.

In summary, data from the STS ACSD have facilitated several important contributions in the areas of clinical outcome enhancement and quality measurement over the past year. Clinically oriented outcome analyses were published in key areas of adult cardiac surgery including CABG, aortic arch surgery, TAVR/SAVR, atrial fibrillation, postoperative pneumonia, and tricuspid repair in concomitant MVRR. Finally, updated contemporary clinical practice patterns and procedural trends were provided along with the development of a new composite measure for MVRR plus CABG as the STS ACSD continues its leadership of quality measurement for our specialty.

References

1. Jacobs JP, Shahian DM, Prager RL, et al. Introduction to the STS National Database series: outcomes analysis, quality improvement, and patient safety. Ann Thorac Surg 2015;100: 1992–2000.
2. Shahian DM. The Society of Thoracic Surgeons National Database: "What's past is prologue." Ann Thorac Surg 2016;101:841–5.
3. Winkley Shroyer AL, Bakaeen F, Shahian DM, et al. The Society of Thoracic Surgeons Adult Cardiac Surgery Database: the driving force for improvement in cardiac surgery. Semin Thorac Cardiovasc Surg 2015;27:144–51.
4. D'Agostino RS, Jacobs JP, Badhwar V, et al. The Society of Thoracic Surgeons Adult Cardiac Surgery Database: 2018 update on outcomes and quality. Ann Thorac Surg 2018;105: 15–23.
5. Schwann TA, Habib RH, Wallace A, et al. Operative outcomes of multiple-arterial versus single-arterial coronary bypass grafting. Ann Thorac Surg 2018;105:1109–19.
6. Keeling B, Thourani V, Aliawadi G, et al. Conversion from off-pump coronary bypass grafting to on-pump coronary bypass grafting. Ann Thorac Surg 2017;104:1267–74.
7. Badhwar V, Rankin JS, Ad N, et al. Surgical ablation of atrial fibrillation in the United States: trends and propensity matched outcomes. Ann Thorac Surg 2017;104: 493–500.
8. Badhwar V, Rankin JS, Damiano RJ, et al. The Society of Thoracic Surgeons 2017 clinical practice guidelines for the surgical treatment of atrial fibrillation. Ann Thorac Surg 2017;103:329–41.
9. Friedman DJ, Piccini JP, Wang T, et al. Association between left atrial appendage occlusion and readmission for thromboembolism among patients with atrial fibrillation undergoing concomitant cardiac surgery. JAMA 2018;319: 365–74.
10. Bavaria JE, Prager RL, Naunheim KS, et al. Surgeon involvement in transcatheter aortic valve replacement in the United States: a 2016 Society of Thoracic Surgeons survey. Ann Thorac Surg 2017;104:1088–93.
11. Brennan JM, Thomas L, Cohen DJ, et al. Transcatheter versus surgical aortic valve replacement: propensity-matched comparison. J Am Coll Cardiol 2017;70:439–50.
12. Englum BR, He X, Gulack BC, et al. Hypothermia and cerebral protection strategies in aortic arch surgery: a comparative effectiveness analysis from the STS Adult Cardiac Surgery Database. Eur J Cardiothorac Surg 2017;52: 492–8.
13. Badhwar V, Rankin JS, He M, et al. Performing concomitant tricuspid valve repair at the time of mitral valve operations is not associated with increased operative mortality. Ann Thorac Surg 2017;103:587–93.
14. Brescia AA, Rankin JS, Cyr DD, et al. Determinants of variation in pneumonia rates after coronary artery bypass grafting. Ann Thorac Surg 2018;105:513–20.
15. Shroyer ALW, Gioia WE, Bishawi M, et al. Single versus multicenter surgeons' risk-adjusted coronary artery bypass graft procedural outcomes. Ann Thorac Surg 2018;105: 1308–14.
16. Shapira OM, Badhwar V, Shahian D, et al. International participation in the Society of Thoracic Surgeons National Database. Ann Thorac Surg 2014;97:1127–30.
17. Shapira OM, Blumenfeld O, Bolotin G, et al. International participation in The Society of Thoracic Surgeons Adult Cardiac Surgery Database: from institutional to national. Ann Thorac Surg 2017;103:1683–6.
18. Rankin JS, Badhwar V, He X, et al. The Society of Thoracic Surgeons mitral valve repair/replacement plus coronary artery bypass grafting composite score: a report of The Society of Thoracic Surgeons Quality Measurement Task Force. Ann Thorac Surg 2017;103:1475–81.
19. Badhwar V, Rankin JS, He X, et al. The Society of Thoracic Surgeons mitral repair/replacement composite score: a report of The Society of Thoracic Surgeons Quality Measurement Task Force. Ann Thorac Surg 2016;101: 2265–71.