Penetration, Completeness, and Representativeness of The Society of Thoracic Surgeons Adult Cardiac Surgery Database

Jeffrey P. Jacobs, MD, David M. Shahian, MD, Xia He, MS, Sean M. O'Brien, PhD, Vinay Badhwar, MD, Joseph C. Cleveland, Jr, MD, Anthony P. Furnary, MD, Mitchell J. Magee, MD, Paul A. Kurlansky, MD, J. Scott Rankin, MD, Karl F. Welke, MD, Giovanni Filardo, PhD, MPH, Rachel S. Dokholyan, MPH, Eric D. Peterson, MD, MPH, J. Matthew Brennan, MD, Jane M. Han, MSW, Donna McDonald, RN, MPH, DeLaine Schmitz, MSHL, RN, Fred H. Edwards, MD, Richard L. Prager, MD, and Frederick L. Grover, MD

Division of Cardiac Surgery, Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland (JPJ); Division of Cardiovascular Surgery, Department of Surgery, Johns Hopkins All Children's Heart Institute, All Children's Hospital and Florida Hospital for Children, Saint Petersburg, Tampa, and Orlando, Florida (JPJ); Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts (DMS); Duke Clinical Research Institute (DCRI), Duke University, Durham, North Carolina (XH, SMO, RSD, EDP, JMB); University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania (VB); University of Colorado Denver, School of Medicine, Aurora, Colorado (JCC, FLG); Starr-Wood Cardiac Group, Portland, Oregon (APF); Medical City Dallas Hospital, Baylor University Medical Center Dallas, Dallas, Texas (MJM); Columbia University, New York, New York (PAK); Vanderbilt University, Nashville, Tennessee (JSR); Section of Congenital Cardiovascular Surgery, University of Illinois College of Medicine at Peoria, Children's Hospital of Illinois, Peoria, Illinois (KFW); Institute for Health Care Research and Improvement, Baylor Health Care System, Dallas, Texas (GF); The Society of Thoracic Surgeons (STS), Chicago, Illinois (JMH, DM, DS); University of Florida College of Medicine, Jacksonville, Florida (FHE); and University of Michigan, Ann Arbor, Michigan (RLP)

Background. **The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) has been successfully linked to the Centers for Medicare and Medicaid (CMS) Medicare database, thereby facilitating comparative effectiveness research and providing information about long-term follow-up and cost. The present study uses this link to determine contemporary completeness, penetration, and representativeness of the STS ACSD.**

Methods. **Using variables common to both STS and CMS databases, STS operations were linked to CMS data for all CMS coronary artery bypass graft (CABG) surgery hospitalizations discharged between 2000 and 2012, inclusive. For each CMS CABG hospitalization, it was determined whether a matching STS record existed.**

Results. **Center-level penetration (number of CMS sites with at least one matched STS participant divided by the total number of CMS CABG sites) increased from 45% in 2000 to 90% in 2012. In 2012, 973 of 1,081 CMS CABG sites (90%) were linked to an STS site.**

Patient-level penetration (number of CMS CABG hospitalizations done at STS sites divided by the total number of CMS CABG hospitalizations) increased from 51% in 2000 to 94% in 2012. In 2012, 71,634 of 76,072 CMS CABG hospitalizations (94%) occurred at an STS site.

Completeness of case inclusion at STS sites (number of CMS CABG cases at STS sites linked to STS records divided by the total number of CMS CABG cases at STS sites) increased from 88% in 2000 to 98% in 2012. In 2012, 69,213 of 70,932 CMS CABG hospitalizations at STS sites (98%) were linked to an STS record.

Conclusions. **Linkage of STS and CMS databases demonstrates high and increasing penetration and completeness of the STS database. Linking STS and CMS data facilitates studying long-term outcomes and costs of cardiothoracic surgery.**

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The Society of Thoracic Surgeons (STS) adult cardiac surgery database (STS ACSD) captures detailed clinical data on adults undergoing cardiac surgical

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Address correspondence to Dr Jacobs, Division of Cardiovascular Surgery, John Hopkins All Children's Heart Institute, 601 Fifth St S, Saint Petersburg, FL 33701; email: jeffjacobs@msn.com.

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procedures performed by STS database participants [1]. An STS database participant is typically a "practice group of cardiothoracic surgeons" or a hospital-based cardiothoracic division or department; uncommonly, an STS database participant is an individual cardiothoracic surgeon. The STS ACSD now encompasses the entire spectrum of adult cardiac surgery, including coronary artery bypass graft (CABG) surgery; surgery of the aortic, mitral, tricuspid, and pulmonary valves; surgery of the thoracic aorta; arrhythmia procedures; and less commonly performed procedures such as pulmonary thromboendarterectomy and removal of tumors of the heart and vena cava.

Data from the STS ACSD are reported back to participants on a quarterly basis in feedback reports. Twice yearly, these feedback reports contain reports of performance on National Quality Forum-endorsed STS metrics and on the various STS composite performance metrics for specific procedures (eg, isolated CABG, isolated aortic valve replacement, aortic valve replacement plus CABG) [2–5]. These performance reports provide numerical point estimates with credible intervals based on a Bayesian hierarchical model, and they also assign participants to a "star rating" category based on the true Bayesian probabilities (eg, 99% for isolated CABG) that the provider is an average, above average, or below average performer. In addition to these regular confidential feedback reports, STS ACSD data are used for quality assessment, performance improvement initiatives, research, public reporting [6–8], and to satisfy regulatory and reimbursement imperatives. Demonstration of high national penetration of STS ACSD and high completeness of data in the STS ACSD are of critical importance when using these data for accountability, reimbursement, quality improvement, and public reporting. Conversely, lack of high national penetration of clinical databases is a commonly used rationale for continued use of claims-based administrative metrics for quality improvement and public reporting.

Evaluation of long-term patient outcomes is also a key goal of the STS. While recognizing the many strengths of the STS National Database, an ongoing limitation has been the lack of longitudinal follow-up information beyond hospital discharge and 30 days after a procedure. Furthermore, the accuracy of information collected after discharge and as long as 30 days after a procedure varies among institutions, and addressing this variability is a major goal of the STS. The Medicare database of the Centers for Medicare and Medicaid Services (CMS) complements the detailed clinical records available in the STS database by providing information about longitudinal long-term outcomes and cost. A prior publication has outlined the methods and initial success of linking the CMS Medicare database to the STS database [1]. Linking these two data sources facilitates comparative effectiveness research and provides information about cost as well as long-term survival, rehospitalizations, and reinterventions. The 2007 STS-CMS link was previously used to examine completeness, penetration, and representativeness of the STS ACSD [1]. The purpose of the present study is to use the STS-CMS link to determine contemporary penetration, completeness, and representativeness of the STS ACSD.

Patients and Methods

Institutional Review Board Approval

This study was approved by the Duke University Health System Institutional Review Board. Because the data used in analysis represent a limited data set (no direct patient identifiers) that was originally collected for nonresearch purposes, and the investigators do not know the identity of individual patients, the analysis of these data was declared by the Duke University Health System Institutional Review Board to be research not involving human subjects [9]. This manuscript was also reviewed and approved by the STS National Database Access and Publications Task Force and the STS National Database Quality Measurement Task Force.

Medicare Database of Centers for Medicare and Medicaid Services

Medicare is health insurance provided by the federal government of the United States of America for the following groups of patients: (1) people aged 65 years or older; (2) people younger than 65 with certain disabilities; and (3) people of any age with end-stage renal disease, defined as "permanent kidney failure requiring dialysis or a kidney transplant." The CMS administrative claims data source for this study is the 100% Medicare inpatient claims file, which contains information on hospitalizations of patients enrolled in fee-for-service Medicare. It includes dates of service and diagnostic codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). The database contains anonymous patient identifiers that enable follow-up of beneficiaries over time, but does not allow identification of any beneficiary through their Medicare health insurance number. In addition, the 100% Medicare denominator file, which links to the inpatient file, contains information on beneficiary eligibility, demographic characteristics, and date of death.

The STS ACSD was linked to CMS claims files using combinations of nonunique indirect identifiers [1, 9, 10]. Records in the two databases were considered to be the same patient if they matched on a set of indirect identifiers including hospital, date of birth, sex, admission date, and discharge date. The matching algorithm required an exact match on a few of these variables or partial matching on a larger number of variables. In a pilot investigation using claims data for patients with heart failure, almost all (99.9%) CMS records from the same hospital were uniquely identified using date of birth, along with any combination of admission date and discharge date, regardless of patient sex.

The Duke Clinical Research Institute used variables common to both the STS ACSD and the CMS Medicare database to link STS operations to CMS inpatient claims data for all hospitalizations during which a patient underwent CABG surgery, with or without concomitant procedures. These hospitalizations are termed

"CMS CABG hospitalizations." This study was restricted to patients discharged from 2000 through 2012, inclusive, who were 65 years of age or older on the date of discharge. The vast majority of patients included in this analysis were enrolled in traditional fee-for-service Medicare. Although Medicare tends not to receive claims for other types of patients, this analysis includes a few very rare cases of patients who were not traditional fee-for-service Medicare because their managed care plans sent claims to Medicare.

For each CMS CABG hospitalization, it was determined whether a matching STS record existed. The CMS CABG hospitalizations were identified by ICD-9 procedure codes 36.10 to 36.19. For each CABG hospitalization, it was determined whether there was a matching record in the STS ACSD. The term "CMS site" is used as shorthand for sites with a unique CMS provider number, which is the identification number of the institutional provider certified by Medicare to provide services to the beneficiary. (A single hospital can have more than one CMS provider number.) The CMS sites were classified as "performing CABG" and termed "CMS CABG sites" if they had more than 10 CABG hospitalizations in a calendar year. This rule was intended to reduce the chance of misclassifying a non-CABG hospital as a CABG hospital due to ICD-9 coding errors. A CMS site is considered to have STS participation at the time of discharge if there was at least one matched STS record at the site that month.

A CMS CABG claim was considered to be a legitimate CABG admission (ie, not a coding error) if there were at least 10 other CABG claims submitted from the same CMS site (billing center [MCARE_ID]) during the same calendar year. Thus, the analysis only includes claims from CMS sites with more than 10 CABG claims in a given calendar year.

Once the individual patients are linked, longitudinal records can be created containing follow-up information, including subsequent death and subsequent hospitalizations. From this follow-up information, it is possible to identify and capture readmissions, and to obtain data including primary and secondary diagnoses, any repeat surgical procedures, mortality, major morbidity events, and charges.

Penetration, Completeness, and Representativeness

Analyses performed included calculation of the percentage of CMS CABG sites that had at least one matching STS participant, the percentage of CMS CABG hospitalizations that were linked to the STS ACSD, and variations of each of these.

Two types of penetration are defined. Center-level penetration was defined as the number of CMS sites with at least one matched STS participant divided by the total number of CMS CABG sites. A CMS site was defined as a CMS CABG site if it had more than 10 CABG hospitalizations in a calendar year. Patient-level penetration was defined as the number of CMS CABG hospitalizations done at STS sites divided by the total number of CMS CABG hospitalizations. Completeness of case inclusion at STS sites was defined as the number of CMS CABG cases at STS sites linked to STS records divided by the total number of CMS CABG cases at STS sites during months of STS ACSD participation.

Representativeness of STS data was studied by comparing linked and unlinked CMS CABG operations at STS sites. Differences were assessed using the Wilcoxon rank sum test for continuous variables (age) and the χ^2 test for categoric variables (sex, race, admission type, inhospital mortality). Thirty-day mortality rates were estimated for linked and unlinked CABG hospitalizations using the Kaplan-Meier method and compared by a Z-test using the Greenwood standard error estimator.

Results

Center-Level Penetration

A total of 1,246 CMS sites had at least one CABG claim during 2008 to 2012. Of these, 1,108 (89%) had CABG claims in all 5 years, and 138 had CABG claims in fewer than 5 years. Among the 6,230 possible combinations of CMS site and calendar year (ie, $5 \times 1{,}246 = 6{,}230$ site-years), 5,828 site-years had at least one CABG claim. Of these, 5,473 (93.9%) met the more-than-10 case inclusion threshold and were included in the analysis of penetration and completeness for that calendar year. Conversely, 355 site-years fell below the more-than-10 case inclusion criterion and were excluded. Among 450,387 CABG claims submitted in 2008 to 2012, all but 1,807 (1,807 of 450,387 = 0.4%) were done at site-years meeting the more-than-10 case volume threshold and were included.

Among the 1,169 CMS centers that submitted CABG claims in 2012, 1,081 (92.4%) met the more-than-10 case inclusion threshold and were included in the analysis of penetration and completeness in 2012. Conversely, 88

Table 1. Center-Level Results

	Number of CMS CABG Sites		
Year	All N_1	STS Sites N_2	Center-Level Penetration N_2/N_1
2000	983	439	45%
2001	1,006	476	47%
2002	1,034	550	53%
2003	1,056	581	55%
2004	1,071	631	59%
2005	1,079	715	66%
2006	1,092	788	72%
2007	1,101	854	78%
2008	1,105	925	84%
2009	1,101	945	86%
2010	1,095	970	89%
2011	1,091	974	89%
2012	1,081	973	90%

N_1 refers to the number of Centers for Medicare and Medicaid (CMS) sites performing coronary artery bypass graft surgery (CABG) in a calendar year; N_2 is number of CMS CABG sites that participated in The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database for at least 1 month of the year.

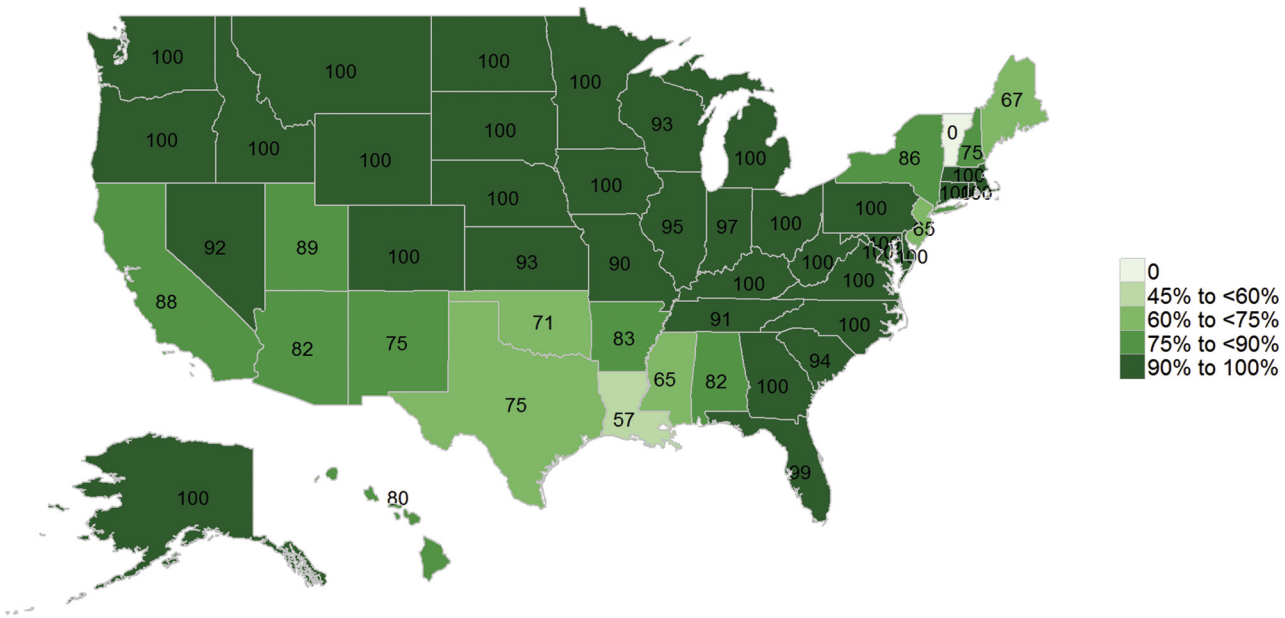

Fig 1. Center-level penetration of The Society of Thoracic Surgeons Adult Cardiac Surgery Database stratified by state (2012). (Lightest green = 0%; light green = 45% to less than 60%; green = 60% to less than 75%; darker green = 75% to less than 90%; darkest green = 90% to 100%.)

centers fell below the more-than-10 case inclusion criterion in 2012 and were excluded. Among 76,555 CABG claims in 2012, all but 483 (483 of 76,555 = 0.6%) were done at sites meeting the more-than-10 case volume threshold and were included. In 2012, the final analysis population included 76,072 CABG admissions from 1,081 CMS sites.

Center-level penetration (number of CMS sites with at least one matched STS participant divided by the total number of CMS CABG sites) increased from 45% to 90% from 2000 to 2012. In 2012, 973 of 1,081 CMS CABG sites (90%) were linked to an STS site. Table 1 documents center-level penetration during the years 2000 to 2012, inclusive. Figure 1 documents center-level penetration of STS ACSD stratified by state for the year 2012.

Patient-Level Penetration

Patient-level penetration (number of CMS CABG hospitalizations done at STS sites divided by the total number of CMS CABG hospitalizations) increased from 51% to 94% from 2000 to 2012. In 2012, 71,634 of 76,072 CMS

Table 2. Patient-Level Results

	Number of CMS CABG Hospitalizations			CMS CABG Hospitalizations at Active STS Sites		
Year	All N_3	At STS Sites N_4	Patient-Level Penetration N_4/N_3	All N_5	Linked to STS N_6	Completeness N_6/N_5
2000	169,633	86,358	51%	79,198	69,408	88%
2001	165,243	86,887	53%	82,267	73,353	89%
2002	164,240	97,260	59%	91,648	80,017	87%
2003	153,685	95,671	62%	91,777	87,554	95%
2004	146,936	97,397	66%	92,155	88,770	96%
2005	135,169	97,840	72%	94,643	91,649	97%
2006	123,320	97,870	79%	94,789	92,016	97%
2007	111,967	94,409	84%	91,363	88,857	97%
2008	104,232	92,829	89%	90,624	88,095	97%
2009	95,657	87,405	91%	86,492	84,637	98%
2010	89,729	83,639	93%	82,372	80,464	98%
2011	82,890	77,988	94%	76,948	75,037	98%
2012	76,072	71,634	94%	70,932	69,213	98%

N_3 is number of Centers for Medicare and Medicaid (CMS) coronary artery bypass graft surgery (CABG) hospitalizations; N_4 is number of CMS CABG hospitalizations at sites with The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database participation during same year; N_5 is number of CMS CABG hospitalizations at sites with STS participation during same month; N_6 is number of CMS CABG hospitalizations linked to STS record.

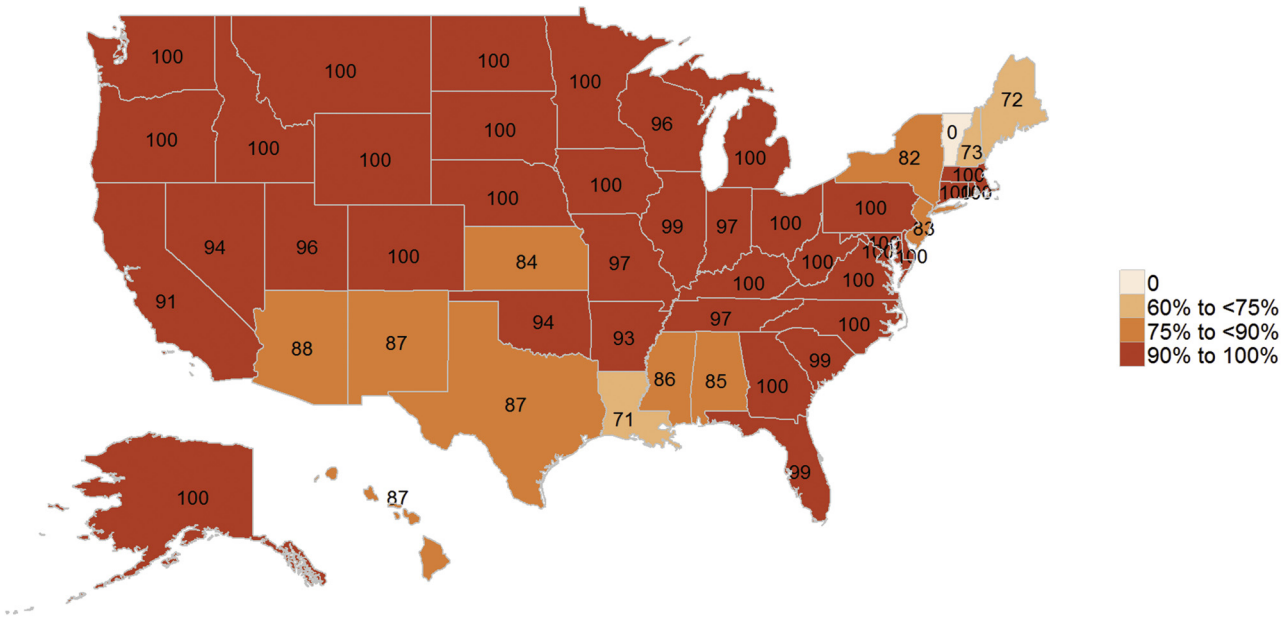

Fig 2. Patient-level penetration of The Society of Thoracic Surgeons Adult Cardiac Surgery Database stratified by state (2012). (Lightest orange = 0%; light orange = 60% to less than 75%; orange = 75% to less than 90%; red = 90% to 100%.)

CABG hospitalizations (94%) occurred at an STS site. Table 2 documents patient-level penetration during the years 2000 to 2012, inclusive. Figure 2 documents patient-level penetration of STS ACSD stratified by state, for the year 2012.

Completeness

Completeness of case inclusion at STS sites (number of CMS CABG cases at STS sites linked to STS records divided the by total number of CMS CABG cases at STS sites during months of STS ACSD participation) increased from 88% to 98% from 2000 to 2012. In 2012, 69,213 of 70,932 CMS CABG hospitalizations at STS sites (98%) were linked to an STS record. Table 2 documents the completeness of case inclusion at STS sites during the years 2000 to 2012, inclusive. (The denominator for calculation of completeness of case inclusion is the number of CMS CABG hospitalizations at sites with STS participation during same month; meanwhile, the numerator for calculation of patient-level penetration is the number of CMS CABG hospitalizations at sites with STS participation during same year.)

Representativeness

Tables 3 and 4 compare linked and unlinked CABG operations in 2012 at STS sites. The data in Tables 3 and 4 are an analysis of CMS records at sites with STS participation in 2012. Tables 3 and 4 present a comparison of CABG claims that were matched versus those that were not matched to records in the STS ACSD during periods of STS participation. Table 3 includes all operations that include CABG surgery, including both isolated CABG and CABG combined with other operations; Table 4 contains only isolated CABG.

Comment

Administrative datasets such as the CMS Medicare database can complement the clinical data contained in the STS National Database. The successful linkage of the STS ACSD to CMS Medicare data provides a rich source of information about long-term mortality, rates of rehospitalization and reintervention, and health care economics. Using this STS-CMS link, the present study provides reassuring information about the penetration and completeness of the STS ACSD. From 2000 to 2012, the penetration and completeness of STS ACSD has steadily increased. Center-level penetration (defined as the number of CMS sites with at least one matched STS participant divided by the total number of CMS CABG sites) increased from 45% to 90%. Patient-level penetration (defined as the number of CMS CABG hospitalizations done at STS sites divided by the total number of CMS CABG hospitalizations) increased from 51% to 94%. These findings suggest that most CMS CABG sites participate in the STS ACSD, and that most CMS CABG hospitalizations nationally are captured in the STS ACSD. Completeness of case inclusion at participating sites (defined as the number of CMS CABG cases at STS sites linked to STS records divided by the total number of CMS CABG cases at STS sites) increased from 88% to 98%, demonstrating that virtually all CMS CABG cases performed at STS sites are captured in the STS ACSD.

These findings have important health care policy implications. A very high percentage of CMS CABG sites submit data to the STS ACSD, nearly all CMS procedures are captured in the STS ACSD, and CMS CABG sites participating in the STS ACSD submit virtually all their cases to STS. Together with the fact that clinical registry data are generally considered the gold standard

Table 3. Representativeness, All Operations That Include CABG Surgery, Including Both Isolated CABG and CABG Combined With Other Operations[a]

Variable	Not Matched to STS (n = 1,719)	Matched to STS (n = 69,213)	*p* Value
Age, years	73.0 (68.0, 78.0)	73.0 (69.0, 78.0)	0.0022
Male	1,162 (67.6)	47,889 (69.2)	0.1577
Race			<0.001
White	1,509 (87.8)	62,699 (90.6)	
Black	129 (7.5)	3,308 (4.8)	
Other/unknown	81 (4.7)	3,206 (4.6)	
Admission type			0.0057
Emergent	535 (31.1)	16,410 (23.7)	
Urgent	366 (21.3)	15,765 (22.8)	
Elective	808 (47.0)	36,711 (53.0)	
Other/unknown	10 (0.6)	327 (0.5)	
Mortality[b]			
In hospital	79 (4.6)	2,260 (3.3)	0.0023
30-day, Kaplan-Meier, %	7.1 (5.9, 8.4)	4.9 (4.8, 5.1)	<0.001

[a] Only includes admissions during months of The Society of Thoracic Surgeons (STS) database participation. Sample size (n = 70,932) matches the number N_5 in Table 2. [b] Mortality is for all coronary artery bypass graft surgery (CABG) cases: isolated CABG and CABG combined with other operations.

Values are mean (1st, 3rd quartile) or n (%).

STS = The Society of Thoracic Surgeons.

for clinical relevance and adequate risk adjustment, these findings strongly support the preferential use of linked STS-Medicare data in federal government accountability and reimbursement programs, instead of administrative claims data. Few sites would have to change current practice, and most cardiac surgery programs would strongly prefer to have their performance evaluations based on STS clinical data rather than claims data. Further supporting this approach are the results of external audit by Telligen, which in 2013 revealed almost 97% concordance between their chart review abstraction and data that had been submitted to the STS ACSD.

Because all hospitals do not submit claims to CMS, it is possible that the data reported in this manuscript about center-level penetration may either slightly overestimate

Table 4. Representativeness, Isolated Coronary Artery Bypass Graft Surgery[a]

Variable	Not Matched to STS (n = 1,218)	Matched to STS (n = 49,153)	*p* Value
Age, years	72.0 (67.0, 77.0)	72.0 (68.0, 77.0)	0.0079
Sex			0.2091
Male	839 (68.9%)	34,675 (70.5%)	
Female	379 (31.1%)	14,478 (29.5%)	
Race			<0.0001
White	1,056 (86.7%)	44,045 (89.6%)	
Black	100 (8.2%)	2,586 (5.3%)	
Other/unknown	62 (5.1%)	2,522 (5.1%)	
Admission type			<0.0001
Emergent	403 (33.1%)	12,739 (25.9%)	
Urgent	260 (21.3%)	11,961 (24.3%)	
Elective	547 (44.9%)	24,195 (49.2%)	
Other/unknown	8 (0.7%)	258 (0.5%)	
Mortality[b]			
In hospital	38 (3.1%)	1,123 (2.3%)	0.0550
30-day, Kaplan-Meier, %	5.6% (4.3%, 6.9%)	3.7% (3.5%, 3.8%)	0.0006

[a] Only includes admissions during months of The Society of Thoracic Surgeons (STS) database participation. [b] Mortality is for isolated CABG only.

Values are mean (1st, 3rd quartile) or n (%).

STS = The Society of Thoracic Surgeons.

or underestimate the true center-level penetration of the STS ACSD (ie, three groups of hospitals that may not submit claims to CMS are Veterans Administration [VA] hospitals, military hospitals, and possibly Kaiser hospitals). The rates of penetration reported in this analysis represent penetration among all hospitals submitting claims to Medicare. However, these same rates of penetration reported in this analysis exclude approximately 41 VA hospitals that perform adult cardiac surgery and perform more than 10 CABGs per year (two of which submit data to STS ACSD) and six military hospitals that perform CABG (two of which submit data to STS ACSD). (Our research also identified six Kaiser Hospitals that perform CABG; all six of these Kaiser hospitals submit both data to the STS ACSD and claims to Medicare. Therefore, these six Kaiser Hospitals are included in the calculation of rates of penetration that is reported in this analysis.) Furthermore, because data from Medicare do not include all CABG surgery performed in the United States, it is possible that the data reported in this manuscript about patient-level penetration and completeness may either slightly overestimate or underestimate the true penetration and completeness the STS ACSD. Finally, because of linking errors, this analysis may overestimate or underestimate completeness.

An important strength of the STS ACSD is its ability to adjust for risk based on preoperative clinical factors; such risk adjustment is not possible with unmatched cases (cases that are present in Medicare data and not present in the STS ACSD) because these detailed clinical variables are not available for these unmatched cases. Higher unadjusted mortality was observed for unmatched cases at STS sites; the reasons for this finding are unclear and merit further investigation. Several potential explanations might contribute, as follows. (1) Selective underreporting of patients with poor outcomes may occur. (2) Higher mortality may occur among patients cared for by surgeons who do not participate in the STS ACSD at a given hospital in comparison with the mortality of patients cared for by surgeons who do participate in the STS ACSD at the same hospital. (3) The STS database may inadvertently fail to capture patients who are not part of the routine "pathway" secondary to lack of systematic protocols to identify these "nonpathway patients" and capture them in the STS ACSD. (These nonpathway patients are patients who are outside the normal pathway of care, including those who die in the operating room and those who have extremely prolonged hospitalization, often dying on a critical care or hospice service. Such nonpathway patients are more likely to be accidently omitted from the STS ACSD.) (4) Errors regarding mortality could exist in the CMS Medicare data as well. (In the future, verification of life status with the Social Security Death Master File or the National Death Index might address this possibility). (5) The demographics of matched and unmatched cases are different. (Unmatched cases are more likely to be black race and emergent admission type, both of which are associated with higher mortality.) (6) Finally, some of the differences identified between matched and unmatched cases may simply be caused by additional important differences in case mix among these groups. (For example, unmatched cases might more often be CABG plus some other procedure. Notably, in a comparison of matched and unmatched patients, the rate of in hospital mortality of isolated CABG, a more homogeneous cohort, is not statistically different in the two groups.)

The utility and power of the STS National Database will increase substantially by transforming it into a platform for longitudinal follow-up [1, 10]. Linking the STS National Database to administrative claims databases through nonunique indirect identifiers represents one of several potential strategies that will allow longitudinal follow-up with the STS National Database: (1) Using nonunique indirect identifiers, the STS National Database can be linked to administrative claims databases and become a valuable source of information about long-term mortality, rates of rehospitalization, long-term morbidity, and cost. (2) Using unique, direct, personal identifiers, such as name and social security number, the STS database can be linked to national death registries like the Social Security Death Master File and the National Death Index, to verify life status over time [1, 10, 11, 12]. (3) Using either direct or indirect identifiers, the STS National Database can link to other clinical registries, such as the National Cardiovascular Data Registry of the American College of Cardiology, to provide enhanced clinical follow-up. (4) The STS National Database can develop clinical longitudinal follow-up modules of its own to provide detailed clinical follow-up.

The STS-CMS link has many important applications. For this paper, the STS-CMS link was used to assess the penetration, completeness, and representativeness of the STS ACSD. The STS-CMS link has also been used successfully to examine long-term outcomes of coronary revascularization [13, 14]. Linked CMS data will also be used to evaluate longitudinal patient outcomes after transcatheter valve therapy [15]. Furthermore, in collaboration with Duke Clinical Research Institute, the STS has recently created a continuous ongoing STS-CMS link to facilitate additional research about longitudinal outcomes after cardiothoracic surgery. This continuous STS-CMS link represents an important advance because a continuous STS-CMS link will facilitate more efficient research in comparison to the extant strategy that involves the creation of a new linked data set for each new study.

As techniques are further refined for linking clinical databases with administrative claims data regarding resource utilization, the ability to determine the long-term comparative effectiveness of various treatment options will be established. Longitudinal data on resource utilization and comparative effectiveness will be necessary as technologic and scientific advances place increasing pressure on societal resources for healthcare. These linkages will allow the examination of a wide variety of data elements across the entire spectrum of care and will serve as a model for other clinical

database networks in the future. As the demand and expectation for public reporting of outcomes increases [6–8], the ability to verify data in the STS National Database with other databases and national death registries, as well as the ability for the STS National Database to function as a tool for longitudinal follow-up, will become even more important [1].

In conclusion, successful linking of the STS ACSD and the CMS Medicare database demonstrates high and increasing penetration and completeness of the STS ACSD. For unclear reasons, higher mortality was observed for unmatched cases at STS sites; however, the rate of in hospital mortality of isolated CABG is not statistically different in matched and unmatched cases. Linking STS and CMS data will facilitate studying long-term clinical and financial outcomes of cardiothoracic surgery.

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DISCUSSION

DR SARA PASQUALI (Ann Arbor, MI): Thanks very much for the opportunity to discuss this paper, and, Jeff, that was a great presentation. I think your results help to demonstrate not only the representativeness of the information contained in the STS Adult Cardiac Surgery Database, but also really lay important groundwork for a number of different studies that could be conducted with this linked information that could not be conducted otherwise with either of the two individual data sets alone.

As you mentioned, we have been fortunate within the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database to be able to study the relationship between quality and cost, for example, using a similar type of linked data set, and have also been able to conduct several different types of comparative effectiveness studies using this type of linked information. And importantly, in this era of decreasing research funding, these types of tools help us to use the data that are available to us most efficiently to conduct both research and support quality improvement initiatives.

I had two questions. One, can you comment on the representativeness or penetration of the other two databases, the STS General Thoracic Surgery Database and the STS Congenital Heart Surgery Database, similar to the information you have presented for the STS Adult Cardiac Surgery Database? And then, two, can you give us any thoughts on some of the more specific types of analyses you think can now be facilitated with this linked information from the STS Adult Cardiac Surgery Database and Centers for Medicare and Medicaid (CMS) data?

DR JACOBS: Thanks, Sara. Those are great questions. I would first like to mention that Sara has done some really groundbreaking research creating similar linkages between the STS Congenital Heart Surgery Database and congenital and pediatric administrative data. This research is very important work on the pediatric side that has made the STS Congenital Heart Surgery Database much more powerful.

As we saw today, the penetration of the STS Adult Cardiac Surgery Database in the United States of America is well over 90%, probably close to 95%, both at the center level and at the level of the patient and the operation. In the STS Congenital Heart Surgery Database, the penetration is quite similar. We estimate that there are 125 hospitals in the United States that perform pediatric heart surgery, and the STS Congenital Heart Surgery Database receives data from 120 of these hospitals. That translates into a 96% penetration of the STS Congenital Heart Surgery Database in the United States of America at the level of the hospital, and probably a higher patient level penetration

because the few programs in the United States of America that do not participate in the STS Congenital Heart Surgery Database are smaller programs.

Determining this penetration for the STS General Thoracic Surgery Database is a little bit more challenging, because it is difficult to obtain a certain denominator of how many hospitals in the United States of America perform general thoracic surgery. Without that denominator, it is somewhat more challenging to calculate penetration. I think that the estimation of the penetration of the STS General Thoracic Surgery Database is probably a project that needs to be taken on by the STS General Thoracic Surgery Database Task Force. Certainly, many of the STS members that perform general thoracic surgery participate in the STS General Thoracic Surgery Database, but it is a little harder to estimate a true denominator across the entire country.

Regarding your second question about what types of analyses can now be facilitated with this linked information from the STS Adult Cardiac Surgery Database and CMS data, I think that linkages between clinical and administrative data, like linkage to Medicare, or linkage to the Pediatric Health Information System (PHIS) database, will facilitate a number of avenues of future research and quality improvement initiatives for the STS National Database. Clearly, studying longitudinal outcomes and transforming the STS National Database into a platform for longitudinal follow-up is one domain that these linkages facilitate. A second domain is the study of health care economics and studying the relationship of outcomes to cost and assessing value. I think that the use of these linkages, with the incorporation of longitudinal follow-up and quality and cost data, can then facilitate not only quality assessment strategies and quality improvement strategies, but also can lead to multiple avenues for future research.

It is an exciting time. The power of the STS National Database will continue to grow through these types of linkages.