Inpatient and 90-Day Postdischarge Outcomes in Cardiac Surgery

DONALD E. FRY, MD; MICHAEL PINE, MD, MBA; SUSAN M. NEDZA, MD, MBA; DAVID G. LOCKE, BS; AGNES M. REBAND, BS; AND GREGORY PINE, BA

ABSTRACT

OBJECTIVES: To develop metrics for objective and risk-adjusted adverse outcomes for cardiac surgical care and to compare hospital performances to define opportunities for care improvement.

STUDY DESIGN: To develop predictive risk models for adverse events that occur during inpatient and postdischarge care, and then apply those models to define comparative hospital performance in cardiac surgery.

METHODS: The population was elective coronary artery bypass and cardiac valve surgery patients in the Medicare Limited Data Set for 2010-2012 in the United States. Logistic prediction models for inpatient deaths, inpatient prolonged length-of-stay outliers, 90-day postdischarge deaths without readmission, and 90-day readmissions among cardiac surgery patients were designed. Observed versus predicted differences for risk-adjusted adverse outcomes (AOs) were then performed among all hospitals that met minimal volume criteria.

RESULTS: A total of 1031 hospitals for coronary artery bypass surgery averaged 27.2% AOs for all 4 measurements of interest; 71 hospitals had observed outcomes that were ≥2 standard deviations (SDs) greater than expected. A total of 794 hospitals for cardiac valve surgery averaged 32.3% AOs; 57 hospitals had observed outcomes that were ≥2 SDs greater than expected. Median risk-adjusted AO rates were 17% for coronary artery bypass and 20.4% for valve surgery in the best performing decile, but were 38.8% and 45.8%, respectively, in the poorest performing deciles.

CONCLUSIONS: The wide range of risk-adjusted AOs in cardiac surgery indicates a genuine opportunity for care improvement.

New technology, refined surgical techniques, and greatly enhanced critical care have translated into progressive improvement in cardiac surgery over the last several decades. A portion of this progressive improvement is secondary to the efforts of the Society of Thoracic Surgeons (STS) to provide risk-adjusted outcomes using clinical data and to provide feedback to providers.[1] Even in the Medicare population, elective coronary artery bypass grafting (CABG) and cardiac valve surgery (CVS) have 30-day death rates of less than 3%. Mortality rates at this level cannot be used alone to evaluate outcomes of care except in extreme circumstances.[2]

Complications of care have been studied for comparative performance evaluation. Although severe complications are easily recognized, many complications (eg, surgical site infection) have definitions that require institutional interpretation and standardized surveillance for recognition. In an era of short inpatient length of stay (LOS), many such complications are not recognized until after discharge and may not be reported. For cardiac surgery, the full array of potential complications has a varying spectrum of severity, and reporting all of them may yield very high observed rates that confound understanding of significant events. In previous studies, we identified that liberally coded complications (eg, hypopotassemia) may result in overall complication rates that approach 70% in elective CABG surgery.[3]

Recent attention has focused on readmissions as a metric for outcomes of inpatient care. Jencks et al[4] identified that all-cause 30-day readmission was 19% and 90-day readmission was 34%, in all Medicare patients. The Readmission Reduction Program (RRP) by Medicare, which began in 2014, is assessing financial penalties on hospitals that exceed an arbitrarily defined rate.[5] The initial penalties affected

Table 1. The Characteristics of the 4 Prediction Models Used in the Developmental Database for Risk-Adjusting Coronary Artery Bypass Grafting and Cardiac Valve Surgery in Medicare Patients

	IpD	prLOS	PD-90	RA-90
	Coronary Artery Bypass Grafting (n = 82,719)			
Total AO events	**1301 (1.6%)**	**6830 (8.3%)**	**583 (0.7%)**	**16,371 (19.8%)**
C statistic with hospital variables	0.821	0.745	0.904	0.673
C statistic without hospital variables	0.750	0.705	0.795	0.647
Number of significant variables	17	35	10	34
	Cardiac Valve Surgery (n = 61,870)			
Total AO events	**1604 (2.6%)**	**5459 (8.8%)**	**685 (1.1%)**	**14,759 (23.9%)**
C statistic with hospital variables	0.808	0.751	0.901	0.652
C statistic without hospital variables	0.708	0.704	0.805	0.622
Number of significant variables	21	35	10	23

AO indicates adverse outcome; IpD, inpatient deaths; PD-90, 90-day postdischarge deaths without readmission; prLOS, prolonged length of stay; RA-90, 90-day readmissions.

over 2600 hospitals,[6] and the second year of the RRP demonstrated little improvement.[7] Other medical and surgical conditions—likely including cardiac surgery—will be added to the RRP. For providers of care, readmissions may have legitimate and unrelated causes to the original hospitalization, and many patients are readmitted to hospitals other than the initial index facility, which makes monitoring of readmission patterns difficult.[8,9] The current Medicare RRP is for 30 days following discharge, but early indications are that 90 days may be the target in the program for bundled payments.[10]

In the current study, we examined elective CABG and CVS patients to identify the full spectrum of adverse outcomes (AOs) from inpatient care through 90 days of postdischarge care. Separate risk-adjusted models have been designed for 4 AOs: inpatient deaths (IpDs), risk-adjusted prolonged LOS (prLOS) outliers as surrogates for severe inpatient complications, 90-day postdischarge deaths without readmission (PD-90), and 90-day readmissions (RA-90), except for specific exclusions. These prediction models were used to compare hospital outcomes to identify opportunities for care improvement.

METHODS

We designed 4 unique prediction models each for CABG and CVS using hospitals that met quality-coding criteria.[11] These patients and hospitals will be referred to as the developmental database. The models from the developmental database were then used for the evaluation of outcomes among all hospitals—the study database—that met minimum volume criteria for each procedural group.

We used the Medicare Limited Data Set for 2010-2012. Patients with an *International Classification of Diseases, 9th Revision, Clinical Modification* procedure code of 36.10-36.19 for CABG, or 35.12, 35.21, 35.22, 35.23, 35.24, or 35.33 for CVS, were identified. CABG cases were required to have a principal diagnosis of 414.00-414.05, and CVS cases were required to have a principal diagnosis of 394.0-395.2, 424.0, or 424.1. Tricuspid and pulmonic valve surgeries were not included. Inclusion criteria required that the procedure was performed on inpatient day 0, 1, or 2; only hospitals with 20 or more eligible cases were included in order to meet the minimum number of cases required for hospital-specific control charts for each procedural group. Cases were excluded if patients were aged under 65 years, had missing patient/hospital identifiers, were transfers from another facility, or were discharged against medical advice.

Model Design

With the developmental database, models for the 4 AOs were created using forward stepwise logistic regression. Candidate risk factors reflected comorbid conditions that were present upon admission. Cases with simultaneous CABG and CVS were classified as CVS, with CABG identified as a risk factor. Hospital effects upon final coefficients were addressed by using hospital-specific dummy variables. Schwarz criterion was used to avoid overfitting final models.[12] C statistics were used to evaluate discrimination of final models. SAS version 9.4 (SAS Institute, Cary, North Carolina) was used for all analyses.

Logistic models of IpD and prLOS were designed individually for CABG and CVS. The prLOS model estimates serious inpatient complications of care by first developing a linear model of inpatient LOS in cases without any coded complications. The predicted LOS was subtracted from the observed LOS of all cases in the developmental

data set. Cases were aligned in temporal order, and a moving-range control chart was constructed to identify cases that were 3-sigma outliers above the upper control limit by methods previously reported.[13-15] PrLOS then became a dependent variable in the development of postdischarge models for CABG and CVS. Previous studies have associated prLOS with severe complications and increased costs[16] and its role as a predictor of postdischarge deaths and readmissions.[17]

Postdischarge AOs were observed across 90 days following discharge separately for CABG and CVS. The PD-90 model was designed using all deaths without readmission as the dependent variable. To study RA-90 cases, we identified all RA-90 and removed cases that were from Medical Diagnostic Categories (MDCs) of the Medicare Severity Diagnosis-Related Groups (MS-DRGs) system: 2 (Eye Diseases), 17 (Myeloproliferative Diseases), 22/24 (Burns/Major Trauma), and all MS-DRGs related to the management of trauma or cancer, regardless of MDC. All valid readmissions were divided into those occurring within 30, 60, and 90 days of discharge. The MS-DRGs were then identified for each readmission. An RA-90 prediction model was then designed with the total RA-90 for CABG and for CVS as the dependent variable. PrLOS events of the index hospitalization were used in PD-90 and RA-90 models to identify the relationship of inpatient complications with postdischarge AOs, but also to remove effects of inpatient complications on coefficients of postdischarge models.

Comparative Hospital Performance

To compare hospital performance, the 4 AO prediction models from the developmental database were applied to all hospitals in the study database with 20 or more qualifying cases. All hospitals had a minimum of 4.6 total predicted AOs for each surgical group. The IpD model was applied to all cases. The prLOS model was used to predict LOS outliers among live discharges. Live discharges without prLOS were used to predict PD-90, and finally, live discharges without prLOS or PD-90 were used to predict readmissions. Among all hospitals, total predicted AOs was set equal to total observed AOs to give an adjusted predicted total. For each hospital, a z score was computed by [observed AOs – predicted AOs]/standard deviation (SD), where SD = $\sqrt{(N \times p \times (1-p))}$. Positive and negative z scores represent outcomes that were poorer or better than predicted, respectively. Z scores were stratified to permit evaluations of outcomes and case volumes at the hospital level. The risk-adjusted AO rate for each hospital was computed by this formula: [overall observed AO rate] × [hospital-observed AOs/hospital-predicted AOs]. Risk-adjusted AO rates were then categorized into deciles for comparison. Cases were also subdivided into deciles of case volume to assess effects upon outcomes.

RESULTS

Table 1 summarizes the 4 AO models from the developmental database for CABG and CVS. C statistics declined when the hospital dummy variables were dropped from the model, although this effect was less in the RA-90 models. Final models between CABG and CVS had similar C statistics. The significant variables with odds ratios for all 4 prediction models are detailed in **eAppendix** Tables 1 through 4 (eAppendix available at **www.ajmc.com**). Among all models for both groups of operations, female gender, age groups over 75 years, and

Table 2. The Number of Patients, Number of Readmissions, and Causes of Readmission for 90 Days Following Discharge in Medicare Patients Undergoing Coronary Artery Bypass Surgery

	MS-DRGs	Patients, n	Readmissions, n	1-30 Days	31-60 Days	61-90 Days
Cardiac events	All MDC, 5 MS-DRGs	6406 (39.1%[a])	8235 (38.5%[b])	4667	1972	1596
Infections	075-076; 094-099; 152-153; 177-179; 193-195; 202-203; 288-289; 371-373; 485-487; 539-541; 548-550; 602-603; 689-690; 757-759; 853-858; 862-872	2853 (17.4%[a])	3798 (17.7%[b])	2270	973	555
Pulmonary events	003-004; 163-168; 175-176; 186-189; 196-201; 204-208	2271 (13.9%[a])	2874 (13.4%[b])	1953	607	314
Gastrointestinal events	326-337; 345-346; 356-358; 368-371; 377-384; 388-395; 408-424	1239 (7.6%[a])	1670 (7.8%[b])	901	448	321
Stroke/acute CNS events	020-027; 034-039; 061-072; 077-081; 100-103	829 (5.1%[a])	1017 (4.7%[b])	386	328	303
Acute associated medical conditions	294-295; 640-641; 682-685; 811-813; 947-948	1371 (8.4%[a])	1901 (8.9%[b])	1138	458	305
All others	Over 200 other MS-DRGs	1396 (8.5%[a])	1922 (9.0%[b])	897	519	506
	Total	**16,365**	**21,417**	**12,212**	**5305**	**3900**

CNS indicates central nervous system; MDC, Medical Diagnostic Category; MS-DRG, Medicare Severity Diagnosis-Related Groups.

[a]Percent of all readmitted patients.

[b]Percent of all readmissions.

Table 3. The Number of Patients, the Number of Readmissions, and the Causes of Readmission for 90 Days Following Discharge in Medicare Patients Undergoing Cardiac Valve Surgery

	MS-DRGs	Patients, n	Readmissions, n	1-30 Days	31-60 Days	61-90 Days
Cardiac events	All MDC, 5 MS-DRGs	6365 (43.0%[a])	8309 (42.0%[b])	5237	1885	1187
Infections	075-076; 094-099; 152-153; 177-179; 193-195; 202-203; 288-290; 371-373; 485-487; 539-541; 548-550; 602-603; 689-690; 757-759; 853-858; 862-872	2301 (15.6%[a])	3209 (16.2%[b])	1836	802	571
Pulmonary events	003-004; 163-168; 175-176; 186-189; 196-201; 204-208	1821 (12.3%[a])	2442 (12.3%[b])	1606	530	306
Gastrointestinal events	326-337; 344-346; 356-358; 368-371; 377-384; 388-395; 408-424	1142 (7.7%[a])	1624 (8.2%[b])	864	431	329
Stroke/acute CNS events	020-027; 034-039; 061-072; 077-081; 100-103	604 (4.1%[a])	783 (4.0%[b])	378	219	186
Acute associated medical conditions	190-198; 637-639; 640-645; 682-685; 811-813; 915-923	1061 (7.2%[a])	1431 (7.2%[b])	859	350	222
All others	Over 200 other MS-DRGs	1462 (9.9%[a])	2006 (10.1%[b])	973	574	459
	Total	**14,756**	**19,804**	**11,753**	**4791**	**3260**

CNS indicates central nervous system; MDC, Medical Diagnostic Category; MS-DRG, Medicare Severity Diagnosis-Related Group.
[a]Percent of readmitted patients.
[b]Percent of all readmissions.

the usual chronic diseases (eg, chronic renal failure) were significant variables. Patients who were prLOS after inpatient care had significant odds ratios (ORs) for both PD-90 (CABG: OR, 11.34; CVS: OR, 13.94) and RA-90 (CABG: OR, 2.07; CVS: OR, 2.10).

The MS-DRGs of readmissions after exclusions are identified in the developmental dataset in **Tables 2** and **3** for days 1 to 30, 31 to 60, and 61 to 90 following discharge. For CABG patients, cardiac events (39.1%), infections (17.4%), and pulmonary events (13.9%) were the most common causes of readmissions. Among all readmissions, 57% occurred during the first 30 days following discharge, 24.8% occurred between days 31 to 60, and 18.2% occurred between days 61 to 90, for a total of 43% of associated readmissions occurring between days 31 to 90.

In Table 3, for CVS patients in the developmental database, cardiac events (43%), infections (15.6%), and pulmonary events (12.3%) were the most common MS-DRGs for first-time readmissions. In examining all readmission events, 59.3% occurred during the first 30 days following discharge, 24.2% between days 31 to 60, and 16.5 % between days 61 to 90, for a total of 40.7% occurring between days 31 to 90.

Hospital Outcomes

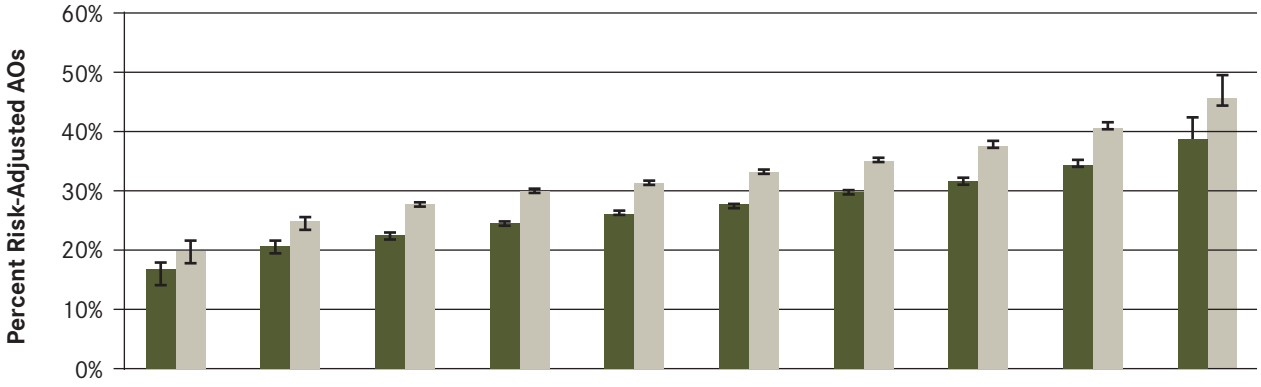
The study database population for CABG consisted of 1031 qualifying hospitals with 96,623 cases, for an average of 97 and a median of 74 per hospital. There were 1540 inpatient deaths (1.6%), 7902 prLOS (8.2%), 1092 deaths at 90-days without readmission (1.1%), and 19,281 readmissions at 90 days (20%). Among RA-90 patients, another 678 died. A total of 3310 (3.4%) patients died from operation through 90 days following discharge. A total of 26,314 (27.2%) patients had 1 or more AOs, with more than 50% due to readmissions.

For favorable outcomes in CABG, z scores among hospitals ranged from –5.05 standard deviations (SDs) less than expected to +4.76 SDs greater than expected. Fifty-six hospitals had outcomes that were at least 2 SDs better than expected, and 71 hospitals that were at least 2 SDs poorer than expected. The risk-adjusted outcomes for all hospitals are illustrated by deciles in **Figure 1**. The top-performing decile had a median risk-adjusted AO rate of 17%, while the poorest performing 10th decile had a median risk-adjusted AO rate of 38.8%. Because all decile samples were both drawn from a population with a known SD and had the same number of hospitals, the standard error of the mean for all decile samples was 0.7%. The error bars in Figure 1 represent the interquartile range to give an accurate representation of the performance variability. In **Figure 2**, hospital risk-adjusted outcomes were divided into deciles based on the number of cases in the study database. The smallest decile hospitals (20-29 cases) had a mean of 28.1% for risk-adjusted AOs; the largest decile (≥179 cases) had a mean of 26.3%. The correlation coefficient was 0.045 ($P = .15$).

For CVS, there were a total of 794 hospitals with 68,825 patients, for an average of 87 and a median of 57 cases per hospital. CVS had 1784 inpatient deaths (2.6%), 6079 prLOS (8.8%), and 1168 postdischarge deaths without readmission (1.7%); 16,342 patients (23.7%) had 1 or more readmissions. An additional 778 patients died after readmission, for a total of 3730 (5.4%) deaths across the inpatient and postdischarge time. A total of 22,256 (32.3%) patients had 1 or more AOs. As with CABG, the majority of AOs were attributable to readmissions.

For CVS, the z scores ranged from –4.68 for the best to 3.61 for the poorest performing facilities. Forty-five hospitals had outcomes that were at least 2 SDs better, and the outcomes of 57 were at least 2 SDs poorer than predicted. In Figure 1, the best performing decile had a median risk-adjusted AO rate of 20.4%, while the poorest performing decile had a median AO rate of 45.8%. The standard error

Figure 1. The Median Risk-Adjusted Adverse Outcomes of Coronary Artery Bypass Grafting and Cardiac Valve Surgery in Medicare Patients



	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10
CABG	17.0%	20.5%	22.8%	24.8%	26.3%	27.9%	29.7%	31.8%	34.7%	38.8%
CVS	20.4%	24.9%	27.7%	29.7%	31.4%	33.3%	35.2%	37.9%	40.9%	45.8%

AOs indicates adverse outcomes; CABG, coronary artery bypass grafting; CVS, cardiac valve surgery.
Black lines indicate interquartile range.

for each decile of hospital performance was 0.9%. The variability of each decile of hospital performance is illustrated by the interquartile range in Figure 1. In Figure 2, hospital volume is shown to not be associated with better outcomes. The smallest decile had 20 to 24 cases and the largest had 177 or more cases. The correlation coefficient was 0.050 ($P = .15$).

DISCUSSION

The risk-adjusted results of this study demonstrate a dramatic difference in the outcomes of cardiac surgery in Medicare patients. With reduced lengths of inpatient hospitalization, clinical outcomes of care cannot be evaluated solely on inpatient events. More than 50% of the deaths observed in this study occurred in the 90 days following discharge with or without readmission, and more than 50% of total AOs were due to RA-90.

Readmissions have not been an outcome focus in previous years, and their inclusion in this study has added a large number of AOs. Many clinicians argue that readmissions should not be counted as an AO, and that readmissions are expected and unavoidable in older patients. The STS database does not include postdischarge readmissions in its evaluation of hospitals or surgeons.[18] However, the MS-DRGs of readmission in Tables 2 and 3 are associated with the operation, and the differences in risk-adjusted rates identified between top- and bottom-performing hospitals in this study would indicate that there are opportunities for improvement in cardiac surgery outcomes, especially in postdischarge events.

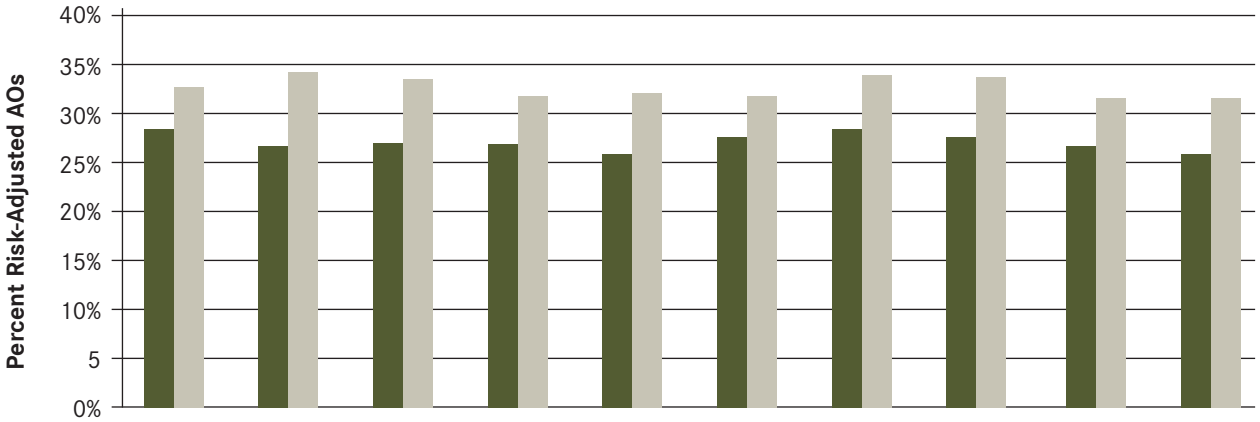
In this current study, the events associated with readmission represent morbidity after cardiac surgery. These events are amenable to preventive strategies, prompt recognition, and clinical rescue. Readmission is predicted in those patients that have prLOS in the index hospitalization. Inpatient complications in cardiac surgery have been identified as having a strong relationship to readmissions.[19,20] Medicare and other payers of care clearly consider readmission to be a marker of suboptimal outcomes, and financial penalties have been the consequence.

A major discussion in readmissions is the postdischarge duration of time for accountability. Most studies of cardiac surgery readmissions have used either 30 days from the time of operation[21,22] or 30 days following discharge as the time interval.[23,24] A single study has reported readmissions at 65 days following the operative date.[25] Our data indicate that 40% of significant readmissions that are linked to the index operation do not occur until the 31-to 90-day time interval. An established private program has successfully used a 90-day postprocedural interval for episode-based payment in cardiac surgery.[26] In the Acute Care Episode Demonstration Project by Medicare, total joint replacement and CABG were the operations of interest.[27] Cardiac surgery will likely be an addition to joint replacement as the bundled payment initiative unfolds, and the postsurgical 90-day period probably will be the target interval for postdischarge accountability.[10]

Limitations

One limitation to this study is that the prediction models are designed from administrative, and not clinical, data. The inpatient mortality model in this study is not the equivalent of the STS model using clinical data. However, the C statistic of the IpD and PD-90 models are good, and the reduction of the C statistic when hospital variables are removed demonstrates that the hospital makes a difference in mortality outcomes. Hopefully, the evolving electronic health record (EHR) will allow the efficient recovery of clinical data to enhance administrative databases. The addition of admission laboratory data has the promise of being easily imported clinical data

Figure 2. The Risk-Adjusted Adverse Outcomes of Coronary Artery Bypass Grafting and Cardiac Valve Surgery by Decile of Increasing Hospital Volume of Cases



	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10
CABG	28.1%	27.1%	27.5%	27.6%	26.0%	27.5%	28.7%	28.3%	27.5%	26.3%
CVS	32.8%	34.4%	33.9%	32.7%	32.2%	32.0%	34.1%	33.8%	31.5%	31.7%

AOs indicates adverse outcomes; CABG, coronary artery bypass grafting; CVS, cardiac valve surgery.

from the EHR to enhance prediction model development.[28,29] The EHR may even permit the inclusion of sophisticated clinical data (eg, ejection fraction) into a hybrid data set. Although administrative data have their shortcomings, they have the advantage of not being self-reported and do capture PD-90 and RA-90. Additional limitations include the need for further refinement of those readmissions that should not be included as dependent variables in risk equations and the need to include socioeconomic risk factors of the patients in the prediction of readmissions. Refinement is necessary to enhance discrimination of readmission models.[30] Finally, this study included only Medicare patients and this may not be representative of the entire experience of any facility when all patients are included.

Comprehensive studies of this nature are not common, and the reality is that most hospitals, and even surgeons, do not know their risk-adjusted rates across the spectrum of AOs as we have defined them. When mechanisms are not in place to permit feedback to providers of their comparative performance to regional or national benchmarks, then improvement initiatives will be lacking. Risk-adjusted results by provider can only be achieved when state or regional all-payer databases are developed that will provide a feedback loop to guide improvement efforts.

CONCLUSIONS

This study identifies a dramatic difference among hospitals in risk-adjusted AO rates for CABG and CVS that cover both inpatient and 90-day postdischarge results. The comparative outcomes indicate opportunities for care improvement. With the exclusion of unrelated readmission events, 40% of readmissions that are associated with the index hospitalization occur at 31 to 90 days postdischarge. As bundled payments for cardiac surgery are developed, a strong case exists for the inclusion of the full 90-day postdischarge period in the payment design.

Author Affiliations: MPA Healthcare Solutions (DEF, MP, SMN, DGL, AMR, GP), Chicago, IL; Department of Surgery (DEF) and Department of Emergency Medicine (SMN), Northwestern University Feinberg School of Medicine, Chicago, IL; and the University of New Mexico School of Medicine (DEF), Albuquerque, NM.

Source of Funding: This study was internally funded by MPA Healthcare Solutions of Chicago, IL.

Author Disclosures: Dr Fry has previously received a surgical site injection grant from IrriMax Corporation, and has received lecture fees for speaking at the invitation of a commercial sponsor (Merck; and Carefusion, on infection topics). Dr Nedza has previously received honoraria from the American College of Emergency Physicians for less than $100. The remaining authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (DEF, SMN, AMR, DGL, MP, GP); acquisition of data (DEF, SMN, AMR, DGL, MP); analysis and interpretation of data (DEF, SMN, AMR, DGL, MP, GP); drafting of the manuscript (DEF); critical revision of the manuscript for important intellectual content (DEF, SMN, AMR, DGL, MP, GP); statistical analysis (DEF, SMN, AMR, DGL, MP, GP); provision of study materials or patients (GP); administrative, technical, or logistic support (MP, GP); and supervision (DEF, MP, GP).

Send correspondence to: Donald E. Fry, MD, MPA, Healthcare Solutions, 1 East Wacker Dr, #1210, Chicago, IL 60601. E-mail: dfry@consultmpa.com.

REFERENCES

1. STS National Database. The Society of Thoracic Surgeons website. http://www.sts.org/national-database. Published 2015. Accessed July 16, 2015.
2. Hogan H, Zipfel R, Neuburger J, Hutchings A, Darzi A, Black N. Avoidability of hospital deaths and association with hospital-wide mortality ratios: retrospective case record review and regression analysis. *BMJ*. 2015;351:h3239. doi: 10.1136/bmj.h3239.
3. Fry DE, Pine M, Jones BL, Meimban RJ. The impact of ineffective and inefficient care on the excess costs of elective surgical procedures. *J Am Coll Surg*. 2011;212(5):779-786. doi: 10.1016/j.jamcollsurg.2010.12.046.
4. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009;360(14):1418-1428. doi: 10.1056/NEJMsa0803563.
5. Readmissions reduction program. CMS website. http://www.cms.gov/Medicare/medicare-fee-for-service-payment/acuteinpatientPPS/readmissions-reduction-program.html. Updated February 4, 2016. Accessed February 2016.
6. Rau J. Medicare fines 2,610 hospitals in third round of readmission penalties. Kaiser Health News website. http://kaiserhealthnews.org/news/medicare-readmissions-penalties-2015/. Published October 2, 2014. Accessed July 2, 2015.
7. Rau J. Half of nation's hospitals fail again to escape Medicare's readmission penalties. Kaiser Health News website. http://khn.org/news/half-of-nations-hospitals-fail-again-to-escape-medicares-readmission-penalties/. Published August 3, 2015. Accessed August 5, 2015.
8. Davies SM, Saynina O, McDonald KM, Baker LC. Limitations of using same-hospital readmission metrics. *Int J Qual Health Care*. 2013;25(6):633-639. doi: 10.1093/intqhc/mzt068.
9. Kim Y, Gani F, Lucas DJ, et al. Early versus late readmission after surgery among patients with employer-provided health insurance. *Ann Surg*. 2015;262(3):502-511, discussion 509-511. doi: 10.1097/SLA.0000000000001429.
10. CMS. Medicare program; comprehensive care for joint replacement payment model for acute care hospitals furnishing lower extremity joint replacement services. *Federal Register* website. https://www.federalregister.gov/articles/2015/07/14/2015-17190/medicare-program-comprehensive-care-for-joint-replacement-payment-model-for-acute-care-hospitals. Published July 14, 2015. Accessed July 16, 2015.
11. Pine M, Fry DE, Jones BL, Meimban RJ. Screening algorithms to assess the accuracy of present-on-admission coding. *Perspect Health Inf Manag*. 2009;6:2.
12. Schwarz GE. Estimating the dimension of a model. *Ann Stat*. 1978;6(2):461-464.
13. Fry DE, Pine M, Jones BL, Meimban RJ. Control charts to identify adverse outcomes in elective colon resection. *Am J Surg*. 2012;203(3):392-396, discussion 396. doi: 10.1016/j.amjsurg.2011.09.011.
14. Pine M, Fry DE, Jones BL, Meimban RJ, Pine GJ. Controlling costs without compromising quality: paying hospitals for total knee replacement. *Med Care*. 2010;48(10):862-868. doi: 10.1097/MLR.0b013e3181eb3176.
15. Fry DE, Pine M, Jones BL, Meimban RJ. Surgical warranties to improve quality and efficiency in elective colon surgery. *Arch Surg*. 2010;145(7):647-652. doi: 10.1001/archsurg.2010.106.
16. Fry DE, Pine M, Jones BL, Meimban RJ. Adverse outcomes in surgery: redefinition of post-operative complications. *Am J Surg*. 2009;197(4):479-484. doi: 10.1016/j.amjsurg.2008.07.056.
17. Fry DE, Pine M, Pine G. Medicare post-discharge deaths and readmissions following elective surgery. *Am J Surg*. 2014;207(3):326-330, discussion 330. doi: 10.1016/j.amjsurg.2013.09.007.
18. STS CABG composite score. The Society of Thoracic Surgeons website. http://www.sts.org/sts-public-reporting-online/cabg-composite-score. Accessed August 6, 2015.
19. Birkmeyer JD, Gust C, Dimick JB, Birkmeyer NJ, Skinner JS. Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg*. 2012;255(1):1-5. doi: 10.1097/SLA.0b013e3182402c17.
20. Greco G, Shi W, Michler RE, et al. Costs associated with health care-associated infections in cardiac surgery. *J Am Coll Cardiol*. 2015;65(1):15-23. doi: 10.1016/j.jacc.2014.09.079.
21. Price JD, Romeiser JL, Gnerre JM, Shroyer AL, Rosengart TK. Risk analysis for readmission after coronary artery bypass surgery: developing a strategy to reduce readmissions. *J Am Coll Surg*. 2013;216(3):412-419. doi: 10.1016/j.jamcollsurg.2012.11.009.
22. Lancey R, Kurlansky P, Argenziano M, et al. Uniform standards do not apply to readmission following coronary artery bypass surgery: a multi-institutional study. *J Thorac Cardiovasc Surg*. 2015;149(3):850-857.e1, discussion 857. doi: 10.1016/j.jtcvs.2014.08.059.
23. Hannan EL, Zhong Y, Lahey SJ, et al. 30-day readmissions after coronary artery bypass graft surgery in New York State. *JACC Cardiovasc Interv*. 2011;4(5):569-576. doi: 10.1016/j.jcin.2011.01.010.
24. Maniar HS, Bell JM, Moon MR, et al. Prospective evaluation of patients readmitted after cardiac surgery: analysis of outcomes and identification of risk factors. *J Thorac Cardiovasc Surg*. 2014;147(3):1013-1018. doi: 10.1016/j.jtcvs.2013.10.066.
25. Iribarne A, Chang H, Alexander JH, et al. Readmissions after cardiac surgery: experience of the National Institutes of Health/Canadian Institutes of Health research cardiothoracic surgical trials network. *Ann Thorac Surg*. 2014;98(4):1274-1280. doi: 10.1016/j.athoracsur.2014.06.059.
26. Casale AS, Paulus RA, Selna MJ, et al. "ProvenCareSM": a provider-driven pay-for-performance program for acute episodic cardiac surgical care. *Ann Surg*. 2007;246(4):613-621, discussion 621-623.
27. Medicare Acute Care Episode (ACE) demonstration. CMS website. http://innovation.cms.gov/initiatives/ACE/. Updated May 29, 2015. Accessed July 7, 2015.
28. Pine M, Jordan HS, Elixhauser A, et al. Enhancement of claims data to improve risk adjustment of hospital mortality. *JAMA*. 2007;297(1):71-76.
29. Fry DE, Pine M, Jordan HS, et al. Combining administrative and clinical data to stratify surgical risk. *Ann Surg*. 2007;246(5):875-885.
30. Kansagara D, Englander H, Salanitro A, et al. Risk prediction models for hospital readmission: a systematic review. *JAMA*. 2011;306(15):1688-1698. doi: 10.1001/jama.2011.1515.