Outcomes of concomitant aortic valve replacement and coronary artery bypass grafting at teaching hospitals versus nonteaching hospitals

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Objective: Hospitals with a high volume and academic status produce better patient outcomes than other hospitals after complex surgical procedures. Risk models show that concomitant aortic valve replacement and coronary artery bypass grafting pose a greater risk than isolated coronary artery bypass grafting or aortic valve replacement. We examined the relationship of hospital teaching status and the presence of a thoracic surgery residency program with aortic valve replacement/coronary artery bypass grafting outcomes.

Methods: By using the Nationwide Inpatient Sample database, we identified patients who underwent concomitant aortic valve replacement/coronary artery bypass grafting from 1998 to 2007 at nonteaching hospitals, teaching hospitals without a thoracic surgery residency program, and teaching hospitals with a thoracic surgery residency program. Multivariate analysis was performed to identify intergroup differences. Risk-adjusted multivariable logistic regression analysis was used to assess independent predictors of in-hospital mortality and complication rates.

Results: The 3 groups of patients did not differ significantly in their baseline characteristics. Patients who underwent aortic valve replacement/coronary artery bypass grafting had higher overall risk-adjusted complication rates in nonteaching hospitals (odds ratio 1.58; 95% confidence interval, 1.39–1.80; $P < .0001$) and teaching hospitals without a thoracic surgery residency program (odds ratio 1.42; 95% confidence interval, 1.26–1.60; $P < .0001$) than in thoracic surgery residency program hospitals. However, no difference was observed in the adjusted mortality rate for nonteaching hospitals (odds ratio 0.95; 95% confidence interval, 0.87–1.04; $P = .25$) or teaching hospitals without a thoracic surgery residency program (odds ratio 1.00; 95% confidence interval, 0.92–1.08; $P = .98$) when compared with thoracic surgery residency program hospitals. Robust statistical models were used for analysis, with c-statistics of 0.98 (complications) and 0.82 (mortality).

Conclusion: Patients who require complex cardiac operations may have better outcomes when treated at teaching hospitals with a thoracic surgery residency program. (J Thorac Cardiovasc Surg 2012;143:648-55)

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Better patient outcomes have been reported when complex surgical procedures (eg, esophagectomies and repairs of thoracoabdominal aortic aneurysm and aortic dissection) are performed at high-volume centers and those with academic affiliations.[1-3] However, in the past decade, surgical training at academic centers has faced challenges and has been a constant subject of scrutiny. In cardiac surgery, straightforward procedures such as isolated coronary artery bypass grafting (CABG) have decreased in volume because of advancements in percutaneous interventions. Today, many more complex cardiac surgical procedures are performed that often involve a combination of a valve operation and myocardial revascularization. This, along with the 80-hour work-week restriction on surgical residents, has accentuated the difficulties associated with cardiothoracic surgical training. Despite the challenges facing academic surgical centers and surgical training programs, we hypothesize that academic centers provide better care for patients who undergo more complex cardiac procedures.

We sought to examine the relationship between the presence of a thoracic surgery residency program (TSRP) and the outcomes of a complex cardiac surgical procedure—concomitant aortic valve replacement (AVR) and CABG.

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MATERIAL AND METHODS

Data Source

Data were obtained from the US Nationwide Inpatient Sample (NIS); these data were collected from 1998 to 2007. The NIS is a database

Abbreviations and Acronyms

AVR = aortic valve replacement
CABG = coronary artery bypass grafting
CI = confidence interval
HCUP = Healthcare Cost and Utilization Project
ICD-9-CM = *International Classification of Diseases, Ninth Revision, Clinical Modification*
NIS = Nationwide Inpatient Sample
OR = odds ratio
TSRP = thoracic surgery residency program

containing records of hospital inpatient stays and is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project (HCUP).[4] A 10-year time span was chosen so that any trends that might have occurred during that time period would probably have affected teaching and nonteaching hospitals uniformly.

The NIS, the largest all-payer inpatient care database, represents 20% of all hospital discharges from nonfederal facilities in the United States and thus was particularly suited for testing our hypothesis. The NIS has numerous internal quality assurance procedures for checking the consistency and validity of data (http://www.hcup-us.ahrq.gov/db/quality.jsp). Furthermore, HCUP validates the NIS annually by comparing its contents with those of 2 similar databases— the National Hospital Discharge Survey and the Medicare Provider Analysis and Review—to assess potential biases in the data (http://www.hcup-us.ahrq.gov/db/nation/nis/nisrelatedreports.jsp). The NIS contains data from more than 1000 hospitals regarding approximately 8 million hospital stays each year, although this number varies slightly on an annual basis. Weights based on sampling probabilities for each stratum are used in the analysis to ensure that the hospitals studied are representative of all US hospitals.

A teaching hospital was defined by the NIS as one with an active teaching residency program, regardless of subspecialty. The NIS hospital core files were used to tally the name of the hospital against the hospitals listed in the fellowship and residency interactive electronic database under the category of thoracic surgery residency. Specifically, the participating hospital rather than the sponsoring program was tallied to ensure that all hospitals that support a TSRP were captured. For the teaching hospital group, cases in which the hospital name and address were not available were excluded from the study. We stratified our samples into 3 groups: nonteaching hospitals, teaching hospitals without a TSRP, and hospitals with a TSRP.

Variables available in the NIS included patient and hospital demographics, payer information, treating and concomitant diagnoses, inpatient procedures, in-hospital mortality, and length of hospital stay (date of admission to date of discharge). For each admission, the NIS captures up to 15 diagnosis and procedure codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM).[5] In addition, the NIS hospital core files allow us to correct for potentially confounding hospital characteristics.

This study was approved by the institutional review board of Baylor College of Medicine. The data reported in our study conform to the Data Use Agreement for the NIS from the HCUP. Additional information about the NIS is available from the Agency for Healthcare Research and Quality, which sponsors the database as part of the HCUP (http://www.hcup-us.ahrq.gov/nisoverview.jsp).

Patient Selection

We used ICD-9-CM procedure codes to query the entire NIS data set and identify all patients who underwent concomitant AVR/CABG operations from 1998 to 2007. The ICD-9-CM procedure codes 3610, 3612, 3613, 3614, 3615, and 3616 were used to select patients who underwent CABG procedures; among this subset of patients, the codes for AVR (3521, 3522) were used to select patients who had concomitant AVR/CABG. Patients who underwent other concomitant valve operations or other noncoronary cardiac procedures (Table 1) and those who were aged less than 18 years were excluded. A total of 202,663 cases of AVR/CABG were identified, of which 65,407 were performed in nonteaching hospitals, 24,125 were performed in TSRP hospitals, and 83, 414 were performed in teaching hospitals without a TSRP; 29,717 cases (14.7%) from 136 teaching hospitals were excluded because TSRP status was not known. Of the 740 hospitals where AVR/CABG procedures were performed, 43.1% were nonteaching hospitals (n = 319). Of the remaining 285 teaching hospitals, 61 supported a TSRP approved by the Accreditation Council for Graduate Medical Education.

Patient Characteristics

The Deyo index[6] was used to compare the 3 groups of patients in terms of preoperative morbidity. Specifically designed to be used with administrative databases, the Deyo index is a weighted comorbidity index that is modified from the Charlson comorbidity index and that assesses 17 prespecified comorbidities. Furthermore, the Deyo index uses more than 600 ICD-9 diagnosis codes to query specific comorbid diagnoses.

Previously, we demonstrated the feasibility of querying the NIS database for cardiac surgical procedures.[7,8] Patient comorbidities were identified from each patient's ICD-9 diagnosis codes recorded in the NIS data set. These codes were then used to produce a summary Deyo index score for each patient.

Study End Points

The primary end point of this study was in-hospital mortality; the secondary end point was rate of complications. All-cause in-hospital complications were recorded according to their ICD-9 diagnosis codes. The following postoperative complications were assessed: cardiac complications, mediastinitis, neurologic complications, respiratory complications, renal complications, deep vein thrombosis, pulmonary embolism, intraoperative complications, and iatrogenic pneumothorax (Appendix 1).

Statistical Analysis

Statistical analysis was performed with SPSS, version 19.0 (SPSS Inc, Chicago, Ill). Multivariate analysis of variance tests and chi-square tests were used to examine intergroup differences in age, race, sex, patient income, expected payer, Deyo index score, mortality, length of hospital stay, and disposition. We analyzed hospital characteristics including hospital volume, ownership, location (ie, rural vs urban), geographic region (ie, Northeast, Midwest, West, and South), and bed size. Hospitals that performed more than 25 AVR/CABG procedures per year were considered high volume. To examine the risk-adjusted association between the presence of a TSRP and in-hospital complications and mortality, hierarchic multiple logistic regression analysis was performed. With the regression model, outcomes of patients who underwent AVR/CABG at nonteaching hospitals and teaching hospitals without a TSRP were compared with outcomes of patients who underwent the same procedure at a hospital with a TSRP.

Because our sample was large, certain differences appeared to be statistically significant even though their practical relevance was negligible. Therefore, 3 different effect-size statistics were computed to assess the practical implications of our findings. Cohen's *d* was calculated for continuous data by using pooled standard deviations and was appropriately weighted for unequal sample size.[9] The *phi* coefficient was calculated

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TABLE 1. Excluded concomitant procedures and procedure codes

Procedure	Corresponding ICD-9-CM procedure code(s)
Valve replacement: mitral	3523, 3524
Valvuloplasty	3510, 3511, 3512, 3513, 3514
Valve replacement: unspecified	3520, 3525, 3526, 3527, 3528
Papillary muscle excision	3531
Chordae excision	3532, 3535
Annuloplasty	3533
Infundibulectomy	3534
Creation of septal defect	3542
Endocushion defect repair	3550, 3551, 3552, 3553, 3554, 3570, 3571, 3572, 3573
Ventricular/atrial repair	3560, 3561, 3562, 3563
Congenital heart defect repair	3581, 3582, 3583, 3584, 3591, 3592, 3593, 3594, 3595, 3596, 3597, 3598, 3599
Transmyocardial revascularization	3631, 3632
Ventricular restoration procedures	3732, 3733, 3734, 3735
Heart transplantation	3751, 3752, 3753, 3754

and used to perform chi-square tests for independence with 1 degree of freedom. Cramer's V was computed for variables with more than 1 degree of freedom.[10] We used the following categories to judge the computed effect sizes: less than 0.32 (small), 0.33 to 0.55 (medium), and 0.56 or more (large).

RESULTS

Patient Characteristics

Although there were several significant differences in the baseline characteristics of patients who underwent AVR/CABG at teaching versus nonteaching hospitals (Table 2), the effect sizes of these differences were minuscule and thus of no clinical consequence. The largest effect sizes were observed for the difference in the distribution of hospital bed size (Cramer's V = 0.261), hospital ownership (Cramer's V = 0.729), and hospital volume (Cramer's V = 0.269). A higher proportion of patients (90%) underwent AVR/CABG in large hospitals with a TRSP than in nonteaching hospitals (87.5%) or teaching hospitals without a TSRP (66.6%). The majority of the procedures performed in hospitals with a TSRP were at high-volume centers (92.2%).

Mortality

The in-hospital mortality rate—our primary outcome measure—was higher at nonteaching hospitals (6.4%; n = 4195) than at teaching hospitals without a TSRP (5.9%; n = 4909) or at TSRP hospitals (5.9%; n = 1413) ($P < .001$). Nonetheless, after adjusting for confounding factors, including the minor differences in baseline characteristics, the components of the Deyo comorbidity index scores, and hospital characteristics, we found no difference in mortality for nonteaching hospitals (odds ratio [OR], 0.95; 95% confidence interval [CI], 0.87–1.04; $P = .25$) or teaching hospitals without a TSRP (OR, 1.00; 95% CI, 0.92–1.08; $P = .98$) when compared with TSRP hospitals (c-statistic = 0.82).

Postoperative Complications

A robust risk-adjusted model with a c-statistic of 0.98 was used for regression analysis of the various postoperative complications of patients who underwent AVR/CABG in nonteaching hospitals and teaching hospitals with or without a TSRP (Table 3). Patients who underwent AVR/CABG had higher overall risk-adjusted complication rates in nonteaching hospitals (OR, 1.58; 95% CI, 1.39–1.80; $P < .0001$) and teaching hospitals without a TSRP (OR, 1.42; 95% CI, 1.26–1.60; $P < .0001$) than in TSRP hospitals. In addition, age, female gender, race, calendar year, small hospital bed size, and case-specific hospital volume independently affected both in-hospital mortality and morbidity. The regression coefficients are summarized in Appendix 2.

DISCUSSION

For patients who underwent concomitant AVR/CABG, a commonly performed yet complex cardiac operation, the overall in-hospital complication rates were 58% higher in nonteaching hospitals and 42% higher in teaching hospitals without a TSRP than in hospitals with a TSRP. However, the risk-adjusted mortality was not different among the 3 groups. Our results indicate that patients who undergo complex procedures in hospitals with a TSRP may be at an advantage.

Traditionally, academic medical centers have been primarily focused on education and research in a setting that also involves patient care. With cardiac surgical cases becoming increasingly complex, the number of straightforward resident "teaching cases" at academic medical centers has declined. With the increased complexity of cardiac cases, the outcomes of these patients are being subjected to increased scrutiny with the application of risk models and nationwide databases.

Studies that have compared surgical outcomes between teaching and nonteaching hospitals have yielded controversial findings. For example, Lee and colleagues[11] found no difference between teaching and nonteaching hospitals in the outcome of pediatric patients treated for appendicitis. However, Hayanga and colleagues[12] showed that colon resection produced poorer outcomes when performed in teaching hospitals than in nonteaching hospitals.

Our study showed no difference in mortality between nonteaching hospitals and teaching hospitals with or without a TSRP for patients who underwent combined AVR/CABG. However, these patients had a lower complication rate in hospitals with a TSRP. This may be because teaching hospitals have multidisciplinary teams that are well equipped to handle problems before they advance to an

TABLE 2. Patient baseline characteristics and demographics

	Nonteaching (n = 65,407)	Teaching without TSRP (n = 83,414)	TSRP (n = 24,125)	*P*	Effect size
Age at admission (y)	72.45 ± 9.27	72.53 ± 9.60	72.56 ± 9.90	<.179	<0.001*
Deyo comorbidity index score	3.95 ± 1.53	3.93 ± 1.57	3.99 ± 1.60	<.001	<0.001*
Elective admission	52,879 (80.8)	63,736 (76.4)	18,358 (76.1)	<.001	0.053†
Male	43,939 (67.2)	54,625 (65.5)	15,642 (64.8)	<.001	–0.019†
Race (Caucasian)	44,732 (91.2)	55,517 (91.1)	14,507 (86.2)	<.001	–0.056‡
Hospital characteristics					
Hospital bed size (large)	57,241 (87.5)	55,555 (66.6)	21,749 (90.1)	<.001	0.261‡
Hospital location (urban)	62,000 (94.8)	80,320 (96.3)	24,125 (100)	<.001	0.087‡
Hospital ownership (public)	22,372 (34.2)	82,042 (98.4)	24,125 (100)	<.001	0.729‡
Hospital volume (>25/y)	41,095 (62.8)	69,682 (83.5)	22,242 (92.2)	<.001	0.269‡
Intraaortic balloon pump	4461 (6.8)	4556 (5.5)	1521 (6.3)	<.001	0.026†
Patient history					
Peripheral vascular disease	6662 (10.2)	8035 (9.6)	2720 (11.3)	<.001	0.018†
Myocardial infarction	190 (0.3)	297 (0.4)	108 (0.4)	.001	0.009†
Congestive heart failure	21,219 (32.4)	25,801 (30.9)	8565 (35.5)	<.001	0.033†
Cerebrovascular disease	5068 (7.8)	6683 (8.0)	1736 (7.2)	<.001	0.01†
Chronic dementia	84 (0.1)	127 (0.1)	36 (0.1)	.46	n/a
COPD	14,052 (21.5)	14,363 (17.2)	3672 (15.2)	<.001	0.061†
Rheumatoid disorders	966 (1.5)	1256 (1.5)	435 (1.8)	<.001	–0.01†
Peptic ulcer disease	679 (1.0)	1015 (1.2)	317 (1.3)	<.001	–0.009†
Chronic mild liver disease	255 (0.4)	264 (0.3)	109 (0.5)	.003	0.008†
Chronic moderate/severe liver disease	91 (0.1)	59 (0.1)	53 (0.2)	<.001	0.015†
Uncomplicated diabetes mellitus	13,569 (20.8)	16,949 (20.3)	5433 (22.5)	<.001	0.018†
Diabetes with complications	1518 (2.3)	2040 (2.4)	644 (2.7)	.010	0.007†
Preexisting hemiplegia or paraplegia	365 (0.6)	437 (0.5)	76 (0.5)	<.001	–0.011†
Renal failure	2144 (3.3)	2799 (3.4)	728 (3.0)	.034	0.006†

Data are presented as number (%) or as the mean ± standard deviation. *COPD*, Chronic obstructive pulmonary disease; *n/a,* not applicable (effect size is not applicable when there is no statistically significant difference). *Cohen's *d* was used to calculate effect size. †*Phi* was used to calculate effect size. ‡Cramer's V was used to calculate effect size.

irreversible stage. In nonteaching settings, the perioperative care of patients is handled by the primary surgeon or by ancillary staff members, such as physician assistants or nurse practitioners. However, in a teaching hospital, residents manage the care of these patients. Although a lay person seeking medical care would assume that the involvement of a trainee physician would result in suboptimal care, our study shows the contrary.

TABLE 3. Patient outcomes at nonteaching hospitals and teaching hospitals with or without a thoracic surgery residency program

	Nonteaching (n = 65,407)	Teaching without TSRP (n = 83,414)	TSRP (n = 24,125)	χ^2	*P*
Cardiac complications	10,875 (16.6)	15,000 (18.0)	5460 (22.6)	430.3	<.001
Systemic complications	900 (1.4)	981 (1.2)	254 (1.1)	19.6	<.001
Wound complications	1780 (2.7)	2297 (2.8)	869 (3.6)	55.7	<.001
GI complications	890 (1.4)	851 (1.0)	176 (0.7)	75.5	<.001
Operative complications	9402 (14.4)	11,824 (14.2)	3866 (16.0)	53.1	<.001
Deep vein thrombosis	371 (0.6)	335 (0.4)	187 (0.8)	56.1	<.001
Infections	5109 (7.8)	7051 (8.5)	2701 (11.2)	261.1	<.001
Mediastinitis	38 (0.1)	102 (0.1)	50 (0.2)	37.9	<.001
Neurologic complications	1966 (3.0)	2636 (3.2)	639 (2.6)	16.8	<.001
Pulmonary embolism	109 (0.2)	112 (0.1)	30 (0.1)	3.5	.175
Pneumothorax	1292 (2.0)	2021 (2.4)	417 (1.7)	59.2	<.001
Respiratory complications	15,555 (23.8)	19,900 (23.9)	5066 (21.0)	92.5	<.001
Renal complications	7545 (11.5)	9130 (10.9)	2502 (10.4)	27.6	<.001
Any complication	33,564 (51.3)	42,886 (51.4)	12,975 (53.8)	48.5	<.001

Data are presented as number (%). *GI*, Gastrointestinal.

Remaining at the forefront of medical care, teaching hospitals are generally acquainted with the latest technologic advancements and research developments. At nonteaching hospitals, physicians and staff members are less likely to stay abreast of these advancements because these clinicians are overwhelmed with other priorities, such as financial issues, maintaining referral relationships, bookkeeping, and, in many cases, direct involvement in floor work. In an academic setting, these duties are delegated to other personnel, thereby allowing academic surgeons to spend more time not only on high-acuity patient care but also on resident education and research. The active involvement of the surgical team in research further ensures better evidence-based care of postoperative patients with complex needs. The lower complication rates that we observed in teaching hospitals with a TSRP may directly result from these institutional differences.

In support of these findings, our analysis showed that the presence of a TSRP contributes to a lower rate of complications and a mortality rate equivalent to those of nonteaching hospitals and teaching hospitals without a TSRP. By definition, teaching hospitals in the NIS database have at least one accredited residency program in a medical or surgical field; from those hospitals, we specifically selected those with a TSRP. At hospitals with a TSRP, residents are more involved in the perioperative aspects of cardiac surgery cases, which may partly explain why the rate of morbidity was lower at these hospitals than at teaching hospitals without a TSRP. The presence of a TSRP was not detrimental or associated with a higher rate of mortality.

Limitations

Our study is subject to the limitations inherent in a retrospective review. The Deyo comorbidity index does not capture variables such as the presence of aortic atheroma or medical treatment (eg, concomitant antiplatelet therapy). Therefore, when used for risk stratification, the Deyo comorbidity index may not reflect all of the important aspects of the clinical scenario. In addition, the NIS is not a clinical database, so details such as ejection fraction, severity of congestive heart failure, intraoperative variables, indications, and precipitating factors for surgery were not available for risk-adjusted analysis. This is a significant limitation of using administrative databases in clinical studies. Furthermore, because of the administrative nature of the NIS database, there may have been reporting bias due to coding errors. However, such a bias would have presumably affected the 3 groups of patients equally. Nonetheless, because of this potential coding bias, we decided to limit our outcome measures to concrete end points.

However, using the NIS has certain advantages. In addition to being nonvoluntary, which eliminates institutional and surgeon bias, this nationwide database provides an enormous sample size, which affords adequate statistical power to detect low-frequency outcomes, such as mortality.

Although our statistical model was adjusted for hospital volume, it was not adjusted for surgeon volume. In the NIS, surgeon identity is captured by individual surgeon or surgical group, with significant year-to-year variation, making a surgeon–volume adjustment impossible. Also, information regarding the extent of resident involvement and the participation of nurse practitioners or physician assistants is not provided by the NIS dataset.

Another limitation of our study is that 29,717 patients (14.7%) who underwent AVR/CABG at 136 teaching hospitals were excluded because we were not able to determine whether the teaching hospitals had a TSRP. In contrast, no patients who underwent AVR/CABG in nonteaching hospitals were excluded for any reason. Also, patient identifiers are eliminated from the NIS dataset, making it impossible to obtain valuable information such as 30-day mortality. The possibility remains that patients in whom a complication developed in nonteaching hospitals after AVR/CABG may have been transferred to an academic or teaching facility for higher-level care or to a nursing home where they may have died. Therefore, our study may underestimate the rate of mortality for patients in nonteaching hospitals, possibly explaining the lack of difference in mortality rates among the 3 groups, despite significant differences in complication rates. These issues introduce a significant selection bias that should be taken into consideration when interpreting our findings.

CONCLUSIONS

Patients who require complex cardiac operations such as AVR/CABG may receive better surgical treatment at teaching institutions with a TSRP. Despite the increasing complexity of both cardiac surgical procedures and the conditions they are performed to treat, resident involvement continues to be an important and integral component of patient care. The presence of residents in teaching hospitals and in the academic environment contributes to better patient outcomes in complex cardiac surgical procedures, and our findings strongly support resident involvement in all aspects of cardiac surgery at teaching institutions.

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APPENDIX 1. Summary and description of ICD-9-CM codes used to identify complications

Cardiac complications	Cardiac arrest, cardiorespiratory failure after procedure (997.1)
	Hemopericardium (423.0)
	Open cardiac massage (37.91)
Systemic complications	Postoperative shock (998.0)
	Other postoperative systemic complications (998.89)
Wound complications	Delayed wound healing (998.83)
	Postoperative hematoma (998.12)
	Postoperative seroma (noninfected) (998.13)
	Disruption of operative wound (998.31, 998.32)
	Persistent postoperative fistula (998.6)
GI complications	Hepatic failure, hepatorenal syndrome, or intestinal obstruction specified as due to a procedure (997.4)
Operative or procedure-related complications	Mechanical complication, prosthesis (996.02)
	Mechanical complication, graft (996.03)
	Complication due to heart valve prosthesis (996.71)
	Complication due to coronary graft (996.72)
	Disruption of internal surgical wound (998.31)
	Hemorrhage complicating a procedure (998.11)
	Foreign body accidentally left during procedure (998.4)
	Accidental puncture or laceration during procedure (998.2)
	Abnormal reaction or later complication from valve prosthesis or graft (E878.1, E878.2)
Deep vein thrombosis	Phlebitis of deep femoral vein (451.11)
	Phlebitis of femoro-popliteal, popliteal, or tibial vein (451.19)
	Thrombosis of unspecified deep vein of lower extremity (453.40)
	Thrombosis of unspecified deep vein of proximal lower extremity (453.41)
	Thrombosis of unspecified deep vein of distal lower extremity (453.42)
Infections	Postoperative infection (998.5)
	Infected postoperative seroma (998.51)
	Postoperative abscess or septicemia (998.59)
	Infection due to coronary graft or valve prosthesis (996.61)
	Septicemia with specific organisms (038.0, 038, 038.1, 038.2, 038.3, 038.4, 038.8, 038.9)
	Urinary tract infection (599.0)
	Nonspecific bacterial infections (041.12, 041.7, 041.4)
Mediastinitis	Mediastinitis, deep sternal wound infection (519.2)
Neurologic complications	Anoxic brain injury (997.01)
	Postoperative stroke (997.02)
	Other nervous system complications (997.03)
Pulmonary embolism	Pulmonary embolism (415.11)
Pneumothorax	Iatrogenic or postoperative pneumothorax (512.1)

(Continued)

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APPENDIX 1. Continued

Respiratory complications	Postoperative atelectasis (997.3)
	Postoperative pneumonia (486, 482.9, 482.89, 481, 482.0–482.2, 482.30–482.32, 482.39–482.41, 482.49, 482.81–482.83)
	Postoperative acute respiratory insufficiency (518.5)
	Postoperative acute pneumothorax (512.1)
	Adult respiratory distress syndrome (518.5)
	Postoperative pulmonary edema (518.4)
	Empyema with fistula (510.0)
	Empyema without fistula (510.9)
	Pleural effusion (511.1, 511.8, 511.9)
	Chronic respiratory failure (518.83)
	Transfusion-related lung injury (518.7)
	Lung abscess (513.0, 513.1)
	Ventilator-associated pneumonia (997.31)
	Procedure-related pneumonia (997.39).
Renal complications	Oliguria or anuria due to procedure (997.5)
	Acute renal failure (584)
	Acute renal failure with tubular necrosis (584.5)
	Acute renal failure with renal cortical necrosis (584.6)
	Acute renal failure with papillary necrosis (584.7)
	Acute renal failure with other specified pathology (584.8)
	Acute renal failure with unspecified pathology (584.9)

APPENDIX 2. Summary of covariates in logistic regression model predicting morbidity and mortality

	Mortality					Morbidity				
				95% CI for OR					95% CI for OR	
	B*	*P*	OR	Lower	Upper	B*	*P*	OR	Lower	Upper
Age	0.019	<.001	1.019	1.016	1.023	0.037	<.001	1.038	1.033	1.042
Female gender	0.531	<.001	1.700	1.616	1.789	–0.372	<.001	0.690	0.639	0.745
Intraaortic balloon pump	2.238	<.001	9.371	8.830	9.945	1.009	<.001	2.743	2.423	3.106
Primary payer	–0.076	<.001	0.927	0.896	0.959	0.002	.926	1.002	0.959	1.048
Peripheral vascular disease	0.652	<.001	1.919	1.781	2.068	0.100	.065	1.105	0.994	1.229
Prior myocardial infarction	–1.131	<.001	0.323	0.172	0.606	0.006	.986	1.006	0.515	1.965
Congestive heart failure	0.339	<.001	1.404	1.334	1.478	0.852	<.001	2.345	2.188	2.514
Cerebrovascular disease	0.322	<.001	1.379	1.268	1.501	–0.137	.049	0.872	0.761	1.000
Chronic pulmonary disease	0.187	<.001	1.205	1.134	1.281	0.069	.124	1.071	0.981	1.169
Rheumatoid disorder	–0.189	.109	0.828	0.657	1.043	–0.814	<.001	0.443	0.305	0.643
Peptic ulcer disease	0.243	.014	1.276	1.050	1.550	0.002	.990	1.002	0.735	1.365
Mild liver disease	0.736	<.001	2.087	1.512	2.880	0.699	.003	2.011	1.266	3.196
Moderate liver disease	1.633	<.001	5.121	3.299	7.950	1.564	<.001	4.778	2.412	9.463
Diabetes mellitus	–0.306	<.001	0.737	0.687	0.790	–0.055	.187	0.947	0.872	1.027
Diabetic complications	0.145	.051	1.156	0.999	1.336	1.170	<.001	3.222	2.801	3.706
Hemiplegia or paraplegia	–0.062	.681	0.940	0.700	1.263	1.508	<.001	4.520	2.821	7.242
Chronic kidney disease	0.675	<.001	1.965	1.752	2.204	1.395	<.001	4.035	3.572	4.558
Malignancy	0.076	.403	1.079	0.903	1.291	0.079	.469	1.082	0.875	1.338
Metastatic malignancy	–0.161	.634	0.851	0.439	1.652	–0.497	.280	0.608	0.247	1.500
Race (Caucasian)	–0.203	<.001	0.816	0.754	0.884	–0.137	.015	0.872	0.780	0.974
Calendar year	–0.065	<.001	0.937	0.929	0.946	0.080	<.001	1.083	1.070	1.096
Small vs large hospital bed size	0.202	<.001	1.224	1.107	1.354	–0.248	.001	0.780	0.672	0.906
Medium vs large hospital bed size	0.065	.076	1.068	0.993	1.147	–0.336	<.001	0.715	0.642	0.796
High vs low hospital volume	–0.191	<.001	0.826	0.775	0.880	0.286	<.001	1.331	1.214	1.459
Hospital location	0.129	.063	1.138	0.993	1.304	0.785	<.001	2.191	1.754	2.737
Hospital region (NE vs W)	0.102	.114	1.107	0.976	1.256	–0.047	.568	0.954	0.812	1.121
Hospital region (MW vs W)	0.048	.476	1.050	0.919	1.199	–0.084	.353	0.919	0.770	1.098
Hospital region (S vs W)	0.396	<.001	1.486	1.315	1.680	0.127	.109	1.136	0.972	1.327
Nonteaching vs teaching with TSRP	–0.050	.255	0.951	0.873	1.037	0.459	<.001	1.582	1.390	1.801
Teaching without TSRP vs with TSRP	0.001	.976	1.001	0.924	1.085	0.353	<.001	1.424	1.263	1.604

CI, Confidence interval; *OR,* odds ratio; *NE*, Northeast; *W*, West; *S*, South; *MW*, Midwest. *Coefficient for regression model analysis.

ACD