Predictors of in-hospital complications after pericardiectomy: A nationwide outcomes study

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Objective: Advances in medical care had caused a paradigm shift in the indications for pericardiectomy. We evaluated the current predictors of in-hospital complications for pericardiectomy.

Methods: Patients who underwent pericardiectomy between 1998 and 2008 were identified from the US Nationwide Inpatient Sample. Risk-adjusted logistic regression model was used to analyze the predictors of surgical outcomes.

Results: A total of 13,593 patients underwent pericardiectomy during this period. Pericardiectomy was performed for constrictive pericarditis (28%; n = 3851), pericardial calcification (15%; n = 2061), secondary malignancies (3%; n = 456), adhesive pericarditis (2%; n = 318), and other causes (40%; n = 5461). Unadjusted mortality and complication rates were approximately 8% and 48%, respectively. Fourteen percent of patients required blood transfusion. Only 62% were routinely discharged home. After risk adjustment, age, female gender, comorbidity index, and the primary diagnosis independently predicted in-hospital mortality and overall complication rates ($P < .05$). Calcific pericarditis was the only etiology associated with lower risk-adjusted mortality (odds ratio [OR], 0.48), operative complications (OR, 0.32), overall complications (OR, 0.32), incidence of transfusion (OR, 0.38), and highest routine discharge rates (OR, 1.84); $P < .001$ for all. Constrictive pericarditis had the highest requirement for cardiopulmonary bypass (OR, 6.41; $P < .01$) and incidence of bleeding complications (OR, 2.61; $P < .01$).

Conclusions: Morbidity remains high for pericardiectomy. In addition to age, gender, and comorbidities, attention should be given to etiology during surgical planning or referral. This significantly influences the requirement for cardiopulmonary bypass, chances of bleeding complications, and transfusion requirements. (J Thorac Cardiovasc Surg 2013;145:1227-33)

Pericarditis, an inflammatory disorder of the pericardium, is a rare condition that occasionally requires surgical management. The etiology of pericarditis is quite diverse but only a few patients progress to development of symptoms severe enough to require surgical intervention. Although pericardiectomy is the procedure of choice for patients with mechanical symptoms, this operation is still associated with high morbidity. In addition, the increase in the incidence of tuberculosis associated with human immunodeficiency viral infection has been correlated with a recurrent increase in the incidence of tuberculous pericarditis.¹ Additionally, the consequence of modern advances in the field of medicine, modalities such as mediastinal radiation and cardiac surgery, contribute to constrictive pericarditis and requirement for surgery.^{2,3} Pericardiectomy, a procedure that cannot be

taken for granted owing to the harrowing problems that can be encountered while attempting to tackle dense adhesions with right-sided cardiac chambers, is typically performed on patients with significant comorbidities that make the outcomes of this procedure much less satisfactory.

Typically, the management of symptomatic pericarditis that has failed medical management requires surgical intervention in the form of pericardiectomy. Usually, antecedent pericardial inflammation and effusion are present in these patients before progression to the symptomatic stage requiring surgical intervention in the form of pericardiectomy. Pericardiectomy is typically performed via median sternotomy and is accomplished by the resection of the entire parietal pericardium between the phrenic nerves. More extensive resection may be required in certain circumstances. With the availability of minimally invasive techniques, this procedure can sometimes be accomplished by thoracoscopic methods.^{4,5} The aim of our study was to analyze the common nonsurgical causes that predispose patients to the need for pericardiectomy and identify predictors of morbidity and mortality in the modern era.

PATIENTS AND METHODS

Data Source

Prospectively collected nationwide in-hospital data over an 11-year time span (1998-2008) were used for the study. We obtained the data

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Abbreviations and Acronyms

ARHQ	= Agency for Healthcare and Research Quality
CI	= confidence interval
CPB	= cardiopulmonary bypass
CPT	= current procedural terminology
<i>df</i>	= degree of freedom
ICD-9-CM	= International Classification of Diseases, Ninth Revision, Clinical Modification
MANOVA	= multivariate analysis of variance
NIS	= Nationwide Inpatient Sample
OR	= odds ratio

from the Nationwide Inpatient Sample (NIS), a government funded federal project through the Agency for Healthcare and Research Quality.⁶ These data include discharge records of about 88 million patients from over 1000 hospitals in 37 participating states and are validated internally and externally on a yearly basis to ensure consistency and accuracy. Consistency of the data is ensured by comparing its contents with the National Hospital Discharge Survey and the Medicare Provider Analysis and Review—to assess and eliminate potential biases in the data.⁷ Weights based on sampling probabilities for each stratum ensure that the hospitals studied can be validly extrapolated for nationwide analysis. This study was reviewed by the Institutional Review Board of the University of Missouri–Columbia School of Medicine and deemed exempt owing to the nonidentifiable nature of the data set. The data reported in our study conform to the Data Use Agreement for the NIS from the Healthcare Cost and Utilization Project. Additional information about the NIS is available from the Agency for Healthcare Research and Quality, which sponsors the database as part of the Healthcare Cost and Utilization Project (<http://www.hcup-us.ahrq.gov/nisoverview.jsp>).

Patient Selection

Only patients who underwent pericardiectomy as primary procedure with International Classification of Diseases procedure code 37.31 were identified. For each admission, the NIS captures up to 15 diagnosis codes per patient from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) manual.⁸ These were used to identify the primary admitting diagnosis and outcomes. The ICD-9-CM codes used to identify the common admitting diagnosis requiring pericardiectomy are summarized in Table 1.

Study Methods and End Points

The study was designed to identify any discrepancy in patient outcomes based on demographics and primary diagnosis. Primary end points for the study were risk-adjusted mortality and secondary end points were occurrence of any complication, requirement for transfusion, requirement for cardiopulmonary bypass (CPB), and incidence of routine discharge. Subgroup analysis to assess intraoperative and bleeding complications was performed. Overall complications were computed on the basis of the following categories of individual postoperative complications, similar to the methods used in previous studies using NIS data for patients undergoing other types of cardiac operations: hemopericardium, cardiac arrest necessitating open massage, mediastinitis, neurologic complications, respiratory complications, renal complications, deep vein thrombosis, pulmonary embolism, and intraoperative complications in addition to hemorrhage.⁹ The ICD-9-CM codes for these complication are listed in Appendix Table 1.

The Charlson-Deyo comorbidity index, which is a weighted composite index validated particularly for administrative databases, was used to adjust for comorbidities in the statistical risk model and has been previously used for risk adjustment in cardiac and thoracic surgery outcomes.¹⁰⁻¹²

Statistical Methods

Statistical analysis was performed with PASW (formerly SPSS), version 18.0 (IBM Corporation, Somers, NY). A general linear model incorporating multivariate testing (ie, multivariate analysis of variance [MANOVA] and χ^2 analysis) was used to compare baseline characteristics, which included age, cost, Charlson-Deyo comorbidity index, and unadjusted primary outcomes. Generalized multivariate regression was used to assess the predictors of primary outcomes with adjustment for potential confounding factors, which included age, gender, race, insurance payer, hospital bed size, admission type, and individual components of the comorbidity index.

Because we were handling a very large sample size, which is typical with NIS-based analysis; effect-size statistics were computed to assess the practical implications of statistically significant *P* values, similar to previous studies.^{10,11} Cohen's *d* was calculated for continuous data by using pooled standard deviations and was appropriately weighted for unequal sample size.¹³ The phi coefficient was used to compute effect sizes in χ^2 tests for variables with a single degree of freedom (*df*). Cramer's *V* was computed for variables with more than 1 *df*. We used the following ranges to categorize the computed effect sizes: less than 0.32 (small), 0.33 to 0.55 (medium), and 0.56 or more (large).¹⁴

RESULTS**Etiology**

We identified 13,593 patients who underwent pericardiectomy over the 11-year time period. Constrictive pericarditis was the most common etiology requiring surgical intervention (28.3%) of the case mix, followed by calcific pericarditis (15.2%), secondary malignancies (3%; *n* = 456), adhesive pericarditis (2%; *n* = 318), and other causes (40.1%; *n* = 5461). The results are summarized in Table 1.

Patient Characteristics

The baseline characteristics are summarized in Table 2. The *F* value represents the overall statistic for the general linear model for multigroup comparisons—MANOVA. Intergroup analyses were performed using the Tukey test for honest significant differences. The aggregate sample (*N* = 13,593) consisted mostly of white (76.6%) men (55.6%) with a mean age of 56 years (standard deviation = 17 years). Comorbid conditions ranged from 0.6% to 26.8% for moderate liver disease and congestive heart failure, respectively. Of the sample, 62.7% had a routine discharge, 22.8% had an urgent admission, and 7.5% died after the operation. Overall Deyo comorbidity score was 3.7 ± 3.3 .

Primary End Points: Mortality and Overall Complications

Overall unadjusted mortality was 7.5% and was lowest among those who had calcific pericarditis (1.9%). Logistic regression analysis, taking comorbidities into consideration, revealed that age, female gender, and comorbidity

TABLE 1. Indications for pericardiectomy in the United States

ICD-9-CM code	Frequency	Percent	Diagnosis
423.2	3851	28.3	Constrictive pericarditis
423.8	2061	15.2	Calcification of pericardium
423.9	1446	10.6	Unspecified disease of pericardium
198.89	456	3.4	Secondaries*
423.1	318	2.3	Adhesive pericarditis
All other	5461	40.1	Other causes†
Total	13,593	100	

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification. *Secondaries include those patients with metastatic disease to the pericardium from an extra-cardiac primary. †Other causes includes all those patients with acute, sub-acute, or viral pericarditis; non-specific chest pain or congestive heart failure as primary diagnoses. These patients were conglomerated to a single control group for statistical analysis.

index were significantly associated with higher mortality. Although age and comorbidity index were associated with higher risk-adjusted complication rates, female gender was associated with lower complication rates. White race, which did not affect mortality, was associated with lower complication rates. Data are summarized in Tables 3 and 4. Etiology affected both mortality and complication rates and is summarized under the subgroup analysis.

Subgroup Analysis: Effect of Etiology

Logistic regression analysis was performed to study the impact of etiology on outcomes of specific interest such

as mortality, disposition, overall complications, transfusion, bleeding complications, and requirement for CPB. Results are summarized in Table 5. Etiology on an overall basis significantly affected all the aforementioned outcomes as evidenced by the significant statistical parameters. Subgroup analysis demonstrates that calcific pericarditis was the only cause independently associated with 52% lower risk-adjusted mortality (odds ratio [OR], 0.48; 95% confidence interval [CI], 0.35-0.66; $P < .001$).

DISCUSSION

Inflammatory disorders of pericardium can be acute or chronic. Acute pericarditis can occur as an isolated entity or as a manifestation of an underlying systemic disease and typically accounts for 5% of admissions for noncardiac chest pain.¹⁵ Constrictive pericarditis can occur as a sequel after an acute process or be idiopathic in etiology. Idiopathic causes, cardiac surgery, pericarditis, and mediastinal radiation therapy are the common causes of chronic pericarditis.^{16,17} With advancement in medical care and decline in complicated tuberculosis, there has been a paradigm shift in the management of constrictive pericarditis owing to a change in etiology.¹⁸ An earlier retrospective report in a single-institution center by Ling and associates¹⁶ showed that the patients requiring pericardiectomy were older and had an operative mortality that was significantly lower, at 6%. Hospital mortality has been reported to be as high as 11% but improving over time.¹⁹ The largest single-center

TABLE 2. Baseline characteristics and unadjusted outcomes

	Study group by etiology						Total	P
	Constrictive pericarditis	Calcific pericarditis	Secondaries	Adhesive pericarditis	Acute Pericarditis	Other		
Age*	57 ± 15	52 ± 16	58 ± 13	58 ± 16	56 ± 19	56 ± 18	56 ± 17	<.001
Deyo index*	2.8 ± 2.1	2.5 ± 3.4	10.0 ± 1.5	3.4 ± 2.8	3.7 ± 3.1	4.3 ± 3.5	3.7 ± 3.3	<.001
Female	1036 (26.9%)	1193 (57.9%)	309 (67.8%)	129 (40.6%)	830 (46.4%)	2540 (46.5%)	6037 (44.4%)	<.001
Race—white	2262 (84.3%)	1191 (80.8%)	232 (68.8%)	194 (74.9%)	939 (70.7%)	2709 (49.6%)	7527 (76.6%)	<.001
Urgent admission	876 (22.7%)	352 (17.1%)	131 (28.7%)	79 (24.8%)	404 (22.6%)	1260 (23.1%)	3102 (22.8%)	<.001
Routine discharge	2357 (61.2%)	1677 (81.4%)	263 (57.7%)	169 (53.1%)	982 (54.8%)	3080 (56.4%)	8528 (62.7%)	<.001
PVD	59 (1.5%)	20 (1.0%)	≤10 (1.1%)	0 (0.0%)	61 (3.4%)	117 (1.03%)	262 (1.9%)	<.001
MI	≤10 (0.2%)	≤10 (0.2%)	≤10 (1.5%)	0 (0.0%)	40 (2.2%)	16 (0.3%)	76 (0.6%)	<.001
CHF	1681 (43.7%)	131 (6.4%)	34 (7.5%)	109 (34.3%)	437 (24.4%)	1256 (22.3%)	3648 (26.8%)	<.001
Cerebrovascular disorders	55 (1.4%)	14 (0.7%)	≤10 (2.2%)	≤10 (1.6%)	20 (1.1%)	89 (1.7%)	193 (1.4%)	.010
COPD	636 (16.5%)	298 (14.5%)	121 (26.5%)	60 (18.9%)	364 (20.3%)	946 (17.3%)	2425 (17.8%)	<.001
Rheumatoid disorders	188 (4.9%)	57 (2.8%)	0 (0.0%)	23 (7.2%)	82 (4.6%)	258 (4.7%)	608 (4.5%)	<.001
Peptic disease	31 (0.8%)	≤10 (0.4%)	≤10 (0.9%)	0 (0.0%)	24 (1.3%)	39 (0.7%)	107 (0.8%)	.025
Mild liver disease	267 (6.9%)	≤10 (0.5%)	0 (0.0%)	18 (5.7%)	16 (0.9%)	65 (1.2%)	376 (2.8%)	<.001
Moderate liver disease	45 (1.2%)	0 (0.0%)	≤10 (1.5%)	0 (0.0%)	≤10 (0.3%)	20 (0.4%)	77 (0.6%)	<.001
Diabetes mellitus	651 (16.9%)	215 (10.4%)	22 (4.8%)	38 (11.9%)	299 (16.7%)	711 (13.0%)	1936 (14.2%)	<.001
Diabetic complication	76 (2.0%)	15 (0.7%)	≤10 (0.9%)	≤10 (3.1%)	44 (2.5%)	163 (2.9%)	312 (2.3%)	<.001
HIV	≤10 (<2.0%)	0 (0%)	≤10 (<2.0%)	≤10 (<2%)	—	98 (1.9%)	137 (1.0%)	<.001
Renal comorbidities	258 (6.7%)	30 (1.5%)	≤10 (1.1%)	14 (4.4%)	112 (6.3%)	376 (6.8%)	795 (5.8%)	<.001
In-hospital mortality	277 (7.2%)	39 (1.9%)	62 (13.6%)	20 (6.3%)	150 (8.4%)	470 (8.6%)	1018 (7.5%)	<.001

PVD, Peripheral vascular disease; MI, myocardial infarction; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; HIV, human immunodeficiency viral infection. *To conform to the US Nationwide Inpatient Sample data use agreement, data with cell counts less than 10 cannot be reported in exact numbers.

TABLE 3. Distribution of cases and outcomes by calendar year

Calendar year	Diagnosis type					
	Constrictive pericarditis	Calcific pericarditis	Secondaries	Adhesive pericarditis	Acute pericarditis	Other
1998	347 (26.6%)	182 (13.9%)	33 (2.5%)	30 (2.3%)	251 (19.2%)	460 (35.2%)
1999	302 (29.6%)	140 (13.7%)	45 (4.4%)	15 (1.4%)	149 (14.6%)	369 (36.1%)
2000	393 (32.0%)	138 (11.1%)	38 (3.1%)	20 (1.6%)	162 (13.1%)	477 (38.8%)
2001	387 (31.8%)	180 (14.8%)	55 (4.5%)	30 (2.4%)	129 (10.6%)	434 (35.6%)
2002	287 (22.1%)	201 (15.5%)	54 (4.1%)	35 (2.7%)	175 (13.5%)	546 (42.0%)
2003	332 (26.9%)	247 (20.0%)	36 (2.9%)	47 (3.8%)	183 (14.7%)	389 (31.4%)
2004	382 (32.9%)	181 (15.6%)	36 (3.1%)	34 (2.9%)	166 (14.3%)	360 (31.0%)
2005	359 (25.6%)	200 (14.2%)	68 (4.8%)	51 (3.6%)	182 (13.0%)	540 (38.5%)
2006	351 (27.0%)	163 (12.5%)	39 (3.0%)	14 (1.0%)	144 (11.0%)	587 (45.2%)
2007	340 (27.6%)	257 (20.8%)	31 (2.5%)	21 (1.7%)	136 (10.9%)	447 (36.3%)
2008	371 (30.6%)	173 (14.2%)	20 (1.6%)	19 (1.5%)	117 (9.6%)	512 (42.2%)
Total	3851 (28.3%)	2061 (15.2%)	454 (3.3%)	316 (2.3%)	1790 (13.2%)	5115 (37.6%)

CPB, Cardiopulmonary bypass; SD, standard deviation.

data published to date included about 395 patients with an associated operative mortality of 7.5%.²⁰ It is indeed surprising to note that despite advancements in our field, this procedure is still associated with significant morbidity.

We have presented a bird's-eye perspective of pericardiectomy in the United States spanning over a decade. Overall in-hospital mortality in the US nationwide series that we analyzed was 7.5%. However, to account for difference in baseline characteristics, we emphasized the importance of a logistic regression model to more accurately interpret our results. Older age, female gender, and extent of comorbidities were associated with higher in-hospital mortality. Age and comorbidities also increased the incidence of complications.

In this nationwide analysis of 13,593 patients, there is an evident correlation between certain types of pericardial disease on surgical outcomes. Calcific pericarditis, although more commonly associated with tuberculosis in the past, continues to be a significant cause and is found in 15% of patients requiring pericardiectomy. Our analysis has shown a 52% lower in-hospital mortality that is independently associated with calcific pericarditis. Subgroup analysis revealed that, in addition to lowering in-hospital mortality, calcific pericarditis was associated with lowest odds of operative complications (OR, 0.32; 95% CI, 0.18-0.58; $P < .001$) and overall complications (OR, 0.32; 95% CI, 0.18-0.58; $P < .001$), highest routine discharge (OR, 1.84; 95% CI, 1.6-2.12; $P < .001$), and lowest incidence of transfusion (OR, 0.38; 95% CI, 0.3-0.47; $P < .001$). The exact pathogenesis of calcific pericarditis in the current era is not clearly understood and its impact on survival has remained somewhat controversial. Whereas some single-center studies have shown that pericardial calcification does not affect long-term survival, other studies have shown a negative impact.^{16,19-22} A limitation to be acknowledged, however, is that our database does not differentiate between pericardial calcification and calcific pericarditis. Calcific

pericarditis is more easily recognized preoperatively from radiology studies or during cardiac catheterization or plain chest x-rays films and is an indicator of chronicity of the disease. In our study, calcification in the pericardium is also independently associated with lower requirement for CPB and higher routine home discharge without ancillary support. The requirement of blood transfusion and incidence of bleeding complications was also significantly low with calcific pericarditis. Our findings contradict some of the single-center findings that have attributed pericardial calcification with higher operative mortality.²² Discrepancy in the directionality of the OR for complications and mortality is evident in female patients. Interestingly, female gender was independently associated with a 33% higher incidence of mortality but a 29% lower incidence of complications. This anomalous finding can be explained by the phenomenon of failure to rescue—a concept that has been in vogue for the past decade, which is reflective of the hospital's ability to handle complications and thereby its ability to prevent the further progression of a complication to a death. The failure to rescue is higher among female patients. Although the occurrence of complications may be lowered by female gender, a complication is very likely to translate to death owing to the higher failure to rescue index in female patients. Our findings raise the suspicion that there are other factors in female patients possibly contributing to a complication, not directly related to gender.²³

Bleeding complications are significantly higher with constrictive (OR, 2.6; $P < .01$) and adhesive pericarditis (OR, 3.9; $P < .01$). Transfusion requirements were highest in patients with adhesive pericarditis (OR, 1.7; $P < .001$), followed by constrictive pericarditis and correlated with the higher bleeding complications. However, the need for CPB was highest among patients with constrictive pericarditis (OR, 6.4; $P < .001$), followed by adhesive pericarditis (OR, 1.8; $P = .001$). Although this could be partly

TABLE 3. Continued

CPB	Complications	Length of stay (d) (mean, SD)	Routine disposition	In-hospital mortality	Total
110 (8.4%)	591 (45.4%)	10.9 ± 9.6	905 (69.5%)	120 (9.2%)	1302
89 (8.7%)	469 (45.9%)	10.8 ± 9.8	642 (62.9%)	84 (8.2%)	1019
157 (12.8%)	588 (47.9%)	11.1 ± 8.4	760 (61.9%)	128 (10.3%)	1227
133 (10.9%)	558 (45.8%)	12.1 ± 12.3	779 (64.0%)	103 (8.4%)	1214
128 (9.8%)	611 (47.1%)	10.5 ± 8.7	898 (69.2%)	83 (6.4%)	1297
123 (9.9%)	574 (46.6%)	11.9 ± 13.7	703 (57.1%)	94 (7.6%)	1233
137 (11.8%)	572 (49.3%)	10.9 ± 9.9	755 (65.0%)	69 (5.9%)	1159
66 (4.7%)	714 (51.0%)	12.2 ± 12.6	841 (60.0%)	120 (8.5%)	1400
92 (7.0%)	666 (51.2%)	11.3 ± 10.5	788 (60.6%)	97 (7.4%)	1298
114 (9.2%)	584 (47.4%)	10.8 ± 15.1	789 (64.0%)	39 (3.1%)	1232
117 (9.6%)	628 (51.8%)	10.7 ± 10.1	669 (55.2%)	81 (6.6%)	1212
1266 (9.3%)	6555 (48.2%)	11.2 ± 11	8529 (62.7%)	1018 (7.5%)	13,593

explained by the higher odds of bleeding in constrictive pericarditis (without calcification), this may also be reflective of a much higher hemodynamic compromise in this subset requiring CPB for safe accomplishment of the operation. As much as the constrictive and calcific pericarditis are associated with better outcomes in our analysis, the indication for pericardiectomy in other circumstances may need to be revisited owing to the dismal in-hospital outcomes. Overall, pericardiectomy is associated with mortality and serious comorbidities and this raises the question as to whether or not these procedures are justified in cases other than constrictive pericarditis.

There are certain inherent advantages in our study design. For one, the large sample size allows for more reliable and consistent statistical analysis. Our study had provided a nationwide insight into some of the predictors of complications and in-hospital mortality that are associated with pericardiectomy. Most published single-center data on outcomes of pericardiectomy are from major centers of cardiothoracic surgery, which introduces an inherent selection bias. Patients requiring pericardiectomy do not usually gravitate to a major

TABLE 4. Predictors of mortality and complications

	<i>P</i>	<i>OR</i>	95% CI for <i>OR</i>	
			Lower	Upper
Mortality				
Age	.016	1.013	1.002	1.023
Female	.001	1.338	1.126	1.590
Deyo	<.001	1.284	1.169	1.412
Race—white	.172	1.162	.937	1.440
Etiology	<.001			
Complications				
Age	.018	1.023	1.004	1.043
Female	.026	.719	.538	.961
Deyo	<.001	1.450	1.177	1.786
Race—white	<.001	.364	.267	.497
Etiology	<.001			

OR, Odds ratio; *CI*, confidence interval.

cardiovascular center. Inasmuch as the data presented capture all patients across the United States, this is a more realistic representation of actual outcomes.

However, our study has certain limitations owing to the nature of the NIS database that is used. No long-term or

TABLE 5. Impact of specific etiology on outcomes

	<i>P</i>	<i>OR</i>	95% CI for <i>OR</i>	
			Lower	Upper
Mortality	<.001			
Constrictive	.115	1.181	.960	1.452
Calcific	<.001	.478	.347	.656
Secondaries	.368	.852	.601	1.208
Adhesive	.355	1.221	.800	1.862
Disposition	<.001			
Constrictive	.003	.844	.754	.944
Calcific	<.001	1.838	1.598	2.115
Secondaries	<.001	1.578	1.244	2.001
Adhesive	<.001	.546	.431	.692
Complications—all	<.001			
Constrictive	.596	.909	.639	1.293
Calcific	<.001	.318	.175	.579
Secondaries	.104	2.159	.854	5.461
Adhesive	.717	1.153	.535	2.482
Transfusion	<.001			
Constrictive	.028	1.170	1.017	1.346
Calcific	<.001	.376	.300	.472
Secondaries	.243	.835	.618	1.130
Adhesive	<.001	1.733	1.334	2.252
Bleeding complications	<.001			
Constrictive	.002	2.609	1.433	4.750
Calcific	.007	.211	.068	.653
Secondaries	.921	1.090	.198	5.989
Adhesive	.006	3.907	1.476	10.347
Cardiopulmonary bypass	<.001			
Constrictive	<.001	6.414	5.432	7.575
Calcific	<.001	.194	.129	.290
Secondaries	.005	.454	.263	.783

OR, Odds ratio; *CI*, confidence interval.

follow-up data on survival can be obtained because this is a deidentified data set. All outcomes are restricted to in-hospital outcomes. Additionally, intraoperative variables, the operative approach (ie, video-assisted thoracic surgery, sternotomy, or thoracotomy), the extent of symptoms, the number of units of blood transfused, and the duration of CPB were not available in this administrative database. Clinical data that would have prompted pericardiectomy would be more important for statistical analysis, and the lack of such data should be considered in light of the findings of high mortality and complications. Whether pericardiectomy is justified in all cases deserves closer evaluation. The use of a single ICD-9-CM code to cull all patients who underwent pericardiectomy is unfortunately the only reliable method when tackling an administrative database that lacks current procedural terminology codes. This makes the descriptor of surgical technique too broad and almost impossible to narrow the procedure based on the extent of the pericardium resected that would have been possible with current procedural terminology codes. The exact cause that prompted the need for pericardiectomy was quite varied in about 40% of the cases and, as best we could determine from the primary diagnosis for admission captured in the database, this included a variety of conditions such as subacute pericarditis, viral pericarditis, acute pericarditis, nonspecific chest pain, and congestive heart failure. To accomplish reliable statistical analysis and limit the complexity of the data for meaningful interpretation, we had to cohort these patients into a single subgroup. These subgroups of patients have different physiologic backgrounds, and the lack of clinical details from an administrative database precludes our ability to understand this subgroup well, although it functioned as an excellent control group for statistical comparison. In light of the high mortality and complications associated with pericardiectomy, the indications for this procedure need to be revisited. A clinical database would be more relevant to address this issue. Additionally, whether patients benefited symptomatically after being subject to such a procedure of high morbidity remains unknown and would need to be further analyzed using data that could track patients across admissions and transfers. Although the inability to study the indications for surgery is a major impediment that cannot be circumvented in this study, our findings raise serious questions as to why so many pericardiectomies are being performed in the United States and whether this procedure is justified. This is a serious limitation in an administrative database that is based on discharge billing codes instead of clear-cut clinical data such as The Society of Thoracic Surgeons database. However, unlike the NIS database, The Society of Thoracic Surgeons database does not include data from all hospitals across the United States for thoracic procedures.

The NIS database also does not track patients across admissions and their status after discharge to a nursing home

facility. Important predisposing factors, such as prior tuberculosis and postradiation status, are not available in the NIS and hence could not be adjusted in the logistic regression models. No long-term follow-up data are available either, which significantly limits our ability to understand the long-term benefits of this procedure from a nationwide perspective. The additional cost burden and mortality experienced by those who were discharged to a nursing home, the readmission rates, and the recurrence of symptoms in those who were sent home could not be assessed from our data. Our statistical analysis was adjusted for baseline hospital characteristics to account for differences in the quality of care that was provided; yet we are unable to adjust for surgeon-specific or surgical team characteristics that could have made the analysis more robust. Nevertheless, our study provides the most comprehensive analysis of outcomes of pericardiectomy in the United States, supported by a large sample set, with limited but definite in-hospital end points.

CONCLUSIONS

Nationwide analysis has demonstrated that pericardiectomy is associated with a mortality of 7.5%. CPB is required in 9.3% of cases. Only about two thirds of patients are routinely discharged home without ancillary support services. Pericardiectomy remains a procedure of high morbidity. Apart from age and gender, etiology has a significant impact on surgical outcomes and strong consideration should be given to this during surgical referral and preoperative evaluation. Pericardial calcification should not preclude surgical intervention but rather should be considered a favorable prognosticator for surgical outcomes, inasmuch as it is associated with lower mortality, complication, transfusion, and bleeding complications. The current indications for pericardiectomy in the United States deserved reevaluation.

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References

1. Kutoloski KS, Salvucci TJ, Dennis C. Tuberculous pericarditis. *J Am Osteopath Assoc*. 1996;96:253-6.
2. Veeragandham RS, Goldin MD. Surgical management of radiation-induced heart disease. *Ann Thorac Surg*. 1998;65:1014-9.
3. Nishimura RA. Constrictive pericarditis in the modern era: a diagnostic dilemma. *Heart*. 2001;86:619-23.
4. Hazelrigg SR, Mack MJ, Landreneau RJ, Acuff TE, Siefert PE, Auer JE. Thoracoscopic pericardiectomy for effusive pericardial disease. *Ann Thorac Surg*. 1993;56:792-5.
5. Krasna M, Fiocco M. Thoracoscopic pericardiectomy. *Surg Laparosc Endosc*. 1995;5:202-4.
6. Healthcare Cost Utilization Project. Overview of Nationwide Inpatient Sample (NIS). Available at: <http://www.hcup-us.ahrq.gov/nisoverview.jsp>.
7. Healthcare Cost and Utilization Project. Nationwide Inpatient Sample section. Available at: <http://www.hcup-us.ahrq.gov/db/nation/nis/nisrelatedreports.jsp>. Accessed January 5, 2011.

8. Department of Health and Human Services PHS, ed. International Classification of Diseases, 9th revision, clinical modification, 5th ed. Washington, DC: 1988.
9. Gopaldas RR, Chu D, Dao TK, Huh J, LeMaire SA, Coselli JS, et al. Predictors of surgical mortality and discharge status after coronary artery bypass grafting in patients 80 years and older. *Am J Surg*. 2009;198:633-8.
10. Gopaldas RR, Huh J, Dao TK, LeMaire SA, Chu D, Bakaeen FG, et al. Superior nationwide outcomes of endovascular versus open repair for isolated descending thoracic aortic aneurysm in 11,669 patients. *J Thorac Cardiovasc Surg*. 2010;140:1001-10.
11. Gopaldas RR, Chu D, Dao TK, Huh J, LeMaire SA, Coselli JS, et al. Impact of ACGME work-hour restrictions on the outcomes of coronary artery bypass grafting in a cohort of 600,000 patients. *J Surg Res*. 2010;163:201-9.
12. Cherkin DC, Deyo RA, Volinn E, Loeser JD. Use of the International Classification of Diseases (ICD-9-CM) to identify hospitalizations for mechanical low back problems in administrative databases. *Spine (Phila Pa 1976)*. 1992;17:817-25.
13. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988.
14. Lipsey M. Design sensitivity: statistical power for experimental research. Los Angeles: Sage Publications; 1990.
15. Khandaker MH, Espinosa RE, Nishimura RA, Sinak LJ, Hayes SN, Melduni RM, et al. Pericardial disease: diagnosis and management. *Mayo Clin Proc*. 2010;85:572-93.
16. Ling LH, Oh JK, Schaff HV, Danielson GK, Mahoney DW, Seward JB, et al. Constrictive pericarditis in the modern era: evolving clinical spectrum and impact on outcome after pericardiectomy. *Circulation*. 1999;100:1380-6.
17. Cameron J, Oesterie SN, Baldwin JC, Hancock EW. The etiologic spectrum of constrictive pericarditis. *Am Heart J*. 1987;113(2 Pt 1):354-60.
18. Quale JM, Lipschik GY, Heurich AE. Management of tuberculous pericarditis. *Ann Thorac Surg*. 1987;43:653-5.
19. Bashi VV, John S, Ravikumar E, Jairaj PS, Shyamsnder K, Krishnaswami S. Early and late results of pericardiectomy in 118 cases of constrictive pericarditis. *Thorax*. 1988;43:637-41.
20. Chowdhury UK, Subramaniam GK, Kumar AS, Airan B, Singh R, Talwar S, et al. Pericardiectomy for constrictive pericarditis: a clinical, echocardiographic, and hemodynamic evaluation of two surgical techniques. *Ann Thorac Surg*. 2006;81:522-9.
21. Bertog SC, Thambidorai SK, Parakh K, Schoenhagen P, Ozduran V, Houghtaling PL, et al. Constrictive pericarditis: etiology and cause-specific survival after pericardiectomy. *J Am Coll Cardiol*. 2004;43:1445-52.
22. Ling LH, Oh JK, Breen JF, Schaff HV, Danielson GK, Mahoney DW, et al. Calcific constrictive pericarditis: is it still with us? *Ann Intern Med*. 2000;132:444-50.
23. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. *Med Care*. 2011;49:1076-81.

APPENDIX TABLE 1. ICD-9-CM diagnosis codes for in-hospital complications used for statistical analysis

Wound complications	Delayed wound healing: 99883 Postoperative hematoma: 99812 Disruption of operative wound: 99831, 99832 Persistent postoperative fistula: 9986
Infections	Postoperative infection: 99851 Postoperative skin abscess: 99859 Postoperative septic wound complications: 99859 Postoperative skin infection: 99859 Postoperative infected seroma: 99851 Mediastinitis: 519.2
Cardiovascular complications	Postoperative deep venous thrombosis: 99779, 45340-45342 Postoperative pulmonary embolism: 41511 Postoperative stroke: 99702 Phlebitis or thrombophlebitis from procedure: 9972 Cardiac arrest/insufficiency during or resulting from a procedure: 9971
Intraoperative complications	Accidental puncture or laceration, complicating surgery: 9982 Foreign body accidentally left during procedure: 9984 Requirement for cardiopulmonary bypass: 3961
Bleeding complications	Bleeding complicating procedure: 99811 Transfusion: 990, 9901-9909
Systemic complications	Postoperative shock (septic, hypovolemic): 9980 Postoperative fever: 99889
Renal and urinary complications	Postoperative urinary tract infection: 9975 Acute renal failure: 9975, 5840, 584, 5848, 5849 Renal tubular necrosis: 5845, 5846, 5847
Neurologic complications	Stroke: 99701, 99702
Pulmonary complications	Postoperative atelectasis: 9973 Postoperative pneumonia: 486, 4829, 48289, 481, 4820-4822, 48230-48232, 48239-48241, 48249, 48281-48283 Postoperative acute respiratory insufficiency: 5185 Postoperative acute pneumothorax: 5121 Adult respiratory distress syndrome: 5185 Postoperative pulmonary edema: 5184 Empyema with fistula: 5100 Empyema without fistula: 5109 Pleural effusion: 5111, 5118, 5119 Lung abscess: 5130, 5131 Pulmonary embolism: 41511

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.