Surgery for aortic and mitral valve disease in the United States: A trend of change in surgical practice between 1998 and 2005

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Objective: The surgical treatment of valvular heart disease has changed significantly in the past decade with more mitral valves being repaired and tissue valves implanted in the aortic position. The National Inpatient Sample was used to document national trends of primary isolated aortic and mitral valve surgical procedures.

Methods: Subjects were adult patients who had an isolated aortic or mitral valve repair or replacement in the United States. Estimated institution cost and total billed charges data were provided by the Centers for Medicare and Medicaid Services.

Results: From 1998 to 2005, an estimated 330,000 aortic or mitral valve procedures were performed in the United States (repair, n = 46,342; replacement, n = 287,989). Since 1998, annual valve repair or replacement procedures increased 186.6% and 12.6%, respectively. Aortic valve repair or replacement procedures increased 102.5% and 28.0%, respectively, with an increased percentage for repairs from 2.0% in 1998 to 3.1% in 2005. Mitral valve repair procedures increased from18.9% in 1998 to 45.8% in 2005, with mitral replacements decreasing 17.2% over the same period. Since 1998, the total hospital billed charges for aortic valve repair procedures increased 80.6% and aortic valve replacement procedures 90.4%; mitral valve repair procedures increased from 37.8%, replacement 42.0%. Annual increases in estimated institution cost increased for both aortic and mitral procedures on average 8% to 9%.

Conclusion: During the last decade the practice of valve surgery has changed significantly. The surgical treatment for mitral disease has transitioned to primarily one of repair, not replacement, with the use of bioprostheses more than doubled. For the aortic position, the primary procedure remained valve replacement with bioprosthesis being the valve of choice. Regardless of valve disease, institutional costs and charges for the surgical treatment have greatly outpaced physician reimbursement.

One in 3 American adults has cardiovascular disease.[1] In 2005, over 6.9 million inpatient cardiovascular surgeries and procedures were performed in the United States (4.1 million men; 2.9 million women) with open heart surgeries accounting for 10%.[1] Valvular heart diseases were among the most predictable causes of heart failure; recent data compiled by the American Heart Association indicate that the mortality due to valvular heart disease in the United States is estimated to be 20,000 patients per annum. The number of direct deaths related to aortic valve disease is estimated at 12,548.[2] Total hospital discharges for aortic valve disease are estimated to be 48,000 patients. Estimates for direct mortality related to mitral valve disease are 2542 persons, with total mentioned mortality estimated at 6600 persons. An estimated 38,000 patients are discharged with mitral valve disease.[1]

Recent reports have demonstrated the cost-effectiveness and decreased rates of perioperative outcomes of valve surgery in the elderly,[3,4] although details regarding annual trends in surgeries for valvular heart disease are scarce.[5,6] This field has evolved dramatically with the increased utilization of a new generation of heart valves, more aggressive repair techniques, and improved results. In this report, data on trends of isolated aortic and mitral valve procedures during the period of 1998 to 2005 were obtained from the National Inpatient Sample (NIS).

METHODS

Data Source

The data related to aortic and mitral valve surgery were obtained through the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, NIS.[7] The NIS is the largest all-payer inpatient care database in the United States, containing data from approximately 8 million hospital stays each year. The 2005 NIS database contains all discharge data from 1054 hospitals located in 37 states, approximating a 20% stratified sample of US community hospitals. The sampling frame for the 2005 NIS database is a sample of hospitals that comprises approximately 90% of all hospital discharges in the United States. The NIS is the only national hospital database containing charge information on all patients, regardless of payer, including persons covered by Medicare, Medicaid, private insurance, and the uninsured patients.

Aortic and Mitral Valve Surgical Procedures

We analyzed the 1998 to 2005 NIS public data file to determine changes in the pattern of use for both isolated aortic and mitral valve procedures. The NIS presents up to 15 procedure codes with the primary International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes listed as the first procedure code. We abstracted codes from coding positions 1 to 3 as either primary aortic or mitral primary

From the Inova Heart and Vascular Institute, Falls Church, Va.
Received for publication May 8, 2008; revisions received July 22, 2008; accepted for publication Aug 5, 2008.
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J Thorac Cardiovasc Surg 2009;137:1422-9
0022-5223/$36.00

doi:10.1016/j.jtcvs.2008.08.071

Abbreviations and Acronyms

CC = Cost to charge
HCUP = Healthcare Cost and Utilization Project
ICD-9-CM = the International Classification of Diseases, Ninth Revision, Clinical Modification
LOS = length of stay
NIS = National Inpatient Sample
STS = Society of Thoracic Surgeons

ICD-9-CM procedures by the following: any occurrences of an aortic (3521, 3522, 3511) or mitral procedure (3523, 3524, 3512) listed in the positions 1 to 3. Procedures were further restricted to only isolated aortic and mitral valve procedures by eliminating patients with any procedure code of 361x (bypass anastomosis for heart revascularization), 376x (implantation of heart or other circulatory assist device), 381 (endarterectomy), or 377x (insertion, revision, replacement, removal of pacemaker leads). Patients with implanted pacemakers were included (378x). Congenital anomalies were ICD-9 codes 746.3 and 746.4. Patients aged < 18 years were removed from the analysis. The NIS provides no data regarding repeat procedures.

Financial Charge Data

The NIS contains data on total billed charges for each hospital. This charge information represents the amount that hospitals billed for services but does not reflect how much hospital services actually cost or the specific amounts that hospitals received in payment. Cost to charge (CC) data were only available for the years 2001 to 2004. Group average CC is a weighted average for the hospitals in the group (defined by state, urban/rural, investor-owned/other, and number of beds) and uses the proportion of group beds as the weight for each hospital. Estimated institution cost data were calculated by multiplying HCUP supplied CC ratios against total charges. Cost will tend to reflect the actual costs of a case, and charges represent what the hospital billed for each case.

Statistics

Continuous data are presented as mean ± standard error. Categorical data are presented as frequency and percent. Standard errors were calculated by taking into account the sampling scheme and sample discharge weights.[8] Hierarchical multilevel analyses were conducted using mixed-effects models on the natural log of total billed charges using a random intercepts and fixed slopes approach. The natural log was chosen to reduce skewness. All analyses were conducted in SAS (Version 9.1, Cary, NC). This analysis was exempt from Institutional Review Board review.

RESULTS

Between 1998 and 2005, approximately 340,000 surgical procedures to address aortic or mitral valve heart pathology were performed in the United States (valve repair, n = 46,342; replacement, n = 287,989) with replacement procedures over 6 times more prevalent (Table 1). Among valve procedures, the proportion of annual valve procedures that were repair increased 187% compared with a 13% increase among valve replacement procedures (Table 1, Figure 1). ICD codes referring to congenital anomalies accounted for 2.3% of repairs and 4.9% of replacements, respectively. Valve insufficiency accounted for 90.3% and 93.7% of replacements and repairs; stenosis accounted for 9.7% and 6.3% of replacements and repairs.

Between 1998 and 2005, the use of mechanical valves decreased from 83.2% to 62.8% with a simultaneous increase in tissue valves from 16.8% to 37.2%. During this period, use of tissue valves among female patients increased from 18.5% to 38.0%, whereas among male patients, tissue valves increased from 14.1% to 36.2%.

Aortic Valve Procedures

From 1998 to 2005, the total volume of aortic valve repair and replacement procedures increased 102.5% and 28.0%, respectively (Table 2). No changes in average age were observed from 1998 (repair: 56.6 ± 42.2; replacement: 64.5 ± 33.6) to 2005 (repair: 53.4 ± 39.8; replacement: 64.9 ± 32.3). As a percentage of annual aortic procedures performed, aortic repairs increased from 2.0% (n = 439) in 1998 to 3.1% (n = 889) in 2005. Female patients represented 40.6% of all aortic valve surgeries performed (repair, 40.0%; replacement, 40.7%). From 1998 to 2005, a small annual decrease in the proportion of women having aortic valve surgical procedures was observed (1998, 41.9%; 2005, 39.1%). ICD codes referring to congenital anomalies accounted for 7.9% and 6.8% of aortic valve repair and replacement procedures, respectively. Of the congenital aortic valve repairs, 93.8% were due to valve insufficiency and 6.2% from valve stenosis; for aortic replacements, 90.4% were insufficiency and 9.3% stenosis.

Over the study period, the use of tissue valves in aortic valve replacement doubled from 26.7% in 1998 to 50.2% in 2005 (Figure 1). Since 1999, aortic valve replacement has primarily been performed with the use of tissue valves (1999, 50.0%; 2005, 71.4%) among patients aged 75 years or greater; all other age groups remained predominantly mechanical but the proportion decreased annually with patients aged 51 to 75 years, approaching tissue usage rates observed among older patients (Table 3). No gender differences in the proportion of aortic tissue valve use were observed over the study period. The implantation of tissue valve doubled over the study period (women: 1998, 29.5% and 2005, 53.2%; men: 1998, 24.8%, and 2005, 48.2%). The use of tissue valves for patients aged < 65 years tripled from 11.4% in 1998 to 31.4% in 2005 compared with a doubling among patients age ≥ 65 years (1998, 37.8%; 2005, 64.6%). Operative mortality for patients receiving a tissue valve was higher overall (4.6% vs 3.7%) but appeared more related to early in the study period (1998, death vs. no death 5.1% vs 3.6%; 2005, 3.1% vs 2.9%). From 1998 to 2005, hospital deaths for aortic valve repairs decreased 20.7% (9.2% vs 7.3%) compared with 25.0% decrease in mortality for aortic valve replacements (4.0% vs 3.0%).

The length of stay (LOS) for patients following aortic valve procedure was frequently observed to be 6 to 10

TABLE 1. Annual change in isolated aortic and mitral valve procedures: National Inpatient Sample, 1998 to 2005

	Procedure	
Year	Repair	Replacement
1998	3025 (8.5)	32,573 (91.5)
1999	4316 (11.7)	32,673 (88.3)
2000	4717 (11.6)	35,964 (88.4)
2001	5869 (13.2)	38,631 (86.8)
2002	6033 (14.3)	36,175 (85.7)
2003	7477 (15.9)	39,450 (84.1)
2004	6236 (14.8)	35,844 (85.2)
2005	8669 (19.1)	36,678 (80.9)
Change (%)	186.6	12.6
Total	46,342	287,989

Change (%), Relative from 2005 to 1998.

days (44.5%). Among patients having aortic valve repair, the proportion of LOS less than 5 days increased from 27.0% in 1998 to 33.3% in 2005. The percentage of aortic replacements with a LOS less than 5 days increased from 25.3% in 1998 to 29.4% in 2005.

Mitral Valve Procedures

From 1998 to 2005, the total volume of mitral valve repair and replacement procedures increased 201.2% and 17.2%, respectively (Table 2). No changes in average age were observed from 1998 (repair: 58.0 ± 33.1; replacement: 62.0 ± 32.0) to 2005 (repair: 58.6 ± 32.1; replacement: 62.1 ± 31.1). As a percentage of annual mitral procedures, valve repair increased from 18.9% (n = 2586) in 1998 to 45.8% (n = 7790) in 2005. Female patients represented 54.3% of mitral procedures (repair, 42.6%; replacement, 59.8%). ICD codes referring to congenital anomalies accounted for 1.6% and 0.7% of mitral valve repair and replacement procedures, respectively. Of the congenital mitral valve repairs, 70.2% were due to valve insufficiency and 29.8% from valve stenosis; for aortic replacements, 69.8% were insufficiency and 30.1% stenosis.

Over the study period, the use of tissue valves in mitral valve replacement doubled from 16.9% in 1998 to 36.5% in 2005 (Figure 1). Since 2003, mitral valve replacement has primarily been performed with the use of tissue valves (2003, 52.2%; 2005, 62.3%) among patients aged 75 years

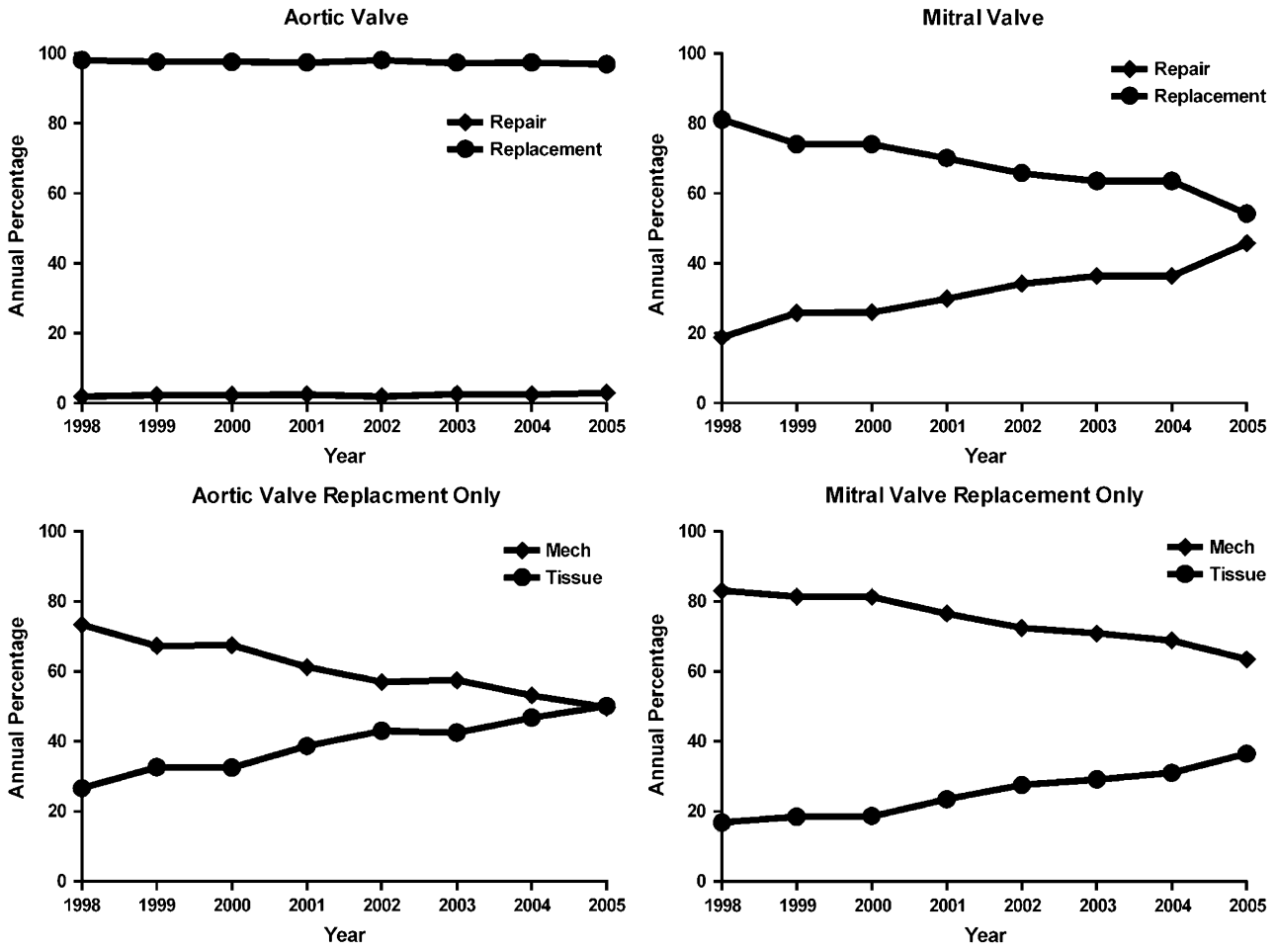

FIGURE 1. Annual changes in primary valve repair and procedure rates.

TABLE 2. Annual change in primary aortic and mitral procedures stratified by valve: National Inpatient Sample, 1998 to 2005

	Aortic		Mitral	
	Repair	Replacement	Repair	Replacement
1998	439 (2.0)	21,459 (98.0)	2586 (18.9)	11,114 (81.1)
1999	541 (2.4)	21,892 (97.6)	3775 (25.9)	10,781 (74.1)
2000	591 (2.4)	24,186 (97.6)	4127 (26.0)	11,778 (74.0)
2001	711 (2.6)	26,568 (97.4)	5158 (29.9)	12,063 (70.1)
2002	524 (2.0)	25,579 (98.0)	5509 (34.2)	10,596 (65.8)
2003	754 (2.7)	27,724 (97.3)	6722 (36.4)	11,726 (63.6)
2004	710 (2.6)	26,181 (97.4)	5526 (36.4)	9664 (63.6)
2005	889 (3.1)	27,471 (96.9)	7790 (45.8)	9207 (54.2)
Change (%)	102.5	28.0	201.2	–17.2

Change (%), Relative from 1998 to 2005.

or greater (Table 3). On average, less than one-quarter of mitral replacement valves in patients were tissue, and one-third were for patients between the ages of 51 and 75. No gender differences in the proportion of mitral tissue valve use were observed over the study period.

Tissue valve use doubled for both genders (women: 1998, 18.9% and 2005, 37.8%; men: 1998, 13.9% and 2005, 34.8%). The implantation rate of tissue valves for patients aged < 65 years tripled from 6.2% in 1998 to 21.1% in 2005 and doubled among patients age ≥ 65 years (1998, 27.4; 2005, 52.7). Operative mortality for patients receiving a tissue valve was higher overall (9.1% vs 5.6%) but appeared more related to years early in the study period (1998, death vs no death: 11.1% vs 5.6%; 2005, 6.6% vs

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TABLE 3. Characteristics of primary aortic and mitral valve procedures from 1998 to 2005

	Aortic				Mitral			
	Repair		Replacement		Repair		Replacement	
	1998	2005	1998	2005	1998	2005	1998	2005
Female, n (%)	197 (44.8)	293 (33.3)	8983 (41.9)	10780 (58.1)	1159 (44.8)	3090 (39.9)	6938 (62.4)	5352 (58.1)
Age (y)								
18–25	24 (5.5)	71 (16.1)	197 (0.9)	267 (1.0)	48 (1.9)	137 (1.8)	106 (1.0)	130 (1.4)
26–50	134 (30.4)	71 (8.1)	3721 (17.3)	4343 (15.8)	715 (27.7)	2177 (27.9)	2312 (20.8)	1807 (19.6)
51–75	211 (48.0)	291 (33.1	12,064 (56.2)	15,271 (55.6)	1582 (61.2)	4427 (56.8)	6813 (61.3)	5580 (60.6)
75+	71 (8.1)	416 (47.4)	5477 (25.5)	7590 (27.6)	241 (9.9)	1050 (13.5)	1882 (16.9)	1691 (18.4)
Elective*	—	453 (51.6)	—	18443 (67.2)	—	6077 (78.1)	—	5591 (60.7)
Hospital death	40 (9.2)	64 (7.3)	851 (4.0)	822 (3.0)	55 (2.1)	115 (1.5)	725 (6.5)	453 (4.9)
Payer								
Medicare	198 (45.1)	262 (29.8)	11,174 (52.1)	15,126 (55.1)	961 (37.2)	2819 (36.2)	5123 (46.1)	4653 (50.5)
Medicaid	27 (6.1)	96 (11.0)	1025 (4.8)	1318 (4.8)	138 (5.3)	386 (5.0)	924 (8.3)	803 (8.7)
Private	190 (43.2)	435 (50.0)	7898 (36.8)	9804 (35.7)	1316 (50.9)	4280 (54.9)	4325 (38.9)	3257 (35.6)
Self-pay	21 (4.7)	56 (6.4)	459 (2.1)	519 (1.9)	26 (1.0)	134 (1.7)	277 (2.5)	244 (2.7)
No charge	4 (0.9)	5 (0.6)	13. (0.1)	76 (0.3)	17 (0.6)	9 (0.1)	26 (0.2)	37.8 (0.4)
Other	0 (0.0)	25 (2.9)	891 (4.2)	629 (2.3)	129 (4.9)	163 (2.1)	441 (4.0)	213 (2.3)
Region								
Northeast	99 (22.5)	122 (14.5)	4736 (22.1)	6363 (24.0)	617 (23.9)	1946 (25.9)	2465 (22.2)	1757 (19.7)
Midwest	170 (38.6)	364 (43.1)	6213 (29.0)	6721 (25.4)	629 (24.3)	2162 (28.8)	3204 (28.8)	2050 (23.0)
South	122 (27.7)	170 (20.2)	6944 (32.4)	6473 (24.4)	935 (36.1)	1794 (23.9)	3772 (33.9)	3003 (33.6)
West	49 (11.1)	188 (22.3)	3566 (16.6)	6956 (26.2)	405 (15.7)	1600 (21.3)	1672 (15.0)	2123 (23.8)
Teaching hospital								
Yes	352 (80.1)	672 (76.5)	16,257 (75.8)	17,806 (64.8)	2052 (79.4)	5356 (68.8)	8665 (78.0)	6157 (66.9)
No	87 (19.9)	206 (23.5)	5203 (24.2)	9664 (35.2)	533 (20.6)	2434 (31.2)	2448 (22.0)	3050 (33.1)
Length of stay (d)								
0–5	118 (27.0)	293 (33.3)	5426 (25.3)	8086 (29.4)	990 (39.3)	3407 (43.7)	2026 (18.2)	1537 (16.7)
6–10	189 (43.0)	294 (33.4)	10,093 (47.0)	12,151 (44.2)	1069 (41.3)	2915 (37.4)	4897 (44.1)	3802 (41.3)
11+	132 (30.0)	293 (33.3)	5940 (27.7)	7235 (26.3)	527 (20.4)	1468 (18.8)	4191 (37.7)	3868 (42.0)

*Available only from 2002.

TABLE 4. Trends in total billed charges and estimated institution cost for primary aortic and mitral valve procedures from 2001–2005

	Aortic				Mitral			
	Repair		Replacement		Repair		Replacement	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Total estimated billed charges								
1998	76,423	12,087	62,055	1841	51,179	2589	97,907	5381
2005	138,005	13,240	118,128	4859	70,520	2334	139,039	5840
% increase	80.6		90.4		37.8		42.0	
Annual institution cost								
2001	36,785	3555	34,480	818	28,405	1143	39,217	1272
2002	56,426	8455	37,564	1163	32,874	1224	42,734	1408
2003	40,930	2761	42,864	1421	35,411	1501	50,026	2000
2004	51,540	5407	42,189	1484	38,321	2398	54,427	2254
2005	55,206	5104	45,594	1547	38,642	1695	53,562	2206
% increase	50.1		32.2		36.0		36.6	

Cost data only available for years 2001–2005. *SE,* Standard error; *% increase,* relative from 2001 to 2005.

4.0%). From 1998 to 2005, hospital deaths for mitral valve repairs decreased 28.7% (2.1% vs 1.5%) compared with 24.6% (6.5% vs 4.9%) for mitral valve replacements.

Among mitral valve procedures, a 6- to 10-day LOS was most frequently observed (41.4%). Among mitral valve repair patients, the proportion of LOS less than 5 days decreased from 41.3% in 1998 to 37.4% in 2005. The percentage of mitral replacements with an LOS less than 5 days decreased from 18.2% in 1998 to 16.7% in 2005.

Institution Cost and Total Billed Charges

Over the study period, total billed charges for aortic valve procedures increased \$62,341 ± \$1867 in 1998 to \$118,762 ± \$4815 (90.5%, Table 4). Total billed charges for aortic valve procedures at least doubled from 1998 to 2005, with aortic replacements showing the greatest increase (90.4%; repair, 80.6%). From 2001 to 2005, annual institution costs for aortic valve procedure increased 50.1% for repairs and 32.2% for replacements (Table 4, Figure 2).

Between 2001 and 2005, institution cost for the replacement with aortic tissue valves increased on average 36.4% compared with 27.0% for mechanical valves (tissue: 2001, \$34,996 and 2005, \$47,723; mechanical: 2001, \$34,121 and 2005, \$43,348). Until recently, the average increased institution cost of implanting an aortic tissue valve versus a mechanical valve was only 2.5%; in 2005, the cost differential was 10.1%.

Over the study period, total billed charges for mitral valve procedures increased from \$66,865 ± \$2131 to \$119,966 ± \$5235 (79.4%, Table 4). Total billed charges for mitral procedures at least doubled from 1998 to 2005, with mitral repairs increasing the least (37.8%). From 2001 to 2005, institution cost increased for mitral repair and replacement procedures 36.0% and 36.6%, respectively (Table 4, Figure 2). The cost of both mitral repair and replacement procedures increased annually on average 8.0% to 8.5%.

Between 2001 and 2005, mitral valve replacement with tissue valves cost increased on average 35.7% compared with 34.3% for mechanical valves (tissue: 2001, \$42,313 and 2005, \$57,405; mechanical: 2001, \$38,158 and 2005, \$51,259). During the study period, the estimated institution cost of a mitral valve repair, regardless of type, increased on average 12.9%.

Hierarchical Regression

We examined the impact of individual hospital variance on procedure type (repair vs replacement) and aortic versus mitral procedure and the natural log(total billed charges) using mixed-effects models. Thirty-nine percent of the total variance in log(total billed charges) was related to hospital variation (intraclass correlation coefficient). Among aortic procedures, log(total billed charges) for repairs was significantly increased (6.1%, $P < .001$) over replacement procedures after adjusting for individual hospital variation. Among mitral procedures, log(total billed charges) for repairs were significantly increased (78.1%, $P < .001$) over replacement procedures after adjusting for individual hospital variation.

DISCUSSION

In this report, we present data and trends from the NIS on aortic and mitral valve procedure performed over the last decade. Significant findings worth noting are the relatively striking lack of changes over the last decade in the percentage of aortic valve replacements as a proportion of all performed aortic valve procedures. More than 95% of the aortic valve procedures performed during the mid 1990s were for replacement and remained so during the mid 2000s.

The most significant change in the practice of aortic valve surgery is the opposite trend in the percentage of mechanical and tissue valve implantation. In the mid 1990s, the majority of the replaced aortic valves were mechanical prosthesis, and

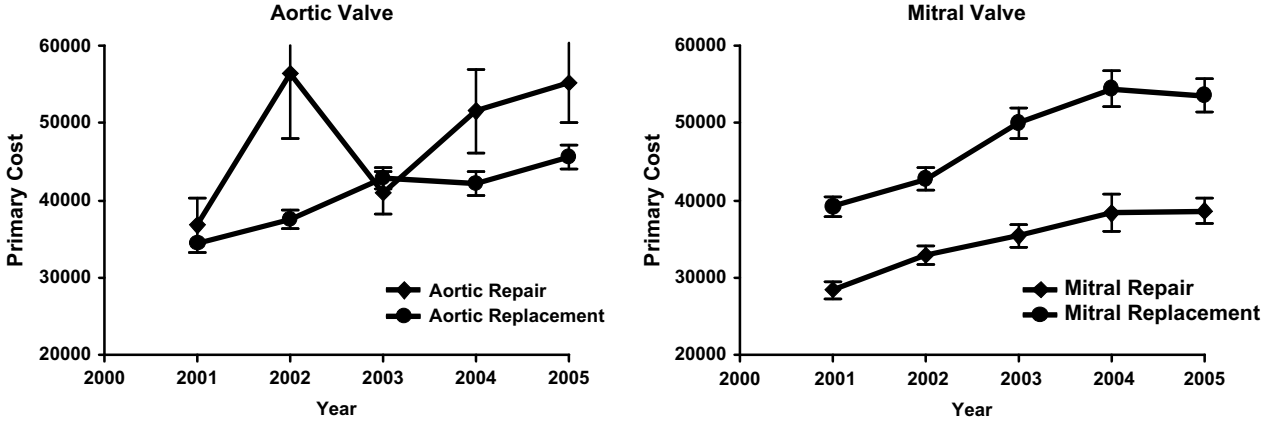

FIGURE 2. Estimated institution cost trends of primary aortic and mitral valve procedures from 2001–2004.

the majority of implants in 2005 were tissue valves. This trend may relate to extensive publications regarding the long-term results of aortic valve replacement and, more specifically, comparisons between tissue and mechanical prosthesis showing comparable outcome with a slightly lower valve-related complication rates, especially in patients over the age of 60 years.[9-11]

Mitral valve procedures present a completely opposite trend. The use of mitral valve replacement over the last decade declined from 80% of all mitral valve procedures to a current use of approximately 50%, with figures from different institutions that suggest higher repair rate for certain mitral valve pathologies with very good durability.[12,13] This trend represents a significant change in the cardiac surgery practice for mitral valve surgery, and it may be related to extensive publications in support of the mitral valve repair over replacement both in the perioperative phase and in late follow-up.[14,15] Trends toward decreases in mitral valve replacement procedures may largely be explained due to increased understanding of the mitral valve pathophysiology leading to greater surgical proficiency, comparable perioperative outcomes,[16-21] and long-term survival[18,21,22] and an increased focus on patient quality of life by decreased use of warfarin.[23-25]

Last, data suggest a steady 8% to 9% annual increase in hospital cost for both aortic and mitral procedures. When total billed charges were analyzed using hierarchical regression to adjust for hospital variation within HCUP, approximately 39% of total variance (aortic: 41%; mitral: 37%) in billed charges between procedure type or valve type was due to individual hospitals. This suggests that although Medicare reimbursements for aortic and valve procedures remains standardized, individual hospital billing is not. Although total billed charges for aortic and valve procedures have at least doubled since 1998, Medicare physician reimbursement fees for vascular and general surgery have decreased.[26,27] Data from our own practice suggest a 14% decrease in reimbursement for aortic valve replacements, with a subsequent 10% and 16% decrease in mitral valve replacements and mitral valve repair reimbursement over the same period of time.

Published data from the Society of Thoracic Surgeons (STS) National Adult Cardiac Surgery Database suggest a 629% increase in aortic valve replacement procedures from 1990 (n = 1246) to 1997 (n = 9095).[25] During the same period, mitral valve replacement procedures increased 600% (1990, n = 657; 1997, n = 4605) and mitral valve repair procedures increased 796% (1990, n = 223; 1997, n = 2000). When stratified by gender, the proportion of female patients having aortic valve replacement increased 2.5% percentage points (1990, 40.3%; 1997, 42.8%). The proportion of female patients having mitral valve replacement increased slightly (1990, 61.4%; 1997, 61.8%) but decreased with mitral valve repair (1990, 59.8%; 1997, 40.8%).[28] Published STS data from spring 2007 (unpublished participant data) showed observed operative mortality rates for isolated aortic and mitral replacement in the year 2006 were 3.1% and 5.6%, respectively, with reported STS observed mortality rates for mitral valve repair of 1.9%. With the exception of aortic repair mortality rates (not reported at the STS), the STS and HCUP rates are comparable. Differences in aortic valve repair rates may be the HCUP sampling strategy actually capturing data from one of the few centers that continue to perform aortic valve repairs and may not be reflective of the overall success rates found within the STS. The STS database remains the largest cardiac surgery database in the world and, as such, remains an excellent source for cardiac surgery clinical data. An increasing number of institutions use the STS database, although participation remains voluntary. As it currently exists, the STS national database offers a greater level of clinical detail than the HCUP, but the STS database is not a nationally probabilistic sample of cases and participation without financial data.

Although the STS data are helpful in viewing trends, interpretation must be made with caution. The STS is the

largest cardiac surgery database in the world, but increased volume is most likely due to increased participation by number of centers. The NIS by contrast uses different sources and methods to capture data; however, the data are well correlated with previous publications using the STS Adult Cardiac Surgery Registry and those in Europe. Savage and colleagues[29] and Keogh and associates[30] reported mitral valve repair rate of 42.4% and 35% for the United States and Britain, respectively, at the year 2000.

These changes in trends might be attributed to several important but individually separate factors relating to the complexity of valve procedures. For aortic valve procedures, the complexity of the valve and underlying root structure does not lend itself to repair in most cases. In addition, when attempted, repair procedures have not demonstrated comparable perioperative[31] or late outcomes.[32] However, recent developments in aortic root remodeling with preservation of the native valve can minimize anticoagulation therapies and minimize valve-related complications.[32-34]

LIMITATIONS

Although the NIS represents the largest publicly available sample of inpatient hospitalization in the United States, some limitations are present. Despite rigorous attempts to use advanced probabilistic models to generate randomly sampled institutions, only 20% of nationwide institutions were sampled, and we cannot guarantee that institutions serving cardiac needs were completely represented. To our knowledge, the NIS sampling design does not subsample based on medical populations. Furthermore, as with any nationally sampled data, some populations of disease and procedure populations are undoubtedly underrepresented due to variations in ICD-9-CM coding schemes and interpretations. We feel this limitation is most likely minimal as we restricted our analysis to primary aortic and mitral valve procedures, both serious interventional procedures that are highly unlikely to be miscoded or missed by institution coders altogether. CC ratios should be examined with caution due to various differences in state reporting mechanisms. Several states report individual participating institution CC ratios, but several states only report state average. Although this makes for a difficult state-by-state comparison, overall national trends will be similar as individual state methodologies remain constant. Strengths of this database are its large size, representative quality, and standardized methodology.

Although these national data suggest different patterns of aortic and mitral valve procedure patterns over the last decade, these data only reflect sampled US medical data. Data may not reflect those of individual institutions. Further studies reporting data from individual high-volume centers would be helpful in confirming these trends and generating more detailed data. Assuming these aortic and mitral valve procedure trends continue, considerable effort should be made to ensure that allocation of hospital resources will be commensurate.

References

1. American Heart Association. Heart Disease and Stroke Statistics—2008 Update. Dallas: American Heart Association; 2008.
2. Supino PG, Borer JS, Preibisz J, Bornstein A. The epidemiology of valvular heart disease: a growing public health problem. *Heart Fail Clin*. 2006;2:379-93.
3. Wu Y, Jin R, Gao G, Grunkemeier GL, Starr A. Cost-effectiveness of aortic valve replacement in the elderly: an introductory study. *J Thorac Cardiovasc Surg*. 2007;133:608-13.
4. Wu Y, Grunkemeier GL, Starr A. The value of aortic valve replacement in elderly patients: an economic analysis. *J Thoracic Cardiovascular Surg*. 2007;133:603-7.
5. Pfitzner R, Sadowski J, Drwita R, Dziatkowiak A. Valvular surgery-multiannual experience, trends and perspectives. *Acta Cardiol*. 2004;59:222-3.
6. Thourani VH, Weintraub WS, Craver JM, Jones EL, Mahoney EM, Guyton RA. Ten-year trends in heart valve replacement operations. *Ann Thorac Surg*. 2000; 70:448-55.
7. HCUP Nationwide Inpatient Sample (NIS). Healthcare Cost and Utilization Project (HCUP). 2000–2001. Agency for Healthcare Research and Quality, Rockville, MD. Available at: www.hcup-us.ahrq.gov/nisoverview.jsp.
8. Houchens R, Elixhauser A. Final Report on Calculating Nationwide Inpatient Sample (NIS) Variances, 2001. HCUP Methods Series Report #2003-2. ONLINE. June 6, 2005. US Agency for Healthcare Research and Quality. Available at: www.hcup-us.ahrq.gov/reports/calculatingNIS_Variances200106092005.pdf.
9. Hammermeister K, Sethi GK, Henderson WG, Grover FL, Oprian C, Rahimtoola SH. Outcomes 15 years after valve replacement with a mechanical versus a bioprosthetic valve: final report of the Veterans Affairs randomized trial. *J Am Coll Cardiol*. 2000;36:1152-8.
10. Ruel M, Chan V, Bédard P, Kulik A, Ressler L, Lam BK, et al. Very long-term survival implications of heart valve replacement with tissue versus mechanical prostheses in adults <60 years of age. *Circulation*. 2007;116(11 suppl):I294-300.
11. Chan V, Jamieson WR, Germann E, Chan F, Miyagishima RT, Burr LH, et al. Performance of bioprostheses and mechanical prostheses assessed by composites of valve-related complications to 15 years after aortic valve replacement. *J Thorac Cardiovasc Surg*. 2006;131:1267-73.
12. Hayek E, Gring CN, Griffin BP. Mitral valve prolapse. *Lancet*. 2005;9458:507-18.
13. Ad N, Barnett SD, Speir AM, Massimiano PS. Institutional and national trends in isolated mitral valve surgery over the past decade. *Curr Opin Cardiol*. 2008;23:99-104.
14. Mohty D, Orszulak TA, Schaff HV, Avierinos JF, Tajik JA, Enriquez-Sarano M. Very long term survival and durability of mitral valve repair for mitral valve prolapse. *Circulation*. 2001;104:I1-7.
15. Braunberger E, Deloche A, Berrebi A, Abdallah F, Celestin JA, Meimoun P, et al. Very long-term results (more than 20 years) of valve repair with Carpentier's techniques in nonrheumatic mitral valve insufficiency. *Circulation*. 2001;104:I8-11.
16. Reece TB, Tribble CG, Ellman PI, Maxey TS, Woodford RL, Dimeling GM, et al. Mitral repair is superior to replacement when associated with coronary artery disease. *Ann Surg*. 2004;239:671-5.
17. Al-Radi OO, Austin PC, Tu JV, David TE, Yau TM. Mitral repair versus replacement for ischemic mitral regurgitation. *Ann Thorac Surg*. 2005;79:1260-7.
18. Ruttmann E, Legit C, Poelzl G, Mueller S, Chevtchik O, Cottogni M, et al. Mitral valve repair provides improved outcome over replacement in active infective endocarditis. *J Thorac Cardiovasc Surg*. 2005;130:765-71.
19. Kouris N, Ikonomidis I, Kontogianni D, Smith P, Nihoyannopoulos P. Mitral valve repair versus replacement for isolated non-ischemic mitral regurgitation in patients with preoperative left ventricular dysfunction. A long-term follow-up echocardiography study. *Eur J Echocardiogr*. 2005;6:435-42.
20. Kuwaki K, Kawaharada N, Morishita K, Koyanagi T, Osawa H, Maeda T, Higami T. Mitral valve repair versus replacement in simultaneous mitral and aortic valve surgery for rheumatic disease. *Ann Thorac Surg*. 2007;83:558-63.
21. Feringa HH, Shaw LJ, Poldermans D, Hoeks S, van der Wall EE, Dion RA, Bax JJ. Mitral valve repair and replacement in endocarditis: a systematic review of literature. *Ann Thorac Surg*. 2007;83:564-70.
22. Suri RM, Schaff HV, Dearani JA, Sundt TM 3rd, Daly RC, Mullany CJ, et al. Survival advantage and improved durability of mitral repair for leaflet prolapse subsets in the current era. *Ann Thorac Surg*. 2006;82:819-26.
23. Goldsmith IR, Lip GY, Patel RL. A prospective study of changes in the quality of life of patients following mitral valve repair and replacement. *Eur J Cardiothorac Surg*. 2001;20:949-55.

24. Immer FE, Donati O, Wyss T, Immer-Bansi AS, Schmidli J, Berdat PA, Carrel TP. Quality of life after mitral valve surgery: differences between reconstruction and replacement. *J Heart Valve Dis*. 2003;12:162-8.
25. Jokinen JJ, Hippeläinen MJ, Pitkänen OA, Hartikainen JE. Mitral valve replacement versus repair: propensity-adjusted survival and quality-of-life analysis. *Ann Thorac Surg*. 2007;84:451-8.
26. York JW, Lepore MR, Opelka FG, Sternbergh WC, Money SR. A decade of decline: an analysis of Medicare reimbursement for vascular surgical procedures. *Ann Vasc Surg*. 2002;16:115-20; Epub 2002 Jan 18.
27. Hoballah JJ, Liao J, Salameh M, Weigel RJ. Physician reimbursement for general surgical procedures in the last century: 1906-2006. *J Am Coll Surg*. 2008;206: 670-7; Epub 2008 Feb 21.
28. STS Data Analyses—January 1999. Annual Trends and Summaries [serial on Internet]. Available at: http://www.sts.org/doc/3160. Last accessed January 30, 2008.
29. Savage EB, Ferguson TB Jr, DiSesa VJ. Use of mitral valve repair: analysis of contemporary United States experience reported to the Society of Thoracic Surgeons National Cardiac Database. *Ann Thorac Surg*. 2003;75:820-5.
30. Keogh BE, Kinsman R. Fifth National Adult Cardiac Surgical Database Report 2003. Henley-on-Thames: Dendrite. 2004.
31. Davierwala PM, David TE, Armstrong S, Ivanov J. Aortic valve repair versus replacement in bicuspid aortic valve disease. *J Heart Valve Dis*. 2003;12:679-86.
32. David TA, Feindel CM. An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta. *J Thorac Cardiovasc Surg*. 1992;103:617-22.
33. Sarsam MA, Yacoub M. Remodeling of the aortic valve annulus. *J Thorac Cardiovasc Surg*. 1993;105:435-8.
34. Schäfers HJ, Fries R, Langer F, Nikoloudakis N, Graeter T, Grundmann U. Valve-preserving replacement of the ascending aorta: remodeling vs. reimplantation. *J Thorac Cardiovasc Surg*. 1998;116:990-6.