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Survey Reported Participation in Cardiac Rehabilitation and Survival after Mitral or Aortic Valve Surgery

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Abstract

We sought to measure the impact of cardiac rehabilitation (CR) on mortality among patients with mitral or aortic heart valve surgery (HVS) and non-obstructive coronary artery disease. We surveyed all patients (or a close family member if the patient was deceased) who had HVS without coronary artery bypass in 2006 through 2010 at the Mayo Clinic to assess if they attended CR after their HVS. We performed a propensity-adjusted landmark analysis to test the association between CR attendance and long-term all-cause mortality conditional upon surviving the first year after HVS. Survey response rate was 40% (573/1420), with responders more likely to be older, have longer hospitalizations, and have more aortic valve disease. A total of 547 patients (59% aortic surgery, ejection fraction 64%) with valid survey responses and 1-year follow-up were included in the propensity analysis, of whom 296 (54%) attended CR. There were 100 deaths during a median follow-up of 5.8 years. For all patients, the propensity-adjusted model suggested no impact of CR on mortality (HR 1.03, 95% CI, 0.66 to 1.62). When stratified by procedure, results suggested a potentially favorable, but non-significant, effect among patients with mitral valve surgery (HR 0.49, 95% CI 0.15 to 1.56), but not among patients with aortic valve surgery (HR 1.00, 95% CI 0.61 to 1.64.) In conclusion, we found no survival advantage for patients with normal pre-operative ejection fraction who attended CR after surgical "correction" of their severe aortic or mitral valve disease.

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Disclosures

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Keywords

cardiac rehabilitation; heart surgery; quality and outcomes of care

Introduction

Although cardiac rehabilitation (CR) improves mortality among patients with atherosclerotic cardiovascular disease in observational studies,[1–6] there is little evidence to date that CR improves mortality after isolated heart valve surgery (HVS.)[7] Furthermore, given the significant differences in disease etiology and disease pathophysiology, the effects of CR may differ in patients with HVS compared to those with coronary artery disease (CAD.) Accordingly, we examined the impact of CR on mortality following HVS and hypothesized that CR attendance would be associated with improved survival.

Methods

We utilized the cardiothoracic surgical database at Mayo Clinic in Rochester, MN to identify all patients who underwent valve-only surgery during a 5-year period between January 2006 and December 2010. This database is modeled after the Society of Thoracic Surgery database[8] and utilizes standard definitions for valve disease severity, clinical risk factors, surgical interventions, and post-operative complications. This database also recorded hospital-initiated referral to CR and the Charlson comorbidity index.[9]

We included patients who underwent isolated surgical aortic valve repair or replacement, mitral valve repair or replacement, or a combination of these valve procedures, while excluding patients who with concurrent coronary artery bypass graft surgery (CABG). We excluded patients who underwent transcutaneous aortic valve replacement, isolated tricuspid or pulmonary valve surgery, and patients <50 years old due to their small numbers and heterogeneity of disease states. We further excluded patients with in-hospital mortality, international home mailing addresses, or those without a valid consent for medical record-based retrospective research.

Because the majority of patients lived outside Olmsted County MN, we could not confirm attendance at CR through direct medical record review. As a result, we surveyed patients (or a close family member if the patient was deceased) to assess if the patient attended CR in the year following their HVS. We mailed the initial survey in spring 2013 and received the final survey response in fall 2013. If no response to the initial mailing was received, we sent a second survey about 4 weeks later. To increase our response rate, we additionally telephone-surveyed family members of decease patients if there was no response to the second mailing. Attempts to complete the telephone survey continued until family members completed the survey, could not be contacted, or declined to participate. All survey administration, survey collection, and data entry was performed by Mayo Clinic survey research center personnel following standard protocols. All patients participating in the survey gave written informed consent. This study was approved by the Mayo Clinic Institutional Review Board.

Survey questions were developed primarily by the principal investigator (QP) with help from research staff in the survey research center. Co-authors carefully reviewed the full survey for face and content validity. To further increase out accuracy and reliability, we performed cognitive testing of the survey questionnaire with 5 patients to further improve the survey as necessary. The survey contained 9 primary questions that assessed referral to CR, attendance at CR orientation, and the length and frequency of CR attendance. In the survey, CR was defined as an exercise-based intervention commonly coupled with medical educational sessions with the overall goal of hastening recovery from surgery. We used slightly different wording depending upon which group was being surveyed. See online appendix for the 2 survey instruments.

The primary predictor variable was attendance at CR, as determined by the response to survey question #6, which asked, “In the year following your heart surgery, did you ever attend at least 1 exercise session in an outpatient cardiac rehabilitation program?” We excluded patients who skipped this question, did not remember, or gave inconsistent answers to follow-up questions about when and where they attended CR. We assessed the reliability of our primary predictor by comparing survey-reported attendance at CR with medical record-verified CR attendance among the small portion of eligible patients who were living in Olmsted County, MN at the time of their surgery during the years 2006–2008. During the study period, the Mayo Clinic CR program was the only CR program available in Olmsted County.

The primary outcome was all-cause mortality as assessed in October 2014. We used the Mayo Clinic registration database in conjunction with the Minnesota death tapes and obituaries in the local newspapers to determine patient’s vital status. For anyone not indicated as deceased by Mayo Clinic records, patients were censored as alive at their last known medical visit, or at the date of survey completion (for self-respondents only.) Cause of death was unknown.

Descriptive statistics on baseline patient characteristics and survey responses were presented as frequency (%) for categorical variables and as quartiles (median, 25^{th} and 75^{th} percentiles) for continuous variables, as appropriate. To assess potential survey response bias, group differences between respondents and non-respondents were determined using standard 2-sample tests (Wilcoxon rank sum test, chi-square test or Fisher’s exact test, as appropriate). The survey-based indication of CR attendance was assessed for concordance using the Kappa statistic. Median follow-up time was estimated using the reverse Kaplan-Meier method.

Given the possibility that baseline factors played a role in the decision to attend CR (participation bias), this potential confounding on the association of CR attendance with long-term mortality was addressed using propensity score adjustment.[10] In particular, >50 factors were entered as possible explanatory variables into a multivariable logistic regression model to predicted CR attendance. The logit-transformed predicted probability of attending CR from this model determined the propensity score, which was then included as an adjusting covariate along with CR attendance for predicting time-to-death. We also

performed alternative forms of propensity score analysis that involved matching, weighting and stratifying.

We then analyzed the association between attending any CR within 1-year of HVS with long-term mortality, with and without propensity score risk adjustment, using Cox proportional hazards regression. We utilized a landmark analysis approach that conditioned on patients having 1-year censor-free survival, thus allowing CR attendance within 1 year to be treated as a baseline predictor of post 1-year mortality. We further augmented this multivariable model by adjusting for factors thought to be predictive of mortality, including age, gender, atrial fibrillation, end stage renal disease, peripheral vascular disease, and Charlson Index. We then repeated the propensity analyses within clinically-relevant subgroups of mitral or aortic valve surgery. Given the small number of patients with combined aortic and mitral valve surgery, these patients were included in both subgroups (aortic and mitral) for respective subset analyses. All data analysis was performed using the SAS statistical software package (version 9.3, SAS Institute, Cary, NC). A type I error rate of 0.05 was used to determine statistical significance.

Results

We identified 1,460 potentially eligible patients, excluded 40 patients due to lack of valid research consent, and then surveyed the remaining 1,420 patients including 208 who were known to be deceased. A total of 573 patients returned a completed survey for a response rate of 40%. Family members completed 123 (21%) of these surveys, while patients completed 450 (79%). Survey respondents were different from non-respondents in several ways. See Table 1.

We identified 19 patients who resided in Olmsted County, MN at the time of their surgery between 2006 and 2007, in whom their attendance in the Mayo Clinic CR program was previously known via chart abstraction. In this subset, there was “moderate to substantial” agreement between survey-reported attendance and medical record verified CR attendance. Agreement was 84% with a kappa = 0.62 (95% CI, 0.23 to 1.00).

For the survival analysis, we excluded 11 (2%) patients due to incomplete or inconsistent answers about CR attendance and 15 (3%) patients due to insufficient follow-up (censor-free survival was < 1 year). Of the remaining 547 patients, 296 (54%) reported attending CR for ≥1 exercise session. The reported median (IQR) frequency was 3 (2–3) CR sessions per week for 6 (6–10) total weeks, corresponding to an estimated median of 18 (12–26) total CR sessions. Most patients [235/275 (85%)] reported completing their recommended course of CR.

On propensity analysis, several factors were associated with CR attendance on univariable analysis (Table 2), although all available factors were included in the multivariable model that derived the propensity scores. On outcomes analysis, we recorded 100 deaths between the 1st year after surgery and the end of follow-up, with an estimated median (IQR) follow-up time of 5.8 (4.8–6.8) years following surgery. There was no impact of CR on all-cause mortality rate, either from unadjusted, propensity-adjusted, or propensity- and covariate-

adjusted analyses (Table 3). Sensitivity analyses utilizing different forms of propensity score adjustment, such as propensity-matched analyses, showed similar non-significant effects of CR (results not shown.) Sub-group results were similar for patients with aortic valve surgery. However, for patients who underwent mitral valve surgery, there was a non-significant ~51% improvement in long-term survival in both unadjusted and propensity-adjusted analyses. (Table 3) Finally, in a dose-response analysis performed only on CR participants, the estimated number of CR sessions completed was not significantly associated with long-term mortality (HR, per 10-session increment: 1.10, 95% CI, 0.93 – 1.29; p = 0.27).

Discussion

In this analysis of more than 500 patients with minimal CAD and normal preoperative left ventricular function, we were unable to demonstrate a significant benefit on 5-year survival among patients who self-reported attending CR after their HVS compared with patients who reported not attending CR. This finding persisted despite careful adjustment for propensity to attend CR, exploration of sub-groups by surgical valve type, and the use of similar methods as other notable positive studies about CR.[1–4] To our knowledge, this is the first study to directly examine the association between all-cause mortality and CR participation after isolated HVS. Our findings run directly counter to our hypothesis that CR attendance would be associated with improved long-term survival among patients with HVS.

There are at least two reasons why our null findings may be true findings. First, surgical correction of severe aortic or mitral valve disease in most cases interrupts or potentially “cures” the underlying valvular disease, which gives patients nearly equivalent survival as the general population,[11,12] especially if HVS is performed before there is left ventricular dysfunction, such as in our cohort.[13] As a result, there may be little role for medicine or exercise in these patients (except in the role of primary prevention, general overall health, and quality of life), which stands in contrast to patients with CAD, where these interventions are known to prevent progression of atherosclerosis.[14] Secondly, it is possible that CR may not lower total mortality, as suggested by a recent meta-analysis of randomized trials in patients with CAD.[15] However, this appears to be an unlikely explanation of our results since previous meta-analyses[16] and several contemporary large observational cohorts[17,18] have found a significant mortality benefit with CR in patients with CAD, including several studies from our group over the same time period.[1–4]

On the other hand, due to several potential methodological limitations, it is possible that CR attendance after HVS improves survival, but that our study limitations prevented us from finding such a difference. First, we had only a 40% response rate and we found differences between survey respondents and non-respondents on several measures, so the results determined in survey respondents may not be generalizable. Second, because this was a survey of patients referred to the Mayo Clinic for HVS from locations across the US, our population could have been either sicker or healthier than a typical population of patients with HVS. Third, attendance at CR was assessed through a patient survey and may be susceptible to recall bias. However, we found that our survey had moderate reliability for assessing medical-record verified attendance several years after CR, consistent with a prior publication suggesting that patient recall of CR attendance is substantial.[19] Lastly,

attendance at any kind of CR program across the US qualified as CR exposure for the present study, and, as a result, the various CR interventions for patients in their local communities could have varied widely in content and efficacy. That said, we found that the median "dose" of CR for our patients was about 18 sessions/patient with 85% of respondents stating they completed CR. If our patients had symptomatic CAD, this dose should be expected to improve mortality[5,6] so we doubt that our null findings are all simply from treatment heterogeneity across CR centers in the US.

One additional issue that might explain our negative results, particularly among patients with mitral valve surgery, is low statistical power. However, to our knowledge, our study is the only study to date on the subject, had a 15–20% event rate, and for the overall results, did not suggest even a small survival benefit. As the average surgical center performs < 30 isolated HVS's per year, we doubt that any other single surgical center would be adequately powered to perform a definitive study. Additionally, we are aware of only 1 randomized control trial of HVS in CR; however, with only 210 patients, it will be inadequately powered for mortality.[20] Consequently, it appears that a large national, regional, or insurance data set will be required to answer this question more definitively.

One potentially important finding in our analysis is significant treatment heterogeneity according to sub-groups. These suggested a favorable, but non-significant, effect among patients with mitral valve surgery with no benefit noted among patients with aortic valve surgery. This discordance has been noted previously, although it was among patients undergoing simultaneous CABG and HVS.[3] The reasons for this heterogeneity are unclear, but may stem from the fact that patients who require mitral valve surgery are more deconditioned and have more heart failure than patients undergoing aortic valve surgery.[21] Furthermore, patients after aortic stenosis surgery typically experience an increase in left ventricular ejection fraction, but patients with mitral regurgitation experience a decrease in ejection fraction.[22] Given that CR can impact mortality in patients with reduced ejection fraction heart failure [23] this may explain some of the observed, but non-significant, treatment effect for patients with mitral valve surgery.

We believe that physicians and policymakers should apply our findings with caution, as mortality impact should not be the only factor in deciding participation in and reimbursement for CR. In particular, there are several other known benefits to CR in patients with HVS. First, functional capacity improves in patients with HVS.[24–27] Secondly, CR generally improves mental health[15] and quality of life,[28] although the evidence base for such benefits is relatively sparse in patients with HVS, [24] and financial limitations prevented us from assessing this in our survey. Third, CR has been reported to significantly reduce hospital readmissions in patients with cardiovascular disease,[1] a finding attributed to the case management effect provided in CR.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Dunlay SM, Pack QR, Thomas RJ, Killian JM, Roger VL. Participation in cardiac rehabilitation, readmissions, and death after acute myocardial infarction. Am J Med. 2014; 127:538–546. [PubMed: 24556195]
2. Pack QR, Goel K, Lahr BD, Greason KL, Squires RW, Lopez-Jimenez F, Zhang Z, Thomas RJ. Participation in cardiac rehabilitation and survival after coronary artery bypass graft surgery: a community-based study. Circulation. 2013; 128:590–597. [PubMed: 23836837]
3. Goel K, Pack QR, Lahr B, Greason KL, Lopez-Jimenez F, Squires RW, Zhang Z, Thomas RJ. Cardiac rehabilitation is associated with reduced long-term mortality in patients undergoing combined heart valve and CABG surgery. Eur J Prev Cardiol. 2015; 22:159–168. [PubMed: 24265289]
4. Goel K, Lennon RJ, Tilbury RT, Squires RW, Thomas RJ. Impact of cardiac rehabilitation on mortality and cardiovascular events after percutaneous coronary intervention in the community. Circulation. 2011; 123:2344–2352. [PubMed: 21576654]
5. Hammill BG, Curtis LH, Schulman KA, Whellan DJ. Relationship between cardiac rehabilitation and long-term risks of death and myocardial infarction among elderly Medicare beneficiaries. Circulation. 2010; 121:63–70. [PubMed: 20026778]
6. Suaya JA, Stason WB, Ades PA, Normand SL, Shepard DS. Cardiac rehabilitation and survival in older coronary patients. J Am Coll Cardiol. 2009; 54:25–33. [PubMed: 19555836]
7. Williams MA, Ades PA, Hamm LF, Keteyian SJ, LaFontaine TP, Roitman JL, Squires RW. Clinical evidence for a health benefit from cardiac rehabilitation: an update. Am Heart J. 2006; 152:835–841. [PubMed: 17070142]
8. The Society of Thoracic Surgeons. [Accessed November 10th, 2015] The Society of Thoracic Surgeons Adult Cardiac Surgery Database. http://www.sts.org/national-database
9. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Diseases. 1987; 40:373–383. [PubMed: 3558716]
10. D'Agostino RB Jr. Propensity scores in cardiovascular research. Circulation. 2007; 115:2340–2343. [PubMed: 17470708]
11. Lassnigg A, Hiesmayr M, Frantal S, Brannath W, Mouhieddine M, Presterl E, Isetta C, Bachmann LM, Andreas M, Seitelberger R, Schmidlin D. Long-term absolute and relative survival after aortic valve replacement: a prospective cohort study. Eur J Anaesth. 2013; 30:695–703.
12. Stahle E, Kvidal P, Nystrom SO, Bergstrom R. Long-term relative survival after primary heart valve replacement. Eur J Cardio-Thoracic Surg. 1997; 11:81–91.
13. Enriquez-Sarano M, Sundt TM 3rd. Early surgery is recommended for mitral regurgitation. Circulation. 2010; 121:804–811. discussion 812. [PubMed: 20159841]
14. Squires RW, Montero-Gomez A, Allison TG, Thomas RJ. Long-term disease management of patients with coronary disease by cardiac rehabilitation program staff. J Cardiopulm Rehabil Prev. 2008; 28:180–186. quiz 187–188. [PubMed: 18496316]
15. Anderson L, Oldridge N, Thompson DR, Zwisler AD, Rees K, Martin N, Taylor RS. Exercise-Based Cardiac Rehabilitation for Coronary Heart Disease: Cochrane Systematic Review and Meta-Analysis. J Am Coll Cardiol. 2016; 67:1–12. [PubMed: 26764059]

16. Heran BS, Chen JM, Ebrahim S, Moxham T, Oldridge N, Rees K, Thompson DR, Taylor RS. Exercise-based cardiac rehabilitation for coronary heart disease. Cochrane Database Syst Rev. 2011:CD001800. [PubMed: 21735386]
17. de Vries H, Kemps HM, van Engen-Verheul MM, Kraaijenhagen RA, Peek N. Cardiac rehabilitation and survival in a large representative community cohort of Dutch patients. Eur Heart J. 2015; 36:1519–1528. [PubMed: 25888007]
18. Martin BJ, Hauer T, Arena R, Austford LD, Galbraith PD, Lewin AM, Knudtson M, Ghali WA, Stone JA, Aggarwal S. Cardiac Rehabilitation Attendance and Outcomes in Coronary Artery Disease Patients. Circulation. 2012; 126:677–687. [PubMed: 22777176]
19. Kayaniyil S, Leung YW, Suskin N, Stewart DE, Grace SL. Concordance of self- and program-reported rates of cardiac rehabilitation referral, enrollment and participation. Can J Cardiol. 2009; 25:e96–99. [PubMed: 19340365]
20. Sibilitz KL, Berg SK, Hansen TB, Risom SS, Rasmussen TB, Hassager C, Kober L, Gluud C, Thygesen LC, Lindschou J, Schmid JP, Taylor RS, Zwisler AD. Update to the study protocol, including statistical analysis plan for a randomized clinical trial comparing comprehensive cardiac rehabilitation after heart valve surgery with control: the CopenHeartVR trial. Trials. 2015; 16:38. [PubMed: 25887433]
21. Gohlke-Barwolf C, Gohlke H, Samek L, Peters K, Betz P, Eschenbruch E, Roskamm H. Exercise tolerance and working capacity after valve replacement. J Heart Valve Disease. 1992; 1:189–195. [PubMed: 1341626]
22. Dubroff JM, Clark MB, Wong CY, Spotnitz AJ, Collins RH, Spotnitz HM. Left ventricular ejection fraction during cardiac surgery: a two-dimensional echocardiographic study. Circulation. 1983; 68:95–103. [PubMed: 6602009]
23. O'Connor CM, Whellan DJ, Lee KL, Keteyian SJ, Cooper LS, Ellis SJ, Leifer ES, Kraus WE, Kitzman DW, Blumenthal JA, Rendall DS, Miller NH, Fleg JL, Schulman KA, McKelvie RS, Zannad F, Pina IL. Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. JAMA. 2009; 301:1439–1450. [PubMed: 19351941]
24. Kiel MK. Cardiac rehabilitation after heart valve surgery. PM & R. 2011; 3:962–967. [PubMed: 22024327]
25. Savage PD, Rengo JL, Menzies KE, Ades PA. Cardiac Rehabilitation After Heart Valve Surgery: COMPARISON WITH CORONARY ARTERY BYPASS GRAFT PATIENTS. J Cardiopulm Rehabil Prev. 2015; 35:231–237. [PubMed: 25622220]
26. Voller H, Salzwedel A, Nitardy A, Buhlert H, Treszl A, Wegscheider K. Effect of cardiac rehabilitation on functional and emotional status in patients after transcatheter aortic-valve implantation. Eur J Prev Cardiol. 2015; 22:568–574. [PubMed: 24577878]
27. Meurin P, Iliou MC, Ben Driss A, Pierre B, Corone S, Cristofini P, Tabet JY. Working Group of Cardiac Rehabilitation of the French Society of C. Early exercise training after mitral valve repair: a multicentric prospective French study. Chest. 2005; 128:1638–1644. [PubMed: 16162769]
28. Puetz TW, Beasman KM, O'Connor PJ. The effect of cardiac rehabilitation exercise programs on feelings of energy and fatigue: a meta-analysis of research from 1945 to 2005. Eur J Cardiovasc Prev Rehabil. 2006; 13:886–893. [PubMed: 17143119]

Table 1

Differences in Patient Characteristics According to Survey Response Category

		Survey Respondent		
Variable	**N**	**Yes (n=573)**	**No (n=847)**	**P-value**
Age at surgery (median, IQR, years)	1420	72.0 (63.9, 78.3)	70.2 (61.4, 78.6)	**0.009**
Male	1420	368 (64%)	523 (62%)	0.34
Body mass index (median, IQR, kg/m^2)	1420	27.7 (24.9, 31.6)	28.0 (25.2, 31.8)	0.29
White	1370	539 (98%)	793 (97%)	0.27
Geographic region:	1420			0.84
Minnesota		222 (39%)	340 (40%)	
States (ND, SD, IA, WI, IL)		186 (32%)	273 (32%)	
All other states		165 (29%)	234 (28%)	
Medicare/Medicaid insurance	1420	411 (72%)	564 (67%)	**0.04**
Hospital length of stay	1420	6.0 (5.0, 8.0)	6.0 (4.0, 8.0)	**0.003**
Readmission within 30 days	1420	61 (11%)	50 (6%)	**0.001**
Cardiac rehabilitation referral in hospital	1420	324 (57%)	474 (56%)	0.83
Coronary artery disease risk factors				
Smoking (current, former)	1420	309 (54%)	428 (51%)	0.21
Family history of coronary artery disease	1420	45 (8%)	64 (8%)	0.84
Peripheral vascular disease	1420	39 (7%)	61 (7%)	0.78
Cerebral vascular disease	1420	67 (12%)	118 (14%)	0.22
Hypertension	1420	404 (71%)	558 (66%)	0.07
Normal coronary arteries	1337	161 (30%)	241 (30%)	0.90
Coronary artery disease**	1420	171 (30%)	219 (26%)	0.10
Comorbidities				
Charlson index	1420	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	0.70
Moderate/severe renal disease	1420	89 (16%)	126 (15%)	0.74
Chronic pulmonary disease	1420	153 (27%)	229 (27%)	0.89
Infectious endocarditis	1420	29 (5%)	48 (6%)	0.62
Creatinine level	1420	1.0 (0.9, 1.2)	1.0 (0.9, 1.2)	**0.05**
Dialysis	1420	7 (1%)	12 (1%)	0.75
Heart failure	1420	94 (16%)	159 (19%)	0.25
Prior cardiac interventions				
Cardiac operations	1420	136 (24%)	157 (19%)	**0.018**
Coronary artery bypass surgery	1420	84 (15%)	88 (10%)	**0.016**
Valve surgery	1420	66 (12%)	94 (11%)	0.81
Aortic valve replacement	1420	29 (5%)	48 (6%)	0.62
Mitral valve replacement	1420	10 (2%)	30 (4%)	**0.045**
Pulmonary valve repair	1420	37 (6%)	39 (5%)	0.13
Atrial septal defect	1420	4 (1%)	2 (0%)	0.19
Aortic aneurysm (ascending)	1420	3 (1%)	4 (0%)	0.89

		Survey Respondent		
Variable	**N**	**Yes (n=573)**	**No (n=847)**	**P-value**
Internal cardiac defibrillator	1420	9 (2%)	17 (2%)	0.55
Pacemaker	1420	24 (4%)	41 (5%)	0.56
Percutaneous coronary intervention	1420	55 (10%)	92 (11%)	0.44
Heart rhythm:	1419			**0.03**
Normal sinus rhythm		530 (92%)	749 (89%)	
Atrial fibrillation or flutter		33 (6%)	85 (10%)	
Heart block		0 (0%)	1 (0%)	
Paced		10 (2%)	11 (1%)	
Any arrhythmia	1420	95 (17%)	173 (20%)	0.07
Cardiac function				
Ejection fraction, %	1420	64.0 (59.0, 68.0)	64.0 (57.0, 67.0)	0.11
Cardiac output, L/Min	1420	5.9 (5.2, 6.7)	5.9 (5.4, 6.7)	0.13
Cardiac index, L/Min/M^2	1420	3.0 (2.7, 3.5)	3.0 (2.7, 3.5)	0.66
Aortic valve stenosis	1420	370 (65%)	463 (55%)	**<.001**
Aortic valve insufficiency (severity~)	1420	1.0 (1.0, 2.0)	1.0 (0.0, 2.0)	0.31
Mitral valve stenosis	1420	62 (11%)	55 (6%)	**0.004**
Mitral valve insufficiency (severity~)	1420	2.0 (1.0, 4.0)	3.0 (2.0, 4.0)	**<.001**
Aortic valve surgery:	1420			**<.001**
No		169 (29%)	349 (41%)	
Replacement		398 (69%)	488 (58%)	
Repair/Reconstruction/Other		6 (1%)	10 (1%)	
Mitral valve surgery:	1420			**<.001**
No		365 (64%)	450 (53%)	
Annuloplasty only		18 (3%)	22 (3%)	
Replacement		69 (12%)	105 (12%)	
Reconstruction w/annuloplasty		111 (19%)	257 (30%)	
Reconstruction w/o annuloplasty		10 (2%)	13 (2%)	
Operative characteristics				
Robotic-assisted op approach	1420	6 (1%)	87 (10%)	**<.001**
Intra-aortic ballon pump used	1420	14 (2%)	22 (3%)	0.86
Intra-operative blood products	1420	306 (53%)	409 (48%)	0.06
Post-operative blood products	1420	249 (43%)	333 (39%)	0.12
Ventilation hours	1420	9.0 (5.6, 14.4)	7.5 (5.0, 12.8)	**<.001**
Hospital complications				
Any in-hospital complication	1420	279 (49%)	412 (49%)	0.99
Operative complication	1420	29 (5%)	27 (3%)	0.08
Infection complication	1420	32 (6%)	41 (5%)	0.53
Neurologic complication	1420	15 (3%)	19 (2%)	0.65
Pulmonary complication	1420	35 (6%)	52 (6%)	0.98
Renal complication	1420	10 (2%)	13 (2%)	0.76

		Survey Respondent		
Variable	**N**	**Yes (n=573)**	**No (n=847)**	**P-value**
Other complication	1420	249 (43%)	372 (44%)	0.86
Medications at Discharge				
Aspirin	1420	459 (80%)	651 (77%)	0.15
ACE inhibitors	1420	167 (29%)	221 (26%)	0.21
Beta blockers	1420	450 (79%)	681 (80%)	0.39
Warfarin	1420	317 (55%)	533 (63%)	0.004
Lipid lowering medication	1420	348 (61%)	475 (56%)	0.08
Antiarrhythmics	1420	200 (35%)	315 (37%)	0.38
ADP inhibitors	1420	24 (4%)	40 (5%)	0.63
Non-home discharge location	1420	80 (14%)	143 (17%)	0.17
Deaths (Survival rate until time of survey) [+]	1420			**<.001**
2 years		27 (95%)	47 (91%)	
4 years		63 (88%)	81 (81%)	
6 years		91 (80%)	109 (61%)	
Total # deaths		96	112	

[+] K-M (# Events); p-value derived from log-rank test

Death or censoring information were ascertained from Mayo electronic databases, except in the case where survey self-responders had a prior last known alive date (for these the survey date was imputed as the censoring date)

[*] Neighboring states includes North Dakota, South Dakota, Wisconsin, Illinois, and Iowa

[**] Any coronary artery disease defined by as having one or more coronary arteries with >50% stenosis.

Table 2

Propensity Analysis for Estimating Cardiac Rehabilitation Participation

Variable	CR Exercise (n=296)	No CR Exercise (n=251)	P-value
Age at surgery (median, IQR, years)	71.8 (63.6, 77.6)	72.0 (63.6, 79.1)	0.86
Male	200 (68%)	152 (61%)	0.09
Body mass index (median, IQR, kg/m^2)	28.1 (25.4, 32.3)	26.6 (24.2, 30.9)	**0.003**
Caucasian race, yes *(missing, n=22)*	282 (98%)	232 (98%)	0.98
Geographic Region:			0.81
Minnesota	111 (38%)	100 (40%)	
States (ND, SD, IA, WI, IL)	97 (33%)	82 (33%)	
All other states	88 (30%)	69 (27%)	
Medicare/Medicaid insurance,	213 (72%)	175 (70%)	0.57
Hospital length of stay	6.0 (5.0, 8.0)	6.0 (5.0, 8.0)	0.57
Readmission within 30 days	28 (9%)	27 (11%)	0.62
Cardiac rehabilitation referral while in hospital	214 (72%)	94 (37%)	**<.001**
Coronary artery disease risk factors			
Smoking	169 (57%)	125 (50%)	0.09
Family history of coronary artery disease	20 (7%)	23 (9%)	0.30
Hypertension	212 (72%)	173 (69%)	0.49
Normal coronary arteries *(missing, n=32)*	90 (32%)	65 (27%)	0.20
Diagnosis of coronary artery disease	80 (27%)	80 (32%)	0.21
Comorbidities			
Charlson index	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	0.63
Moderate/severe renal disease	38 (13%)	47 (19%)	0.06
Chronic pulmonary disease	77 (26%)	64 (25%)	0.89
Peripheral vascular disease	18 (6%)	18 (7%)	0.61
Cerebral vascular disease	34 (11%)	30 (12%)	0.87
Infectious endocarditis	13 (4%)	15 (6%)	0.40
Creatinine level	1.0 (0.9, 1.2)	1.1 (0.9, 1.2)	**0.044**
Dialysis	0 (0%)	5 (2%)	**0.02**
Heart failure	46 (16%)	43 (17%)	0.62
Prior cardiac interventions			
Cardiac operations	70 (24%)	60 (24%)	0.94
Coronary artery bypass surgery	46 (16%)	33 (13%)	0.43
Valve surgery	30 (10%)	34 (14%)	0.22
Aortic valve replacement	12 (4%)	15 (6%)	0.30
Mitral valve replacement	4 (1%)	6 (2%)	0.37
Pulmonary valve repair	17 (6%)	20 (8%)	0.30
Atrial septal defect	3 (1%)	1 (0%)	0.63*
Aortic aneurysm (ascending)	1 (0%)	2 (1%)	0.60*
Internal cardiac defibrillator	5 (2%)	3 (1%)	0.63
Pacemaker	14 (5%)	10 (4%)	0.67

Variable	CR Exercise (n=296)	No CR Exercise (n=251)	P-value
Percutaneous coronary intervention	33 (11%)	20 (8%)	0.21
Heart rhythm:			0.93
Normal sinus rhythm	274 (93%)	233 (93%)	
Atrial fibrillation/flutter	16 (5%)	14 (6%)	
Paced	6 (2%)	4 (2%)	
Any arrhythmia	50 (17%)	39 (16%)	0.67
Cardiac function			
Ejection fraction, %	64.0 (58.0, 68.0)	65.0 (58.0, 68.0)	0.70
Cardiac output, L/Min	5.9 (5.2, 6.7)	5.9 (5.1, 6.6)	0.57
Cardiac index, L/Min/M^2	3.0 (2.7, 3.3)	3.0 (2.7, 3.6)	0.24
Aortic valve stenosis	201 (68%)	149 (59%)	**0.04**
Aortic valve insufficiency (severity~)	1.5 (1.0, 2.0)	1.0 (0.0, 2.0)	0.18
Mitral valve stenosis	29 (10%)	27 (11%)	0.71
Mitral valve insufficiency (severity~)	2.0 (1.0, 4.0)	2.0 (1.0, 4.0)	0.06
Aortic valve surgery:			0.15
None	78 (26%)	85 (34%)	
Replacement	215 (73%)	163 (65%)	
Repair/Reconstruction	3 (1%)	3 (1%)	
Mitral valve surgery:			0.69
None	195 (66%)	151 (60%)	
Annuloplasty only	9 (3%)	9 (4%)	
Replacement	35 (12%)	31 (12%)	
Reconstruction with annuloplasty	52 (18%)	55 (22%)	
Reconstruction w/o annuloplasty	5 (2%)	5 (2%)	
Operative Characteristics			
Robotic-assisted op approach	2 (1%)	4 (2%)	0.30
Intra-aortic ballon pump used	9 (3%)	4 (2%)	0.27
Intra-operative blood products used	153 (52%)	137 (55%)	0.50
Post-operative blood products used	125 (42%)	107 (43%)	0.93
Ventilation hours	8.0 (5.5, 13.5)	9.5 (6.4, 14.5)	**0.045**
Hospital complications			
Any in-hospital complication	153 (52%)	111 (44%)	0.08
Operative complication	18 (6%)	10 (4%)	0.27
Infection complication	17 (6%)	14 (6%)	0.93
Neurologic complication	8 (3%)	4 (2%)	0.38
Pulmonary complication	16 (5%)	15 (6%)	0.78
Renal complication	2 (1%)	7 (3%)	0.05
Other complication	137 (46%)	98 (39%)	0.09
Medications at Discharge			
Aspirin	240 (81%)	200 (80%)	0.68
ACE inhibitors	84 (28%)	73 (29%)	0.86
Beta blockers	246 (83%)	185 (74%)	**0.007**

Variable	CR Exercise (n=296)	No CR Exercise (n=251)	P-value
Warfarin	165 (56%)	139 (55%)	0.93
Lipid lowering medication	180 (61%)	152 (61%)	0.95
Antiarrhythmics	113 (38%)	79 (31%)	0.10
ADP inhibitors	13 (4%)	10 (4%)	0.81
Non-home discharge location	40 (14%)	35 (14%)	0.88

Continuous and ordinal variables are summarized with median (25^{th} and 75^{th} percentiles) and compared between groups with and without CR exercise using the Wilcoxon rank sum test; categorical variables were tested for group differences using the Chi-square or Fisher's exact test, as appropriate

IQR = Interquartile range ADP = Adenosine diphosphate, ACE = angiotensive converting enzyme, CR = cardiac rehabilitation

Table 3

Association Between Cardiac Rehabilitation Attendance and 5.8-year Mortality by Adjustment Technique and Patient Subgroup in Patients with Heart Valve Surgery

Group	No. Subjects in Analysis	No. with CR Exercise	No. without CR Exercise	No. Events (Total)	CR Exercise Effect: HR (95% CI) [p-value]^		
					Unadjusted	Adjusted for PS	Adjusted for PS and Mortality Risk Factors+
All Patients*	547	296	251	100	0.81 (0.54, 1.20) [0.293]	1.03 (0.66, 1.62) [0.882]	0.99 (0.63, 1.54) [0.954]
Subgroups							
Aortic Valve	384	218	166	88	0.76 (0.50, 1.15) [0.197]	1.00 (0.61, 1.64) [0.993]	0.96 (0.58, 1.59) [0.883]
Mitral Valve	201	101	100	23	0.49 (0.20, 1.19) [0.113]	0.49 (0.15, 1.56) [0.226]	-

^ Effect of participating in CR exercise on all-cause mortality (conditional on 1-year survival) derived from Cox PH regression

* Among the total set of 573 patients with a survey response, 547 fulfilled inclusion criteria of having a definable measure of exercise participation and ≥1 year of follow-up

+ Pre-selected adjusting factors included age, sex, EF, Charlson Index, chronic pulmonary disease, and moderate/severe renal disease; no adjustment was done on the mitral valve subgroup due to insufficient power from only 23 deaths