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Do Past Mortality Rates Predict Future Hospital Mortality?

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Abstract

Background—This study aimed to determine whether hospitals with higher historical mortality rates are independently associated with worse patient outcomes.

Methods—Observational study of in-hospital mortality in open AAA repair, AVR, and CABG in a California in-patient database. Hospitals' annual historical mortality rates between 1998 and 2010 were calculated based on three years of data prior to each year. Results were adjusted for race, sex, age, hospital teaching status, admission year, insurance status, Charlson comorbidity index.

Results—Hospitals were divided into quartiles based on historical mortality rates. For AAA, the odds ratio (OR) for in-hospital mortality for hospitals within the highest quartile of prior mortality was 1.30 compared to the lowest quartile (95%CI:1.03–1.63). For AVR, the OR was 1.41 for the 3rd quartile (95%CI:1.15–1.73) and 1.54 for the highest quartile (95%CI:1.27–1.87). For CABG, the OR was 1.33 for the 3rd (95%CI:1.2–1.49) and 1.58 for the highest (95%CI:1.41–1.76).

Conclusion—Patients presenting to hospitals with high historical mortality rates have a 30%–60% increased mortality risk compared to patients presenting to hospitals with low historical mortality rates.

Keywords

Surgical outcomes; historical mortality rates; outcomes prediction

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Introduction

The relationship between hospital volume and patient outcomes has been extensively studied and a hospital's past procedure volume has been shown to predict subsequent mortality[1]. The predictive value of a hospital's past mortality rate is less well known. One might argue that historical mortality rates are not as reliable due to random complications, an unpredictable case mix or immeasurable factors. These factors may not be accounted for by past mortality rates, thus complicating its predictive value[2]. For example, Glance et al found that while 2-year-old data could predict the future performance of individual trauma centers, data that are older than 3 years did not accurately predict trauma centers future performance[3]. On the other hand, procedures that are commonly performed at a hospital should have consistent results, thus supporting the use of mortality rates as a measure of hospital quality.

The purpose of this study is to analyze whether a hospital's past experience with a procedure has an independent impact on future in-patient mortality. Specifically, we hypothesize that hospitals with higher historical mortality rates would be independently associated with higher future all-cause in-patient mortality rates for the same procedure, even after accounting for patient confounders.

Methods

We performed an observational study of in-hospital mortality in open abdominal aortic aneurysm (AAA) repair, aortic valve replacement (AVR), and coronary artery bypass graft surgery (CABG) in a statewide in-patient database from the California Office of Statewide Health Planning and Development (OSHPD).

The study included three cohorts: AAA repair, AVR, and CABG. Starting with the list of Leapfrog procedures, operations were selected with high in-hospital mortality risks, since our primary outcome variable was in-hospital mortality, and large patient populations in order to have sufficient sample size for calculations. Patients undergoing AAA repairs were identified by admissions with ICD-9 procedure codes 38.34, 38.44, 38.64, 39.25 or 39.71. Aortic valve replacement admissions were identified by ICD-9 procedure codes 35.21 and 35.22. CABG admissions included procedure codes 36.10-17.

The primary outcome variable was all-cause in-hospital mortality for each procedure. The primary independent variable was a hospital's all-cause historical mortality for each procedure. These historical mortality rates were calculated for each year between 1998 and 2010. They were calculated based on three years of data prior to each index year. For example, for the 2000 data, the hospital's historical mortality rate was based on their procedural mortality rates from 1997 through 1999. For the 2003 data, those hospitals' historical rates were recalculated based on data from 2000 through 2002. These varying historical mortality rates are the primary independent variable for each year's adjusted analysis. Additional covariates included race, gender, age, hospital teaching status, admission year, insurance status, and Charlson comorbidity index. The Charlson comorbidity index is a measure of comorbidities based on the presence or absence of certain diagnoses in the patient. These are then combined together in a weighted formula[4]. Hospital teaching status was defined by the presence of a general surgical residency program. Statistical analyses were performed using STATA 11.1 software (StataCorp, College Station, TX, USA), with statistical significance set at a *P*-value ≤ 0.05.

Results

A total of 455,161 patients were analyzed (Table 1). For AAA and AVR, the patients were primarily non-Hispanic white males covered by Medicare or private coverage while for CABG the average patient was female. Patients typically had a Charlson comorbidity score between 1 and 2 and 8.9% of patients presenting for AAA repair had a ruptured aneurysm. The mortality rates for AAA repair, AVR and CABG were 7.9%, 5.2% and 3.4% respectively.

Unadjusted analyses of 3-year historical mortality versus current year mortality in 2000, 2005 and 2010 are shown in Figure 1. In general, hospitals in the highest past mortality rate quartile had a significantly higher annual mortality rate for the current year when compared to hospitals in the lowest past mortality rate quartile. For AAA repair, the mortality rate decreased by 65.9% over time in the lowest quartile, and 56.5% in the highest quartile. For AVR, mortality decreased by 46.5% and 23.7% in the lowest and highest quartiles respectively. For CABG, mortality decreased by 22.9% and 31.5% in the lowest and highest quartiles respectively.

Figure 2 plots a hospital's past three-year mortality versus their current year mortality, with each point representing one hospital per year. Hospitals with less than 25 cases were excluded. For AAA repair, AVR and CABG, the slopes of the trend lines are 0.3321, 0.3695 and 0.5762 respectively.

On multivariate analyses for AAA repair, the odds ratio for in-hospital mortality for hospitals within the highest quartile of prior mortality rates was 1.270 compared to hospitals in the lowest quartile (95% CI 1.01–1.60). For AVR, the odds ratio was 1.413 for hospitals in the 3rd quartile (95% CI 1.15–1.73) and 1.545 for hospitals in the highest quartile (95% CI 1.27–1.88). For CABG, the odds ratio was 1.332 for hospitals in the 3rd quartile (95% CI 1.19–1.49) and 1.582 for hospitals in the highest quartile (95% CI 1.41–1.77) (Figure 3). Additionally, female gender was found to be associated with higher mortality across all three procedures (Table 2). Older age, as would be expected, was associated with higher mortality, but at different thresholds for different procedure groups; at age 60 for CABG, at age 70 for AVR, and at age 70 for AAA. Over time, there were some significant changes in mortality risk for some of the years: for AAA, there was a significant decrease in mortality risk that was achieved in 2007, 2009 and 2010; there were no significant changes in mortality per year for AVR while for CABG, mortality rate was significantly decreased in 2006–2010. Indian and other race was associated with a decreased mortality in AVR and CABG and Hispanic race as well for CABG. There was also no significant mortality difference between teaching and non-teaching hospitals. Private and Medicare insurance was associated with lower mortality risks in AAA and CABG patients, but had no effect in AVR patients. And as expected, increased number of comorbidities was associated with mortality risks.

Discussion

This study demonstrates that a patient presenting to a hospital with a higher procedural past mortality rate has a higher risk of death than if they had presented with the same condition to a hospital with a lower past mortality rate. Specifically, patients presenting to hospitals with high historical mortality rates have a 30% to 60% increased mortality risk compared to patients presenting to hospitals with low historical mortality rates. In other words, hospital quality, for which "historical mortality" is a surrogate measure, is an independent predictor of patient outcomes, in addition to the common predictors of patient demographics and comorbidities. Unlike the stock market where "past performance is no guarantee of future results," in hospital quality analyses, past performance strongly correlates with future results.

Our study is similar to the findings of Krell et al, which also show that a hospitals' past surgical performance, specifically in patients undergoing colectomy, can predict a hospitals' future performance[5]. Our study expands upon these findings in a specific gastrointestinal procedure by demonstrating similar trends in three separate vascular procedures. In addition, Glance et al found that the NYS CABG report card predicted future hospital performance, with hospitals ranked in the top 20% having superior future outcomes[6]. Our study shows similar results for CABG outcomes on a larger scale throughout California.

Surgical outcomes are a combination of patient, provider and hospital factors. Health system factors such as volume, teaching status, staffing patterns and more recently, hospital complexity, have been shown to independently affect patient outcomes[7, 8]. Many quality-measurement systems have been developed to address surgical outcomes including the National Surgical Quality Improvement Program and the use of selective referral and centers of excellence[9]. As performance measures become more common, further investigation into other systems-level factors is necessary to determine their role in both immediate surgical outcomes and outcomes reporting systems. Historical mortality is a relevant hospital factor that can be used to assess hospital quality. In addition, these reporting systems are essential to help guide patient healthcare decisions.

One may speculate that our findings are due to differences in patient case mix at different hospitals, and that hospitals with worse outcomes may be attracting sicker patients. This is unlikely, given our multivariate analysis controlling for comorbidities. Furthermore, the persistence of poor outcomes across time makes it less likely that case mix is to blame since that would mean that hospitals have consistently sicker patients across multiple consecutive years. While this may be the case for teaching hospitals, hospital teaching status is also adjusted for in our analysis, which eliminates that as a possible confounder.

We noted several other interesting findings in our paper. We did not find widespread differences between racial groups in their mortality risks in this population. While racial disparity in outcomes have been reported widely [10], we have noted in prior analysis in

California datasets that such racial differences do not exist[11]. In addition, in contrast to other literature that has demonstrated improved outcomes for female patients in trauma [12] and in gastrointestinal surgery[13], we found worse outcomes for female patients in our study. It is possible that surgical outcomes involving the vascular system have different outcomes than GI system. Of note in CABG, there was more improvement in mortality rate from 2000 to 2010 in the worst quartile than in the best; in contrast, for AAA repair and AVR, the improvement was stronger in outcomes in hospitals in the best category. This could be due to the implementation of the California Cardiac Surgery and Intervention Project, which was created as a reporting program and quality improvement project for CABG[14]. It is possible that a quality system may have a greater impact on worse hospitals, because it provides external incentives and pressure to change. In the absence of a quality improvement system, it is more difficult for poor-performing hospitals to change, and thus improvement is limited to hospitals that are already performing well.

There are important limitations to this study. First, using the endpoint of mortality limits the ability to assess finer nuances of hospital quality such as complication rates. Additionally, the OSHPD database is a large database and thus is susceptible to coding discrepancies. These are likely to be random and evenly distributed across all groups, leading to no significant biases. Another limitation is the way in which a hospital's teaching status was defined. We defined teaching hospitals as those with an NRMP-approved surgical residency program. This is less likely to play a significant role, as we are assessing vascular and cardiothoracic procedures, which are often performed by fellows as opposed to residents; thus the presence of an advanced fellowship might have provided more information about surgeon-level differences. However, having a residency implies a certain infrastructure and number of trainees that differs from non-teaching hospitals. A major strength of this study is it's broad applicability. Since we used the OSHPD database, it is representative of California residents as opposed to being limited to Medicare recipients, as are many studies of this type. This provides valuable data on patients with a wide variety of ages and insurance statuses.

Our study has important policy implications. It speaks to the importance of having an outcomes reporting system to help patients make healthcare decisions. In addition, the difference in improvement over time between procedures that have a public reporting system in place versus others that do not, suggest that poor-performing hospitals may not change unless they are driven by an outside system. This further highlights the value of a population-level quality reporting and improvement system.

In conclusion, hospital quality plays a significant role in patient outcomes and poor quality is a predictor of patient mortality. This emphasizes the critical role of non-patient factors in determining patient outcomes and the importance of recognizing the affects of health systems on individual patient outcomes.

References

1. Birkmeyer JD, Dimick JB, Staiger DO. Operative mortality and procedure volume as predictors of subsequent hospital performance. Ann Surg. 2006; 243(3):411–417. [PubMed: 16495708]

2. Pitches DW, Mohammed MA, Lilford RJ. What is the empirical evidence that hospitals with higher-risk adjusted mortality rates provide poorer quality care? A systematic review of the literature. BMC Health Serv Res. 2007; 7:91. [PubMed: 17584919]

3. Glance LG, Mukamel DB, Osler TM, et al. Ranking trauma center quality: can past performance predict future performance? Ann Surg. 2014; 259(4):682–686. [PubMed: 24368643]

4. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987; 40(5):373–383. [PubMed: 3558716]

5. Krell RW, Staiger DO, Dimick JB. Reliability of surgical outcomes for predicting future hospital performance. Med Care. 2014; 52(6):565–571. [PubMed: 24783994]

6. Glance LG, Dick AW, Mukamel DB, et al. How well do hospital mortality rates reported in the New York State CABG report card predict subsequent hospital performance? Med Care. 2010; 48(5): 466–471. [PubMed: 20351585]

7. McCrum ML, Lipsitz SR, Berry WR, et al. Beyond volume: does hospital complexity matter?: an analysis of inpatient surgical mortality in the United States. Med Care. 2014; 52(3):235–242. [PubMed: 24509361]

8. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. N Engl J Med. 2002; 346(15):1128–1137. [PubMed: 11948273]

9. Cevasco M, Ashley SW. Quality measurement and improvement in general surgery. Perm J. 2011; 15(4):48–53. [PubMed: 22319416]

10. Haider AH, Scott VK, Rehman KA, et al. Racial disparities in surgical care and outcomes in the United States: a comprehensive review of patient, provider, and systemic factors. J Am Coll Surg. 2013; 216(3):482-92.e12. [PubMed: 23318117]

11. Ramirez M, Chang DC, Bickler SW. Pediatric injury outcomes in racial/ethnic minorities in California: diversity may reduce disparity. JAMA Surg. 2013; 148(1):76–80. [PubMed: 22986983]

12. Haider AH, Crompton JG, Chang DC, et al. Evidence of hormonal basis for improved survival among females with trauma-associated shock: an analysis of the National Trauma Data Bank. J Trauma. 2010; 69(3):537–540. [PubMed: 20838123]

13. Peterson CY, Osen HB, Tran Cao HS, et al. The battle of the sexes: women win out in gastrointestinal surgery. J Surg Res. 2011; 170(1):e23–e28. [PubMed: 21693379]

14. Carey JS, Danielsen B, Junod FL, et al. The California Cardiac Surgery and Intervention Project: evolution of a public reporting program. Am Surg. 2006; 72(10):978–983. [PubMed: 17058749]

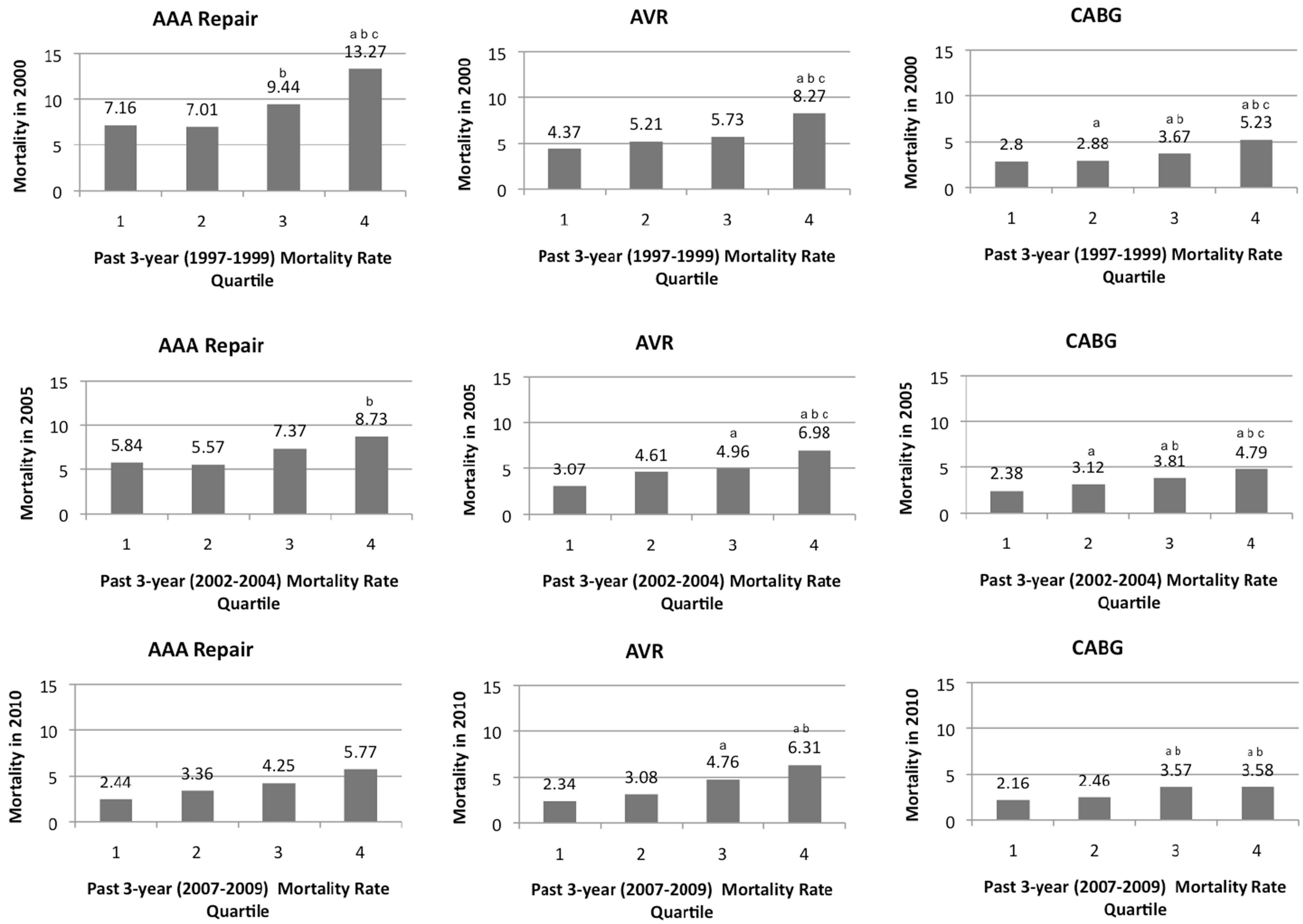

Figure 1.

Unadjusted analysis of 3-year historical mortality versus current year mortality in 2000, 2005 and 2010 for AAA Repair, AVR and CABG. Significance denoted by: a, b, c are significantly different than quartiles 1, 2 and 3 respectively.

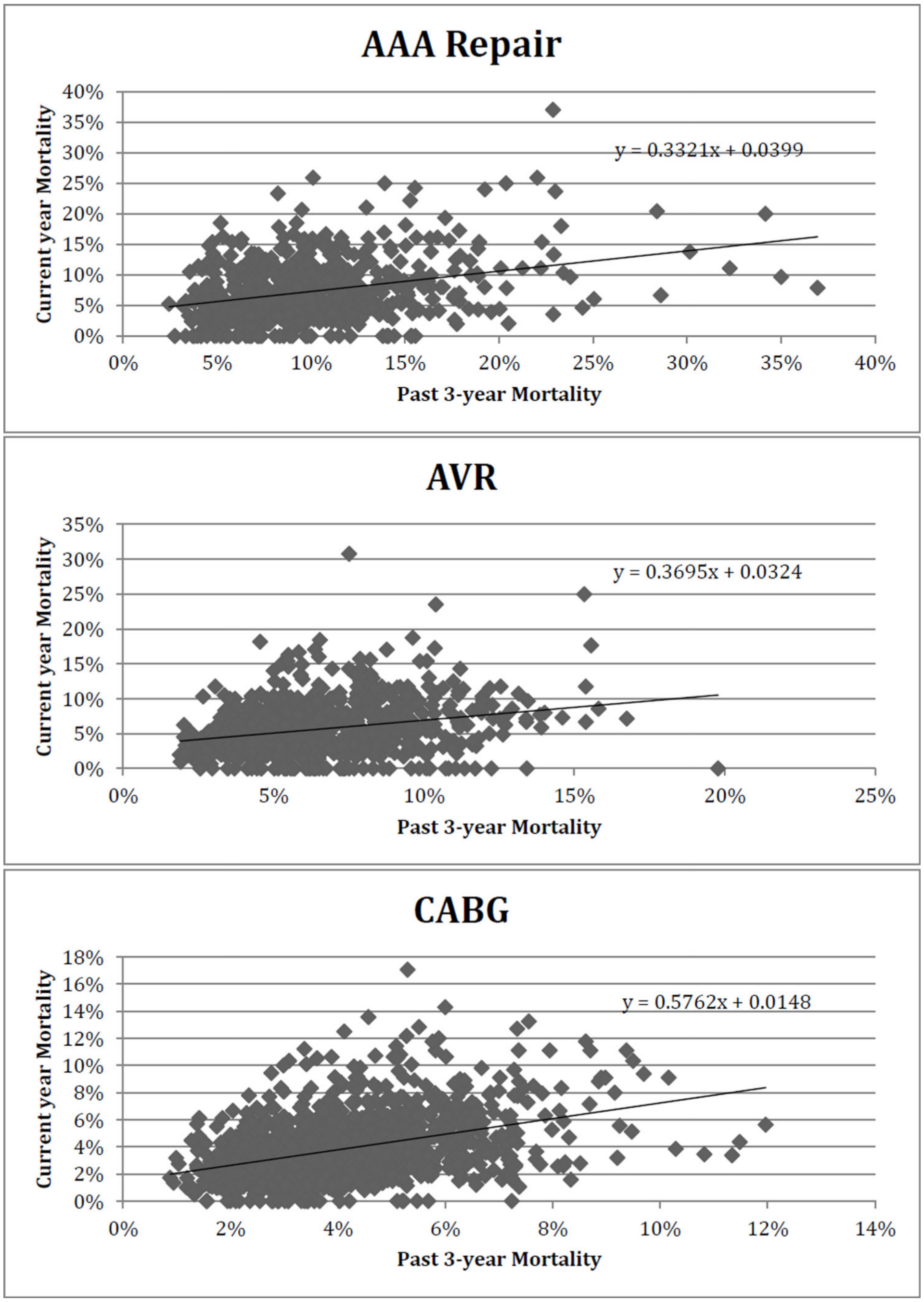

Figure 2.

Past three-year mortality versus current year mortality. Each point represents one hospital per year. Hospitals with less than 25 cases were excluded.

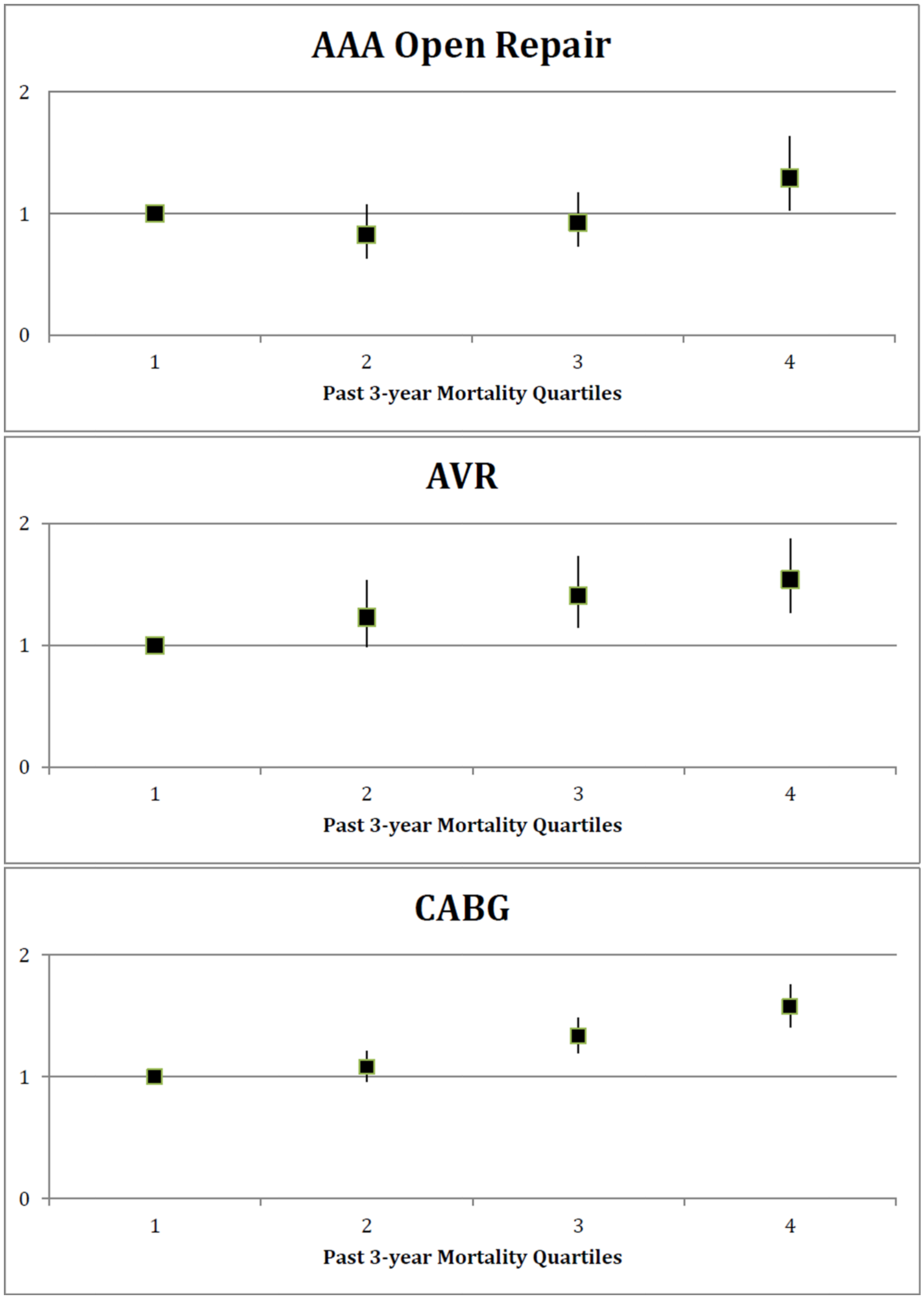

Figure 3.
Multivariate analysis of in-hospital mortality and past 3-year mortality quartiles.

Table 1

Patient characteristics

	AAA	AVR	CABG
Total Admissions	60,154	77,967	317,040
Age, mean (sd), years	69.4 (16.4)	71.1 (13.2)	68.8 (10.5)
Sex			
Female	12,013 (26.72%)	19,837 (38.02%)	162,511 (71.51%)
Male	32,948 (73.28%)	32,342 (61.98%)	64,761 (28.49%)
Race			
Non-Hispanic White	34,993 (85.18%)	38,734 (82.56%)	157,976 (79.05%)
Black	1,484 (3.61%)	1,280 (2.73%)	5,543 (2.77%)
Hispanic	2,658 (6.47%)	4,598 (9.80%)	20,554 (10.28%)
Asian	1,494 (3.64%)	1,540 (3.28%)	11.644 (5.83%)
Indian/Other	450 (1.10%)	764 (1.63%)	4,131 (2.07%)
Insurance			
Medicare or Private Coverage	51,558 (91.54%)	67,462 (90.96%)	250,448 (88.37%)
Other	4,767 (8.46%)	6,705 (9.04%)	32,976 (11.63%)
Charlson comorbidity index			
0	6,584 (10.95%)	24,410 (31.31%)	73,177 (23.08%)
1–2	40,037 (66.56%)	41,868 (53.70%)	180,323 (56.88%)
3+	13,533 (22.50%)	11,689 (14.99%)	63,540 (20.04%)
Mortality			
Inpatient mortality	4,746 (7.89%)	4,065 (5.21%)	10,803 (3.41%)
Hospital Factors			
Teaching Hospital	10,833 (18.01%)	13,875 (17.80%)	32,633 (10.29%)
Ruptured AAA	5,356 (8.90%)		

Table 2

Multivariate analysis of in-hospital mortality.

	AAA				AVR				CABG			
	Odds Ratio	95% CI		P Value	Odds Ratio	95% CI		P Value	Odds Ratio	95% CI		P Value
3 -year historical mortality rate												
Lowest quartile	(Reference)				(Reference)				(Reference)			
Second quartile	0.823	0.63	1.07	0.144	1.235	0.99	1.54	0.061	1.084	0.97	1.22	0.166
Third quartile	0.919	0.73	1.16	0.475	1.413*	1.15	1.73	<0.001	1.332*	1.19	1.49	<0.001
Highest quartile	1.290*	1.01	1.60	0.042	1.545*	1.27	1.88	<0.001	1.582*	1.42	1.77	<0.001
Sex												
Male	(Reference)				(Reference)				(Reference)			
Female	1.47*	1.27	1.70	<0.001	1.204*	1.06	1.36	0.003	1.416*	1.32	1.52	<0.001
Race												
Non-Hispanic White	(Reference)				(Reference)				(Reference)			
Black	1.087	0.72	1.64	0689	0.828	0.36	1.24	0.361	0.811	0.65	1.02	0.07
Hispanic	0.904	0.64	1.27	0.565	0.906	0.43	1.16	0.430	0.732*	0.64	0.83	<0.001
Asian	0.945	0.65	1.38	0.770	0.971	0.87	1.38	0.868	0.878	0.76	1.02	0.086
Indian/Other	0.988	0.37	2.62	0.981	0.338	0.02	0.82	0.017	0.579*	0.40	0.84	0.004
Age												
18– <55	(Reference)				(Reference)				(Reference)			
55– <60	0.915	0.55	1.52	0.734	1.003	0.66	1.53	0.987	1.183	0.94	1.49	0.152
60– <65	0.965	0.61	1.53	0.879	0.935	0.63	1.40	0.744	1.313*	1.06	1.63	0.013
65– <70	1.425	0.92	2.20	0.109	1.084	0.76	1.55	0.660	1.826*	1.50	2.22	<0.001
70– <75	1.603*	1.05	2.44	0.029	1.648*	1.21	2.25	0.002	2.573*	2.13	3.10	<0.001
75– <80	1.852*	1.22	2.81	0.004	1.842*	1.36	2.49	<0.001	3.370*	2.80	4.05	<0.001
80– <85	2.267*	1.48	3.46	<0.001	2.619*	1.95	3.53	<0.001	4.525*	3.75	5.46	<0.001
85– <90	2.986*	1.94	4.60	<0.001	2.744*	2.02	3.74	<0.001	6.553*	5.38	7.98	<0.001
Hospital Teaching Status												
Non-teaching Hospital	(Reference)				(Reference)				(Reference)			

	AAA				AVR				CABG			
	Odds Ratio	**95% CI**		**P Value**	**Odds Ratio**	**95% CI**		**P Value**	**Odds Ratio**	**95% CI**		**P Value**
Teaching Hospital	0.936	0.75	1.16	0.549	0.860	0.72	1.03	0.105	0.922	0.81	1.05	0.209
Insurance Status												
Other	(Reference)				(Reference)				(Reference)			
Medicare or Private Coverage	0.544*	0.395	0.751	<0.001	0.920	0.68	1.24	0.584	0.869*	0.76	1.00	0.043
Charlson												
0	(Reference)				(Reference)				(Reference)			
1–2	1.751*	1.15	2.67	0.009	1.753*	1.48	2.07	<0.001	2.318*	2.05	2.62	<0.001
>3	2.573*	1.70	3.90	<0.001	2.739*	2.25	3.33	<0.001	4.208*	3.70	4.78	<0.001
Year of admission												
1998	(Reference)				(Reference)				(Reference)			
1999	1.208	0.79	1.83	0.376	1.590	0.89	2.83	0.114	0.490	0.19	1.28	0.145
2000	1.025	0.67	1.56	0.907	1.399	0.79	2.49	0.254	0.427	0.16	1.12	0.083
2001	0.979	0.64	1.49	0.921	1.735	0.98	3.07	0.058	0.504	0.19	1.32	0.162
2002	1.013	0.66	1.56	0.954	1.687	0.95	2.98	0.072	0.444	0.17	1.16	0.098
2003	1.054	0.68	1.63	0.812	1.382	0.77	2.47	0.274	0.401	0.15	1.05	0.063
2004	0.863	0.55	1.35	0.521	1.384	0.78	2.47	0.271	0.412	0.16	1.08	0.071
2005	0.751	0.47	1.20	0.231	1.337	0.75	2.38	0.325	0.426	0.16	1.12	0.083
2006	0.726	0.44	1.19	0.204	1.452	0.81	2.59	0.207	0.368*	0.14	0.97	0.043
2007	0.625	0.38	1.02	0.060	1.131	0.62	2.05	0.684	0.372*	0.14	0.98	0.045
2008	0.652	0.39	1.08	0.100	1.110	0.61	2.01	0.728	0.353*	0.13	0.93	0.035
2009	0.585*	0.35	0.98	0.041	1.121	0.62	2.03	0.707	0.311*	0.12	0.82	0.019
2010	0.566*	0.33	0.96	0.034	0.909	0.50	1.66	0.757	0.291*	0.11	0.77	0.013
Aneurysm rupture status												
Non-ruptured	(Reference)											
Ruptured	12.166*	10.58	13.99	<0.001								