Trends in Hospitalizations Among Medicare Survivors of Aortic Valve Replacement in the United States From 1999 to 2010

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Background. **Mortality rates after aortic valve replacement have declined, but little is known about the risk of hospitalization among survivors and how that has changed with time.**

Methods. **Among Medicare patients who underwent aortic valve replacement from 1999 to 2010 and survived to 1 year, we assessed trends in 1-year hospitalization rates, mean cumulative length of stay (average number of hospitalization days per patient in the entire year), and adjusted annual Medicare payments per patient toward hospitalizations. We characterized hospitalizations by principal diagnosis and mean length of stay.**

Results. **Among 1-year survivors of aortic valve replacement, 43% of patients were hospitalized within that year, of whom 44.5% were hospitalized within 30 days (19.2% for overall cohort). Hospitalization rates were higher for older (50.3% for >85 years), female (45.1%), and black (48.9%) patients. One-year hospitalization rate decreased from 44.2% (95% confidence interval, 43.5 to 44.8) in 1999 to 40.9% (95% confidence interval, 40.3 to 41.4) in 2010. Mean cumulative length of stay decreased from 4.8 days to 4.0 days ($p < 0.05$ for trend); annual Medicare payments per patient were unchanged ($5,709 to $5,737; $p = 0.32$ for trend). The three most common principal diagnoses in hospitalizations were heart failure (12.7%), arrhythmia (7.9%), and postoperative complications (4.4%). Mean length of stay declined from 6.0 days to 5.3 days ($p < 0.05$ for trend).**

Conclusions. **Among Medicare beneficiaries who survived 1 year after aortic valve replacement, 3 in 5 remained free of hospitalization; however, certain subgroups had higher rates of hospitalization. After the 30-day period, the hospitalization rate was similar to that of the general Medicare population. Hospitalization rates and cumulative days spent in hospital decreased with time.**

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Aortic valve disease is one of the most frequent types of valvular heart disease in the United States [1], and aortic valve replacement (AVR) in appropriate patients with severe stenosis or regurgitation can produce substantial improvements in symptoms and life expectancy [2]. Over time, rates of AVR in the United States have increased while mortality rates have declined [3]. Among Medicare beneficiaries undergoing AVR, 1-year mortality declined by 20% from 1999 to 2010. By 2010, almost 9 in 10 patients undergoing AVR were alive after 1 year [4].

Survival is often considered to be the success rate of the procedure, but there can be heterogeneity of experience among survivors. Hospitalizations indicate acute events of consequence and impose significant psychological and physical burden on patients, especially in the elderly [5]. There is a paucity of information on the risk of hospitalization among survivors of AVR, and how that has changed with time. Furthermore, there is little information on the timing, duration, causes, and costs of these hospitalizations and the characteristics of patients at higher risk of hospitalization. To date, no large, national studies have assessed and characterized these events. This information is important to better characterize the full range of outcomes among the vast majority of patients who survive the surgery, to provide information that can influence decisions, and to identify targets for improvement.

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Accordingly, we analyzed all data for Medicare fee-for-service beneficiaries who survived at least 1 year after AVR from 1999 through 2010 to describe the trend in hospitalization rates, cumulative hospitalization days, and associated costs and characterized individual hospitalizations by principal diagnosis, length of stay (LOS), and discharge disposition. We analyzed for differences by age, sex, race, and receipt of concomitant coronary artery bypass grafting (CABG).

Patients and Methods

Study Population

Using inpatient administrative claims data from the Centers for Medicare & Medicaid Services (CMS), we identified all Medicare Fee-for-Service beneficiaries who underwent an AVR between January 1, 1999, and December 31, 2010, and survived at least 1 year after the procedure. Aortic valve replacement was defined by the International Classification of Diseases, Ninth Revision, Clinical Modification procedure codes 35.21 (AVR with bioprosthesis) and 35.22 (AVR with mechanical prosthesis). We excluded patients who underwent aortic valve repair (35.11) or multivalvular surgery, ie, concurrent mitral (35.12, 35.23, 35.24) or tricuspid (35.14, 35.27, 35.28) valve repair or replacement, as well as those with endocarditis (421.0, 421.1, 421.9). We identified patients with concomitant CABG using the codes 36.10 to 36.16. If a patient had more than one AVR during an index year, we selected the first hospitalization. For patients who underwent AVR during 2010 we used 2011 claims data to permit 1-year follow-up. Institutional review board approval was obtained from the Yale University Human Investigation Committee.

Patient Characteristics

We collected information on patients' age, sex, race (white, black, other), and comorbidities. Comorbidities included those used for profiling hospitals by the CMS 30-day mortality measures for acute myocardial infarction [6] and heart failure [7]. They were identified from secondary discharge diagnosis codes in the index hospitalization for AVR as well as principal or secondary diagnosis codes of all inpatient hospitalizations up to 1 year before. Comorbidity data from 1998 were used for patients hospitalized for AVR in 1999.

Outcomes

Primary outcome was all-cause hospitalization within 1 year of discharge for AVR. In addition, we studied mean cumulative LOS and annual Medicare payments per patient toward hospitalizations. Mean cumulative LOS was defined as the average number of hospitalization days (excluding the index hospitalization) per patient in the entire year after the index AVR hospitalization.

We further characterized individual hospitalizations by principal diagnosis, mean LOS (for all hospitalizations excluding the index hospitalization), and discharge disposition. Major discharge disposition included discharge to home, home with home care, skilled nursing facility, long-term care facility, hospice, or rehabilitation.

We reported Medicare payments as both unadjusted and adjusted for inflation. To calculate adjusted payments we used the annual Consumer Price Index inflation rate reported by the Bureau of Labor Statistics to adjust the dollar amounts with year 2000 expenditure as baseline [8]. We have chosen not to use the medical care component of the CPI for inflation adjustments because of expressed concerns that it can overstate the growth in health-care costs [9].

Statistical Analysis

We reported baseline characteristics in 2-year intervals and outcomes in alternate years to simplify presentation. We used the Cochran-Armitage test to examine the significance of trends and Cox proportional hazards regression model to assess annual trends in 1-year all-cause hospitalization rates, adjusted for patient characteristics. We fitted separate Cox models to assess the annual trends for age, sex, and race subgroups and with and without CABG groups. All models included an ordinal time variable, ranging from 0 to 11, corresponding to years 1999 (time = 0) through 2010 (time = 11), to represent the adjusted annual trends in 1-year hospitalization rate. All statistical analysis was conducted using SAS 9.3 64-bit version (SAS Institute Inc, Cary, NC). All statistical tests were two-sided at a significance level of 0.05.

Results

Patient Characteristics

Of the 337,846 patients who underwent AVR from 1999 to 2010, 293,853 patients survived to at least 1 year, comprising the study cohort. Patient characteristics are shown in Table 1. Between 1999/2000 and 2009/2010, the proportion of patients 85 years or older increased from 7.8% to 12.7%, whereas the proportion of female patients decreased from 42.3% to 39.9%. Patients increasingly had coexistent hypertension (54.1% to 62.9%), diabetes (20.8% to 25.9%), and renal failure (1.8% to 7.8%). The proportion of patients who underwent concomitant CABG along with AVR decreased from 56.2% to 44.8% (all p for trend < 0.05).

Outcomes

ONE-YEAR HOSPITALIZATIONS AFTER AORTIC VALVE REPLACEMENT. Overall, 43% patients had at least one hospitalization within 1 year of the index hospitalization for AVR. The 1-year crude hospitalization rate (95% confidence interval) decreased from 44.2% (43.5 to 44.8) in 1999 to 40.9% (40.3 to 41.4) in 2010. Crude hospitalization rates stratified by age, sex, race, and receipt of concomitant CABG are shown in Table 2. With time, the rate of 1-year hospitalizations decreased for all age groups. Among patients 85 years or older, who had the overall highest rate of hospitalizations, 1-year hospitalizations declined from 52.2% (49.8 to 54.7) to 48.0% (46.3 to 49.7), whereas in

Table 1. Patient Characteristics

Patient Characteristics	Number (%) of Patients					
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010
No. of patients	43,043	46,668	49,624	50,452	49,935	54,131
Demographics						
Mean age, years (standard deviation)	76.0 (5.8)	76.2 (5.9)	76.3 (6.0)	76.4 (6.1)	76.5 (6.3)	76.7 (6.5)
Female[a]	18,199 (42.3)	19,401 (41.6)	20,446 (41.2)	20,425 (40.5)	20,193 (40.4)	21,607 (39.9)
White	40,399 (93.9)	43,782 (93.8)	46,386 (93.5)	47,285 (93.7)	46,879 (93.9)	50,736 (93.7)
Black	1,410 (3.3)	1,470 (3.1)	1,643 (3.3)	1,562 (3.1)	1,552 (3.1)	1,677 (3.1)
Other race[b,c]	1,234 (2.9)	1,416 (3.0)	1,595 (3.2)	1,605 (3.2)	1,504 (3.0)	1,718 (3.2)
Risk factors and cardiovascular conditions						
Hypertension[a]	23,300 (54.1)	27,240 (58.4)	30,096 (60.6)	30,550 (60.6)	31,526 (63.1)	34,045 (62.9)
Diabetes[a]	8,933 (20.8)	10,309 (22.1)	11,789 (23.8)	12,593 (25.0)	12,881 (25.8)	14,045 (25.9)
Atherosclerotic disease[a]	26,469 (61.5)	28,945 (62.0)	30,794 (62.1)	30,529 (60.5)	29,824 (59.7)	31,051 (57.4)
Unstable angina[a]	2,208 (5.1)	2,021 (4.3)	1,746 (3.5)	1,475 (2.9)	1,320 (2.6)	1,227 (2.3)
Prior heart failure[a]	7,122 (16.5)	7,355 (15.8)	7,549 (15.2)	7,186 (14.2)	7,170 (14.4)	8,008 (14.8)
Prior myocardial infarction[b]	1,509 (3.5)	1,606 (3.4)	1,639 (3.3)	1,688 (3.3)	1,718 (3.4)	2,046 (3.8)
Stroke	404 (0.9)	463 (1.0)	412 (0.8)	478 (0.9)	499 (1.0)	562 (1.0)
Cerebrovascular disease other than stroke[a]	1,726 (4.0)	1,866 (4.0)	1,813 (3.7)	1,881 (3.7)	1,819 (3.6)	1,902 (3.5)
Peripheral vascular disease[a]	2,176 (5.1)	2,493 (5.3)	2,721 (5.5)	2,821 (5.6)	2,906 (5.8)	3,049 (5.6)
Other conditions						
Malnutrition[a]	450 (1.0)	547 (1.2)	645 (1.3)	801 (1.6)	1,193 (2.4)	1,752 (3.2)
Dementia[a]	468 (1.1)	540 (1.2)	648 (1.3)	699 (1.4)	752 (1.5)	960 (1.8)
Functional disability[b]	343 (0.8)	363 (0.8)	382 (0.8)	353 (0.7)	442 (0.9)	482 (0.9)
Renal failure[a]	794 (1.8)	1,099 (2.4)	1,385 (2.8)	2,129 (4.2)	3,264 (6.5)	4,212 (7.8)
Respiratory failure[a]	849 (2.0)	870 (1.9)	887 (1.8)	1,060 (2.1)	1,464 (2.9)	1,829 (3.4)
Chronic obstructive pulmonary disease[a]	7,710 (17.9)	8,913 (19.1)	9,517 (19.2)	10,131 (20.1)	8,577 (17.2)	7,839 (14.5)
Pneumonia[a]	2,507 (5.8)	2,776 (5.9)	3,036 (6.1)	3,352 (6.6)	3,701 (7.4)	4,285 (7.9)
Cancer[b]	2,012 (4.7)	2,099 (4.5)	2,249 (4.5)	2,290 (4.5)	2,213 (4.4)	2,353 (4.3)
Liver disease[b]	205 (0.5)	258 (0.6)	278 (0.6)	296 (0.6)	295 (0.6)	350 (0.6)
Trauma in past year[a]	1,179 (2.7)	1,418 (3.0)	1,722 (3.5)	1,828 (3.6)	1,758 (3.5)	1,734 (3.2)
Major psychiatric disorders[b]	359 (0.8)	423 (0.9)	413 (0.8)	420 (0.8)	489 (1.0)	557 (1.0)
Depression[a]	898 (2.1)	1,171 (2.5)	1,550 (3.1)	1,509 (3.0)	1,642 (3.3)	1,722 (3.2)

[a] $p < 0.001$. [b] $p < 0.05$. [c] Other race includes Asian, Hispanic, North American Native, or other not specified.

ADULT CARDIAC

Table 2. Trend in 1-Year Hospitalization Rate, Overall and by Subgroups

Group	1-Year Hospitalization Rate, % (95% CI)						
	1999	2001	2003	2005	2007	2009	2010
Overall	44.2 (43.5–44.8)	43.9 (43.3–44.6)	43.5 (42.9–44.2)	42.8 (42.2–43.5)	42.5 (41.9–43.1)	41.9 (41.3–42.5)	40.9 (40.3–41.4)
65–74 years	41.1 (40.0–42.1)	40.3 (39.3–41.3)	39.4 (38.4–40.3)	39.1 (38.1–40.0)	38.3 (37.3–39.3)	37.2 (36.3–38.1)	36.7 (35.8–37.6)
75–84 years	45.6 (44.6–46.5)	45.5 (44.6–46.4)	45.6 (44.7–46.4)	44.2 (43.4–45.1)	44.2 (43.3–45.0)	43.5 (42.7–44.4)	42.3 (41.4–43.1)
≥85 years	52.2 (49.8–54.7)	51.7 (49.5–53.9)	51.0 (48.9–53.1)	51.2 (49.2–53.3)	49.7 (47.8–51.6)	50.6 (48.9–52.3)	48.0 (46.3–49.7)
Female	46.5 (45.5–47.5)	46.5 (45.5–47.5)	45.9 (44.9–46.9)	44.4 (43.5–45.4)	44.9 (43.9–45.9)	44.6 (43.6–45.5)	42.2 (41.3–43.2)
Male	42.5 (41.6–43.3)	42.1 (41.3–42.9)	41.9 (41.1–42.7)	41.7 (41.0–42.5)	40.8 (40.0–41.6)	40.1 (39.4–40.9)	39.9 (39.2–40.7)
Black	48.6 (44.9–52.3)	50.8 (47.1–54.5)	50.8 (47.3–54.3)	47.6 (44.1–51.2)	47.2 (43.6–50.8)	45.7 (42.2–49.1)	47.6 (44.2–50.9)
White	43.9 (43.2–44.6)	43.7 (43.0–44.3)	43.2 (42.6–43.9)	42.7 (42.1–43.4)	42.3 (41.6–42.9)	41.7 (41.1–42.3)	40.6 (40.0–41.2)
Other	46.6 (42.4–50.7)	44.4 (40.6–48.2)	44.7 (41.2–48.2)	41.4 (38.1–44.7)	44.9 (41.4–48.4)	44.0 (40.6–47.4)	41.4 (38.2–44.7)
AVR with CABG	45.9 (45.0–46.8)	45.5 (44.6–46.4)	45.2 (44.3–46.0)	44.7 (43.9–45.6)	43.8 (42.9–44.7)	43.5 (42.7–44.4)	42.8 (41.9–43.7)
Isolated AVR	41.9 (40.9–42.9)	42.1 (41.1–43.0)	41.7 (40.8–42.6)	40.7 (39.8–41.6)	41.3 (40.4–42.1)	40.5 (39.7–41.3)	39.3 (38.5–40.1)

AVR = aortic valve replacement; CABG = coronary artery bypass grafting; CI = confidence interval.

the younger (65 to 74 years) age group it declined from 41.1% (40.0 to 42.1) to 36.7% (35.8 to 37.6). Women had higher 1-year hospitalization rates than men although both groups experienced declines with time (women, 46.5% [45.5 to 47.5] to 42.2% [41.3 to 43.2]; men, 42.5% [41.6 to 43.3] to 39.9% [39.2 to 40.7]). Among race subgroups, black patients had higher hospitalization rates than white patients and had minimal decline with time (48.6% [44.9 to 52.3] to 47.6% [44.2 to 50.9]). Hospitalization rates tended to be higher overall in the group with concomitant CABG than isolated AVR, but both groups showed a decline with time.

These findings remained unchanged after adjustment for patient characteristics. Compared with 1999, the adjusted hazard ratio representing the annual change in 1-year all-cause hospitalization rate was 0.987 (0.986 to 0.989). We analyzed race and sex subgroups to evaluate a race–sex interaction and found that black male patients had no significant decline in 1-year hospitalizations in contrast to all other race and sex subgroups (Fig 1).

Among those patients with 1-year hospitalizations, in a large proportion the first hospitalization occurred within 30 days (44.5%). With time, the 30-day hospitalization rate declined from 19.7% (19.1 to 20.2) in 1999 to 18.2% (17.8 to 18.7) in 2010 and the proportion of patients hospitalized for the first time in the 31 to 365-day period declined from 24.5% (24.0 to 25.1) to 22.6% (22.1 to 23.1; Appendix Table 1).

Although the 1-year hospitalization rate decreased overall, among those patients with 1-year hospitalizations the average number of hospitalizations remained similar with time (1.80 hospitalizations per patient in 1999 and 1.83 in 2010; Appendix Table 1).

MEAN CUMULATIVE LENGTH OF STAY AND ANNUAL MEDICARE PAYMENTS PER PATIENT. Overall, the mean cumulative LOS (average number of hospitalization days per patient in the entire year after AVR) decreased from 4.8 days in 1999 to 4.0 days in 2010 ($p < 0.05$ for trend). It declined among all subgroups of age, sex, and receipt of CABG. Among race subgroups, in black patients the mean cumulative LOS was unchanged (6.4 days in 1999 and 2010; $p = 0.22$ for trend; Fig 2).

Unadjusted annual Medicare payments per patient toward hospitalizations increased from $5,524 in 1999 to $7,265 in 2010. However, adjusted for inflation, it remained unchanged from $5,709 in 1999 to $5,737 in 2010 ($p = 0.32$ for trend). Older patients had higher adjusted annual CMS payments for hospitalizations, and among patients 85 years or older it increased with time from $6,043 per patient in 1999 to $6,607 per patient in 2010 ($p <$ 0.05 for trend; Appendix Table 2).

Characteristics of the Hospitalizations

The top five principal diagnoses combined explained only about 31.1% of hospitalizations. The three most common principal diagnoses for hospitalizations were heart failure (12.7%), arrhythmia (7.9%), and postoperative complications (hemorrhage, postoperative shock, or surgical site complications; 4.4%), and the proportions of these three

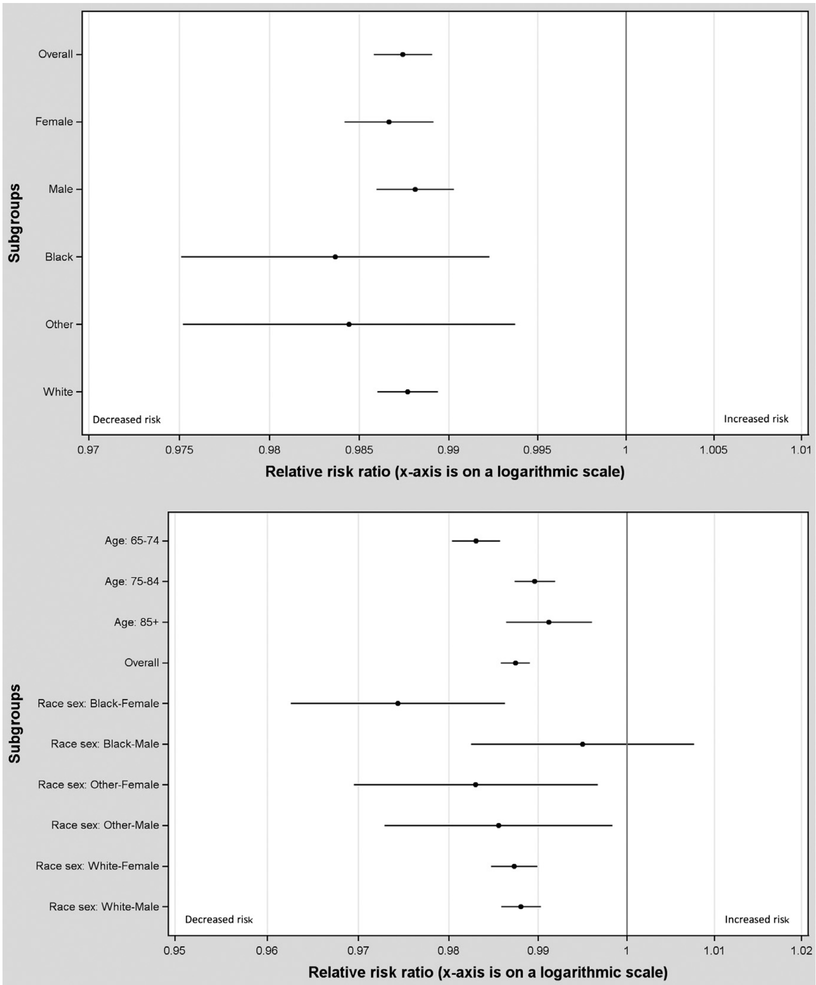


Fig 1. Risk-adjusted annual hazard ratio of 1-year hospitalization, overall and by subgroups. The hazard ratios represent the annual change in readmission rate after adjustment for patient characteristics, as estimated by the Cox model. (Top) Overall, sex, and race subgroups. (Bottom) Overall, age, and race-sex subgroups.

principal diagnoses remained similar for all the study years.

The mean LOS per hospitalization declined from 6.0 days to 5.3 days. All subgroups showed a decline in mean LOS. Mean LOS for black patients showed a minimal decline (from 6.6 days to 6.5 days; Fig 3) Proportion of prolonged hospitalizations (LOS > 30 days) declined with time as well, from 2.8% to 2.2%. Discharges to home decreased with time (48.6% to 34.5%), whereas discharges to home with home care (12.2% to 17.7%) and to skilled nursing facilities (10.6% to 14.7%) increased (Appendix Fig 1; all above $p < 0.05$ for trend).

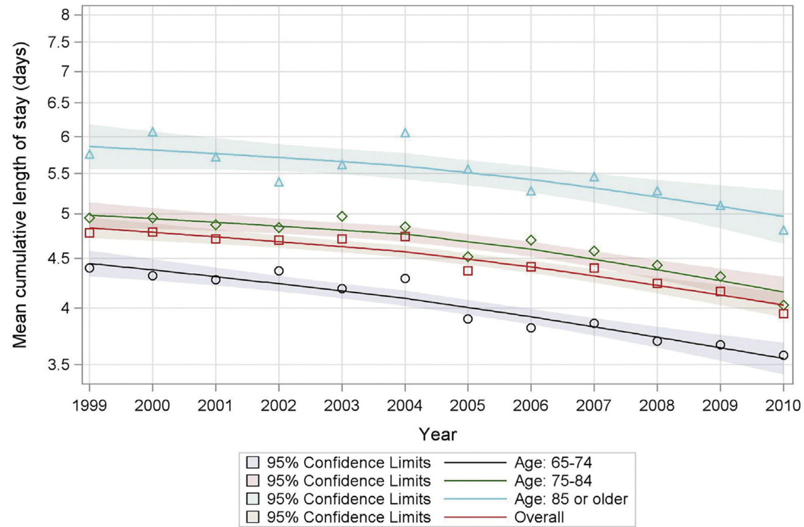
Comment

Among Medicare fee-for-service beneficiaries who survived 1 year after AVR—which represented 87% of patients undergoing the surgery—we found that 3 of 5 patients were free from hospitalization. Moreover, about half of those hospitalized had their first hospitalization within 30 days. Older, female, black, and concomitant CABG patients had higher hospitalization rates. However, there were continual improvements in 1-year hospitalization rate and mean cumulative LOS with time.

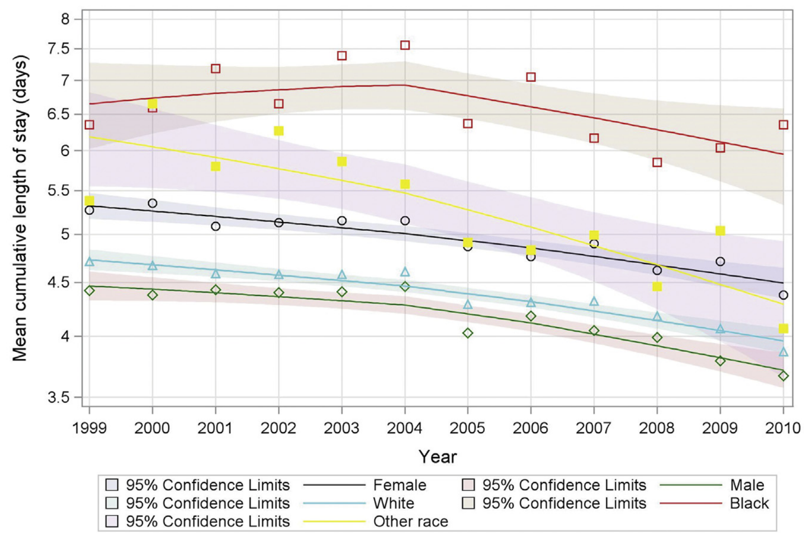
Studies of long-term outcomes after AVR are limited to measuring mortality [10, 11]. To our knowledge, in the United States, this is the first nationally representative study addressing long-term hospitalizations among AVR survivors. Most studies evaluating hospitalizations after cardiac surgery have assessed shorter time frames, such as 30 days [12]. We focused specifically on survivors to understand the heterogeneity in outcomes among the majority of patients who survive AVR, those who most studies would consider a success. This study also provides useful information for those who ask what they can expect if they do survive.

We found that among 1-year survivors of AVR, 43% were hospitalized in the year after surgery. Of those, almost half were hospitalized within 30 days, indicating the critical need to monitor patients closely during the

Fig 2. Trend in mean cumulative length of stay, overall and by subgroups. Shaded areas around each line represent 95% confidence interval. (Top) Overall (red line and symbols) and age groups: 65–74 years (black line and symbols), 75–84 years (green line and symbols), and 85 years and older (aqua line and symbols). (Bottom) Sex: female black line and symbols), male (green line and symbols); and race: white (aqua line and symbols), black (red line and symbols), and other (yellow line and symbols).



Circle,triangle,square, and diamond denote observed values; lines represent trend over time (all $p<0.05$)

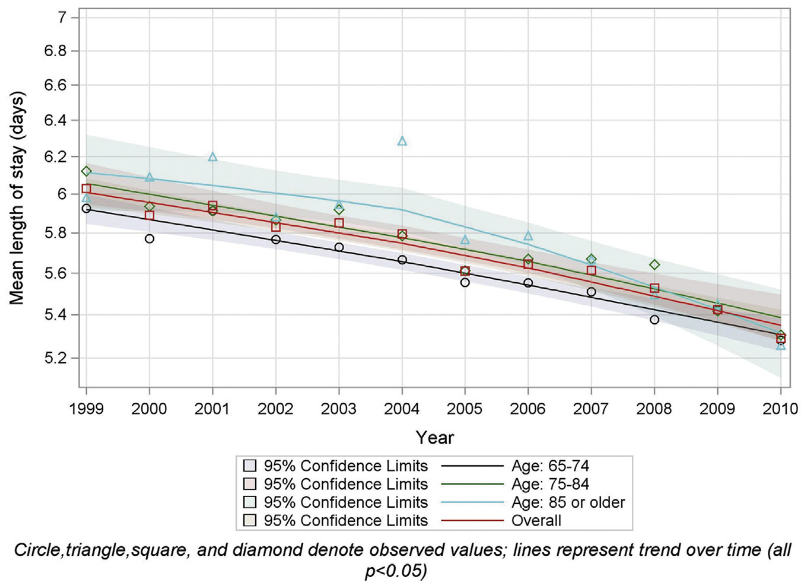


Circle,triangle,square, and diamond denote observed values; lines represent trend over time (all $p<0.05$, except black [$p=0.155$])

30-day postsurgery period of heightened risk. Nevertheless, among the patients who do not require a hospitalization during this 30-day period, which was the case for 4 in 5 patients in the cohort, the hospitalization rate is similar to the Medicare basal hospitalization rate of 23% [13]. These findings indicate that recovery is quite good for the majority of these older individuals.

Furthermore, during the study period we observed a decline in hospitalization rates and mean cumulative LOS despite the increasing age and burden of comorbidities in the population. Improvements were seen in both the isolated AVR and concomitant CABG groups. Reductions in postoperative complications [14] with time and improvements in the management of valve recipients in the ambulatory setting are likely contributors to this decline. The increased usage of bioprosthetic valves [4] may have also played a role by reducing bleeding complications. To further improve outcomes, focused efforts on the postoperative and ambulatory care of AVR patients, especially during the first 30 days, are needed; the emergence of public reporting in cardiac surgery may provide an additional impetus to reduce rehospitalizations [15].

However, it was notable that among patients who were hospitalized after discharge after AVR, the mean



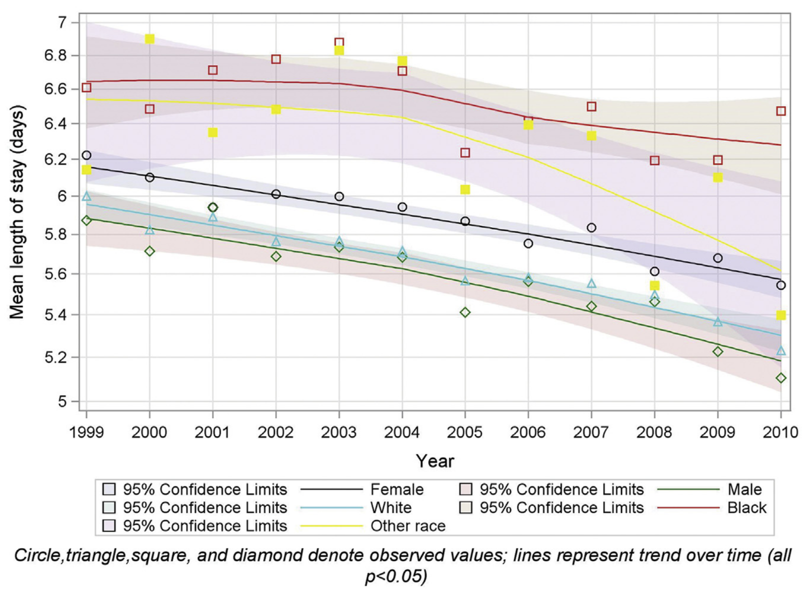


Fig 3. Trend in mean length of stay, overall and by subgroups. Shaded areas around each line represent 95% confidence interval. (Top) Overall (red line and symbols) and age groups: 65–74 years (black line and symbols), 75–84 years (green line and symbols), and 85 years and older (aqua line and symbols). (Bottom) Sex: female black line and symbols), male (green line and symbols); and race: white (aqua line and symbols), black (red line and symbols), and other (yellow line and symbols).

number of hospitalizations remained unchanged with time. Thus, there is room for improvement in preventing multiple hospitalizations, and this highlights the need for increased vigilance in the care of rehospitalized patients.

The top three causes for hospitalizations remained similar with time, with heart failure being the most common. However, even the top five causes for hospitalization combined accounted for less than a third of all hospitalizations, indicating that patients are hospitalized for a variety of reasons beyond the reason for the initial admission. This has been observed with other cardiovascular conditions such as heart failure, and patients after discharge seem to have a period of generalized heightened risk for acute events, which extends up to many months, a condition termed posthospital syndrome [16, 17].

The mean LOS per hospitalization decreased with time and compared with the LOS for all hospitalizations among Medicare beneficiaries, it was longer by only 0.6 days [13]. Although mean cumulative LOS and mean LOS declined with time, annual Medicare payments per patient toward hospitalizations remained unchanged. This may reflect the changing population of AVR recipients to one that is older and with more comorbidity, necessitating greater resources. The increase in costs may also be caused in part by the generalized increase in the costs of in-hospital care [18].

Subgroup analysis revealed important differences in hospitalization rates among different patient populations. Patients with concomitant CABG, a group known to have higher mortality compared with isolated AVR [4], had higher hospitalization rates among survivors as well. Older age and female sex were also associated with higher hospitalization rates, but findings have been mixed in previous studies [19, 20]. In addition, black patients were associated with higher rates of hospitalization similar to those reported in prior literature in surgical patients [19, 21]. Although all subgroups experienced a decline in crude hospitalization rates with time, the decline was unequal. Black patients experienced only a 2.1% relative decline in hospitalizations versus 7.5% for white patients. In the risk-adjusted model, black male patients specifically had no significant change in the hospitalization rate in contrast to all other subgroups. Further, among black patients the mean cumulative LOS was unchanged with time and the mean LOS of hospitalizations only showed a minimal decline. These findings call for increased attention to these subgroups after AVR, owing to their vulnerability for rehospitalizations, to eliminate disparities and improve outcomes.

Moving forward, steady improvements in mortality [4] and our findings of decreased need for hospitalization among survivors with time indicate that surgical AVR is continually evolving into a safer and effective procedure. Although the advent of percutaneous devices has been a disruptive innovation in the treatment of aortic valve disease, the outcomes of patients undergoing surgical AVR have never been better and continue to improve. This elevates the benchmark that these newer, more expensive and labor-intensive therapies need to supersede.

Our study has a few limitations. First, data were limited to Medicare fee-for-service beneficiaries, and conclusions drawn from this population may not apply to patients enrolled in Medicare managed-care programs, in which enrollment has increased with time, as well as for patients younger than 65 years. Second, comorbidity information from administrative data may not entirely capture the medical complexity of the patient, and also the pattern and extent of coding for comorbidities may have changed with time. Third, other factors may have influenced the observed trends, such as changes in patient selection and acuity, surgical factors, social factors, and health-care system changes; given the administrative nature of our data we are unable to deeply explore the reasons for decreased hospitalizations with time.

Among Medicare beneficiaries surviving to 1 year after AVR, 3 in 5 were free from hospitalization, indicating good recovery for the majority of patients. After an initial 30-day period of increased risk, these patients had a hospitalization rate similar to the general Medicare population. The hospitalization rate declined from 1999 to 2010; however, certain subgroups had higher rates of hospitalization, which warrants increased attention.

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INVITED COMMENTARY

The 30-day milestone is the standard by which therapies in cardiac surgery are assessed. Operative mortality is a major component used to generate quality scores for public reporting. But are we doing a good job just because we have met the 30-day milestone? One-year mortality after aortic valve replacement in Medicare patients decreased from 13.6% in 1999 to 10.95% in 2011, while the average age at surgery increased from 76.1 to 77.1 years [1]. Murugiah and colleagues [2] report that 43% of the survivors were rehospitalized within the first year after surgery, with almost half of these within the first 30 days [2]. The readmission rate declined from 1999 to 2010, but was still high at 40.9%. Interestingly, the rate declined despite increasing emphasis on earlier discharge.

As scrutiny of our profession continues to increase, surgeons will not only be judged by 30-day outcomes but also long-term outcomes and readmissions. Furthermore, outcomes will be judged based on economics and quality. The causes of readmission in this study were multiple, but the three most common were heart failure, arrhythmia, and postoperative complications (25%), all of which were directly attributable to the primary operation. Soon CMS will be reporting readmission rates after coronary bypass surgery. This reporting will likely extend to aortic valve surgery in the future.

All patients included in this report had fee-for-service health care plans. Were outcomes better or worse for patients with managed care plans? No information is presented to identify good or bad practice patterns and to suggest methods to lower readmission rates. Studies have shown that close follow-up can reduce complications and readmission. Hopefully the authors in future work can identify practice patterns that successfully reduce readmissions.

Cardiac surgeons have been successful in reducing immediate complications and mortality rates. The next challenge is to anticipate these problems and to reduce readmission rates and the associated costs. Coordinated care teams incorporating other physicians and nurses are essential. Cardiac surgeons have been the vanguard in quality assessment and improvement. Addressing these issues is an extension of what we have already accomplished.

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