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Influence of Age on Cardiac Surgery Outcomes in United States Veterans

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ABSTRACT

Objective: Heart disease is still the leading cause of death for both men and women in the United States, and the rate of cardiovascular disease in veterans is even higher than in civilians. This study examines age-related outcomes for veterans undergoing cardiac surgeries at a single institution.

Methods: We included all veterans undergoing coronary artery bypass grafting (CABG) and/or valve surgery between 1997 to 2017 at a single Veterans Affairs (VA) medical center. We stratified this cohort into 4 age groups: ≤59 years old, 60–69 years old, 70–79 years old, and ≥80 years old. Outcomes in age groups were compared using standard statistical methods with the ≤59 years old group as reference.

Results: A total of 2,301 patients underwent open cardiac procedures at our institution. The frequency of simultaneous CABG and valve operations increased with age. Usage of cardiopulmonary bypass versus off-pump CABG and operative time was not associated with age. Increased pulmonary and renal complications as well as rates of postoperative arrhythmias all were associated with increasing age. There was no statistically significant difference in 30-day mortality. However, multivariable analysis adjusted for covariates showed all-cause mortality significantly was increased with older age groups (aHR ≥80 years old: 2.94 [2.07-4.17], $P < .01$; aHR 70-79 years old: 2.15 [1.63-2.83], $P < 0.01$, with ≤59 years old as reference).

Conclusions: Older patients may have comparable perioperative mortality as their younger counterparts. However, age still is a significant predictor of all-cause mortality, pulmonary and renal complications, and postoperative arrhythmia, and should be considered as a major factor in preoperative risk assessment.

INTRODUCTION

The United States population continues to struggle with the burden of cardiovascular disease. In Western countries, epidemiological trends such as the perpetual rise in obesity rates have contributed to an increasing prevalence of various cardiovascular and metabolic diseases [Hales 2018; Hales 2018; Iliodromiti 2018]. Despite the rise in comorbid conditions and demographic shifts toward an increasingly elderly population, advancements in surgical techniques and technology have enabled surgeons to operate on sicker and older patients than in the past [Bongaarts 2009; Coelho 2019; Friedrich 2009; Krane 2011; Peterson 1995]. US military veterans are no exceptions to these trends. In fact, US veterans are at near double the risk of developing cardiovascular diseases throughout their lifetime [Assari 2014].

The broad array of new medical techniques and improvements in perioperative care have allowed surgeons across different specialties to perform major operations in elderly patients with excellent results [Khan-Kheil 2016; Pemberton 1998; Scandroglio 2015]. These successful results have called into question the true importance of chronological age and its bearing on patient selection and decision-making for cardiac surgery [Alexander 2000; Crudeli 2015; Farquharson 2001]. While certainly other measures, such as frailty or "biologic age" have been considered in crafting more comprehensive perioperative risk stratification models (for instance, the Society of Thoracic Surgeons (STS) cardiac surgery risk models, the European system for cardiac operative risk evaluation (EuroSCORE), and the 'Age, Creatinine, and Ejection

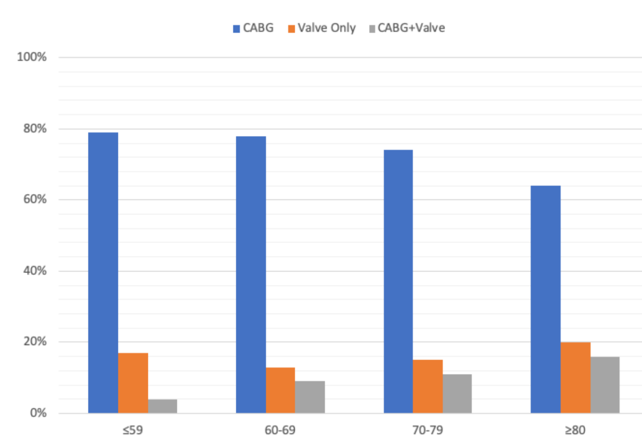

Figure. 1. Distribution of procedures performed stratified by age group. As shown, the proportion of combined CABG + Valve cases increases with increasing age. CABG = coronary artery bypass grafting.

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Table 1. Patient and Operative Variables by Age Group

	Age Groups (years)				
Patient variable	<59 (N = 656) N(%)	60-69 (N = 902) N(%)	70-79 (N = 583) N(%)	≥ 80 (N = 160) N(%)	*P*
Mean age (years)	53.6 ± 4.9	64.5 ± 2.8	74.1 ± 2.7	82.7 ± 2.5	<.01
Female	18 (3%)	7 (1%)	4 (1%)	3 (2%)	<.01
BMI (kg/m²)	30.1 ± 6.1	30.1 ± 6.4	30.0 ± 4.9	27.6 ± 4.4	<.01
Myocardial Infarction					
None	358 (55%)	493 (55%)	303 (52%)	96 (60%)	.18
1 occurrence	242 (37%)	303 (34%)	221 (38%)	0.18	
2 or more occurrences	56 (9%)	106 (10%)	59 (10%)	14 (9%)	.18
Hypertension	490 (90%)	767 (95%)	466 (95%)	138 (95%)	.01
CVD	74 (11%)	183 (20%)	182 (31%)	39 (24%)	<.01
COPD	214 (33%)	386 (43%)	284 (49%)	82 (51%)	<.01
PVD	140 (21%)	224 (25%)	197 (34%)	44 (28%)	<.01
Diabetes Mellitus					
None	432 (66%)	502 (56%)	350 (60%)	111 (69%)	<.01
Diet and/or Oral Meds	79 (12%)	168 (19%)	102 (18%)	22 (14%)	<.01
Insulin Requiring	145 (22%)	232 (26%)	131 (22%)	27 (17%)	<.01
Mean CCS classification	2.8 ± 1.0	2.7 ± 1.1	2.7 ± 1.1	2.7 ± 1.1	.20
Mean NYHA classification	2.4 ± 0.9	2.4 ± 1.0	2.4 ± 1.0	2.5 ± 0.8	.13
Current smoker	322 (49%)	257 (29%)	88 (15%)	10 (6%)	<.01
Functional status					
Independent	502 (77%)	742 (82%)	450 (77%)	118 (74%)	<.01
Partially dependent	110 (17%)	125 (14%)	101 (17%)	36 (23%)	<.01
Totally dependent	44 (7%)	35 (4%)	32 (5%)	6 (4%)	<.01
Prior heart surgery	14 (2%)	23 (3%)	22 (4%)	3 (2%)	.28
Prior IABP	55 (8%)	81 (9%)	67 (11%)	21 (13%)	.11
Hemoglobin (g/dL)	13.5 ± 1.7	13.3 ± 1.7	13.0 ± 1.7	12.3 ± 1.6	<.01
Creatinine (mg/dL)	1.4 ± 1.8	1.3 ± 1.1	1.4 ± 0.6	1.3 ± 0.4	<.01
Albumin (g/dL)	3.8 ± 0.5	3.8 ± 0.5	3.8 ± 0.5	3.7 ± 0.5	<.01
Cardiopulmonary Bypass	378 (58%)	489 (54%)	333 (57%)	85 (53%)	.44
Surgery Priority					
Elective	602 (92%)	845 (94%)	552 (95%)	149 (93%)	.35
Urgent	44 (7%)	50 (6%)	24 (4%)	8 (5%)	.35
Emergent	10 (2%)	7 (1%)	7 (1%)	3 (2%)	.35
Mean Operative time (hours)	3.98 ± 1.3	3.90 ± 1.2	4.08 ± 1.5	3.91 ± 1.4	.09

SD, Standard Deviation; BMI, Body Mass Index; COPD, Chronic Obstructive Pulmonary Disease; CVD, Cerebrovascular Disease; CCS: Canadian Cardiovascular Society; NYHA: New York Heart Association

Fraction' (ACEF) score), how to specifically account for the influence of age remains in question [Nashef 2012; O'Brien 2009; Ranucci 2010; Shahian 2009; Shahian 2009]. For instance, the STS and EuroSCORE models differ in whether age is handled as a linear or exponential variable in prediction models [Afilalo 2016]. Moreover, the validity of some of these models in patients older than 70 years old has been called into question, again highlighting the nuanced relevance of chronological age on operative risk stratification [Poullis 2015].

While recent literature has explored the effect of chronological age on outcomes after cardiac surgery in civilian populations, there is a paucity of literature investigating this effect

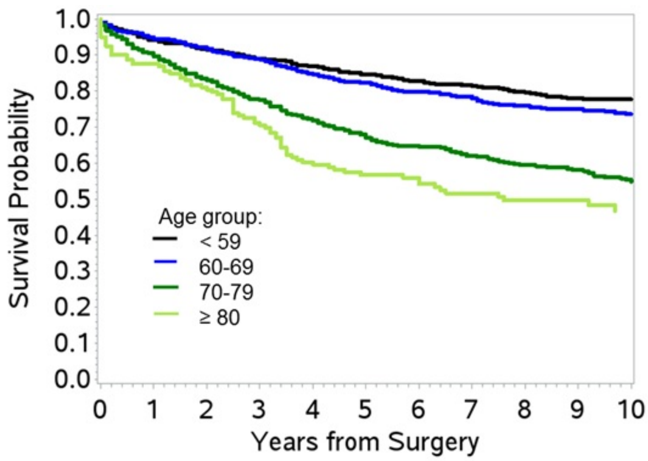

Figure. 2. Risk-adjusted survival estimates stratified by age group. The difference in mortality is statistically significant for the 70–79 years old group and 80 years or older group.

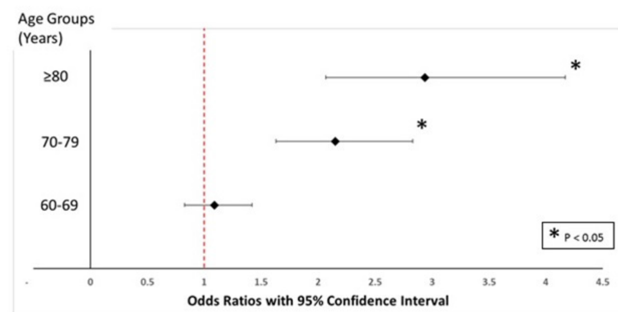

Figure. 3. Adjusted hazard ratio for mortality stratified by age group. The mortality hazard ratio was compared for each age group against the 59 years old or younger group.

specifically in the veteran population [Johnson 2005; Wang 2014]. This distinction is important as there is mixed evidence on whether Department of Veterans Affairs (VA) patients experience higher morbidity and mortality as compared with civilian patients across surgical fields [Matula 2010].

Specific to cardiac surgery, one such study suggests worse severity adjusted mortality outcomes for patients undergoing coronary artery bypass grafting (CABG) at VA medical centers as compared with private sector hospitals [Rosenthal 2003]. It is unclear whether this purported risk is an assumed function of healthcare delivery at VA medical centers, or if it may be linked to an inherent higher risk attached to VA patients. One prior study demonstrated a slightly higher morbidity and mortality for veterans who underwent cardiac revascularization in private sector hospitals as compared with civilians at the same institutions [Vaughan-Sarrazin 2007]. These reports are few in number and over a decade old. Despite the aforementioned demographic and epidemiological trends, the continued implementation of the Veterans Affairs Surgical Quality Improvement Program (VASQIP) more recently has demonstrated significant reductions in morbidity and mortality for non-cardiac surgeries [Massarweh 2016]. However, there is a lack of inquiry into how the VA healthcare system has performed with respect to cardiac surgery in an older and sicker population.

This study compares age stratified morbidity and mortality outcomes for US veterans undergoing open heart surgery for CABG and valve replacement at a VA medical center. The objective of the study is to determine the influence of age as an independent predictor of outcomes in veterans undergoing major cardiac surgery.

MATERIALS AND METHODS

We received the standard approval for this retrospective study from our institution's Institutional Review Board (IRB). We performed a retrospective review of patients, who underwent cardiothoracic surgeries at a single VA medical center between 1997 to 2017 from a preexisting in-house database based on the National Veterans Affairs database and Continuous Improvement in Cardiac Surgery Program (CICSP). The data was entered prospectively by a surgical nurse reviewer, including preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes. Periodic reviews of longitudinal follow-up mortality information through April 2018 for patients who underwent cardiac surgery at this center also was accrued in this database. We identified patients undergoing CABG, valvular, and combined CABG/valvular cardiac surgery. Inclusion criteria included patients 18 years of age or older and less than 100 years of age. Patients were further stratified into 4 age groups: ≤59 years old, 60-69 years old, 70-79 years old, and ≥80 years old. Each patient's procedure was coded into 3 categories (CABG only, valve only, or CABG and valve) based on the operative note. The valve-only group was defined as any isolated valvular procedure involving one or more valves including valve replacement or ring valvuloplasty. Patients with any other structural reconstruction, myomectomy, reconstruction of great vessels, or Cox-Maze procedure were excluded from the study.

Univariable associations with age group were examined using chi-square or Fisher's Exact test for categorical variables and Analysis of Variance (ANOVA) for continuous variables. Kruskal-Wallis test was used if the variable had a non-normal distribution of continuous variables. We determined the predictors of mortality and morbidity using a multivariable logistic regression model for outcomes that had a significant univariable association with age. Clinically relevant covariates purposefully were selected to adjust for preoperative risks among age groups. We examined the association between age group and survival time (time to all-cause mortality) using Kaplan-Meier analysis and tested the differences between age groups using the log-rank test. To determine whether age group had an independent association with time to all-cause mortality, we used a Cox proportional hazards model adjusted with a purposeful selection of clinically relevant covariates.

Table 2. Surgical Outcomes by Age Group

Surgical Outcomes	<59 (N = 656) N(%)	60-69 (N = 902) N(%)	70-79 (N = 583) N(%)	≥80 (N = 160) N(%)	*P*
All-cause mortality	137 (21%)	199 (22%)	231 (40%)	76 (48%)	<.01
30-day mortality	9 (1.4%)	15 (1.7%)	14 (2.4%)	7 (4.4%)	.07
Cardiac	19 (3%)	28 (3%)	21 (4%)	9 (6%)	.35
Stroke	3 (0.5%)	4 (0.4%)	1 (0.2%)	0	.67
Pulmonary	33 (5%)	62 (7%)	51 (9%)	18 (11%)	.01
Renal failure	0	7 (0.8%)	12 (2.1%)	4 (2.5%)	<.01
Wound infections	2 (1.5%)	5 (1.5%)	3 (1.9%)	1 (2.1%)	.97
Mediastinitis	3 (0.5%)	9 (1.0%)	3 (0.5%)	2 (1.3%)	.47
Reoperation	14 (2%)	25 (3%)	12 (2%)	6 (4%)	.54
Postop atrial fibrillation	5 (3.3%)	49 (12.8%)	29 (17.0%)	13 (24.1%)	<.01

Cardiac = Cardiac arrest, postoperative myocardial infarction; Pulmonary = failure to wean from ventilator 48 hours in the postoperative period, reintubation, tracheostomy. Note: All-cause mortality captures all deaths through observed follow up period, which includes 30-day mortality

The variables used for risk adjustments were type of procedure, sex, body mass index (BMI), preoperative hemoglobin, albumin, history of cardiopulmonary disease profile, smoking status, diabetes mellitus, history of cerebrovascular disease, and baseline functional status.

RESULTS

There were in total 2,301 cases that met the inclusion criteria. The patient cohort included 656 patients less than 59 years old (28.5%), 902 patients 60-69 years old (39.2%), 583 patients 70-79 years old (25.3%), and 160 patients 80 years old or older (7.0%). The patient groups had some differences in their clinical profiles, which are highlighted in Table 1. Most notably, the rates of current smokers progressively decreased with increasing age, and the rates of chronic obstructive pulmonary disease (COPD) progressively increased with increasing age groups. Patients older than 70 years old had higher rates of cerebrovascular disease (CVD) and peripheral vascular disease (PVD). However, cardiac comorbidities did not significantly differ; patients across different age groups had comparable Canadian Cardiovascular Society (CCS) angina severity grade and New York Heart Association (NYHA) functional class for heart failure. There were no significant differences in rates of prior myocardial infarction (MI) or usage of preoperative intra-aortic balloon pump (IABP). The number of patients undergoing combined CABG and valve procedures progressively increased by increasing age group (Figure 1: 4% versus 9% versus 11% versus 16%, $P < .01$). There were no significant differences in cardiopulmonary bypass use or operative time. The median follow-up time was 7.0 years (interquartile range, 3.0-12.1 years) (Table 1) (Figure 1).

With all age groups combined, the cohort had an all-cause mortality of 27.9% and a 30-day mortality of 2.0%. All-cause mortality progressively increased with increasing age groups (19% versus 25% versus 47% versus 46%, $P < .01$). In contrast, 30-day mortality among age groups demonstrated a trend only and was not statistically significant across age groups (1.4% versus 1.7% versus 2.4% versus 4.4%, $P = .07$). The postoperative morbidity profile significantly differed ($P < .01$) between groups, with increased rates of pulmonary complications, renal failure, and postoperative atrial fibrillation seen in older age groups (Table 2). Of note, there was no statistically significant differences in all-cause mortality for off-pump versus on-pump CABG (26.3% versus 29.3%; $P = .18$).

Risk-adjusted survival analysis was performed to analyze the independent effect of age on survival. Kaplan-Meier survival analysis showed that age remained significantly associated with time to all-cause mortality (log-rank $P < .01$). (Figure 2) Significant differences in survival were observed with lower long-term survival rates noted in the 70-79 years old and ≥80 years old groups. Multivariable analysis showed using patients 59 years old or younger as a reference point, the 70-79 years old group had a mortality hazard ratio of 2.15 (95% CI, [1.63 – 2.83], $P < .01$) and the ≥80 years old group had a hazard ratio of 2.94 (95% CI, [2.07 – 4.17], $P < .01$) (Figure 3). Adjusted hazard ratio for the 60-69 years old group was not statistically significant (aHR 1.09 [0.83-1.42], $P = .53$).

DISCUSSION

In this study, we gained valuable insights about our veterans who undergo cardiac surgery in the modern era. The analysis of our 20-year data has shown that select patients of varying ages, including the elderly population, can have good outcomes after cardiac surgery. However, chronological age still is a significant predictor of morbidity and long-term mortality in veterans undergoing cardiac surgeries, despite significant improvement in perioperative care and improved medical therapy.

In terms of patient demographics, as expected, the veterans at our institution demonstrated higher overall rates of most measured preoperative comorbidities across all age groups versus what is reported in the literature on the civilian population [Ngaage 2011]. Comparable to the pattern seen in the civilian literature, more elderly patients had higher rates of most preoperative comorbidities versus younger patients. However, unlike civilian populations, our observed cardiac comorbidity rates did not significantly differ and were found to be uniformly high across age groups [Ngaage 2011]. A larger proportion of our elderly veterans required more complex and combined procedures compared with their younger counterparts, which also has been observed in civilian data [Wang 2014]. The progressively higher rates of smoking in younger patients needing cardiac surgery was a similar finding also seen in Medicare civilian data [Jones 2011; Saxena 2013]. Unlike the civilians undergoing cardiac surgery, our cohort of patients were mostly male [McNeely 2016]. Over 50% of this particular cohort from the VA underwent procedure off-pump, which is due to the operator expertise in our center and likely a deviation from the majority of practices nationwide.

We found the overall outcomes of our veterans undergoing cardiac surgery at our center over the last 20 years to be very encouraging. The 30-day mortality at our center was 2.0%, which was comparable to the top-ranked hospitals around the country and general reports of Medicare-age patients undergoing cardiac surgeries in the civilian population [McNeely 2016; Wang 2018]. For example, one recent study showed an average 30-day mortality of 2.3% for patients undergoing a CABG procedure from 2014-2017 at the 50 top-ranked private sector US hospitals [Wang 2018].

The advancement in technology and perioperative care has pushed the boundaries of cardiac surgery, allowing older patients to safely undergo procedures. The proportion of older patients undergoing cardiac surgeries only has increased over the years and likely will continue to do so given the baby boomer generation reaching ages above 70 years old [McNeely 2016; Wang 2014]. As several centers around the country have observed positive outcomes, a growing amount of data has been presented suggesting that survival for octogenarians is comparable to that of the matched population, and the surgical risk of octogenarians undergoing cardiac surgery has been overestimated [Alexander 2000; Cane 1995]. Select groups of elderly patients clearly have shown in randomized trials and other observational studies an improved long-term survival compared with optimum medical therapy even in age groups greater than 80 years old [Graham 2002; TIME Investigators 2001]. These studies have resulted in an increased focus on the patient frailty or the "biological age" of the patient being the more relevant factor in outcomes after cardiac surgery [Farquharson 2001; Lee 2010; Rowe 2014]. Our study echoed these sentiments in that the 30-day mortality across different age groups was comparable. However, in long-term follow up, age still became a strong predictor of death, especially in patients older than 70 years old. Although it is imperative to take into account the full clinical picture of patient- and pathology-related factors when making decisions to move forward with surgery, the effect of chronological age cannot be discounted. Moreover, technical choices regarding the conduct of operations play a key role, as the high rate of off-pump CABG in our elderly patients with low perioperative mortality suggests off-pump CABG may be a preferred technique to attenuate perioperative risks for select high-risk older patients.

There are two interesting findings, regarding age in our data. The survival difference between the ≤59 years old group and the 60-69 years old group was not significant, while there was a significant decline in survival in the higher age groups, starting with the 70-79 years old group. Survival also diverged between the 70-79 years old group versus the ≥80 years old group, but not until more than 2 years after the initial surgery. This result echoes similar findings in the civilian sector that the relationship between age and prognosis is a non-linear relationship [Afilalo 2016]. The result of our study shows that, regarding our veterans, a more sophisticated accounting for prognosis-based age cutoffs for cardiac surgeries is in order.

There are several limitations to our study. This is a retrospective study of a prospectively collected database and is subject to certain biases and confounding variables inherent to such a design. Also, the data collected primarily were derived from a single experienced operator, and therefore this limits the ability of the study to be extrapolated to all practices. Lastly, although the VA healthcare system, due to its integration with governmental data, has an excellent follow up in terms of long-term mortality, we are not able to describe the patient's functional status and quality of life following the surgery using our database.

In conclusion, age still is an important predictor of survival in veterans undergoing cardiovascular surgery. Although it is important to consider the overall clinical picture of the patient, patient age should be taken into account, when making decisions to proceed with surgery. Our data show that although older patients perform well in the perioperative period, the incremental long-term mortality risk with increasing age after 70 years old sharply increases in a nonlinear fashion. A more sophisticated prognostic model may help us guide more informative discussion with our veterans who plan to undergo cardiac surgery.

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