Proximal aortic surgery in the elderly population: Is advanced age a contraindication for surgery?

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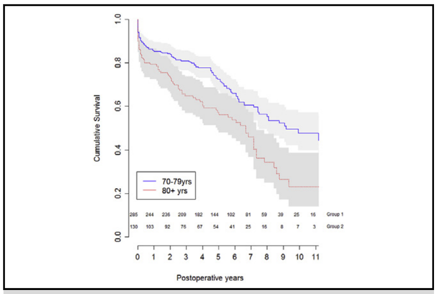
ABSTRACT

Objective: The study objective was to describe the clinical outcomes of elderly patients undergoing ascending aortic surgery.

Methods: Patients aged 70 years or older who underwent ascending aortic surgery between January 2002 and December 2013 were examined. Of 415 included patients, 285 were elderly patients (age 70-79 years) and 130 were very elderly (age $\geq$80 years). Logistic regression and Cox proportional hazards models were used to evaluate operative mortality and long-term survival, respectively.

Results: Surgical indications included aortic aneurysm (63.1%), calcified aorta with need for other cardiac procedure (26.4%), and type A dissection (10.5%). Compared with elderly patients, the very elderly patients had a higher burden of comorbidities and operative mortality (13% vs 7%, $P < .04$). The very elderly patients were also more likely to be discharged to a rehabilitation facility than home ($P < .001$). However, risk-adjusted operative mortality and 30-day readmissions rates were similar ($P > .05$). Kaplan–Meier estimates of survival at 1 and 5 years were 85.6% and 72.6% for elderly patients versus 79.2% and 57.1% for the very elderly patients. Age was a strong risk variable for late mortality in the unadjusted and adjusted analyses.

Conclusions: After adjusting for these comorbidities, the cause of aortic disease, and the type of procedure, age was not an independent predictor of operative mortality, but was strongly associated with reduced late survival. Thus, advanced age alone should not be an absolute contraindication for ascending aortic surgery. (J Thorac Cardiovasc Surg 2019;157:53-63)



Cox proportional hazards survival for elderly patients who underwent AA surgery.

Central Message

Advanced age alone should not be an absolute contraindication for AA surgery in elderly patients. Instead, AA cause and comorbidities are determinants of clinical outcomes.

Perspective

There is an increasing prevalence of older patients undergoing cardiac surgery. This study demonstrates adequate short- and long-term outcomes in this population after proximal aortic surgery. After careful consideration of patient comorbidities, aortic cause, and procedure type, advanced age alone should not be an absolute contraindication for ascending aortic surgery.

See Editorial Commentary page 64.

The proportion of patients aged 80 years or older undergoing coronary artery bypass grafting (CABG) and aortic valve surgeries has been growing steadily over the past 2 decades.[1] Operative mortality and risks of serious complications after these procedures have also greatly decreased over the years.[2,3] Several studies have examined outcomes in older patients undergoing aorta replacement for acute dissection.[4,5] However, there is insufficient literature on patients undergoing replacement for calcified or aneurysmal aorta.[6] Most of these studies have further shown poor outcomes, which have been largely attributed to patient factors such as age, emergency surgery,

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Abbreviations and Acronyms

AA	= ascending aorta
CABG	= coronary artery bypass grafting
CI	= confidence interval
DHCA	= deep hypothermic circulatory arrest
HR	= hazard ratio
IQR	= interquartile range
LVEF	= left ventricular ejection fraction
NYHA	= New York Heart Association

and preoperative shock.[7,8] These patients are also at increased risk of stroke, bleeding, and progressive organ dysfunction, which negatively affect postoperative survival.

Despite advancements in surgical techniques, anesthesia care, and perioperative management, cardiac surgeons are often hesitant to operate on older patients because of concerns of frailty and comorbidities.[9] Furthermore, these concerns may often tend to preclude such patients from being referred for surgery.[10] Some clinicians have further argued that ascending aorta (AA) surgery in the elderly and very elderly carries a prohibitive risk, particularly when it requires hypothermic circulatory arrest.[11] Thus, there is still debate on whether the benefits of AA surgery in very elderly patients outweigh the risks.

The current study examines outcomes in elderly and very elderly patients undergoing AA surgery at a single academic tertiary care center. We sought to investigate the impact of age on outcomes after AA surgery and whether age-associated risks were mediated by surgical indication or other patient comorbidities. We hypothesized that advanced age alone would not be a contraindication to AA surgery.

MATERIALS AND METHODS

Patient Cohort and Data Collection

After approval from Brigham and Women's Hospital Institutional Review Board, we identified all patients aged 70 years or older who underwent surgical replacement of the AA for aneurysm, calcified aorta, or acute dissection between January 2002 and December 2013. Patients with other surgical indications, patients who underwent nonascending aortic surgery, and patients who underwent an isolated aortic endarterectomy were excluded. A total of 415 patients, 285 elderly patients (age 70-79 years or group 1) and 130 very elderly patients (age ≥80 years or group 2) met inclusion criteria. Patient characteristics, perioperative data, laboratory results, and in-hospital outcomes, without any missing data, were recorded at the time of presentation and extracted from hospital electronic medical records. Variables were coded to Society of Thoracic Surgeons Adult Cardiac database, version 2.52 specifications unless otherwise noted. Long-term survival data were obtained from our internal research data repository, routine patient follow-up, and our state Department of Public Health.

Surgical Technique

The selection criteria for performing a surgical replacement of the AA was left at the surgeons' discretion at the time of the surgery and in accordance with the guidelines.[12] Most of the frailty assessment was only done informally by the surgeon during preoperative evaluation without an objective score. Operative techniques were consistent across the institution and have been previously described.[13,14] In terms of cerebral protection strategies, deep hypothermic circulatory arrest (DHCA) was performed to 18°C. Cerebral protection adjuncts such as retrograde cerebral perfusion, antegrade cerebral perfusion, or both were used at the discretion of the surgeon. This is because our group has previously demonstrated comparable outcomes and survival using DHCA alone or adjunct cerebral protection methods during noncomplex hemiarch surgery. Antegrade cerebral perfusion was unilateral with axillary cannulation. Cerebral oximetry was also used. Moderate hypothermic circulatory arrest was started from 2015 after the study's inclusion.[15]

Outcomes of Interest

Primary outcomes of interest were operative mortality and long-term survival. Secondary outcomes included postoperative complications and length of stay. These outcomes were examined in both the overall cohort and between the 2 groups. Because patients in each group underwent aortic surgery for different indications, we also further stratified these patients according to their aortic disease pathology, that is, in terms of dissection, aneurysm, and calcified disease requiring surgical replacement of the AA to complete the primary surgery. There was 99% follow-up for patient survival. Survival time was calculated in months from the date of surgery to the date of death or October 30, 2015, or censored at last known clinical contact if lost to follow-up. Comparison data of survival in an age- and gender-matched cohort were calculated using 2008 United States census data.[16] Median follow-up time was 58 months (interquartile range [IQR], 27-84) for the entire cohort and 60 months (IQR, 32-88) and 48 months (IQR, 20-78) for group 1 and group 2, respectively.

Statistical Analyses

Normally distributed continuous variables are expressed as mean with standard deviation and were compared using Student *t* tests with Levene's test for homogeneity of variance. Non-normally distributed variables are expressed as median and IQR, and were compared using Mann–Whitney *U* tests. Categoric variables are presented as frequencies and percentages, and compared using chi-square or Fisher exact tests. Longitudinal survival was estimated by Kaplan–Meier analyses. A forward logistic regression was used to evaluate adjusted operative mortality, and a forward-stepwise Cox proportional hazards model was used to evaluate long-term survival. For both multivariable analyses, variables were selected on the basis of their known association with operative mortality or contribution to all-cause mortality, or if deemed clinically relevant, retention criteria was set at .05 and removal was set at .10. All analyses were conducted using IBM SPSS Statistics version 23.0 (IBM Corporation, Armonk, NY).

RESULTS

Overall Patient Demographics

The mean age for the entire cohort was 77 ± 4.8 years, which included 190 women (45.8%). Overall, these patients had a high burden of cardiovascular disease; 79.5% had hypertension, 40% had peripheral vascular disease, 7.4% had (permanent) stroke history, and 35.7% were in congestive heart failure in the 2 weeks before surgery. Aortic aneurysm was the most common surgical indication (63.1%), followed by calcified aorta (26.4%), which was significantly more common in group 2 than group 1 ($P = .03$). A total of 43 patients (10.5%) presented with type A dissections, including 32 patients (74.4%) who presented with acute dissections. Of these, 18 patients (56.2%) had an uncomplicated presentation profile per Penn Class Aa classification. The proportion of patients with Class

Ab (localized ischemia with branch perfusion), Class Ac (generalized ischemia with circulatory collapse), and Class Abc (localized and generalized ischemia) presentation profile was 9 patients (28.1%), 3 patients (9.4%), and 2 patients (6.3%), respectively. Moreover, of the 46 patients (11.1%) who had prior cardiac surgery, only 5 patients (1.2%) had previous aortic aneurysm or AA surgery. In terms of patient groups, group 2 patients were more likely to be women (55% vs 42%, $P = .019$), with a greater prevalence of preoperative renal failure ($P = .043$) and congestive heart failure ($P = .036$) compared with group 1 patients (Table 1).

TABLE 1. Preoperative demographics characteristics of elderly patients undergoing proximal aortic surgery

	All (n = 415)	Age 70-79 y (group 1) (n = 285)	Age 80-93 y (group 2) (n = 130)	Standardized differences	*P*
Age (y)	77.0 (4.8)	74.4 (2.8)	82.8 (2.5)		
Women	190 (45.8)	119 (41.8)	71 (54.6)	−0.21	≤.019*
BSA	1.88 (0.22)	1.92 (0.23)	1.79 (0.19)	−0.27	≤.001*
BMI	27.3 (5.1)	27.8 (5.1)	26.1 (4.9)	−0.73	≤.002*
Renal failure	31 (7.4)	16 (5.6)	15 (11.5)	0.17	≤.043*
Preoperative creatinine	1.18 (0.65)	1.16 (0.7)	1.21 (0.53)	0.068	≤.441
Estimated GFR	61.4 (19.9)	63.2 (19.2)	57.3 (20.8)	−1.33	≤.006*
Diabetes	64 (15.4)	48 (16.8)	16 (12.3)	−0.12	≤.305
Hypercholesterolemia	286 (68.9)	203 (71.2)	83 (63.8)	−0.13	≤.138
HTN	330 (79.5)	227 (79.6)	103 (79.2)	−0.080	≤1.000
History of stroke (permanent)	31 (7.4)	22 (7.7)	9 (6.9)	−0.025	≤.843
Cerebrovascular disease	66 (15.9)	47 (16.5)	19 (14.6)	−0.043	≤.667
PVD	166 (40)	114 (40)	52 (40)	0.00	≤1.000
Previous MI	59 (14.2)	44 (15.4)	15 (11.5)	−0.10	≤.363
CHF	148 (35.7)	92 (32.3)	56 (43.1)	0.18	≤.036*
NYHA Class III/IV	144 (34.7)	90 (31.6)	54 (41.5)	0.17	≤.059
euroSCORE II	7.24 (4.6-12.5)	6.29 (4.11-11.1)	9.57 (6.5-13.0)	0.014	≤.001
Cardiogenic shock	4 (1)	1 (0.4)	3 (2.3)	0.13	≤.093
Ejection fraction (%)†	60 (50-60)	60 (50-60)	55 (45-60)	−0.47	≤.265
Emergency/salvage status	24 (5.7)	18 (6.3)	6 (4.6)	−0.063	≤.651
Previous CABG or valve procedure (cardiac surgery)	46 (11.1)	30 (10.5)	16 (12.3)	0.045	≤.615
Previous AA surgery	5 (1.2)	3 (1.1)	2 (1.5)	0.028	≤.615
Indication for aorta surgery					
Aneurysm	262 (63.1)	189 (66.3)	73 (56.1)		≤.050
Calcified	110 (26.4)	66 (23.3)	43 (33.3)		≤.033
Dissection	43 (10.5)	30 (10.4)	14 (10.6)		≤1.000
Acute	32 (74.4)	23 (76.7)	9 (69.2)		≤.710
Chronic	11 (25.6)	7 (23.3)	4 (30.8)		≤.710
Penn Classification‡					
Aa	18 (56.2)	13 (56.5)	5 (55.6)		≤1.000
Ab	9 (28.1)	6 (26.1)	3 (33.3)		≤.654
Ac	3 (9.4)	2 (8.7)	1 (11.1)		≤1.000
Abc	2 (6.3)	2 (8.7)	0 (0)		≤1.000
Follow-up time (mo)	58 (27-84)	60 (32-88)	48 (20-78)		

Penn classifications: Aa (no ischemia), Ab (localized ischemia with branch malperfusion), Ac (generalized ischemia with circulatory collapse), Abc (localized and generalized ischemia). *BSA*, Body surface area; *BMI*, body mass index; *GFR*, glomerular filtration rate; *HTN*, hypertension; *PVD*, peripheral vascular disease; *MI*, myocardial infarction; *CHF*, congestive heart failure; *NYHA*, New York Heart Association; *euroSCORE*, European System for Cardiac Operative Risk Evaluation; *CABG*, coronary artery bypass grafting; *AA*, aortic aneurysm. *Denotes statistical significance ($P \leq .05$). Continuous variables are presented as mean/standard deviation unless otherwise noted as median/IQR; categoric variables are summarized as n (%). †All and age 70 to 79 years have same distributions at 25th and 75th percentiles (but not at 10th and 90th). ‡Penn classification for only patients presenting with acute dissection.

Operative Characteristics and In-Hospital Outcomes of Overall Cohort

Table 2 shows the operative and postoperative outcomes between the 2 groups. More than half (231 patients) of the surgeries involved only the AA, followed by AA with hemiarch or total arch (21%), and concurrent aortic root and AA (14.9%). The operative characteristics of both groups were substantially similar, except for cerebral protection techniques. Notably, DHCA was used in most patients (72.1%), followed by retrograde cerebral perfusion

TABLE 2. Operative characteristics and in-hospital outcomes of elderly patients undergoing proximal aortic procedures

Operative	All (n = 415)	Age 70-79 y (group 1) (n = 285)	Age 80-93 y (group 2) (n = 130)	*P*
Aorta intervention				
AA	231 (55.7)	153 (53.7)	78 (60)	≤.242
AA + arch/hemiarch	87 (21)	65 (22.8)	22 (16.9)	≤.194
Root + SAA	62 (14.9)	34 (11.9)	28 (21.5)	≤.017*
Root + AA + arch/hemi-arch	29 (7)	29 (10.2)	0 (0.0)	≤.001*
Root	6 (1.4)	4 (1.4)	2 (1.5)	≤1.000
Concomitant procedures				
CABG	182 (43.9)	122 (42.8)	60 (46.2)	≤.525
AV	291 (70.1)	199 (69.8)	92 (70.8)	≤.908
MV	59 (14.3)	38 (13.4)	21 (16.2)	≤.818
TV	13 (3.2)	11 (3.8)	3 (2.0)	≤.782
Perfusion time (min)	189 (148-238)	187 (150-238)	191 (144-233)	≤.965
Cerebral protection				≤.001*
DHCA	299 (72.1)	187 (65.6)	112 (86.4)	
Antegrade	15 (3.6)	14 (4.9)	1 (0.8)	
Retrograde	47 (11.4)	39 (13.7)	8 (6.2)	
Lower body perfusion	18 (4.3)	18 (6.3)	0 (0)	
Crossclamp time (min)	116 (82-155)	121 (89-156)	110 (74-151)	≤.099
Transfused with pRBC	184 (44.3)	119 (41.4)	65 (50)	≤.044*
pRBC transfused	3 (2-4)	2 (2-4)	3 (2-4)	≤.732
Postoperative				
Reoperative for bleed	15 (3.6)	12 (4.2)	3 (2.3)	≤.409
Stroke/TIA	33 (8)	22 (7.5)	11 (8.5)	≤.845
Renal failure (new onset)	30 (7.1)	14 (4.8)	16 (12.1)	≤1.000
Ventilation time (h)	11 (6-23)	10 (6-20)	15 (8-38)	≤.010*
ICU stay (h)	71 (38-131)	71 (35-121)	71 (42-158)	≤.263
Transfused with pRBC	181 (43.6)	118 (41.4)	63 (48.5)	≤.138
pRBC transfused	3 (2-6)	2 (2-5)	4 (2-8)	≤.131
Postoperative LOS (d)	9.0 (7)	9.0 (6.5)	9.5 (8.5)	≤.034*
Operative mortality	36 (8.7)	19 (6.7)	17 (13.1)	≤.039*
Operative mortality with Penn Classification†				
Aa	5 (1.2)	1 (0.4)	4 (3.1)	
Ab	1 (0.2)	1 (0.4)	0 (0)	
Ac	1 (0.2)	1 (0.4)	0 (0)	
Abc	0 (0)	0 (0)	0 (0)	
Discharged status				
Home	197 (51.7)	160 (59.7)	37 (32.7)	≤.001*
Rehabilitation facility	180 (47.1)	108 (40.3)	72 (63.3)	≤.001*
Readmission with 30 d	65 (17.1)	42 (15.7)	23 (20.4)	≤.297

Penn classifications: Aa (no ischemia), Ab (localized ischemia with branch malperfusion), Ac (generalized ischemia with circulatory collapse), Abc (localized and generalized ischemia). *AA*, Ascending aorta; *SAA*, saccular aortic aneurysm; *CABG*, coronary artery bypass grafting; *AV*, aortic valve; *MV*, mitral valve; *TV*, tricuspid valve; *DHCA*, deep hypothermic circulatory arrest; *pRBC*, pack of red blood cells; *TIA*, transient ischemic attack; *ICU*, intensive care unit; *LOS*, length of stay. *Denotes statistical significance ($P \leq .05$). Continuous variables are presented as mean/standard deviation unless otherwise noted as median/IQR; categoric variables are summarized as n (%). †Penn classification for only patients presenting with acute dissection.

(11.4%). Group 2 was more likely to require packed red blood cell transfusion in the operating room ($P = .044$), but the units per transfused patients did not differ. Additionally, operative mortality was significantly higher among group 2 versus group 1 patients (13.1% vs 6.7%, $P = .039$), with 9 of the 36 (21%) deaths occurring in patients presenting with dissection. Postoperatively, the incidence of stroke was 8%, reoperations rate for bleeding was 3.6%, and new-onset renal failure was 7.1%. Overall, median length of stay was 9 days (IQR, 7-14) and was statistically significant between the 2 groups (9.0 in group 1 vs 9.5 in group 2, $P = .034$). Group 2 patients were more likely to be discharged to a rehabilitation facility (63.3% vs 40.3%, $P = .001$) than home (32.7% vs 59.7%), compared with group 1 patients. However, there was no difference in 30-day readmission rates between the 2 groups. Moreover, percentage mortality in Class Aa was 1.2%, whereas that in Class Ab and Ac was 0.2% and 0.2%, respectively. There was no mortality observed in the Class Abc group. However, these numbers were too low to assess the relationship between the Penn classification and the perioperative outcomes.

Patient Demographics and In-Hospital Outcomes Stratified by Aortic Disease Cause

Demographic characteristics of elderly and very elderly patients, stratified by the indication for proximal aortic surgery, are summarized in Table 3. In both groups, patients with calcified aorta notably had significantly higher incidences of comorbidities associated with metabolic disorders such as diabetes and hypercholesterolemia compared with those with aortic aneurysms.

In terms of in-hospital outcomes by disease indication as highlighted in Table 4, overall operative mortality was 4.2% in the aneurysm group and similar between group 1 and group 2 ($P = .19$). Likewise, operative mortality was 14.4% in the overall calcified aorta group, but there was no statistical difference between group 2 and group 1 patients (18.2% vs 12.3%, $P = .42$). Rates of stroke, new-onset renal failure, intensive care unit length of stay, and number of units of packed red blood cells transfused in the operating room were similar between the 2 groups of patients undergoing surgery for aneurysm or calcified aorta indications ($P > .05$). The acute dissection group overall had the highest proportion of in-hospital mortality (21%), and it was almost twice as much among group 2 patients (30.8%) compared with group 1 patients (16.7%).

With only 36 events (deaths) overall, we did a sparse logistic regression modeling to assess the contribution of age to operative mortality. Surgical indication (for calcified aorta or acute dissection), concomitant CABG, New York Heart Association (NYHA) class III/IV, and elevated preoperative creatinine were all predictive of operative mortality ($P < .05$). When adjusting for these confounders, age was not a significant predictor of operative mortality ($P = .20$).

Long-Term Survival

Kaplan–Meier estimates of survival at 1 and 5 years were 85.6% and 72.6% for elderly patients versus 79.2% and 57.1% for the very elderly patients, respectively (Figure 1). The estimated median survival for very elderly patients (group 2) was 6.8 years (95% confidence interval [CI], 5.5-7.9), compared with the US population expected median survival of 7.4 years (Figure 2). Stratified by cause, the estimated median survival was 7.6 years (95% CI, 6.3-8.9) for aortic aneurysm, 4.2 years (95% CI, 3.1-5.7) for the calcified aorta, and 3.9 years (95% CI, 1.8-6.1) for the acute dissection group.

Significant patient characteristics adversely affecting survival were determined using a multivariable Cox proportional hazard model (Table 5). Our analysis showed concomitant CABG (hazard ratio [HR], 1.76; 95% CI, 1.27-2.45; $P = .001$), increased serum creatinine (HR, 1.29; 95% CI, 1.09-1.52; $P = .003$), presence of cerebrovascular disease (HR, 1.78; 95% CI, 1.26-2.55; $P = .002$), NYHA class III/IV (HR, 1.69; 95% CI, 1.22-2.34; $P = .001$), and increasing age (HR, 1.07/year; 95% CI, 1.04-1.10/year; $P = .001$) as significant risk factors for decreased long-term (late) survival.

In our model, there was also a significant interaction between the cause of aortic disease and left ventricular ejection fraction (LVEF), stratified into low LVEF (≤35%) or normal LVEF (>35%), for decreased long-term survival ($P = .001$). Compared with patients whose underlying aortic disease was an aortic aneurysm with a normal LVEF, all other groups had a progressively higher risk for long-term mortality. For instance, patients with aortic dissection with low LVEF had the highest (ie, 5-fold) increased risk of long-term mortality (HR, 5.46; 95% CI, 1.95-15.33; $P = .001$).

Gender, smoking status, diabetes, prior (permanent) stroke, peripheral vascular disease, congestive heart failure, aortic stenosis, and aortic insufficiency were not contributory (all $P > .12$). We also performed a trend analysis to assess whether there was an era effect. Our temporal analysis of outcomes of interest did not reveal any significant variation across the selected study period and no era effect (Figure 3).

DISCUSSION

Elderly patients undergoing aortic surgery have satisfactory outcomes despite their burden of comorbidities, which often places them at increased surgical or prohibitive risk. Our study highlighted several noteworthy findings. First, patients aged 80 to 93 years (group 2 or very elderly), irrespective of the underlying aortic disease pathology or indication, had relatively higher unadjusted operative mortality

TABLE 3. Demographic characteristics of elderly patients, stratified by the indication for proximal aortic surgery

Age 70-79 y (group 1)	Aneurysm (n = 190)	Calcified (n = 65)	Dissection (n = 30)	P*
Age (y)	74.2 (2.9)	74.5 (2.8)	75.2 (2.6)	≤.388
Women	70 (36.9)	35 (53.8)	14 (46.7)	≤.020
BSA	1.93 (0.22)	1.88 (0.25)	1.87 (0.22)	≤.247
BMI	27.6 (4.5)	28.4 (6.4)	27.9 (5.7)	≤.082
Renal failure	5 (2.6)	11 (16.9)	0.0 (0)	≤.001
Preoperative creatinine	1.11 (0.53)	1.39 (1.10)	1.02 (0.32)	≤.005
Estimated GFR	65.0 (17.5)	55.2 (19.3)	69.9 (23.7)	≤.001
Diabetes	23 (12.1)	21 (32.3)	4 (13.3)	≤.001
Hypercholesterolemia	128 (67.3)	60 (92.3)	15 (50)	≤.001
HTN	144 (75.8)	58 (89.2)	25 (83.3)	≤.021
History of stroke (permanent)	11 (5.8)	7 (10.8)	4 (13.3)	≤.259
Cerebrovascular disease	24 (12.6)	18 (27.7)	5 (16.7)	≤.007
PVD	61 (32.1)	37 (56.9)	16 (53.3)	≤.001
Previous MI	18 (9.5)	22 (33.8)	4 (13.3)	≤.001
CHF	48 (25.3)	39 (60.0)	5 (16.7)	≤.001
NYHA class III/IV	50 (26.3)	34 (52.3)	2 (6.7)	≤.001
Cardiogenic shock	0.0 (0)	0.0 (0)	1 (3.3)	
Ejection fraction (%)	60 (45-65)	55 (40-60)	60 (45-55)	≤.262
Emergency/salvage status	0.0 (0)	3 (4.6)	15 (50)	≤.016
Previous CABG or valve procedure	15 (7.9)	7 (10.8)	8 (26.7)	≤.453
Age ≥80 y (group 2)	**Aneurysm (n = 73)**	**Calcified (n = 44)**	**Dissection (n = 13)**	***P****
Age (y)	82.6 (2.4)	83.1 (2.9)	82.8 (2.2)	≤.296
Women	39 (53.4)	25 (56.8)	7 (53.8)	≤.705
BSA	1.80 (0.19)	1.78 (0.18)	1.76 (0.25)	≤.468
BMI	25.8 (4.5)	26.3 (4.3)	27.3 (7.3)	≤.595
Renal failure	2 (2.7)	10 (22.7)	3 (23.1)	≤.001
Preoperative creatinine	1.09 (0.31)	1.34 (0.48)	1.13 (0.30)	≤.003
Estimated GFR	60.9 (18.1)	50.7 (19.9)	59.3 (31.5)	≤.028
Diabetes	4 (5.5)	10 (22.7)	2 (15.4)	≤.007
Hypercholesterolemia	41 (56.2)	34 (77.3)	8 (61.5)	≤.029
HTN	57 (78.1)	37 (84.1)	9 (69.2)	≤.483
History of stroke (permanent)	4 (5.5)	4 (9.1)	1 (7.7)	≤.469
Cerebrovascular disease	11 (15.1)	6 (13.6)	2 (15.4)	≤1.000
PVD	28 (38.4)	18 (40.9)	6 (46.2)	≤1.000
Previous MI	7 (9.6)	7 (15.9)	1 (7.7)	≤.379
CHF	27 (37)	26 (59.1)	3 (23.1)	≤.022
NYHA Class III/IV	24 (32.9)	26 (59.1)	4 (30.8)	≤.007
Cardiogenic shock	0.0 (0)	2 (4.5)	1 (7.1)	≤.137
Ejection fraction (%)	60 (45-65)	55 (40-60)	55 (45-55)	≤.693
Emergency/salvage status	0.0 (0)	1 (2.3)	5 (38.5)	≤1.000
Previous CABG or valve procedure	10 (13.7)	3 (6.8)	3 (23.1)	≤.366

BSA, Body surface area; *BMI*, body mass index; *GFR*, glomerular filtration rate; *HTN*, hypertension; *PVD*, peripheral vascular disease; *MI*, myocardial infarction; *CHF*, congestive heart failure; *NYHA*, New York Heart Association; *CABG*, coronary artery bypass grafting. *Denotes statistical significance ($P \leq .05$). *P* value corresponds to comparison between aneurysm and calcified categories because the n for dissection group was too small. Continuous variables are presented as mean/standard deviation unless otherwise noted as median/IQR; categoric variables are summarized as n (%).

TABLE 4. In-hospital outcomes in elderly patients, stratified by the indication for proximal aortic surgery

Aneurysm	All (n = 263)	Age 70-79 y (group 1) (n = 190)	Age 80-93 y (group 2) (n = 73)	*P*
Reoperation for bleed	9 (3.4)	8 (4.2)	1 (1.4)	≤.452
Stroke/TIA	19 (7.2)	17 (8.9)	2 (2.7)	≤.110
Renal failure (new onset)	13 (4.9)	6 (3.1)	7 (9.5)	≤.052*
Ventilator time (h)	9 (6-17)	9 (6-16)	12 (7-21)	≤.038*
ICU stay (h)	52 (29-97)	50 (27-96)	65 (41-115)	≤.366
Transfused with pRBC	92 (35)	64 (33.7)	28 (28.4)	≤.475
pRBC transfused	2 (1-5)	2 (1-5)	4 (1-6)	≤.463
Operative mortality	11 (4.2)	6 (3.2)	5 (6.8)	≤.185
Calcified	**(n = 109)**	**(n = 65)**	**(n = 44)**	***P***
Reoperation for bleed	2 (1.8)	1 (1.5)	1 (2.3)	≤1.000
Stroke/TIA	7 (6.3)	2 (3.1)	5 (11.4)	≤.116
Renal failure (new onset)	12 (10.7)	5 (7.5)	7 (15.9)	≤.213
Ventilator time (h)	15 (9-40)	14 (8-42)	16 (9-39)	≤.824
ICU stay (h)	92 (44-170)	97 (51-185)	76 (43-169)	≤.488
Transfused with pRBC	60 (54.1)	34 (52.3)	26 (59.1)	≤.558
pRBC transfused	3 (1-4)	3 (1-4)	3 (2-7)	≤.632
Operative mortality	16 (14.4)	8 (12.3)	8 (18.2)	≤.420
Dissection*	**(n = 43)**	**(n = 30)**	**(n = 13)**	
Reoperation for bleed	4 (9.3)	3 (10)	1 (7.7)	
Stroke/TIA	7 (16.3)	3 (10)	4 (30.8)	
Renal failure (new onset)	5 (11)	3 (10)	2 (13.3)	
Ventilator time (h)	24 (9-98)	21 (8-56)	98 (16-249)	
ICU stay (h)	237 (56-262)	109 (47-173)	215 (91-501)	
Transfused with pRBC	23 (54.2)	14 (46.7)	9 (71.4)	
pRBC transfused	5 (2-11)	3 (2-7)	13 (8-17)	
Operative mortality	9 (21)	5 (16.7)	4 (30.8)	

Denotes statistical significance ($P \leq .05$). Continuous variables are presented as mean/standard deviation unless otherwise noted as median/IQR; categoric variables are summarized as n (%). *TIA*, Transient ischemic attack; *ICU*, intensive care unit; *pRBC*, pack of red blood cells. *For dissection category, n too small to determine *P* values.

and morbidity compared with patients aged 70 to 79 years (group 1 or elderly). In the adjusted analysis, however, age was not a significant risk variable for operative mortality. Instead, only the underlying aortic disease (aortic dissection and calcified aorta), increased serum creatinine levels, presence of cerebrovascular disease, NYHA class III/IV, and concomitant CABG, instead of age, were significant contributors of operative mortality. The 30-day readmission rates were also similar between the 2 groups, although group 2 patients were half as likely to be discharged to home. Advanced age was strongly associated with reduced late survival. Together, these findings are significant and raise the argument that advanced age alone should not be an absolute contraindication for ascending aortic surgery in the elderly (Video 1).

In the current era, mortality rates for elective proximal AA replacement for aneurysmal disease reportedly range from 1.7% to 3.6% in the general population.[17] Although there is a paucity of literature examining outcomes on elective AA replacement in the elderly, mortality nearly quadrupled for those aged 80 years or more.[18] Moreover, patients undergoing AA replacements have an increased incidence of de novo stroke and death.[19] In our study, very elderly patients undergoing AA repairs for aneurysmal disease had an acceptable postoperative mortality rate (7%). Although unadjusted mortality differed significantly between the elderly (3%) and very elderly patients (7%), it compared favorably to previously reported studies in which mortality ranged from 9% to 16% in the very elderly patients undergoing any cardiac surgery. Interestingly, the incidence of postoperative stroke between these 2 patient cohorts was similar. However, we observed a statistically significant higher postoperative renal failure rate (12.1% vs 4.8%) among the very elderly cohort, keeping in mind that these patients

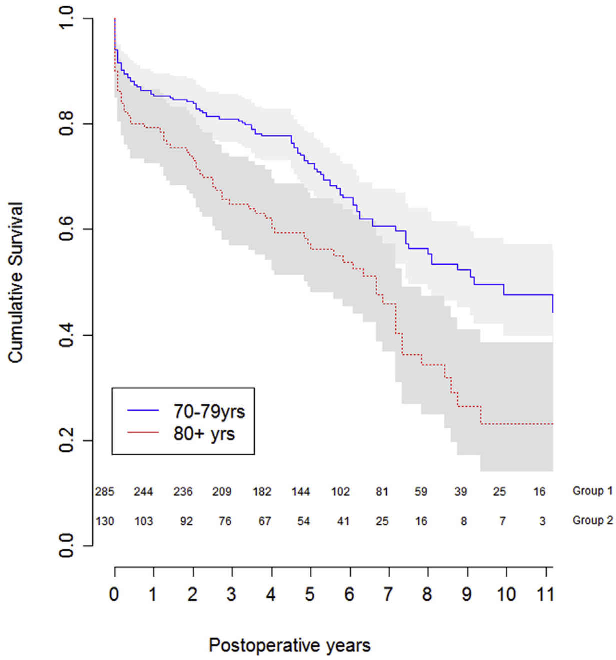


FIGURE 1. Cox proportional hazards survival for elderly patients who underwent AA surgery. The HR for age is 1.07/year, with stratification of the groups by decade (elderly, [70-79 years] vs very elderly [80+ years]) resulting in nonoverlapping survival curves.

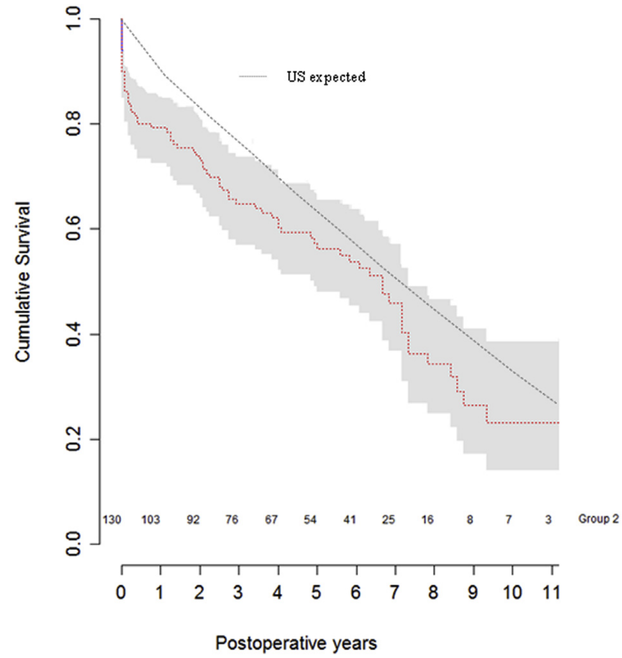


FIGURE 2. Kaplan–Meier survival curve for all patients aged 80 years and more (ie, very elderly; *red line*) who underwent AA surgery compared with the US expected median survival for 2008. US expected median survival was 7.4 years compared with estimated median survival of 6.8 years (IQR, 5.5-7.9) in the very elderly cohort.

already had a higher prevalence of existing renal failure within the 2 weeks before surgery (11.5% vs 5.6%; $P = .043$). It remains unclear whether these observed incidences of renal failure were a consequence of these patients' existing renal disease or secondary to the procedure itself, in the context of higher burden of other comorbidities.

In the context of this study, 110 (26.4%) of the 415 patients had resection for calcified aorta, which was proportionately more prevalent in the very elderly. These patients (ie, the very elderly) were also more chronically ill, with a higher burden of comorbidities. Not surprisingly, the number of concomitant operations was also high and greater in the very elderly. Moreover, aortic calcification in older patients is a relatively common perioperative finding, and although not an indication for surgery in most cases, it can increase the complexity of the procedure and the incidence of postoperative stroke. For instance, Zingone and colleagues[20] studied outcomes of aortic replacement in 64 patients with severe aortic atherosclerosis and reported mortality and stroke rates of 11% and 6%, respectively. Likewise, our institution previously reported outcomes in 122 patients with atherosclerotic aorta who underwent cardiac surgery and found similar mortality (8%) and stroke rates (10%).[21] The very elderly patients with calcified aorta clinically also seemed to have the second highest operative mortality (18.2%), but was not significantly different than in the elderly patients (12.3%; $P = .42$). Likewise, the very elderly cohort with calcified aorta had an approximately 4-fold increased incidence of stroke (11.3% vs 3.1%), which also did not reach statistical significance ($P = .12$).

Stroke is a feared complication in older patients and is perhaps the most important determinant in the decision-making process given the dire consequences both short- and long-term. The availability of percutaneous approaches has also shifted the paradigm in the selection process. With the inclusion of calcified aorta to the American College of Cardiology/American Heart Association guidelines as a high-risk feature for aortic valve replacement,[22] the majority of patients with aortic stenosis and calcified aorta will likely be expected to undergo transcatheter aortic valve replacement (TAVR) in the current era, given the results of recent Placement of AoRTic TraNscathetER Valve trials.[23] Likewise, there were patients receiving CABG and mitral valve surgery in this series, some of whom may also be candidates for percutaneous coronary interventions, hybrid revascularization approaches, minimally invasive cardiac surgery, including off-pump CABG without aortic manipulation, or transcatheter mitral valve operation.[24,25] Thus, the role of a heart team will be essential in determining the optimal treatment strategy and improving overall resource use.

Age and emergency procedure status have both been reported to individually increase the risk for operative

TABLE 5. Cox proportional hazard modeling for long-term survival in elderly patients undergoing proximal aortic surgery

Variable	HR	95% CI	*P*
Age (y)	1.07	(1.04-1.10)	≤.001
Creatinine (mg/dL)	1.29	(1.09-1.52)	≤.003
Cerebrovascular disease	1.78	(1.26-2.55)	≤.002
Concomitant CABG	1.76	(1.27-2.45)	≤.001
NYHA class III/IV	1.69	(1.22-2.34)	≤.001
Cause * LVEF			≤.001
Aortic aneurysm + LVEF ≤35%	1.41	(0.70-2.84)	≤.331
Calcified aorta + LVEF >35%	1.64	(0.66-4.05)	≤.284
Calcified aorta + LVEF ≤35%	1.87	(1.01-3.25)	≤.025
Aortic dissection + LVEF >35%	1.95	(1.23-3.09)	≤.004
Aortic dissection + LVEF ≤35%	5.46	(1.95-15.33)	≤.001

n = 415 patients and 178 deaths. The comparison group for the description of the interaction between aortic cause and LVEF are patients with an aortic aneurysm and a normal LVEF (>35%). Noncontributory variables include male gender, smoking history, diabetes, previous permanent stroke, peripheral vascular disease, congestive heart failure, aortic stenosis, and aortic insufficiency >2+. *HR*, Hazard ratio; *CI*, confidence interval; *CABG*, coronary artery bypass grafting; *NYHA*, New York Heart Association; *LVEF*, left ventricular ejection fraction.

mortality,[5] but controversy still exists on their association in older patients undergoing aortic surgery. Of note, in our study, elderly and the very elderly patients (who are the subject of this review) were all accepted for surgery, because they were considered to be operable. Conversely, although age is not an absolute contraindication, operability does decrease as the patient's age increases. Data from the International Registry of Acute Aortic Dissection showed less favorable outcomes for elderly patients (age ≥70 years) with a type A aortic dissection, with operative mortality as high as 37%.[26] Moreover, surgical compared with conservative management of acute aortic dissections in the elderly have shown significantly worse in-hospital mortality, respectively (26.7% vs 55.9%).[26] In our study, the very elderly patient cohort presenting with an acute type A dissection had almost twice the operative mortality compared with the elderly cohort (30.8% vs 16.7%), which was up to 4 times higher than that of a replacement for nonurgent indications (aneurysm or calcified aorta).

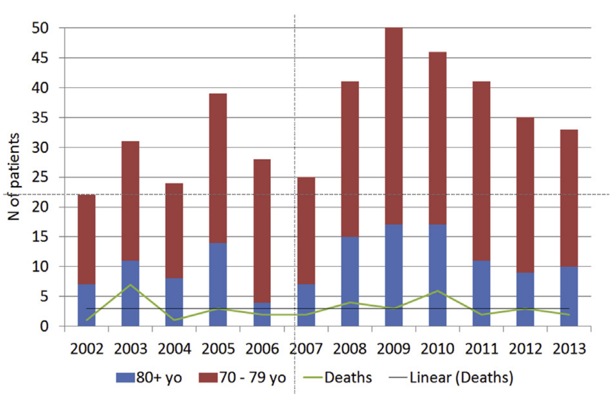
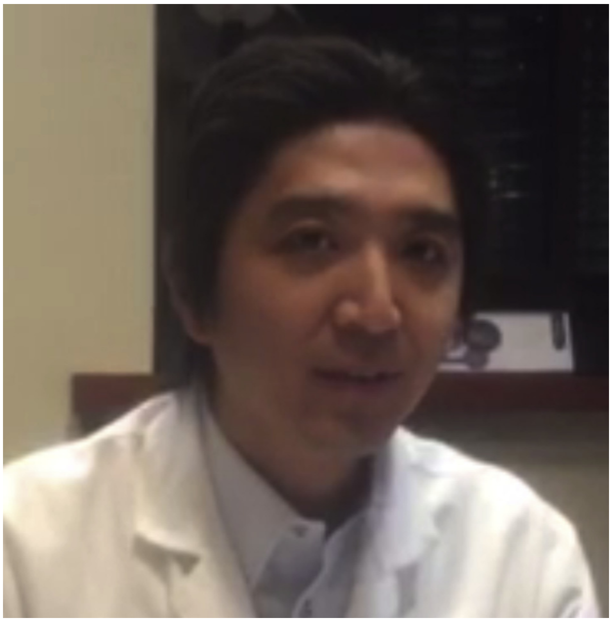


FIGURE 3. Temporal analysis of aortic procedures and hospital mortality from 2002 to 2013, stratified by age. Overall outcomes of interest did not vary significantly across the selected study period, with no learning effect observed.



VIDEO 1. Video showcasing the importance of our study and clinical implications. Video available at: https://www.jtcvs.org/article/S0022-5223(18)31239-X/fulltext.

Furthermore, age remains an important risk factor for aortic dissection, with a bimodal peak at age 60 and 80 years.[27,28] Although medical management has a high mortality (58%), there is often reluctance to operate on the elderly,[26] especially when their operative mortality is also still high (ie, 26%).[29] Previous studies have demonstrated the utility of Penn classification for acute dissections in predicting perioperative outcomes.[30-32] However, in our study, mortality numbers observed in Class Aa, Ab, Ac, and Abc patients were too low to assess the relationship between Penn classification and mortality. Although the sample size of patients with aortic dissection in our series was small, to substantially make any conclusions, our results raise an important argument suggesting that perhaps surgical treatment may have a role in low-risk patients, regardless of their age. Improvements in surgical technique and management of very elderly patients with acute dissections have also yielded significant reductions in operative mortality and morbidity throughout the decade, demonstrating the pivotal role of careful patient selection.[33]

In contrast, previous studies in very elderly patients, which focused on surgical outcomes after valvular and coronary procedures, have shown a constant linear relation between operative mortality and age, inelastic at extreme ages.[34] The validity of the age–mortality relationship is often questioned in the context of complex procedures such as aortic surgery, where age alone is often thought to have a higher impact on operative outcomes. Our findings dispute this perception; after adjusting for various operative risk factors, age did not have a significant effect on operative mortality in the adjusted analysis. The higher proportion of operative deaths in the very elderly was explained (in our model) by the heavier burden of significant comorbidities in these patients. Advanced age also was strongly associated with reduced late survival.

Study Limitations

Our study has a few limitations worth mentioning. Our study is subject to all the limitations of a single-center retrospective design, including unmeasured confounders and confounding by indication. In addition, selection bias is inherent to the decision process for surgical intervention, which was difficult to capture in our analysis. Moreover, patient frailty, quality of life, and independence are also important determinants of outcomes and decision making in the elderly population.[9,35] A single-center study by Ganapathi and colleagues[9] in elderly patients undergoing proximal aortic surgery found an association between patient frailty and discharge to other than home, and 30-day and 1-year mortality.[9] Unfortunately, all these factors were difficult to assess and adjust for in our analysis given the retrospective nature of this study. Further studies are warranted to elucidate and quantify the impact of frailty on preoperative patient selection and outcomes. Likewise, we limited the study to older patients only, so likely our ability to assess the incremental effect of older age may have been diminished. We presume that the ability to detect the influence of age would have been greater if younger patients were also included in this study. We also studied the elderly and the very elderly patients who were all accepted for surgery, because they were considered to be operable. We did not examine or study patients who were never referred for surgery or were turned down by the surgeon. This information is difficult to gather given our study design. Thus, our findings may not be readily generalizable to other populations but should be interpreted with caution in the decision-making process.

CONCLUSIONS

Our findings highlight the positive outcomes of aortic surgeries in the elderly and contextualize the importance of patient comorbidities. After adjusting for these comorbidities, the cause of aortic disease, and the type of procedure, age was not an independent predictor of operative mortality. However, advanced age was strongly associated with reduced late survival. The very elderly patients with aortic dissections had the lowest survival, followed by calcified aorta, whereas patients with aneurysm had similar estimated median survival compared with the expected median survival of the US population. Thus, advanced age alone should not be a contraindication for AA surgery, especially in patients with aneurysms and dissections. Additionally, the choice to operate on this patient population should be based more on their comorbidities and the cause of their aortic disease rather than advanced age alone.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

References

1. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, et al. Heart disease and stroke statistics-2016 update: a report from the American Heart Association. *Circulation*. 2016;133:e38-360.
2. Ghanta RK, Shekar PS, McGurk S, Rosborough DM, Aranki SF. Long-term survival and quality of life justify cardiac surgery in the very elderly patient. *Ann Thorac Surg*. 2011;92:851-7.
3. Thourani VH, Myung R, Kilgo P, Thompson K, Puskas JD, Lattouf OM, et al. Long-term outcomes after isolated aortic valve replacement in octogenarians: a modern perspective. *Ann Thorac Surg*. 2008;86:1458-65.
4. Piccardo A, Regesta T, Zannis K, Gariboldi V, Pansini S, Tapia M, et al. Outcomes after surgical treatment for type A acute aortic dissection in octogenarians: a multicenter study. *Ann Thorac Surg*. 2009;88:491-7.
5. Trimarchi S, Eagle KA, Nienaber CA, Rampoldi V, Jonker FH, De Vincentiis C, et al. Role of age in acute type A aortic dissection outcome: report from the international registry of acute aortic dissection (IRAD). *J Thorac Cardiovasc Surg*. 2010;140:784-9.
6. Okita Y, Ando M, Minatoya K, Tagusari O, Kitamura S, Nakajjma N, et al. Early and long-term results of surgery for aneurysms of the thoracic aorta in septuagenarians and octogenarians. *Eur J Cardiothorac Surg*. 1999;16:317-23.
7. Long SM, Tribble CG, Raymond DP, Fiser SM, Kaza AK, Kern JA, et al. Preoperative shock determines outcome for acute type A aortic dissection. *Ann Thorac Surg*. 2003;75:520-4.
8. Stevens LM, Madsen JC, Isselbacher EM, Khairy P, MacGillivray TE, Hilgenberg AD, et al. Surgical management and long-term outcomes for acute ascending aortic dissection. *J Thorac Cardiovasc Surg*. 2009;138:1349-57.e1.
9. Ganapathi AM, Englum BR, Hanna JM, Schechter MA, Gaca JG, Hurwitz LM, et al. Frailty and risk in proximal aortic surgery. *J Thorac Cardiovasc Surg*. 2014;147:186-91.e181.
10. Varadarajan P, Kapoor N, Bansal RC, Pai RG. Clinical profile and natural history of 453 nonsurgically managed patients with severe aortic stenosis. *Ann Thorac Surg*. 2006;82:2111-5.
11. Krane M, Voss B, Hiebinger A, Deutsch MA, Wottke M, Hapfelmeier A, et al. Twenty years of cardiac surgery in patients aged 80 years and older: risks and benefits. *Ann Thorac Surg*. 2011;91:506-13.
12. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *Circulation*. 2010;121:e266-369.
13. Kim BS, Soltesz EG, Cohn LH. Minimally invasive approaches to aortic valve surgery: Brigham experience. *Semin Thorac Cardiovasc Surg*. 2006;18:148-53.
14. Cohn LH, Soltesz EG. Selection of techniques for combined valve surgery and coronary artery bypass grafting: the impact of combined procedures involving the aortic or mitral valve. *Adv Cardiol*. 2004;41:164-71.
15. Kaneko T, Aranki SF, Neely RC, Yazdchi F, McGurk S, Leacche M, et al. Is there a need for adjunct cerebral protection in conjunction with deep hypothermic circulatory arrest during noncomplex hemiarch surgery? *J Thorac Cardiovasc Surg*. 2014;148:2911-7.

16. US Census Bureau. The Older Population in the United States: 2008. Available at: https://www.census.gov/data/tables/2008/demo/age-and-sex/2008-older-population.html. Accessed March 15, 2018.
17. Cohn LH, Rizzo RJ, Adams DH, Aranki SF, Couper GS, Beckel N, et al. Reduced mortality and morbidity for ascending aortic aneurysm resection regardless of cause. *Ann Thorac Surg*. 1996;62:463-8.
18. Shah PJ, Estrera AL, Miller CC III, Lee TY, Irani AD, Meada R, et al. Analysis of ascending and transverse aortic arch repair in octogenarians. *Ann Thorac Surg*. 2008;86:774-9.
19. Ehrlich MP, Ergin MA, McCullough JN, Lansman SL, Galla JD, Bodian CA, et al. Predictors of adverse outcome and transient neurological dysfunction after ascending aorta/hemiarch replacement. *Ann Thorac Surg*. 2000;69:1755-63.
20. Zingone B, Gatti G, Spina A, Rauber E, Dreas L, Forti G, et al. Current role and outcomes of ascending aortic replacement for severe nonaneurysmal aortic atherosclerosis. *Ann Thorac Surg*. 2010;89:429-34.
21. Kaneko T, Neely RC, Shekar P, Javed Q, Asghar A, McGurk S, et al. The safety of deep hypothermic circulatory arrest in aortic valve replacement with unclampable aorta in non-octogenarians. *Interact Cardiovasc Thorac Surg*. 2015;20:79-84.
22. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP III, Guyton RA, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. *J Thorac Cardiovasc Surg*. 2014;148:e1-132.
23. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med*. 2011;364:2187-98.
24. Lamy A, Devereaux PJ, Yusuf S. Off-pump or on-pump coronary-artery bypass grafting. *N Engl J Med*. 2013;369:196.
25. Van Mieghem NM, Piazza N, Anderson RH, Tzikas A, Nieman K, De Laat LE, et al. Anatomy of the mitral valvular complex and its implications for transcatheter interventions for mitral regurgitation. *J Am Coll Cardiol*. 2010;56:617-26.
26. Mehta RH, O'Gara PT, Bossone E, Nienaber CA, Myrmel T, Cooper JV, et al. Acute type A aortic dissection in the elderly: clinical characteristics, management, and outcomes in the current era. *J Am Coll Cardiol*. 2002;40:685-92.
27. Juvonen T, Ergin MA, Galla JD, Lansman SL, McCullough JN, Nguyen K, et al. Risk factors for rupture of chronic type B dissections. *J Thorac Cardiovasc Surg*. 1999;117:776-86.
28. Braverman AC. Acute aortic dissection. Clinician update. *Circulation*. 2010;122:184-8.
29. Hagan PG, Nienaber CA, Isselbacher EM, Bruckman D, Karavite DJ, Russman PL, et al. The international registry of acute aortic dissection (IRAD): new insights into an old disease. *JAMA*. 2000;283:897-903.
30. Kimura N, Ohnuma T, Itoh S, Sasabuchi Y, Asaka K, Shiotsuka J, et al. Utility of the Penn classification in predicting outcomes of surgery for acute type a aortic dissection. *Am J Cardiol*. 2014;113:724-30.
31. Pisano C, Balistreri CR, Torretta F, Capuccio V, Allegra A, Argano V, et al. Penn classification in acute aortic dissection patients. *Acta Cardiol*. 2016;71:235-40.
32. Zindovic I, Sjogren J, Bjursten H, Danielsson E, Ingemansson R, Nozohoor S. Impact of hemodynamic instability and organ malperfusion in elderly surgical patients treated for acute type A aortic dissection. *J Card Surg*. 2015;30:822-9.
33. Hata M, Suzuki M, Sezai A, Niino T, Unosawa S, Furukawa N, et al. Less invasive quick replacement for octogenarians with type A acute aortic dissection. *J Thorac Cardiovasc Surg*. 2008;136:489-93.
34. Alexander KP, Anstrom KJ, Muhlbaier LH, Grosswald RD, Smith PK, Jones RH, et al. Outcomes of cardiac surgery in patients > or = 80 years: results from the national cardiovascular network. *J Am Coll Cardiol*. 2000;35:731-8.
35. Reynolds MR, Magnuson EA, Wang K, Thourani VH, Williams M, Zajarias A, et al. Health-related quality of life after transcatheter or surgical aortic valve replacement in high-risk patients with severe aortic stenosis: results from the PARTNER (Placement of AoRTic TraNscathetER Valve) Trial (Cohort A). *J Am Coll Cardiol*. 2012;60:548-58.

Key Words: aortic surgery, advanced age, calcified aorta