Reoperative aortic valve replacement in the octogenarians—minimally invasive technique in the era of transcatheter valve replacement

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Objective: Reoperative aortic valve replacement (re-AVR) in octogenarians is considered high risk and therefore might be indicated for transcatheter AVR. The minimally invasive technique for re-AVR limits dissection and might benefit this patient population. We report the outcomes of re-AVR in high-risk octogenarians who might be considered candidates for transcatheter AVR to assess the safety of re-AVR and minimally invasive operative techniques.

Methods: We identified 105 patients, aged ≥80 years, who underwent open re-AVR at our institution from July 1997 to December 2011. Patients requiring concomitant coronary bypass surgery and/or other valve surgery were excluded. The outcomes of interest included operative mortality, postoperative complications, and midterm postoperative survival.

Results: Of the 105 patients, 51 underwent minimally re-AVR through upper hemisternotomy (Mre-AVR) and 54 standard full sternotomy (Fre-AVR). The mean patient age was 82.8 ± 3.8 years. No significant differences were found in the patient risk factors. Postoperatively, 6 patients (5.7%) underwent reoperation for bleeding, 4 (3.8%) experienced permanent stroke, 4 (3.8%) developed new renal failure, and 22 (21.0%) had new-onset atrial fibrillation. Overall, the operative mortality was 6.7%, and the 1- and 5-year survival was 87% and 53%, respectively. When Mre-AVR and Fre-AVR were compared, the operative mortality was 9.2% in the Fre-AVR group and 3.9% in the Mre-AVR group ($P = .438$). Kaplan-Meier analysis showed a survival benefit at both 1 year (79% ± 11.7% vs 92% ± 7.8%) and 5 years (38% ± 17.6% vs 65% ± 15.7%, $P = .028$) favoring Mre-AVR. Cox regression analysis identified heparin-induced thrombocytopenia, reoperation for bleeding, older age, full sternotomy, and an infectious complication as predictors of mortality.

Conclusions: Octogenarians who undergo re-AVR are thought to be high-risk surgical candidates. The present single-center series revealed acceptable in-hospital outcomes and operative mortality. Mre-AVR was associated with better survival compared with Fre-AVR and might benefit this population. (J Thorac Cardiovasc Surg 2014;147:155-62)

Reoperative aortic valve replacement (re-AVR [AVR after previous cardiac surgery]) is increasing owing to the population surviving after cardiac surgery and longer life expectancy.[1] Cardiac surgery in octogenarians and nonagenarians is becoming more common.[2] However, because of the increased perioperative risk of morbidity and mortality compared with that in the younger generation, the elderly population has viewed surgical intervention as a last resort. Re-AVR can be performed with low risk, with an operative mortality of 4% to 7% in the present era,[3,4] although data focused on the older population are lacking. Cardiac surgeons are faced with the question of whether surgical intervention will improve the outcomes in these high-risk patients. Transcatheter AVR (TAVR) has emerged as a procedure for high-risk candidates, such as older patients and those undergoing reoperation. Valve-in-valve (VIV) TAVR can be performed in patients with previously placed bioprostheses in the aortic position. It has been anticipated that more and more patients requiring re-AVR will be treated with TAVR in the future.

Re-AVR through a minimal access approach using upper hemisternotomy avoids dissection of the mediastinum and limits bleeding and blood transfusion.[5] No other study has compared the outcomes of re-AVR between a minimally invasive technique (Mre-AVR) and standard full sternotomy technique (Fre-AVR). The Mre-AVR approach has potential benefit, especially for the elderly, given the limited tissue damage and avoiding major postoperative complications.

The aim of the present study was to assess the outcome in octogenarians undergoing re-AVR and to analyze whether Mre-AVR will result in improved outcomes compared with Fre-AVR as a benchmark in the upcoming era of TAVR.

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Abbreviations and Acronyms

CI	= confidence interval
HIT	= heparin-induced thrombocytopenia
HR	= hazard ratio
LITA	= left internal thoracic artery
LV	= left ventricular
Fre-AVR	= standard full sternotomy reoperative aortic valve replacement
Mre-AVR	= minimally invasive reoperative aortic valve replacement
re-AVR	= reoperative aortic valve replacement
STS	= The Society of Thoracic Surgeons
TAVR	= transcatheter aortic valve replacement
TEE	= transesophageal echocardiography
VIV	= valve-in-valve

METHODS

Patients

We identified 105 consecutive patients aged ≥80 years at surgery who had undergone isolated AVR after previous cardiac surgery from July 1997 to June 2012. Patients with concomitant coronary bypass, other valve surgery, and/or aortic surgery were excluded. The institutional review board of Brigham and Women's Hospital approved the present study.

Contraindications and Choices

The contraindications to Mre-AVR included other concomitant cardiac procedures, such as coronary artery bypass grafting and mitral and tricuspid valve operations, which were excluded from the present study. No other contraindications were included. In our institution, the choice of the minimally invasive approach versus full sternotomy was mainly surgeon preference.

Minimally Invasive Approach

Before the incision, all patients had had a pulmonary artery catheter with a pacing port placed by the anesthesiologist. Also, an external defibrillator pad was placed and transesophageal echocardiography (TEE) performed.

When peripheral cannulation was chosen, right axillary artery or femoral artery cannulation and femoral venous cannulation were accessed. For arterial cannulation, an 8- to 10-mm polytetrafluoroethylene graft was sewn into the right axillary artery or femoral artery, which was connected to an arterial circuit. For venous cannulation, a femoral venous cannula was placed using a modified Seldinger technique, and the position was confirmed with TEE. In all other cases, central cannulation was used after partial sternotomy and mediastinal dissection.

Upper hemisternotomy was performed using an oscillating saw. Sternotomy was performed in a J-fashion to the fourth intercostal space. Cardiopulmonary bypass was initiated in some cases before dividing the posterior sternal table. Limited mediastinal dissection of the aorta, right atrium, and right superior pulmonary vein was then performed. The left internal thoracic artery (LITA) graft was left without dissection (no dissection technique). The proximal anastomoses of vein grafts were dissected. After dissection, a retrograde cardioplegia catheter was placed from the right atrial appendage under TEE guidance, and a left ventricular (LV) vent was placed from the aorta, right atrium, and right superior pulmonary vein, when possible.

The patient was cooled after aortic crossclamp application to prevent ventricular fibrillation. The goal of cooling was to 28°C to 32°C if no LITA graft was present and 25°C to 30°C if the LITA was intact. Antegrade and retrograde cardioplegia was given after aortic crossclamping. Direct coronary cardioplegia was given if we could not achieve retrograde access and the left ventricle was distended owing to aortic insufficiency. Our cardioplegia strategy was to repeat the dose every 20 to 30 minutes and use blood cardioplegia in all cases. LV distension was carefully monitored using TEE. The LV vent was placed from the aorta, right atrium, and right superior pulmonary vein or through the aortic valve after aortotomy. Standard ARV was then conducted.

When cardiac activity was observed because of a patent LITA graft, additional systemic potassium was given through the pump (40 mEq) to a dosage of 6.0 to 7.0 mEq. Ultrafiltration was used to lower the potassium level at the end of the case if this technique had been used. When the field was obscured by blood return from the left coronary ostium, the pump flow was temporarily lowered for a few seconds to place the annular sutures. Details of the steps in patients with a patent LITA have been discussed in our previous study.[6]

Defibrillation after unclamping was obtained through external pads. De-airing was monitored using TEE, and carbon dioxide was used in the field to limit the amount of air. A ventricular pacing wire was placed in right ventricular muscle if a transvenous pacing wire was unable to be inserted. A chest tube was placed from the right pleural space, and the chest was closed in a standard fashion.

Data Collection

The patient characteristics, medications, laboratory values, and in-hospital outcomes of the index surgery were collected at presentation and extracted from the hospital's electronic medical records. The data were coded according to The Society of Thoracic Surgeons (STS) National Adult Cardiac Database, version 2.52, definitions, unless otherwise noted.

The primary outcomes of interest were operative mortality, frequency of postoperative complications, and long-term survival. The postoperative complications included cerebrovascular accident, respiratory failure, atrial fibrillation, renal failure, and reoperation for bleeding. Cerebrovascular accidents included strokes, transient ischemic attacks, and coma. Infectious complications included urinary infections, pneumonia, bacteremia and/or sepsis, deep sternal wound infections, medically managed endocarditis, and leg infections. Infectious complications were confirmed by positive culture findings and collected by chart review. A composite outcome of any infectious complication was also calculated. Mortality data were collected from the hospital records, routine patient follow-up visits, our state Department of Public Health, and query of the Social Security Death Index.

Statistical Analysis

Evaluation of dichotomous variables was done using Fisher exact test, and the data are presented as percentages and number of cases. Continuously distributed variables were evaluated using Student t test with Levine's homogeneity of variance. These data are presented as the mean ± standard deviation. Mann-Whitney U tests were used to evaluate non-normally distributed continuous variables, which are presented as the median and interquartile range. Survival was evaluated using Kaplan-Meier analyses. The risk factors for late mortality were examined using both univariate and multivariate Cox regression analyses; for the latter, interaction terms were examined. Statistical analyses were performed using the Statistical Package for Social Sciences, version 13.0 (SPSS, Chicago, Ill), and $P < .05$ was considered statistically significant.

RESULTS

Study Population

From January 1997 to December 2011, 105 patients >80 years old underwent isolated re-AVR. Of these 105 patients, 54 underwent Fre-AVR and 51 underwent Mre-AVR. The total follow-up period was 376.2 patient-years. The median follow-up duration was 3.0 years (interquartile range, 1.2-5.3).

TABLE 1. Preoperative patient characteristics

Characteristic	Re-AVR at >80 y (n = 105)	Full sternotomy (n = 54)	Minimally invasive (n = 51)	*P* value
Age (y)	82.8 ± 3.8	82.4 ± 4.6	83.3 ± 2.7	≤.270
Female gender	40.0 (42)	50.0 (27)	29.4 (15)	≤.046
Diabetes	33.3 (35)	20.4 (11)	31.4 (16)	≤.264
Hypercholesterolemia	84.8 (89)	87.0 (47)	82.4 (42)	≤.592
Hypertension	83.8 (88)	81.5 (44)	86.3 (44)	≤.600
Renal failure	4.8 (5)	7.4 (4)	2.0 (1)	≤.364
Preoperative creatinine	1.2 ± 0.4	1.3 ± 0.5	1.2 ± 0.3	≤.510
Preoperative hematocrit (%)	36.2 ± 4.0	36.3 ± 4.3	36.0 ± 3.9	≤.768
CVA	10.5 (11)	11.1 (6)	9.8 (5)	≤1.000
NYHA class III-IV	62.9 (66)	63.0 (34)	62.7 (32)	≤1.000
Ejection fraction (%)	55.0 (50-60)	57.0 (55-65)	55.0 (50-60)	≤.701
Previous CABG	85.7 (90)	79.6 (43)	92.2 (47)	≤.094
Previous valve surgery	26.7 (28)	27.8 (15)	25.5 (13)	≤.828

Data presented as mean ± standard deviation, n (%), or median (interquartile range). *Re-AVR*, Reoperative aortic valve replacement; *CVA*, cerebrovascular accident; *NYHA*, New York Heart Association; *CABG*, coronary artery bypass grafting.

Patient Characteristics

The preoperative patient characteristics are listed in Table 1, stratified by the technique used (Fre-AVR vs Mre-AVR). For the total cohort, the mean age was 82.8 ± 3.8 years, and 40.0% were women. The incidence of medical comorbidities such as hypercholesterolemia (84.8%), hypertension (83.8%), and previous cerebrovascular accident (10.5%) was high. The incidence of heart failure symptoms was 62.9% for New York Heart Association class III-IV, but cardiac function was preserved with a median ejection fraction of 55.0%. Of those who had undergone previous cardiac surgery, 85.7% had undergone coronary artery bypass grafting and 26.7% valve operations.

When comparing the Fre-AVR and Mre-AVR groups, both were similar in age (82.4 vs 83.3 years; $P = .27$). The Fre-AVR group had more women (50.0% vs 29.4%; $P = .05$). The presence of preoperative conditions such as renal failure (7.4% vs 2.0%; $P = .36$), hypercholesterolemia (87.0% vs 82.4%; $P = .59$), diabetes (20.4% vs 31.4%; $P = .26$), and hypertension (81.5% vs 86.3%; $P = .60$) was similar between the 2 groups. More patients in the Mre-AVR group had undergone previous coronary artery bypass grafting (79.6% vs 92.2%; $P = .09$). Finally, 75.9% of the Fre-AVR group (41 of 54) and 80.4% of the Mre-AVR group (41 of 51) had undergone preoperative computed tomography.

Operative Data

The patients' operative characteristics are summarized in Table 2. Of the total cohort, 81.9% underwent reoperation

TABLE 2. Operative characteristics

Characteristic	Re-AVR at >80 y (n = 105)	Full sternotomy (n = 54)	Minimally invasive (n = 51)	*P* value
Etiology				
Stenosis	81.9 (86)	85.2 (46)	78.4 (40)	≤.450
Insufficiency	6.7 (7)	7.4 (4)	5.9 (3)	≤1.000
Stenosis and insufficiency	11.4 (12)	7.4 (4)	15.7 (8)	≤.223
Cannulation strategy				
Aorta directly	31.4 (33)	50 (27)	11.8 (6)	≤.001
Axillary artery	48.6 (51)	31.5 (17)	66.6 (34)	≤.001
Femoral artery	20.0 (21)	18.5 (10)	21.6 (11)	≤.809
Direct RA cannulation	18.1 (19)	29.6 (16)	5.9 (3)	≤.002
Femoral vein	81.9 (86)	70.4 (38)	94.1 (48)	≤.002
CP strategy				
Antegrade CP	46.7 (49)	22.2 (12)	72.5 (37)	≤.001
Antegrade and retrograde CP	53.3 (56)	77.8 (42)	27.4 (14)	≤.001
Perfusion time (min)	139 (116-167)	142 (115-165)	139 (125-180)	≤.936
Crossclamp time (min)	73 (61-94)	75 (63-93)	73 (62-92)	≤.240
Transfused in OR	62.9 (66)	70.4 (38)	54.9 (28)	≤.111
PRBC units per patient	3 (2-4)	3 (2-4)	2 (2-3)	≤.321

Data presented as n (%) or median (interquartile range). *Re-AVR*, Reoperative aortic valve replacement; *RA*, right atrial; *CP*, cardioplegia; *OR*, operating room; *PRBC*, packed red blood cell.

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for aortic stenosis, 6.7% for insufficiency, and 11.4% for stenosis and insufficiency. Also, 31.4% underwent central cannulation and 68.6% peripheral cannulation. Finally, 62.9% required transfusion in the operating room, with a median number of 3 packed red blood cell transfusions.

Both groups had a similar incidence of aortic stenosis (85.2% vs 78.4%; $P = .45$) and stenosis and/or insufficiency (7.4% vs 15.7%; $P = .22$). In the Mre-AVR group, more peripheral cannulation was used, especially axillary cannulation (31.5% vs 66.6%; $P \leq .001$), and less central cannulation (50% vs 11.8%; $P \leq .001$). More direct right atrial cannulations were performed in the Fre-AVR group (29.6% vs 5.9%, $P = .002$) and more femoral venous cannulations were performed in the Mre-AVR group (94.1% vs 70.4%; $P = .002$). Mre-AVR used more antegrade cardioplegia alone (72.5% vs 22.2%; $P = .001$) and Fre-AVR used more antegrade and retrograde cardioplegia (77.8% vs 27.5%; $P = .001$). The 2 groups had no difference in perfusion time (Fre-AVR, 142 minutes vs Mre-AVR, 139 minutes; $P = .96$) or crossclamp time (75 vs 73 minutes; $P = .23$). The Mre-AVR group had a trend toward fewer transfusions in the operating room (70.4% vs 54.9%; $P = .11$).

Operative Morbidity and Mortality

The operative morbidity and mortality is summarized in Table 3. For the total cohort, the operative mortality was 6.7%. Also, 5.7% underwent reoperation for bleeding, 3.8% experienced permanent stroke, and 21% had new-onset atrial fibrillation. Combined infectious complications included urinary tract infection, pneumonia, endocarditis, and bacteremia or sepsis; overall 30.5% had ≥ 1 infectious complication. The median intensive care unit stay was 73.0 hours, and the median length of stay in the hospital was 8.0 days.

Cannulation-related morbidity occurred as follows: 4 of 86 patients (4.7%) developed a venous complication (3 in the Fre-AVR and 1 in the Mre-AVR group); 3 developed deep vein thrombosis, and 1 developed a retroperitoneal hematoma requiring surgery. One patient had a pseudoaneurysm after femoral artery cannulation that required intervention. The source of bleeding for reoperations were diffuse oozing (no source) in 1 and aortotomy in 1 patient in the Fre-AVR group and sternal wires in 3 patients and diffuse oozing in 1 patient in the Mre-AVR group. Stroke occurred mainly in the patients who had undergone femoral artery cannulation (3 of 4), with fewer occurring in those who had undergone axillary artery cannulation (1 of 4).

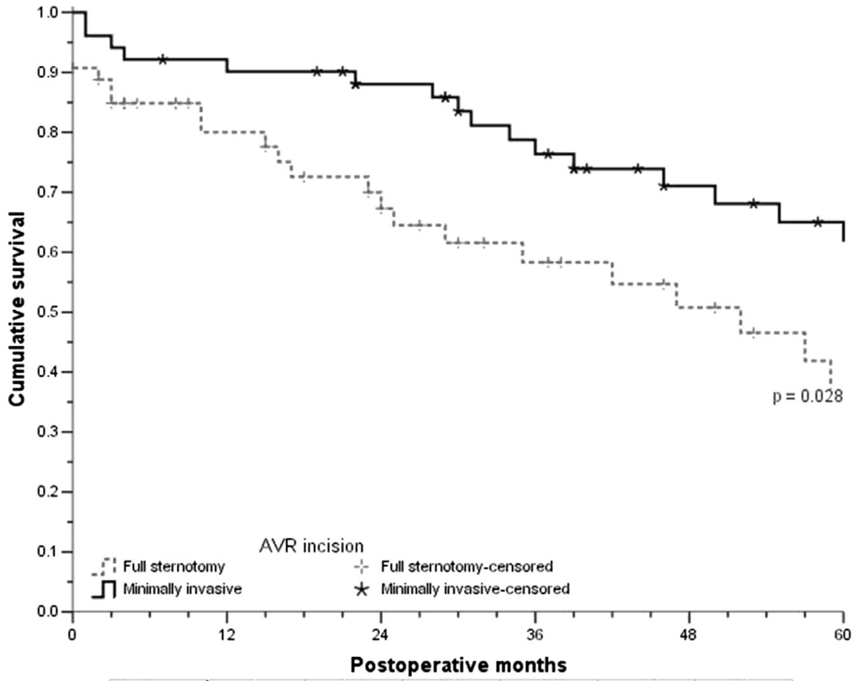
Heparin-induced thrombocytopenia (HIT) was seen in 4 patients. The incidence of HIT did not differ between the Fre-AVR and Mre-AVR groups. HIT occurred within postoperative day 3 to 7 (median, 5.5). No cases of preoperative HIT occurred. One patient developed HIT thrombosis, resulting in renal failure, which led to multiorgan failure and death in the Mre-AVR group.

Operative mortality was statistically similar between the 2 groups (Fre-AVR, 9.3% vs Mre-AVR, 3.9%; $P = .44$). The Mre-AVR group showed a trend toward fewer cases of new-onset renal failure (7.4% vs 0.0%; $P = .12$) and fewer cases of new-onset atrial fibrillation (28.7% vs 15.7%; $P = .16$). Infectious complications (33.3% vs 27.5%; $P = .53$), reoperation for bleeding (3.7% vs 7.8%; $P = .42$), and permanent stroke (1.9% vs 5.9%; $P = .35$) were similar between the 2 groups. The Fre-AVR group had a greater incidence of fresh frozen plasma

TABLE 3. Postoperative outcomes

Outcome	Re-AVR at >80 y (n = 105)	Full sternotomy (n = 54)	Minimally invasive (n = 51)	*P* value
Reoperation for bleeding	5.7 (6)	3.7 (2)	7.8 (4)	≤.428
Permanent stroke	3.8 (4)	1.9 (1)	5.9 (3)	≤.354
New-onset renal failure	3.8 (4)	7.4 (4)	0.0 (0)	≤.118
New-onset AF	21.0 (22)	28.7 (15)	15.7 (8)	≤.161
HIT	3.8 (4)	3.7 (2)	3.9 (2)	≤1.000
Infectious complications	30.5 (32)	33.3 (18)	27.5 (14)	≤.533
UTI	26.7 (28)	27.8 (15)	25.5 (13)	≤.828
Pneumonia	5.7 (6)	3.7 (2)	7.8 (4)	≤.428
Postoperative endocarditis	1.0 (1)	1.9 (1)	0.0 (0)	≤1.000
Bacteremia and/or sepsis	2.0 (2)	1.9 (1)	2.0 (1)	≤1.000
Transfused postoperatively	61.0 (64)	59.3 (32)	62.7 (32)	≤.307
RBC units per patient	3.0 (2-4)	3.0 (1-4)	3.0 (2-4)	≤.233
FFP transfusion	39.0 (41)	48.1 (26)	29.8 (15)	≤.071
Platelet transfusion	38.1 (40)	40.7 (22)	35.3 (18)	≤.688
Ventilation time (h)	11.2 (7-20)	10.8 (7.1-19.8)	13.1 (7.2-22.9)	≤.617
ICU stay (h)	73.0 (42-121)	73.0 (45-121)	73.0 (33-129)	≤.860
Postoperative LOS (d)	8.0 (7-12)	8.0 (7-12)	9.0 (7-15)	≤.108
Operative mortality (%)	6.7 (7)	9.3 (5)	3.9 (2)	≤.438

Data presented as n (%) or median (interquartile range), or median (n). *Re-AVR*, Reoperative aortic valve replacement; *AF*, atrial fibrillation; *HIT*, heparin-induced thrombocytopenia; *UTI*, urinary tract infection; *RBC*, red blood cell; *FFP*, fresh frozen plasma; *ICU*, intensive care unit; *LOS*, length of stay.



Start mo.	0	12	24	36	48	60
Full	49	32	24	17	12	8
Mini	51	44	39	30	23	18

	All re-AVR			Full sternotomy			Minimally invasive		
	N at risk	%	SE	N at risk	%	SE	N at risk	%	SE
1 year- Survival	99	87%	0.04	49	79%	0.06	51	92%	0.04
3 year- Survival	63	69%	0.05	24	58%	0.08	39	79%	0.06
5 year- Survival	35	53%	0.06	12	38%	0.09	23	65%	0.08

SE: standard error

FIGURE 1. Survival analysis between full sternotomy group and minimally invasive group. *AVR*, Aortic valve replacement; *re-AVR*, reoperative aortic valve replacement.

transfusions (48.1% vs 29.4%; $P = .071$) but a similar incidence of packed red blood cell transfusions (median, 3 U vs 3 U; $P = 1.0$), platelet transfusions (40.7% vs 35.3%; $P = .688$), and overall postoperative transfusions (59.3% vs 62.7%; $P = .307$). The postoperative intensive care unit stay and length of stay were similar between the 2 groups.

Disposition and Readmission

No difference was found in the discharge locations. Of the 105 patients, 49 were alive at discharge. Of these patients, 28 in the Fre-AVR group and 29 in the Mre-AVR were discharged to a rehabilitation facility ($P = 1.0$) and 21 patients in the Fre-AVR group and 20 patients in the Mre-AVR group were discharged to home ($P = 1.0$). The readmission rates were similar (14.3% for Fre-AVR and 16.7% for Mre-AVR; $P = .785$).

Survival Analysis

Figure 1 shows the Kaplan-Meier analysis of survival through 5 years. After that, the patients at risk in the Fre-AVR group had decreased below a number amenable to meaningful analysis.

The analysis showed overall survival at 1 year of 87% and at 5 years of 53%. The Mre-AVR group had significant better survival statistically compared with the Fre-AVR both at 1 (79% vs 92%; $P = .03$) and 5 (38% vs 65%; $P = .03$) years. The median survival duration was 65.3 months (95% confidence interval [CI], 43.2-77.2) overall and 52.0 months (95% CI, 29.1-74.9) in the Fre-AVR group and 81.2 months (95% CI, 60.7-105.3) in the Mre-AVR group.

Multivariate Analysis

Because our patients were not randomized, we sought to examine the contributors to long-term mortality using

TABLE 4. Cox regression analysis: predictors of mortality in the elderly

Variable	*P* value	HR	95% CI
HIT	≤.001	9.801	2.397-40.071
Reoperation for bleeding	≤.001	7.983	2.666-23.904
Older age (>80 y)	≤.002	1.150	1.052-1.256
Full sternotomy	≤.017	2.162	1.149-4.071
Any postoperative infection	≤.026	2.158	1.096-4.251

HR, Hazard ratio; *CI*, confidence interval; *HIT*, heparin-induced thrombocytopenia.

multivariate analyses. We examined the variables listed in Table 1 that were significantly different statistically and those deemed clinically important in an initial forward-stepwise Cox regression analysis. Significant contributors were then evaluated using the enter-method analysis to address overfitting concerns. A total of 52 mortality events occurred during the study observation period.

The significant contributors in the final model are listed in Table 4. In order of significance, HIT (hazard ratio [HR], 9.80; 95% CI, 2.40-40.07; $P \leq .001$), reoperation for bleeding (HR, 7.98; 95% CI, 2.67-23.90; $P \leq .001$), full sternotomy (HR, 2.16; 95% CI, 1.15-4.07; $P = .02$), infectious complication (HR, 2.16; 95% CI, 1.10-4.25; $P = .03$), and increasing age (HR, 1.15; 95% CI, 1.05-1.26; $P = .002$) were all significantly predictive of decreased postoperative survival. Nevertheless, survival for the Mre-AVR group was significantly longer ($P \leq .001$) than that for the Fre-AVR group (Figure 2).

DISCUSSION

Cardiac surgery performed in octogenarians has been becoming more common, and this trend is expected to continue, because the elderly population is the fastest growing population in the United States. Although considered high risk, cardiac surgery for octogenarians can be performed safely. A low operative mortality of 4% to 8% and 5-year survival of 50% has been reported in current studies for patients aged >80 years.[7-9] Despite these data, the elderly have generally not been considered ideal candidates for cardiac surgery. In 1 study, as many as 40% of patients aged >70 years were denied cardiac surgery because of their age.[10]

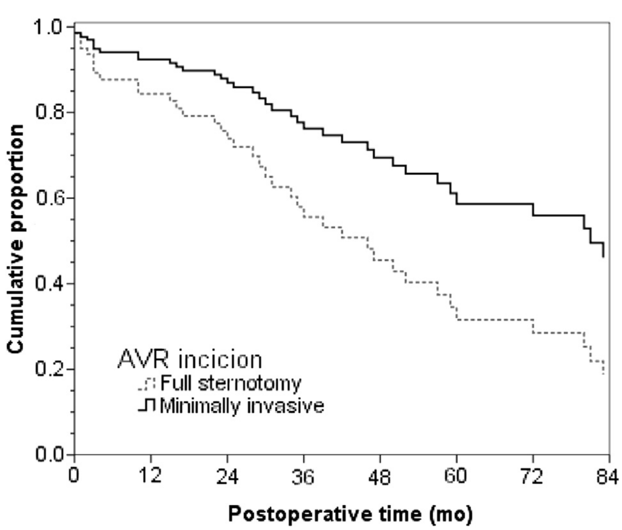


FIGURE 2. Cox regression analysis for predictors of mortality. *AVR*, Aortic valve replacement.

Reoperation cardiac surgery in this age group imposes a greater risk, making the decision even more difficult for surgeons. In the general population, re-AVR has been shown to have good outcomes, with an operative mortality of 5% to 7% in recent reports.[3,6] Few data exist for re-AVR in older patients. Limited published data have shown high hospital mortality (12%-16.4%) and a 5-year survival of 50% to 60% in the elderly population.[11,12] This has resulted in greater enthusiasm for the later discussed TAVR procedure.

In the present report, we assessed the outcomes for 105 octogenarians who had undergone re-AVR. The outcomes showed that this operation can be performed safely, with an operative mortality of 6.7% and 1- and 5-year survival of 87% and 53%, respectively. Our operative mortality was low compared with the published data and was comparable to the re-AVR risk in the general population.

Mre-AVR has been reported with good outcomes. Both the right minithoracotomy approach[13,14] and the partial upper hemisternotomy approach[5,15,16] have been used for minimally invasive procedures. The benefits of Mre-AVR have included more patients discharged to home, a shorter length of stay,[13,14,17] less pain,[18] a shorter ventilation duration,[13,18] and less blood loss and transfusion requirements compared with Fre-AVR.[13,15,18] Few studies have shown decreased operative mortality after re-AVR using a minimally invasive technique.[13,14] Sharony and colleagues[14] compared 161 (61 aortic and 100 mitral) cases of minimally invasive right thoracotomy reoperation with 337 (160 aortic, 177 mitral) cases of full sternotomy. In their report, the minimally invasive group had lower operative mortality (5.6% vs 11.3%; $P = .04$) and lower long-term mortality, with a follow-up of 24 months.[14]

The population that could benefit the most from minimally invasive techniques would be the elderly population, because these techniques create less tissue trauma and do not result in complications. ElBardissi and colleagues[19] reported on 249 octogenarians who had undergone minimally invasive primary AVR. They reported an operative mortality of 3%, significantly lower than the calculated median EuroSCORE (11%) and STS score (10.5%). The EuroSCORE and STS risk scores have had a poor correlation in the elderly. No study has compared the benefit of Mre-AVR in the elderly population.

Although not statistically significant, the Mre-AVR group had trends toward fewer cases of new-onset renal failure and new-onset atrial fibrillation and fewer intraoperative

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transfusions and fresh frozen plasma transfusion. The benefits seen in other studies, such as a shorter hospital stay and intensive care unit stay and fewer postoperative transfusions were not observed in the present study.

Perioperative strokes, respiratory failure, and renal failure are known risks associated with operative mortality and survival in octogenarians.[6,19,20] Very elderly patients will have reduced biologic reserves and will therefore be more vulnerable to the deleterious effects of postoperative complications. Preventing and minimizing postoperative complications using methods such as early extubation and ambulation and aspiration precautions are particularly important for these patients. Other measures such as maintaining an adequate fluid balance, avoiding overdiuresis, and minimizing the use of nephrotoxic drugs are important for preventing renal failure. Fewer postoperative infections can be achieved by the adequate use of antibiotics, early removal of the urinary catheter, and early ambulation.

Three Mre-AVR patients experienced a postoperative stroke, likely attributable to peripheral cannulation; 75% of strokes in our patients were from femoral artery cannulation. We began performing Mre-AVR in 1996, and the initial cases were all performed using peripheral cannulation. With more strokes seen with femoral artery cannulation, our current practice has been to selectively perform peripheral cannulation (axillary artery preferably) in high-risk cases and central cannulation in low-risk cases. Preoperative evaluation using 3-dimentional computed tomography will allow the surgeons to assess the relationship between the sternum and aorta and has aided this decision-making process. In some cases, such as coronary grafts traversing the lower sternum or ventricle attached to the lower sternum, the minimally invasive technique was chosen to avoid injury.

The Mre-AVR group had excellent operative mortality at 3.9%. Evaluating long-term survival, statistically significant improvements in both 1- and 5-year survival (92% and 65%, respectively) were seen for the Mre-AVR group compared with the conventional Fre-AVR group.

Cox regression analysis of long-tem survival showed that the significant predictors of long-term survival included HIT, increasing age, reoperation for bleeding, full sternotomy, and postoperative infectious complications. Of these, HIT had the greatest HR. HIT is a known serious complication of cardiac surgery,[21] and our study results emphasize the importance of active investigation and early intervention to minimize harm and improve the outcomes after HIT.

The indication for reoperation for bleeding in the Mre-AVR patients was mainly bleeding from sternal wires (75%), possibly owing to the decreased visualization of the wire sites during sternal closure using this approach. This likely contributed to the somewhat greater postoperative transfusion needs in these patients, which might have been the reason the Mre-AVR group did not show a benefit in postoperative bleeding. Reoperation for bleeding was 1 of the predictors of mortality, and surgeons must pay careful attention to prevent this problem.

The full sternotomy procedure was a predictor of mortality, indicating that a minimally invasive approach could benefit postoperative survival in this population. The Mre-AVR group experienced fewer events of new-onset renal failure, new-onset atrial fibrillation, and infectious complications postoperatively. Although these differences between the 2 groups were not statistically significant, each of these events will be more serious in the very elderly than in younger patients. It is likely that the physiologic sequelae from such events will shorten postoperative survival in this population. With a lower cumulative rate of such events, postoperative survival can be maximized in Mre-AVR patients.

TAVR has emerged as 1 of the innovative and most anticipated treatments for high-risk surgical patients such as older patients. For primary AVR in high-risk patients, the Placement of Aortic Transcatheter Valve (PARTNER) trial showed that TAVR had outcomes equivalent to those of surgical AVR for $\leq$2 years.[22,23] The perioperative mortality was 3.4% after TAVR in a group of patients with an STS-predicted mortality estimated at >10%. However, TAVR is not risk-free. More paravalvular leaks (7% rate at 1 year of moderate to severe paravalvular leaks) have occurred with TAVR compared with surgical intervention and was directly associated with mortality.[23] If a bioprosthetic valve is present, TAVR can be used to perform a VIV technique. In the largest review of 202 patients undergoing VIV TAVR, the 30-day mortality was 8.4% and the calculated 1-year survival was 85.8%.[24] Although promising outcomes have been reported, coronary ostial obstruction and a persistent gradient remain problems for VIV TAVR.

The future identification of a high-risk group for TAVR could allow us to tailor patient treatment, and minimally invasive techniques will likely have a significant role by providing good outcomes after re-AVR in octogenarians.

Study Limitations

This was a single-institution, observational cohort study and was subject to all the limitations inherent in such a design. Generalizing our findings to the larger population of octogenarian aortic valve patients should be done with caution. Because the patients were not randomly assigned to treatment, selection biases we could not control for could have contributed to our findings. Propensity matching analysis is another method to limit the bias; however, propensity matching would decrease the number of patients in each arm, which would not result in any meaningful statistical conclusion. Therefore, we did not perform such an analysis. The absolute numbers of the present study were low; thus, we lacked the power to detect statistically significant differences between the 2 groups for low frequency events such as operative mortality. Also, because multiple surgeons performed the procedures, a possibility exists for selection bias by surgeon.

CONCLUSIONS

Re-AVR can be performed safely even in octogenarians, with a similar risk to that of the general population. A minimally invasive technique can improve the outcomes in this population by minimizing trauma and preventing postoperative complications. This could be a valuable option for patients requiring re-AVR.

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