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ORIGINAL ARTICLE

Minimally invasive aortic valve replacement through a right anterolateral mini-thoracotomy for the treatment of octogenarians with aortic valve stenosis

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Abstract
Because of concerns about the high risk of perioperative complications, the feasibility of minimally invasive aortic valve replacement (MIAVR) for elderly patients remains controversial. Here, we review our results of MIAVR in octogenarians with aortic valve stenosis (AS). Between October 2012 and December 2017, 110 patients with AS underwent MIAVR via a right anterolateral mini-thoracotomy; 41 patients were octogenarian (Group O). The perioperative outcomes of these patients were compared with those of the 69 patients who were less than 80 years of age (Group Y). A preoperative contrast-enhanced computed tomography (CT) scan was performed in all patients to guide the patient selection and aid the decision regarding cannulation sites. Among all cases of isolated aortic valve replacement, MIAVR accounted for 47% cases during this study period. The mean age of Group O was 83.6 ± 2.9 years, with a maximum age of 89. In Group O, there were no in-hospital deaths or morbidity, including stroke. The rate of blood transfusion was significantly higher in Group O than in Group Y ($P = 0.01$). However, there was no significant difference in ventilation time, the length of intensive care unit stay, the length of hospital stay, or in the rates of cumulative survival and freedom from valve-related complications. With careful patient selection and a perfusion strategy based on preoperative CT scan, equivalent outcomes of MIAVR were even achieved in octogenarians.

Keywords Minimally invasive aortic valve replacement · Aortic stenosis · Anterolateral thoracotomy · Octogenarian

Introduction

Recently, technological advances and the accumulation of knowledge about percutaneous approaches have made transcatheter aortic valve implantation (TAVI) a safe therapeutic option for aortic valve stenosis (AS). The use of TAVI for elderly or high-risk patients with severe AS has now spread rapidly worldwide [1]. On the other hand, the recent technical developments in minimally invasive surgery are also remarkable. Gilmanov et al. [2] reported good results of minimally invasive aortic valve replacement (MIAVR) through a right anterior thoracotomy compared with a median sternotomy even in octogenarians. However, a consensus statement of the International Society of Minimally Invasive Cardiothoracic Surgery demonstrated that cross-clamp time, cardiopulmonary bypass (CPB) time, and procedure time in minimally invasive mitral surgery were prolonged, as compared to those in open mitral surgery, and that minimally invasive surgery was related to an increased risk of stroke [3]. Furthermore, patients with AS are generally older than those with mitral regurgitation. Hence, there is a concern about the higher risk of postoperative complications, including stroke, especially in elderly patients, since peripheral cannulation is indispensable for MIAVR through an intercostal mini-thoracotomy. The contemporary results of MIAVR, particularly in elderly patients, should be defined to determine the most appropriate therapeutic intervention. Since October 2012, we have been actively performing MIAVR via a right anterolateral mini-thoracotomy to treat AS in octogenarians. Here, we investigated whether the short- and mid-term results of MIAVR in octogenarians were different from those in younger patients and evaluated our therapeutic strategy to treat elderly patients with AS.

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Patients and methods

Patients

Between October 2012 and December 2017, excluding 3 cases of prompt conversion to sternotomy due to severe pleural adhesions, 186 patients underwent MIAVR including double-valve surgery via an anterolateral mini-thoracotomy. Among these patients, 128 had AS. Excluding 18 cases of concomitant mitral valve surgery and/or arrhythmic surgery, 41 patients were octogenarian (Group O). The demographic characteristics, perioperative outcomes, and mid-term results of these patients were compared with those of the 69 patients who were less than 80 years of age (Group Y). In addition, we reviewed 126 patients with AS who underwent conventional aortic valve replacement (AVR) via a full sternotomy during the same study period. The reasons to avoid MIAVR are as follows: diseased and/or narrow peripheral arteries (67%); atherosclerotic change at the ascending aorta (51%); respiratory problems including pleural adhesion (17%); obesity (14%); narrow aortic annulus or annular enlargement (10%); redo surgery (9%); heart failure or cardiogenic shock (6%); low ejection fraction (3%); and thoracic deformity (3%). The present study was approved by the in-hospital ethics committee and written informed consent was provided by all patients.

Preoperative evaluation with contrast-enhanced computed tomography scan

For appropriate patient selection, a contrast-enhanced computed tomography (CT) scan was performed in all patients, even in patients with renal dysfunction requiring hemodialysis. We focused on atherosclerotic changes in the entire aorta, especially the ascending aorta, and the sizes and properties of peripheral vessels, including the right axillary artery and bilateral femoral arteries. If there was any atherosclerotic change in the aorta (Fig. 1a), we considered right axillary cannulation in addition to the femoro-femoral bypass for the prevention of stroke. In addition, because thoracic shape and ascending aorta location greatly influence the difficulty of performing MIAVR, we preoperatively confirmed the sternum-to-vertebra, skin-to-aorta, and skin-to-valve distances.

Contraindications for MIAVR

Absolute contraindications in our institute are as follows: previous cardiovascular surgery; thoracic deformity including pectus excavatum; narrow and/or diseased peripheral arteries inappropriate for cannulation; atheromatous plaques or wall calcifications at the aortic cross-clamping site; severe chronic obstructive pulmonary disease; evidence of pleural adhesion; left ventricular ejection fraction less than 35%; cardiogenic shock; and New York Heart Association functional class IV heart failure. Relative contraindications are current smoker; morbid obesity; wall calcifications at the sinus of Valsalva; atherosclerosis obliterans; cerebrovascular diseases; a small aortic annulus, possibly requiring annular enlargement; and a dilated ascending aorta over 45-mm in diameter. Advanced age and severity of aortic annular calcifications are not contraindications for MIAVR in our institute. Furthermore, a leftward shift of the ascending aorta, which is unsuitable for MIAVR via right anterior

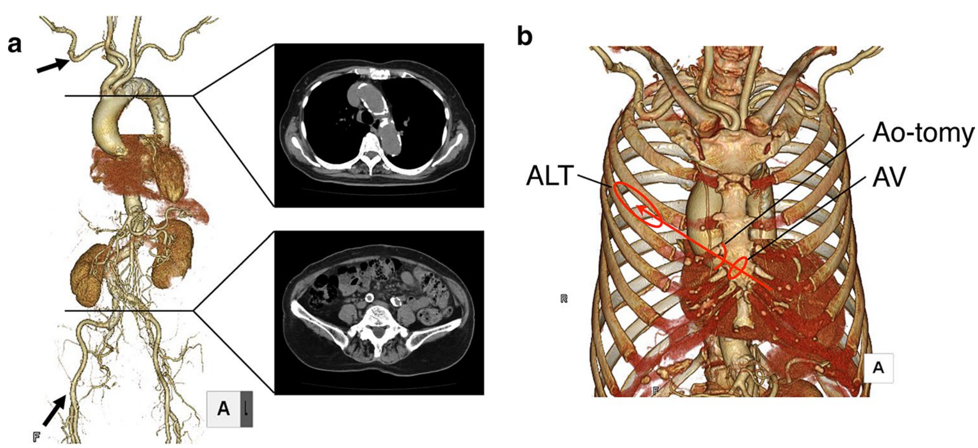

Fig. 1 Preoperative contrast-enhanced computed tomography (CT) scan of an 83-year-old female patient. **a** Marked atherosclerotic changes are shown at the aortic arch and the bilateral iliac arteries. In this case, cardiopulmonary bypass was established with the femoro-femoral bypass together with additional axillary cannulation (arrows). **b** The optimal intercostal space for thoracotomy was determined based on a 3-dimensional CT scan, as the aortic valve, the aortotomy, and the anterolateral thoracotomy were located on a straight line (long arrow). ALT, anterolateral thoracotomy; Ao-tomy, aortotomy; AV, aortic valve

thoracotomy, is not a contraindication for MIAVR through an anterolateral thoracotomy.

Surgical technique

We adopted anterolateral thoracotomy for the surgical approach to MIAVR in October 2012, as we previously reported [4]. Our MIAVR procedure has been updated with some modifications. General anesthesia is performed with a double-lumen endotracheal tube for one-lung ventilation. The patient is set in the left mid-lateral decubitus position, as for minimally invasive mitral valve surgery. The heart is accessed through a right anterolateral mini-thoracotomy at the 3rd or 4th intercostal space (ICS). In the early period of this procedure, skin incision was set using the tip of the right atrial appendage as a landmark, and the 4th ICS was used in 81% of patients. However, the ICS for thoracotomy is currently set using the aortic axis as a landmark, and aortotomy and thoracotomy are performed along a straight line determined using three-dimensional CT scan (Fig. 1b). Almost all MIAVR procedures are now performed through the 3rd ICS. There is no need to sacrifice the right internal thoracic artery at any ICS in the anterolateral thoracotomy approach.

Femoro-femoral cannulation is a standard method used to establish CPB. The arterial cannula size is based on 70% of the femoral artery diameter. Axillary artery cannulation using a 14-Fr cannula is sometimes added in cases with atherosclerotic changes in the aorta, and bifemoral arterial cannulation is occasionally used when the femoral arteries have a narrow caliber. We limit the use of bifemoral arterial cannulation to cases with narrow femoral arteries and rare atherosclerotic changes in the aorta. The bifemoral cannula sizes are usually 14 Fr + 14 Fr or 14 Fr + 16 Fr. The ascending aorta is cross-clamped with a flexible clamp, instead of the previously used transthoracic Chitwood clamp. Cardiac arrest is induced via delivery of antegrade and/or selective cold modified St. Thomas' solution. A loading dose of 30 ml/kg of cardioplegic solution was administered and a maintenance dose of 10 ml/kg was administered hourly, as previously reported [5]. The aortic valve is inspected after a modified transverse aortotomy, J-shaped aortotomy, and setting of traction sutures. The annular calcifications are completely removed with an ultrasonic aspirator and pledgeted non-everting mattress sutures are placed at the aortic annulus. Digital knot tying is usually impossible; therefore, sutures are tied using a knot pusher. A prosthetic valve is then placed in a supra-annular position. The aortotomy is closed in two layers with a running 4–0 polypropylene suture. After inflation of the right lung, most of the air is evacuated from the aortic root vent and the aortic clamp is removed. Although not validated, the right lung is ventilated as long as possible during CPB weaning to prevent unilateral reperfusion pulmonary edema. After de-airing procedures, CPB is terminated. The pericardium is loosely closed and two chest tubes are placed. Patients undergo cryoablation of the intercostal nerve to reduce postoperative pain. The thoracotomy incision is closed in a usual manner.

We have actively performed concomitant septal myectomy during MIAVR, although the indication is still controversial, anticipating left ventricular mass regression and improvement in diastolic function [6]. Our criteria for concomitant myectomy are as follows: asymmetric septal hypertrophy with AS; left ventricular hypertrophy with a narrow ventricular chamber; and sigmoid septum that might cause left ventricular outflow tract stenosis after valve replacement. However, the resected septum is usually thinner, at approximately 5 mm, than that in surgery for hypertrophic obstructive cardiomyopathy.

Statistical analysis

All values are presented as mean ± standard deviation or number (percentage). Patients' demographic characteristics and perioperative data were compared using the unpaired Student *t* test or the Wilcoxon test for quantitative variables, and the Chi-square test or Fisher's exact test for categorical variables. Mid-term cumulative survival rate and the rate of freedom from valve-related complications were assessed using Kaplan–Meier survival curves with a log-rank test. All values of $P < 0.05$ were considered to be of statistical significance. JMP 10.0.2 for Macintosh (SAS Institute Inc.) software was used for all analyses.

Results

Patients' demographic characteristics

Patients' demographic characteristics are summarized in Table 1. Among all cases of isolated AVR, MIAVR accounted for 47% cases during this study period. The mean age of Group O was 83.6 ± 2.9 years, with a maximum of 89. The number of patients with congenital bicuspid aortic valve was significantly larger in Group Y than in Group O ($P = 0.004$). In Group O, only 1 patient (2%) was at high risk (STS score > 8) and 17 (42%) were at intermediate risk (STS score 4 to 8), whereas Group Y had no high-risk cases and only 1 case (1.4%) of intermediate risk.

Surgical data

Details of the surgical data are shown in Table 2. No significant differences were found in times of operation, CPB, and aortic cross-clamping between the 2 groups ($P = 0.20$, $P = 0.88$, and $P = 0.60$, respectively). Bioprostheses were used in all patients (100%) in Group O and in 56 patients

Table 1 Patients' demographic characteristics

	Group Y, ($n=69$)	Group O, ($n=41$)	P value
Age (years)	69.7 ± 8.4	83.6 ± 2.9	< 0.0001
Male:female	28:41	10:31	0.08
Body surface area (m^2)	1.58 ± 0.19	1.45 ± 0.14	0.0002
Diabetes mellitus	19 (28%)	5 (12%)	0.09
Hypertension	53 (77%)	31 (76%)	0.89
Dyslipidemia	22 (32%)	15 (37%)	0.61
Congenital bicuspid valve	31 (45%)	7 (17%)	0.004
Chronic renal failure on hemodialysis	2 (3%)	2 (5%)	0.63
Hemoglobin (g/dl)	13.1 ± 1.6	11.5 ± 1.3	< 0.0001
Creatinine (mg/dl)	1.0 ± 1.6	1.1 ± 1.5	0.43
NYHA functional class	1.9 ± 0.6	1.9 ± 0.6	0.85
Ejection fraction (%)	68.2 ± 6.9	68.0 ± 8.0	0.87
Japan score (30 days mortality) (%)	2.0 ± 0.9	2.9 ± 1.3	< 0.0001
Japan score (30 days mortality + major morbidity) (%)	10.8 ± 3.7	13.6 ± 6.0	0.003
STS score (risk of mortality) (%)	1.9 ± 1.0	4.4 ± 2.7	< 0.0001
STS score (morbidity or mortality) (%)	13.3 ± 4.0	20.1 ± 5.6	< 0.0001

NYHA New York Heart Association, *STS* The Society of Thoracic Surgeons

Table 2 Surgical data

	Group Y, ($n=69$)	Group O, ($n=41$)	P value
Operation time (min)	268 ± 58	254 ± 35	0.20
Cardiopulmonary bypass time (min)	157 ± 23	154 ± 23	0.88
Aortic cross-clamping time (min)	103 ± 16	100 ± 16	0.60
Additional axillary artery cannulation	18 (26%)	12 (29%)	0.72
Bifemoral arterial cannulation	9 (13%)	1 (2.4%)	0.09
Prosthetic valve			
ATS AP360	8 (12%)	0 (0%)	
SJM regent	1 (1.4%)	0 (0%)	
CEP Magna ease	54 (78%)	36 (88%)	
Mosaic Ultra	5 (7%)	5 (12%)	
Trifecta	1 (1.4%)	0 (0%)	
Prosthetic valve size (mm)	21.6 ± 2.3	21.3 ± 1.8	0.59
Concomitant septal myectomy	6 (9%)	12 (29%)	0.007
Conversion to a full sternotomy	2 (3%)	0 (0%)	0.53

(88%) in Group Y ($P=0.02$). Twelve patients (29%) in Group O and 18 (26%) in Group Y underwent MIAVR under CPB with additional cannulation in the right axillary artery ($P=0.72$). Bifemoral arterial cannulation was performed for 1 patient (2.4%) in Group O and 9 (13%) in Group Y ($P=0.09$). The number of patients who underwent concomitant septal myectomy with AVR was significantly larger in Group O than in Group Y ($P=0.007$). Conversion to a full sternotomy was required in 2 patients in Group Y ($P=0.53$); 1 was for repair of paravalvular leakage and 1 for repair of bleeding from the apex. Only 1 patient in Group O underwent AVR following aortic root enlargement through a mini-thoracotomy [7].

Clinical outcome

Clinical outcomes are summarized in Table 3. There were no cases of in-hospital mortality, stroke, or reexploration for bleeding in the present study. Only 1 patient in Group Y, who had taken corticosteroids and immunosuppressants for primary biliary cirrhosis, developed superficial surgical site infection after MIAVR. Pacemaker implantation was required in 3 patients in Group Y ($P=0.29$): 1 patient was diagnosed with sick sinus syndrome before surgery; 1 underwent concomitant transaortic septal myectomy for hypertrophic obstructive cardiomyopathy [8]; and 1 developed bleeding from the apex resulting in conversion to full

Table 3 Clinical outcome

	Group Y, ($n=69$)	Group O, ($n=41$)	P value
In-hospital mortality	0 (0%)	0 (0%)	1.00
Stroke	0 (0%)	0 (0%)	1.00
Reexploration for bleeding	0 (0%)	0 (0%)	1.00
Surgical site infection	1 (1.4%)	0 (0%)	1.00
Pacemaker implantation	3 (4%)	0 (0%)	0.29
Blood transfusion	19 (28%)	21 (51%)	0.01
Ventilation time (hours)	6.5 ± 4.7	8.7 ± 8.2	0.07
Intensive care unit stay (days)	1.9 ± 0.8	2.0 ± 0.6	0.47
Hospital stay after surgery (days)	16.8 ± 6.9	16.4 ± 5.0	0.87
Postoperative mean AVPG (mmHg)	11.8 ± 4.0	11.2 ± 3.9	0.45
EOAI (cm^2/m^2)	0.98 ± 0.17	1.00 ± 0.16	0.37
Paravalvular leakage	0 (0%)	0 (0%)	1.00

AVPG aortic valve pressure gradient, *EOAI* effective orifice area index

sternotomy. A significant difference was found in the rate of blood transfusion ($P=0.01$); however, there was no significant difference between the 2 groups in ventilation time, length of intensive care unit (ICU) stay, and length of hospital stay ($P=0.07$, $P=0.47$, and $P=0.87$, respectively). Regarding postoperative echocardiographic data, there were no cases of paravalvular leakage in both groups, and no significant differences were found in mean aortic valve pressure gradient or effective orifice area index (EOAI) ($P=0.45$ and $P=0.37$, respectively). The mean EOAI was 0.98 ± 0.17 (range 0.67–1.50) cm^2/m^2 in Group Y and 1.00 ± 0.16 (range 0.73–1.38) cm^2/m^2 in Group O, and there were no cases of severe prosthesis-patient mismatch, defined as <0.65 cm^2/m^2 of EOAI in both groups.

Mid-term outcome

The overall 5-year survival rate calculated by Kaplan–Meier analysis was 0.93. The mean follow-up period of Group O was 34 ± 15 months and that of Group Y was 35 ± 19 months. Cumulative survival rate and the rate of freedom from valve-related complications, such as cerebral hemorrhage and infective endocarditis, are represented by Kaplan–Meier survival curves in Fig. 2. There were no significant differences between the 2 groups in the rates of cumulative survival and freedom from valve-related complications. Regarding valve-related complications, 1 patient in Group O developed cerebral hemorrhage 6 months after surgery and 1 patient in Group Y developed prosthetic valve endocarditis within a month after surgery. Structural valve deterioration was not seen in either group.

Discussion

Although full median sternotomy is the standard approach for cardiac surgery, a less-invasive approach that preserves the sternum partially or totally emerged in the 1990s. Upper partial sternotomy is now the most common approach for MIAVR procedures [9], since it does not require special instruments and offers almost the same surgical view of the aortic valve as does the conventional approach. On the other hand, many cardiac surgeons have come to focus on the right mini-thoracotomy approach, because of the lower incidence of postoperative atrial fibrillation and blood transfusion, as well as the shorter ventilation time

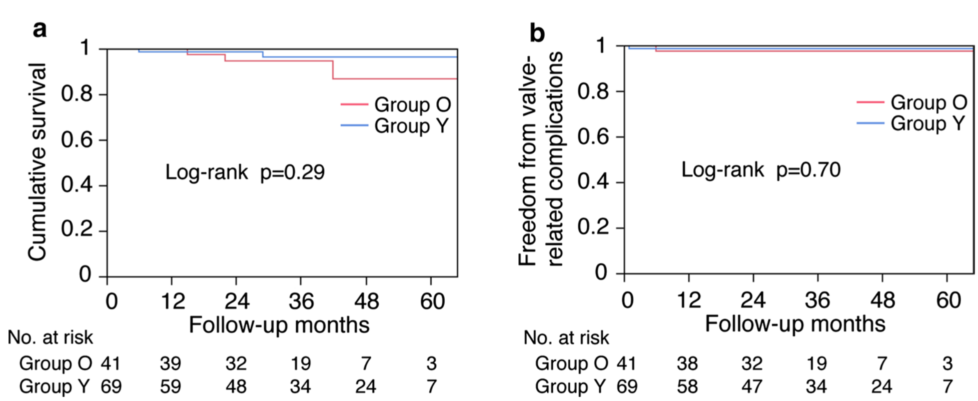

Fig. 2 Cumulative survival rate (**a**) and the rate of freedom from valve-related complications (**b**) are shown in Kaplan–Meier survival curves

and length of hospital stay [10]. We demonstrated that the mini-thoracotomy approach was superior to the partial sternotomy approach in a propensity-score matched study [11]. Although right anterior thoracotomy is the standard approach for MIAVR through the intercostal thoracotomy, infra-axillary thoracotomy [12] and anterolateral thoracotomy [4] have been reported as variations of the right mini-thoracotomy approach. A leftward shift of the ascending aorta is considered to be inappropriate for MIAVR via right anterior thoracotomy because of the poor exposure of the aortic valve [13]. However, the leftward shift of the aorta is not a contraindication in our institute, although the surgical difficulty is increased. Lateral shift of the surgical window offers a panoramic view around the aortic valve. By contrast, special instruments are necessary, such as a knot pusher and a needle holder, because the skin-to-valve distance is greater in the anterolateral approach than in a right anterior thoracotomy. The times of CPB and aortic cross-clamping in the anterolateral approach were significantly longer than those in anterior thoracotomy; however, the 2 approaches showed no significant difference as regards clinical outcomes [4].

In the present study, we investigated the clinical outcomes of MIAVR in octogenarians compared with younger patients. As regards the patients' demographic characteristics, the patient population of Group O mainly consisted of elderly patients with senile AS, whereas Group Y comprised patients with AS due to a congenital bicuspid aortic valve. The STS score in Group O was naturally higher than that in Group Y; 44% of patients in Group O had intermediate or higher risk (STS score > 4). Therefore, there is a concern about the higher risk of postoperative complications including stroke, especially in elderly patients. Since peripheral cannulation is indispensable for MIAVR through an anterolateral thoracotomy and a consensus statement of the International Society of Minimally Invasive Cardiothoracic Surgery demonstrated that minimally invasive surgery should be considered against the increased risk of stroke [3]. We consider that retrograde perfusion itself is not a risk factor for stroke, and that inappropriate patient selection would lead to an increased risk of cerebral infarction. Hence, we regard preoperative contrast-enhanced CT scan as the most important modality for performing MIAVR safely in elderly patients. In our series of isolated AVR, the main reason to avoid MIAVR was the presence of narrow and/or diseased peripheral arteries. If there are any atherosclerotic changes in the aorta, we usually add right axillary cannulation to the femoro-femoral bypass for prevention of stroke. As a result, there were no cases of cerebral infarction in patients who underwent MIAVR. In contrast, bifemoral arterial cannulation was rare in octogenarians because the indication was limited to cases with narrow femoral arteries and rare atherosclerotic changes in the aorta. Although bifemoral arterial cannulation is technically easier than additional axillary cannulation, we consider that the latter can be used for a variety of situations, other than cases with a narrow axillary artery. Our perfusion strategy, based on preoperative evaluation using a contrast-enhanced CT scan, could lead to appropriate patient selection, proper management of high-risk patients, prevention of postoperative cerebral infarction, and satisfactory results, even in octogenarians. In the future, central aortic cannulation may be an issue to perform MIAVR in patients with peripheral artery disease.

Regarding the surgical data, concomitant septal myectomy were more frequently performed in Group O than in Group Y. Advanced age was related to complicated surgical procedures as a result of left ventricular hypertrophy. Despite the complicated procedure, no significant differences were found in the times of operation, CPB, and aortic cross-clamping between the 2 groups. The smaller body surface area in Group O could be a factor, because a shorter skin-to-valve distance makes the entire surgical procedure easier in MIAVR. We always used conventional stented tissue valves in MIAVR because sutureless valves have not yet been approved in Japan. A knot-pusher is required for tying of annular sutures through an anterolateral mini-thoracotomy. We prefer the Carpentier-Edwards PERIMOUNT Magna Ease aortic valve (Edwards Lifesciences, Irvine, CA, USA) because of its well-balanced performance and implantability. To prevent paravalvular leakage in MIAVR, we focus on the difference between the sewing cuff and the stent base of the Magna Ease valve, and on introducing the tip of a knot-pusher just onto the sewing cuff. The CPB and aortic cross-clamping times in the present study were longer than those in other reports [2,10,13]. This could be because rapid-deployment valves, titanium fasteners, and some types of crystalloid cardioplegia including Bretschneider's histidine tryptophan ketoglutarate solution have not been approved in Japan. However, our short-term results are satisfactory. Once sutureless valves and minimally-invasive devices are approved in Japan in the near future, some issues with MIAVR, including placing annular sutures and complicated knot-tying, may be resolved. In addition, an 88-year-old patient in Group O underwent AVR following aortic root enlargement through a mini-thoracotomy [7], although a small aortic annulus requiring enlargement has been a contraindication in our hospital. Since bleeding from the edge of the patch can be lethal through a mini-thoracotomy, the indication should be limited. However, avoiding sternotomy-related complications such as dehiscence is especially useful for elderly or obese patients and can contribute to early rehabilitation. Aortic root enlargement would be the next step in MIAVR.

There were no cases of in-hospital death, stroke, bleeding requiring reexploration, or surgical site infection in Group O, in spite of the significantly higher risk scores. The rate of blood transfusion was significantly higher in Group O than in Group Y, since the preoperative hemoglobin level in Group O was significantly lower than that in Group Y. However, there were no significant differences in ventilation time, the length of ICU stay, and the length of hospital stay. Preserving the sternum decreased sternotomy-related complications, including bleeding, infection, and dehiscence, and enabled early rehabilitation in elderly patients, thus reducing mortality and morbidity. The hospital stay in the present study is longer than that in other reports [2,10,13]. Patients who underwent MIAVR, and even octogenarians, could be almost discharged within a week. However, many patients, even in Group Y, preferred continued hospitalization for further rehabilitation. Our policy for postoperative patient care prolonged mean hospital stay in the 2 groups. Postoperative echocardiography showed no case of paravalvular leakage and prosthetic valve performance was satisfactory in octogenarians. Furthermore, the cumulative survival rate and the rate of freedom from valve-related complications were excellent in Group O. Elderly patients to whom MIAVR is recommended usually have less atherosclerotic change in the aorta. This, together with the early rehabilitation, might contribute to the good mid-term results in octogenarians.

Recent advances in percutaneous treatment have made TAVI a safe therapeutic option for AS. Some clinical trials focused on elderly patients at intermediate risk indicate that the outcome of TAVI is as good as that of conventional surgery [14]; TAVI has now become the first treatment of choice for elderly or high-risk patients with AS. However, there are some cases in which TAVI is inappropriate for anatomical reasons, such as low takeoff of coronary ostia and left ventricular outflow tract calcifications. In our case of aortic root enlargement, TAVI was inappropriate because the annulus was too narrow [7]. A propensity-score-matched analysis comparing TAVI with MIAVR reported by Miceli et al. [15] demonstrated that the rate of paravalvular leakage was significantly lower in the MIAVR group and that there was a non-significant trend toward better mid-term survival in the MIAVR group. Compared with TAVI, the surgical approach has the advantage of removing the calcified valve. This may reduce the risk of paravalvular leakage, which is a well-known risk factor for decreased survival [16]. Furthermore, concomitant mitral surgery and arrhythmia surgery can be performed during MIAVR [17,18]. These concomitant procedures could be of added value for active elderly patients with AS.

Our study has some limitations. First, the present study was a retrospective analysis with a small sample size. Further studies with larger patient populations might identify significant differences in other variables, such as ventilation time and cumulative survival. Second, MIAVR cannot be performed in all elderly patients with AS. In our institute, MIAVR was performed in only 47% of patients who underwent isolated AVR. Third, MIAVR was performed by a single surgeon in the present study. To evaluate the efficacy of MIAVR, a multicenter study by multiple surgeons is necessary and more detailed clinical parameters should be investigated.

Conclusion

With careful patient selection and a perfusion strategy based on preoperative CT scan, there were no cases of hospital death or stroke, and equivalent outcomes of MIAVR were even achieved in octogenarians. In the future, central aortic cannulation and aortic root enlargement would be the next step in MIAVR.

Compliance with ethical standards

Conflict of interest The authors have no conflict of interest to declare.

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