Outcome comparison of different approaches to aortic root aneurysm

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ABSTRACT

Background: The treatment of aortic root aneurysm remains challenging for both cardiac surgeons and cardiologists.

Aims: This study aimed to assess and compare the long-term outcomes of different approaches to aortic root replacement (ARR).

Methods: All elective patients operated for aortic root aneurysm with or without aortic regurgitation at our institution over a 10-year period were included. We excluded patients with any degree of aortic stenosis and with active endocarditis. We assessed mortality, freedom from reoperation, freedom from aortic valve regurgitation, and the rate of hemorrhagic and thromboembolic complications.

Results: Two hundred and four patients underwent elective aortic root replacement: 107 (53%) valve-sparing aortic root replacement (VSARR), 35 (17%) mechanical Bentall procedure (MB), and 62 (30%) Bio-Bentall procedure (BB). Early mortality for VSARR, BB, and MB group was 2.8%, 4.8%, and 0%, respectively ($P = 0.40$). Estimated 5-year survival was: 90.2% vs. 78.4% vs. 94.2%, respectively ($P = 0.12$), 5-year freedom from reoperation: 97.8%, 96.6%, and 96.8%, respectively ($P = 0.99$). Estimated 5-year freedom from complications was: 94.2%, 83.1% and 57.3% in the VSARR, BB and MB group, respectively ($P < 0.001$). On last follow-up echocardiography, 90.5%, 98.4%, and 97.1% ($P = 0.08$) of patients were free from aortic regurgitation grade 2 or higher. The median (IQR) aortic valve peak gradient was 9 (6–12) mm Hg, 12 (10–18) mm Hg and 16 (14–22) mm Hg, respectively ($P < 0.001$). Complications were predicted by mechanical Bentall (hazard ratio, 6.70 [2.54–17.63]; $P < 0.001$).

Conclusion: With the same mortality, freedom from reoperation, and a minimal late complication rate in comparison with mechanical Bentall and Bio-Bentall, VSARR might be the preferred approach to aortic root aneurysm.

Key words: aortic root aneurysm, aortic root replacement, Bio-Bentall, mechanical Bentall, valve-sparing

INTRODUCTION

The only effective treatment method for aortic root aneurysm is aortic root replacement (ARR) [1]. Currently, the „gold standard" for ARR is represented by the procedure proposed in 1968 by Bentall, which consists of the replacement of both the aortic root and the aortic valve with the use of a composite mechanical valved conduit [2]. In older patients, the available alternatives to the classical Bentall procedure include the ARR with the homograft [3], xenograft [4], or bio-conduit [5]. However, in younger patients who want to avoid the adverse effects of mechanical or biological aortic valve prostheses, the procedure of valve-sparing aortic root replacement (VSARR) has been proposed. This approach enables the replacement of the enlarged aortic root, with the preservation of the native aortic valve. Two main techniques of

WHAT'S NEW?

This analysis of long-term outcomes of different surgical approaches to aortic root aneurysm is the largest performed to date in Poland (and one of the largest in Europe). The analysis of mortality, freedom from reoperation, aortic valve regurgitation, and hemorrhagic and thromboembolic complications identified valve-sparing aortic root replacement as a surgical approach associated with low early morbidity and a very low rate of late hemorrhagic and thromboembolic complications.

VSARR are currently available in clinical practice: the aortic valve re-implantation introduced by David and Feindel in 1992 [6] and aortic root remodeling proposed by Sarsam and Yacoub in 1993 [7].

The selection of an approach to ARR is important both for patients, whose expectations it has to meet, and for their cardiologist.

Several studies on late outcomes of different approaches to ARR have been published recently; however, only a few include the direct comparison of these approaches [8, 9].

This study aimed to assess and compare the long-term outcomes of different approaches to ARR.

METHODS

The local Institutional Review Board did not consider the study to be a medical experiment. Therefore, approval was not required (no. KNW/0022/KB/284/17 dated December 12, 2017).

Study population

The study included patients who underwent an elective ARR with or without co-existing aortic valve regurgitation at our institution from January 2010 to December 2020 but excluded those with aortic valve stenosis. Patients with acute aortic dissection or active endocarditis were also excluded. However, we included patients requiring additional surgical procedures (Figure 1).

The study group was divided into 3 subgroups, depending on the approach to ARR: VSARR, Bentall procedure with mechanical aortic valve prosthesis (MB), and Bentall procedure with biological aortic valve prosthesis (BB).

Clinical outcomes

We assessed mortality, freedom from reoperation, recurrence of aortic valve regurgitation, rate of hemorrhagic and thromboembolic complications, and infective endocarditis. The functional status was determined according to the New York Heart Association (NYHA) class. Aortic regurgitation was assessed by transthoracic echocardiography (TTE) and was classified according to the 4-grade scale: 0 — none or trivial, 1 — mild, 2 — moderate, 3 — moderately severe, 4–severe [10, 11]. Freedom from aortic valve regurgitation was defined as grade <2. Definitions of complications followed the guidelines for reporting morbidity and mortality [12]. Only major thromboembolic and hemorrhagic

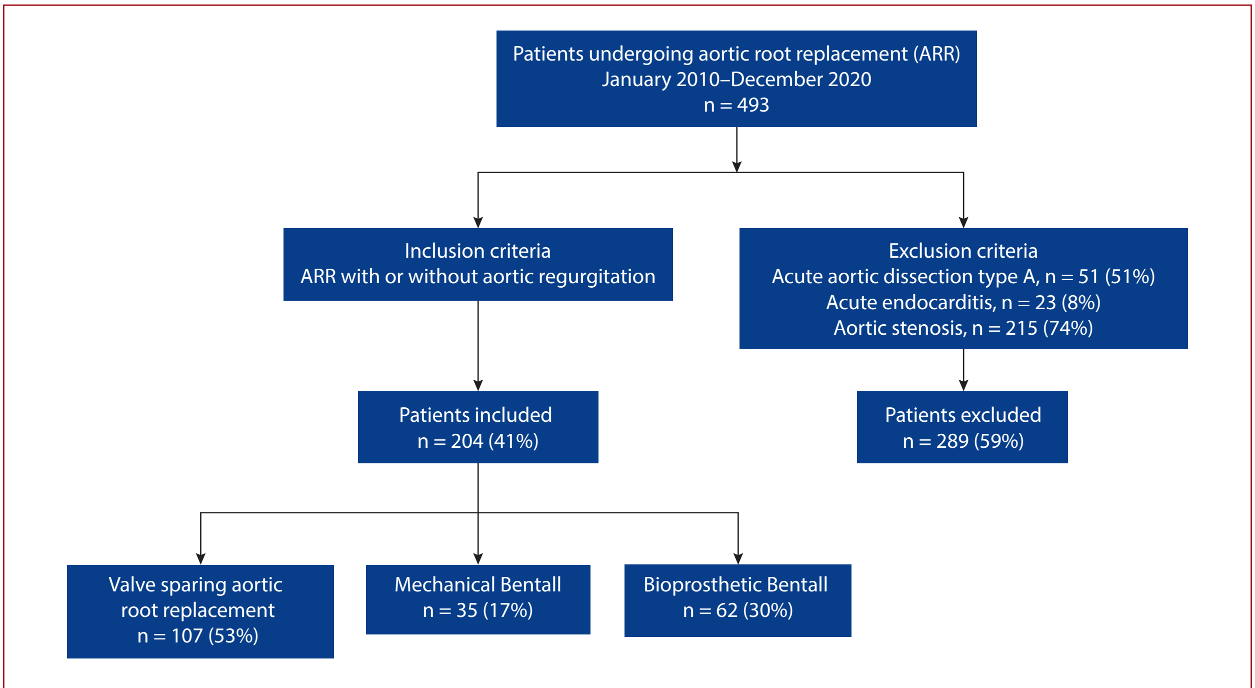

Figure 1. Study cohort flow chart

complications requiring hospitalization were analyzed. Thromboembolic complications were defined as stroke, peripheral organ ischemia, or dysfunction of the prosthetic valve leaflet, whereas hemorrhagic complications as cardiac tamponade or any bleeding from the upper or lower gastrointestinal tract, intracranial bleeding, or hemarthrosis. Freedom from complications defined as freedom from reoperation, endocarditis, and thromboembolic, or hemorrhagic events was analyzed. Death was considered early when it occurred within 30 days of surgery.

Follow-up

Mortality, the occurrence of complications, and freedom from reoperation status were ascertained from one or more of the following: the patient's visit in the outpatient clinic, telephone contact with the patient or patient's relatives, National Registry of Cardiac Surgical Procedures (www.krok.csioz.gov.pl). This registry contains the mortality data obtained from the National Health Fund. Death from all causes and only reoperations due to aortic valve dysfunction were included in the analysis. Freedom from aortic valve regurgitation was assessed in the TTE performed during the follow-up visit or ascertained based on the latest TTE report available from the outpatient clinic.

Surgical technique

Before surgery, the TTE was performed to evaluate left ventricular ejection fraction (LVEF), end-diastolic (LVEDV), and end-systolic (LVESV) volumes, the diameters of the left ventricular outflow tract (LVOT), aortic annulus, aortic root, and ascending aorta. Computed tomography was performed to plan accordingly the surgery on the aorta.

The decision about the type of ARR (valve-sparing vs. mechanical vs. biological Bentall) was made by the operating surgeon and the patient.

For aortic valve reimplantation, two types of vascular conduits were used: Vascutec Gelweave Valsalva (Vascutek, Renfrewshire, UK) and Hemashield (Maquet, Rastatt, Germany). For aortic root remodeling, two types of vascular conduits were used: Hemashield (Maquet, Rastatt, Germany) and Bioseal (Jotec Inc., Hechingen, Germany). For MB procedures we used 2 types of mechanical valved conduits: St. Jude Medical (SJM, St. Paul, MN, US) and Carbomedics Carbo-Seal (Sorin, Milano, Italy) and 2 types of bio-conduits (BB subgroup): Freestyle (Medtronic, Minneapolis, MN, US) and Biovalsalva biological valved conduit (Vascutek, Renfrewshire, UK) (Supplementary material, *Video S1*).

Statistical analysis

Data are presented as median (interquartile range [IQR]). Categorical data are expressed as a percentage. χ^2 or Fisher's exact tests were used where appropriate to compare proportions with *post hoc* comparisons using the z test. *P*-values were adjusted for multiple comparisons using the Bonferroni correction. To compare the groups, the Kruskal-Wallis H test for the independent sample with Bonferroni adjusted pairwise comparisons was used. Kaplan-Meier time to event curves were generated, and the 5-year event probability estimate with the standard error was reported. The groups were compared with the log-rank (Mantel-Cox) test. A *P*-value of less than 0.05 was considered significant. The predictors of mortality and complications were identified by the parsimonious multivariable Cox regression. The backward conditional method was used for variables selection with variables with score statistics below <0.1 retained in the model. In the case the final model did not include the variable of interest (i.e. Root replacement method), this variable was entered into the final model manually to assess its impact on the outcome.

IBM SPSS Statistics, version 27 (IBM Corp. Armonk, NY, US) was used for all statistical analysis except Kaplan-Meier analysis which was done using GraphPad Prism 9.1 (GraphPad Software, San Diego, CA, US).

RESULTS

Study cohort

Of the 493 patients who underwent the ARR procedure, only 204 patients (41.4%) met the inclusion criteria (Figure 1). The numbers of patients in particular study subgroups were: VSARR — 107 (52.5%), MB — 35 (17.1%), BB — 62 (30.4%) (Figure 2).

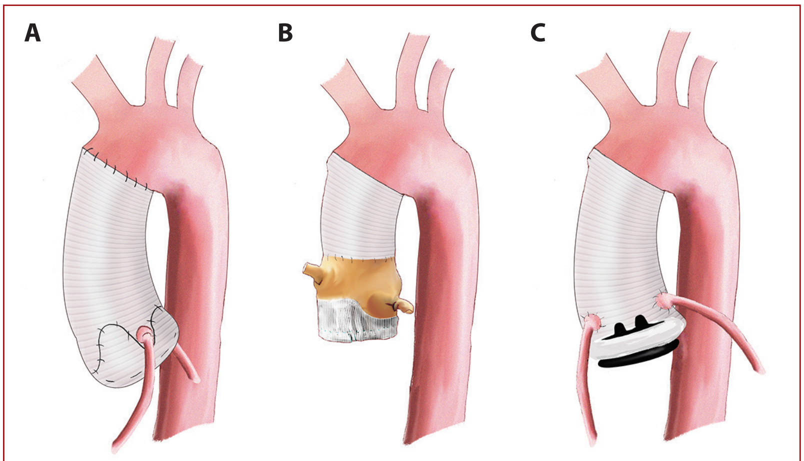

Figure 2. Surgical techniques of aortic root replacement. **A.** Valve-sparing aortic root replacement. **B.** Biological Bentall. **C.** Mechanical Bentall

Table 1. Clinical and echocardiographic characteristics.

Variable	All (n = 204)	VSARR (n = 107)	MB (n = 35)	BB (n = 62)	*P*-value
Clinical data					
Male gender, n (%)	181 (88.7)	94 (87.9)	32 (91.4)	55 (88.7)	0.85
Age, years, median (IQR)	55 (39–64)	52 (36–64)[a]	50 (39–59)[b]	60.5 (46.7–69)	0.02
BMI, kg/m², median (IQR)	27 (24–30)	27.0 (24–30)	28 (24–31)	27.5 (25–31)	0.56
NYHA, median (IQR)	2 (1–2)	2 (1–2)[a]	2 (1–3)	2 (2–3)	0.004
NYHA class, n (%)					0.02
I	70 (34.3)	44 (41.1)[a]	12 (34.3)	14 (22.6)	
II	97 (47.5)	53 (49.5)	14 (40.0)	30 (48.4)	
III	31 (15.2)	8 (7.5)[a]	7 (20)	16 (25.8)	
IV	6 (2.9)	2 (1.9)	2 (5.7)	2 (3.2)	
BAV, n (%)	91 (44.6)	43 (40.2)	18 (51.4)	30 (48.4)	0.39
Marfan syndrome, n (%)	26 (12.7)	17 (15.9)	4 (11.4)	5 (8.1)	0.33
Coronary artery disease, n (%)	30 (14.7)	14 (13.1)	8 (22.9)	8 (12.9)	0.33
Reoperation, n (%)	15 (7.4)	4 (3.7)[c]	6 (17.1)	5 (8.1)	0.03
At least moderate mitral regurgitation, n (%)	30 (14.7)	12 (19.4)	6 (17.1)	12 (11.2)	0.32
At least moderate tricuspid regurgitation, n (%)	17 (8.3)	12 (11.2)	2 (5.7)	3 (4.8)	0.29
Arterial hypertension, n (%)	150 (73.5)	76 (71.0)	25 (71.4)	49 (79.0)	0.50
Atrial fibrillation, n (%)	27 (13.2)	11 (10.3)	5 (14.3)	11 (17.7)	0.38
Diabetes mellitus, n (%)	19 (9.3)	7 (6.5)	3 (8.6)	9 (14.5)	0.23
Chronic renal failure, GFR <50 ml/min, n (%)	9 (4.4)	4 (3.7)	1 (2.9)	4 (6.5)	0.63
EuroSCORE II, median (IQR)	3.38 (2.48–6.22)	3.41 (2.48–5.06)	4.8 (2.76–9.46)	2.89 (1.83–6.53)	0.08
Echocardiographic data					
Aortic regurgitation grade, median (IQR)	3.5 (3.0–4.0)	3.0 (2.0–4.0)[c,a]	4.0 (3.0–4.0)	4.0 (3.0–4.0)	<0.001
Aortic regurgitation grade, n (%)					0.001
0	12 (5.9)	11 (5.4)[a]	0	1 (1.6)	
1	10 (4.9)	9 (8.4)	1 (2.9)	0	
2	18 (8.8)	14 (13.1)	1 (2.9)	3 (4.8)	
3	62 (30.4)	32 (29.9)	13 (37.1)	17 (27.4)	
4	102 (50)	41 (38.3)[a]	20 (57.1)	41 (66.1)	
LVOT, mm, median (IQR)	n = 145 24 (22–26)	n = 53 25 (22.5–27.0)[a]	n = 35 25 (23–27)	n = 57 23 (21–25)	0.02
Aortic annulus, mm, median (IQR)	n = 185 28 (26–30)	n = 93 27 (26–20)	n = 35 28 (26–31)	n = 57 28 (26–30)	0.54
Aortic root, mm, median (IQR)	50 (46–54)	50 (46–55)[a]	50 (47–55)	48 (44–52)	0.04
Ascending aorta, mm, median (IQR)	49 (40–55)	51 (46–56)[a]	51 (44–56)[b]	41.5 (36–50)	<0.001
LVEF, n (%)	55 (50–60)	55 (50–60)	53 (43–57)	55 (49.5–60)	0.13
LVEDV, ml, median (IQR)	n = 169 200 (160–253)	n = 81 195 (156–245)	n = 33 220 (162–310)	n = 55 198 (162–241)	0.23
LVESV, ml, median (IQR)	n = 169 94 (73–123)	n = 81 85 (65–123)	n = 33 100 (80–154)	n = 55 97 (75–123)	0.07

[a]P <0.05 VSARR vs. BB. [b]P <0.05 MB vs. BB. [c]P <0.05 VSARR vs. MB

Abbreviations: BAV, bicuspid aortic valve; BB, Bio-Bentall; BMI, body mass index; LVEDV, end-diastolic volume; LVEF, left ventricular ejection fraction; LVESV, end-systolic volume; LVOT, left ventricular outflow tract; MB, mechanical Bentall; NYHA, New York Heart Association; TAV, tricuspid aortic valve; VSARR, valve-sparing aortic root replacement

Patient characteristics

Detailed demographic and echocardiographic data are presented in Table 1. Patients in the MB subgroup were the youngest — median (IQR) age 50 (39–59) years, and those in the BB subgroup were the oldest — median (IQR) age 60.5 (46.7–69) years. All 3 groups did not differ with regard to co-morbidities. In the MB subgroup, a significantly higher rate of reoperations was noted — 6 patients (17.1%) vs. 4 patients (3.7%) in the VSARR subgroup and 5 patients (8.1%) in the BB subgroup ($P = 0.03$).

The echocardiographic data revealed a significantly lower grade of aortic valve regurgitation in the VSARR subgroup — median 3 (2–4) vs. the MB subgroup — median 4 (3–4) and the BB subgroup — median 4 (3–4) (P <0.001). Patients in the VSARR and MB subgroups had statistically larger diameters of LVOT, aortic root, and ascending aorta (Table 1).

Operative details

Detailed operative data are presented in Supplementary material, *Table S1*. In the VSARR subgroup, the remodeling procedure was performed in 53 (49.5%) patients and the reimplantation procedure in 54 (50.5%) patients. In the BB subgroup, the Freestyle xenograft was implanted in 59 (95.2%) patients and the BioValsalva biological valved conduit in 3 (4.8%) patients. In the MB subgroup, the

St. Jude Medical conduit was implanted in 13 (37.1%) patients and the Carbomedics Carbo-Seal conduit in 22 (62.9%) patients. There were fewer formal ascending aorta replacements in the BB subgroup — 31 patients (50%) vs. the VSARR subgroup — 97 (90.7%) patients and the MB subgroup — 35 (100%) patients (*P* <0.001). The shortest cardiopulmonary bypass and cross-clamp times were recorded in the BB subgroup, and the longest in the VSARR subgroup (Supplementary material, *Table S1*).

Early outcomes

Early mortality in the whole study population was 2.9% (6 patients). The numbers for subgroups VSARR, BB, and MB were 2.8% (3 patients), 4.8% (3 patients), and 0%, respectively (*P* = 0.40). There were no significant differences between the subgroups as to the rate of postoperative bleeding, tamponade, stroke, renal failure, pneumonia, wound infection, and permanent pacemaker implantation (Supplementary material, *Table S1*). The shortest stay in the intensive care unit and the cardiac surgical ward was recorded in the VSARR subgroup — 2 (2–3) days and 8 (7–10) days, respectively (*P* = 0.003).

Late outcomes

Median follow-up was 52.4 (27.4–5.4) months.

Mortality: Twenty-three (11.6%) patients died during the follow-up period. Kaplan-Meier estimated 5-year survival with standard error (SE) was: 90.2 (3.2) % in the VSARR, 78.4 (5.6) % in the BB, and 94.2 (4) % in the MB subgroup (*P* = 0.12, log-rank test) (Figure 3A).

Reoperations: A reoperation was performed in 6 patients (2.9%) during the follow-up period. The number of reoperations was: VSARR–3 patients (2.8%) due to severe aortic valve regurgitation, BB — 2 patients (3.2%) due to endocarditis and MB — 1 patient (2.9%) due to endocarditis (*P* = 0.99). Kaplan-Meier estimated 5-year freedom from reoperation (SE) was: 97.8 (1.5) % in the VSARR, 96.6 (2.4) % in the BB subgroup, and 96.8 (3.2) % in the MB subgroup (*P* = 0.99, log-rank test) (Figure 3B, Table 2).

Complications: Kaplan-Meier estimated 5-year freedom from complication was: 94.2 (2.6) % in the VSARR, 83.1 (5.6) % in the BB, and 57.3 (9.7) % in the MB subgroup (*P* <0.001, log-rank test) (Figure 3C, Table 2).

Hemorrhagic complications occurred in 13 patients (7.3%): nose bleeding in 8 (61.5%), cardiac tamponade in 3 (23.1%), hemarthrosis in 1 (7.7%), and hemorrhoids bleeding in 1 (7.7%). The hemorrhagic complication rate in particular subgroups was: VSARR — 1 patient (1%), BB — 3 patients (6.4%), and MB — 9 patients (27.3%) (*P* <0.001). Kaplan-Meier estimated 5-year freedom from hemorrhagic complications (SE) was: 99 (1)% in the VSARR, 92.2 (4.4) % in the BB, and 71.1 (8.9) % in the MB subgroup (*P* <0.001, log-rank test) (Figure 4A, Table 2).

Thromboembolic complications were recorded in 9 patients (5.1%): stroke in 8 (88.8%) and popliteal artery embolism in 1 (11.2%) (*P* <0.001). The thromboembolic complication rate was: VSARR — none, BB — 3 patients (6.4%), and MB — 6 patients (18.2%) (*P* <0.001). Kaplan–Meier estimated 5-year freedom from thromboembolic complications (SE) was: 100% in the VSARR, 94.1 (4.2) % in the BB, and 78.2 (10) % in the MB subgroup (*P* <0.001, log-rank test) (Figure 4B, Table 2).

The multivariable analysis showed that none of the approaches to ARR is a predictor of mortality: MB (hazard ratio [HR], 0.13; 95% confidence interval [CI], 0.09–1.36; *P* <0.13) and BB (HR, 1.35; 95% CI, 0.56–3.26; *P* <0.51). However, it revealed the following predictors of death: New York Heart Association (NYHA) functional class, LVEF, reoperation, and concomitant TV repair. Following predictors of complications were identified: the mechanical Bentall procedure (HR, 6.70; 95% CI, 2.54–17.63; *P* <0.001) and atrial fibrillation (HR, 2.83; 95% CI, 1.25–6.42; *P* <0.013) (Table 3).

Echocardiographic follow-up: Follow-up echocardiography for the assessment of the aortic valve regurgitation was performed in 93.8% of patients at the median of 46.8 (20.8–74.7) months after surgery. On last echocardiography, 98.1%, 98.4%, and 97.1% (*P* = 0.91) patients were free from ≥grade 3 aortic valve regurgitation in VSARR, BB and MB subgroups respectively. Freedom from ≥grade 2 aortic regurgitation was 90.5%, 98.4%, and 97.1% (*P* = 0.08).

Additionally, the echocardiographic follow-up revealed, that patients in the VSARR subgroup had the lowest median (IQR) aortic valve peak gradient of 9 (6–12) mm Hg, whereas in the BB and MB subgroups these medians of gradients were 12 (10–18) mm Hg and 16 (14–22) mm Hg, respectively (*P* <0.001) (Figure 5).

Discussion

The classic Bentall procedure currently represents the gold standard approach to ARR, particularly in younger patients, for whom it seems to be a lifelong solution [13]. In elderly patients, to avoid the need for oral anticoagulation, the BB procedure can be performed alternatively [13]. With a growing number of reports reporting a considerable ratio of thromboembolic complications after MB [14, 15], new stentless valves have been proposed for younger patients [16]. Moreover, VSARR procedures have been introduced to clinical practice [6, 7], which not only obviate the need for oral anticoagulation but also enable the preservation of the patient's native valve, thus ensuring a better hemodynamic profile in comparison to MB and BB. There is no consensus in the literature, whether during the ARR procedure the aortic valve should be repaired or replaced, and in the case of replacement, whether a mechanical or biological prosthesis should be preferred [17, 18]. Our analysis provides some guidance as to which approach to ARR yields the best outcomes and is associated with the lowest complication rate. Even though we have performed almost 500 ARR procedures during 10 years at our institution, we had to exclude patients with aortic valve stenosis to directly compare different approaches to ARR as in this group a VSARR procedure is usually not feasible and the

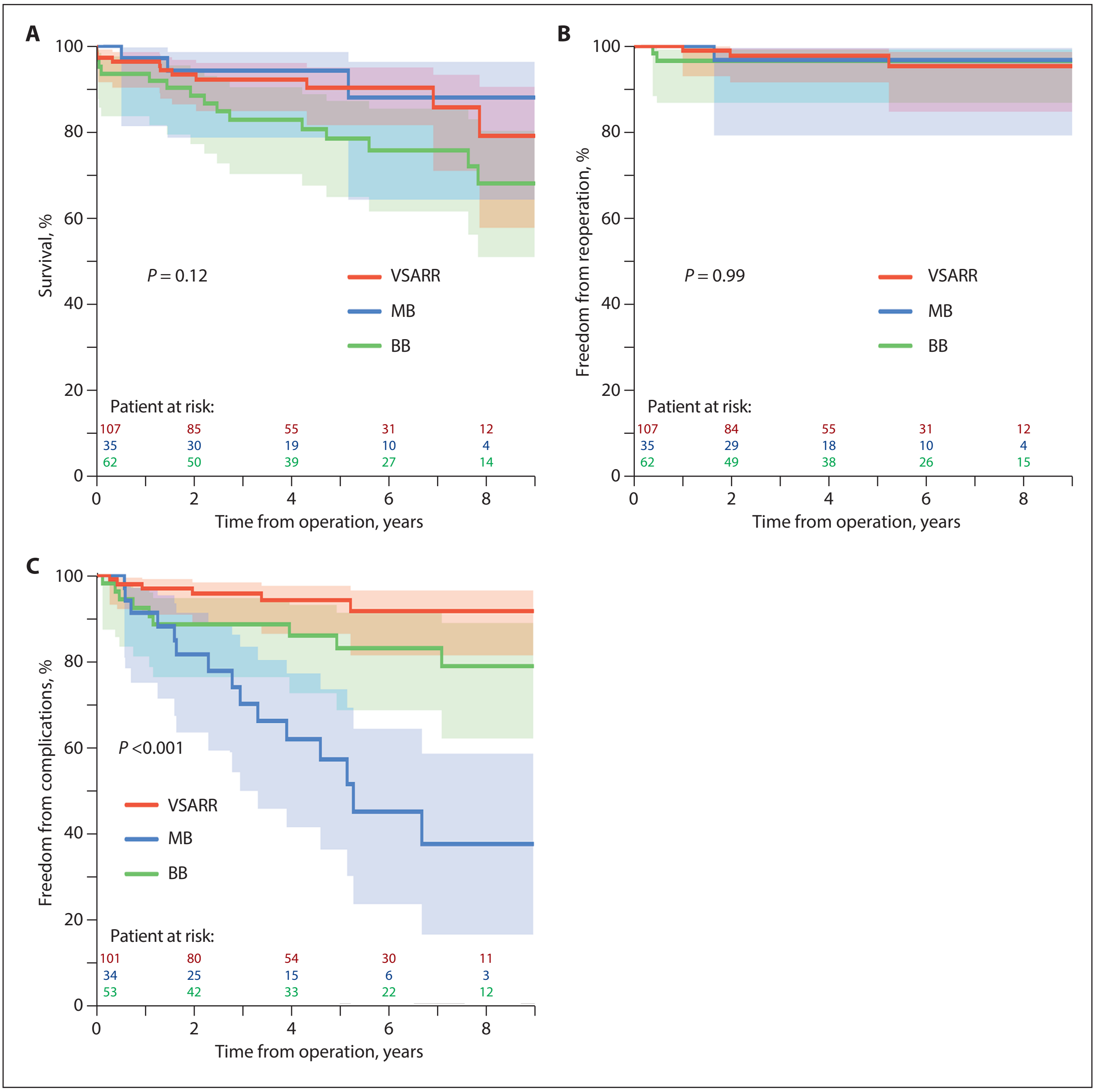

Figure 3. Kaplan-Meier curves after root replacement according to the surgical procedure. **A.** Survival. **B.** Freedom from reoperation. **C.** Freedom from complications (reoperation, endocarditis, hemorrhagic complications, and thromboembolic complications). Kaplan-Meier curves with 95% confidence interval. *P* from the log-rank (Mantel-Cox) test

Abbreviations: see Table 1

Table 2. Complications during the follow-up period

Variable	All (n = 204)	VSARR (n = 107)	MB (n = 35)	BB (n = 62)	*P*-value
Aortic valve reoperation	6 (2.9)	3 (2.8)	1 (2.9)	2 (3.2)	0.99
Thromboembolic complications	9 (5.1)	0	6 (18.2)	3 (6.4)	<0.001
Hemorrhagic complications	13 (7.3)	1 (1.0)[a]	9 (27.3)[b]	3 (6.4)	<0.001
Infective endocarditis	2 (1.0)	0	1 (2.9)	1 (1.6)	0.27

Data are presented as n (%); [a]*P* <0.05 VSARR vs. MB. [b]*P*<0.05 MB vs. BB

Abbreviations: see Table 1

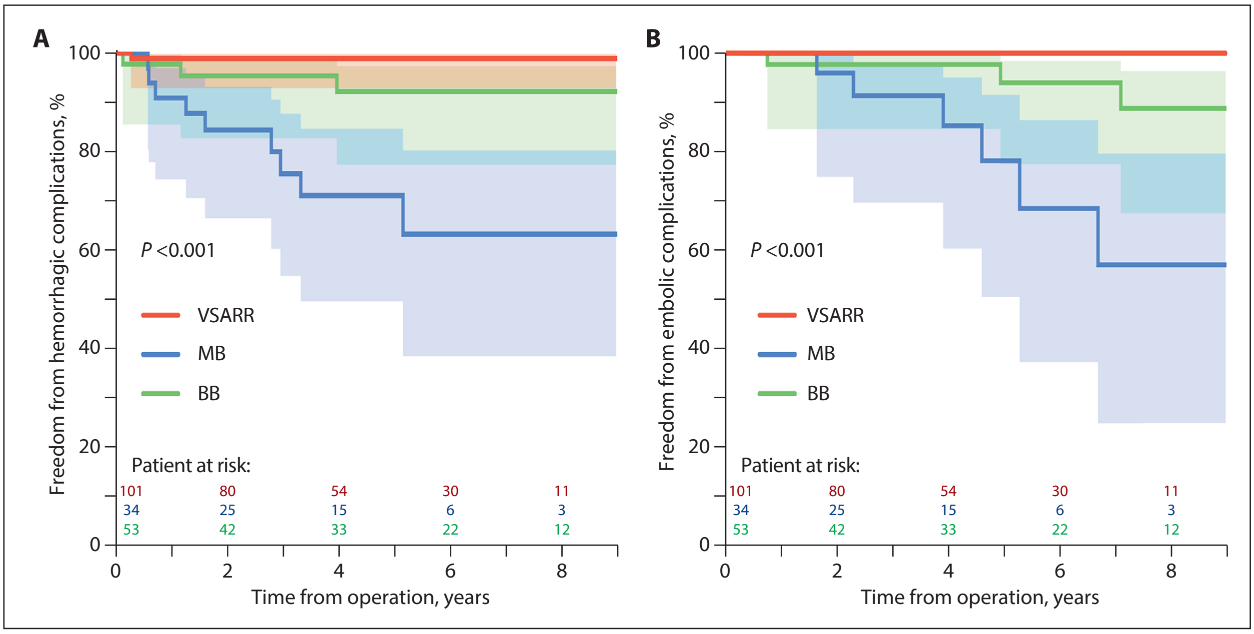

Figure 4. Freedom from complications after root replacement according to the surgical procedure. **A.** Hemorrhagic complications. **B.** Thromboembolic complications; Kaplan-Meier curves with 95% confidence interval. *P* from the log-rank (Mantel-Cox) test

Abbreviations: see Table 1

Table 3. Multivariable analysis of risk factors for mortality and complications.

Risk factors	Multivariable analysis	
	HR (95% CI)	*P*-value
Predictors of mortality		
Root replacement method (vs. VSARR)		
Mechanical Bentall	0.13 (0.09–1.36)	0.13
Biological Bentall	1.35 (0.56–3.26)	0.51
NYHA class (vs. NYHA I)		
NYHA II	5.88 (1.25–27.63)	0.03
NYHA III	8.62 (1.742–42.59)	0.008
NYHA IV	73.58 (13.49–401.27)	<0.001
LVEF	0.96 (0.92–1.0)	0.03
Concomitant tricuspid valve annuloplasty	7.02 (1.28–38.55)	0.03
Redo surgery	2.97 (0.98–9.07)	0.055
Predictors of complications		
Root replacement method (vs. VSARR)		
Mechanical Bentall	6.70 (2.54–17.63)	<0.001
Biological Bentall	2.19 (0.77–6.21)	0.14
Atrial fibrillation	2.83 (1.25–6.42)	0.01
NYHA class III–IV	2.07 (0.96–4.50)	0.07

Abbreviations: CI, confidence interval; HR, hazard ratio; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; VSARR, valve-sparing aortic root replacement

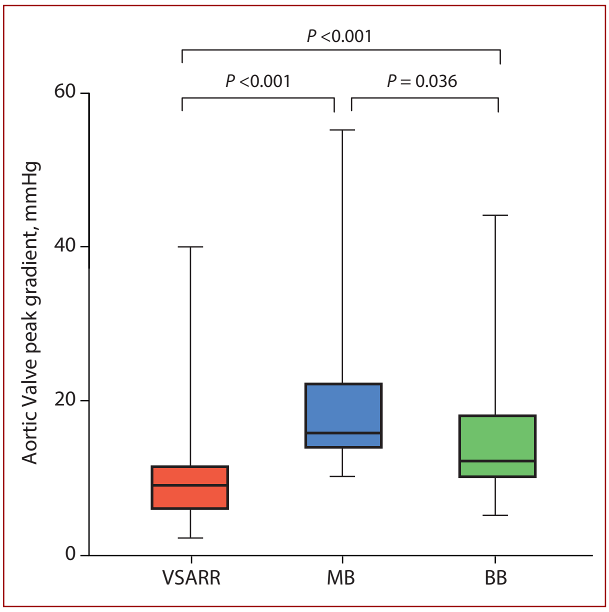

Figure 5. Aortic valve peak gradient at follow-up. Data are presented as median (IQR)

Abbreviations: see Table 1

pathology of the left ventricular wall muscle is different. All exclusions narrowed the study group to 204 patients; however, the selected study subgroups did not differ significantly as to baseline characteristics. The only difference was age, and it seems obvious, as the oldest patients were in subgroup BB and the youngest in subgroup MB. The baseline age heterogeneity seems to be inseparably associated with the analysis of different approaches to ARR and is present in several investigations published to date [17–19]. This is the consequence of age being one of the major factors impacting the choice of the valve prosthesis (biological vs. mechanical).

The assessment of early mortality did not reveal significant differences between the 3 subgroups ($P = 0.40$), and the overall mortality in the entire study group of 2.9% does not significantly differ from the early mortality of

1.9% reported by Yamabe et al. [20], who analyzed a large cohort of 371 patients.

Similarly, the estimated survival did not differ between the subgroups (P = 0.12, log-rank test). The best 5-year survival was noted in the MB subgroup, while the worst was in the BB subgroup (94.2% and 78.4%, respectively). Conversely, Bilkhu et al. [21], who analyzed 344 patients, reported the best 5-year survival in the VSARR group (100%) and the worst in the BB group (87%).

Interestingly, our analysis of freedom from reoperation also failed to reveal a significant difference between the subgroups (P = 0.99, log-rank test), and the proportion of patients who underwent reoperation during the follow-up period was rather low at 2.9%. In this regard, particularly good outcomes were noted in the VSARR subgroup where the 5-year freedom from reoperation (97.8%) was better in comparison to the 5-year freedom from reoperation of 87.9% reported by Badiu et al. [17].

This is the consequence of the small proportion of patients (1.9%) who developed severe aortic valve regurgitation during the follow-up. Notably, all 3 reoperations in the VSARR group were elective procedures performed due to severe aortic valve regurgitation, and all patients survived the surgery. In contrast, the reoperations in MB (1 patient) and BB subgroup (2 patients) were urgent procedures performed due to endocarditis with high operative risk, and 1 patient did not survive the surgery.

Considering that the comparison of early and late mortality, freedom from reoperation, and freedom from aortic valve regurgitation failed to demonstrate the advantage of any particular approach, it seems that the outcome which differs across the analyzed approaches is the rate of complications, both hemorrhagic and thrombo-embolic.

It is universally accepted that these complications not only substantially compromise the quality of life but also affect prognosis. Therefore, they should be taken into account while planning ARR surgery.

The analysis of complications that occurred during follow-up, revealed major differences between the assessed approaches. The VSARR procedures are associated with a very low risk of late complications both thromboembolic (0 patients) and hemorrhagic (1 patient, 1%), which translates into 99% estimated 5-year freedom from hemorrhagic complications and 100% estimated 5-year freedom from thromboembolic complications. Our results are in line with those published by Badiu et al. [17] who report in the VSARR group the 5-year freedom from hemorrhagic complications at 99.3%.

In our study, the highest rate of the above-mentioned complications was noted in the MB subgroup, where thromboembolic complications occurred in 18.2% of patients and hemorrhagic complications in 27.3%. This results in low estimated 5-year freedom from hemorrhagic and thromboembolic complications of 71.1% and 78.2%, respectively.

Similar low 7-year freedom from hemorrhagic and thromboembolic complications of 74.3% and 87.7%, respectively in the MB group was reported by Radu et al. [15].

The multivariable analysis confirmed that MB is an independent risk factor for complications (HR, 6.70; 95% CI, 2.54–17.63; P <0.001).

In conclusion, based on our findings it seems that VSARR procedures represent the best option for patients undergoing ARR surgery. This approach is associated with low mortality, a low reoperation rate, and a very low rate of late complications. Among the analyzed approaches, VSARR is also favored by the lowest follow-up NYHA class and the lowest aortic valve peak gradient.

Study limitations

The major limitation of our study is its retrospective design and non-randomized assignment to the analyzed subgroups. This is a single-center study, and the selection of the approach to ARR was left at the discretion of the operating surgeon.

Conclusions

With the same mortality, freedom from reoperation, and a small complication rate in comparison with mechanical Bentall and Bio-Bentall, VSARR might be the preferred approach to aortic root aneurysm.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska.

Article information

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