International Journal of Cardiology 296 (2019) 38–42

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Modified Bentall procedure: Mechanical vs biological valved conduits in patients older than 65 years☆

Andrea Lechiancole [a,*], Michele Celiento [b], Miriam Isola [c], Giuseppe Gatti [d], Giovanni Melina [e], Igor Vendramin [a], Claudio Battistella [c], Aniello Pappalardo [d], Riccardo Sinatra [e], Uberto Bortolotti [b], Ugolino Livi [a]

[a] Cadiothoracic Department, University Hospital of Udine, Italy
[b] Section of Cardiac Surgery, University Hospital of Pisa, Italy
[c] Department of Medicine, University of Udine, Italy
[d] Cardiothoracic and Vascular Department, University Hospital of Trieste, Italy
[e] Department of Cardiac Surgery, S. Andrea University Hospital, Rome, Italy

ARTICLE INFO

Article history:
Received 29 April 2019
Received in revised form
20 June 2019
Accepted 15 July 2019

Keywords:
Bentall procedure
Mechanical valved conduit
Biological valved conduit
Elderly patients

ABSTRACT

Background: The modified Bentall procedure is still the treatment of choice for patients requiring combined replacement of the ascending aorta and aortic valve. We compared the long-term outcome of patients >65 years of age undergoing Bentall procedure with biological vs mechanical valved conduits in a multi institutional study.
Methods: A total of 282 patients, undergoing a Bentall operation (January 1994–May 2015), with a biological (Group 1, 173 patients) or a mechanical (Group 2, 109 patients) conduit were reviewed, the primary outcome being analysis of late survival and freedom from major adverse events.
Results: Hospital mortality was 5% (9 patients) and 2% (2 patients) for Group 1 and Group 2 ($p = 0.2$). Median follow-up was 77 months (range Q1–Q3: 49–111) for Group 1 vs 107 months (range Q1–Q3: 63–145) for Group 2 ($p < 0.001$). A not statistically significant advantage in late survival was found in patients receiving mechanical valved conduits (36% for Group 1 vs 58% for Group 2 at 12 years; $p = 0.09$), although freedom from major adverse events was similar between the 2 groups (33% in Group 1 vs 50% in Group 2 at 12 years; $p = 0.3$).
Conclusions: In conclusion, mechanical-valved conduits employed for the modified Bentall procedure show a trend towards an improved late survival in patients ≥65 years of age and particularly in those between 65 and 75 years, despite a higher incidence of major adverse events. Our results indicate the need for specific guidelines to better define the ideal age limit for each type of valved conduit.

1. Introduction

The first successful simultaneous replacement of the entire ascending aorta and aortic valve was reported by Wheat et al. in 1964 [1]. Subsequently, Bentall and De Bono in 1968 described a more radical technique using a composite conduit [2]; the Bentall procedure and its subsequent modification by Kouchoukos et al. [3] has become for many years the procedure of choice for patients requiring combined replacement of the aortic valve and ascending aorta regardless of the underlying pathology. Recently, after the seminal paper by David and Feindel [4] the widespread diffusion of aortic valve-sparing operations in patients with annuloaortic ectasia has reduced the number of suitable candidates for a modified Bentall procedure (MBP). Nevertheless, due to increased life expectancy, a MBP may be still required in a fairly large number of elderly patients with aortic valve disease and ascending aorta pathology. In an aging population biological prostheses are preferred because of avoidance of long-term anticoagulation and a longer expected durability [5–7]; furthermore, for the same reason, even in younger patients, tissue valves with proven long-term durability may be also indicated, especially considering the potential future diffusion of valve-in-valve procedures [8–10].

In patients requiring a MBP, mechanical conduits have demonstrated excellent long-term results particularly in freedom from prosthesis-related events and stability of the procedure [11–15]; however, biological conduits are currently increasingly used being considered particularly suitable for elderly patients requiring a MBP [16–19]. There are however few studies comparing the results of mechanical versus biological conduits and few data are available

☆ The authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

* Corresponding author at: University Hospital, P.le S.M. della Misericordia 15, Udine, Italy.
E-mail address: andrea.lechiancole@asuiud.sanita.fvg.it (A. Lechiancole).

https://doi.org/10.1016/j.ijcard.2019.07.053
0167-5273/

defining the ideal age limit to prefer one over the other. To specifically address this issue we have compared the long-term performance of mechanical versus biological conduits in patients ≥65 years of age undergoing a MBP.

2. Material and methods

We have retrospectively reviewed 282 patients ≥65 years of age undergoing a MBP (January 1994–May 2015) with a biological (Group 1, 173 patients) or a mechanical (Group 2, 109 patients) conduit at 4 Italian institutions. Institutional approval for the study was obtained (3416/2011, prot. 64168) and patient informed consent was waived due to its retrospective nature.

The main indication for surgery was aortic valve disease associated with ascending aorta or root dilatation; patients with acute or chronic aortic dissection or aortic root endocarditis were excluded.

The type of valved conduit was chosen mostly based on patient age; furthermore, patient lifestyle, preference, compliance to oral anticoagulants, and risk factors for bleeding or thrombosis were also taken into account.

The primary outcome of the study was overall survival defined as freedom form all-cause mortality. Secondary outcome was freedom from a composite of major adverse events (MAEs), that include death and prosthesis-related complications, defined according to established guidelines [20]. Particularly, major haemorrhages were intended as intracranial, gastrointestinal or any other bleeding requiring transfusion or patient readmission; thrombo-embolic events (TEs) included all major thrombo-embolic episodes, with and without sequelae, documented clinically or by imaging techniques.

2.1. Clinical data

Relevant preoperative data of the population are summarized in Table 1. Patients of Group 1 were older ($p < 0.001$), had more coronary artery disease ($p = 0.02$), concomitant coronary artery bypass grafting (CABG) ($p = 0.003$) and worse NYHA class ($p = 0.001$); Group 2 patients had more AF ($p = 0.002$) and aortic regurgitation as native valve pathology ($p = 0.02$).

2.2. Surgical technique

All operations were performed through a median sternotomy using moderately hypothermic cardiopulmonary bypass (CPB), with cannulation of the ascending aorta or proximal aortic arch in most cases. When required, open distal anastomosis of the graft was performed during a period of hypothermic circulatory arrest using either antegrade or retrograde cerebral perfusion according to each Institutional protocol or surgeon's preference. Biological conduits employed were either those commercially available in each centre, including stentless porcine roots, or those obtained by sewing a stented valve inside a Dacron prosthesis.

Following surgery all patients received subcutaneous heparin; Group 1 patients were kept on oral anticoagulants for 3 months, replaced by antiplatelet drugs thereafter in the absence of AF or other risk factors for TEs. Recently patients without established risk factors receiving biological conduits were given only antiplatelet medications [7,21]. Group 2 patients were kept on chronic anticoagulants with a target international normalized ratio between 2 and 3.

Table 1
Baseline clinical and surgical characteristics.

	Group 1	Group 2	*p*-Value
Patients, n	173	109	
Male, n (%)	125 (72)	69 (63)	0.1
Median age, years (Q_1–Q_3)	72 (69–76)	70 (67–73)	<0.001
Median LVEF, % (Q_1–Q_3)	56 (49–60)	55 (48–60)	0.9
Median creatinine, mg/dl (Q_1–Q_3)	1.1 (0.9–1.2)	1.0 (0.9–1.2)	0.9
Preoperative AF, n (%)	9 (5)	18 (16)	0.002
Coronary artery disease, n (%)	56 (32.4)	21 (19)	0.02
Reoperation, n (%)	11 (6)	11 (10)	0.3
NYHA ≥3, n (%)	48 (28)	52 (48)	0.001
Arterial hypertension, n (%)	147 (85)	86 (79)	0.2
COPD, n (%)	31 (18)	18 (16)	0.8
Peripheral vascular disease, n (%)	15 (9)	4 (4)	0.1
Diabetes mellitus type 2, n (%)	20 (12)	14 (13)	0.7
Previous stroke, n (%)	7 (4)	6 (5)	0.6
Aortic valve disease			
Regurgitation, n (%)	93 (54)	73 (67)	0.02
Stenosis, n (%)	46 (26)	27 (25)	
Mixed lesion, n (%)	34 (20)	9 (8)	
Bicuspid aortic valve, n (%)	47 (27)	28 (26)	0.8
Concomitant surgery, n (%)	59 (34)	28 (26)	0.1
Associated CABG, n (%)	50 (29)	15 (14)	0.003
Associated valve, n (%)	9 (5)	10 (9)	0.2
Associated – other	5 (3)	6 (5)	0.3
Median CPB time, min (Q_1–Q_3)	201 (167–239)	186 (130–237)	0.006
Median aortic cross-clamp time, min (Q_1–Q_3)	160 (130–186)	139 (104–178)	0.001
Circulatory arrest, n (%)	63 (36)	15 (14)	<0.001
Euroscore 2, (Q_1–Q_3)	3.7 (2.8–5.3)	3.7 (3–5)	0.9

Q_1–Q_3: interquartile range; AF: Atrial fibrillation; LVEF: Left ventricular Ejection Fraction; CABG: Coronary artery bypass grafting; NYHA: New York Heart Association; COPD: Chronic obstructive pulmonary disease; CPB: Cardiopulmonary bypass.

2.3. Follow-up

Patients were reviewed in each centre to evaluate the incidence of postoperative complications. For those unable to refer for direct evaluation data were obtained from phone interviews with the patients, relatives or referring physicians. Median follow-up was 77 months for Group 1 vs 107 months for Group 2 ($p < 0.001$); 5 patients were lost at follow-up.

2.4. Statistical analysis

Continuous variables were expressed as mean ± standard deviation or median and interquartile range (Q1–Q3), according to data distribution after performing the Shapiro-Wilk test for normality. Categorical variables were expressed as absolute frequency and percentage. Continuous variables were compared with Student *t*-test or the Mann-Whitney *U* test while categorical variables were compared with χ^2 analysis or the Fisher exact test, as appropriate.

Overall survival and MAEs-free survival were estimated using the Kaplan-Meier approach. Comparisons between survival distributions were performed using a univariate and multivariate Cox regression model, with estimation of the hazard ratio (HR), after the proportional hazards assumption had been verified. The stepwise multivariate Cox-regression analysis included covariates with $p < 0.10$ at univariate analysis and the variables that were significantly different at baseline among the 2 groups, in order to control for potential confounders, according with the algorithm proposed by Biondi-Zoccai et al. [22]. All statistical analyses were performed using the commercially available software (Stata/SE 14.1, *Stata Corp LP, USA*) and the Statistical Package for Social Sciences (SPSS) program (*Chicago, IL, USA*).

3. Results

3.1. Surgical data

Almost all operations were performed in each centre by the senior surgeon (AP, RS, UB, UL). In Group 1 the following conduits were used: hand-sewn composite conduits containing a Perimount Magna pericardial bioprosthesis (*Edwards Lifesciences Corp., Irvine, CA*) in 110 patients or a Mosaic porcine bioprosthesis (*Medtronic Inc., Minneapolis, MN*) in 18; pre-formed stentless porcine aortic roots in 23 (Medtronic Freestyle in 17 and Edwards Prima in 6) and BioValsalva conduits (*Vascutek Terumo, Renfrewshire, Scotland*) in 22. Mean size of bioprostheses was 25.5 ± 1.5 mm.

The percentage of preformed conduits in the total pool of biological conduits varied according to the policy of each centre and to the preference and experience of each surgeon: 1% in the University Hospital of Trieste, 28% and 36% in the University Hospitals of Udine and Rome, and 93% in the University Hospital of Pisa. Patients who received a preformed biological conduit were older (median age 74 years: Q1–Q3: 68–76 vs 72 years; Q1–Q3: 68–78 ($p = 0.006$) than those who received a hand-sewn device, but did not differ significantly for other baseline characteristics.

In Group 2 a Carbo-Seal or Carbonart conduit (*Liva Nova, Saluggia, Italy*) was implanted in 64 and 7 patients, respectively, and a St. Jude conduit (*Abbott Laboratories, Chicago, IL*) in 38 patients. Mean size of mechanical prostheses was 26 ± 2 mm.

In Group 1 a longer median myocardial ischaemic (160 min vs 139 min, $p < 0.001$), and median CPB time (201 min vs 186 min, $p = 0.001$) were observed together with greater employment of circulatory arrest (36% vs 14%, $p < 0.001$), and higher rate of concomitant procedures, particularly CABG (29% vs 14%, $p = 0.003$). Among biological MBP, cross-clamp time was longer in patients with hand-sewn devices (median 169 min; Q1–Q3: 133–196 vs 148 min; Q1–Q3: 103–198 ($p = 0.02$), mainly due to the time spent to suture the valve prosthesis to the tube graft.

3.2. Early and late mortality

Overall hospital mortality was similar in the two Groups: 5% (9 patients) and 2% (2 patients) for Group 1 and 2, respectively ($p = 0.2$). In Group 1, causes of death were: sepsis in 4, multiorgan failure in 3, bowel ischaemia in 1 and cerebral haemorrhage in 1; in Group 2, 2

patients died of multiorgan failure. Hospital mortality was 5% ($n = 6$) and 7% ($n = 3$) for patients receiving hand-sewn and pre-formed devices ($p = 0.4$).

There were 111 late deaths, 65 in Group 1 and 46 in Group 2. In Group 1, 46 patients died of non-cardiac causes, while 19 died of cardiac causes, 9 being valve-related: 4 patients had sudden death, 2 died at reoperation, 2 of stroke and 1 of endocarditis. In Group 2, 29 patients died of non-cardiac causes and 17 for cardiac causes, 9 being valve-related: sudden death in 3, stroke in 2, endocarditis in 2 and prosthetic thrombosis in 1 and cerebral haemorrhage in 1.

The Kaplan-Meier estimated 4, 8 and 12-year survival was 85%, 69% and 36% for Group 1, vs 83%, 72% and 58% for Group 2 ($p = 0.09$) (Fig. 1A).

Crude univariate Cox regression analysis didn't show any difference in mortality between Group 1 and 2 patients ($p = 0.09$). Analysis of the relationship between mortality and other variables is reported in Table 2. Stepwise multivariate Cox regression analysis (Table 2) included type of conduit, age, sex, associated CABG, atrial fibrillation, NYHA ≥3, LVEF, serum creatinine, peripheral vasculopathy, CPB time, aortic cross clamp time, circulatory arrest, aortic valve disease and Euroscore 2. The analysis showed that risk factors for late mortality were male sex ($p = 0.004$), age ($p < 0.001$), preoperative serum creatinine ($p = 0.01$), and Euroscore 2 ($p = 0.002$).

Long-term survival ($p = 0.99$) and freedom from MAEs ($p = 0.5$) did not differ according to the type of biological device employed (hand-sewn or pre-formed).

3.3. Postoperative complications

TEs occurred after a median interval from operation of 12 months (range 2–217 months) in 20 patients: 5 in Group 1 (all ischaemic strokes), with 2 deaths and 15 in Group 2 (14 ischaemic strokes and 1 valve thrombosis), with 3 deaths. Overall, during the follow-up the incidence of stroke was 3% in Group 1 and 13% in Group 2 ($n = 14$).

Major haemorrhages were reported in 12 patients occurring after a median interval from MBP of 21.5 months (range 5–140 months); in Group 1, 4 patients, all on anticoagulants because of AF, had a severe haemorrhage (3 intestinal and 1 cerebral) with 1 death, and 8 in Group 2 (7 intestinal and 1 cerebral) with 1 death.

There were 7 cases of endocarditis (4 in Group 1 and 3 in Group 2). This complication occurred at a median interval of 36 months (range, 4 to 93 months); 4 patients were reoperated with 2 deaths.

During follow-up, 6 patients underwent reoperation on the conduit, 4 in Group 1 (2, 36, 43 and 93 months) with 2 deaths and 2 in Group 2 (97 and 140 months) with no deaths. Causes of reoperation were infective endocarditis in 4 (3 in Group 1 and 1 in Group 2), and pseudoaneurysm in 2. None of the patients of Group 1 underwent a valve-in-valve procedure.

Long-term MAEs-free survival was similar in the two groups ($p = 0.3$). Estimated 4, 8 and 12 years MAEs-free survival was 81%, 65% and 33% in Group 1 vs 74%, 63% and 50% in Group 2 (Fig. 1B). Stepwise multivariate Cox regression analysis (Table 3) included conduit, age, sex, associated CABG, atrial fibrillation, NYHA ≥3, LVEF, serum creatinine, peripheral vasculopathy, CPB time, aortic cross clamp time, circulatory arrest, aortic valve disease, reoperation and Euroscore 2. The analysis showed that risk factors for MAEs were male sex ($p = 0.001$), age ($p = 0.02$), preoperative serum creatinine ($p = 0.008$) and Euroscore 2 ($p < 0.001$); LVEF was found to be a protective factor ($p = 0.01$).

4. Discussion

In patients requiring simultaneous replacement of the aortic valve and ascending aorta the MBP still represents the treatment of choice. Although mechanical conduits have been associated with gratifying results even in the long-term [11–15], biological conduits are currently gaining widespread acceptance due to increasing age of patients referred for surgery [16,17,19,23,24]. The so called 'bio Bentall' is preferred in elderly patients, usually >75 years since in them avoidance of anticoagulation and its potential complications renders such devices particularly appealing; furthermore, the risk that recipients would outlive the new generation tissue valves inside the graft with the need for reoperation because of structural valve deterioration (SVD) at a much older age appears extremely low [25–27]. For younger patients, particularly those >65 years, the choice of the type of conduit appears less straightforward, representing a still debated issue; in these patients one should weight the risks of reoperation, due to the limited prosthetic durability, against those related to life-long anticoagulation or its possible inadequate management. A grey zone appears therefore to be represented by patients with an age between 65 and 75 years scheduled for MBP, since in this population which should be the most suitable conduit is still unclear. To add further data to help clarifying this issue we are here reporting the experience from a multi institutional registry.

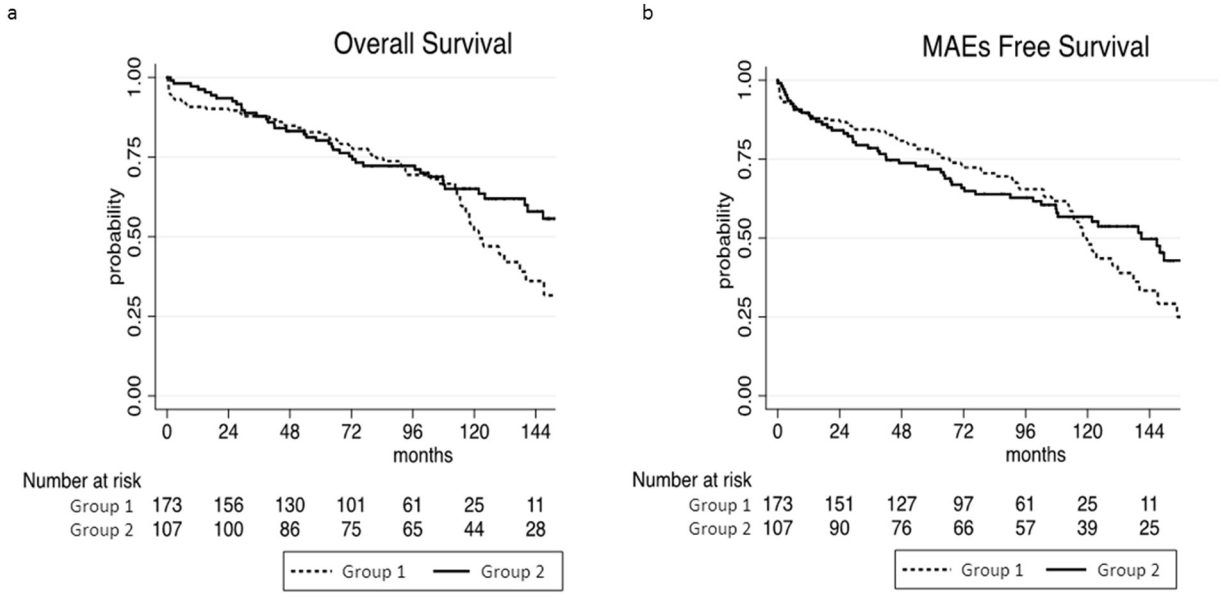

Fig. 1. A) Actuarial survival in the population. B) Actuarial freedom from major adverse events (MAEs).

Table 2
Univariate and stepwise multivariate analysis for death.

	Univariate		Multivariate (stepwise)	
	HR (95% CI)	*p*-Value	HR (95% CI)	*p*-Value
Mechanical valved conduit	0.71 (0.48–1.05)	0.09		
Male sex	1.87 (1.18–2.97)	0.008	1.99 (1.25–3.17)	0.004
Age	1.11 (1.06–1.15)	<0.001	1.10 (1.05–1.14)	<0.001
Preoperative AF	0.90 (0.44–1.84)	0.8		
Aortic valve disease				
Mixed lesion	1	–		
Aortic stenosis	0.85 (0.44–1.64)	0.6		
Aortic regurgitation	1.13 (0.64–2.01)	0.7		
Bicuspid aortic valve	0.75 (0.47–1.19)	0.2		
Reoperation	1.38 (0.72–2.66)	0.3		
Associated CABG	1.49 (0.98–2.28)	0.06		
Associated valve	1.09 (0.51–2.34)	0.8		
Associated – other	0.69 (0.25–1.89)	0.5		
LVEF	0.97 (0.95–0.99)	0.001		
NYHA ≥3	1.46 (0.99–2.14)	0.05		
Arterial hypertension	0.80 (0.51–1.27)	0.3		
COPD	0.96 (0.57–1.61)	0.9		
Serum creatinine	2.45 (1.56–3.87)	<0.001	1.96 (1.16–3.29)	0.01
Peripheral vasculopathy	2.09 (1.15–3.82)	0.02		
Diabetes mellitus	1.31 (0.75–2.29)	0.4		
CPB time	1.00 (0.998–1.003)	0.8		
Aortic cross-clamp time	1.00 (0.997–1.003)	1.0		
Circulatory arrest	0.91 (0.59–1.39)	0.7		
Euroscore 2	1.15 (1.09–1.22)	<0.001	1.11 (1.04–1.19)	0.002

AF: Atrial fibrillation; LVEF: Left ventricle ejection fraction; AF; CABG: Coronary artery bypass grafting; NYHA: New York Heart Association; COPD: Chronic obstructive pulmonary disease; Cardiopulmonary bypass.

Table 3
Univariate and stepwise multivariate analysis for MAEs.

	Univariate		Multivariate (stepwise)	
	HR (95% CI)	*p*-Value	HR (95% CI)	*p*-Value
Mechanical valved conduit	0.84 (0.58–1.20)	0.3		
Male sex	1.91 (1.24–2.95)	0.003	2.10 (1.34–3.30)	0.001
Age	1.08 (1.03–1.12)	<0.001	1.05 (1.01–1.10)	0.02
Preoperative AF	1.08 (0.58–2.01)	0.8		
Aortic valve disease				
Mixed lesion	1	–		
Aortic valve stenosis	0.85 (0.47–1.53)	0.6		
Aortic valve regurgitation	1.04 (0.62–1.74)	0.9		
Bicuspid aortic valve	0.69 (0.45–1.07)	0.1		
Reoperation	1.68 (0.94–3.00)	0.08		
Associated CABG	1.51 (1.02–2.23)	0.04		
Associated valve	0.88 (0.41–1.89)	0.7		
LVEF	0.96 (0.95–0.98)	<0.001	0.98 (0.96–0.995)	0.01
NYHA ≥3	1.48 (1.04–2.11)	0.03		
Arterial hypertension	0.86 (0.56–1.34)	0.5		
COPD	1.11 (0.69–1.78)	0.7		
Serum creatinine	2.64 (1.76–3.96)	<0.001	1.90 (1.18–3.07)	0.008
Peripheral vasculopathy	1.70 (0.94–3.09)	0.08		
Diabetes mellitus	1.32 (0.79–2.20)	0.3		
Previous stroke	0.85 (0.35–2.08)	0.7		
CPB time	1.00 (0.999–1.004)	0.4		
Aortic cross-clamp time	1.00 (0.998–1.004)	0.5		
Circulatory arrest	0.99 (0.68–1.46)	1.0		
Euroscore 2	1.17 (1.11–1.23)	<0.001	1.12 (1.06–1.20)	<0.001

MAEs: Major adverse cardiovascular events; AF: Atrial fibrillation; LVEF: Left ventricular ejection fraction; AF: Atrial fibrillation; CABG: Coronary artery bypass grafting; NYHA: New York Heart Association; COPD: Chronic obstructive pulmonary disease; CPB: Cardiopulmonary bypass.

In this retrospective analysis we have compared 2 Groups of patients ≥65 years of age according to the type of conduit employed, either biological or mechanical. The results of such comparison did not show any significant difference between Group 1 and 2 patients in terms of late survival and freedom from MAEs. Similar results were found also by Pantaleo et al. who, after reviewing their experience with biological versus mechanical MBP for aortic root replacement, concluded that the choice of the type of graft did not have any influence in the clinical outcome [24]. However, their data are analysed only at a mid-term follow-up (7 years) without any specific reference to patient age as possible risk factor.

In patients requiring combined replacement of the aortic valve and ascending aorta the choice of the best type of composite valve conduit may be still a matter of debate. Indeed, there are few reports specifically designed to compare the long-term performance of mechanical versus biological conduits for MBP [24,28–30], while in many large reported series of the MBP the number of biological conduits employed is extremely low to allow a meaningful comparison with mechanical conduits in terms of overall performance [12,16,17,30–32]. Only the paper by Etz et al. [30] specifically deals with the problem of age in patients undergoing the MBP. Considering patients between 50 and 60 years of age they found equivalent results in those receiving a biological (albeit only stentless porcine aortic roots) or a mechanical conduit questioning the use of the latter in quinquagenarians in view of the possible role of future transcatheter valve-in-valve procedures, should SVD of a biological conduit occur at a later stage. However, considering that in their population very few patients were at risk at 8 years post-MBP with a stentless conduit, their conclusions may appear too optimistic; indeed, one could be faced with the need for a valve-in-valve procedure in a 60-year-old patient with a failing, calcified porcine aortic root which does not appear particularly appealing, while total aortic root re-replacement is still an extremely challenging operation in this setting.

Several studies focusing on aortic valve replacement have shown that mechanical prostheses confer a survival advantage over biological devices, especially in the late period, even when employed in older patients [26]. However, patients with mechanical aortic valve replacement were reported to be at a higher risk of bleeding and thrombo-embolic complications [25,26].

Recent guidelines indicate that for isolated aortic valve replacement a mechanical prosthesis should be considered in patients <65 years of age in the absence of specific contraindications [7]. For patients requiring combined replacement of the aortic valve and ascending aorta there are not, however, specific guidelines and particularly no clear indications concerning any specific age threshold for biological or mechanical conduits. Furthermore, it is still unclear whether the presence of a fabric conduit might have any impact of valve performance, particularly valve durability and rate of TEs by eliminating a potentially thrombogenic tract of the aorta as suggested by the Yale group [33].

As expected, in our experience mechanical MBP was associated to a higher incidence of TEs and anticoagulant-related bleeding. In fact, the major limitation of contemporary mechanical valved conduits still remains the required life-long anticoagulation with subsequent complications. This should be in favour of a biological conduit for MBP also in this age range; however, it must be considered that in view of a possible later valve-in-valve procedure, a bio-prosthetic valve of adequate size should be implanted to avoid the potential risk of creating a subsequent patient-prosthesis mismatch. Indeed, previous aortic valve replacement with a small surgical bio-prosthesis was reported to be a strong predictor for 1-year mortality after valve-in-valve procedure [10]. Otherwise, a mechanical conduit should be preferable, combining the advantage of an excellent long-term durability with an acceptably low rate of overall MAEs. However, it must be underlined that, despite the use of various bio-prosthetic models, no cases of reoperation for SVD have occurred in our series, most likely due to the shorter median

follow-up of Group 1. With increasing follow-up, reoperation for bioprosthetic failure might become more frequent thus significantly influencing the rate of MAEs in this group unless a less invasive trans aortic valve-in-valve procedure is indicated; however, should a bioprosthetic valve outlive older patients this complication would become clearly undetectable. Based on our data late results after MBP appear to be similar in both Groups at least up to the 10th postoperative interval, after which there is a strong trend towards a difference in late survival and freedom from MAEs curves. It could be speculated that after this period, a certain grade of SVD might develop negatively affecting survival. However, which one among possible incidence of SVD, difference in median age or small number of patients at risk at further follow-up, may be considered as most probable explanation remains unclear.

One of the major limitations of the present study is represented by its retrospective nature and by the absence of randomization. However, including observed confounders in the Cox regression analysis has reported to be a robust and precise method for limiting the possibility of biases [22]. Another limitation is represented by the lack of a complete clinical and echocardiographic assessment in many of our patients. Furthermore, the diagnosis of prosthetic dysfunction was based only on the rate of reoperations; this did not allow defining the precise incidence of this complication using the methods suggested by the recent consensus statement [34].

A strength of the present series lies in the fact that we considered only patients undergoing elective aortic valve and ascending aorta replacement, excluding those with acute or chronic aortic dissection and those with destructing endocarditis; this yielded a more uniform population eliminating potentially confounding factors.

5. Conclusions

In conclusion, among patients ≥65 years of age, and particularly in those between 65 and 75 years, the MBP represents a valid surgical option, with satisfactory early and long-term results. Mechanical valved conduits are associated with a trend towards better late survival than biological valved conduits; however, patients receiving mechanical devices are more likely to experience thromboembolic and bleeding complications. In this specific subset a bio Bentall procedure may also appear indicated provided that the aortic valve is replaced by a tissue valve of adequate size to allow a subsequent valve-in-valve procedure with avoidance of patient-prosthesis mismatch. Our results may stimulate to better define the ideal age limits for the use of each composite conduits in patients requiring a MBP by specific guidelines endorsed by the cardiac surgical societies.

Declaration of Competing Interest

The authors have not conflict of interest to declare.

References

[1] M.W. Wheat Jr., J.R. Wilson, T.D. Bartley, Successful replacement of the entire ascending aorta and aortic valve, J. Am. Med. Assoc. 188 (1964) 717–719.
[2] H. Bentall, A. De Bono, A technique for complete replacement of the ascending aorta, Thorax 23 (1968) 338–339.
[3] N.T. Kouchoukos, W.G. Marshall Jr., T.A. Wedige-Stecher, Eleven-year experience with composite graft replacement of the ascending aorta and aortic valve, J. Thorac. Cardiovasc. Surg. 92 (1986) 691–705.
[4] T.E. David, M. Feindel, An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta, J. Thorac. Cardiovasc. Surg. 103 (1992) 617–622.
[5] T.L. Leiria, R.D. Lopes, J.B. Williams, J.N. Katz, R.A. Kalil, J.H. Alexander, Antithrombotic therapies in patients with prosthetic heart valves: guidelines translated for the clinician, J. Thromb. Thrombolysis 31 (2011) 514–522.
[6] M. Celiento, G. Ravenni, L. Tomei, S. Pratali, A.D. Milano, U. Bortolotti, Excellent durability of the Mosaic porcine aortic bioprosthesis at extended follow up, J Heart Valve Dis 27 (2018) 97–193.
[7] H. Baumgartner, V. Falk, J.J. Bax, et al., 2017 ESC/EACTS guidelines for the management of valvular heart disease, Eur. Heart J. 36 (2018) 2739–2791.
[8] D. Attias, M. Nejjari, F. Nappi, J. Dreyfus, M.F. Eleid, C.S. Rihal, How to treat severe symptomatic structural deterioration of aortic surgical bioprosthesis: transcatheter valve-in-valve implantation or redo valve surgery? Eur. J. Cardiothorac. Surg. 54 (2018) 977–985.
[9] K. Pechlivanidis, F. Onorati, G. Petrilli, et al., In which patients is transcatheter aortic valve replacement potentially better indicated than surgery for redo aortic valve disease? Long-term results of a 10-year surgical experience, J. Thorac. Cardiovasc. Surg. 148 (2014 Aug) 500–508.
[10] D. Dvir, J.G. Webb, S. Bleiziffer, , et al.Valve-in-Valve International Data Registry Investigators, Transcatheter aortic valve implantation in failed bioprosthetic surgical valves, JAMA. 312 (2014) 162–170.
[11] B.P. Van Putte, S. Ozturk, S. Siddiqi, M.A.A.M. Schepens, R.H. Heijmen, W.J. Morshuis, Early and late outcome after aortic root replacement with a mechanical valve prosthesis in a series of 528 patients, Ann. Thorac. Surg. 93 (2012) 503–509.
[12] A. Varrica, A. Satriano, C. de Vincentiis, et al., Bentall operation in 375 patients: long-term results and predictors of death, J Heart Valve Dis 23 (2014) 127–134.
[13] M. Celiento, G. Ravenni, R. Margaryan, et al., The modified Bentall procedure: a single-institution experience in 249 patients with a maximum follow-up of 21.5 years, J Hear Valve Dis 25 (2016) 448–455.
[14] C.D. Etz, K. Von Aspern, F.F. Girrbach, et al., Long-term survival after composite aortic root replacement: a consecutive series of 448 cases, J. Thorac. Cardiovasc. Surg. 145 (2013) S41–S47.
[15] A. Mookhoek, N.M. Korteland, B. Arabkhani, et al., Bentall procedure: a systematic review and meta-analysis, Ann. Thorac. Surg. 101 (2016) 1684–1689.
[16] M. Bashir, A. Harky, S. Froghi, et al., A systematic review and meta-analysis of mechanical vs biological composite aortic root replacement, early and 1-year results, Gen. Thorac. Cardiovasc. Surg. 67 (2019) 70–76.
[17] C.C. Badiu, M.A. Deutsch, C. Sideris, et al., Aortic root replacement: comparison of clinical outcome between different surgical techniques, Eur. J. Cardiothorac. Surg. 46 (2014) 685–692.
[18] I. Vendramin, M. Meneguzzi, S. Sponga, et al., Bicuspid aortic valve disease and ascending aortic aneurysm: should an aortic root replacement be mandatory?†, Eur. J. Cardiothorac. Surg. 49 (1) (2016 Jan) 103–109.
[19] A. Mazzola, M. Di Mauro, F. Pellone, et al., Freestyle aortic root bioprosthesis is ca suitable alternative for aortic root replacement in elderly patients: a propensity score study, Ann. Thorac. Surg. 94 (2012) 1185–1190.
[20] C.W. Akins, D.C. Miller, M.I. Turina, et al., Guidelines for reporting mortality and morbidity after cardiac valve operations, Ann. Thorac. Surg. 85 (2008) 1490–1495.
[21] A.A. Gryaznov, A. Saeyeldin, M. Abdelbaky, et al., Antithrombotic therapy after bioprosthetic aortic valve replacement: a therapeutic morass, Cardiology 140 (4) (2018) 213–221.
[22] G. Biondi-Zoccai, E. Romagnoli, P. Agostoni, et al., Are propensity scores really superior to standard multivariable analysis? Contemp. Clin. Trials 32 (5) (2011) 731–740.
[23] A. Kaya, R.H. Heijmen, J.C. Kelder, W.J. Morshuis, First 102 patients with the Biovalsalva conduit for aortic root replacement, Ann. Thorac. Surg. 94 (2012) 72–77.
[24] A. Pantaleo, G. Murana, L. Di Marco, et al., Biological versus mechanical Bentall procedure for aortic root replacement: a propensity score analysis of a consecutive series of 1112 patients, Eur. J. Cardiothorac. Surg. 52 (2017) 143–149.
[25] A.B. Goldstone, P. Chiu, M. Baiocchi, et al., Mechanical or biologic prostheses for aortic-valve and mitral-valve replacement, N. Engl. J. Med. 377 (2017) 1847–1857.
[26] J.M. Brennan, F.H. Edwards, Y. Zhao, , et al.DEcIDE AVR (Developing Evidence to Inform Decisions about Effectiveness–Aortic Valve Replacement) Research Team, Long-term safety and effectiveness of mechanical versus biologic aortic valve prostheses in older patients: results from the Society of Thoracic Surgeons Adult Cardiac Surgery National Database, Circulation. 127 (2013) 1647–1655.
[27] S. Sponga, M.D. Barbera, D. Pavoni, et al., Ten-year results of the Freedom Solo stentless heart valve: excellent haemodynamics but progressive valve dysfunction in the long term, Interact. Cardiovasc. Thorac. Surg. 24 (5) (2017 May 1) 663–669.
[28] D.C. Etz, M.S. Bischoff, C. Bodian, et al., The Bentall procedure: is it the gold standard? A series of 597 consecutive cases, J. Thorac. Cardiovasc. Surg. 140 (2010) S64–S70.
[29] J.G. Byrne, T. Gudbjartsson, A.N. Karavas, et al., Biological vs. mechanical aortic root replacement, Eur. J. Cardiothorac. Surg. 23 (2003) 305–310.
[30] C.D. Etz, F.F. Girrbach, K. von Aspen, et al., Longevity after aortic root replacement. Is the mechanically valved conduit really the gold standard for quinquagenarians? Circulation 128 (Suppl. 1) (2013) S253–S262.
[31] C. Hagl, J.T. Strauch, D. Spiegelvogel, et al., Is the Bentall procedure for ascending aorta or aortic valve replacement the best approach for long-term event-free survival? Ann. Thorac. Surg. 76 (2003) 698–703.
[32] T. Tsunekawa, H. Ogino, H. Matsuda, et al., Composite valve graft replacement of the aortic root: twenty-seven years of experience at one Japanese center, Ann. Thorac. Surg. 86 (2008) 1510–1517.
[33] M.A. Zafar, E.A. Farkas, A. Javier, M. Anderson, O. Gilani, J.A. Elefteriades, Are thromboembolic and bleeding complications a drawback for composite aortic root replacement, Ann. Thorac. Surg. 94 (2012) 737–743.
[34] D. Capodanno, A.S. Petronio, B. Prendergast, et al., Standardized definitions of structural deterioration and valve failure in assessing long-term durability of transcatheter and surgical aortic bioprosthetic valves: a consensus statement from the European Association of Percutaneous Cardiovascular Interventions (EAPCI) endorsed by the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS), Eur. J. Cardiothorac. Surg. 52 (2017) 408–417.