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Mortality and reoperation rate of biological versus mechanical Bentall-De Bono operation: a propensity-matched study

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Abstract

Objective: To assess follow-up mortality and reoperation rate in patients undergoing Bentall-De Bono operation according to the type of composite valve graft used.

Methods: All consecutive adult patients operated on between May 1997 and December 2019 at our institution were included in the analysis and classified according to the use of a biological or a mechanical composite valve graft (bCVG or mCVG). The primary outcomes were follow-up mortality and reoperation rate. Secondary outcomes were operative mortality and major adverse events (MAEs) including operative mortality, myocardial infarction, cerebrovascular accident, dialysis, tracheostomy, and re-exploration for bleeding. Kaplan-Meier and competing risk analyses were used. Propensity matching analysis was used to balance differences in baseline characteristics between procedures.

Results: Of 1,210 included patients, 798 received a bCVG and 412 a mCVG. The mean follow-up was 6.64 ± 0.21 years. The ten-year mortality rate was higher in the mCVG group (25.3% *vs.* 16.4%, P = 0.023). The ten-year reoperation rate was higher in the bCVG group (7.4% *vs.* 1.1%, P < 0.001). Overall operative mortality was 0.7%, and MAEs occurred in 6.2% of patients, with no significant differences between groups. Older age (hazard ratio

[HR] 1.06, 95% confidence interval [CI: 1.04-1.08], $P < 0.01$), chronic obstructive pulmonary disease (HR 1.63, 95%CI: [1.01-2.64], $P = 0.04$), preoperative renal dysfunction (HR 3.08, 95%CI: [1.98-4.78], $P < 0.001$), New York Heart Association Class III/IV (HR 1.48, 95%CI: [1.04-2.10], $P = 0.031$), and mCVG (HR 2.15, 95%CI: [1.42-3.26], $P < 0.001$) were associated with higher risk of follow-up mortality. After propensity matching, the differences in mortality and reoperation remained significant.

Conclusions: The Bentall-De Bono operation can be performed with consistently good results in experienced centers. Early outcomes are excellent regardless of the valve choice. In our study, the Bentall-De Bono operation with bCVG was associated with lower 10-year mortality but carried a higher risk of aortic reoperation. While the risk of reoperation is largely tied to valve choice, follow-up mortality is more likely to be influenced by patient comorbidities and risk factors.

Keywords: Aortic root surgery, mechanical prosthesis, biological valve, composite valve graft, Bentall-De Bono, survival, reoperation

INTRODUCTION

The Bentall-De Bono operation is the preferred treatment for patients with ascending aortic/aortic root dilation and aortic valve pathology in need of surgical repair[1]. While the use of a Dacron graft is universal for the procedure, the decision to use either a biological or mechanical valve is individualized based on patients' characteristics and preferences[2,3]. Valve-sparing root replacement has evolved as a reliable aortic root replacement technique, offering the unique advantage of preserving the native valve[4]. While this may be an option for patients with good quality aortic valves, the Bentall-De Bono procedure remains the mainstay of treatment, especially in those with concomitant aortic stenosis.

Both types of aortic valve grafts have different profiles that favor their use in certain subgroups of patients. On one hand, mechanical composite valve grafts (mCVGs) are associated with low rates of structural valve deterioration but require lifelong anticoagulation. Currently, the only approved anticoagulant is warfarin, which requires dietary compliance and strict monitoring of therapeutic drug levels. Conversely, biological composite valve grafts (bCVG) do not require anticoagulant therapy but are associated with higher rates of structural valve degeneration, leading to a higher reoperation rate. Consequently, age is one of the most relevant determinants of the type of valve used, with patients younger than 60 years old usually receiving a mCVG and older patients a bCVG[5,6].

The aim of this paper is to assess the follow-up mortality and reoperation rate in patients who underwent a Bentall-De Bono operation at our institution based on the type of composite valve graft used.

METHODS

Study design

This is a retrospective cohort study based on prospectively collected data from our institutional aortic surgery database (Weill Cornell Medicine, New York, USA).

Ethics

This analysis was approved by the Weill Cornell Institutional Review Board (#1607017424, January 9, 2022) in New York. The need for individual consent was waived.

Inclusion and exclusion criteria

All consecutive adult patients who underwent aortic valve and root replacement with either mCVG or bCVG between May 1997 and December 2019 at our institution were included. Valve-sparing aortic root procedures were excluded.

Study outcomes

The primary outcomes were follow-up mortality (defined as any death from the time of operation until last follow-up) and reoperation rate (considering all reoperations related either to the valve or the graft). The secondary outcomes were operative mortality (defined as death within 30 days after surgery or during index hospitalization) and major adverse events (MAEs) including operative mortality, myocardial infarction, cerebrovascular accident, dialysis, tracheostomy, and re-exploration for bleeding.

Indications for surgery and selection of composite valve graft

Indications for the Bentall-De Bono operation were related to the severity of valvular dysfunction and the size of aortic dilatation, following the American Heart Association/American College of Cardiology guidelines[2]. The type of composite valve graft used was determined using guideline recommendations, but also individualized based on patients' preferences. In brief, most patients younger than 50 years without major risk factors for bleeding while on anticoagulation (e.g., no contact sports), likely to be compliant with dietetic restrictions and INR monitoring, those having additional indications for long-term anticoagulation (e.g., atrial fibrillation) or those in which a reoperation would be high-risk (e.g., porcelain aorta, prior radiation) were counseled to receive a mCVG. Conversely, most patients older than 65 years, unlikely to be compliant with dietary restrictions or INR monitoring, those at high risk of bleeding while on anticoagulation or patients considered good candidates for potential future valve-in-valve replacement were counseled to receive a bCVG.

Surgical technique

Details of the surgical technique have been previously published[7]. In brief, all operations were carried out using a median sternotomy incision, standard hypothermic cardiopulmonary bypass and myocardial protection with cold antegrade blood cardioplegia. When concomitant arch disease was present, deep hypothermic circulatory arrest with retrograde cerebral perfusion was utilized for cerebral protection; ε-aminocaproic acid was used as an antifibrinolytic[8]. Both mCVG and bCVG were implanted using the modified Bentall technique[9]. After establishing cardioplegic arrest, the ascending aorta was resected down to the annulus, leaving 3-4 mm of aortic tissue. Coronary buttons were cut from the surrounding aortic tissue. The annulus was sized. The mCVG were prefabricated mechanical valve-conduit grafts. For patients in need of a bCVG, a stented valve (porcine or bovine) was sewn inside a polyester graft (Dacron) 3 to 5 mm larger than the valve using a continuous 3-0 polypropylene suture. Mattressed 2-0 Ethibond pledgeted sutures were placed through the annulus using an everting intra-annular technique and passed through the valve conduit. The conduit was tied down and the left coronary button was reimplanted. The distal anastomosis was performed and then the right coronary button was reimplanted. Four different surgeons were responsible for the total surgical volume.

Statistical analysis

Categorical data were presented as frequency count and percentage and compared across groups using $\chi 2$ or Fisher's test, as appropriate, while continuous data were presented as median and interquartile range (IQR) or mean with standard deviation and compared using Mann-Whitney U test or t-test after testing for normality. Follow-up mortality was assessed using the Kaplan-Meier method. Cumulative incidence of reoperation was calculated using the Fine and Gray method[10], accounting for the competing risk of death.

Multivariable analysis was performed to identify associations with follow-up mortality and reoperation; results were reported as hazard ratios (HR) with their 95% confidence intervals (CI). Included variables were age, sex, chronic obstructive pulmonary disease (COPD), diabetes, urgent or emergent operation, preoperative renal dysfunction, the New York Heart Association (NYHA) class, underlying connective tissue disorders, and type of composite valve graft used. A 2-tailed p-value threshold of 0.05 was used to determine statistical significance without multiplicity adjustment.

Because of the heterogeneity in patient characteristics among the mCVG and bCVG groups, propensity score matching (PSM) was used to adjust for baseline differences and reduce confounding. The probability of being assigned to different surgical treatments was calculated from demographic and preoperative patients' characteristics; the most clinically important variables were then entered into the PSM model. Selected variables were age, family history of aortic disease, hypertension, diabetes, urgent/emergency procedure, previous open-heart surgery, dissection at presentation, aneurysm size, connective tissue disorders, and the New York Heart Association (NYHA) class. These covariates were used to compare both surgical techniques by logistic regression algorithm in 1-1 PSM. The nearest neighbor matching algorithm without replacement and a caliper size of 0.10 was used. Propensity matching models were assessed using balance diagnostics and standardized mean differences (SMD), with SMD < 0.10 reflecting a proper balance between groups.

Data were stored using Microsoft Access 2010 (Microsoft) and analyzed using R version 3.6.2 (R Foundation for Statistical Computing) within RStudio. Tableone, Survival, Survminer, and MatchIt were used.

RESULTS

From May 1997 to December 2019, 1,210 patients underwent aortic valve and root replacement with a Bentall-De Bono operation at our institution. Of these, 798 (65.9%) received a bCVG, while 412 (34.1%) received a mCVG. Among those who received a bCVG, 759 (95.1%) had a bovine valve, while 39 (4.9%) had a porcine prosthesis. The mean follow-up time was 6.64 ± 0.21 years.

Baseline characteristics

Compared to patients with bCVG, those with mCVG were younger (P < 0.001), with a positive family history of aortic disease (P = 0.007). Patients with mCVG had a higher prevalence of connective tissue disorders (P < 0.001) and were more likely to have undergone previous open-heart surgery (P < 0.001). They were also more likely to undergo urgent or emergent procedure (P < 0.001). Patients with bCVG were older, with a higher prevalence of hypertension (P < 0.001) and diabetes (P = 0.03). They were also more likely to present with a worse NYHA functional class (P < 0.001). Details of the preoperative variables are summarized in Table 1.

Intraoperative characteristics

At surgery, deep hypothermic circulatory arrest was more frequently used in patients with mCVG (P < 0.001). This group also had longer cardiopulmonary bypass time (P < 0.001) and cardio-ischemic (circulatory arrest + aortic cross-clamp) time (P < 0.001). Details of the intraoperative data are available in Table 2.

In-hospital outcomes

Overall, operative mortality was 0.7%, with no significant difference between groups (0.4% for bCVG *vs.* 1.2% for mCVG, P = 0.18). MAEs occurred in 6.2% of patients and no significant difference was found

Table 1. Preoperative variables

Variable	Overall (n = 1,210)	bCVG (n = 798)	mCVG (n = 412)	P-value
Age (years), median [IQR]	59.00 [49.00, 69.00]	64.00 [55.00, 71.00]	50.00 [40.00, 59.00]	< 0.001
Women	154 (12.7)	92 (11.5)	62 (15.0)	0.10
Men	1056 (87.3)	706 (88.5)	350 (85.0)	0.10
Family history of aortic disease	66 (5.5)	33 (4.1)	33 (8.0)	0.007
Smoking	473 (39.1)	309 (38.7)	164 (39.8)	0.76
Hypertension	1054 (87.1)	728 (91.2)	326 (79.1)	< 0.001
Diabetes	77 (6.4)	60 (7.5)	17 (4.1)	0.03
Peripheral vascular disease	43 (3.6)	29 (3.6)	14 (3.4)	0.96
Chronic obstructive pulmonary disease	81 (6.7)	53 (6.6)	28 (6.8)	1.00
Connective tissue disease	97 (8.0)	24 (3.0)	73 (17.7)	< 0.001
Renal dysfunction	121 (10.0)	70 (8.8)	51 (12.4)	0.06
Previous myocardial infarction	99 (8.2)	67 (8.4)	32 (7.8)	0.79
Previous cerebrovascular accident	120 (9.9)	78 (9.8)	42 (10.2)	0.89
Previous open-heart surgery	232 (19.2)	118 (14.8)	114 (27.7)	< 0.001
Previous revascularization	73 (6.0)	58 (7.3)	15 (3.6)	0.02
NYHA Class III/IV	407 (33.6)	307 (38.5)	100 (24.3)	< 0.001
LVEF (%), median [IQR]	49.00 [40.00, 50.00]	45.00 [45.00, 50.00]	50.00 [40.00, 50.00]	0.07
Hypotensive at presentation	14 (1.2)	7 (0.9)	7 (1.7)	0.33
Dissection at presentation	147 (12.1)	68 (8.5)	79 (19.2)	< 0.001
Paraparesis at presentation	4 (0.3)	2 (0.3)	2 (0.5)	0.88
Urgent/emergent procedure	236 (19.5)	99 (12.4)	137 (33.3)	< 0.001
Aneurysm size (cm), median [IQR]	5.50 [5.30, 6.00]	5.40 [5.20, 5.80]	5.90 [5.40, 6.50]	< 0.001

Variables are presented as frequency count and percentage, unless otherwise noted. bCVG: Biological composite valve graft; IQR: interquartile range; LVEF: left ventricular ejection fraction; mCVG: mechanical composite valve graft; NYHA: New York Heart Association.

Table 2. Intraoperative data

Variable	Overall (n = 1,210)	bCVG (n = 798)	mCVG (n = 412)	P-value
Deep hypothermic circulatory arrest	281 (23.2)	162 (20.3)	119 (28.9)	0.001
Circulatory arrest time (min), median [IQR]	21.00 [18.00, 24.25]	21.00 [17.00, 23.50]	21.00 [18.00, 26.00]	0.58
CPB time (min), median [IQR]	129.00 [109.50, 157.00]	124.00 [104.50, 149.00]	138.00 [119.00, 171.00]	< 0.001
Cardio-ischemic time (min)[a], median [IQR]	105.00 [89.00, 128.00]	102.00 [85.00, 121.00]	112.00 [96.00, 138.00]	< 0.001
RCP time (min), median [IQR]	20.50 [18.00, 24.00]	21.00 [17.00, 23.50]	20.00 [18.00, 24.00]	0.77
Graft size (cm): Mean ± SD	25.65 ± 2.24	25.51 ± 1.99	25.91 ± 2.65	0.003

Variables are presented as count and percentage, unless otherwise noted. [a]Cardio-ischemic time includes circulatory arrest time and cross-clamp time. bCVG: Biological composite valve graft; CPB: cardiopulmonary bypass; IQR: interquartile range; mCVG: mechanical composite valve graft; RCP: retrograde cerebral perfusion; SD: standard deviation.

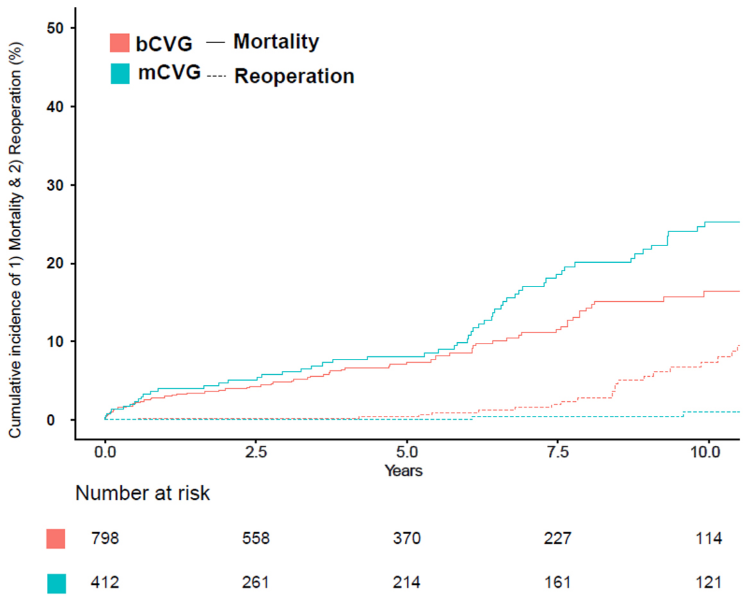
between groups (6% for bCVG *vs.* 6.6% for mCVG, P = 0.81). Details of the postoperative outcomes are available in Table 3.

Out of the 236 urgent/emergent procedures, 59 were acute dissections (25%). Operative mortality for all urgent/emergent procedures was 2.1% and, for acute dissections, 1.7%.

Table 3. Postoperative outcomes

Variable	Overall (n = 1,210)	bCVG (n = 798)	mCVG (n = 412)	P-value
In-hospital events				
Operative mortality	8 (0.7)	3 (0.4)	5 (1.2)	0.18
Major adverse events[a]	75 (6.2)	48 (6.0)	27 (6.6)	0.81
Myocardial infarction	3 (0.2)	2 (0.3)	1 (0.2)	1
Cerebrovascular accident	8 (0.7)	6 (0.8)	2 (0.5)	0.87
Dialysis	9 (0.7)	7 (0.9)	2 (0.5)	0.69
Tracheostomy	8 (0.7)	5 (0.6)	3 (0.7)	1
Re-exploration for bleeding	49 (4.0)	32 (4.0)	17 (4.1)	1
Follow-up events				
Mortality	143 (11.8)	75 (9.4)	68 (16.5)	< 0.001
Reoperation	49 (4.0)	47 (5.9)	2 (0.5)	0.02[b]

Variables are presented as count (%). [a]Major adverse events include operative mortality, myocardial infarction, cerebrovascular accident, dialysis, tracheostomy, and re-exploration for bleeding. [b]*P*-value was calculated using the Fine and Grey method (competing risk). bCVG: Biological composite valve graft; mCVG: mechanical composite valve graft.

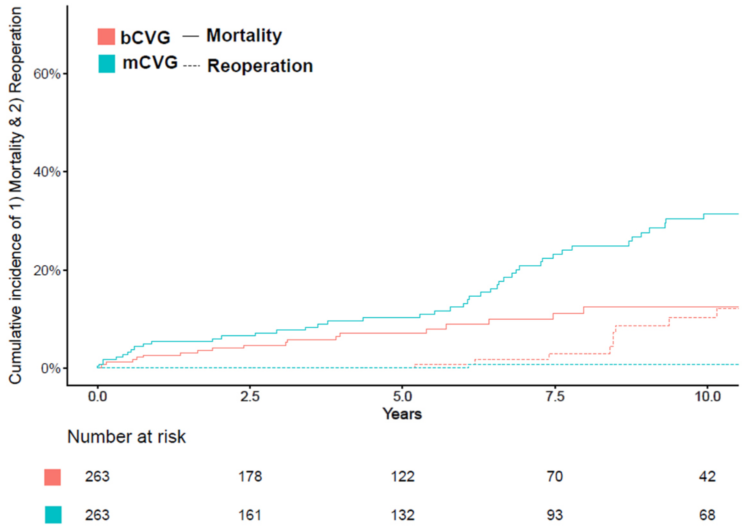


Competing risks	Valve type	10-year estimate	*P*-value
Follow-up mortality	bCVG	16.4%	0.023
	mCVG	25.3%	
Reoperation	bCVG	7.4%	< 0.001
	mCVG	1.1%	

Figure 1. Competing risk analysis for follow-up mortality and reoperation. bCVG: Biological composite valve graft; mCVG: mechanical composite valve graft.

Follow-up outcomes

Kaplan Meier estimates showed higher follow-up mortality in the mCVG group (25.3% *vs.* 16.4%, P = 0.023; Figure 1) at 10 years. Ten-year reoperation was higher in the bCVG group (7.4% *vs.* 1.1%, P < 0.001; Figure 1).



Competing risks	Valve type	10-year estimate	*P*-value
Follow-up mortality	bCVG	15.7%	< 0.001
	mCVG	24.7%	
Reoperation	bCVG	7.4%	< 0.001
	mCVG	1.1%	

Figure 2. Competing risk analysis for follow-up mortality and reoperation among matched groups. bCVG: Biological composite valve graft; mCVG: mechanical composite valve graft.

Overall, 89.8% of the 49 reoperations were valve-related (75% aortic valve replacements and 25% transcatheter aortic valve replacements; 2 reoperations due to prosthetic valve endocarditis, 15 due to prosthetic valve insufficiency, 20 due to prosthetic valve stenosis, and 7 due to double lesion of the prosthetic valve), 6.1% graft-related (1 due to aortic graft infection and 2 due to anastomotic stricture), and 4.1% of patients required a redo Bentall-De Bono operation (both due to prosthetic valve endocarditis and aortic graft infection). The four cases of prosthetic valve endocarditis and all the cases of prosthetic valve stenosis occurred in patients with a bCVG. The median time to reoperation was 10.4 years (IQR 8.3-13.0).

Multivariable analyses

Older age (HR 1.06, 95%CI: [1.04-1.08], P < 0.001), COPD (HR 1.63, 95%CI: [1.01-2.64], P = 0.04), preoperative renal dysfunction (HR 3.08, 95%CI: [1.98-4.78], P < 0.001), NYHA Class III/IV (HR 1.48, 95%CI: [1.04-2.10], P = 0.03), and mCVG (HR 2.15, 95%CI: [1.42-3.26], P < 0.001) were associated with higher risk of follow-up mortality.

Older age (HR 0.96, 95%CI: [0.94-0.98], P < 0.001), male sex (HR 0.45, 95%CI: [0.22-0.94], P = 0.03), and mCVG (HR 0.02, 95%CI: [0.01-0.10], P < 0.001) were inversely associated with the risk of reoperation. A summary of multivariable analyses is provided in Table 4.

Propensity-matched analysis

After PSM, two groups of 263 patients were identified. Balance was achieved based on SMD for baseline characteristics [Table 5]. No difference in in-hospital outcomes was found between bCVG and mCVG [Table 6]. Kaplan Meier estimates showed higher follow-up mortality in the mCVG group (24.7% *vs.* 15.7%, P < 0.001; Figure 2) at 10 years. Ten-year reoperation was higher in the bCVG group (7.4% *vs.* 1.1%, P < 0.001; Figure 2).

Table 4. Multivariable analysis for associations with follow-up mortality and reoperation

	Follow-up mortality	**Reoperation**
Variable	Hazard ratio (95%CI), *P*-value	Hazard ratio (95%CI), *P*-value
Age	1.06 [1.04; 1.08], *P* < 0.001	0.96 [0.94; 0.98], *P* < 0.001
Male sex	0.68 [0.42; 1.11], *P* = 0.12	0.45 [0.22; 0.94], *P* = 0.03
Chronic obstructive pulmonary disease	1.63 [1.01; 2.64], *P* = 0.04	0.84 [0.11; 6.35], *P* = 0.87
Diabetes	0.95 [0.52; 1.73], *P* = 0.86	1.26 [0.30; 5.32], *P* = 0.76
Urgent/emergent procedure	1.21 [0.80; 1.81], *P* = 0.37	0.85 [0.29; 2.52], *P* = 0.77
Preoperative renal dysfunction	3.08 [1.98; 4.78], *P* < 0.001	0.81 [0.11; 6.18], *P* = 0.84
NYHA Class III/IV	1.48 [1.04; 2.10], *P* = 0.03	1.20 [0.57; 2.52], *P* = 0.63
Connective tissue disorders	1.34 [0.72; 2.50], *P* = 0.36	0.37 [0.09; 1.46], *P* = 0.15
Valve replacement type (mCVG *vs*. bCVG)	2.15 [1.42; 3.26], *P* < 0.001	0.02 [0.01; 0.10], *P* < 0.001

bCVG: Biological composite valve graft; CI: confidence interval; mCVG: mechanical composite valve graft; NYHA: New York Heart Association.

Table 5. Comparison of baseline characteristics among matched groups

Variable	**bCVG (*n* = 263)**	**mCVG (*n* = 263)**	**SMD**	***P*-value**
Age (years), median [IQR]	54.00 [46.00, 62.00]	55.00 [45.5, 62.00]	0.04	0.68
Family history of aortic disease	17 (6.5)	15 (5.7)	0.03	0.86
Hypertension	216 (82.1)	224 (85.2)	0.08	0.41
Diabetes	15 (5.7)	15 (5.7)	< 0.001	0.99
Connective tissue disease	20 (7.6)	23 (8.7)	0.04	0.75
Previous open-heart surgery	65 (24.7)	62 (23.6)	0.03	0.84
Previous revascularization	12 (4.6)	10 (3.8)	0.04	0.83
NYHA Class III/IV	67 (25.5)	67 (25.5)	< 0.001	0.99
Dissection at presentation	34 (12.9)	39 (14.8)	0.06	0.61
Urgent/emergent procedure	57 (21.7)	61 (23.2)	0.04	0.75
Aneurysm size (cm), median [IQR]	5.60 [5.30, 6.05]	5.70 [5.40, 6.25]	0.09	0.16

Variables are presented as frequency count and percentage, unless otherwise noted. bCVG: Biological composite valve graft; IQR: interquartile range; mCVG: mechanical composite valve graft; NYHA: New York Heart Association; SMD: standardized mean difference.

Table 6. Postoperative outcomes among matched groups

Variable	**bCVG (*n* = 263)**	**mCVG (*n* = 263)**	***P*-value**
In-hospital events			
Operative mortality	0	4 (1.5)	0.13
Major adverse events[a]	16 (6.1)	13 (4.9)	0.70
Myocardial infarction	1 (0.4)	0	0.99
Cerebrovascular accident	0	2 (0.8)	0.48
Dialysis	2 (0.8)	1 (0.4)	0.99
Tracheostomy	2 (0.8)	2 (0.8)	0.99
Re-exploration for bleeding	13 (4.9)	7 (2.7)	0.25
Follow-up events			
Mortality	22 (8.4)	51 (19.4)	< 0.001
Reoperation	23 (8.7)	1 (0.4)	< 0.001[b]

Variables are presented as count (%). [a]Major adverse events include operative mortality, myocardial infarction, cerebrovascular accident, dialysis, tracheostomy, and re-exploration for bleeding. [b]*P*-value was calculated using Fine and Grey method (competing risk). bCVG: Biological composite valve graft; mCVG: mechanical composite valve graft; SMD: standardized mean difference.

DISCUSSION

An increase in the use of bCVG has been reported in the last 20 years, even in patients below the recommended cut-off age established by American and European guidelines[2,3,11-13]. This has been driven largely by patient preference and the desire of the younger generations to avoid lifelong anticoagulation with warfarin due to its associated risks and restrictions[14]. Additionally, some patients may have a perception that transcatheter aortic valve replacement may rescue them from further open-heart surgery. This change in valve preference is concerning because it increases the risk of reoperation by two mechanisms. First, the lifespan of the bCVG is reduced due to accelerated deterioration in younger patients, and second, the increase in life expectancy results in a larger window for aortic valve graft failure to ensue[5]. The median age of patients that received a bCVG in our cohort was 64 years old, slightly below the 65-year cut-off established by European and American guidelines[2,3].

Studies have reported lower mortality rates for patients receiving mCVG compared to bCVG for isolated aortic valve replacement[15,16]. When looking only at Bentall-De Bono cohorts, results are mixed. In a study by Svensson *et al*. including 453 patients that underwent a Bentall-De Bono operation either with a mCVG or bCVG, the authors found a higher 15-year mortality rate in patients with bCVG (57% *vs.* 26%, $P < 0.0001$), which was attributed to a higher prevalence of comorbidities and older age in that group[17]. Conversely, Etz *et al*. found a slightly higher mortality rate in Bentall-De Bono patients with mCVG at 10 years after the procedure, although the difference was not significant (25% *vs.* 20%, $P = 0.84$)[18]. In our study, we observed a higher mortality rate in patients with mCVG, which became apparent approximately 6 years after surgery and could be partially explained by patients' baseline characteristics. Although patients receiving mCVG were younger, 33.3% were urgent or emergent procedures and 19.2% were acute aortic dissections. This was partly due to a preference to use a prefabricated graft in patients with acute aortic dissection earlier in the series. Additionally, a significantly larger proportion of patients had connective tissue disorders (17.7%) and a third of the procedures were reoperations. While in most series, the bCVG patients are older and higher-risk, in our series, the mCVG patients comprised the higher-risk group due to their high-acuity clinical presentations.

At high-volume centers focusing on aortic root surgery, excellent results can be reliably reproduced. In our series, operative mortality was low for all patients (0.4% *vs.* 1.2%; $P = 0.18$) and the incidence of all individual postoperative complications was less than 1% except for re-exploration for hemorrhage, which was required in 4% of patients. Despite the higher risk preoperative profile of the mCVG group, operative outcomes were equivalent. The incidence of a composite outcome of MAE was only 6.2%.

Often, mCVGs are recommended to younger patients in order to reduce the risk of reoperation. In older patients, bCVG is often preferred since the valve is likely to last the patient's lifetime and the risk of needing reoperation for structural valve degeneration is low. In a study conducted by Kyto *et al*., including 2,928 aortic valve replacements, the risk of reoperation was significantly lower for patients with mCVG (HR 0.30, 95%CI: [0.12-0.74], $P = 0.009$)[19]. In Bentall-De Bono patients, Pantaleo *et al*. reported no significantly different 7-year reoperation rate for mCVG and bCVG, albeit the trend favored the mCVG group (0.9% *vs.* 7%, log-rank $P = 0.07$)[20]. In the present study, the 10-year reoperation rate of 1.1% in mCVG is consistent with the generally believed notion that mechanical valves should last a lifetime, except for rare cases. The 10-year reoperation rate of 7.4% for bCVG is also reasonable since a majority of these are placed in older patients, who may not outlive the lifespan of the valve. The higher need for reoperation in bCVG patients became evident approximately 7.5 years after surgery.

This study must be interpreted considering its limitations. This is an observational study and lacks the rigor of a randomized controlled trial. Additionally, this represents the experience of a single high-volume aortic center. Moreover, thromboembolic and hemorrhagic events, as well as echocardiographic data, are not collected in our database and could not be included in the present analysis. On the other hand, prospective data collection in our institutional database and a large population are strengths of the present study.

In Conclusion, The Bentall-De Bono operation can be performed with consistently good results in experienced centers. Early outcomes are excellent regardless of the valve choice. In our study, the Bentall-De Bono operation with bCVG was associated with lower 10-year mortality but carried a higher risk of aortic reoperation. While the risk of reoperation is largely tied to valve choice, survival is more likely to be influenced by patient comorbidities and risk factors.

DECLARATIONS

Authors' contributions

Conception of the manuscript: Gaudino M, Lau G, Girardi LN
Data extraction: Cancelli G, Yaghmour M, Polk H, Closkey B, Wright J
Writing the first draft of manuscript: Perezgrovas-Olaria R, Soletti G Jr, Harik L, Dimagli A
Statistical analysis: Rahouma M, Dimagli A
Writing and Revision of the main manuscript: All authors.

Availability of data and materials

Deidentified data collected for the study will be made available by the corresponding author upon reasonable request after publication.

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

This analysis was approved by the Weill Cornell Institutional Review Board (#1607017424, January 9, 2022) in New York. The need for individual consent was waived.

Consent for publication

Written informed consent for inclusion in our institutional database and subsequent publication was provided by all the patients in this analysis. No personal identifying information for any patient is provided in this work.

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