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# Repair of aortic root in patients with aneurysm or dissection: comparing the outcomes of valve-sparing root replacement with those from the Bentall procedure

*Reparação de raiz aórtica em pacientes com aneurisma ou dissecção: comparando os resultados da técnica de substituição valve-sparing com os da operação de Bentall*

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## Abstract

**Introduction:** Management of aortic root aneurysm or dissection has been the subject of much discussion that has led to some modifications. The current trend is a valve-sparing root replacement. We compared the outcome following valve sparing root repair with Bentall procedure.

**Methods:** We retrospectively evaluated 70 patients who underwent root replacement for aneurysm or dissection and compared the outcomes of valve-sparing root replacement with those of the Bentall procedure from January 2007 to December 2011 at our institution.

**Results:** Twenty-five patients had valve-sparing aortic root replacement (VSR, including reimplantation or remodeling) (23 males and 2 females), and 45 patients had the Bentall procedure (34 males and 11 females). Patients who underwent a VSR were younger with a mean age of  $55.4 \pm 14.8$  years compared to those who underwent the Bentall procedure with a mean age of  $60.6 \pm 12.7$  ( $P=ns$ ). The preoperative aortic insufficiency (AI) in the VSR group was moderate in 8 (32%) patients, and severe in 6 (24%). Preoperative creatinine was  $1 \pm 0.35$  mg/dl in the VSR group and  $1.1 \pm 0.87$  mg/dl in the Bentall group. In the VSR group, 3 (12%) patients had emergency surgery; by contrast, in

the Bentall group, 8 (17%) patients had emergent surgery. Concomitant coronary artery bypass grafting (excluding coronary reimplantation) was performed in 8 (32%) patients in the VSR group and in 12 (26.6%) patients in the Bentall group ( $P=0.78$ ); additional valve procedures were performed in 2 (8%) patients in the VSR group and in 11 (24.4%) patients in the Bentall group. The perioperative mortality was 8% ( $n=2$ ) and 13.3% ( $n=6$ ), for the VSR and Bentall procedures, respectively ( $P=0.7$ , ns). The total duration of intensive care unit stay was  $116.6 \pm 106$  hours for VSR patients and  $152.5 \pm 218.2$  hours for Bentall patients ( $P=0.5$ ). The overall length of stay in the hospital was  $10 \pm 8.1$  days for VSR and  $11 \pm 9.52$  days for Bentall ( $P=0.89$ ). The one-year survival was 92% for the VSR group and 79.0% for the Bentall group. The seven-year survival for the VSR group was 92% and 79% for the Bentall group (95% CI [1.215 to 0.1275],  $P=0.1$ ).

**Conclusion:** Aortic valve-sparing root replacement can be performed with acceptable morbidity and mortality with a comparable long-term survival to the Bentall procedure.

**Descriptors:** Aorta. Aortic aneurysm, thoracic. Aortic valve. Aortic diseases. Organ sparing treatments.

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# Abbreviations, acronyms & symbols

AI	Aortic insufficiency
AV	Aortic valve
AVR	Aortic valve replacement
INR	International normalized ratio
MI	Myocardial infarction
RBC	Red blood cells
STJ	Sinotubular junction
VSR	Valve-sparing root replacement

## Resumo

**Introdução:** Manejo de aneurisma da aorta ou dissecação da raiz tem sido objeto de muita discussão que levou a algumas modificações. A tendência atual é o uso da técnica de substituição *valve-sparing* (VSR). Nós comparamos o resultado da reparação da raiz utilizando a técnica de substituição *valve-sparing* com o procedimento de Bentall.

**Métodos:** Foram avaliados, retrospectivamente, 70 pacientes submetidos à substituição da raiz de aneurisma ou dissecação, comparando os resultados da técnica de substituição *valve-sparing* com os do procedimento Bentall de janeiro de 2007 a dezembro de 2011 em nossa instituição.

**Resultados:** Vinte e cinco pacientes foram submetidos à substituição da valva aórtica com o uso da técnica *valve-sparing* (VSR, incluindo o reimplante ou remodelação) (23 homens e duas mulheres), e 45 pacientes pelo procedimento de Bentall (34 homens e 11 mulheres). Pacientes que se submeteram à VSR eram mais jovens, com idade média de  $55,4 \pm 14,8$  anos em comparação àqueles que foram submetidos ao procedimento

Bentall, idade média de  $60,6 \pm 12,7$  anos ( $P = ns$ ). A insuficiência aórtica pré-operatória no grupo VSR foi moderada em oito (32%) pacientes e grave em seis (24%). Creatinina pré-operatória foi  $1 \pm 0,35$  mg/dl, no grupo do VSR, e  $1,1 \pm 0,87$  mg/dl, no grupo de Bentall. No grupo VSR, três (12%) pacientes foram operados em caráter de emergência e, no grupo de Bentall, oito (17%). Revascularização do miocárdio concomitante (excluindo reimplante coronariano) foi realizada em oito (32%) pacientes no grupo VSR e, em 12 (26,6%), no grupo de Bentall ( $P=0,78$ ); procedimentos valvares adicionais foram realizados em 2 (8%) pacientes no grupo do VSR e em 11 (24,4%) no grupo de Bentall. A mortalidade perioperatória foi de 8% ( $n = 2$ ) e 13,3% ( $n = 6$ ), para os procedimentos de VSR e Bentall, respectivamente ( $P=0,7$ , ns). O tempo de internação na unidade de terapia intensiva foi de  $116,6 \pm 106,0$  horas para pacientes VSR e  $152,5 \pm 218,2$  horas para pacientes Bentall ( $P=0,5$ ). O tempo de permanência no hospital foi de  $10 \pm 8,1$  dias para VSR e  $11 \pm 9,52$  dias para Bentall ( $P=0,89$ ). A sobrevida em um ano foi de 92,0 % para o grupo VSR e 79,0% para o grupo de Bentall. A sobrevida de sete anos para o grupo VSR foi de 92% e 79% para o grupo de Bentall (IC95% [1,215 a 0,1275],  $P=0,1$ ).

**Conclusão:** A técnica *valve-sparing* substituição da raiz aórtica pode ser realizada com a morbidade e mortalidade aceitáveis, e sobrevida aceitável a longo prazo comparável com o procedimento de Bentall.

**Descritores:** Aorta. Aneurisma da aorta torácica. Valva aórtica. Doenças da aorta. Tratamentos com preservação do órgão.

## INTRODUCTION

Management of aortic root aneurysm or dissection has been evolving in recent decades. The current trend is a valve-sparing aortic root (VSR) replacement as well as restoring the diameter of the aortic annulus and sinotubular junction (STJ) [1-3]. Preservation of the native aortic valve (AV) results in maintenance of proper hemodynamics and prevention of thromboembolic complications by avoiding the use of a prosthetic valve and anticoagulation [1,4-6]. Preserving the native valve is particularly important in younger patients who refuse a mechanical valve. The crucial factors when attempting to preserve the function of the AV include adequate size and morphology of the leaflets, diameter of the STJ, and the diameter of the aortic annulus [2]. If the AV leaflets are grossly normal and aortic insufficiency (AI) is secondary to dilation of the STJ or aortic root, the native valve can be spared [6-9].

The purpose of this study was to evaluate the overall survival and compare the short- and mid-term outcomes in patients who underwent VSR with patients who underwent the Bentall procedure.

## METHODS

We retrospectively analyzed data on 70 patients with aortic root pathology (aneurysm or dissection), who underwent aortic root replacement with either the valve-sparing technique (VSR) or the Bentall procedure between 2007 and 2011 at our institution. All operations were performed using a standard approach with a median sternotomy and extracorporeal circulation. A right axillary artery or innominate artery cannulation was performed in selected cases. The patients who underwent the Bentall procedure, who received a mechanical valve, were postoperatively started on anticoagulation using warfarin, and an international normalized ratio (INR) ranging from 2.5 to 3.0 was maintained.

## Statistical Analysis

Patients' demographics, risk factors, and postoperative outcomes were reviewed retrospectively. Perioperative mortality was defined as death for any reason occurring within 30 days after the operation or any time during the same hospitalization, regardless of the length. Survival curves were generated using Kaplan-Meier methods. For continuous

variables, correlations were calculated with the Student *t*-test. Data analysis was performed with the GraphPad Prism program (GraphPad Software Inc., La Jolla, USA). This study was approved by the institutional review board at our institution.

## RESULTS

We evaluated 70 patients who had undergone a dissection or aneurysm of the aortic root: 25 patients had VSR (23 males and two females) and 45 patients (34 males and 11 females) had the Bentall procedure. Patients with VSR were younger with a mean age of  $55.4 \pm 14.8$  years compared to the Bentall patients who had a mean age of  $60.6 \pm 12.7$  years ( $P=ns$ ). Overall, 57 patients had an aneurysm and 13 patients had dissection of the aortic root. In patients who had replacement of the aortic root and valve, 30 patients had the traditional Bentall procedure with a mechanical aortic valve prosthesis, 10 patients had the Bio-Bentall (replacement of the aortic valve with a bioprosthesis) procedure, and five patients had a homograft. Table 1 illustrates the patients' characteristics, which were similar in both groups; however, seven patients in the Bentall group had previous

myocardial infarction (MI) whereas none in the VSR group had previously experienced MI ( $P=0.044$ ). There was no significant difference in mild or severe preoperative AI between the two groups; however, more patients in the SVR group (32%,  $n=8$ ) had moderate AI, compared to those in the Bentall group (8.8%,  $n=4$ ), ( $P=0.02$ ). In the VSR group, three patients had undergone emergency surgery, and the remaining patients had had an elective procedure. The total perfusion time was shorter in the VSR group ( $222.7 \pm 81.1$  min) compared to the Bentall group ( $246.9 \pm 89.8$  min),  $P=0.27$ .

The intraoperative need for blood transfusion was less in the VSR group compared to the Bentall group (3 units vs. 20 units,  $P=0.0074$ ), which may be due to higher preoperative hematocrit in VSR patients in our series ( $41.8 \pm 3.99$  vs.  $31.6 \pm 4.33$ ,  $P=0.0018$ ). Concurrent CABG was performed in 8 (32%) patients in the VSR group and in 12 (26.6%) in the Bentall group ( $P=0.78$ ). There was no significant difference in perioperative mortality between the two groups; 8% ( $n=2$ ) and 13.3% ( $n=6$ ), for VSR and Bentall groups, respectively ( $P=0.7$ ,  $ns$ ). Table 2 demonstrates the intraoperative parameters and differences between the two groups.

Table 1. Preoperative characteristics of both groups.

Pre-operative parameter	Valve sparing aortic root repair (n = 25)	Aortic valve replacement (n = 45)	P-value
Age (years)	$55.4 \pm 14.8$	$60.6 \pm 12.7$	0.12
Sex			
-Male	23	34	0.12
-Female	2	11	0.12
BMI (kg/m <sup>2</sup> )	$29.2 \pm 6.00$	$29.6 \pm 7.43$	0.82
BSA (m <sup>2</sup> )	$2.07 \pm 0.24$	$1.98 \pm 0.23$	0.13
Hypertension	19	38	0.52
Hypercholesterolemia	5	4	0.27
Diabetes	4	11	0.55
Current smoking	0	4	0.29
Coronary artery disease	2	2	0.61
Cerebrovascular disease	3	8	0.74
Peripheral-vascular disease	5	4	0.27
COPD/ Asthma	3	7	1.00
Renal failure requiring dialysis	0	2	0.53
Any angina pectoris	1	2	1.00
Any myocardial infarction	0	7	0.0449*
Cardiogenic shock	0	2	0.53
Any arrhythmia	3	11	0.35
Stroke	3	5	1.00
Dissection	6	7	0.52
Aortic regurgitation			
- Mild	3	3	0.66
- Moderate	8 (32%)	4 (8.8%)	0.0209*
- Severe	6	11	1.00
Bicuspid aortic valve	0	3	0.55
Hematocrit (%)	$41.8 \pm 3.99$	$31.6 \pm 4.33$	0.0018**
White blood cells (x 10 <sup>3</sup> / μL)	$9.6 \pm 2.2$	$11.0 \pm 2.89$	0.36
Platelets (x 10 <sup>3</sup> / μL)	$204.1 \pm 60.6$	$214 \pm 87.6$	0.64

Table 2. Comparing operative parameters

Intraoperative parameters	Valve sparing aortic root repair, (n = 25)	Bentall Procedure, (n = 45)	P-value
Any previous cardiac surgery	2	15	0.07
- Re-OP Sternotomy	2	9	0.31
-Re-OP Aortic Root/ Aorta ascendens	1	6	0.41
Concomitant CABG	8	12	0.78
Mitral/ tricuspid valve repair/ replacement	2	11	0.12
Cross-clamp time (min)	185.0 ± 63.3	170.3 ± 63.0	0.37
Perfusion time (min)	222.7 ± 81.1	246.9 ± 89.8	0.27
Longest ischemic interval (min)	28.1 ± 9.87	25.4 ± 4.28	0.15
Total cardioplegic solution (mL)	5042.3 ± 2445.2	4646.0 ± 3083.1	0.61
Cardioversion	13	27	0.62
Highest lactate (mmol/ L)	2.94 ± 1.49	3.54 ± 2.59	0.34
Hematocrit after cardiopulmonary bypass (%)	28.4 ± 4.11	26.5 ± 3.64	0.67
Red blood cell units (total)	3	20	0.0074**
Platelet units	6	21	0.08
Fresh frozen plasma units	5	15	0.28
Cryoprecipitate units	5	8	1.00

Table 3. Postoperative outcome and complications.

Post-operative complications	Valve sparing aortic root repair, (n = 25)	Bentall procedure, (n = 45)	P-value
Red blood cell units	17	28	0.80
Platelet units	10	13	0.43
Fresh frozen plasma units	6	11	1.00
Cryoprecipitate units	1	2	1.00
Any complications	11 (44%)	24 (53.3%)	0.62
Atrioventricular block	1 (4%)	0 (0%)	0.36
Atrial fibrillation	6 (24%)	11 (24.4%)	1.00
Multisystem failure	2 (8%)	1 (2.2%)	0.29
Bleeding requiring reoperation	2 (8%)	1 (2.2%)	0.29
Infection	1 (4%)	0 (0%)	0.36
-Septicemia	1 (4%)	0 (0%)	0.36
-Sternal Infection	3 (12%)	0 (0%)	0.0420*
Neurological event	1 (4%)	1 (2.2%)	1.00
Renal failure requiring dialysis	1 (4%)	1 (2.2%)	1.00
Prolonged post-operative ventilation	9 (36%)	9 (20%)	0.16
Total duration of post-operative ventilation (h)	51.7 ± 84.2	56.2 ± 121.9	0.89
Readmission to ICU	3 (12%)	4 (8.8%)	0.69
Total duration of ICU stay (h)	116.6 ± 106.0	152.5 ± 218.2	0.50
Length of stay surgery – discharge (d)	10.0 ± 8.10	11.0 ± 9.52	0.89
Readmission (< 30 days)	3 (12%)	7 (15.5%)	1.00
Perioperative mortality	2 (8%)	6 (13.3%)	0.70

Further, the incidence of postoperative adverse events remained similar between both groups (Table 3). Postoperatively, 17 and 26 patients in the VSR and Bentall groups, respectively, required red blood cell (RBC) transfusion ( $P=ns$ ). Total duration of post-operative ventilation was  $51.7 \pm 84.2$  hours for the VSR group and  $56.2 \pm 121.9$  for the Bentall group ( $P=0.89$ ). The overall length of stay in the critical care unit was slightly longer for the Bentall group ( $152.5 \pm 218.2$

hours) compared to for the VSR group ( $116.6 \pm 106.0$  hours) ( $P=0.5$ ). The overall length of stay was  $10 \pm 8.10$  days for the VSR group and  $11 \pm 9.52$  days for the Bentall group ( $P=0.89$ ).

The prolonged length of stay for Bentall patients may be related to anticoagulation and required time to adjust the INR prior to discharge from the hospital. The one-year survival was 92% for the VSR group and 78% for the Bentall group; the estimated survival at seven years was 92% for the VSR group

and 78% for the Bentall group (95% CI [0.1275 to 1.215],  $P=0.1$ ). The type of procedure did not impact readmission rate to the hospital. Postoperative echocardiogram was performed in 18 VSR patients (18/25; 64.3%), of which only one patient (1/18; 5.5%) had mild to moderate AI, 7 patients (7/18; 38.9%) had mild AI, and the remaining 10 patients (10/18; 55.5%) had trace AI at a median follow-up of 20 months. The freedom from aortic valve replacement following VSR at a median follow-up of 20 months was 100% (Figure 1).

## DISCUSSION

The Bentall approach has traditionally been the gold standard for aortic root pathology; however, this approach has been challenged by the valve-sparing root replacement [1, 10-13].

The VSR can be performed without increased mortality and morbidity compared to the Bentall procedure [1,11,14,15]. The perioperative mortality in our series was 8.0% ( $n=2$ ) and 13.3% ( $n=6$ ) for the VSR and Bentall procedures, respectively ( $P=0.7$ , ns), which is in line with the published literature [1,11,13-15]. The better survival in the VSR group in our series may be a reflection of younger age in these patients ( $55.4 \pm 14.8$  years compared to  $60.6 \pm 12.7$  years in the Bentall group); however, the difference in survival was not statistically significant. The perioperative mortality was higher in patients presenting with cardiogenic shock [15,16], long cardiopulmonary bypass and cross clamp times, concomitant CABG, and red blood cell transfusion [15]. In the Bentall group, 8 patients had undergone emergent surgery and the remaining patients had had elective surgery.

Considering the small number of patients, we did not find emergency surgery to be a risk factor for operative mortality. The one-year survival in our series was 92% for the VSR group and 79% for the Bentall group; the seven-year survival was 92% for the VSR group and 79% for the Bentall group. Although survival was favorable following VSR, this difference was not statistically significant. Cameron et al. [11] reported favorable survival following aortic valve reimplantation in a series of 372 Marfan patients; 269 patients

underwent the Bentall procedure, and 85 patients had VSR (the David reimplantation procedure was performed in 44 patients).

This observation was supported by Sheick-Yousif et al. [17], who reported a favorable outcome of valve reimplantation in 209 Marfan patients with AI secondary to dilatation of the aortic root or the STJ. Kerendi et al. [18] reported their experience with root replacement in 110 patients: 73 Bentall procedures and 37 David procedures. There was a slight, but non-significant increase in mortality with the Bentall procedure (8.2%) compared with the David procedure (5.4%), which is in concert with our results. We did not observe any significant differences with respect to postoperative stroke, renal failure, or respiratory failure between the two approaches, which has been confirmed by other authors [1,10-12,18]. Freedom from aortic valve replacement (AVR) at a mean follow-up of 8.8 months in Kerendi et al. [18] series was 94.3%. The authors argued that a VSR replacement can be performed safely in the setting of acute dissection, severe AI, and reoperations with acceptable early results. The freedom from AVR following VSR was 100% in our series; however, our results are limited by a short median follow up of 20 months.

Our data demonstrated that VSR is not associated with increased postoperative morbidities; in fact, intubation time, length of stay in the critical care unit, and overall length of stay were favorable following VSR compared to those in the Bentall group. The most common complications are bleeding and neurological sequelae [15]. In a series of 388 patients (reimplantation 72, remodeling 77, tailoring 239), stroke occurred in 4.6% (18/388) [1]. In a large series of 430 patients [19] who underwent VSR (remodeling in 401, reimplantation in 29) the early mortality was 2.8%, and actuarial survival at 10 years was 83.5%. Ten-year freedom from AI grade II or greater was 85%. Operative technique (remodeling vs. reimplantation) was not associated with an increased risk of late AV regurgitation or need for AV replacement. Long-term outcome of VSR was not influenced by the technique of root repair but by the preoperative aortic root geometry and postoperative cusp configuration [19].

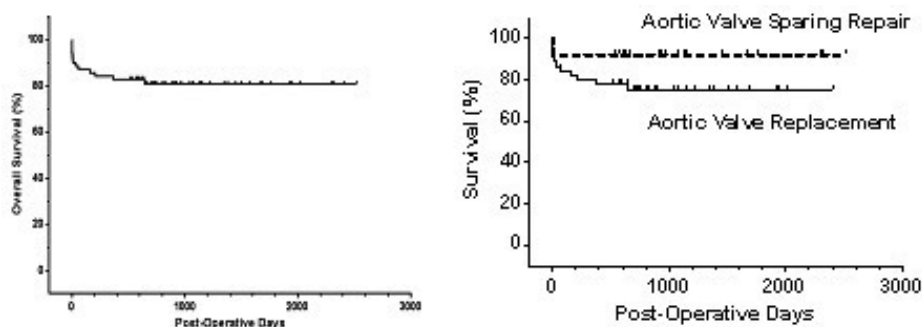


Fig. 1A - The overall survival. 1B. Kaplan Meier curve, comparing the survival between two groups (95% CI, 1,225 to 0,1265,  $P=0,10$ )



Some authors reported that a preoperative aortoventricular junctional diameter greater than 28 mm was predictive of valve repair failure [19,20]. Although we did not evaluate the AV junction diameter, in our small series with a short median follow up (20 months), the AV function in the VSR group was excellent and none of the patients had significant AI. In David et al. [10] series 228 patients underwent reimplantation of the aortic valve, and 61 patients underwent remodeling of the aortic root, with excellent results. The 12-year survival was 82.9% with no difference between both techniques.

The incidence of AI requiring reoperations was higher following remodeling of the aortic root. Freedom from reoperation at 12 years was 90.4% after remodeling, and 97.4% after reimplantation (not statistically significant). Freedom from moderate or severe aortic insufficiency at 12 years was 91.0% after reimplantation [10]. Dias et al. [3] reported favorable outcome with an actuarial survival and freedom from reoperation of 94.4% and 96% within 11 years of follow-up, respectively [3]. In a series of 388 patients (72 reimplantation, 77 remodeling, and 239 tailoring), the hospital survival rate was 97.4% (378/388) [1].

## CONCLUSION

Aortic VSR can be performed with acceptable morbidity and mortality. The mid-term follow up demonstrates adequate freedom from aortic insufficiency. Log-term follow up in larger series may demonstrate possibly superior long-term survival following valve sparing root repair compared to the Bentall procedure. In addition, a valve-sparing approach reduces all of the risks inherent to a mechanical or biologic prosthetic, particularly in younger patients.

Author's roles & responsibilities	
ES	Collecting data, manuscript writing
REM	Manuscript writing
VH	Statistical analysis
SNM	Design of the project, manuscript writing

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