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Early Regional Assessment of LV Mass Regression and Function after Stentless Valve Replacement: Comparative Randomized Study

M. J. Jasinski, MD, PhD, FETCS,[1] P. Ulbrych, MD,[2] M. Kolowca, MD,[1]
A. Szafranek, MD,[1] J. Baron, MD, PhD,[2] S. Wos, MD, PhD[1]

[1]2nd Department of Cardiac Surgery, [2]Department of Magnetic Resonance, Medical University of Silesia, Katowice, Poland

ABSTRACT

Early regional performance and hypertrophy regression after stentless aortic valve replacement are still incompletely characterized. We compared early postoperative changes of segmental thickness and function after stentless and stented aortic valve replacement as assessed by cardiac magnetic resonance (CMR). In 16 patients randomly assigned to stented (Mosaic, 8 patients) and stentless (Freestyle, 8 patients) groups, 4 parallel short-axis images at the level of the apex (slice 4), midventricle (slices 2-3), and mitral valve (slice 1) were obtained with a 1.5 T CMR scanner (Magnetom Sonata, Siemens) before and 1 month after surgery. Cine images were obtained using an echo gradient sequence. Left ventricle mass was calculated as the difference between the left ventricular end-diastolic volume at the epicardial and endocardial borders multiplied by a myocardium density factor (1.05). Each slice was divided into 8 segments (octants) from anterior (octant I-II) to septal (octant V-VIII). A total of 32 segments encompassed the entire heart. From each of these elements end diastolic thickness and systolic function (fractional thickening) were calculated. In stentless valves significant reduction of septal octant thickness on the midventricular slice was noted. There was no difference in regional systolic function-segment thickening. In stented valves no segmental thickness changes were observed. In stentless valves there was early postoperative thickness reduction of septal segments at the midventricular level. However, this finding did not coincide with changes in segmental function.

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Address correspondence and reprint requests to: Marek J. Jasinski, MD, FETCS, 2nd Dept of Cardiac Surgery, 40650 Katowice, 46 Ziolowa, Poland (e-mail: marekjas@hotmail.com).

INTRODUCTION

Early regional performance and hypertrophy regression after stentless aortic valve replacement (AVR) are still incompletely characterized. Moreover, low sensitivity of echogardiographic assessment has been highlighted. High accuracy and reproducibility of cardiac magnetic resonance (CMR) in assessment of left ventricle (LV) mass and function has been proven.

We sought to compare early postoperative changes of segmental thickness and function after stentless and stented AVR as assessed by CMR.

METHODS

This study included 30 patients with aortic stenosis who had AVR with either stentless (Freestyle; Medtronic, Minneapolis, MN, USA) or stented (Mosaic, Medtronic) valves (Table 1). Sixteen of these patients were randomly assigned to receive stented (Mosaic, 8 patients) or stentless (Freestyle, 8 patients) valves and entered the CMR trial, undergoing assessment with the 1.5 T CMR scanner (Magnetom Sonata; Siemens AG, Munich, Germany) before and 1 month after surgery. After it was determined that ferromagnetic materials were not present, the patients were placed supine in the clinical 1.5 T scanner. A phased-array radiofrequency receiver coil was placed on the patient's chest. All the images were obtained during repeated patient breath-holds and were electrocardiogram gated. There were specific acquisitions: 4 parallel short-axis images at the level of the apex (slice 4), midventricular (2-3), and mitral valve (slice 1) level were obtained. Each slice was divided into 8 segments (octants) from anterior (octant I-II) to septal (octant V-VIII); 4 of the segments were free-wall sectors (anterior I, central II, lateral III, inferolateral IV) and the other 4 were septal (inferoseptal V, lateroseptal VI, anterolateral septal VII, anteroseptal VIII). A total of 32 segments encompassed the entire heart. From each of these elements end diastolic thickness and systolic function (fractional thickening) were calculated. Cine images were obtained using an echo gradient sequence.

Table 1. Preoperative Characteristics

	Total	Stentless	Stented	*P*
Female, n	13	7	6	NS
Male, n	17	8	9	NS
Age, *y*	71.6 ± 7.4	68 ± 5	73 ± 6	NS
Body surface area	1.78 ± 0.4	1.77 ± 0.5	1.78 ± 0.3	NS
New York Heart Association Class, n (%)				
I	-	-	-	NS
II	10 (33%)	4	6	NS
III	12 (40%)	7	5	NS
IV	8 (27%)	4	4	NS
Size, mean ± SD		23.2 ± 1.5	22.1 ± 1.2	NS

LV mass was calculated as the difference between the LV end-diastolic volume (LVEDV) at the epicardial and endocardial borders multiplied by a myocardium density factor (1.05). LV ejection fraction (EF) was determined as LV stroke volume divided by LVEDV.

RESULTS

In stentless valves significant reduction of septal octant thickness on the midventricular slice was noted (Table 2). There was no difference in regional systolic function-segment thickening. In stented valves no segmental thickness changes were observed. In stentless valves there was early postoperative thickness reduction of septal segments at the midventricular level. However, this finding did not coincide with changes in segmental function.

In the stentless group the mass of the LV decreased significantly, $P = .033$ (Table 3). Overall systolic function (EF) did not change in either of the groups (Table 4).

In the overall group and specifically in the stentless valve group, significant reduction of thickness occurred in septal octant sectors V-VIII and on the level of the third transverse plane-midventricular slice (Tables 5-7). There was no difference in regional systolic function-segment thickening.

Table 2. Reduction of Septal Octant Thickness in Stentless Valves*

	Octant V	Octant VI	Octant VII	Octant VIII	*P*
Slice 1, mitral valve	3.5 (5)	2.5 (4.1)	3.6 (5.5)	3.79 (5.1)	.1
Slice 2, midventricular	4.3 (9.1)	6.2 (11.1)	6.2 (11)	6.1 (10)	.2
Slice 3, midventricular	**5.3 (5.1)**	**5.1 (4.7)**	**4.1 (3.9)**	**3.9 (4.6)**	**.04**
Slice 4, apex	1.2 (3.4)	-0.1 (2.7)	0.2 (4.5)	-2.6 (1.7)	.4
P	*.04*	*.008*	*.05*	*.05*	

*Data are expressed as mean (SD). Significant reduction of septal octant thickness was noted on the midventricular slice 3 (bold values).

Table 3. Left Ventricular Mass of Stentless versus Stented Valves (n = 16)*

	Preoperative	1 Month Postoperative	*P*†
Stentless	235 ± 74.1 g	189 ± 37 g	.033
Stented	244 ± 88 g	220 ± 95 g	NS
P‡	NS	NS	

*Assessed by cardiac magnetic resonance.
†*P* within groups.
‡*P* between groups.

DISCUSSION

LV hypertrophy (LVH) is associated with an increased risk of sudden death and other major cardiovascular complications [Levy 1989, Lytle 1989, Lund 1990, He 1995]. After AVR, a decrease in LVH could be associated with a better outcome. In aortic stenosis the reduction in the aortic orifice area is usually compensated for by the development of LVH. The same increased risk has been postulated for patients with aortic stenosis and LVH [Lund 1993]. After AVR, incomplete regression of LVH has been shown to significantly reduce 10-year survival [Lund 1998]. The degree of reduction of LVH after AVR could be related to the type valve used and is essential to guarantee clinically optimal long-term results. In our trial we were able to detect substantial regression of LV mass as quickly as 1 month postoperatively; however, it was significant in the stentless group only.

After AVR, persistent hypertrophy may be due to the obstructive nature of the valve ring and the supporting stent, resulting in a relative obstruction to flow or a mismatch in the valve size compared to the patient's needs. The effective orifice area (EOA) of a prosthesis valve is less than that of a normal native valve in the same aorta. Stented valves create a relative obstruction to flow, and it has been shown that the EOA available for blood flow represents 40% to 70% of the total area occupied by the valve [Yoganathan 1983, Yoganathan 1984, Yoganathan 1986, Carrel 1996]. Stentless valves were in part developed to alleviate this problem by providing a greater EOA, thus improving the hemodynamics of the flow through the valve and LV function [Kon 1995, Jin 1996, Thompson 1998, Collinson 1999, Walther 1999]. Such

Table 4. Ejection Fraction of Stentless versus Stented Valve (n=16)*

	Preoperative	1 Month Postoperative	*P*†
Stentless	64.4% ± 15%	63.7% ± 16%	NS
Stented	64.5% ± 14%	63.5% ± 17%	NS
‡*P*	NS	NS	

*Assessed by cardiac magnetic resonance.
†*P* within groups.
‡*P* between groups.

Table 5. Thickness of Segments of Stentless and Stented Valve (n=16)*

	Octant I	Octant II	Octant III	Octant IV	Octant V	Octant VI	Octant VII	Octant VIII	*P*†
Plane 1	1.8 (6.1)	2.2 (7.4)	1.7 (7.4)	1.2 (6.3)	2.1 (6.5)	1.4 (6.4)	1.6 (5.9)	1.6 (5.7)	.3
Plane 2	2.2 (6.6)	1.9 (5.2)	1.5 (6.1)	1.6 (7.9)	4 (7.9)	**4.9 (8.2)**	3.5 (8.7)	2.8 (8.3)	.14
Plane 3	1.3 (4.4)	1.1 (6.1)	0.1 (4.2)	**2.6 (3.7)**	**3.5 (4.3)**	**3.9 (4.6)**	**2.3 (4.2)**	**3.4 (3.7)**	**.01**
Plane 4	2.6 (3.7)	**-3 (4.3)**	-1.8 (4.6)	-0.9 (3.6)	-0.3 (3)	-0.3 (3)	-0.7 (4)	-1.7 (3)	0.3
P‡					**.02**	**.008**	**.03**	**.03**	

*Assessed by cardiac magnetic resonance. Data are expressed as mean (SD). Bold values indicate *P* < .05.

†*P* within groups.

‡*P* between groups.

Table 6. Thickness of Segments: Stentless Group (n=8)*

	Octant I	Octant II	Octant III	Octant IV	Octant V	Octant VI	Octant VII	Octant VIII	*P*†
Plane 1	**4.3 (3.9)**	**4.1 (5.3)**	2.9 (5.2)	2.9 (4.9)	3.5 (5)	2.5 (4.1)	3.6 (5.5)	3.79 (5.1)	.1
Plane 2	3.2 (7.5)	3.3 (5.6)	2.2 (5.5)	2.4 (6.2)	4.3 (9.1)	6.2 (11.1)	6.2 (11)	6.1 (10)	.2
Plane 3	1.1 (5.7)	2.5 (8.1)	1.1 (4.7)	**4.1 (3.5)**	**5.3 (5.1)**	**5.1 (4.7)**	**4.1 (3.9)**	**3.9 (4.6)**	**.04**
Plane 4	-2.8 (4.7	-4 (4.9)	-0.8 (5.4)	-0.1 (4.8)	1.2 (3.4)	-0.1 (2.7)	0.2 (4.5)	-2.6 (1.7)	.4
P‡	NS	NS	NS	NS	**.04**	**.008**	**.05**	**.05**	

*Assessed by cardiac magnetic resonance. Thickness of segments (octants) with regard to horizontal (planes) and perpendicular (sectors). Data are expressed as mean (SD). Bold values indicate *P* < .05.

†*P* within groups.

‡*P* between groups.

Table 7. Thickness of Segments: Stented Group (n = 8)*

	Octant I	Octant II	Octant III	Octant IV	Octant V	Octant VI	Octant VII	Octant VIII	*P*†
Plane 1	-0.6 (7)	0.4 (9)	0.46 (9)	-0.56 (7)	0.57 (7.8)	0.17 (8)	-0.4 (6)	-0.5 (5)	NS
Plane 2	1.2 ((5)	0.5 (4.8)	0.8 (7)	0.7 (9)	3.6 (7.5)	3.5 (4)	0.9 (5.5)	-0.4 (5)	NS
Plane 3	1.5 ((3)	-0.5 (2)	-1.3 (3)	1.07 (3.5)	1.8 (2.8)	2.6 (4.6)	0.6 (4.3)	2.7 (2)	NS
Plane 4	-2.5 (3)	-2.5 (4)	-2.7 (4)	-1.7 (2)	0.6 (3.3)	-0.5 (3)	-1.8 (4)	-1.2 (3)	NS
P‡	NS	NS	NS	NS	NS	NS	NS	NS	

*Assessed by cardiac magnetic resonance. Thickness of segments (octants) with regard to horizontal (planes) and perpendicular (sectors). Data are expressed as mean (SD).

†*P* within groups.

‡*P* between groups.

features would permit more complete resolution of LVH, as was noted in our patients. Interestingly, marked LV regression was noticed even as early as at 1 month postoperatively. It is difficult to discuss these finding because there is very limited evidence regarding such early postoperative LV mass regression, possibly because of difficulties and shortcomings of the classic echocardiographic method of LV mass assessment. Echocardiography is widely available, but image acquisition is operator- and acoustic-window dependent. Reproducibility is reasonable in normal ventricles [White 1987], but quantification of LV volumes and mass is limited by geometric assumptions that do not hold true in abnormal ventricles, for example in patients with hypertension [Levy 1990], myocardial infarction [Baur 1996], dilated cardiomyopathy [Sharpe 1998, Strohm 2001], and ventricles undergoing cardiac remodeling [Gordon 1983, Missouris 1996]. CMR can be used to tomographically section the entire heart, providing accurate 3-dimensional measurements of global and segmental LV volume and mass independent of geometrical assumptions. Thus we can not only very precisely measure overall mass, we can also analyze function and regional thickness of particular segments and sectors. Indeed, the accuracy and reproducibility of the assessment of LV mass, function, and volumes by CMR are better than those of echocardiogram assessment [Walther 1994, Bottini 1995, Jin 1995, Dujardin 1997, Gardin 1999, Williams 1999]. Thus the sample size to detect a difference in a parameter is lower with CMR than with echocardiography [Bellenger 2001]. In our trial, data from a minimal number of patients (16) were calculated accordingly.

We could prove that there is substantial regression of LV mass as quickly as 1 month postoperatively. There is also certain pattern of above-mentioned LV mass regression that is detected only at septal segments, particularly at the level of the midventricle transverse plane.

On the other hand there was no change of either overall (EF) or segmental (segmental thickening) systolic function. This result correlates with others showing no significant changes of those parameters, even for longer time. One of the contributing factors may be lack of systolic function impairment prior to surgery in most of the patients undergoing surgery for aortic stenosis.

CONCLUSIONS

1. In stentless valves there is early postoperative thickness reduction of septal segments at the midventricular level. However, this does not coincide with changes in segmental function.

2. CMR allows for detection of very distinct early postoperative segmental changes.

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REVIEW AND COMMENTARY

CTT Reviewer Writes:

This is an interesting, yet small, study comparing the early changes in calculated LV mass and EF between a small group of stentless versus stented porcine bioprostheses in the aortic position. The authors use gated magnetic resonance imaging to quantify the wall thickness of the LV in different locations and create a scoring system and a calculated mass based on the myocardial density factor by MR. Their data seem to show a slight, but statistically significant, reduction in the septal mass within 1 month of surgery in the stentless AVRs but not in the stented group.

There is often akinesia or hypokinesia of the septum in early postoperative echoes after any type of cardiac surgery associated with pericardiotomy and cardioplegic arrest. Can the small degree of LV mass reduction seen at 1 month actually be this same process and unrelated to valvular surgery at all? Were the patients treated with β-blockers (a drug known to reduce LVH)? If so, was there a difference in the incidence of β-blocker administration between the 2 groups that may explain the findings?

Finally, if the septum is the only area that regresses (and the EF and other wall segments are unchanged), is this clinically significant at all? Do the authors feel that if only the septum improves postoperatively the use of stentless AVR will be effective in reducing the incidence of congestive heart failure and sudden death in patients who undergo AVR?

Author's Response by Marek Jasinski, MD:

Regarding the myocardial protection issue, all patients had the same model, so any differences are obviously unrelated. Also β-blockers have been routinely prescribed for atrial fibrillation prophylaxis in the same protocol.

As far as clinical relevance is concerned, it was not an major issue of this paper because follow-up time was too short to be able to draw any conclusions. However, I would like to point out that there was not only septal-segment reduction but also inferior-segment reduction in the stentless group. The degree was not small, because it caused significant reduction in overall mass. Of some importance also is certain localization of reduced segments on the short-axis view (so-called planes). Besides, additional analysis showed that significant simultaneous EDV reduction occurred in the stentless group, that may contribute to functional improvement in longer follow up.