Clinical Investigation

Effect of Elective Bentall Procedure on Left Ventricular Systolic Function and Functional Status:

Long-Term Follow-Up in 90 patients

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Because there are so few data on the long-term effects on left ventricular systolic function and functional status in patients who electively undergo Bentall procedures, we established a retrospective study group of 90 consecutive patients. This group consisted of 71 male and 19 female patients (mean age, 54 ± 10 yr) who had undergone the Bentall procedure to correct aortic valve disease and aneurysm of the ascending aorta, from 1997 through 2003 in a single tertiary-care center. We monitored these patients for a mean period of 117 ± 41 months for death, left ventricular ejection fraction and volume indices, and functional capacity as determined by New York Heart Association (NYHA) class.

There were no operative deaths. The survival rate was 73.3% during follow-up. There were 10 cardiac and 13 noncardiac deaths, and 1 death of unknown cause. Echocardiography was performed before the index procedure and again after 117 ± 41 months. In surviving patients, statistically significant improvement in left ventricular ejection fraction, in comparison with preoperative values (0.49 ± 0.11 vs 0.41 ± 0.11; P *<0.0001), was noted at follow-up. Similarly, we observed statistically significant reductions in left ventricular end-systolic (39.24 ± 28.7 vs 48.77 ± 28.62 mL/m²) and end-diastolic volumes (54.63 ± 6.97 vs 59.17 ± 8.92 mL/m²; both* P *<0.0001). Most patients (53/66 [80.3%]) progressed from a higher to a lower NYHA class during the follow-up period.*

The Bentall procedure significantly improved long-term left ventricular systolic function and functional status in surviving patients who underwent operation on a nonemergency basis. ***(Tex Heart Inst J 2016;43(2):114-8)***

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The Bentall has become the procedure of choice for treating aortic valve disease that involves the ascending aorta. Since the procedure was introduced more than 40 years ago, investigators have found excellent mid- and long-term survival rates in patients who have undergone surgery via this technique.[1,2] The Bentall procedure improves patients' clinical and hemodynamic status, as well as their quality of life.[3] There are, however, surprisingly few data on the long-term impact of the Bentall procedure on left ventricular (LV) systolic function and functional status in patients who underwent elective treatment of ascending aortic valve disease.

Therefore, we designed the current study to reveal exactly those things.

Patients and Methods

This study involved 90 patients at Dedinje Cardiovascular Institute who had undergone surgery from 1997 through 2003 for chronic ascending aortic aneurysm and significant aortic regurgitation (AR). The study was performed in compliance with international guidelines and with the human-study guidelines of our Institute. This was a retrospective study, and all patients signed informed, written consent after the nature of the study was explained.

All patients underwent operation via the standard Bentall procedure (composite graft with implantation of an artificial aortic valve). Excluded from the study were acute aortic dissection patients, concomitant bypass-graft patients, and patients who had died perioperatively or within 30 days of the index surgery. Seventy-one of the 90 (78.8%) accepted patients were men. Patients' mean age at inclusion was 54.3 ± 10.3

years (range, 28–72 yr). No death was observed perioperatively, but 2 patients died within 30 days of operation, as a consequence of acute heart failure or stroke. The following perioperative complications or sequelae were noted: infection (4 patients), bleeding (2), acute renal failure (2), and stroke (4).

Echocardiography. Transthoracic echocardiographic examinations were performed upon admission for the index surgery with use of a Sonos 2500 (Hewlett-Packard; Andover, Mass), and again after 117 ± 41 months with use of a Vivid® 7 (GE Healthcare; Wausheka, Wisc). All examinations were recorded and stored on videotape or hard disk for later analysis. Left ventricular diameter and volume index, LV ejection fraction (LVEF) (using a modified Simpson biplane formula), and LV mass (using a truncated ellipsoid model) were calculated according to recommendations proposed by the American Society of Echocardiography.[4] Echocardiographic measurements were made by 2 experienced echocardiographers who were blinded to the study design. After careful consideration, one patient was excluded from the echocardiographic analysis on the ground of poor-quality recordings.

Functional Status. Patients' functional status was determined on admission and after a mean period of 117 ± 41 months by an independent observer who used the New York Heart Association (NYHA) classification system. Patients were classified as NYHA functional class I if there were no symptoms and no limitations during ordinary physical activity; NYHA class II if there were mild symptoms (mild shortness of breath, angina, or both) and slight limitations during ordinary activity; NYHA class III if there were marked symptoms and limitations during less-than-ordinary activity; and NYHA class IV if there were symptoms even during rest.[5]

Surgical Technique. Operations, by one of the 5 staff surgeons in the tertiary-care center, were performed through a standard median sternotomy, and cardiopulmonary bypass was instituted by cannulation of the ascending aorta. The arterial line was inserted into either the distal ascending aorta or the proximal aortic arch. The venous line was in all cases inserted through the right atrial appendage. Myocardial protection was achieved by cardioplegia, specifically by the intermittent antegrade–retrograde (or simultaneous antegrade and retrograde) administration of a cold hyperkalemic solution of blood. All patients underwent operation via the standard technique, and a composite graft (St. Jude Medical, Inc.; St. Paul, Minn) was implanted in all patients.

Follow-Up Evaluation. Patients were monitored for a mean period of 117 ± 41 months after the index surgery. Follow-up examination consisted of complete echocardiographic examination and determination of functional capacity in accordance with the NYHA classification system.

Statistical Analysis

All data are expressed as mean ± SD. The *t* test for paired samples was used for comparisons between the subgroups for continuous variables; $P < 0.05$ was considered statistically significant. A Kaplan-Meier curve was constructed to evaluate survival rates during the follow-up period. All statistical analyses were performed with use of SPSS version 12.0 (IBM Corporation; Armonk, NY).

Results

Preoperatively, all 90 patients had hypertension requiring medical therapy; 66 (73%) of those had hyperlipidemia, 21 (23%) had diabetes mellitus, and 51 (57%) were active smokers. None of the patients had experienced myocardial infarction or undergone surgical or percutaneous myocardial revascularization.

At 117 ± 41 months after the index surgery, 66 (73.3%) patients were alive, and all 66 attended the follow-up visit. Of the 24 (26.7%) patients who died, 10 died of cardiac causes (4 of myocardial infarction, 4 of heart failure, and 2 of aortic dissection), 13 of noncardiac causes (5 of malignancy, 3 of stroke, 1 of pulmonary embolism, 1 of renal failure, and 3 of hemorrhagic sequelae), and 1 of unknown cause (Fig. 1).

In the 66 surviving patients, the LVEF significantly increased after 117 ± 41 months, in comparison with the immediate preoperative values (0.49 ± 0.11 vs 0.41 ± 0.11; $P < 0.0001$) (Fig. 2A). Similarly, LV end-systolic and end-diastolic volume indices were significantly reduced on follow-up echocardiographic examination, in comparison with the baseline values (39.24 ± 28.7 vs 48.77 ± 28.62 and 54.63 ± 6.97 vs 59.17 ± 8.92 mL/m^2, respectively; both $P < 0.0001$) (Figs. 2B and C). In addition, LV mass decreased after the index surgery from 245.53 ± 63.25 to 234.99 ± 64.39 g ($P < 0.01$) (Fig. 3).

During follow-up echocardiographic examination, survivors' mean peak gradients over the mechanical aor-

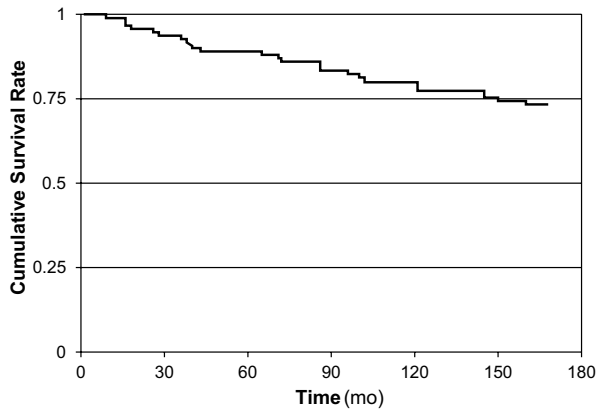

Fig. 1 *Kaplan-Meier curve shows the cumulative survival rate during the follow-up period.*

tic valve were 28 ± 9 mmHg, and their mean gradients were 12 ± 4 mmHg. Their NYHA functional class also improved over the baseline during the follow-up period (3.1 ± 0.8 vs 1.7 ± 1.1; *P* <0.0001).

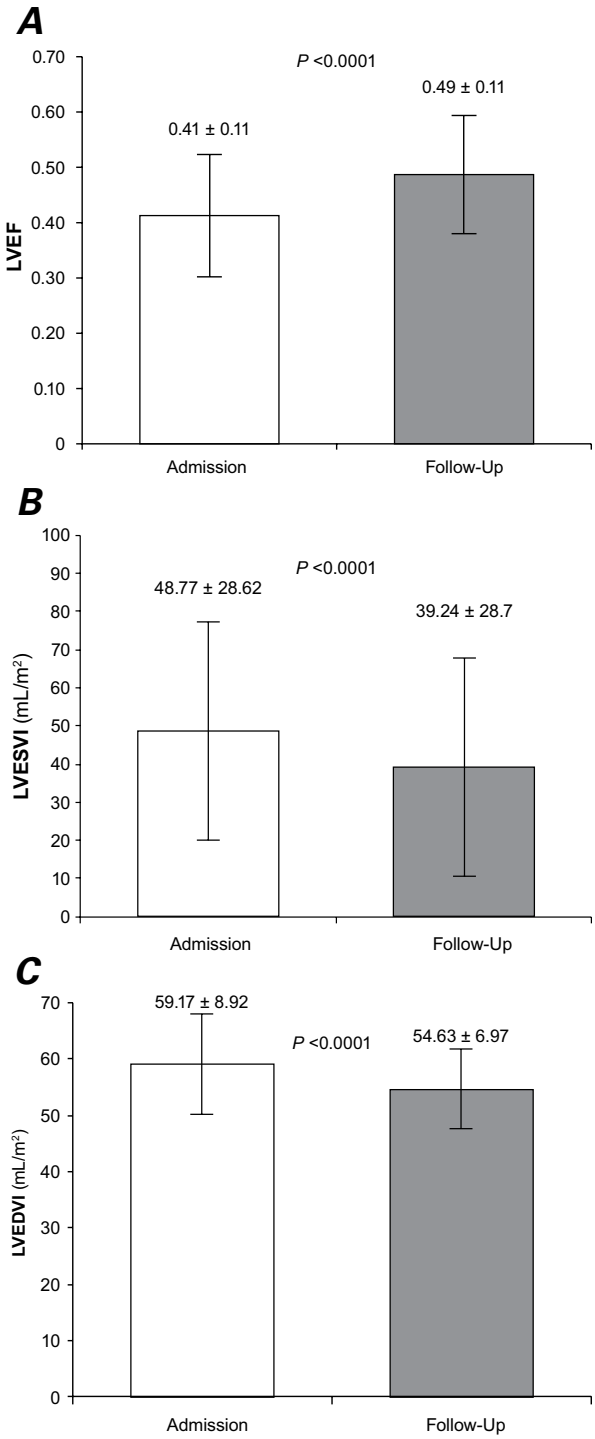

Fig. 2 *Graphs show **A**) left ventricular ejection fraction (LVEF), **B**) left ventricular end-systolic volume index (LVESVI), and **C**) left ventricular end-diastolic volume index (LVEDVI), upon admission and upon follow-up.*

P *<0.05 was considered statistically significant.*

Immediately before the index surgery, 37/90 (41.1%) patients were in NYHA class I or II, whereas 53/90 (58.9%) belonged to NYHA class III or IV. The vast majority of surviving patients (63/66, or 95.4%) 117 ± 41 months after the index surgery were in NYHA class I or II, and only 3/66 (4.6%) were in NYHA class III or IV (*P* <0.0001 vs baseline) (Fig. 4). More importantly, most patients (53/66 [80.3%]) improved: at the follow-up examination, only 2 (3%) patients were in a worse NYHA class than at initial examination.

Discussion

Of those patients who undergo aortic valve replacement for aortic regurgitation alone, the "root cause" of the regurgitation is (more often than not) aortic root dilation. Therefore, the Bentall procedure has been used with increasing frequency, and its long-term results might well have a substantial impact on the healthcare system.

The main finding of our study is that the Bentall procedure significantly improves long-term LV systolic

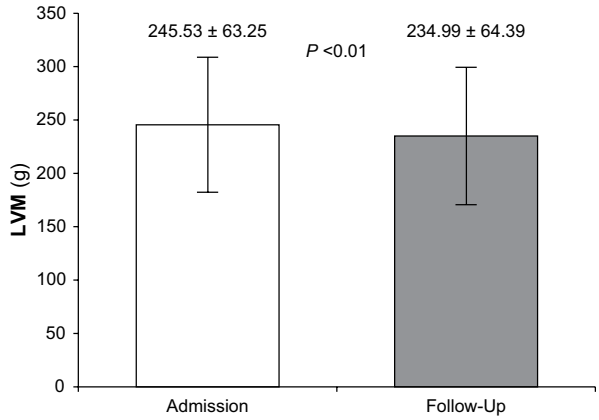

Fig. 3 *Graph shows the mean left ventricular mass (LVM) upon admission and upon follow-up.*

P *<0.05 was considered statistically significant.*

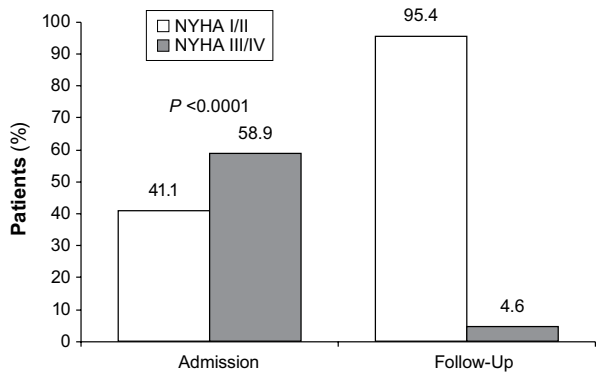

Fig. 4 *Graph shows changes in New York Heart Association (NYHA) functional class during the follow-up period.*

P *<0.05 was considered statistically significant.*

function and decreases LV mass in survivors of elective surgical intervention. The available literature contains very few data on the long-term impact of the Bentall procedure on LV systolic function, volume, and mass.

Jiang and associates[6] examined the impact of cardiac surgical procedures in 126 patients who had severe LV dilation caused by either mitral or aortic valve disease. Among these patients, only 6 underwent the Bentall procedure. The mean LV end-diastolic diameter, which was 77 ± 6 mm preoperatively, decreased to 63 ± 12 mm (postoperative days 7–14) and to 58 ± 10 mm (postoperative months 6–12) (P <0.01). On the other hand, the mean LVEF, which was 0.49 ± 0.12 preoperatively, decreased to 0.42 ± 0.09 at postoperative days 7 to 14, and returned to 0.51 ± 0.07 after 6 to 12 postoperative months (P <0.01).

Tanoue and colleagues[7] analyzed the mid-term LV performance after aortic valve replacement in 263 patients who underwent surgery for either aortic stenosis or AR. The LV elastance decreased after aortic valve replacement in operations for aortic stenosis, but increased in operations for AR. The LV efficiency decreased soon after aortic valve replacement in the AR group, but subsequently improved in all groups during the year after the index surgery. The authors concluded that midterm LV contractility and efficiency were excellent after aortic valve replacement, in treating either aortic valve stenosis or AR.[7] In a similar fashion, the same group of authors[8] analyzed 15 patients with annuloaortic ectasia and AR and concluded that approximately 1 year after a Bentall operation both LV contractility and efficiency were significantly improved, in comparison with preoperative values.

A total of 142 elective patients younger than 65 years, who had undergone replacement of the thoracic aorta and aortic valve without concomitant procedures, were analyzed for long-term survival rates.[1] The overall survival rate was 0.95 (95% confidence interval [CI], 0.9–0.99) at 5 years and 0.93 (95% CI, 0.86–0.99) at 8 years; the event-free survival rate was 0.85 (95% CI, 0.78–0.92) at 5 years and 0.78 (95% CI, 0.68–0.88) at 8 years. These same authors concluded that the Bentall procedure can be performed with excellent short- and long-term results in relatively noncomplex, elective cases in which aortic valve disease is combined with dilation of the ascending aorta.[1] Similar results have been reported by Mataraci and associates,[9] who performed the Bentall de Bono procedure on 254 patients in need of aortic root replacement. Actuarial survival for the 254 patients overall was 88.4% ± 2.1%, 87.4% ± 2.2%, and 84.5% ± 2.56% at 1, 3, and 10 years, respectively. The late mortality rate was significantly affected by Marfan syndrome (P=0.025).[9] These results are comparable to the results of the present study.

After a mean follow-up of 65 ± 44 months in 23 patients with Marfan syndrome, in whom Bentall aortic root replacement had been performed with a composite mechanical-valve conduit, echocardiography revealed significant improvement in LVEF (0.60 ± 0.10 vs 0.52 ± 0.09 preoperatively, P=0.01) and end-systolic diameter (34 ± 5 vs 47 ± 14 mm, respectively; P=0.001).[10] Again, these results are comparable to our data. We have extended these observations with a larger number of patients, longer follow-up times, and the inclusion of LV volume indices.

In patients with AR, LV mass is usually increased, often to levels even higher than in isolated aortic stenosis, and sometimes exceeding 1,000 g. To our knowledge, no previous investigators have examined the long-term impact of the Bentall procedure on LV mass. Our data indicate that there is a significant decrease in LV mass over 8 postoperative years, in comparison with preoperative values.

On the other hand, prior investigators have shown that the Bentall procedure improves long-term functional capacity. In a study by Sun and co-authors,[11] which included patients who underwent the Bentall procedure via a ministernotomy, 169/175 (96%) patients who were monitored for 2 weeks to 65 months after surgery were classified as NYHA class I or II at the follow-up examination. Bhan and associates[12] showed that 72% of patients, 1 to 96 months after a Bentall operation, were in NYHA class I or II.

Limitations of the Study

The major limitation of our study is its retrospective nature. Therefore, functional capacity and echocardiographic data could not be measured in the patients who died before we gathered our data. It can be assumed that these patients had worse functional capacity and LV function than did the survivors, which could bias our results.

Conclusion

The Bentall procedure significantly improved long-term LV systolic function and functional status and decreased LV mass in surviving patients who underwent the procedure on an elective basis.

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