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Ventricular energetics in aortic root replacement for annuloaortic ectasia with aortic regurgitation

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Abstract Aortic root replacement (Bentall operation) is the standard operation for patients who have lesions of the ascending aorta associated with aortic valve disease. We analyzed the mid-term results for left ventricular energetics after the Bentall operation for annuloaortic ectasia with aortic regurgitation. We measured left ventricular contractility (end-systolic elastance; Ees), afterload (effective arterial elastance; Ea), and efficiency (ventriculoarterial coupling; Ea/Ees, and the ratio of stroke work and pressure–volume area; SW/PVA) based on transthoracic echocardiography data before, after, and approximately 1 year after the Bentall operation in 15 patients with annuloaortic ectasia with aortic regurgitation. Left ventricular volume was calculated by the Teichholz M-mode method. Ees and Ea were approximated as follows: Ees = mean blood pressure/minimal left ventricular volume, and Ea = systolic blood pressure/(maximal left ventricular volume – minimal left ventricular volume). Ea/Ees and SW/PVA were then calculated. Left ventricular volume was normalized with body surface area. Ees increased after the Bentall operation and around 1 year later (from 2.17 ± 1.09 to 3.92 ± 2.26 and 5.33 ± 1.90 mmHg·m²/ml, P < 0.001), thus resulting in an improvement in SW/PVA (from 68.8 ± 8.2 to 70.9 ± 9.5 and 74.7 ± 5.2%, P = 0.045). Ea also increased after the Bentall operation and 1 year later (from 1.77 ± 0.61 to 2.88 ± 1.28 and 3.54 ± 1.43 mmHg·m²/ml, P < 0.001). The mid-term results for ventricular contractility and efficiency after the Bentall operation for annuloaortic ectasia with aortic regurgitation are excellent and satisfactory.

Key words Aortic root · Aortic surgery · Aortic valve replacement · Cardiac function

Introduction

Aortic root replacement (Bentall operation) is the standard operation for patients who have lesions of the ascending aorta and aortic root associated with aortic valve disease. In this procedure, the aortic valve and the ascending aorta are replaced as an en bloc with a composite prosthesis containing a mechanical cardiac valve enclosed within a slightly larger tubular graft, involving coronary ostial anastomoses. Several modifications have been reported due to the complication and difficulty of this procedure. Recently, post-operative mortality and morbidity are low because of the evolving modifications in surgical techniques and improvement in the materials of prosthesis grafts and valves. However, a few reports have referred to ventricular performance after the Bentall operation due to the difficulty and complexity of the analysis.

The concept of end-systolic elastance (Ees), effective arterial elastance (Ea), and ventriculoarterial coupling (Ea/Ees) provides a useful framework for analyzing the interplay between contractility and afterload. We previously reported the approximation of Ees, Ea, and Ea/Ees using a canine right-heart bypass preparation with a conductance catheter in the left ventricular (LV) cavity, and then analyzed the cardiac performance of Fontan candidates and patients with postinfarction dyskinetic anterior left ventricular aneurysms who underwent the Dor procedure. The Bentall operation is one of the treatments of choice for annuloaortic ectasia (AAE) with aortic regurgitation (AR). Using the approximation of Ees, Ea, and Ea/Ees, we analyzed left ventricular energetics before and after the Bentall operation in patients with AAE with AR based on the transthoracic cardiac echocardiography data in the present study. The purpose of this study was to quantify the ventricular performance before and after the Bentall operation from the concept of Ees and Ea.
Materials and methods

Patient information

From 1991 to 2005, 29 consecutive patients underwent the Bentall operation at Kyushu University Hospital, and no patient died in hospital. Fifteen patients with AAE with AR, consisting of 12 men and 3 women, were retrospectively selected for this study. Fourteen patients were excluded from this study as emergency cases, aortic dissection cases, and/or total arch replacement cases. The mean age of the studied patients was 54.1 ± 13.1 years (range 22–73 years) and the mean weight was 61.2 ± 9.8 kg (range 45–77 kg). The grade of AR was moderate in 1 patient and severe in 14 patients. The New York Heart Association functional grade was I in 4 patients, II in 10 patients, and III in 1 patient. Informed consent of operation was obtained from all patients.

Operative techniques

The replacement of the aortic valve and ascending aorta as an en bloc was performed with a composite prosthesis valve conduit. CarboMedics mechanical valves (CarboMedics, Inc, Austin, TX, USA) were used as an aortic prosthesis valve, and 21-mm valves were used in 2 patients, 23-mm in 7, 25-mm in 2, and 27-mm in 4. Hemashield grafts (Meadow Medicals, Oakland, NJ, USA) were used in 10 patients, Gelseal grafts (Sulzer Vascutek, Renfrewshire, Scotland, UK) in 2, and DeBakey Dacron grafts (USCI, a division of C. R. Bard, Inc, Billerica, MA, USA) in 3 as a prosthesis graft. Coronary ostial anastomosis was carried out according to the button technique in all patients. Myocardial preservation was achieved by cold crystalloid cardioplegic solution14 and ice slush.

Data analysis

All patients underwent transthoracic cardiac echocardiography both before and approximately 2–3 weeks after the operation in hospital, and around 1 year after leaving hospital except two patients. These two patients underwent transthoracic cardiac echocardiography 3 years after operation. The LV volume was calculated by the Teichholz M-mode method based on the data of cardiac echocardiography.15 The arterial blood pressure was measured with the M-mode method based on the data of cardiac echocardiography. The LV volume was calculated by the Teichholz transthoracic cardiac echocardiography 3 years after operation are shown in Table 1. The analyzed data are from all patients.

Statistical analysis

The results are presented as mean ± SD. Analysis of variance with repeated measures (RM-ANOVA) on one factor was used for the variables measured at three points (before and after operation, and 1 year after operation). The Student–Newman–Keuls test was used as a post hoc test.

Results

Operative results

The mean cardiopulmonary bypass time was 217 ± 61 min (range 154–388 min) while the mean aortic cross-clamp time was 152 ± 38 min (range 114–245 min). There were no hospital deaths.

Analyzed results

Conventional hemodynamic variables before and after operation are shown in Table 1. The analyzed data are shown in Figs. 1 and 2. EDVI and ESVI decreased after the Bentall operation and around 1 year later (from 200.2 ± 64.4 to 122.6 ± 52.0 and 103.0 ± 35.4 ml/m², Fig. 1A, P < 0.001 by RM-ANOVA; from 73.2 ± 34.1 to 47.4 ± 29.6 and 33.6 ± 14.9 ml/m², Fig. 1B, P < 0.001 by RM-ANOVA, respectively). EF did not change remarkably after the Bentall operation and 1 year later (from 64.3 ± 8.0 to 63.3 ± 10.2 and 67.6 ± 6.2%, Fig. 1C, P = 0.18 by RM-ANOVA). Ees increased after the Bentall operation and 1 year later (from 2.17 ± 1.09 to 3.92 ± 2.26 and 5.33 ± 1.90 mmHg·m²/ml, Fig. 2A, P < 0.001 by RM-ANOVA), thus resulting in an improvement in SW/PVA (from 68.8% ± 8.2% to 70.9% ± 9.5% and 74.7% ± 5.2%, Fig. 2D, P = 0.045 by RM-