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Left ventricular volume reduction surgery

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Abstract

Left ventricular volume reduction has recently been introduced as a surgical treatment for end stage dilated cardiomyopathy. This operation involves the resection of a slice of viable left ventricular myocardium in order to reduce the wall tension imposed upon the contracting heart chamber. Early results are encouraging, but clinical evaluation on a larger scale is required. In the present article, we describe the indications, surgical principles and results of left ventricular volume reduction surgery with reference to our group's experience. © 1997 Elsevier Science Ireland Ltd.

1. Introduction

An alternative surgical procedure for the treatment of end stage dilated cardiomyopathy called left ventricular volume reduction has been proposed by Batista [1]. This technique involves resection of a portion of viable left ventricular contractile muscle in order to reduce the diameter of the chamber and thereby restore the volume/mass/diameter relationship. Important questions such as patient selection, surgical technique, post-operative management and operative mortality remain unanswered. Nevertheless, a number of surgeons from major institutions both in Europe and North America are showing interest in this procedure, motivated by the apparent benefits suggested by the results from Brazil, albeit unpublished, and by the limitations of current surgical options for patients with end stage heart failure. In an attempt to increase the awareness of this operation, the present article will discuss the preparation, surgical principles and post-operative management of

patients undergoing left ventricular volume reduction in our institution.

2. Hypothetical basis

Dilated cardiomyopathy is associated with an increase in left ventricular cavity dimensions, leading to a disproportionate increase in wall tension according to the law of Laplace:

$$\text{Pressure} = \frac{2 \times \text{Wall Tension}}{\text{Radius}}$$

The theoretical foundation of left ventricular remodelling has been based upon observations by Dr. Batista in the hearts of animals of different sizes who all appear to have a constant muscle mass ratio that maintains normal cardiac function ($M=4.18 R^3$ where M is the muscle mass and R the heart radius). Any increase in cardiac radius is suggested to require an increase in muscle mass by a power factor of 3 to maintain this ratio. By removing a slice of the wall of a dilated left ventricle and remodelling it, the dis-

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turbed mass/volume ratio of the diseased myocardium may be re-established. Data from sheep studies where ventricular dysfunction is artificially created by insertion of a pericardial patch to increase left ventricular dimension, followed by subsequent removal and restoration of function lends some support to these hypotheses [1].

3. Indications and patient selection

Despite dramatic improvements in the pharmacological treatment of heart failure, the prognosis for the most severely affected patients remains poor, with as many as 50% dying within 3 years. Cardiac transplantation is currently the only treatment of proven benefit. However, this procedure can only be performed on a small proportion of patients with end stage heart failure and limitations in the donor pool prolong the waiting time for surgery once acceptance into a transplant program has been established [2]. Left ventricular volume reduction may be suitable for patients who are too old to be considered for transplantation, or in younger patients in whom heart transplant surgery is contraindicated. Some institutions are also selecting patients as a bridge to transplantation on the basis that if the operation is unsuccessful, transplantation may still be an option.

In Batista's experience of over 300 cases, the etiology of cardiomyopathy has included Chagas' disease (18%), idiopathic dilated cardiomyopathy (30%), valvular disease (30%) and others (22%). These predisposing factors are very different to those seen in developed countries where ischemic cardiomyopathy is predominant. Patients undergoing salvage rather than elective procedures may also do badly, and the presence of concomitant diseases, such as renal and hepatic failure, which is not uncommon in patients with dilated cardiomyopathy, may be contraindications to surgery.

Patients with left ventricular end diastolic diameter <7 cm are unlikely to benefit from volume reduction.

4. Preoperative investigations

Routine investigations such as full blood count,

urea and electrolytes, liver function tests, chest radiography and electrocardiography are performed to assess the general state of the patient. Direct coronary angiography is undertaken to evaluate the need for concomitant coronary artery bypass grafting and magnetic resonance imaging (MRI) is used to document both the size and thickness of the left ventricle. The importance of these measurements have already been mentioned above. Transthoracic echocardiography can be performed to document the inter-papillary distance but this is difficult, even for the experienced operator. Nevertheless, the measure does give a useful indication as to whether intra-papillary or extra-papillary resection will be required (see below).

5. Surgical technique

Following careful induction of anesthesia, monitoring with intra-pulmonary balloon catheterization is undertaken for continuous measurement of mixed venous oxygen saturation, cardiac output and index and systemic vascular resistance. A transesophageal echocardiography probe is positioned for hemodynamic assessment of ventricular and valvular function at various stages during the operation. Intra-aortic balloon pump (IABP) insertion is carried out prior to sternotomy, to provide assistance during the critical period prior to institution of cardiopulmonary bypass and in the early post-operative period. Following sternotomy, initial heparinisation is accomplished with 3 mg/kg body weight of heparin and supplemented as needed to maintain an activated clotting time of 480 s. Preparation for cardiopulmonary bypass (CPB) consists of ascending aortic and bicaval venous cannulation via the right atrial appendage. A standard CPB circuit is used including PVC tubing (Sorin Biomedica, Midhurst, UK), a Cobe roller pump (Cobe, Lakewood, CO, USA), hollow fibre membrane oxygenator (Monolyth, Sorin Biomedica Cardio, Saluggia, Italy), and a 40- μ m arterial line filter (Sorin Linea ABF 40). The extracorporeal circuit is primed with 1000 ml Hartmann's solution, 500 ml Gelofusine (Braun, Emmenbrücke, Switzerland), 60 mg of heparin and 0.5 g/kg of mannitol. Before CPB is commenced valvular dysfunction is

assessed by TOE. CPB is then commenced and the systemic perfusion temperature is reduced to 33°C (flow-rate 2.0 l/m²/min with a perfusion pressure maintained at 50–60 mm Hg). A left ventricular vent is then placed via the left atrial appendage or a pulmonary vein.

If significant tricuspid regurgitation was present on

the TOE, a modified DeVega annuloplasty is performed on the beating heart. Interrupted sutures are used and tied after each one is positioned.

If the tricuspid valve is normal, the aorta is cross clamped and the heart is arrested using intermittent antegrade warm cold blood cardioplegia.

Ventricular remodelling can take two forms de-

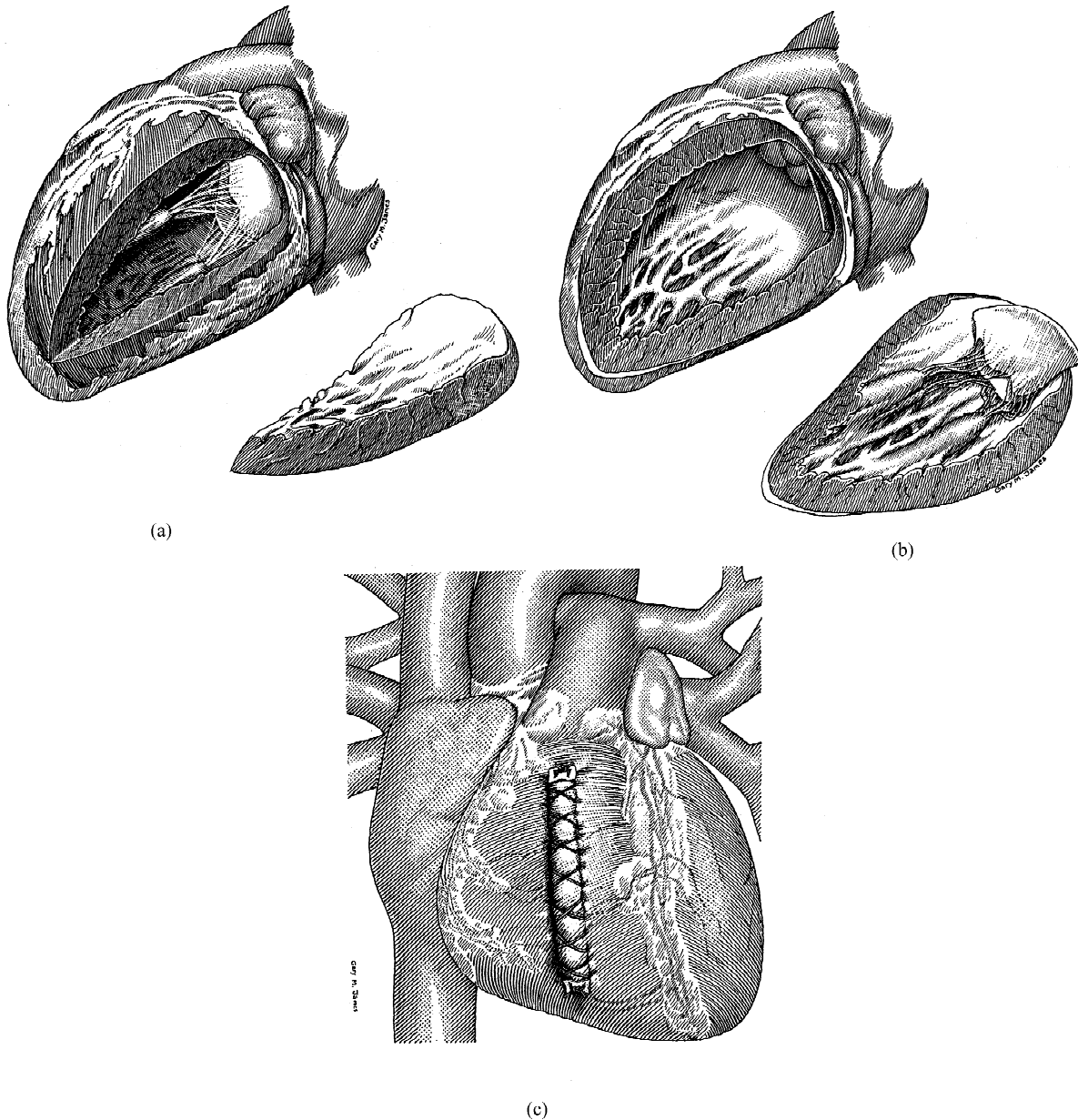


Fig. 1. (a) Posterior view of the heart showing the typical segment of left ventricular free wall removed at operation (inter-papillary resection); (b) In some cases to achieve a satisfactory reduction in volume the segment resected includes the papillary muscles and mitral valve (extra-papillary resection). Prosthetic valve replacement of the mitral valve then precedes reconstruction of the left ventricular free wall; (c) Plication of right ventricle.

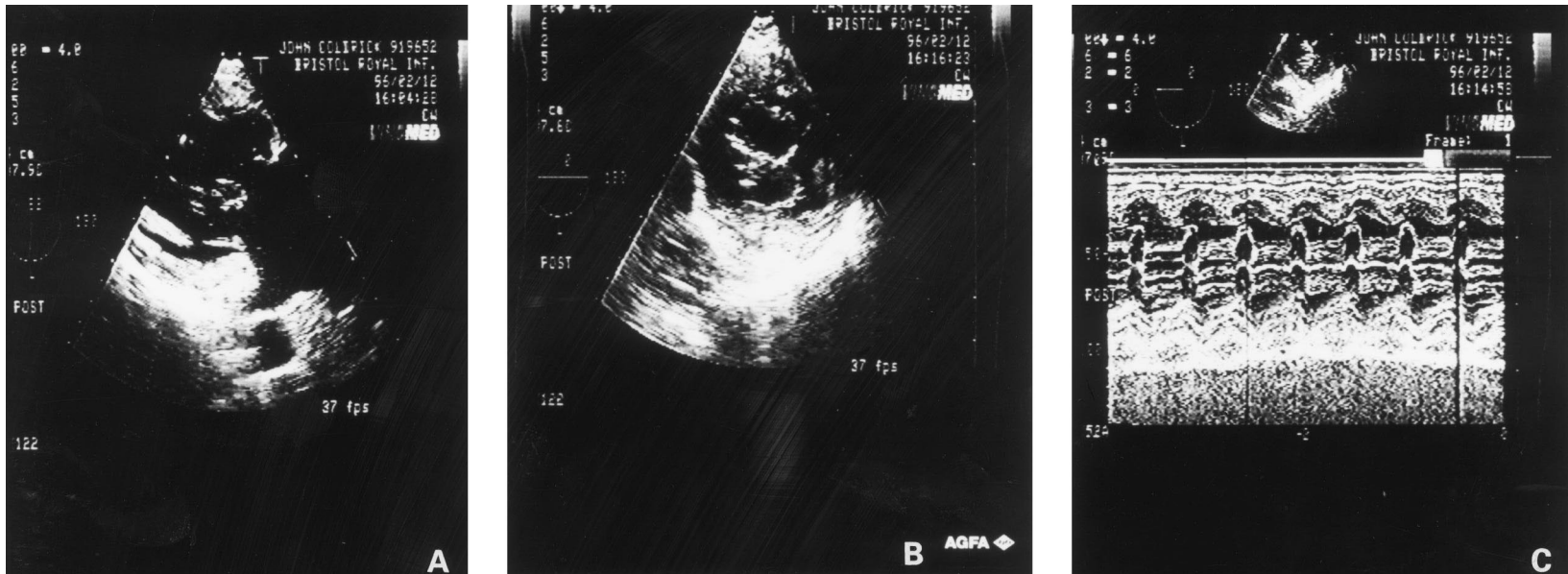


Fig. 2. (a) Long axis view showing two orifices; (b) Short axis view of the same structures; (c) M-mode imaging from the same portion showing two separate 'mitral' traces.

pending upon the amount of ventricle that needs to be excised. During intrapapillary resection (Fig. 1a) a ventricular incision is made extending from the apex to the mitral valve annulus and viable myocardium between the anterior and posterior papillary muscles is excised. If the intra-operative TOE demonstrated central functional mitral regurgitation, usually due to annular dilatation, then repair using the Alfieri Kissling [3] stitch is performed from the ventricular side. This converts the incompetent mitral valve orifice into a figure of eight opening (Fig. 2). Extra-papillary resection (Fig. 1b) is a more extensive procedure which is undertaken when excision of a larger slice of the left ventricle is required and involves removal of the mitral valve and both papillary muscles. The mitral valve is then replaced with a mechanical or tissue valve prosthesis through the ventriculotomy. The free wall of the ventricle is then closed in a linear fashion using a full thickness 0-ethibond suture on a 4-cm needle with teflon strips and Glubran glue (GEM, Viareggio, Italy) for added reinforcement. Simple linear closure, as performed by Batista, was associated with suture line dehiscence in one patient in our early experience and this technique is no longer favoured. In patients with right ventricular failure, plication of the right ventricle can be performed starting at the acute margin and extending towards the pulmonary outflow tract (Fig. 1c). Any other associated procedures are then undertaken (e.g. coronary artery bypass grafting, aortic valve replacement etc.) and when completed, terminal blood cardioplegia hot shot is administered, the heart is de-aired and the cross clamp is removed. At this stage a second ventricular suture line using 3-0-prolene on a 5-cm needle is performed. Atrial and ventricular pacing wires are placed directly onto the heart and sequential pacing at 80–100 beats/min is routinely performed along with balloon counterpulsation prior to weaning from CPB. At this stage, intra-operative TOE is used to reassess the size and function of the remodelled left ventricle. A ventricular diameter of <6 cm during diastole is desirable and we have revised intra-papillary resection for a more extensive extra-papillary procedure in patients because of inadequate reduction in ventricular dimensions. If TOE is satisfactory, the sternum is closed after placing chest drains as appropriate.

6. Post-operative management

In order to prevent disruption of the ventriculotomy and at the same time, maintain good myocardial function, a combination of enoximone and noradrenaline are used to maintain a systolic pressure of 90–110 mm Hg with a systemic vascular resistance of 600–800 dyne·s·cm⁻⁵. IABP counterpulsation is continued, amiodarone is administered intravenously, for anti-arrhythmia prophylaxis and heart rate is maintained at 80–100 beats/min using sequential atrioventricular pacing as necessary. Once hemodynamic stability has been established and chest drain loss is <100 ml/h, sedation is weaned and the patient is allowed to wake up. Early extubation is desirable and is performed when the patient has adequately rewarmed and is well oxygenated (e.g. arterial oxygen tension greater than 80 mm Hg on an FiO₂ of 60%).

There is often a transient decline in myocardial function 24 h post-operatively and for this reason, hemodynamic support is continued for at least 48 h. Patients with dilated cardiomyopathy also have varying degrees of multi-organ dysfunction and aggressive support of these systems is critical to satisfactory outcome.

If renal function is not impaired, an angiotensin converting enzyme inhibitor is commenced once IABP counterpulsation and inotropic support has been discontinued. Oral diuretic therapy is often necessary and consists of a combination of Spironolactone and Frusemide. Repeat transthoracic echocardiography to reassess left ventricular function and 24-h continuous ambulatory electrocardiography to exclude the presence of malignant ventricular arrhythmia's are performed on day 5.

7. Results

Dr. Batista has now performed left ventricular volume reduction in more than 500 patients with dilated cardiomyopathy all of whom were in pre-operative New York Heart Association (NYHA) class III and IV (personal communication). In his experience, 80% of survivors were considered to be in NYHA class I or II post-operatively. The main

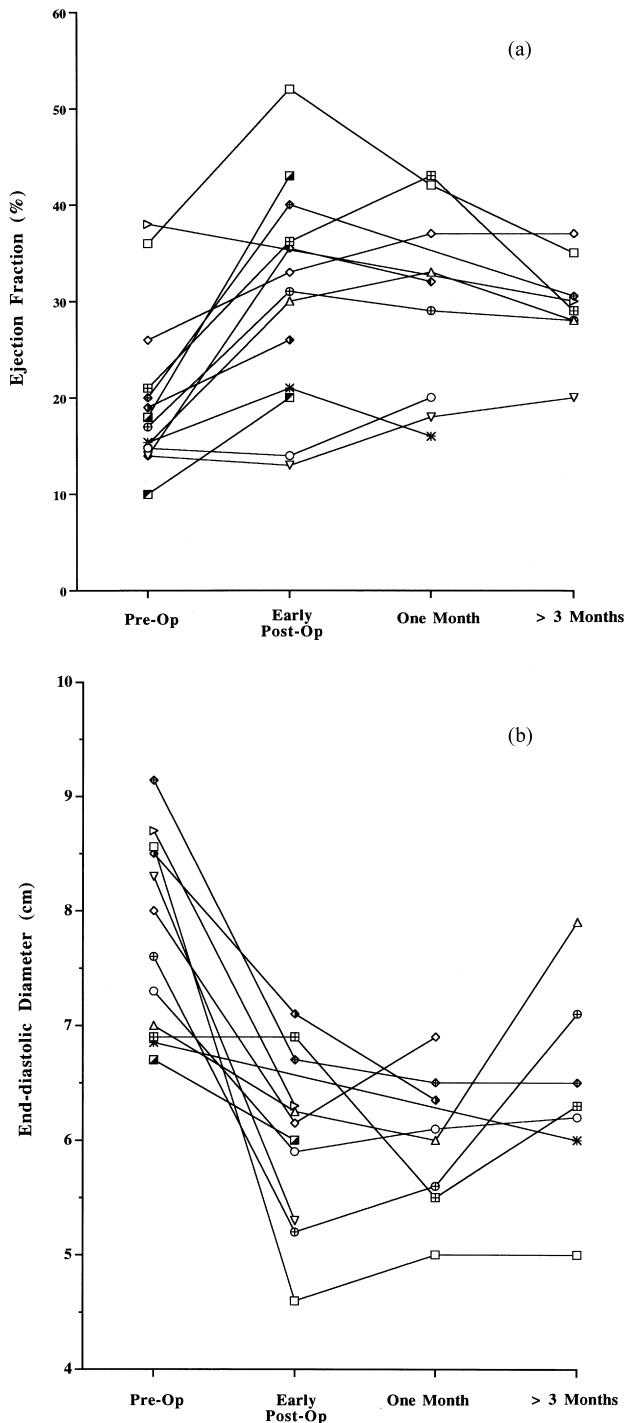


Fig. 3. (a) Transthoracic echocardiography assessment of ejection fraction; (b) Transthoracic echocardiography assessment of left ventricular end diastolic diameter.

problem at present is the high hospital mortality of 15–20%. It should also be recognized that the results from Brazil remain unpublished to date. Early results from the Cleveland Clinic Foundation researchers (OH, USA) in 32 patients was presented at the American College of Cardiology meeting in Anaheim, CA, USA [4]. All had dilated cardiomyopathy with left ventricular diameters of >7 cm in NYHA class III ($n=16$) and class IV ($n=16$) and were candidates for transplantation. No operative deaths were reported and following removal of between 30–220 g of viable muscle (mean 90 g), ejection fraction increased from 15% preoperatively to 34%. Five patients required left ventricular assistance and subsequent heart transplantation. In the remaining 27 patients, 75% are in functional class I or II. Our group has recently reported the results of left ventricular reduction in 14 patients [5]. In contrast to the Cleveland Clinic series, the aetiology of heart failure was not exclusively idiopathic, age was not a contraindication (mean age 65 versus 50 years in the Cleveland Clinic series) and 13 of the candidates were unsuitable for heart transplantation. In-hospital mortality was 21% ($n=3$, of which two deaths occurred in the first four procedures performed), and one patient died within 3 months of surgery. Cardiac index improved significantly from 1.9 ± 0.4 l preoperatively, to 2.27 ± 0.61 post-operatively. Of the survivors, nine patients were in NYHA class I or II and one was in class III at a mean follow-up of 6 months (range 1–20 months). Haemodynamic data was also encouraging with sustained improvements in ejection fraction (Fig. 3a) and end-diastolic diameter (Fig. 3b) at follow up.

8. Summary

Left ventricular volume reduction is technically feasible and with greater experience and appropriate patient selection the hospital mortality can be reduced. The early results from the Cleveland Clinic and our group cannot be dismissed and further evaluation of this procedure is now mandatory. ‘A consensus conference bringing together heart failure physicians and surgeons for the purposes of unifying protocols’ [6] is welcomed.

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