Current perspectives of partial left ventriculectomy in the treatment of dilated cardiomyopathy

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Received 14 July 2000; received in revised form 3 November 2000; accepted 4 November 2000

Abstract

Objectives: Partial left ventriculectomy has been performed as an alternative to heart transplantation in the treatment of severe cardiomyopathies. This investigation documents the clinical and left ventricular (LV) function effects of this procedure, associated, when necessary, with mitral insufficiency correction, in 43 patients with idiopathic dilated cardiomyopathy. Methods: Eighteen patients were in New York Heart Association class III and 25 in class IV. Seven of them were operated in cardiogenic shock. The procedure was associated with mitral annuloplasty in 32 patients and mitral replacement in three. Results: Nine patients (20.9%) died during the hospital period and the cause of death was associated with ventricular failure in seven patients. The other patients were followed up from 2 to 57 months (mean, 28.3 months). At 6 months of follow-up, eight patients were in functional class I, 13 in class II, three in class III and one patient was in class IV ($P<0.001$). On the other hand, nine patients died during the first 6 months and another six in the later postoperative period. The cause of late death was progressive heart failure in eight patients, and seven patients died because of arrhythmia related events. The actuarial survival was $58.1 \pm 7.5\%$ at 1 year and $43.9 \pm 8.1\%$ at 4 years of follow-up. Regarding ventricular function modifications, the LV diastolic volume decreased by around 25% and the LV ejection fraction increased from $17.8 \pm 4.7$ to $22.3 \pm 7.9\%$ ($P<0.001$), whereas significant changes in the cardiac index, stroke index and pulmonary pressures were also found 1 month after the operation. In the later follow-up, despite the maintenance of hemodynamic improvement, the LV diastolic volume tended to increase and returned to preoperative levels at 4 years, while a concomitant decrease in the LV ejection fraction was also observed. Conclusion: Partial left ventriculectomy associated with mitral insufficiency correction improves LV function and ameliorates congestive heart failure in patients with idiopathic cardiomyopathy. Otherwise, the LV function benefits seem to be restricted by the possibility of progressive LV redilatation. Furthermore, the clinical application of this procedure is limited by the high mortality observed in the first postoperative months and by the possibility of heart failure progression and arrhythmia related events at late follow-up. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Heart failure; Dilated cardiomyopathy; Ventricular remodeling; Ventricular volume reduction

1. Introduction

Since its first clinical application by Batista et al. [1] in 1994, partial left ventriculectomy has been performed worldwide by several authors as an alternative to heart transplantation in the treatment of patients with severe dilated cardiomyopathies. The improvement of left ventricular (LV) function and reversion of congestive heart failure have been demonstrated after this surgical procedure [2–8]. Nevertheless, high incidences of heart failure progression and arrhythmia related deaths have been reported in the early postoperative period in most of the clinical series [2–5,8–11]. Furthermore, the absence of previous studies about the long-term clinical outcome and late modifications of LV function after partial ventriculectomy has precluded definitive conclusions about its value.

The purpose of this report is to document the clinical and LV function effects of partial left ventriculectomy, associated, when necessary, with mitral insufficiency correction, for up to 4 years of follow-up in patients with advanced heart failure caused by idiopathic dilated cardiomyopathy.

2. Patients and methods

2.1. Study population

Partial left ventriculectomy was indicated by the Heart
Failure and Heart Transplantation Program of the Heart Institute, University of São Paulo Medical School, for patients at high risk of dying due to severe dilated cardiomyopathies and significant functional limitation despite attempts to optimize medical therapy with maximal doses of diuretics and angiotensin converting enzyme inhibitors or vasodilators. They also had reduced LV function characterized by a radioisotopic ejection fraction of less than 25% and persistently high filling pressures. Medical or psycho-social contraindications to heart transplantation were present or this procedure was refused by the patients, and they signed a special informed consent form according to our Ethical and Scientific Review Board.

Accordingly, partial left ventriculectomy was performed in 43 patients with idiopathic dilated cardiomyopathy between April 1995 and March 1999. Eighteen patients were in New York Heart Association (NYHA) class III and 25 were in persistent class IV. Fourteen of these patients also had reversible cardiogenic shock under the use of intravenous inotropic drugs. The mean duration of symptoms was 3.7 years and patients had at least two hospitalizations for heart failure treatment in the year preceding the operation. The patients’ ages ranged from 28 to 72 years (mean, 45.5 years), and 36 patients were male.

Preoperative LV ejection fractions documented by radioisotopic angiography ranged from 9 to 25% (mean, 16.6%). Patients also presented a mean LV end-diastolic pressure of 24.9 ± 9.2 mmHg and a mean cardiac index of 2.12 ± 0.46 l/min per m² at heart catheterization. An absence of significant coronary artery compromise was shown in every patient. Mitral valve insufficiency was present in 35 patients, being severe in four, moderated in 13 and mild in 18 patients. Significant tricuspid valve insufficiency was observed in 11 patients, being moderated in seven and severe in four patients.

2.2. Surgical procedure

Partial left ventriculectomy was performed as an isolated procedure or associated with atrioventricular valve annuloplasty or replacement. The procedures were done under standard cardiopulmonary bypass. The first 34 patients were operated in normothermia and on the beating heart. In the last nine patients, the procedures were performed under hypothermic myocardial arrest induced by the use of cold blood cardioplegia.

LV volume reduction was performed according to the technique described by Batista et al. [1]. As large a slice as possible of the ventricular myocardium was resected between the papillary muscles, from the apex of the heart up to 2 or 3 cm from the mitral annulus. The left ventricle was then repaired with a double 3-0 polypropylene suture anchored in bovine pericardium strips.

Mitral valve annuloplasty was done in the presence of any degree of mitral regurgitation. The mitral valve was assessed through the left atrium and the mitral annulus was reduced by plication of the posterior leaflet region with sutures anchored in a bovine pericardium strip. In patients with malposition of the papillary muscles, precluding an effective myocardial resection, these muscles were resected and the mitral valve was replaced by a bovine pericardium bioprosthesis. The De Vega tricuspid annuloplasty was performed in patients with moderate to severe tricuspid regurgitation. Endocardial automatic cardioverter-defibrillators were implanted in patients who presented with episodes of sustained ventricular tachycardia or ventricular fibrillation before the operation or at the immediate postoperative period.

2.3. Follow-up protocol

The patients were studied at the first postoperative month and at every 6 months of follow-up by means of radioisotopic angiography and right heart catheterization. They continue to use diuretics and angiotensin converting enzyme inhibitors or vasodilators. Amiodarone was routinely used at the first 2 weeks of follow-up and in patients who presented with episodes of sustained ventricular tachycardia or atrial fibrillation.

LV radioisotopic angiography was obtained after in vivo labeling of red blood cells by Tc99mTechnetium. Gated blood pool imaging was acquired in the left anterior oblique view with a Siemens model LEM+ camera (Siemens Corp., Union, USA). The images were analyzed in a Microvax model 3300 computer (Siemens), and the LV volumes and ejection fractions were calculated. Right heart catheterization was performed with a thermodilution balloon-tipped catheter positioned in the left pulmonary artery.

2.4. Statistical analysis

The cumulative mortality and event rates over time were determined by the Kaplan–Meier method, and the differences between them were assessed by the log-rank test. Repeated measures analysis of variance and the Dunnet’s test were used to compare data obtained before and after the operation. The data are presented as means ± SD, whereas the survival rates are presented as means ± SEM.

3. Results

3.1. Clinical outcome

Partial left ventriculectomy was performed as an isolated procedure in eight patients. It was associated with mitral annuloplasty in 32 patients and with mitral replacement in three. Ten of those patients who underwent the mitral valve operation were also submitted to De Vega tricuspid valve annuloplasty. The resected myocardial specimen measured 10.9 ± 1.7 cm in length and 5.1 ± 0.9 cm in width.

There were no intraoperative deaths, but nine patients (20.9%) died during the hospital period. The causes of
death were: cardiogenic shock in four patients; cardiogenic shock associated with septicemia in one patient; biventricular failure in one patient maintained under LV circulatory support with a centrifugal pump; multiple organ failure in one patient submitted to pulsatile LV assist device implantation; incessant sustained ventricular tachycardia in one patient; and bleeding associated with disseminated intravascular coagulation in one patient. This mortality was similar when the operations were performed under hypothermic cardioplegic arrest (22.2%) or on the beating heart (20.5%).

Episodes of sustained ventricular tachycardia occurred in nine patients (20.9%) at the first 2 weeks of follow-up. Five of these patients were submitted to automatic cardioverter-defibrillator implantation before hospital discharge and this procedure was prophylactically performed on seven other patients.

The 34 patients discharged from the hospital were followed up from 2 to 57 months (mean, 28.3 ± 20.2 months), representing 80.1 patient-years. During this follow-up period, another 15 patients died. Nine of these deaths occurred in the first 6 months and the other six in the later postoperative period. The actuarial survival curve presented in Fig. 1 shows survivals of 58.1 ± 7.5% at 6 months and at 1 year, 50.5 ± 7.7% at 2 years, 47.9 ± 7.8% at 3 years, and 43.9 ± 8.1% at 4 years of follow-up.

The cause of late death was progressive heart failure in eight patients, and seven patients died suddenly or because of incessant ventricular tachycardia. Accordingly, progressive heart failure leading to death presented an incidence of 29.6 ± 7.2% in the first 6 months of follow-up, while the incidence of arrhythmia related deaths was 14 ± 5.8% in the same period. In the later follow-up, the prevalence of cardiogenic shock due to heart failure progression and of sudden cardiac death were 3.2 and 3.9%/year, respectively (Fig. 2).

On the other hand, the NYHA functional class improved at 6 months of follow-up from 3.6 ± 0.5 to 1.8 ± 0.7 in the 26 patients who completed that period (P < 0.001). Seven of the surviving patients are currently in functional class I, eight in class II, and two in class III, some of them using fewer drugs or lower doses than they did in the preoperative period.

Apart from this fact, however, urgent heart transplantation had to be performed in one patient at 7 months of follow-up because of heart failure progression. Furthermore, three patients who had automatic cardioverter-defibrillators presented episodes of sustained ventricular tachycardia reverted by appropriated shocks at 30, 33 and 40 months of follow-up, respectively.

Despite the absence of a significant impact of automatic cardioverter-defibrillator implantation on patients’ long-term survival, arrhythmia related deaths did not occur in patients that were submitted to this procedure. On the other hand, seven out of the 24 patients who did not undergo defibrillator implantation died suddenly after hospital discharge, which represents an incidence of this event of 14.8%/year.

Fig. 3 shows the actuarial survival according to LV myocytes hypertrophy, a factor that was previously identified as the unique predictor of early mortality after partial left ventriculectomy in this patient-population. In those
patients with mean myocyte diameters of greater than 22 μm, the actuarial freedom from failure was only 25.7 ± 10.9% at 4 years of follow-up, while patients without important myocyte hypertrophy presented a survival rate of 57.9 ± 11.3% without the necessity of transplantation in the same period (P = 0.034). Regarding the preoperative NYHA functional class, deaths during the hospital period occurred in 16.6 and 24% of the patients operated in class III or IV, respectively. The actuarial survival of class III patients was 58.3 ± 12.4% at 4 years of follow-up, while the survival of patients operated in functional class IV was 34.3 ± 9.8% in the same period (P = 0.052).

3.2. Ventricular function data

The data obtained by radioisotopic angiography are depicted in Table 1. The LV ejection fraction improved early after partial ventriculectomy from 16.8 ± 4.7 to 23.9 ± 8.2% (P < 0.01), and its values tended to be maintained at around 21% up to 4 years of follow-up. On the other hand, the significant decrease in LV diastolic volume documented immediately after the operation was maintained only during the first postoperative year. After that period, this parameter tended to increase and returned to preoperative levels at 3 years of follow-up.

The hemodynamic evaluation showed that significant improvements in the stroke index, cardiac index and arterial pressure were associated with significant decreases in pulmonary artery pressure and pulmonary wedge pressure immediately after the partial left ventriculectomy (Table 2). In the later postoperative period, despite the maintenance of significant positive modifications of the cardiac index, stroke index and arterial pressure, pulmonary pressures tended to increase, but without achieving the preoperative levels.

4. Discussion

The primary objective of partial left ventriculectomy is to decrease LV wall tension by the reduction of the chamber volume/mass relationship, resulting in partial restoration of myocardial contractility and slow progression of the underlying disease. This concept has been evaluated by several authors, and currently, there is significant evidence that partial ventriculectomy really decreases LV systolic and diastolic wall stresses [12,13]. These changes seem to be associated with the improvement of the contractile characteristics of the failing myocardium, as demonstrated by the increase of maximal elastance and other systolic indices in studies using pressure–volume loops [12,14,15]. Furthermore, although in theory, the reduction of LV volume could result in a secondary impairment of diastolic function [16], some studies have additionally shown significant decreases in end-diastolic pressure and in stress–strain loops immediately after the operation [12,13].

Accordingly, an improvement of the LV ejection fraction has been demonstrated in the overall clinical experience with partial left ventriculectomy [4,5,7,8,10]. Despite the fact that this modification also occurs based on geometric rearrangement, hemodynamic benefits have been reported after the procedure as well. More precisely, significant increments in stroke volume and cardiac output were demonstrated in the presence of decreased pulmonary pressures [4,5,8]. Although this operation was associated with different procedures and performed in patients with different heart failure etiologies in some studies, hemodynamic changes were detected in series which included only patients with dilated cardiomyopathy, as in the present experience [4,5,8]. In these patients, partial left ventriculectomy has been normally associated with mitral insufficiency correction, but similar modifications in LV function were documented whether or not this association occurs [8].

Nevertheless, improvement of LV function after partial ventriculectomy does not occur in every patient, and immediate and early mortalities after the procedure have been high. This fact has been regularly observed worldwide, being responsible for a procedure failure rate, defined as death or the necessity of urgent heart transplantation, varying by around 40% during the first postoperative year [2,3,5,8–11,17].

The early deaths in partial left ventriculectomy follow-up occur especially due to LV failure or arrhythmia related events [2,3,5,8–11,17]. Acute LV failure and early progression of the underlying disease are probably related to an absence of myocardial contractility improvement in response to LV volume reduction, as suggested by previous reports [8,9]. This fact was advised by theoretical studies [16] and seems to be related to the condition of the myocardial cells [18]. Compensatory mechanisms of heart failure in patients with severe cardiomyopathies can cause irreversi-

### Table 1

<table>
<thead>
<tr>
<th>Radioisotopic angiography data(^a)</th>
<th>Preoperative</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 month (n = 28)</td>
<td>6 months (n = 21)</td>
</tr>
<tr>
<td>LVDV (ml)</td>
<td>567 ± 187</td>
<td>438 ± 140(^b)</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>16.8 ± 4.7</td>
<td>23.9 ± 8.2(^b)</td>
</tr>
</tbody>
</table>

\(^a\) LVDV, left ventricular diastolic volume; LVEF, left ventricular ejection fraction. Numbers in parentheses indicate the patients evaluated at each time.

\(^b\) P < 0.05 in relation to preoperative data of matched patients.
ble structural remodeling of the heart because of slippage and elongation of myocardial fibers.

The elevated incidence of ventricular arrhythmias early after partial left ventriculectomy seems otherwise to involve mechanisms related to the procedure itself. The existence of areas of fibrosis and myocardial infarction around the ventricular scar may modify the electrophysiological substrate, leading to ventricular arrhythmias in dilated cardiomyopathy patients, perhaps by new re-entrant pathways. In this regard, the relationship observed between the high incidence of ventricular arrhythmias and the existence of bilateral papillary muscle infarction in necropsy specimens of the present population is of great importance [19]. Based on this finding, the performance of partial left ventriculectomy without an aggressive resection close to the mitral annulus can contribute towards decreasing cardiac rhythm complications.

Regarding the influence of partial left ventriculectomy on the underlying cardiomyopathy progression, the maintenance of clinical and LV function improvements for up to 4 years after the procedure in this study is very encouraging. Other published results about this procedure mainly include follow-up data up to 1 year and have documented a relative stability of patients who survived the first postoperative months, advising similar long-term results [4,5,17]. Nevertheless, LV redilatation was documented after the first year of follow-up in the present series, suggesting that partial left ventriculectomy benefits in patients with idiopathic dilated cardiomyopathy may be limited to a period of a few years.

On the other hand, the observation that the incidence of arrhythmia related events continue to be high at the late partial left ventriculectomy follow-up clearly shows that this procedure does not decrease the occurrence of this event in patients with dilated cardiomyopathy. The same fact was previously observed with the use of other palliative surgical procedures in the treatment of heart failure, such as dynamic cardiomyoplasty [20]. In this regard, the use of automatic implantable cardioverter-defibrillators has been proposed for patients who present with episodes of sustained ventricular tachycardia after partial left ventriculectomy because of the important decrease in arrhythmia related deaths observed with this approach. However, the routine use of these devices for every patient submitted to this procedure is still controversial, as also observed for patients in heart transplantation waiting lists [21].

In this scenario, only the identification of proper patient selection criteria for partial left ventriculectomy could place this procedure as a real alternative in the spectrum of the surgical treatment of heart failure. The factors currently identified as associated with an unfavorable outcome in the first postoperative months are related to the patient’s clinical condition prior to operation [2,17] and to the intrinsic compromise of the myocardial fibers [18,22,23]. The influence of the severity of myocardial cell damage on partial left ventriculectomy results was first identified by our group [18] and was recently confirmed by other authors [22]. This finding may really contribute towards improving the outcome of this procedure, as suggested by the observation that patients operated with a mean diameter of LV myocardial cells of less than 22 μm in this series had a survival of 57.9% without the necessity of urgent heart transplantation at 48 months of follow-up. However, further studies are needed to validate this idea and to evaluate if myocardium specimens obtained by preoperative endomyocardial biopsies may contribute towards separating out patients who with a higher probability of partial left ventriculectomy failure. In this regard, Lim et al. [6] proposed the analysis of the contractile characteristics of isolated myocyte preparations and the determination of the intracellular calcium to evaluate the physiological myocardial differences at the cellular level. Similarly, the preoperative evaluation of myocardial contractile reserve by echocardiographic and scintigraphic studies may also potentially contribute towards anticipating the existence of a positive myocardial response to LV volume reduction [24,25].

The current clinical experience with partial left ventriculectomy in patients with idiopathic dilated cardiomyopathy shows that this procedure, associated, when necessary, with mitral insufficiency correction, improves LV function and ameliorates congestive heart failure. The early survival after this operation continues to be limited by high incidences

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Table 2
Hemodynamic dataa

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 28</td>
<td></td>
</tr>
<tr>
<td>MRAP (mmHg)</td>
<td>9.7 ± 4.6</td>
<td>8.2 ± 4.3</td>
</tr>
<tr>
<td>MPAP (mmHg)</td>
<td>36.3 ± 11</td>
<td>31.8 ± 10.2</td>
</tr>
<tr>
<td>MPWP (mmHg)</td>
<td>23.6 ± 6.8</td>
<td>19.3 ± 7.1b</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>80 ± 8.5</td>
<td>84.6 ± 8.6b</td>
</tr>
<tr>
<td>CI (l per min/m²)</td>
<td>2.14 ± 0.47</td>
<td>2.45 ± 0.51b</td>
</tr>
<tr>
<td>SI (ml/m²)</td>
<td>23.9 ± 6.8</td>
<td>24.6 ± 8.9b</td>
</tr>
</tbody>
</table>

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a MRAP, mean right atrium pressure; MPAP, mean pulmonary artery pressure; MPWP, mean pulmonary wedge pressure; MAP, mean arterial pressure; CI, cardiac index; SI, stroke index. Numbers in parentheses indicate the patients evaluated at each time.

b p < 0.05 in relation to preoperative data of matched patients.
of heart failure progression and arrhythmia related deaths, but these events seem to be influenced by myocardial cells intrinsic compromise, opening the possibility of the preoperative identification of patients with a higher probability to benefit from the surgical reduction of LV volume. On the other hand, the long-term course of the surviving patients after partial left ventriculectomy seems to be characterized by the stabilization of the underlying disease for up to 4 years of follow-up, contributing to maintain this procedure as a promising alternative in the treatment of advanced heart failure, despite the tendency of LV redilatation and the maintenance of a high incidence of arrhythmia related events.

References


Appendix A. Conference discussion

Dr B. Messmer (Aachen, Germany): I would like to know more about the last thing you said that dilated cardiomyopathy is a rather heterogeneous group. Therefore, I assume you have to select the patients for your operation preoperatively. Do you consider performing endomyocardial biopsies which are also possible on the left ventricular side before you go ahead with the operation?

Dr Moreira: We are now doing biopsies prior to the operation and we are trying to accumulate data which will, in reality, better define this kind of thing for the future. Another possibility is, in reality, to use different testes to look for the myocardial response, to a stress test, for example, in order to define a better myocardial response.

Dr A. Carpenter (Paris, France): As always, it is a very well-documented presentation from a group who has a large experience in heart failure surgery. I do have two questions. Taking into consideration that after 2 or 3 years you have a progressive dilatation of the ventricle and the diastolic volume, would you consider associating this operation with cardiomyoplasty, which has the advantage of maintaining the diastolic volume? The second question is, have you had any experience in ischemic cardiac
disease, since it has been said that your results were not as good. You didn’t mention that. Have you selected your patients only to dilated cardiomyopathy or have you tried ischemic heart disease as well?

Dr Moreira: Thank you, Dr Carpentier, for your comments, and regarding your first question, we looked for the possibility to combine this procedure with cardiomyoplasty, and, in reality, we performed two cases with this combination. It is a feasible procedure and may be a possibility for the future. Otherwise, 5 years is a good time for an operation like this.

Regarding the other question, we don’t have experience with partial ventriculectomy in ischemic cardiomyopathy.

Dr F.-W. Mohr (Leipzig, Germany): You have done about 27 mitral valve repairs, and you did not comment on the severity of mitral valve disease prior to surgery. We know from other groups, and our own experience is the same, that mitral valve repair as a stand-alone procedure may have the same effect. Can you comment on that, especially on the outcome, if there is an effect of mitral valve repair only?

Dr Moreira: All patients had just mild or moderate mitral insufficiency, so the impact of this procedure was not so great as in patients with severe mitral regurgitation. On these patients we do just the annuloplasty.

Dr P. Paulista (Sao Paulo, Brazil): I would like to know if you related the functional class of your patients from the preoperative period with the long postoperative follow-up, and, of course, your results?

Dr Moreira: About the preoperative?

Dr Paulista: Yes. In our experience, we had different results with the patients in functional class III and in functional class IV; the differences were remarkable in our experience, so I would like to know your experience in this.

Dr Moreira: We didn’t observe any important difference in this regard, inclusive in relation to the survival curve of these patients. Patients, including cardiogenic shock, presented similar results to those operated in functional class III or IV.