The Dor procedure for left ventricular reconstruction. 
Ten-year clinical experience

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Abstract

Objective: Surgical ventricular restoration by means of the Dor procedure is a surgical option with coronary artery disease, postinfarction left ventricular aneurysm or ischemic dilated cardiomyopathy with or without ventricular tachycardia. The aim of this study was to evaluate the 10-year clinical experience of this procedure in our institution. Methods: From May 1994 to June 2004, surgical ventricular restoration was performed in 101 patients (77 males), mean age 63.8 (35-80) years. All patients presented with angina and/or heart failure and/or ventricular tachycardia. Postinfarction left ventricular aneurysm was present in 97 patients and ischemic dilated cardiomyopathy with a large akinetic left ventricle in 4. The preoperative left ventricular ejection fraction was 27 ± 10 (7-50) %. Multi-vessel disease was present in 80 patients. Ventricular tachycardia was diagnosed in 53 patients (spontaneous VT in 25). Mitral regurgitation more than grade 2 was found in 13 patients. The mean Euroscore was 7.1 ± 2.9 (3-17). Results: All patients underwent the Dor procedure, which in 53 patients included a non-guided endocardectomy and cryoablation for treatment of ventricular tachycardia. Coronary artery bypass grafting was performed in 99 patients and a mitral valve procedure was performed in 29. Intra-aortic balloon pumping was used postoperatively in 14 cases and 24 patients needed inotropic support for more than 24 h. Mean time on the ventilator was 16 ± 25 (3-168) hours and mean stay in the intensive care unit was 2.1 ± 2.2 (0-13) days. Postoperative stroke occurred in 7 patients. Early mortality was 8/101 (7.9%). Mean follow-up in operative survivors was 4.4 ± 2.8 (0.1-10.4) years. Actuarial survival at 1, 3 and 5 years was 88, 79 and 65%. Conclusions: The Dor procedure is a reproducible surgical option for treatment of postinfarction left ventricular aneurysm. Early and long-term results are good in terms of survival. © 2005 Elsevier B.V. All rights reserved.

Keywords: Coronary disease; Ventricular remodeling; Tachycardia; Ventricular; Heart failure; Congestive; Cardiac surgical procedures; Coronary artery bypass

1. Introduction

Heart failure is a major health problem with increasing prevalence due to an aging population and more patients surviving acute myocardial infarction (AMI). Patients with moderate or severe heart failure have a poor 3-year prognosis, and despite major advances, long-term medical treatment alone may be insufficient. Cardiac transplantation and ventricular assist technologies are definite or temporary alternative surgical methods to treat the diseased ventricle [4].

Postinfarction left ventricular (LV) remodeling is characterized by LV dilatation and abnormal geometry leading to systolic and diastolic dysfunction. Development of a left ventricular aneurysm (LVA) is a serious long-term complication of AMI, often leading to heart failure, ventricular tachycardia (VT) and thromboembolic events. VT after AMI is associated with a high risk of sudden cardiac death [5]. The most common cause of LVA is acute occlusion of the left anterior descending artery (LAD), with aneurysm formation in the anterior wall and septum. Historically, about 10-30% of patients surviving a major myocardial infarction will develop a LVA. However, at present the incidence of LVA appears to have decreased due to improved revascularization treatment of patients with AMI, likely reducing the incidence of permanently occluded LADs. Other improvements include better management of hypertension and avoidance of corticosteroids, both of which are known risk factors for LVA development.

Surgical repair of LVA was first performed by Charles Bailey in 1954, and the first resection under cardiopulmonary bypass was reported by Denton Cooley in 1958. In 1985, Vincent Dor described an original surgical technique, the Endoventricular Circular Patch Plasty [6] built on prior...
contributions by Cooley and Jatene [7,8]. Subsequently, Dor and associates have reported excellent clinical and hemodynamic results of this procedure in several hundreds of patients [9]. The Dor procedure excludes akinetic or dyskinetic portions of the anterior wall and septum, reshapes the LV with a stitch that encircles the transitional zone between contractile myocardium and aneurysmal tissue, and uses a patch to reestablish ventricular wall continuity [6,10]. By this technique, the operation improves size and geometry of the LV, reduces wall tension and paradox movement and enhances overall systolic function. In addition, the procedure may treat the ventricular arrhythmia problem and also allows for removal of intracavitary thrombi. Myocardial revascularization is almost always performed, and mitral valve procedures are feasible through the ventriculotomy or by a standard atrial approach.

Left ventricular reconstruction by the Dor procedure has subsequently been applied to patients with large akinetic ventricles [11,12]. The present study describes our 10-year experience with this procedure for postinfarction LVA and ischemic heart disease.

2. Material and methods

2.1. Patient selection and preoperative investigations

Dyskinetic LVA is commonly defined as a segment of left ventricular wall protruding from the expected outline of the ventricular chamber during systole, displaying paradoxical motion on left ventriculogram. However with increasing size of the LVA, paradoxical movement becomes more difficult to identify and the distinction of the two separate entities, namely LVA or large akinetic ventricle, may be hard to make. Patients were considered suitable for surgical ventricular restoration (SVR) if they demonstrated an enlarged either dyskinetic or akinetic LV accompanied by LV dysfunction after myocardial infarction and had symptoms of angina, congestive heart failure (CHF), VT or a combination of these.

Coronal angiography was performed in all patients, and the diagnosis and assessment of the LV was made by ventriculography. Transthoracic or transesophageal echocardiography was subsequently used to assess LV dimensions and function, as well as valvular function.

2.2. Patient characteristics

From May 1994 to July 2004, 101 consecutive patients underwent the Dor procedure for post-infarction dyskinetic LVA or large non-aneurysmal akinetic LV. Follow-up was completed on October 15, 2004. Baseline characteristics and indications for surgery are presented in Tables 1–3. There were 77 men and 24 women, with a mean age of 63.8 (35-80) years. Seventy-four patients were in New York Heart Association (NYHA) functional class III or IV. Multi-vessel disease was present in 80 patients. The mean preoperative left ventricular ejection fraction (LVEF) was 27 ± 10% (7-50%). All patients except one were operated electively. Operative risk was evaluated before surgery in all patients. Fifty-three patients had a confirmed diagnosis of VT preoperatively and 25 of these had spontaneous VT.

Table 1
Preoperative patient characteristics (mean ± SD (range) or number of patients)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n = 101</th>
</tr>
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<tbody>
<tr>
<td>Male/female</td>
<td>77/24</td>
</tr>
<tr>
<td>Age (years)</td>
<td>63.8 ± 9.77 (35-80)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.1 ± 3.76 (18.8-35.0)</td>
</tr>
<tr>
<td>BMI &gt; 30 (kg/m²)</td>
<td>19</td>
</tr>
<tr>
<td>Diabetes mellitus*</td>
<td>21</td>
</tr>
<tr>
<td>Impaired renal function</td>
<td>22</td>
</tr>
<tr>
<td>Renal transplant recipient</td>
<td>2</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>4</td>
</tr>
<tr>
<td>NYHA class II</td>
<td>27</td>
</tr>
<tr>
<td>NYHA class III-IV</td>
<td>74</td>
</tr>
<tr>
<td>Operative risk evaluation</td>
<td></td>
</tr>
<tr>
<td>Euroscore</td>
<td>7.2 ± 2.9 (3-17)</td>
</tr>
<tr>
<td>Higgins</td>
<td>4.2 ± 3.0 (0-14)</td>
</tr>
<tr>
<td>Parsonnet</td>
<td>16.3 ± 8.0 (5-38)</td>
</tr>
</tbody>
</table>

BMI, body-mass index; NYHA, New York Heart Association.
* Treated with insulin and/or oral anti-diabetics.

<table>
<thead>
<tr>
<th>Diag. category</th>
<th>n = 101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angina + CHF + VT</td>
<td>42</td>
</tr>
<tr>
<td>Angina + VT</td>
<td>32</td>
</tr>
<tr>
<td>CHF + VT</td>
<td>24</td>
</tr>
<tr>
<td>VT</td>
<td>3</td>
</tr>
</tbody>
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CHF, congestive heart failure; VT, ventricular tachycardia.

2.3. Surgical technique

The operation was performed using cardiopulmonary bypass (CPB) and moderate systemic hypothermia. Standard cardiac anesthesia was used. A transesophageal echocardiography (TEE) probe was used to evaluate preoperative and postoperative LV and mitral valve function. CPB was instituted in a routine fashion. In all cases, the aorta was cross-clamped, and myocardial protection was achieved with intermittent cold antegrade and retrograde blood cardioplegia. The aneurysm was incised parallel to the interventricular septum and LAD, clots were removed, and a subtotal nonguided endocardectomy was conducted on the septum and anterior wall if spontaneous or inducible VT existed. In such circumstances linear cryo lesions (Frigitronics CCS-200, CooperSurgical, Inc, Trumbull, CT, USA) were applied at the edge of the endocardial resection [13]. Another indication for endocardectomy in some instances was the presence of severe calcification, making closure of the LV incision difficult. In case of mitral insufficiency, the valve could be repaired for instance with an edge-to-edge Alfieri stitch [14] or replaced through the ventriculotomy. A purse-string suture (2-0 Prolene, Ethicon, Somerville, NJ, USA) was placed around the circumference of the scar at the transition zone (usually near the base of the papillary muscles) and tied down to determine the size of the new ventricular opening (the Fontan stitch). A bovine pericardial patch (Periguard; Synovis Life Technologies, Inc., St Paul, MN, USA) was then secured over the ventricular opening with a running 2-0 Prolene suture. The edges of the ventricular free wall were then closed over the patch with a running 2-0 Prolene suture. The distal coronary anastomoses were performed. The cross-clamp was removed and the proximal...
anastomoses to the ascending aorta were done with a side-biting clamp. The patient was then weaned from CPB in a standard fashion. TEE was used to assess filling, contractility and mitral valve function.

2.4. Follow-up

All patients were followed until mid-October 2004. Follow-up consisted of review of patients’ charts and our institutional database, as well as data from the Total Register of the Swedish Population, Statistics Sweden and the Cause of Death Register, Centre for Epidemiology at the National Board of Health and Welfare, Sweden. No patient was lost to follow-up.

2.5. Statistical analysis

Continuous variables are reported as mean ± standard deviation and range. Cumulative survival rates are presented as Kaplan-Meier estimates.

2.6. Ethical considerations

The present study was approved by the regional Human Research Ethics Committee, Stockholm, Sweden.

3. Results

3.1. Operative data

All patients underwent SVR by means of the Dor procedure (endoventricular circular patch plasty), and 99 patients had concomitant CABG with a mean of 2.4 ± 1.2 (1-5) grafts. In 92 patients, LITA was used as a conduit to the LAD or a diagonal branch. Of the two patients who did not have revascularization, one patient had previously undergone CABG and had patent grafts, and the other was the only urgent case with a contained rupture of the LVA. Surgery for VT including subtotal septal endocardectomy and cryoablation was performed in 53 patients. In another 4 patients, endocardectomy was performed because of severe calcification of the aneurysm. Mitral valve surgery was performed in 29 patients, using predominantly the Alfieri edge-to-edge technique. Operative data are summarized in Table 4.

3.2. Early findings

3.2.1. Postoperative complications

Early-mortality was 8/101 (7.9%). Early mortality is defined as death within 30 days of the operation or death before discharge from the hospital. Two patients died during surgery, both due to heart failure/low output syndrome (LOS). Six patients died in the ICU (1-50 days after primary operation) due to LOS in 5 cases and severe anoxic/hypoxic brain injury in one case.

Fourteen patients underwent early reoperation for various reasons. Inotropic support was needed for more than 24 h in 25 patients. Intra-aortic balloon pumping was used postoperatively in 14 patients. Postoperative stroke occurred in 7 patients, of whom 3 had complete regression of symptoms before discharge. A summary of postoperative data is presented in Table 5.

3.3. Long-term findings

Mean follow-up of operative survivors (n=93) was 4.4 ± 2.8 (0.1-10.4) years. The actuarial survival curve (including early mortality) is shown in Fig. 1. Overall survival was 88% at 1 year, 79% at 3 years and 65% at 5 years. Late causes of death were cardiac in 14 cases, non-cardiac in 4 cases (cancer, renal failure, stroke, pneumonia) and undetermined in 6 cases. There was no confirmed arrhythmia related death or sudden cardiac death. There was no loss to follow-up. Four patients underwent reoperation, 3-13 months after the primary operation, all due to mitral regurgitation (MR). Two of these did not
undergo mitral valve procedure at the primary operation. In one case there was also patch failure. All underwent mitral valve replacement. In one case the cardiac function deteriorated and the patient subsequently underwent uneventful cardiac transplantation. Two patients received a biventricular pacemaker/ICD due to congestive heart failure (CHF). Thirteen (13)/93 patients had spontaneous and/or inducible VT postoperatively, thus freedom from clinical and inducible VT was 80/93 (86%). Detailed results in patients undergoing VT-surgery will be presented elsewhere (manuscript in preparation).

Mean LVEF, assessed by echocardiography 1-6 months after the operation, was 33% ± 9.3 (15-50).

4. Discussion

This study presents our experience and results in a consecutive series of patients undergoing the Dor procedure for predominantly LVA. We report early- and long-term results in terms of survival in a group of patients with severely depressed cardiac function. The operative goal of the Dor procedure is to achieve complete coronary revascularization, reduce LV volume and restore its shape. Findings of mitral regurgitation and VT are addressed when necessary. The hypothesis is that SVR, by means of the Dor procedure, improves quality of life and survival in patients with LVA or IDCMP suffering from angina, CHF or VT following myocardial infarction. Excellent single-center long-term results of hemodynamic data and survival have been published by Dor [9] and Menicanti [10] and multi-center results published by the international Reconstructive Endoventricular Surgery returning Torsion Original Radius Elliptical shape to the left ventricle (RESTORE) team are equally satisfactory [12].

Our results presented in this study are comparable to those previously reported. However, the study populations differ in the respect that patients in our study had predominantly dyskinetic LVAs, whereas 2/3 of the patients in the study by the RESTORE group [12] had akinetic rather than dyskinetic LVs. The authors also found that survival at five years were better in the group of patients that had dyskinetic as compared to akinetic morphology (80 vs 65%; P < 0.001). This finding is interesting, since DiDonato [11] demonstrated that outcome in a large series of SVR patients was more strongly linked to the extent of asynergy than to the type of asynergy (akinetic vs dyskinetic). However, it is our experience that the distinction between LVA and enlarged akinetic non-aneurysmal ventricle is less clear the larger the akinetic area, thus there is a continuum between pure dyskinesia and pure akinesis. The grading of the extent and type of asynergy in our study has been based on visual estimation from the ventriculogram before surgery and should others reclassify all patients in this study, the proportion of LVA:IDCMP might very well be different. However, the aim of this study has not been to compare results in different subgroups of LV morphology but instead report our overall surgical outcome in terms of survival.

4.1. Is the outcome a result of revascularization or did the patients receive added benefit from SVR?

Complete revascularization is mandatory for a good outcome. Specifically, the LAD should receive a graft, preferably the LITA, due to the fact that although the distal part may be occluded, the proximal part supports the septal branches which are critical for the blood supply of the basal portions of the ventricle and septum. However, recent reports [2,15] support the belief that revascularization alone is not sufficient in the dilated ventricle. More precisely, patients with ischemic cardiomyopathy and a substantial amount of viable myocardium and a high end-systolic volume due to LV remodeling have a decreased likelihood of improvement of global function following myocardial revascularization [2]. In addition, patients with a large LV end-systolic volume have a worse long-term prognosis.
as compared to patients with a smaller LV end-systolic volume [15]. Recently published data [16] also suggest that geometric rebuilding by SVR leads to restoration of a more synchronous contractile pattern which improves LV performance.

4.2. Revascularization and mitral valve repair

It is well known that patients with ischemic cardiomyopathy and mitral insufficiency have lower life expectancy and poorer quality of life. At present, it is generally accepted that patients with MR, even of a moderate degree, undergoing CABG benefit from generally accepted that patients with MR, even of a moderate degree, undergoing CABG benefit from a concomitant mitral valve procedure [17–19]. MR is common in the dilated ventricle. We have therefore found it reasonable to adapt an aggressive approach in patients with LVA and severely depressed LV function and performed mitral valve procedures in 29% (29/101) of the cases in this series. Only 45% (13/29) of these patients had MR grade 3 or 4, the rest had MR grade 2 (55%, 16/29). Nevertheless, four patients had to undergo repeat surgery due to residual or recurrent MR. In two cases there were no mitral procedure at the primary operation and in two cases we had done mitral valve repair by Alfieri edge-to-edge technique. Correction of MR should preferably be done by repair [20,21] but occasionally replacement is necessary. Both procedures can be performed through the ventriculotomy [10,12].

4.3. Sizing of the new ventricle?

Dor and Menicanti [10] advocates the use of a sizing balloon or mannequin in order to get a more objective assessment of postoperative LV size. We have not used any kind of sizer and instead relied on eye-balling and experience. In our series, about 90% of the operations have been performed by the same surgeon who has therefore gained proficiency in determining the correct size and placement of the patch. In most cases with thin-walled, fibrotic, dyskinetic LVA, which includes almost all of the patients in our series, there is a clear transitional zone between dysfunctional tissue and viable contracting myocardium, which makes it easy to define the new ventricle. In other cases where the border is not so well morphologically defined, a sizer might very well be of help, especially to avoid overcorrection. To leave the patient with a too small ventricle is deleterious.

4.4. On/off clamp?

There have been, and still is, some debate regarding performing the ventricular reconstruction part of the operation with the heart beating or in cardioplegic arrest. Dor initially described the procedure on the arrested heart, but in the recent report from the RESTORE group [12], in about half of the cases the ventricular portion of the procedure was done on the beating heart. One recent retrospective study showed no additional advantage of the beating heart approach over the continuous aortic crossclamping method in a group of 53 patients undergoing the Dor procedure [22].

4.5. Linear or patch repair?

Traditionally a linear repair technique has been used on thin-walled left ventricular aneurysms. This technique does not allow for exclusion of the septal portion of the aneurysm. A recent retrospective study comparing simple linear repair and endoventricular patch plasty for LVA has shown lower surgical risk and higher long-term survival after endoventricular patch plasty. The authors clarify that the differences in outcome should be interpreted with care due to study design [23]. Mickleborough have reported excellent results in a series of 285 patients, who had akinesia or dyskinesia and wall thinning, with a modified linear closure technique. In select cases (n=64, 22%) a patch septoplasty was performed due to dyskinetic septum [24]. Thus, different methods for aneurysm repair and septal exclusion have been described apart from simple excision and linear closure. We believe that the patch plasty described by Dor is the method of choice after LAD occlusion and anterior infarction since, in these cases, the septum is always affected, and the patch technique is the best way to effectively exclude the septum and safely ensure diastolic capacity. Furthermore, the linear repair often makes grafting of the LAD impossible as LAD might be included in the LV suture line.

4.6. Limitations of the study

The lack of a control group is the major limitation of this study. Another limitation of this series is the lack of postoperative invasive studies in most patients, which are needed for detailed analysis of changes in ventricular volume and geometry. We have not had complete follow-up of concurrent medication, but all patients have had regular contact with a cardiologist and/or family physician. The use of beta-blockers and ACE-inhibitors for patients with left ventricular dysfunction was common during the study period. However, the pre- and peri- and post-operative data have been prospectively gathered in our clinic’s database and no patient was lost to follow-up.

On the basis of our findings, which concur with the results from other studies, we feel encouraged to continue offering an aggressive surgical treatment consisting of revascularization, surgical ventricular restoration and, when needed, mitral valve repair and surgery for ventricular tachycardia to patients presenting with coronary disease, dilated akinetic/dyskinetic ventricle and poor left ventricular function. We believe that, although not proven in a randomized clinical trial, surgical ventricular restoration and revascularization is superior to revascularization alone in patients where the ventricle is starting to dilate to prevent further remodeling and functional deterioration. We find that the Dor procedure is a reproducible procedure, but technical challenges such as determination of post-reconstruction left ventricular size and techniques and indications for concomitant mitral valve surgery remain an issue.
Acknowledgements

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References


