Indication of posterior restoration and surgical results in patients with dilated cardiomyopathy

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Abstract

Objective: Nontransplant surgery for dilated cardiomyopathy (DCM) has been in the process of development. Anterior restoration for anterior akinesis has shown favourable outcome. Posterior restoration and surgical results are also discussed. Methods: At the Hayama Heart Center in Japan, between 2005 and 2009, posterior restoration for DCM was performed in 36 patients (10 with ischaemic and 26 with nonischaemic, including muscular dystrophy in three). There were 32 men and four women with a mean age of 53 years. The mean preoperative ejection fraction was 23% and the preoperative New York Heart Association (NYHA) classification was class III in 16 patients and class IV in 20 with eight emergent operations. To identify the posterior lesion before operation, speckle-tracking echocardiography was used, with a Vivid 7 ultrasound machine. The short-axis images from the middle level of the left ventricle (LV) were obtained to assess myocardial segmental viability. Based on the results of speckle-tracking echocardiography, posterior restoration was performed in patients with postero-lateral akinesis and septal kinesis. After the cardioplegic arrest, mitral plasty or coronary artery bypass grafting (CABG) was performed and the posterior LV muscle between bilateral papillary muscles was partially resected under beating heart. The LV apex was preserved and cryoablation was applied between the cut edge and the mitral annulus. All the patients were followed with cardiac echocardiography. Results: In addition to LV restoration, mitral plasty was successfully performed in all the patients. Concomitant CABG was performed in seven, tricuspid surgery in 11 and cardiac resynchronisation therapy (CRT) in eight. Perioperative intra-aortic balloon pumping (IABP) was used in six and there was no hospital mortality, including eight emergent operations. After the operation, 29 patients (80.6%) improved their functional class into class I or II. In the late follow-up, there were two cardiac deaths and one noncardiac death and the 4-year survival rate was 85.8%. Conclusions: The site selection with speckle-tracking echocardiography demonstrated the accurate akinetic lesion of the posterior LV wall. The posterior restoration with preservation of bilateral papillary muscles and LV apex based on the site selection improved operative and mid-term results in the selected patients with DCM.

Keywords: Dilated cardiomyopathy; Left ventricle; Posterior restoration; Speckle-tracking echocardiography

1. Introduction

The medical treatment for dilated cardiomyopathy (DCM) has been developing with pharmacological or pacemaker treatment. The surgical treatment of left ventricular restoration (LVR) for ischaemic or nonischaemic DCM has also been developing for the patients with medically refractory heart failure [1—6]. Anterior restoration for anterior akinesis, described by Dor et al. [2], has shown favourable outcome. However, the partial left ventriculectomy (PLV) for DCM as described by Batista et al. [1] was abundant because of poor operative and mid-term results; Cereceda et al. reported that the PLV was not an alternative to heart transplantation [7]. We have been performing LVR by selecting the lesion of the left ventricle (LV) [8]. In this article, we report the surgical results and mid-term results with posterior LVR in patients with DCM and posterior akinesis, and show the encouraging results of the procedures in indicated patients.

2. Patients and methods

Since 2005, 36 patients with DCM were evaluated by speckle-tracking echocardiography before operation and were indicated for the posterior restoration of the LV at the Hayama Heart Center in Japan. The diagnosis of DCM was made by echocardiography, coronary angiography (CAG) and/or myocardial biopsy. The mean age was 53 ± 13 years (range 15—75 years) and there were 32 men and four women. Preoperative New York Heart Association (NYHA) classification was class III in 16 patients and class IV in 20. Twenty-two
patients were dependent on inotrope before operation and eight of them required emergent operation because of shock status in five. Moderate-to-severe mitral regurgitation (MR) was observed in all the patients and tricuspid regurgitation in eight patients. The aetiology of DCM was ischaemic in 10 and nonischaemic in 26.

2.1. Image acquisition

Echocardiograms were carried out using a Vivid 7 ultrasound machine (GE Medical Systems, Milwaukee, Wisconsin, USA) with a M3S probe. Short-axis images from mid-level (i.e. papillary muscle level) of the LV were obtained from the parasternal window to assess myocardial segmental viability and LV dys-synchrony (Fig. 1). Caution was exercised to ensure short-axis images with circular cross section and minimal out-of-plane movement.

2.2. Image analysis

Short-axis images were analysed by EchoPAC platform (2DS-software package, version 7, GE Medical Systems), which employs a speckle-tracking technique to derive rotation and strain for selected regions of the myocardium. LV torsion was also calculated from the LV basal and apical rotation data in the platform automatically.

For assessing segmental myocardial viability, we divided the myocardial region obtained from the short-axis images of the mid-level LV into four segments (septal, antero-lateral, posterior and infero-septal segment), and analysed the circumferential strain (Sc) profile, which was closely related to myocardial viability [9,10].

Indication of cardiac resynchronisation therapy was evaluated with radial strain profile of each segment as previously reported [11] and LV torsion behaviour was evaluated from the LV base and the apical rotation profile [12].

Based on the findings of echocardiography speckle, the operative procedures of posterior restoration were selected in patients with postero-lateral lesion (Fig. 2). Mitral or tricuspid surgery was indicated when there was moderate-to-severe (grade +3 or +4) regurgitation in association with DCM.

Using ordinal cardiopulmonary bypass (CPB) with cardioplegic heart arrest, mitral or tricuspid surgery, or complete coronary artery bypass grafting (CABG) was performed, followed by LVR under the beating heart.

The procedures consisted of posterior restoration with preservation of bilateral papillary muscle and LV apex, and the prevention of late occurrence of vein thrombosis (VT). The LV was incised at the posterior wall 1 cm apart from the LV apex and the incision reached 1 cm from the mitral annulus and the LV muscle between the bilateral papillary muscles was resected. The cryoablation was performed inside the LV muscle between the edge of the incision and the mitral annulus. The bilateral papillary muscle was then re-approximated with two 0-TI-CRON, United State Surgical, Tyco Healthcare) stitches. The incised LV wall was then sutured with two layers to secure haemostasis.

After the operation, the patients were treated with inotrope for at least 1 week, which was then weaned. Before discharge from the hospital, cardiac echocardiography and catheter study were performed and the patients were followed up every 6–12 months. Regular follow-up was made by the outpatient clinic, and by telephone calls or mail questionnaires; the follow-up was closed in September 2009. The follow-up complete rate was 97% and the length of follow-up after surgery was 30.3 ± 1.0 months (range, 3.0–51.3 months). Statistical analysis

Continuous variables are expressed as the mean ± standard deviation (SD). Cumulative survivals were calculated by the Kaplan–Meier estimation with the dates of the operation and of the most recent follow-up. In comparisons between the two groups, p-values were obtained by the x2 test or Wilcoxon’s signed-rank test. The differences in the survival rate were determined by log-rank analysis. A p-value of <0.05 was considered significant.

3. Results

Concomitant procedures included mitral surgery in all 36 patients, tricuspid surgery in 11 and CABG in 7. In the mitral surgery, 35 patients received mitral valve plasty with one or two under-sized Carpentier—Edwards physio ring (Edwards Lifesciences LLC, Irvine, CA, USA) and one patient received mitral valve replacement with Carpentier—Edwards pericardial bioprosthesis. For the tricuspid surgery, tricuspid annuloplasty with the Edwards MC3 annuloplasty ring (Edwards LifeSciences, Irvine, CA, USA) was performed in 10 patients and tricuspid valve replacement with Carpentier—Edwards pericardial bioprosthesis in one. In eight patients with dys-synchrony by speckle-echocardiography findings, biventricular pacemaker implantation was introduced during the surgery.

The mean aortic cross-clamp time was 68 ± 35 min and the mean extracorporeal circulation (ECC) time was 125 ± 40 min. Intra-aortic balloon pumping (IABP) was inserted in six patients preoperatively and it was weaned 1–3 days after the operation. There were no patients requiring left ventricular assist device (LVAD). Hospital mortality was zero (0%), including emergent operation. After the operation, left ventricular ejection fraction (LVEF) remained unchanged (24.1 ± 6.1% before operation and 26.1 ± 7.7% at discharge after operation), and left ventricular diastolic dysfunction (LVDD) was significantly improved, from 76 ± 7 to 63 ± 8 mm (p = 0.001). The end-systolic volume index and the end-diastolic index also significantly improved after the operation and the improvement was sustained during the follow-up, as shown by echocardiographic data, which were examined at a mean of 26.4 ± 12.4 months after the operation (Table 1). After the operation, MR was none in 33 and trivial in three patients.

Table 1

<table>
<thead>
<tr>
<th>Left ventricular function.</th>
<th>Before OP</th>
<th>After OP</th>
<th>p Value</th>
<th>Late follow-up</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVDD (mm)</td>
<td>76 ± 7</td>
<td>63 ± 8</td>
<td>0.0001</td>
<td>65 ± 9</td>
<td>0.0001</td>
</tr>
<tr>
<td>LVEDVI (ml)</td>
<td>179 ± 33</td>
<td>128 ± 43</td>
<td>0.0001</td>
<td>126 ± 39</td>
<td>0.0001</td>
</tr>
<tr>
<td>LVESVI (ml)</td>
<td>133 ± 30</td>
<td>98 ± 33</td>
<td>0.0001</td>
<td>87 ± 42</td>
<td>0.0001</td>
</tr>
<tr>
<td>EF (%)</td>
<td>24.1 ± 6.1</td>
<td>26.1 ± 7.7</td>
<td>0.1061</td>
<td>30.0 ± 8.0</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

LVDD: left ventricular diastolic diameter; LVEDVI: left ventricular end-diastolic volume index; LVESVI: left ventricular end-systolic index; EF: ejection fraction.
During the follow-up, late death was noted in one patient due to noncardiac suicide and three with congestive heart failure. The late death with congestive heart failure occurred in two out of 26 patients with nonischaemic DCM and in one out of 10 patients with ischaemic DCM. Postoperative NYHA functional class was in class I or II for 29 patients (80.5%; Table 2). The longest survivor was 50 months after the procedures, and the 4-year survival rate was 85.8%. As in Fig. 3, we compared the survival rate of this report to the survival rate in 93 patients with original PL V[1] in our early experience [8] between 1997 and 2004. There were 86 patients with nonischaemic DCM and seven with ischaemic DCM. The survival rate was 44.3% and there was a significant difference in late survival between posterior restoration and conventional PLV ($p = 0.0007$).

### 4. Discussion

Surgical treatments for severe congestive heart failure due to DCM have been performed over the last decade and the surgical results have been improving. The PLV for nonischaemic and ischaemic DCM was first reported by Batista et al. [1]; however, as reported by Cereceda et al. [7], the procedure seemed to have failed to show optimal results. In contrast, the endoventricular circular patch plasty (EVCPP) in ischaemic DCM, reported by Dor et al. [2], has been widely acknowledged to have acceptable late surgical results [13]. The reason for the different results in the two different operations was due to not only the surgical procedures but also the site of lesion of the LV. In ischaemic DCM, antero-septal akinesis occurred due to previous left anterior descending (LAD) occlusion and therefore the exclusion of antero-septal lesion by EVCPP is the correct procedure to exclude akinetic antero-septal lesion. However, in patients with large LV caused by nonischaemic DCM, the

### Table 2
Operative and follow-up results.

<table>
<thead>
<tr>
<th></th>
<th>2005—2009 (n = 36)</th>
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<tbody>
<tr>
<td>Hospital death</td>
<td></td>
</tr>
<tr>
<td>Elective (n = 28)</td>
<td>0</td>
</tr>
<tr>
<td>Emergent (n = 8)</td>
<td>0</td>
</tr>
<tr>
<td>Follow-up (n = 36)</td>
<td></td>
</tr>
<tr>
<td>NYHA</td>
<td></td>
</tr>
<tr>
<td>Class I—II</td>
<td>29 (80.5%)</td>
</tr>
<tr>
<td>Class III</td>
<td>3</td>
</tr>
<tr>
<td>Late death</td>
<td>4 (CHF3, noncardiac 1)</td>
</tr>
</tbody>
</table>

![Fig. 1](image1.png)  
**Fig. 1.** (A) Regional representative myocardial circumferential strain profile in a cardiac cycle. Posterior site (i.e., inter papillary muscle region) in the mid-level LV was passively stretched (positive value) during systole, which means the segment could not cooperate LV systolic contraction due to the severe myocardial lesion in the posterior site. (B) Operative findings of the left ventricle in indicated patient for posterior restoration. The posterior wall shows mostly white scar as an akinetic site which is demonstrated by speckle-tracking echocardiography.

![Fig. 2](image2.png)  
**Fig. 2.** Regional strain. Regional heterogeneity of Sc value at end systole in each segments of mid-level of the LV myocardial wall before the surgical procedures of posterior restoration.

![Cumulative survival rate after posterior restoration of LV](image3.png)  
**Fig. 3.** Cumulative survival rate after posterior restoration of left ventricle. The 4-year survival rate in 36 patients with newly developed posterior restoration is 85.8%. The results are better than the rate of 44.3% in 93 patients with conventional partial left ventriculectomy (PLV) in our experience. There was significant difference in late survival between posterior restoration and conventional PLV ($p = 0.0007$).
detection of accurate akinetic lesion is difficult by ordinal examination, including cardiac echocardiography, scintigram or left ventriculography (LVG). Therefore, the previous report for PLV by Batista and et al. does not seem to include a proper site selection for LVR. We have previously reported the site-selection method and the selection of the procedures with better surgical results [8,14]. We used colour kinesis to detect the akinetic site during ECC with volume unloading of LV, although, in this method, determination of the kinetic or akinetic site could not be done preoperatively.

The speckle-tracking echocardiography shows the segmental deformation of the LV myocardium. Becker et al. [9] and Popovic et al. [10] reported that the speckle-tracking echocardiography, that is, circumferential strain profile, correctly identified segmental LV dysfunction due to myocardial infarction. In our study, we applied this method for both ischaemic and nonischaemic DCM and found that the speckle-echocardiography reflected well in patients with DCM in different aetiologies.

With the selection of the akinetic lesion by the speckle-tracking echocardiography, the indication for posterior LVR can be decided before the operation and the posterior restoration improved surgical results. Although further detailed analysis of the LV mechanisms needs to be addressed, the findings after the operation show that the removal of akinetic site by the posterior restoration seemed to contribute to an improvement of the global LV function, suggesting a mechanical resynchronisation.

MR is usually associated with the deterioration of congestive heart failure in end stage. MR is not only caused by the dilatation of the mitral annulus but also by the tethering of the mitral leaflet. The surgical intervention for such functional MR consists of under-sized ring annuloplasty and repair of the mitral tethering to correct subvalvular apparatus [15]. In the described procedures for posterior restoration, bilateral papillary muscle was preserved and they were re-approximated during the closure of the incised LV muscle. In these procedures, the papillary muscles are approximated in side-by-side position and the mitral tethering is corrected.

The described posterior restoration also preserved LV apex during the resection of the postero-lateral side of the LV, because, as reported by Buckberg et al. [16], normal heart showed the torsion of the LV apex and the apex seemed to be playing an important role for LV function.

In the late follow-up period after the surgery for DCM, sudden death due to ventricular arrhythmia is one of the major factors for the late prognosis. During the operation, the postero-lateral wall was excised and the macro-re-entry between the mitral annulus and the cutting edge of the LV muscle might cause the late VT. Therefore, cryoablation between these sites was applied during the procedures for prevention of the late VT and there was no VT in the follow-up period.

5. Conclusion

Using speckle-tracking echocardiography, a scar or the most damaged posterior lesion of the LV in DCM could be detected correctly and the operative results improved by the posterior restoration in indicated patients. In mid-term follow-up, the improvement of the surgical results encourages the performance of the posterior LV restoration by preserving the bilateral papillary muscle and the LV apex.

References


Appendix A. Conference discussion

Dr H. Suma (Tokyo, Japan): You and I have worked together for about eight years in Hayama Heart Center, and we have made an aggressive challenge to treat congestive heart failure by using several left ventricular reconstruction procedures to restore the failing heart, because heart transplantation has been extremely slow in Japan. I have two questions.

You presented the results of the procedure in ischaemic and nonischaemic cardiomyopathy mixed together, but I think they are different. For the
ischaemic patient, it is easy to understand that the Dor operation is good for
the antero-septal infarction and the posterior plication is appropriate to the
posterior infarction. However, in nonischaemic patients, can you tell us more
clearly how the speckle tracking is important and why the linear plication is
better than the wide excision as Batista did?

The second question is how the other variables like end-diastolic pressure,
stroke volume or oxygen consumption have changed after the operation? Is
there any risk of diastolic dysfunction following the operation?

Dr Isomura: First, I agree with your comments about the difference
between the nonischaemic cardiomyopathy and the ischaemic cardiomyopa-
thy. It is pretty hard to detect the lesion site for nonischaemic cardiomyopathy.
In my series since 2005, we have done 130 patients with dilated
cardiomyopathy, including 78 patients with nonischaemic cardiomyopathy.
For the speckle-tracking echo detector, out of them, 28, almost 30% of the
patients, showed a posterior akinesis as shown in my paper. So I think speckle-
tracking echo is very useful before surgery to detect those lesions. And to
preserve the papillary muscle, we have done resection of the bilateral
papillary muscle for our initial experience, but we preserve the papillary
muscle, because probably it will be to keep the sphericity between the
papillary muscle and the mitral annulus. Like the paper described by Tirone
David, preservation of the posterior mitral leaflet is very functional and
beneficial for mitral valve replacement.

And the second question, I think for the parameters like ejection fraction
or the volume, we also check the cardiac index; before the operation it was 2.2
to after the operation 3.0. There is no change of heart rate. I think stroke
volume is also increased after the surgery, and systolic PA pressure is a little bit
down, and left ventricular end-diastolic volume and pressure is also improved
in my series.

Dr Suma: How about diastolic dysfunction after the operation?

Dr Isomura: We are checking the diastolic dysfunction by echo. We call it
e’, which is measured by tissue Doppler echo. The number is usually normal;
non-diastolic dysfunction showed more than 8 cm/s. However, in this series
before operation, the number was 6 cm/s and then a little bit lower after the
operation, 5.5, but there was no significant difference before and after
surgery. So I think there was no significant diastolic dysfunction after the
partial left ventriculectomy in my series.