Surgical Treatment for Heart Failure
—— Left Ventricular Restoration for Cardiomyopathy ——

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Congestive heart failure has become a major problem and the only surgical treatment for end-stage heart failure caused by dilated cardiomyopathy (DCM) had been heart transplantation. However, because of the shortage of donors, several procedures for non-transplant surgery have been developed. Published literature on left ventricular (LV) restoration was searched to review the new surgical procedures for treating patients with ischemic or non-ischemic DCM. LV restoration was initiated in the 1980s for repairing LV aneurysm. In the 1990s several surgical procedures were introduced for treating DCM, and the new evolving surgical treatment plays an important role in the management of DCM in the 21st century. (Circ J 2009; Suppl A: A-6–A-12)

Key Words: Dilated cardiomyopathy; Ischemic heart disease; Left ventricle; Non-ischemic heart disease; Restoration

Left Ventricular (LV) Restoration and Ischemic Cardiomyopathy (ICM)

ICM is defined as diffuse akinesia of the ventricle after myocardial ischemia, and the pathology is different from LV aneurysm, which is dyskinesia after myocardial infarction. The etiology has been described as chronic LV remodeling after the ischemia, and the surgical treatment of ICM was thought to be heart transplantation only. However, the new surgical procedure of endoventricular circular patch plasty (EVCPP) showed to be an alternative treatment for ICM. The EVCPP is performed with cardioplegic heart arrest. After complete coronary revascularization, the LV is opened in the center of the anterior lesion. Clots, if present, are removed. In akinetic segments, the junction between scarred and normal muscle is not as clearly defined as in dyskinetic aneurysms, though the endocardial scar determines the border zone between totally fibrous tissue and the beginning of muscular tissue. With ventricular arrhythmia, the endocardial scar is mobilized and resected, and cryotherapy is applied to the edge of the resection. A 2-0 Prolene endoventricular circular suture, as described by Fontan, is placed to restore the “neck” of the contracting ventricle and thereby provide a more normal oval curvature of the chamber. The circular suture is passed in the fibrous tissue above the transitional zone between normal and scarred tissue to construct the “artificial neck” that will be closed with a Dacron patch. The area excluded includes almost half of the septum and the “artificial neck” that will be closed with a Dacron patch. The LV is restored at the anteroseptal site with small patch. The volume and the size of the LV decreases; however, the spherical shape of the LV does not become elliptical. The conical pattern of normal cardiac size and shape is well known. The spatial arrangements of this structural pattern is closely linked to the helical ventricular myocardial band, a myocardial fold that separates the surrounding wrap of the basal loop from the oblique fibers that form the apical loop, composed of descending and ascending segments with a spiral vortex at the apex.

Based on this structural morphology, the normal motion of the heart brings suction and ejection with apical torsion and an elliptical shape. Size and shape changes follow dilated cardiomyopathy (DCM) as the enlarged ventricle develops a spherical configuration. A postulated geometric component is spherical widening of the apical loop, whereby the architecture of the oblique apical loop fibers becomes more transverse to more closely resemble the horizontal fiber orientation of the basal loop. In end-stage DCM, the shape becomes spherical with no torsion of the LV apex.

The septal anterior ventricular exclusion (SAVE or Pacopexy) technique was developed to exclude large antero-septal akinesia and restore the shape of the LV as shown in Figure. Following initiation of cardiopulmonary bypass and blood cardioplegic heart arrest, complete coronary revascularization is performed, and mitral repair for mitral regurgitation (MR) via left atriotomy or tricuspid surgery via right atriotomy, is performed as necessary. The aortic cross-clamp is then released to allow the heart to start beating, as the SAVE operation is usually performed on the beating heart, and perfusion pressure is kept above 75 mmHg to ensure ongoing coronary perfusion.

In a study of cardioplegia in the failing heart it was found that the operation, cardioplegic delivery for protection is “time dependent” (ie, needing ischemic intervals), whereas beating nourishment is “procedure dependent” and continuous perfusion is provided throughout the procedure is suggested. The importance of maintaining high perfusion pressure is emphasized. In normal hearts, venting
and exposure ventriculotomy do not affect flow. In the failing heart decompressed by venting, coronary flow is lower during beating and cardioplegic delivery than during control conditions at the same perfusion pressure of 80 mmHg. Mean cardioplegic flow during ventricular decompression by venting exceeds beating flow by 97%. The changing ventricular shape changes coronary vascular resistance in the failing heart during beating or cardioplegic delivery. Coronary blood flow alterations occur only in the failing heart when the geometry changes from a closed to an open state. The beating method provides more endocardial flow than cardioplegic delivery during ventricular exposure for restoration. Vascular remodeling raises the coronary vascular resistance in the failing heart, thereby requiring higher pressure for similar blood flow.16

For the SAVE operation under a beating heart, the LV is opened from the apex to the base along to the left anterior descending artery. Although kinesis of the LV wall is examined preoperatively, palpation of the LV muscle during its contraction allows differentiation of akinetic and normal muscle. Multiple mattress stitches with 0-Tycron are placed along the exclusion line of the septum, proceeding from the apex to a septal site 1 cm below the aortic valve. Sutures are placed above the scar. Anterior lateral wall exclusion direction is also performed in a similar fashion using multiple mattress sutures. The Haemashield patch is trimmed to create a longitudinal shape, approximately 3×8 cm, and placed along the site of exclusion, with sutures placed 1 cm from the patch edge to leave a rim outside the sutures.

After the SAVE operation16 the conical shape is restored by inserting an oblique patch between the apex and high septum, just below the aortic valve, with subsequent closure of the excluded wall over the patch. It has been proposed that successful surgical LV restoration should restore normal helical myofiber orientation.17 The helical myofiber orientation does not change after myocardial infarction; however, aneurysm plication causes the myofibers in the anterior border zone to rotate counterclockwise (–35.6°, P<0.01) compared with isolated CABG (53.±17°). Surgical restoration alters the conical shape is restored however, increased usage of intra-aortic balloon pumping should be anticipated.

Because a preoperative LVESVI >100 ml/m² has been demonstrated to be an independent predictor of long-term mortality following isolated CABG, LV reconstruction (LVR) has been concomitantly performed in patients with a dilated LV because of ICM.21,22

In a study of 48 patients with EF <0.3 and LVESVI <100 ml/m², Cox’s proportional hazards model identified LVR and renal failure as independent factors that affected actuarial survival with odds ratios of 0.28 and 3.64, respectively (P<0.05). The 5-year actuarial survival (Kaplan-Meier) was significantly greater following LVR (90±11%) compared with isolated CABG (53±17%).

In combined LVR and CABG, the operative risk is 5–
10% hospital mortality and it is shown that the mid- or long-term results improve with LVR for ICM.

The question to be addressed is whether it is worth performing surgical ventricular restoration (SVR) in patients with ICM and akinetic, but non-aneurysmal segments, in the LV.22,23 Altogether, 237 published studies were identified and 15 presented the best evidence to answer that clinical question.23-34 The RESTORE group and others have demonstrated that in patients with ICM and an akinetic anterior ventricular wall, significant improvements in survival and symptoms can be obtained with an acceptable operative risk. Improvements in EF of 10-15% have been consistently demonstrated, with significant improvements in symptoms also. The RESTORE group’s peripertural mortality was 5.3%. Currently, 25% of US centers participating in the National Cardiac Database have performed at least 1 SVR procedure, although most only perform low numbers. In that database over the 2 years from 2002, there were 731 procedures. The mortality was 9.4% and 33% of patients suffered a major complication or death, cautioning that in the “real-world” results may not be as good as those from high-volume tertiary referral centers. Patient selection may be a reason for these differences.

At San Donato Hospital, a total of 1,161 consecutive patients (83% men, 62±10 years) had anterior SVR performed with or without CABS and with or without mitral repair/replacement. A complete echocardiographic study was performed in 488 of the 1,161 patients operated on between January 1998 and October 2005 (study group). The 30-day cardiac mortality was 4.7% (55/1161) in the overall group and 4.9% (24/488) in the study group. Determinants of hospital mortality were mitral valve regurgitation and need for a mitral valve repair/replacement. MR (>2+) associated with New York Heart Association (NYHA) class greater than II and with diastolic dysfunction (early-to-late diastolic filling pressure >2) further increases mortality risk. Long-term survival in the overall population was 63% at 120 months. Predictors of operative mortality are MR of 2+ or more, NYHA class greater than II, and diastolic dysfunction (early-to-late diastolic filling pressure >2).

In a multicenter study for LVR in ischemic DCM, 72 patients (58 males, mean age 62±10 years) underwent LVR between January 1999 and June 2007. Of them, 50 (68.5%) were in NYHA functional class III or IV and the mean LVEDVI and LVESVI was 145±43 ml/m² and 111±40 ml/m², respectively, and the EF was 25±7.4%. The 30-day mortality was 2.8%. Actuarial survival at 1, 3, and 5 years was 95.3%, 80.45% and 71.0%, respectively. Mean EF significantly improved to 39±11%, and after a mean of 3.3±2.4 years of follow-up, 90% of the survivors were in NYHA functional class I or II.

In patients with ischemia, the prognosis is associated with the presence of more than moderate MR. In ischemic DCM, the operative results are different with and without ischemic MR. In patients with MR, the prooperative status is severe and operative mortality seems to be high because of the severity of the disease and requirement for emergency operation.

Patients with ICM and MR are at an extremely high risk of death and ischemic events. In a study of 26 patients (46–80 years, mean 64 years) with a severely dilated heart (LVESVI ≥100 ml/m²) who underwent CABS (2.8±1.3), mitral valve surgery, and LVR, LVEDVI and LVESVI significantly decreased (from 169±44 to 130±41 ml/m², P = 0.0005, from 120±33 to 89±43 ml/m², P = 0.0012). LVEF showed no change. MR showed significant improvement (from 2.7±0.6 to 1.0±0.4, P = 0.0001) and NYHA functional class also improved (from 3.2±0.8 to 1.5±0.9, P = 0.0001). The 5-year survival rate was 71.2%.

When MR is associated with ICM, emergency operation is required more often and the perioperative mortality rate is high. However, aggressive combined mitral operation in addition to CABG and LVR shows improvement of both clinical symptoms and postoperative quality of life. At operation, MR usually decreases with anesthesia, so MR that is more than mild before operation should be repaired at the time of operation. Regarding mild MR, SVR improves mitral valve function by improving the geometric abnormalities and mitral repair in conjunction with SVR is therefore unnecessary in patients with ICM and mild MR.

In a series of 136 consecutive patients undergoing LVR from 1994 to 2005, the early mortality was 10/136 (7.4%). At 1, 3, 5 and 9 years, the overall actuarial survival was 89%, 80%, 68% and 62%, respectively. Increasing age, diabetes and MR of grade III–IV were associated with an increased risk of late mortality. Freedom from re-hospitalization because of heart failure or cardiac death in operative survivors at 1, 3 and 5 years were 78%, 72% and 58%, respectively. Risk factors for re-hospitalization or cardiac death in operative survivors were increasing age and increasing grade of MR.

In a study of edge-to-edge mitral valve plasty, early mortality was 5 (16%) and freedom from hospital admission or cardiac death was 56% at 1 year and 48% at 3 years. Combined mitral valve repair and SVR carries a high operative risk and long-term prognosis is worse than SVR alone. The edge-to-edge repair without annuloplasty for functional ischemic MR seems to be fairly durable in conjunction with SVR. To improve results, a transventricular annuloplasty may be added.

In a study of late results after the Dor operation (EVCPP), MR recurred after EVCPP in 17 patients among 44 operations, and 14 of them had no MR before operation. Recurrence of MR after operation caused poor late prognosis after restoration. In EVCPP, the apex was restored with circumferential direction and the dislocation of the bilateral papillary muscles was not repaired. In ICM, MR occurred because of dilatation of the mitral anulus and the tethering effect of the mitral leaflet caused by dilatation of the LV. The recurrence of MR in ICM gives a poor prognosis and based on the etiology of MR in ICM, the restoration of LV seems to also restore the tethering of the mitral leaflet by surgical reverse remodeling of the LV. MR is also repaired by papillary muscle approximation to repair the mitral tethering.

Mid-term postoperative results of repair of papillary muscle geometry and annuloplasty with a semi-rigid ring and partial resection of the dilated LV and MR included no recurrence of functional MR.

For surgical treatment of complex lesions of ICM, aggressive treatment is required and the surgical risk seems to increase; however, the long-term results are improved after aggressive surgical treatment. The indication for LVR is applied to patients even with pulmonary hypertension or severe LV dysfunction.

Non-Ischemic DCM and LVR

A Japanese nationwide study of non-ischemic DCM was conducted in 1999 to ascertain the prognosis and prognostic factors. Among the randomly selected hospitals, 147
departments participated in the 5-year follow-up survey. The vital status of 1,554 idiopathic DCM patients was collected in 2004 using medical records and residence-based registers. The crude 5-year survival rate for those diagnosed in 1998 was 78.6%. Cox’s regression model selected 5 independent predictors of mortality: male sex, higher age, higher NYHA functional class, higher LV diameter index, and lower LVEF. A predictive score using these 5 variables effectively predicted prognosis; 5-year survival rates were 90.6% in patients with a score of 4 or less and 49.0% in patients with a score of 9 or 10. It was concluded that the nationwide survey revealed the present prognostic status of non-ischemic DCM in Japan and the 5 independent predictors of prognosis could be used in clinical practice as a predictive score.

As in the high score, the prognosis of end-stage non-ischemic DCM is poor and heart transplantation or mechanical assist have been the only surgical procedures. However, the shortage of donors and the poor prognosis of mechanical assist devices means that non-transplant surgery for DCM with a non-ischemic etiology has been also reported since the 1990s. Severe MR is usually associated with end-stage non-ischemic DCM and mitral repair with 2-undersized mitral rings has been used to improve the symptoms. In a study of 41 patients with mitral valve prolapse causing MR in DCM, operative death occurred as a result of right ventricular failure. There were 10 late deaths, 2–47 months after mitral reconstruction. The 1- and 2-year actuarial survival was 82% and 71%, respectively. After a mean follow-up of 22 months, the number of hospitalizations for heart failure had decreased, and 1 patient had had heart transplantation. Significantly, NYHA class improved from 3.9±0.3 before operation to 2.0±0.6 after operation.

Isolated undersized mitral annuloplasty for severe functional MR in non-ischemic DCM for 6 patients showed no hospital deaths and improved clinical symptoms and functional MR.

Therefore, mitral repair for cardiomyopathy with MR is a new treatment strategy for these patients. However, the results are not as good as for heart transplantation. LVR is performed to decrease the diameter of the LV in patients with a severely dilated chamber. In the procedure reported as partial left ventriculotomy (PLV or Batista operation), part of the posterolateral LV muscle is resected, without any documented data of muscle viability. Therefore, although the PLV had been performed in many centers, most of them showed high hospital mortality and poor mid-term results. It has also been reported that performing the PLV did not alter the indication for heart transplantation.

Reports of the operation of PLV are as follows. In 120 patients, cardiopulmonary bypass was instituted at normothermia and a double caval cannulation procedure was performed in the beating heart except in 2 patients with aortic insufficiency who underwent cardioplectic arrest. An incision was made at the apex of the LV and extended toward the base. The inferior cavity of the LV was inspected, and the distance between the anterior and posterior papillary muscles was determined. Early in the experience, an attempt was made to preserve the papillary muscles. Mitral valve repair was performed by approximating the center of the free wedges of the mitral leaflets by a single suture of 4-0 Prolene, or most of the patients had mitral valve replacement with a tissue prosthesis. The left ventriculotomy was closed with a single layer of 1-0 Vicryl sutures, followed by a second layer of hemostatic 1-0 Vicryl sutures.

Between May 1996 and December 1998, the late effectiveness of PLV and the risk factors for failure were studied in 62 patients (95% transplant candidates) with a mean age of 54 years (range 17–72 years). All patients were in NYHA functional class III (38%) or IV (62%) because of idiopathic DCM (59 patients) or ischemic, valvular, or familial cardiomyopathy (1 patient each). PLV reduced the LV end-diastolic diameter immediately preoperatively to 18±4.1 cm to 5.92±0.8 cm (P<0.01), reduced the LVEDVI (from 133±48.6 ml to 64.1±26 ml; P<0.0001), and increased the LVEF (from 16±7.6 to 31.5±10.9; P<0.0001). Survival was 80% and 60% at 1 and 3 years after surgery and freedom from failure was 49% and 26%, respectively. Increased systolic pulmonary artery pressure, decreased maximum exercise oxygen consumption, and increased left atrial pressure were associated with failure and/or death. However, in view of its sometimes beneficial effect, the use of PLV in situations that do not allow for transplantation or as a biologic bridge to transplantation may be appropriate.

To determine the lesion of non-ischemic DCM, several methods of preoperative or intra-operative examination have been reported. Between December 1996 and July 1999, 56 patients with DCM were surgically treated. After the initial PLV in 18 patients (initial group), operative procedures were selected in 21 with PLV, five with LV plasty, or 12 with valve surgery without LV surgery according to the findings of the LV wall motion by intraoperative echogram (select group). There were six hospital deaths and late follow-up deaths within 1 year in initial group, however, the mortality decreased significantly after the selection of the operative procedures; 3 hospital deaths and 2 late deaths in the select-group (P<0.05). The survival rate improved significantly after the selection of the operative procedures; the 14-month survival rates was 50.0% in the initial group and 73.1% in the select group (P<0.05). Operative mortality decreased and late follow-up results improved after selection of the operative procedure according to the intraoperative volume reduction test.

When the lesion of the LV is detected before operation and it is located at the posterolateral wall, as seen in three muscle dystrophies, the PLV seems to be an effective procedure for non-ischemic DCM. In non-transplant surgery for non-ischemic DCM, most patients are referred for the operation at the end-stage of CHF, and the operative results are not acceptable if the patients depend on inotropic support or it is an emergency situation.

Selected ventriculoplasty in combination with mitral annuloplasty is a useful option for patients with an extremely dilated LV in idiopathic DCM. Surgery should be considered before inotropic dependency occurs when prior medical treatment has failed. The operative results improve with the selection of the procedure, with elective operation, and mitral plasty for less cardiac dilatation. The mid-term results of clinical status and LV function show the effectiveness of the operation. The anterosetal exclusion of LV restoration is effective when the lesion is anterosetal akinesis because of left anterior descending ischemia, and the PLV operation seems to be effective when the lesion is located at the posterior wall. Either the lateral wall is excluded by PLV or the SAVE or Pacopexy technique is used if the septum is primarily diseased. In the results of 107 high-risk patients (43% NYHA class III and 57% class IV) with idiopathic DCM, the overall hospital mortality was 7.1% in 84 elective operations and 60.9% in 23 emergency
Surgical Treatment for Ischemic Heart Failure (STICH) Trial

The STICH trial is ongoing. It is a National Heart, Lung, and Blood Institute-funded multicenter international randomized trial addressing 2 specific primary hypotheses: (1) CABG with intensive medical therapy improves long-term survival compared with survival with medical therapy alone, and (2) in patients with anterior LV dysfunction, SVR to a more normal LV size plus CABG improves survival free of subsequent hospitalization for cardiac cause when compared with that with CABG alone. Randomization of consenting patients with heart failure, LVEF <0.35, and coronary artery disease is based on whether patients are judged by attending physicians to be candidates only for CABG or can be treated with medical therapy without CABG. Patients eligible for SVR because of significant anterior wall akinesis or dyskinesis, but ineligible for medical therapy, are randomly assigned to CABG with or without SVR. Patients eligible for medical therapy are randomly assigned between medical therapy only and medical therapy with CABG. Patients eligible for all 3 are randomly assigned evenly to medical therapy only, medical therapy and CABG, or medical therapy and CABG and SVR. Major substudies will examine quality of life, cost-effectiveness, changes in LV volumes, effect of myocardial viability, selected biomarkers, and selected polymorphisms on treatment differences. Enrollment is now complete in both STICH hypotheses. Follow-up will continue until sufficient endpoints are available to address both hypotheses with at least 90% power. The primary outcome of hypothesis 2 is expected to be reported in 2009. The primary outcome of hypothesis 1 is expected to be reported in 2011.

Conclusions

Non-transplant surgery has been emerging as an alternative to heart transplantation. The EVCP or SAVE operation can be performed for anterosapetal lesions and the PLV can be used for the posterolateral lesion of DCM. In addition to the surgical restoration of the LV, mitral surgery is also important to improve the late recurrence of CHF. The diagnostic procedure for the lesion of DCM can provide the indication for SVR of the LV. Accumulating surgical knowledge may provide new opportunities for the treatment of DCM. In ischemic DCM, the primary outcome, whether surgical restoration improve the late symptoms or not, is expected to be reported in 2009.

References

LV Restoration


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