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Original article

Feasibility and limitations of mitral valve repair, with or without left ventricular reconstruction in non-ischemic dilated cardiomyopathy

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ABSTRACT

Background: Although non-transplant surgical interventions for non-ischemic dilated cardiomyopathy (NIDCM) are relatively effective, their feasibility and limitations have not been fully elucidated. The aim of this study was to define the feasibility and limitations of mitral valve repair, with or without surgical ventricular reconstruction for patients with NIDCM in terms of postoperative low cardiac output syndrome (LOS).

Methods: Twenty non-transplant candidates (aged 57 ± 13 years) with NIDCM and significant mitral regurgitation had undergone mitral valve repair combined with submitral procedures. Using a 72-mL plastic ellipsoidal sizer, left ventricular reconstruction was performed concomitantly in 14/20 (70%) patients with extremely large ventricles. Total stroke volume, deceleration time of early trans-mitral flow wave, and the slope (Mw) in the preload recruitable stroke-work relationship were assessed using transthoracic echocardiography. LOS was defined as in-hospital death due to heart failure or a cardiac index less than 2.2 L/min/m^2 before discharge.

Results: There were three in-hospital deaths and four patients with postoperative cardiac index less than 2.2 L/min/m^2 [n = 7 (35%), LOS group]. Preoperative total stroke volume, deceleration time, and the Mw were significantly lower in the LOS group compared to those in the non-LOS group; the predicted cut-off values for LOS were 84 mL/beat (p = 0.008), 133 ms (p = 0.015), and 45 erg cm^{-3} × 10^3 (p = 0.036), respectively. Preoperative left ventricular ejection fraction and ventricular size could not predict postoperative LOS. The one-year survival rate was 0% in the LOS group and 84% in the non-LOS group ($p < 0.001$).

Conclusions: Mitral valve repair, with or without left ventricular reconstruction, could be contraindicated for NIDCM patients with low total stroke volume, deceleration time, and Mw in terms of high postoperative incidence of LOS. For high-risk patients, other therapeutic strategies might be necessary.

Introduction

Although the definitive therapy for non-ischemic dilated cardiomyopathy (NIDCM) patients with end-stage heart failure is heart transplantation, the number of transplantations is still limited in Japan. Non-transplant surgical interventions including mitral valve repair and left ventricular reconstruction for NIDCM are sometimes effective [1,2], but their feasibility and limitations have not yet been elucidated.

Mitral valve repair for patients with secondary severe mitral regurgitation (MR) and low left ventricular ejection fraction (LVEF), less than 30%, is still not a gold standard (class IIb) [3]. The elimination of MR increases the left ventricular (LV) afterload and may induce low cardiac output syndrome (LOS) after surgery. However, recent favorable results with MitraClip (Abbott, Menlo Park, CA, USA) [4] and other minimally invasive therapies [5,6] for functional MR underscore the impact of interventions to the mitral

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valve, even when the LVEF is relatively low. On the other hand, there is a report of ineffectiveness (high early mortality) of MitraClip in patients with end-stage heart failure [7]. Furthermore, there is no contractile functional parameter that can predict postoperative LOS.

Within a decade, we have performed mitral valve repairs, with or without LV reconstruction, for NIDCM patients who were not candidates for transplantation. The aim of this study was to determine the feasibility and limitations of this surgery for NIDCM patients in terms of postoperative LOS predicted by preoperative contractile functional parameters.

Materials and methods

Subjects

This retrospective longitudinal, observational study was performed at a single center (Hokkaido University Hospital). Initially, 23 patients with NIDCM who had undergone surgery between 2006 and 2013 were potentially eligible for the study. None of the patients had registered for heart transplantation due to old age and/or their personal refusal. Mitral repair was indicated for those with severe functional MR and heart failure symptoms refractory to medications (class IIb in European Society of Cardiology guidelines) [3]. We regarded patients as inoperable when they had severe organ failure due to LOS before surgery (total bilirubin > 3.0 mg/dl and serum creatinine > 3.0 mg/dl). We did not take LVEF into consideration for the decision making. All the patients were consulted for surgical intervention by local cardiologists or those at the University Hospital. The exclusion criteria were emergent surgeries and non-applicability to comprehensive echocardiographic parameters. After implementation of the exclusion criteria, 20 patients were selected. The University Ethics Committee approved of the research protocol and waived the informed consent requirements for the study.

Surgical procedures

Mitral valve annuloplasty, papillary muscle approximation, and suspension (mitral complex reconstruction) were performed for all the patients: (1) The papillary muscles were approximated side-by-side from the bases to the heads using three pledgeted mattress sutures; (2) A CV-4 ePTFE suture was placed between the site of the chordal attachment of the approximated papillary muscles and the anterior mitral annulus. This suture was then passed through the true-sized semi-rigid total annuloplasty ring [8].

Overlapping left ventriculoplasty was also performed when the LV end-diastolic dimension was greater than 75 mm [9]. A 72-mL plastic ellipsoidal sizer (minimum ventricular size) was inserted into the LV to remodel an ellipsoidal shape. The lateral wall was sutured onto the deep septal wall using 3-0 polypropylene sutures with large specially designed curved needles. The medial wall was then overlapped onto the lateral wall using interrupted 4-0 polypropylene sutures.

The mean semi-rigid total ring size was 28 ± 2 mm. LV reconstruction was conducted in 14/20 (70%) (overlapping left ventriculoplasty – 13; Batista type – one). Tricuspid ring annuloplasty was performed for all the patients and MAZE procedure for 8/20 (40%) (chronic atrial fibrillation – seven; paroxysmal atrial fibrillation – one). Cardiopulmonary bypass and aortic cross clamp time were 228 ± 61 min and 112 ± 24 min, respectively. Intra-aortic balloon pumping was performed preoperatively for 2/20 (10%) and intraoperatively for 5/20 (25%) patients. Histological examination using LV muscle obtained during surgery was performed in 14/20 patients. We introduced a semiquantitative, visual evaluation of the grade of interstitial fibrosis as follows: 0, absent; 1, mild; 2, moderate; 3, severe).

Transthoracic echocardiography

We used a Sonos 5500 ultrasound system (Philips Medical Systems, Andover, MA, USA) with a 3S transducer (3–5 MHz), a Vivid Seven system (GE/Vingmed, Milwaukee, WI, USA) with an M3S (2.5–3.5 MHz) transducer, or an Aplio system (Toshiba Medical Systems, Tokyo, Japan) with a 2.5 MHz transducer. LV end-diastolic (LVDd) and end-systolic (LVDs) dimensions (mm), interventricular septal thickness (IVST), and LV posterior wall thickness (LVPWT) (mm) were measured from the parasternal long-axis view. The MR volume and grade were determined by the volumetric method (1 – mild; 2 – mild-to-moderate; 3 – moderate-to-severe; 4 – severe [10]). The forward stroke volume was calculated using pulse wave Doppler at the LV outflow tract. The total stroke volume was calculated as follows: forward stroke volume + MR volume (mL). The LV end-diastolic volume (EDV), end-systolic volume (ESV), and LVEF were measured using the modified Simpson method. Deceleration time was determined as the duration from the peak to baseline of the early LV filling velocity (E-wave). Short deceleration time reflects operative ventricular stiffness [11].

The slope (Mw) in preload recruitable stroke work (PRSW) relationship – a relatively load-independent parameter of contractile function was estimated from a formula according to Lee et al.: $\mathrm{Mw} = (\text{total stroke work})/[\mathrm{EDV} - k \times \mathrm{EDV} + (1-k) \times \text{LV wall}]$ ($\mathrm{erg\,cm^{-3}} \times 10^3$) [12,13]. EDV was derived from the total stroke volume and LVEF. LV wall was estimated by the echocardiography-derived LV mass. Constant k was calculated as follows: $k = 0.0004 \times \text{LV mass} + 0.6408$ [13]. The total stroke work was calculated as follows: $(\text{total stroke volume}) \times (\mathrm{SBP} - \mathrm{LAP})$ (mL mmHg), where SBP and LAP indicate systolic blood pressure and left atrial pressure, respectively [14]. LAP was derived from continuous wave Doppler of the MR jet as follows: (systolic blood pressure) − (peak pressure gradient of the wave) (mmHg) [15]. The single-beat technique for Mw has been reported to closely match that by the invasive catheter method for different LV sizes, LV mass, and the presence of regional wall motion abnormalities [13]. All the specialized examiners were mutually blinded for this study.

Validation of functional parameters in patients registered for heart transplantation

In order to examine whether the contractile functional parameters can predict prognosis also in patients without valve surgery, we analyzed them in NIDCM patients who were newly registered for heart transplantation from 2013 to 2016 in our hospital. Those patients with less than moderate MR and catecholamine infusion at registration were excluded from the analysis. A total 9 out of 23 patients were finally analyzed. Using the parameters detected in the surgical group, Cox regression analysis was performed to examine the prediction of LV assist device implantation.

Statistical analysis

All the data were represented as mean ± standard deviation. Statistical analysis was performed with SPSS version 17.0 software (SPSS Inc., Chicago, IL, USA). Categorical data were compared using Fisher's exact test. The Mann–Whitney *U*-test was used to compare the continuous variables between the groups and Wilcoxon test to compare the pre- and post-operative values. Postoperative LOS was defined as either in-hospital death due to heart failure or cardiac index less than $2.2\,\mathrm{L/min/m^2}$ before discharge (39 ± 30 days after surgery). The receiver operating characteristic (ROC) curve was used to analyze the sensitivity and specificity of the parameters for detecting postoperative LOS. We selected the cut-off values that maximized sensitivity plus specificity. The area under the curve (AUC) was used to compare

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