Ischemic Mitral Regurgitation

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Ischemic mitral regurgitation (MR) is defined as functional MR caused by myocardial ischemia. Apical and posterior displacement of papillary muscles, referred to as tethering, positively correlates with maximal regurgitation area. Surgical intervention for patients with moderately ischemic MR at the time of coronary artery bypass (CABG) remains controversial. However, patients with uncorrected mild or moderate MR who undergo CABG are at increased risk of death and hospitalization. Restrictive MV annuloplasty and coronary artery bypass surgery has become accepted as the standard technique for severe functional MR. However, even after downsizing simple annuloplasty by two sizes, MR persists or recurs in >20% of patient. Furthermore, recurrent and progressive MR after MV plasty is associated with high mortality rates. Predictors for recurrent mitral regurgitation are flexible ring usage, left ventricle diameter, continuous LV remodeling, sphericity index at end-systole and end-diastole, and preoperative posterior leaflet angle >45°. Second chordal cutting, papillary muscle approximation and so on are recommended as additional procedures. Whether to replace or repair severe chronic ischemic MV regurgitation has remained controversial. Replacement results in long-term secure MV sufficiency, whereas mitral repair still confers some risk of MR recurrence. Percutaneous MV repair using the MitraClip procedure can offer clinical improvement even in patients with high surgical risk and severe functional MR. The long-term outcomes of the this procedure should be determined. Ischemic MR remains a significant complication of myocardial infarction, and deeper understanding of the mechanism of ischemic MR has led to continuous improvements in surgical treatment. Complex mechanisms involving the mitral annulus, chordae tendineae, papillary muscle, and LV are involved, and optimal surgical repair should consider the overall pathology of each patient.

KEY WORDS: functional mitral regurgitation, ischemic mitral regurgitation, left ventricular remodeling, papillary muscle, tethering

I. Definition and mechanism of ischemic mitral regurgitation

Ischemic mitral regurgitation (MR) is defined as functional MR caused by myocardial ischemia including myocardial infarction and ischemic cardiomyopathy that results in disturbed left ventricular (LV) geometry. It does not usually coexist with rheumatic heart valve disease, degenerative disease, or congenital defect of the mitral valve (MV)¹⁾ and is associated with excess mortality independently of baseline characteristics and the severity of ventricular dysfunction²⁾. The mechanism of regurgitation is independently multifactorial, including LV dilation, LV sphericity, apical and posterior displacement of the papillary muscle, and LV function. Apical and posterior displacement, referred to as tethering, positively correlates with maximal regurgitation area^{1,3)}.

II. Moderate mitral regurgitation at coronary artery bypass surgery

That severe ischemic MR should be corrected has reached consensus among surgeons and physicians, but surgical intervention for patients with moderately ischemic MR at the time of coronary artery bypass (CABG) remains controversial. However, a comparison of long-term results after CABG according to MR grade evaluated by intraoperative TEE⁴⁾ found that even mild MR predicts worse outcomes after CABG. The report of that study emphasized that patients with uncorrected mild or moderate MR who undergo CABG are at increased risk of death and hospitalization for heart failure, leading to consideration for further surgical repair or more aggressive medical management. Others have also found that even preoperative moderate grade of MR that improves immediately after CABG worsens during the late phase^{5,6)}.

On the other hand, preoperative moderate ischemic MR can be relieved by off-pump CABG in selected patients⁷⁾. The predictors are ejection fraction >37.1%, posteroinferior volume ra-

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tio >31.6%, and surgery <3 months after myocardial infarction. Penicka et al. also found that moderate MR improved after isolated CABG only if patients had concomitant viable myocardium and no dyssynchrony between papillary muscles⁸⁾. Fattouch et al. concluded that papillary muscle relocation plus nonrestrictive mitral annuloplasty at the time of CABG might promote a significant reversal in LV remodeling, with a considerable decrease in the tenting area and coaptation depth⁹⁾. Chan et al. concluded from the randomized control RIMA study that adding mitral annuloplasty to CABG for patients with moderately ischemic MR might improve functional capacity, LV reverse remodeling, MR severity, and B-type natriuretic peptide values more effectively than CABG alone¹⁰⁾. Bouchard et al. concluded from another randomized control study that although initially effective at reducing moderate functional ischemic MR, adding a ring did not change the clinical course after CABG surgery and an echocardiographic difference was not identified in terms of residual mitral regurgitation, LV dimensions and function, or clinical outcomes at 12 months¹¹⁾.

In contrast, Kang et al. did not find any difference between additional MV repair and CABG alone, and considered that the latter might be a preferable treatment option for patients with moderate MR and high operative risk factors such as advanced age or atrial fibrillation¹²⁾. Altarabsheh et al. concluded from a systemic review and meta-analysis that concomitant repair of moderate ischemic MR leads to improved MV competence at follow-up, whereas adding valve repair to CABG did not translate into a functional or survival benefit at five years of follow-up¹³⁾. Another study showed that adding repair or replacement to CABG in patients with moderately ischemic MR did not result in improved early or overall mortality, stroke risk, or intermediate markers of LV function compared with CABG alone¹⁴⁾.

III. How and what to repair

Although the methods of treating degenerative MV disease have reached general consensus, the management of ischemic MR remains controversial. Restrictive MV annuloplasty and coronary artery bypass surgery, which had mostly been applied to treat cardiomyopathy, has become accepted as the standard technique for functional MR¹⁵⁾. However, even after downsizing simple annuloplasty by two sizes, MR persists or recurs in >20% of patients¹⁶⁾. Furthermore, recurrent and progressive MR after MV plasty is associated with high mortality rates. Crabtree et al. found better long-term survival rates after MV repair among patients with 0 to 2+ than 3+ to 4+ MR. However, MR progresses despite repair in many patients and it is associated with poorer survival rates¹⁷⁾.

IV. Predictors of MR recurrence

1. Flexible versus rigid rings

Ischemic MR can be corrected in selected patients using restrictive annuloplasty with either flexible or rigid annular rings. Flexible rings are associated with an increased likelihood of MR recurrence that will require reoperation, whereas rigid rings appear to significantly reduce the need for repeat surgical procedures^{18, 19)}.

2. LV dysfunction

Braun et al. compared long-term outcomes according to LV diameter cutoff. They concluded that intermediate-term cutoff values for LV reverse remodeling at 4.3 years of follow-up were predictors of later mortality. Restrictive mitral annuloplasty with revascularization for patients with preoperative LV end diastolic diameter ≤ 65 mm can cure ischemic mitral regurgitation and heart failure²⁰⁾.

3. Continuous LV remodeling

Hung reviewed serial echoes in 30 patients with recurrent MR versus early after ring annuloplasty (RA) for ischemic MR²¹⁾. That review showed that even if ischemic MR is corrected immediately after mitral ring repair, LV remodeling, that is, progression with increasing LV volume and sphericity index at end-systole and end-diastole, continues. Kuwahara et al. investigated the characteristics of leaflet configurations long after postoperative MR in 30 patients who underwent annuloplasty for ischemic MR²²⁾. They found significantly worse posterior than anterior tethering of mitral leaflets soon after surgery. In addition, posterior tethering became progressively worse in patients with late MR recurrence. Magne showed that patients with a preoperative posterior leaflet angle $>45^\circ$ should be considered poor candidates for RA²³⁾.

V. Additional procedures

1. Second chordal cutting

Messas showed that second-order strut chordae that insert symmetrically into the central ventricular surfaces of both leaflets pull the leaflets down into the ventricle with considerable leaflet distortion that resembles the shape of a seagull. They showed that cutting secondary chordae limits progressive increases in LV volume^{24–26)}. Borger et al. reported clinical findings showing that cutting the chordae improves the mobility of MV leaflets and reduces mitral regurgitation recurrence without obvious deleterious effects on LV function²⁷⁾. Calafiore et al. reported that cutting the chordae is related to lower incidence of MR return or persistence, improved EF, and a lower New York Heart Association class in selected patients with an anterior leaflet angle $>145^\circ$ and a coaptation depth <10 mm²⁸⁾.

2. Papillary muscle approximation

Hvass et al. developed a new functional approach to mitral repair for ischemic LV dysfunction and functional MR. They described that the position of the anterior papillary muscle (PM) is usually normal, whereas the posterior PM is dislocated medially. Passing a 4-mm Gore-Tex tube around both PM causes the posterior PM to become closer to the anterior PM. Postoperative echocardiography revealed that the tenting effect decreased from 14 to 1.4 mm²⁹⁾. Rama et al. also described a similar technique³⁰⁾. Kron relocated the posterior PM close to the posterior annulus for effective coaptation of the leaflet³¹⁾. Langer and Arai et al. changed the relocation direction towards the anterior annulus^{32, 33)} and Nappi et al. concluded that RA + papillary muscle approximation exerted a long-term beneficial effect on LV remodeling and more effectively restored the MV geometric configuration compared with RA alone, but overall mortality and quality of life did not significantly differ between the two procedures³⁴⁾.

VI. MVR or MVP or MitraClip

Whether to replace or repair severe chronic ischemic MV regurgitation has remained controversial. Replacement results in long-term secure MV sufficiency, whereas mitral repair still confers some risk of MR recurrence. Although surgical techniques for MV repair have evolved as noted above, continuous LV remodeling resulting in recurrent valve incompetence has remained a major downside of this approach. The tradeoff is between the durability of MV repair to correct a regurgitant valve and the adverse consequences of prosthetic valve insertion. Lorusso et al. concluded that MV replacement is a suitable option for patients with chronic ischemic MR and impaired LV function. This strategy provides better outcomes in terms of freedom from reoperation with comparable valve-related complication rates. However, MV repair remains the most powerful predictor of a need for MV re-operation^{35, 36)}. The randomized CSTN trial found that mid-term survival and LV reverse remodeling did not significantly differ between restrictive annuloplasty repair and chordal-sparing valve replacement in patients with severely ischemic MR, but the incidence of recurrent MR and heart failure complications was greater after repair³⁷⁾. Matsui proposed that MV replacement preservation and further approximation of the PM might be more effective³⁸⁾.

1. MitraClip procedure

Percutaneous MV repair using the MitraClip procedure can offer clinical improvement even in patients with high surgical risk and severe functional MR. Giannini et al. assessed the survival rates and clinical outcomes of severely ischemic MR after optimal medical therapy (OMT) compared with those treated with a MitraClip. They demonstrated better overall survival as well as freedom from cardiac death and readmission due to car-

diac disease when patients were treated with this device than with OMT³⁹⁾. Mendirichaga et al. reviewed 12 studies including 1,695 patients with moderate or severe functional MR and high surgical risk. The rate of mitral reintervention at 12 months was 3%, indicating the feasibility and safety of transcatheter MV treatment using a MitraClip⁴⁰⁾. The long-term outcomes of the MitraClip procedure should be determined.

VII. Conclusions

Ischemic MR remains a significant complication of myocardial infarction, and deeper understanding of the mechanism of ischemic MR has led to continuous improvements in surgical treatment. Complex mechanisms involving the mitral annulus, chordae tendineae, papillary muscle, and LV are involved, and optimal surgical repair should consider the overall pathology of each patient. Repair or replacement, as well as whether moderate ischemic MR should be addressed by coronary revascularization alone at the time of CABG and the type of subvalvular manipulation remain matters of debate.

Conflicts of interest

None.

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