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Original Article

The Kay Mitral Valve Repair in Coronary Artery Disease Concomitant With Ischemic Mitral Regurgitation

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ABSTRACT

Background: Ischemic mitral regurgitation is a major source of morbidity and mortality of myocardial infarction. Surgical intervention for significant ischemic mitral regurgitation at the time of coronary artery bypass grafting (CABG) is controversial and has always presented a great challenge. The purpose of this study was to describe the current surgical options for ischemic mitral incompetency and to discuss when mitral valve repair via the Kay method may be favored over mitral valve replacement.

Methods: Twelve patients candidated for the Kay mitral valve repair plus CABG were recruited. The efficacy of mitral valve repair was echocardiographically recorded at follow-up. To validate the diagnosis of ischemic mitral regurgitation, we conducted a detailed chart review—which included all preoperative cardiac imaging tests at the first, sixth, and 12th postoperative months, as well as the operative records and pathology reports.

Results: Twelve patients (5 male and 7 female) underwent CABG plus the Kay mitral valve repair. All the patients had significant mitral valve incompetency, which was resolved in all of them ($P<0.05$). There was no preoperative or postoperative mortality. No further postoperative mortality was reported at 1 year's follow-up. The Kay technique for mitral valve repair had a desirable result insofar as 8 (72.7%) patients had only mild mitral regurgitation and 4 (33.3%) had mild-to-moderate mitral regurgitation.

Conclusions: In the current era and in Iran, mitral valve repair—especially via the Kay method—has been proven to confer improved short and long-term survival, decreased valve-related morbidity, and enhanced left ventricular function. Future randomized prospective clinical trials are needed to compare this cost-effective surgical technique with its counterparts. ***(Iranian heart Journal 2018; 19(3): 6- 14)***

KEYWORDS: Mitral regurgitation, Coronary artery bypass graft (CABG), Mitral valve repair, Kay method

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Mitral valve incompetency coexisting with coronary artery disease is termed "ischemic mitral regurgitation (IMR)" and is seen in 10% to 25% of patients candidated for coronary artery bypass grafting (CABG). [1-3] Of these patients, 3.4% have severe types of IMR. MR is one of the most common valvular pathologies, and its prevalence has risen in recent years. [4, 5] MR has various mechanisms and etiologies. The classifications of MR which are based on etiologies consist of ischemic and non-ischemic types, while the classifications based on mechanisms comprise functional and non-functional or structural. The Carpentier classification for IMR is an acceptable way the world over for a better understanding of the mechanisms of IMR. In Class I, the mechanism of IMR is only the dilation of the mitral annulus; in Class II, the etiology is the rupture of the papillary muscles and the chordae tendineae; and in Class III, the mechanism is the tethering of the posterior papillary muscles. [6, 7, 12, 13] Despite the consensus among most cardiac surgeons as to the need for intervention for the mitral valve pathology in cases of severe mitral valve incompetency, the clinical presentations of ischemic mitral incompetency in acute and chronic settings are different. Acute mitral valve incompetency, which is usually seen after acute myocardial infarction, has the symptoms and signs of acute heart failure and cardiogenic shock, while subgroups of patients with chronic mitral incompetency in the Carpentier functional Classes II and III have exertional and resting dyspnea. Patients with acute MR usually have pulmonary edema, systemic hypotension, and poor peripheral perfusion. [8] On the other hand, patients with chronic MR suffer from the symptoms and signs of chronic heart failure with variable degrees of chest pain from coexisting coronary artery disease. [8] Transthoracic echocardiography and transesophageal echocardiography are both useful studies for the evaluation of the degree of mitral valve insufficiency and its main mechanism, especially vis-à-vis the size of the annulus and the morphology of the leaflets. The information gained via echocardiography helps assess the feasibility of the repair of the incompetent valve or the replacement of the diseased mitral valve. [6]

When it comes to CABG, there is a great deal of controversy regarding the optimal management of cases with mild-to-moderate IMR. [9, 10] The options in such patients with IMR vary from no intervention on the mitral valve to some types of mitral valve repair and finally mitral valve replacement. [10] Some of the authors who do not believe in the need for intervention in cases with moderate IMR argue that after complete revascularization with CABG alone and the reverse remodeling of the left ventricle, the severity of IMR steadily diminishes. [10]

In light of the abovementioned reports, in the present study, we sought to describe the current surgical options for ischemic mitral incompetency and to discuss when mitral valve repair via the Kay method may be favored over mitral valve replacement repair.

METHODS

Twelve patients who were known cases of coronary artery disease concomitant with significant IMR were recruited in the current study. All the patients were operated on by a single surgical team. After sternotomy and conduit harvesting, the cannulation of the aorta and the cava was performed and cardiopulmonary bypass was initiated. After the insertion of the graft on the desirable and targeted coronary artery, the left atrium was opened. Following the evaluation of the mechanism of MR and the possibility of mitral valve repair, repair via the Kay technique was performed. With the completion of the procedure and the weaning of the patients from cardiopulmonary bypass, intraoperative transesophageal echocardiography was

conducted to confirm the efficacy of the mitral valve repair. Follow-up echocardiography was performed at discharge and thereafter at the third and 12th postoperative months for the assessment of the mitral valve function.

RESULTS

The study population was comprised of 5 male (41.7%) and 7 female (58.7%) patients at an average age of 60.5±8.27 years. The patients' demographic data and risk factors were evaluated. Diabetes mellitus was reported in 5 (41.7%) patients, hypertension in 6 (50%), hyperlipidemia in 9 (75%), and hypothyroidism in 1 (8.3%). A history of smoking was reported in 2 (16.7%) patients and addiction in 1 (8.3%). Nine (75%) patients had a history of myocardial infarction (6 patients with inferior myocardial infarction). The angiographic data showed triple-vessel disease in 11 (91.7%) cases and double-vessel disease in 1 (8.3%). The ejection fraction index was 32.91±8.11% preoperatively and 42.5±7.54% postoperatively (*P*=0.0001). The mean cardiopulmonary bypass time in the Kay repair was 150.25 minutes (± 30.34 min). The mean length of stay at the intensive care unit was 2.50±0.8 days, and the mean length of hospital stay was 6.17±1.89 days. The severity of MR before and after the Kay procedure is depicted in Table 1.

Table 1. Severity of mitral regurgitation before and after the Kay procedure

	Preoperative = 12		Postoperative = 11		*P*
	No.	%	No.	%	
Severity of Mitral Regurgitation					
Mild	0	0%	8	72.7	0.003
Mild to moderate	0	0%	4	33/3	
Moderate to severe	6	50%	0%	0%	
Severe	6	50%	0%	0%	

DISCUSSION

Surgical intervention for significant IMR at the time of CABG is controversial and has always presented great challenges. Different options range from CABG without any intervention on the mitral valve to various types of mitral valve repair and ultimately mitral valve replacement.[10, 11] The etiology of ischemic mitral incompetency can be based on the Carpentier classification with respect to the main cause of the IMR: Type I: normal leaflet motion with annular dilation; Type II: leaflet prolapse with chordal rupture or chordal elongation or papillary muscle rupture or papillary muscle elongation; and Type III: restricted leaflet motion—divided into Type IIIa (during diastole) and Type IIIb (during systole). [12, 13]

The first and foremost question is which cases of IMR concomitant with CABG necessitate mitral valve intervention, however.Aklog et al[14] studied patients suffering from moderate IMR and found that CABG alone could be sufficient in moderate IMR inasmuch as the severity of MR showed a steady decline at follow-up. In other studies on valvular intervention for significant IMR, the results of mitral valve repair were compared with those of mitral valve replacement. In most of these studies, [15-18] for instance that by Al-Radi et al, [15] the results of short- and long-term mitral valve repair were better than those of mitral valve replacement in that the former modality obviated the need for long-time anticoagulation therapy and also conferred a better quality of life. Concomitant intervention for mitral valve incompetency with CABG is associated with a higher mortality rate than with CABG alone. [18] Despite the agreement among almost all cardiac surgeons that mild IMR requires no intervention, in cases of severe IMR, the correction of the incompetent valve is usually necessary. On the other hand, in the subgroup of coronary artery

disease and moderate IMR, controversy abounds. [18] A consensus has yet to emerge as to what constitutes the best management for moderate IMR. At the time of revascularization, some parameters such as long-time survival, the left ventricular ejection fraction index, and the left ventricular diameter for the repair of the mitral valve are of great significance. [19] In patients suffering from IMR, some types of mitral valve repair such as those involving the use of rigid rings, semi-rigid rings, and flexible rings, as well as those entailing the reconstruction of the papillary muscles with new chordae are performed. The advantages of mitral valve repair over mitral valve replacement are clear in that the former modality obviates the need for the long- time use of anticoagulation and confers a better quality of life. However, in some cases of IMR, the cardiac surgeon has options with regard to the repair of the mitral valve depending on the subtype of the IMR and the size of the annulus of the mitral valve. [17-20] In IMR cases in which the main etiology of the regurgitation is the dilation of the mitral annulus, the most common technique for the reduction of the diameter is the use of a designed ring. An increase in the distance between both fibrous trigones in IMR results in the enlargement of the mitral annulus, for which most surgeons prefer rigid or semi-rigid rings. [20] Some cardiac surgeons tend to draw upon the suture annuloplasty technique for the reduction of the mitral valve annulus. Ring annuloplasty is one of these techniques that use non-absorbable suture in both commissural regions to correct the dilation of the mitral valve annulus. In the past, suture annuloplasty was used for the correction of some types of MR in the pediatric group; recently, however, suture annuloplasty in commissural regions has been used successfully for the correction of IMR. [16, 23, 24] In 1963, Kay and Egerton reported on the surgical treatment of 10 patients with ruptured chordae tendineae. Since then, 22 patients—including the aforementioned cases—have undergone surgery for this entity. [23, 24]

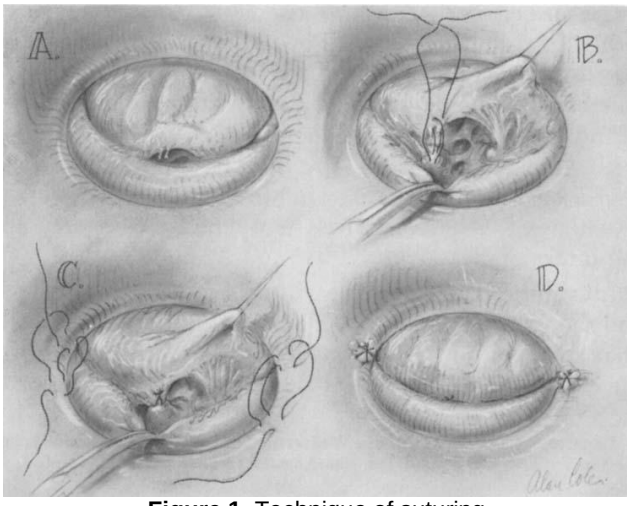

Figure 1. Technique of suturing

The involved area of the valve is sutured down to the nearer papillary muscle with 2 or 3 figure-of-eight sutures of nylon 2-0 (Fig. 1). All the sutures are placed before any of them is tied; otherwise, the papillary muscle is obscured from vision. Good bites of the valve and the papillary muscle are thereafter taken. It should be stressed that new chordae tendineae are not constructed with the sutures; instead, the involved area of the valve with the torn chordae tendineae is sutured to the top of the nearer papillary muscle. The sutures are subsequently tied snugly. This technique is possible because the mural and aortic leaflets are redundant. When the annulus is greatly dilated, a posterior–medial annuloplasty is performed. The annulus of the mural leaflet is decreased without encroaching on the annulus of the aortic leaflet area. Two or 3 figure-of-eight sutures of Ethibond 2 or nylon are placed at this area before tying. The sutures are pulled taut, and if the valve appears competent and the annulus admits 2 fingers, no more sutures are placed and the previously placed sutures are tied. Sometimes, it may be necessary to place sutures at the anterolateral commissure. Again these sutures must be placed to encroach on the annulus of the mural leaflet area and not the annulus of the aortic leaflet area. In repairing the valve, it is necessary not only to correct the tear but also to narrow the annulus. In these

patients, the repair of the valve can usually be accomplished as it can in those patients with annular dilatation unassociated with torn chordae tendineae. [24]

In some of these patients, the severity of valve regurgitation after CABG alone is constant or decreasing, whereas in some other patients without valve intervention at the time of CABG, the degree of MR worsens steadily. [21] Notably, these patients suffer from exertional and resting dyspnea, pulmonary congestion, and edema from mitral valve regurgitation. Ultimately, some of these patients need redo surgery for the repair or the replacement of the regurgitate valve with the risk of the reopening of the sternum in cases of recent CABG with patent grafts at risk of damage. Accordingly, careful and precise management in patients with coronary artery disease concomitant with ischemic mitral incompetency is of vital importance and decision must be made on a case-by-case basis. Moreover, sufficient attention must be paid to several factors like age, the severity of the MR, the presence of acute or chronic MR, and the mechanism and pathophysiology of the MR. There is substantial evidence that patients who have residual significant MR after CABG have lesser survival and quality of life and may, thus, need hospital admission after the primary surgery. [22]

Today, at the time of surgery on patients with IMR, most referral centers believe that for an MR greater than moderate, some type of mitral valve repair should be considered. [19, 26]

Mitral valve reconstructive surgery has been established as the treatment of choice in patients with a favorable anatomy. Long-term follow-up has shown favorable survival rates; low incidence rates of thromboembolism, endocarditis, and neurological events; a low need for mitral valve-related reoperations; and favorable ventricular functions after valve repair by comparison with valve replacement. [25]

No-ring mitral valve repair by shortening the posterior annulus through pericardial strip augmentation to address the lack of leaflet coaptation is a simple reproducible and highly effective technique to restore valve competence in ischemic myocardial infarction. [27, 28]

CABG is most effective in the treatment of functional IMR in patients with viable myocardium (at least 5 viable segments) and the absence of dyssynchrony between the papillary muscles (<60 ms).

Apropos of mitral valve ring annuloplasty, there is a vast array of designs with variations over the theme of complete/partial and rigid/semi-rigid/flexible. Additionally, the 3D shape of rigid and semi-rigid rings is the subject of great variation. A rigid or semi-rigid downsized mitral valve ring annuloplasty is the most advocated treatment in chronic functional IMR of grade 2+ or higher.

As regards CABG combined with mitral valve ring annuloplasty, it should be noted that this procedure can lead to reverse left ventricular remodeling and reduced volumes. Nonetheless, the recurrence rate following CABG combined with mitral valve ring annuloplasty is between 20% and 30% at 2 to 4 years' follow-up. This is also true for studies strictly using downsized mitral valve ring annuloplasty in 2 sizes. A number of preoperative risk factors for the development of recurrent functional IMR have been identified; they include a left ventricular end-diastolic dimension of between 65 and 70 mm, a coaptation depth of greater than 10 mm, an anterior leaflet angle of greater than 27° to 39.5°, a posterior leaflet angle of greater than 45°, and an interpapillary muscle distance of greater than 20 mm.

In regard to CABG alone in comparison with CABG combined with mitral valve ring annuloplasty, the available literature includes 3 randomized studies and a meta-analysis, which indicate that CABG in combination with mitral valve ring annuloplasty has no late survival difference compared with CABG alone, and early mortality might even be higher. Meanwhile, adding mitral valve ring annuloplasty results in a lower New York Heart

Association functional class—most likely as a consequence of a lower incidence rate of persistent or recurrent functional IMR. More randomized studies are underway to further address this topic.

Concerning mitral valve ring annuloplasty in comparison with mitral valve replacement, research shows that the early survival may be higher in the former modality. Nonetheless, the literature is more ambiguous in terms of late survival advantages, with the recent reports having found no late survival advantage from repair over replacement. The recurrence of functional IMR after ring annuloplasty—which was addressed above—was also present in this subset of patients, whereas the incidence of recurrent functional IMR after valve replacement has been scarcely reported. There was an overall tendency of a slightly higher incidence rate of reoperations after ring annuloplasty.

The latest innovation in the design of mitral valve ring annuloplasty includes adjustable rings, allowing the adjustment of septolateral dimensions intra- or postoperatively. Additionally, first in man testing of direct percutaneous catheter-based mitral annuloplasty techniques, both the Alfieri stitch and the minimally invasive MitraClip attach the anterior and posterior leaflets—typically the A2–P2 region—to correct incomplete leaflet coaptation. Patch augmentation of the posterior leaflet in the P2–P3 region increases coaptation in the area most prone to cause functional IMR. Choral cutting of the secondary "strut" chordae releases the anterior leaflet from the tethering due to papillary muscle displacement and improves mitral valve geometry.

Numerous subvalvular approaches to improving the outcome in patients with functional IMR have been introduced; they include very invasive techniques such as surgical ventricular restoration, surgical techniques directly addressing the papillary muscle displacement, and beating-heart procedures with transventricular and epicardial devices applied within a few minutes. The role of transventricular and epicardial devices still remains to be defined, and many of these devices appear to have a hard time gaining a footing in the clinical practice. Meanwhile, the current results with adjunct techniques to CABG and ring annuloplasty such as the papillary muscle approximation technique introduced by Hvass et al and the papillary muscle relocation technique introduced by Kron et al and further developed by Langer et al are gaining continuing support in the surgical community since these techniques can be used with only a little added time but with very good clinical outcomes. [29]

In relation to surgical relocation and papillary muscle sling, research shows improved outcomes in terms of postoperative positive left ventricular remodeling and the recurrence of MR. [30] Still, more investigations are required to confirm the efficacy of subvalvular apparatus surgery. The application of finite element analysis to improve preoperative and intraoperative planning and to achieve a correct and durable repair by means of subvalvular surgery is an exciting new avenue in IMR research. We recently demonstrated in a randomized clinical trial (the Papillary Muscle Approximation Trial) the superiority of papillary muscle approximation in combination with standard restrictive annuloplasty in severe IMR over annuloplasty alone in terms of adverse left ventricular remodeling and MR recurrence.

Papillary muscle displacement is an important element in the pathogenesis of IMR. Preoperative symmetric and asymmetric tethering and isolated inferior wall dyskinesia are an indication for subvalvular apparatus surgery in IMR. [31] Suture annuloplasty can correct ischemia-induced end-systolic distortions in the entire valvular–ventricular complex (ie, inter-leaflet separation, mitral annular dilatation in both axes, and papillary muscle displacement) and abolish acute IMR, independent of any change in the end-systolic

volume. A better understanding of the effects of annular reduction on the papillary muscle geometry may lead to improved subvalvular mitral repair techniques (the Kay method repair). [32]

The Kay method repair is normally achieved by downsizing the mitral valve annulus with suturing and finite element analysis to improve preoperative and intraoperative planning and to achieve a correct and durable repair via subvalvular surgery. [33, 34]

The symmetry of mitral valve tethering and regional left ventricular wall dysfunction have been reported to play a fundamental role in the outcomes and long-term durability of surgical repair in IMR. [34]

CONCLUSIONS

IMR is a complex disorder occurring after myocardial infarction, and it affects both mitral valvular and subvalvular apparatuses. Several abnormalities can be detected in IMR such as annular dilatation, leaflet tethering with impaired coaptation, and papillary muscle displacement along a posterior, apical, or lateral vector. Treatments available include, alongside myocardial revascularization, mitral valve repair or chorda-sparing replacement.

Repair is normally achieved by downsizing the mitral valve annulus with a rigid or semi-rigid ring or suture annuloplasty.

In the current era and in Iran, mitral valve repair—particularly via the Kay method—has been proven to offer improved short- and long-term survival, decreased valve-related morbidity, and augmented left ventricular function. Future randomized prospective clinical trials are needed to compare this cost-effective surgical technique with its counterparts.

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