Keynote Lecture Series

Mitral valve repair versus replacement

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Degenerative, ischemic, rheumatic and infectious (endocarditis) processes are responsible for mitral valve disease in adults. Mitral valve repair has been widely regarded as the optimal surgical procedure to treat mitral valve dysfunction of all etiologies. The supporting evidence for repair over replacement is strongest in degenerative mitral regurgitation. The aim of the present review is to summarize the data in each category of mitral insufficiency and to provide recommendations based upon this data.

Keywords: Mitral; repair; replacement; degenerative; rheumatic; mitral valve endocarditis; ischemic mitral regurgitation

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Introduction

Degenerative, ischemic, rheumatic and infectious (endocarditis) processes are responsible for mitral valve disease in adults. Mitral valve repair has been widely regarded as the optimal surgical procedure to treat mitral valve dysfunction of all etiologies and is currently the most commonly performed surgical procedure for mitral valve regurgitation in North America (1). The aim of the present review is to consider and summarize the available data on the clinical outcomes following mitral valve repair compared with replacement.

Degenerative mitral valve disease

Degenerative disease represents 60-70% of surgical mitral regurgitation (MR) in industrialized nations (2) and is most commonly related to mitral-valve prolapse, a spectrum of conditions ranging from a single prolapsing valve segment to diffuse myxomatous degeneration with bileaflet prolapse and annular dilatation (2,3). Degenerative mitral valve disease is the most repairable form of surgical mitral valve disease, and repair is the most recommended surgical approach (4).

The well-accepted advantages of mitral valve repair consist of lower operative mortality (1,5-8), improved preservation of left ventricular function, and greater freedoms from prosthetic valve-related complications such as thromboembolism, anticoagulant-related hemorrhage and endocarditis (5,6,9-12). Similarly, there is abundant retrospective data supporting the durability of valve repair as equal to or even superior to mitral valve replacement (6,8,9,13-15), even in cases of complex valvular pathology including calcification and anterior or bileaflet prolapse (7,16-18). With regard to the durability of repairs, it is important to note the proper standard for durability comparisons is with mechanical valve replacements, as biological prostheses are known to be associated with limited durability in the mitral position, with reoperation rates markedly increasing at the 10-year mark postoperatively (7,13).

There are no randomized trials comparing outcomes after mitral valve repair and replacement respectively in the context of degenerative disease. When considering the strength of the available retrospective studies with respect to long term survival, it is important to remember that patients undergoing the two procedures commonly exhibit different characteristics pertinent to long term survival at baseline. For instance, the most potent predictor of long term survival following mitral valve operation is preoperative left ventricular ejection fraction (15,19). The strongest studies considering the survival advantages of repair are those that

include risk-adjusted comparisons of outcomes.

The balance of risk-adjusted survival data does show improved mid and long-term survival for mitral valve repair compared with mitral valve replacement (8,9), even in the elderly (20). Of particular interest is the work of Daneshmand and colleagues (9), who considered 989 patients undergoing isolated mitral valve procedures for degenerative disease. Compared to the 284 patients having replacement, the 705 patients undergoing repair were younger (62 *vs*. 68 years old for replacement) and less likely to undergo coronary artery bypass grafting (CABG) (24% *vs*. 32% for replacement) but had lower preoperative ejection fractions (51% *vs*. 58% for replacement), higher rates of congestive heart failure (68% *vs*. 42% for replacement) and preoperative arrhythmia (11% *vs*. 7% for replacement). Survival was significantly superior with repair even with propensity score analysis with survival differences increasing over time: 0.7% superior survival for 0-5 years, 4.9% better for 5-10 years and ~21% superior for 10-15 years. In this analysis, patient age did not diminish the benefit of repair (P=0.66). This data supports an aggressive policy of repair for repairable degenerative mitral valve disease in the vast majority of patients with degenerative mitral regurgitation.

However, it is also useful to consider the extreme end of degenerative mitral valve disease. Gillinov *et al*. have demonstrated that repair is not associated with a survival benefit in the group of patients having extremely complex degenerative disease (6). This subset of patients (~7% of all patients at our own institution) represents a distinct group of patients who are typically older and have higher numbers of symptoms and comorbidities. In this group, long term survival is likely governed more by the patient's comorbidities than the type of mitral valve operation.

In light of all of the above, we recommend pursuing aggressive repair in nearly all patients with degenerative mitral valve disease.

Rheumatic mitral valve disease

Rheumatic mitral valve disease is considerably less common in North America and European countries than in developing countries, where rheumatic heart disease remains by far the leading cause of valvular disease [e.g., 72% of all valvular disease in a South African center (19)] (21). Even so, rheumatic disease can still comprise up to 23% of valvular disease in current mitral practice in the United States (22,23). Rheumatic mitral valve pathology is complex and every component of the mitral valve (annulus, leaflets and subvalvular apparatus) can be affected (23).

Data suggests that repair is associated with mortality and survival benefit, along with greater freedom from thromboembolic complications. Though with some compromise in durability in early series (24,25). For instance, Yau and colleagues considered 573 patients undergoing mitral valve surgery for rheumatic heart disease between 1978 and 1995. In this series, 25% were repaired, 28% were replaced with a biologic prosthesis and 47% replaced with a mechanical prosthesis. After risk adjustment with a Cox model, operative mortality was superior with repair (0.7% *vs*. 5.1% after replacement) and overall long-term survival was superior. At 10 years, reoperation occurred in 28% of patients with repaired valves (with no operative deaths), 31% of patients with bioprostheses and 5% of patients with mechanical valves. A more recent series considered echocardiographic findings in addition to reoperation rates following repair in predominantly regurgitant rheumatic mitral valve disease. While 10-year freedom from reoperation was 97% in this study, freedom from moderate or severe regurgitation or stenosis was only 66% (26), perhaps calling into question the true durability of rheumatic valve repair.

In light of the above, we support current guidelines (4) which recommend consideration of repair of rheumatic heart valves only if a durable and successful repair is likely or when the advisability of long-term anticoagulation management is questionable. The development of newer repair techniques (27-30) is ongoing, but further study is needed to determine the long term outcomes with these approaches.

Endocarditis

The indications for surgical intervention in patients with active infective endocarditis include congestive heart failure, intracardiac extension of infection (abscess), sepsis unresponsive to antibiotics, systemic embolism and occasionally the presence of large vegetations. The main goals of surgical treatment of mitral valve endocarditis are twofold: eradication of infection and patient survival.

In a systematic review of 24 studies on the topic, Feringa and colleagues observed that mitral valve repair was possible in approximately 39% of patients presenting with mitral valve endocarditis (31). Similar to the degenerative MR experience, valve repair was associated with lower in-hospital mortality (2.3% *vs*. 14.4%, P<0.0001) and reduced

long term mortality (7.8% *vs*. 40.5%, P<0.0001), a finding confirmed by meta-regression analysis. However, of course all such findings are likely subject to the bias that patients with fewer comorbidities and less aggressive infections may be more likely to be selected for repair. Additional advantages of repair over replacement included decreased risks of stroke, recurrent endocarditis and reoperation. Based upon their analysis, Feringa and colleagues concluded that valve repair is associated with excellent outcomes and should be considered in patients with mitral valve endocarditis.

Not all patients with endocarditis are candidates for repair due to the variable extent of tissue destruction. In the first aim of surgical treatment (eradication of infection), all grossly infected tissue should be removed without concern for the possibility of repair. Resection technique should err on over-excision of leaflet tissue to ensure eradication of the infectious process and only afterwards can the possibility of reconstruction be assessed (32). Repair can be approached with the full armamentarium of mitral valve repair techniques including patching of perforations, vegetectomy and resection of involved leaflet and leaflet patching with autologous or bovine pericardium, commissural debridement and reconstruction, left ventricular abscess debridement with annular patch reconstruction and leaflet re-suspension with artificial chords (33). Monofilament suture use should be considered over braided suture to prevent bacterial sequestration (32). Mitral valve homografts have been employed for valve replacement in acute endocarditis in patients when repair was not possible (33,34). This has however not enjoyed the success that has been seen with aortic homografts. The procedure is technically challenging and the experience has been daunting.

In the event that replacement is the only option due to the advanced state of infection or delayed presentation, mechanical valve replacement is most suitable for younger patients with native valve endocarditis. Tissue valves are acceptable for patients greater than 60 years of age with either native or prosthetic valve endocarditis and for selected younger patients with prosthetic endocarditis (35).

Ischemic mitral valve disease (IMR)

Ischemic mitral valve disease (IMR) is mitral regurgitation that is a consequence of coronary artery disease. Although IMR may be short-lived and associated with acute ischemia, by and large, IMR is caused by completed myocardial infarction (or infarctions) in the circumflex or right coronary artery distributions. Such infarctions result in complex changes in the geometry and function of the left ventricle (LV) and mitral annulus leading to systolic leaflet restriction and annular dilatation (36-41). Generally, the leaflets and chordae are morphologically normal and regurgitation occurs through a variable combination of Carpentier types IIIb (restriction) and I (annular dilation) dysfunction.

Choices for the surgical treatment of IMR include revascularization alone or revascularization in concert with mitral repair or replacement.

Mild to moderate IMR

At present, there is general agreement that revascularization alone is not an acceptable surgical strategy in the case of severe IMR. The question has remained open, however, in the area of mild to moderate MR and has been extensively debated. Previous retrospective data has demonstrated the frequent return of MR following revascularization alone in cases of moderate IMR [e.g., 30-65% of patients developing MR at 6 weeks postoperatively and 22% progressing to severe MR (42-44)]. The clinical relevance of this residual MR has been unclear, however. Although we have shown that residual mild-to-moderate mitral regurgitation following CABG alone negatively impacts long term survival (42), this finding has not been uniform (45,46). At the same time, while the addition of a mitral valve repair at the time of CABG may improve functional status, no clear improvement in survival has been demonstrated with repair of moderate IMR (47-50) [except for a suggestions of improved survival in selected patients with severe left ventricular dysfunction or severe heart failure (51,52)].

"The Randomized Ischemic Mitral Evaluation (RIME) Trial" was a small prospective trial designed to determine whether repairing the mitral valve during CABG improves functional capacity and left ventricular remodeling compared to CABG alone. Seventy-three patients with moderate IMR and ejection fraction >30% referred for CABG were randomized to receive CABG and mitral valve repair or CABG alone. The trial was stopped early after interim analysis due to difficulties in recruitment along with the pronounced benefit observed in the repair group. At 1 year, there was significant improvement in peak oxygen consumption, volume of mitral regurgitation, left ventricular reverse remodeling and B-type natriuretic peptide levels in the group receiving both CABG and

mitral repair. Operative mortality and 1-year survival were similar between groups. The study endpoints are thought to be powerful predictors of worsening heart failure and survival (53-56) but are only surrogates for clinical outcomes. Although intriguing, this trial was not powered to evaluate clinical events or survival, and longer term follow up will be required for fuller evaluation of the endpoints for which it was powered; significant MR can occur up to 3 years following annuloplasty (57) and LV reverse remodeling can continue for up to 2 years following CABG (58).

The recently reported CTSN trial "Comparing the Effectiveness of a Mitral Valve Repair Procedure in Combination with Coronary Artery Bypass Grafting (CABG) versus CABG Alone in People with Moderate Ischemic Mitral Regurgitation" recently became available and considered a slightly a similar patient population with larger numbers. In this trial, investigators randomly assigned 301 patients with moderate ischemic mitral regurgitation to CABG alone or CABG plus mitral-valve repair as a combined procedure. The primary end point was the left ventricular end-systolic volume index (LVESVI), a measure of left ventricular remodeling, at 1 year. Unlike the RIME trial, this larger study did not show a higher degree of left ventricular reverse remodeling with mitral valve repair patients with moderate ischemic mitral regurgitation. Additionally, there were no significant between-group differences in major adverse cardiac or cerebrovascular events, deaths, readmissions, functional status, or quality of life at 1 year. The addition of mitral-valve repair was associated with a significantly longer bypass time, longer hospital stay after surgery and more neurologic events. Moderate or severe mitral regurgitation was less common in the repair group than in the CABG-alone group (11.2% *vs.* 31.0%, P<0.001). This trial did not show a clinically meaningful advantage of adding mitral-valve repair to CABG at 1 year, but longer-term follow-up is required to determine whether the lower prevalence of mitral regurgitation translates into a net clinical benefit (59).

As we await the results of additional prospective data, we favor a strategy of mitral annuloplasty in addition to revascularization in relatively low-risk CABG patients with moderate functional IMR whose symptoms are dominated by heart failure.

Severe IMR

In patients with severe IMR, current guidelines support mitral valve surgery (repair or replacement) in patients undergoing CABG (60) but do not make a recommendation as to repair versus replacement. In patients with severe IMR, the benefits of repair over replacement have been the subject of controversy. In a recent systematic review under Cochrane guidelines considering 12 studies, Rao *et al*. concluded that existing literature suggests that repair may be associated with improved surgical mortality and long-term survival over replacement. The authors noted that their conclusion was drawn with considerable uncertainty given the heterogeneity of the existing studies and noted an urgent need for high-quality randomized comparison of repair and replacement (61).

Recently, Acker *et al*. reported the results of the first prospective randomized trial considering the relative merits of mitral repair and replacement in the setting of severe IMR. In this trial, 251 patients with severe IMR were randomly assigned to undergo mitral valve repair or chordal-sparing mitral valve replacement, with 74% of repairs and 75% of replacements also undergoing concomitant CABG. The primary endpoint of this trial was LVESVI (62). The investigators found no difference in LVESVI, 30-day mortality or survival at 12 months between patients who underwent mitral valve repair and those underwent mitral valve replacement. The rate of moderate or severe MR at 12 months after surgery was 32.6% in the repair group compared with 2.3% in the replacement group (P<0.001). However, there were no differences in the rate of a composite of major adverse cardiac or cerebrovascular events, in functional status or in quality of life at 12 months overall. Follow-up will continue to 24 months. The study was not powered to detect survival differences and as in the RIME trial, the primary endpoint (LVESVI) is only a surrogate for clinical outcomes although it is strongly correlated with New York Heart Association (NYHA) class, rates of rehospitalization and survival (63-69). The authors note that the patients with MR recurrence in the repair group showed no reverse LV remodeling compared with those without recurrence (LVESVI of 64.1±23.9 with recurrent MR, 47.3±23.0 without recurrence), although differences in functional status or quality of life between these groups were not addressed.

The finding of Acker *et al*. (62) with respect to the frequency of recurrence of MR is similar to previous retrospective data showing the prevalence of moderate or greater MR following repair to be 15-30% and increasing over time (45,57-61). We have previously demonstrated that a mitral annular diameter 3.7 cm or greater along

with a tenting area >1.6 cm^2 in the context of severe IMR is associated with annuloplasty failure in 55% of patients. Other risk factors for failure of repair include more severe left ventricular dysfunction, higher preoperative grade of MR, complex jet (49), increased left ventricular sphericity (70) and severe leaflet tethering (36). One of the limitations of the work of Acker and colleagues is that the presence or absence of such risk factors was not captured in the patients studied.

Meta-analysis of the existing retrospective data have concluded that the balance of the data suggests improved short and long term survival with repair (71); however, inadequate adjustment for baseline differences in observational studies is common and meta-analyses considering such studies should be interpreted with caution. At our own institution, we considered 397 patients undergoing repair for IMR and 85 undergoing replacement (72). Ninety-five percent of patients had concomitant CABG. Patients more likely to undergo replacement were in higher New York Heart Association functional class or underwent operations on an emergency basis. Propensity matching was used to create five groups of patients over a spectrum of risk having either replacement or repair. Patients in group 1 were very high risk patients (highest degree of heart failure, emergency surgery) and patients in group 5 were the lowest risk (lower degrees of heart failure, elective surgery). Overall 5-year survival was poor (58% repair *vs.* 36% replacement, P=0.08). The highest risk patients (group 1) showed the worst survival, but did not differ according to repair or replacement. However, lower risk patients (quintiles 3-5) derived a survival benefit from repair (P=0.003). Echocardiographic factors associated with increased early and late mortality in patients receiving repair included a complex (not central or posterior) jet and lateral wall motion abnormality, respectively. Our study illustrates the heterogeneity of IMR patients and the concept that the decision regarding repair or replacement of IMR should be tailored to the clinical and anatomic characteristics of the patient.

In cases of severe IMR, we continue (36) to recommend revascularization combined with undersized annuloplasty in lower risk patients (lower degrees of heart failure, elective surgery) without echocardiographic features associated with repair failure (e.g., diameter 3.7 cm or greater along with a tenting area >1.6 cm^2, complex jet, lateral wall motion abnormalities). However, in high risk patients, those with more severe heart failure, emergency cases and those with high risk features for repair failure on preoperative echo, chordal sparing bioprosthetic replacement is supported by the existing data.

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References

1. Gammie JS, Sheng S, Griffith BP, et al. Trends in mitral valve surgery in the United States: results from the Society of Thoracic Surgeons Adult Cardiac Surgery Database. Ann Thorac Surg 2009;87:1431-7; discussion 1437-9.
2. Enriquez-Sarano M, Akins CW, Vahanian A. Mitral regurgitation. Lancet 2009;373:1382-94.
3. Chikwe J, Adams DH. State of the art: degenerative mitral valve disease. Heart Lung Circ 2009;18:319-29.
4. Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Thorac Cardiovasc Surg 2014;148:e1-e132.
5. Enriquez-Sarano M, Schaff HV, Orszulak TA, et al. Valve repair improves the outcome of surgery for mitral regurgitation. A multivariate analysis. Circulation 1995;91:1022-8.
6. Gillinov AM, Blackstone EH, Nowicki ER, et al. Valve repair versus valve replacement for degenerative mitral valve disease. J Thorac Cardiovasc Surg 2008;135:885-93, 893.e1-2.
7. Suri RM, Schaff HV, Dearani JA, et al. Survival advantage and improved durability of mitral repair for leaflet prolapse subsets in the current era. Ann Thorac Surg 2006;82:819-26.
8. Zhou YX, Leobon B, Berthoumieu P, et al. Long-term outcomes following repair or replacement in degenerative mitral valve disease. Thorac Cardiovasc Surg 2010;58:415-21.
9. Daneshmand MA, Milano CA, Rankin JS, et al. Mitral valve repair for degenerative disease: a 20-year experience. Ann Thorac Surg 2009;88:1828-37.
10. LaPar DJ, Hennessy S, Fonner E, et al. Does urgent or emergent status influence choice in mitral valve operations? An analysis of outcomes from the Virginia Cardiac Surgery Quality Initiative. Ann Thorac Surg 2010;90:153-60.
11. Akins CW, Hilgenberg AD, Buckley MJ, et al. Mitral

valve reconstruction versus replacement for degenerative or ischemic mitral regurgitation. Ann Thorac Surg 1994;58:668-75; discussion 675-6.
12. Habib G, Thuny F, Avierinos JF. Prosthetic valve endocarditis: current approach and therapeutic options. Prog Cardiovasc Dis 2008;50:274-81.
13. Mohty D, Orszulak TA, Schaff HV, et al. Very long-term survival and durability of mitral valve repair for mitral valve prolapse. Circulation 2001;104:I1-I7.
14. Gogbashian A, Sepic J, Soltesz EG, et al. Operative and long-term survival of elderly is significantly improved by mitral valve repair. Am Heart J 2006;151:1325-33.
15. McNeely CA, Vassileva CM. Long-term outcomes of mitral valve repair versus replacement for degenerative disease: a systematic review. Curr Cardiol Rev 2015;11:157-62.
16. David TE, Ivanov J, Armstrong S, et al. A comparison of outcomes of mitral valve repair for degenerative disease with posterior, anterior, and bileaflet prolapse. J Thorac Cardiovasc Surg 2005;130:1242-9.
17. Carpentier AF, Pellerin M, Fuzellier JF, et al. Extensive calcification of the mitral valve anulus: pathology and surgical management. J Thorac Cardiovasc Surg 1996;111:718-29; discussion 729-30.
18. Grossi EA, Galloway AC, Steinberg BM, et al. Severe calcification does not affect long-term outcome of mitral valve repair. Ann Thorac Surg 1994;58:685-7; discussion 688.
19. Sliwa K, Carrington M, Mayosi BM, et al. Incidence and characteristics of newly diagnosed rheumatic heart disease in urban African adults: insights from the heart of Soweto study. Eur Heart J 2010;31:719-27.
20. Chikwe J, Goldstone AB, Passage J, et al. A propensity score-adjusted retrospective comparison of early and mid-term results of mitral valve repair versus replacement in octogenarians. Eur Heart J 2011;32:618-26.
21. Iung B, Vahanian A. Epidemiology of acquired valvular heart disease. Can J Cardiol 2014;30:962-70.
22. Rankin JS, Burrichter CA, Walton-Shirley MK, et al. Trends in mitral valve surgery: a single practice experience. J Heart Valve Dis 2009;18:359-66.
23. Yankah CA, Siniawski H, Detschades C, et al. Rheumatic mitral valve repair: 22-year clinical results. J Heart Valve Dis 2011;20:257-64.
24. Yau TM, El-Ghoneimi YA, Armstrong S, et al. Mitral valve repair and replacement for rheumatic disease. J Thorac Cardiovasc Surg 2000;119:53-60.
25. Grossi EA, Galloway AC, Miller JS, et al. Valve repair versus replacement for mitral insufficiency: when is a mechanical valve still indicated? J Thorac Cardiovasc Surg 1998;115:389-94; discussion 394-6.
26. Kim GS, Lee CH, Kim JB, et al. Echocardiographic evaluation of mitral durability following valve repair in rheumatic mitral valve disease: impact of Maze procedure. J Thorac Cardiovasc Surg 2014;147:247-53.
27. Rankin JS, Sharma MK, Teague SM, et al. A new approach to mitral valve repair for rheumatic disease: preliminary study. J Heart Valve Dis 2008;17:614-9.
28. Dillon J, Yakub MA, Nordin MN, et al. Leaflet extension in rheumatic mitral valve reconstruction. Eur J Cardiothorac Surg 2013;44:682-9.
29. Kassem S, Al-Faraidy K, Elkady Y, et al. Face-to-face single patch: a new technique to repair the commissures of the mitral valve. J Thorac Cardiovasc Surg 2012;144:1523-7.
30. Lohchab SS, Laller KS, Taxak S, et al. Chordal transfer in rheumatic mitral regurgitation: early experience. Asian Cardiovasc Thorac Ann 2011;19:232-7.
31. Feringa HH, Shaw LJ, Poldermans D, et al. Mitral valve repair and replacement in endocarditis: a systematic review of literature. Ann Thorac Surg 2007;83:564-70.
32. Muehrcke DD, Cosgrove DM 3rd, Lytle BW, et al. Is there an advantage to repairing infected mitral valves? Ann Thorac Surg 1997;63:1718-24.
33. Reardon MJ, Vinnerkvist A, LeMaire SA. Mitral valve homograft for mitral valve replacement in acute bacterial endocarditis. J Heart Valve Dis 1999;8:71-3.
34. Ali M, Iung B, Lansac E, et al. Homograft replacement of the mitral valve: eight-year results. J Thorac Cardiovasc Surg 2004;128:529-34.
35. Moon MR, Miller DC, Moore KA, et al. Treatment of endocarditis with valve replacement: the question of tissue versus mechanical prosthesis. Ann Thorac Surg 2001;71:1164-71.
36. Gillinov AM. Is ischemic mitral regurgitation an indication for surgical repair or replacement? Heart Fail Rev 2006;11:231-9.
37. Miller DC. Ischemic mitral regurgitation redux--to repair or to replace? J Thorac Cardiovasc Surg 2001;122:1059-62.
38. Grossi EA, Goldberg JD, LaPietra A, et al. Ischemic mitral valve reconstruction and replacement: comparison of long-term survival and complications. J Thorac Cardiovasc Surg 2001;122:1107-24.
39. Filsoufi F, Salzberg SP, Adams DH. Current management of ischemic mitral regurgitation. Mt Sinai J Med 2005;72:105-15.
40. Adams DH, Filsoufi F, Aklog L. Surgical treatment of the

ischemic mitral valve. J Heart Valve Dis 2002;11 Suppl 1:S21-5.
41. Srichai MB, Grimm RA, Stillman AE, et al. Ischemic mitral regurgitation: impact of the left ventricle and mitral valve in patients with left ventricular systolic dysfunction. Ann Thorac Surg 2005;80:170-8.
42. Lam BK, Gillinov AM, Blackstone EH, et al. Importance of moderate ischemic mitral regurgitation. Ann Thorac Surg 2005;79:462-70; discussion 462-70.
43. Rydén T, Bech-Hanssen O, Brandrup-Wognsen G, et al. The importance of grade 2 ischemic mitral regurgitation in coronary artery bypass grafting. Eur J Cardiothorac Surg 2001;20:276-81.
44. Aklog L, Filsoufi F, Flores KQ, et al. Does coronary artery bypass grafting alone correct moderate ischemic mitral regurgitation? Circulation 2001;104:I68-75.
45. Arcidi JM Jr, Hebeler RF, Craver JM, et al. Treatment of moderate mitral regurgitation and coronary disease by coronary bypass alone. J Thorac Cardiovasc Surg 1988;95:951-9.
46. Paparella D, Mickleborough LL, Carson S, et al. Mild to moderate mitral regurgitation in patients undergoing coronary bypass grafting: effects on operative mortality and long-term significance. Ann Thorac Surg 2003;76:1094-100.
47. Mihaljevic T, Lam BK, Rajeswaran J, et al. Impact of mitral valve annuloplasty combined with revascularization in patients with functional ischemic mitral regurgitation. J Am Coll Cardiol 2007;49:2191-201.
48. Kang DH, Kim MJ, Kang SJ, et al. Mitral valve repair versus revascularization alone in the treatment of ischemic mitral regurgitation. Circulation 2006;114:I499-503.
49. McGee EC, Gillinov AM, Blackstone EH, et al. Recurrent mitral regurgitation after annuloplasty for functional ischemic mitral regurgitation. J Thorac Cardiovasc Surg 2004;128:916-24.
50. Wong DR, Agnihotri AK, Hung JW, et al. Long-term survival after surgical revascularization for moderate ischemic mitral regurgitation. Ann Thorac Surg 2005;80:570-7.
51. Harris KM, Sundt TM 3rd, Aeppli D, et al. Can late survival of patients with moderate ischemic mitral regurgitation be impacted by intervention on the valve? Ann Thorac Surg 2002;74:1468-75.
52. Prifti E, Bonacchi M, Frati G, et al. Should mild-to-moderate and moderate ischemic mitral regurgitation be corrected in patients with impaired left ventricular function undergoing simultaneous coronary revascularization? J Card Surg 2001;16:473-83.
53. Myers J, Gullestad L, Vagelos R, et al. Cardiopulmonary exercise testing and prognosis in severe heart failure: 14 mL/kg/min revisited. Am Heart J 2000;139:78-84.
54. Arena R, Myers J, Williams MA, et al. Assessment of functional capacity in clinical and research settings: a scientific statement from the American Heart Association Committee on Exercise, Rehabilitation, and Prevention of the Council on Clinical Cardiology and the Council on Cardiovascular Nursing. Circulation 2007;116:329-43.
55. Baughman KL. B-type natriuretic peptide -- a window to the heart. N Engl J Med 2002;347:158-9.
56. Afifi A, Elguindy A. The RIME trial: Are we closer to the answer of when to repair ischemic mitral regurgitation? Glob Cardiol Sci Pract 2013;2013:127-9.
57. Gelsomino S, Lorusso R, De Cicco G, et al. Five-year echocardiographic results of combined undersized mitral ring annuloplasty and coronary artery bypass grafting for chronic ischaemic mitral regurgitation. Eur Heart J 2008;29:231-40.
58. Bondarenko O, Beek AM, Twisk JW, et al. Time course of functional recovery after revascularization of hibernating myocardium: a contrast-enhanced cardiovascular magnetic resonance study. Eur Heart J 2008;29:2000-5.
59. Smith PK, Puskas JD, Ascheim DD, et al. Surgical treatment of moderate ischemic mitral regurgitation. N Engl J Med 2014;371:2178-88.
60. Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;63:2438-88.
61. Rao C, Murphy MO, Saso S, et al. Mitral valve repair or replacement for ischaemic mitral regurgitation: a systematic review. Heart Lung Circ 2011;20:555-65.
62. Acker MA, Parides MK, Perrault LP, et al. Mitral-valve repair versus replacement for severe ischemic mitral regurgitation. N Engl J Med 2014;370:23-32.
63. Konstam MA, Udelson JE, Anand IS, et al. Ventricular remodeling in heart failure: a credible surrogate endpoint. J Card Fail 2003;9:350-3.
64. Carson P, Tognoni G, Cohn JN. Effect of Valsartan on hospitalization: results from Val-HeFT. J Card Fail 2003;9:164-71.
65. Kramer DG, Trikalinos TA, Kent DM, et al. Quantitative evaluation of drug or device effects on ventricular remodeling as predictors of therapeutic effects on

mortality in patients with heart failure and reduced ejection fraction: a meta-analytic approach. J Am Coll Cardiol 2010;56:392-406.
66. White HD, Norris RM, Brown MA, et al. Left ventricular end-systolic volume as the major determinant of survival after recovery from myocardial infarction. Circulation 1987;76:44-51.
67. St John Sutton M, Pfeffer MA, Moye L, et al. Cardiovascular death and left ventricular remodeling two years after myocardial infarction: baseline predictors and impact of long-term use of captopril: information from the Survival and Ventricular Enlargement (SAVE) trial. Circulation 1997;96:3294-9.
68. Moss AJ, Hall WJ, Cannom DS, et al. Cardiac-resynchronization therapy for the prevention of heart-failure events. N Engl J Med 2009;361:1329-38.
69. Ghio S, Freemantle N, Scelsi L, et al. Long-term left ventricular reverse remodelling with cardiac resynchronization therapy: results from the CARE-HF trial. Eur J Heart Fail 2009;11:480-8.
70. Hung J, Papakostas L, Tahta SA, et al. Mechanism of recurrent ischemic mitral regurgitation after annuloplasty: continued LV remodeling as a moving target. Circulation 2004;110:II85-90.
71. Vassileva CM, Boley T, Markwell S, et al. Meta-analysis of short-term and long-term survival following repair versus replacement for ischemic mitral regurgitation. Eur J Cardiothorac Surg 2011;39:295-303.
72. Gillinov AM, Wierup PN, Blackstone EH, et al. Is repair preferable to replacement for ischemic mitral regurgitation? J Thorac Cardiovasc Surg 2001;122:1125-41.

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