Current perspectives

Current status of mitral valve reconstruction in patients with dilated cardiomyopathy

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Congestive heart failure (CHF) is one of the leading causes of hospitalization in the United States today and its incidence is increasing. Despite improvements with medical management approximately 50% of patients with CHF die within 3 years of presentation. Heart transplantation is now considered standard treatment for selected patients with severe CHF and end-stage heart disease; however, it is only applicable to a small percentage of patients. In an effort to solve this problem medical and surgical strategies are rapidly expanding and evolving.

Mitral valve reconstruction represents an alternative surgical strategy in patients with dilated cardiomyopathy that will allow for preservation of the limited number of donor organs for those patients who have no other surgical or medical alternatives.

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Introduction

Congestive heart failure (CHF) is one of the leading causes of hospitalization in the United States today and its incidence is increasing. Heart failure will become even more of a medical challenge as average life expectancy continues to rise. Despite improvements with medical management, approximately 50% of patients with CHF die within 3 years of presentation[1]. Heart transplantation is now considered standard treatment for selected patients with severe CHF and end-stage heart disease; however, it is only applicable to a small percentage of patients. Transplantation is limited both by the small number of donor hearts available and its inapplicability in the older patient or those with comorbid medical conditions[2]. In an effort to solve this problem, alternative medical and surgical strategies are evolving.

Mitral valve annuloplasty

Functional mitral regurgitation is a significant complication of end-stage cardiomyopathy and may effect almost all heart failure patients as a pre-terminal or terminal event. In order to address the issue of heart failure and mitral regurgitation, one needs to understand the anatomy of the mitral valve. The determination of mitral competence depends on the understanding that the mitral valve apparatus consists of the annulus, leaflets, chordae tendinae, papillary muscles and the entire left ventricle. The functional mitral regurgitation that develops in CHF may be attributed to an alteration in the annular-ventricular apparatus[3] and altered ventricular geometry[4], which then results in incomplete leaflet coaptation. A large leaflet area is normally required for coaptation; mitral leaflet area is 2.5 times greater than the area of the mitral valve orifice. As more mitral leaflet tissue is utilized for coverage of the enlarging mitral valve orifice, a critical reduction in the leaflet tissue available for coaptation is reached, such that coaptation of the mitral valve leaflets becomes ineffective, and a central jet of functional regurgitation begins to develop[3,5]. Therefore, one of the most significant determinants of mitral valve coaptation, leaflet orifice area, and subsequent mitral regurgitation is the dimension of the mitral valve annulus. Furthermore, in the setting of chronic CHF, cardiac reserve is depressed and a number of compensatory mechanisms of the neuroendocrine and sympathetic nervous systems are activated and may account for many of the symptoms of heart failure and its progression.

In a recent study of patients with severe heart failure, who were managed with pharmacologic agents (diuretics, nitrates and afterload reduction agents), the observed decrease in filling pressure and systemic vascular resistance led to a reduction in the dynamic mitral regurgitation associated with their heart failure. This was attributed to a reduction in the regurgitant orifice area related to the decrease in left ventricular volume and annular distension[6]. This complex relationship between mitral annular area and leaflet coaptation may explain why, paradoxically, utilizing an undersized annuloplasty ring (one that is smaller than the measured true annular dimension) for a valvular repair can help a muscular problem.

Increases in left ventricular preload, wall tension, diastolic volume, and stroke volume are all documented ventricular adaptations to severe mitral regurgitation. There is a significant decrease in the efficiency of the left ventricular contraction and the work expended by the left ventricle to produce flow that ultimately does not contribute to effective forward cardiac output. In these patients, maintenance of forward flow becomes more difficult because up to 50% of the stroke volume is ejected into the left atrium before the aortic valve even opens[7]. With the elimination of the regurgitant volume, the ventricle no longer has to expend an excessive amount of work on flow that is going in the reverse direction. All blood flow will be in the forward direction, and will contribute to forward flow and effective cardiac output. In cases of severe myocardial dysfunction, the positive effects of the elimination of the regurgitant flow may be even more pronounced.

Further evidence of underlying mechanisms why mitral valve repair for patients with cardiomyopathy may be successful is taken from a study of the coronary flow characteristics in patients with mitral regurgitation, in the absence of coronary artery disease[8]. This study assessed coronary flow characteristics in patients before and after mitral valve reconstruction. Coronary flow reserve was limited in patients with mitral regurgitation due to an increase in baseline coronary flow and flow velocity which was related to left ventricular volume overload, hypertrophy and preload (left ventricular wall stress). The restriction in coronary flow reserve improved following mitral valve reconstruction because of a reduction in the baseline coronary flow and flow velocity once the left ventricular preload, work and mass were reduced. Based on this study, in patients with mitral regurgitation and cardiomyopathy, a restriction in the coronary flow reserve would seem probable and an improvement in flow reserve and velocity would be expected following mitral valve repair. Ultimately the mitral valve repair in this setting would lead to an improvement in left ventricular geometry.

Historically, the surgical approach to patients with mitral regurgitation was mitral valve replacement and little was understood about the adverse consequences that interruption of the annulus-papillary muscle continuity had on left ventricular systolic function[9]. This procedure was associated with very high mortality rates[10,11]. It has been demonstrated in a number of studies that preservation of the annulus-papillary muscle continuity is of paramount importance to preservation of left ventricular function[12,13]. It was the excision of, and geometric distortion of, the subvalvar apparatus that accounted for the significant loss of systolic function due to the destruction of the left ventricle that led to the poor outcome in patients who underwent mitral valve replacement[14,15]. Preservation of the mitral valve apparatus and left ventricle in mitral valve repair has been demonstrated to enhance and maintain left ventricular function and geometry with an associated decrease in wall stress[16,17]. This procedure has been shown to be safe with a significant decrease in operative morbidity and mortality with good long-term outcomes[18-21], and in fact it has been shown that the mortality ascribed to these patients from mitral valve replacement was due to the disruption of the subvalvar apparatus and loss of left ventricular function. Maintenance of the chordal, annular, subvalvar continuity and mitral geometric relationships are important in the preservation of overall ventricular function and may be even more crucial in patients with compromised left ventricular function. In the selection of a surgical approach to the problem of heart failure, one must therefore first recognize that this is a ventricular problem and therefore a solution directed at the mitral valve, which is and encompasses the entire left ventricle, would be ideal.

At the University of Michigan (1993 to 1999), 92 patients with end-stage cardiomyopathy and refractory mitral regurgitation underwent mitral valve repair with an undersized flexible annuloplasty ring. All patients had NYHA functional class III or IV heart failure despite receiving maximal medical therapy, and had severe left ventricular systolic dysfunction as defined by an ejection fraction < 25% (range 8-24%, mean 14%). The patients were equally divided into two groups: nonischemic dilated cardiomyopathy and end-stage ischemic cardiomyopathy without ongoing ischemia. The overall operative mortality was 5%. There were five 30-day mortalities including: intraoperative death due to right ventricular failure (n = 1), cardiac failure (n = 1), stroke (n = 1), and multisystem organ failure (n = 2). Five patients required postoperative intra-aortic balloon pump support, and there were no patients who required the use of a left ventricular assist device. The mean postoperative length of stay was 9 – 4 days (range 4-37 days). The duration of follow-up in these patients has been 1-68 months (mean 38 months), with a 1- and 2-year actuarial survival of 80 and 70%, respectively. There have been 26 late deaths attributable to sudden ventricular arrhythmia (n = 12), progression of heart failure without evidence of recurrent mitral regurgitation (n = 8), postoperative complications following other surgical procedures (n = 2), and suicide (n = 1). Included in this num-

ber are 3 additional patients who had progression of their heart failure and who have undergone successful transplantation. On immediate postoperative echocardiograms, the mean transmitral gradient was 3 – 1 mmHg (range 2-6 mmHg). At 24-month follow-up, all remaining patients are in NYHA functional class I or II, with a mean ejection fraction of 26%. The NYHA functional class improved for each patient and all patients reported subjective improvement in functional status. The matched preoperative and 24-month postoperative echocardiographic data are reported in table I. There was a demonstrated improvement in left ventricular ejection fraction, cardiac output, and end-diastolic volumes for all patients with a reduction in sphericity index and regurgitant fraction. There were no patients who demonstrated evidence of redilation of the mitral annulus. Although significant undersizing of the mitral annulus was employed to overcorrect for the zone of coaptation, no mitral stenosis was induced nor was any systolic anterior motion noted in this study. Systolic anterior motion was avoided due to widening of the aorto-mitral angle and increased left ventricular size seen in myopathic patients. In addition, acute remodeling of the base of the heart from the undersizing of the mitral annular ring may also contribute to the improvement seen in these myopathic hearts. This may reestablish the ellipsoid shape and somewhat normal geometry to the base of the left ventricle[22-25].

Table I. Preoperative and postoperative echocardiographic data.

Echo parameter	Preoperative	Postoperative (24 months)	p
End-diastolic volume (ml)	281 – 86	206 – 88	< 0.001
Ejection fraction (%)	16 – 5	26 – 8	0.008
Regurgitant fraction (%)	70 – 12	13 – 10	< 0.001
Cardiac output (l/min)	3.1 – 1.0	5.2 – 0.8	0.001
Sphericity index	0.82 – 0.10	0.74 – 0.07	0.005

Conclusions

Surgical therapies of heart failure are rapidly expanding and evolving. The concept of the high mortality and morbidity of surgical interventions on patients with end-stage heart disease no longer apply due to improvements in preoperative selection, intraoperative techniques and postoperative care. When operative techniques are combined with optimal medical management of heart failure results can be good and patients can avoid or postpone transplantation. This strategy will allow for preservation of the limited number of donor organs for those patients who have no other surgical or medical alternatives.

References

1. Tavazzi L. Epidemiology of dilated cardiomyopathy: a still undetermined entity. Eur Heart J 1997; 18: 4-6.
2. Hunt SA. Current status of cardiac transplantation. JAMA 1998; 280: 1692-8.
3. Boltwood CM, Tei C, Wong M, et al. Quantitative echocardiography of the mitral complex in dilated cardiomyopathy: the mechanism of functional mitral regurgitation. Circulation 1993; 68: 498-508.
4. Kono T, Sabbah HN, Rosman H, et al. Left ventricular shape is the primary determinant of functional mitral regurgitation in heart failure. J Am Coll Cardiol 1992; 20: 1594-8.
5. Chandraratna PA, Aronow WS. Mitral valve ring in normal vs dilated left ventricle. Cross-sectional echocardiographic study. Chest 1981; 79: 151-4.
6. Rosario LB, Stevenson LW, Solomon SD, et al. The mechanism of decrease in dynamic mitral regurgitation during heart failure treatment: importance of reduction in the regurgitant orifice size. J Am Coll Cardiol 1998; 32: 1819-24.
7. Fann JI, Ingels NB, Miller DC. Pathophysiology of mitral valve disease and operative indications. In: Edmunds LH, ed. Cardiac surgery in the adult. New York, NY: McGraw-Hill, 1997: 959-90.
8. Akasaka T, Yoshida K, Hozumi T, et al. Restricted coronary flow reserve in patients with mitral regurgitation improves after mitral reconstructive surgery. J Am Coll Cardiol 1998; 32: 1923-30.
9. Pitarys CJ II, Forman MB, Panayiotou H, et al. Long-term effects of excision of the mitral apparatus on global and regional ventricular function in humans. J Am Coll Cardiol 1990; 15: 557-63.
10. Pinson CW, Cobanoglu A, Metwdorff MT, et al. Late surgical results for ischemic mitral regurgitation. Role of wall motion score and severity of regurgitation. J Thorac Cardiovasc Surg 1984; 88 (Part 1): 663-72.
11. Phillips HR, Levine FH, Carter JE, et al. Mitral valve replacement for isolated mitral regurgitation: analysis of clinical course and late postoperative left ventricular ejection fraction. Am J Cardiol 1981; 48: 647-54.
12. Sarris GE, Cahill PD, Hansen DE, et al. Restoration of left ventricular systolic performance after reattachment of the mitral chordae tendineae. The importance of valvular-ventricular interaction. J Thorac Cadiovasc Surg 1988; 95: 969-79.
13. David TE, Uden DE, Strauss HD. The importance of the mitral apparatus in left ventricular function after correction of mitral regurgitation. Circulation 1983; 68 (Part 2): II76-II82.
14. Huikuri HV. Effect of mitral valve replacement on left ventricular function in mitral regurgitation. Br Heart J 1983; 49: 328-33.
15. Schuler G, Peterson KL, Johnson A, et al. Temporal response of left ventricular performance to mitral valve surgery. Circulation 1979; 59: 1218-31.
16. Goldman ME, Mora F, Guarino T, et al. Mitral valvuloplasty is superior to valve replacement for preservation of left ventricular function: an intraoperative two-dimensional echocardiographic study. J Am Coll Cardiol 1987; 10: 568-75.
17. Tischler MD, Cooper KA, Rowen M, et al. Myocardial function/valvular heart disease/hypertensive heart disease: mitral valve replacement versus mitral valve repair: a Doppler and quantitative stress echocardiographic study. Circulation 1994; 89: 132-7.
18. Gallino A, Jenni R, Hurni R, et al. Early results after mitral valvuloplasty for pure mitral regurgitation. Eur Heart J 1987; 8: 902-5.
19. Rankin JS, Feneley MP, Hickey MS, et al. A clinical comparison of mitral valve repair versus replacement in ischemic mitral regurgitation. J Thorac Cadiovasc Surg 1988; 95: 165-77.

20. Akins CW, Hilgenberg AD, Buckley MJ, et al. Mitral valve reconstruction versus replacement for degenerative or ischemic mitral regurgitation. Ann Thorac Surg 1994; 58: 668-76.
21. Alvarez JM, Deal CW, Loveridge K, et al. Repairing the degenerative mitral valve: ten to fifteen year follow-up. J Thorac Cardiovasc Surg 1996; 112: 238-47.
22. Bach DS, Bolling SF. Early improvement in congestive heart failure after correction of secondary mitral regurgitation in end-stage cardiomyopathy. Am Heart J 1995; 129: 1165-70.
23. Bolling SF, Deeb GM, Brunsting LA, et al. Early outcome of mitral valve reconstruction in patients with end-stage cardiomyopathy. J Thorac Cardiovasc Surg 1995; 109: 676-83.
24. Bach DS, Bolling SF. Improvement following correction of secondary mitral regurgitation in end-stage cardiomyopathy with mitral annuloplasty. Am J Cardiol 1996; 78: 966-9.
25. Bolling SF, Pagani FD, Deeb GM, et al. Intermediate-term outcome of mitral reconstruction in cardiomyopathy. J Thorac Cardiovasc Surg 1998; 115: 381-8.