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Clinical significance of mitral leaflet flail

Shi-Min Yuan

Department of Cardiac and Thoracic Surgery, The Chaim Sheba Medical Center, Tel Hashomer, Israel

Abstract

Background: *There has been scant academic consideration paid to investigations of mitral leaflet flail in terms of clinical profile, surgical strategy, and surgical outcome.*

Methods: *One hundred consecutive patients with mitral leaflet flail referred for surgical treatment in the past 4²/3 years were included in this study.*

Results: *The most common reasons leading to mitral leaflet flail were chord rupture (38%), myxomatous degeneration (23%), and combined chord rupture and myxomatous degeneration (12%). Mitral leaflet flail was predominantly characterized by independent P_2 flail, followed by $P_{2,3}$ flail and independent A_2 flail. Chord rupture occurred in 54 patients, and the most commonly involved segments were P_2, $P_{2,3}$, and P_3. The most common risk factors for mitral valve replacement were papillary muscle rupture, extensive myxomatous degeneration, extensive chord rupture, and severely dilated mitral valve annulus. Multivariate regression analyses demonstrated that the development of mitral leaflet flail was significantly associated with the pertinent variables tested, especially correlated with insertion of the prosthetic ring, number of artificial chord, and presence of carotid stenosis.*

Conclusions: *Mitral leaflet flail may affect patients of any age, but is more prevalent among males and younger patients. Mitral chord rupture was the leading cause for mitral leaflet flail. Myxomatous degeneration, infective endocarditis, mitral annulus calcification, and papillary muscle rupture were the next most common causes. An increased incidence of mitral leaflet flail was closely related to the chords of the posterior leaflet and the middle scallop. Due to the progressive disappointing prognosis of mitral leaflet flail, surgery should be performed at an early stage.* (Cardiol J 2009; 16, 2: 151–156)

Key words: etiology, mitral chord rupture, mitral leaflet flail, mitral valve repair, myxomatous degeneration

Introduction

Lack of normal mitral leaflet apposition in systole and abnormal systolic pointing of the flail component into the left atrium are classic features of mitral leaflet flail [1]. Hemodynamic disorders develop with a posterior mitral leaflet flail when the jet is directed onto the posterior wall of the aorta, and with an anterior mitral leaflet when the jet is directed towards the posterior wall of the left atrium [2]. Rupture of the chord or papillary muscle was recognized as the major cause of acute severe mitral regurgitation due to mitral leaflet flail [3]. Other etiologies that have been implicated were bacterial endocarditis, myxomatous changes, and severe mitral annular calcification [4]. Myxomatous changes of a floppy valve, even at a microscopic level, may lead to mitral valve flail directly or by way of chord rupture [5]. Echocardiography offers the best means of diagnosis of mitral leaflet flail, as well as

Address for correspondence: Shi-Min Yuan, MD, Department of Cardiac and Thoracic Surgery, The Chaim Sheba Medical Center, Tel Hashomer 52621, Israel, tel: 972 3 5302710, fax: 972 3 5302410, e-mail: shi_min_yuan@yahoo.com

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its underlying causes, due to its high sensitivity and specificity [1]. Pathological observations [6] and mechanical studies [7] have contributed a lot to this subject; however, the surgical strategy can be challenging regarding whether to choose mitral valve repair or replacement in such patients. There have been scant academic considerations paid to the investigations of mitral leaflet flail in terms of clinical profile, surgical strategy, and operative outcome.

Methods

By tracking the records of the perfusionist, materials of all the patients who were referred to this hospital for surgical treatment of mitral regurgitation due to mitral leaflet flail, which was identified by both preoperative echocardiography and surgery, were retrospectively searched and collected from the "Doctor's Record" database. Those who were diagnosed by preoperative echocardiography with mitral leaflet flail, but in whom the flail was absent, as identified by surgery, were excluded from this study. Between 1 January 2004 and 31 August 2008, 100 consecutive patients were diagnosed with mitral leaflet flail of different etiologies. There were 76 males and 24 females, aging from 29 to 81 with a mean of 60.19 ± 12.13 years old. No significant difference was noted in the age of the patients between males and females (59.20 ± 12.27 years *vs*. 61.25 ± 13.34 years, $p = 0.4859$). The clinical features of the patients are listed in Table 1.

The functioning zones of the mitral valve are adequately nominated for the purpose of expression. The posterior leaflet is divided into 3 scallops: P_1, P_2, and P_3. P_1 is adjacent to the anterolateral commissure and is closest to the aorta. The opposing sections of the anterior leaflet are designated as A_1, A_2, and A_3. The mitral valve has a total of 8 functional sections: 2 commissures and 6 leaflet sections.

Etiologies, anatomical features, surgical techniques, and operative outcomes of mitral leaflet flail were summarized. Variables were expressed as mean ± SD. A comparison of echocardiographic evaluation and a multivariable analysis of factors associated with mitral valve flail were made. $P < 0.05$ was considered statistically significant.

The study was approved by the local bioethical committee and all patients gave their informed consent.

Table 1. Clinical features.

Patients' age (year)	60.19 ± 12.13
Gender (male/female)	76/24
Clinical presentation:	
Asymptomatic	17
Shortness of breath	34
Dyspnea	8
Palpitation	1
Chest pain	11
Chest compression	1
Congestive heart failure	8
Pulmonary edema	5
Cardiogenic shock	1
Pulmonary edema + cardiogenic shock	1
Fever	3
Leg pain	1
Not given	9
Associated disorders	1
Atrial fibrillation	18
Pulmonary hypertension	12
Tricuspid insufficiency	15
Coronary artery disease	26
Patent foramen ovale	4
Myocardial infarction	7
Infective endocarditis	10
Aortic valve disorder	2
Carotid stenosis	4
Hypertrophic cardiomyopathy	1
Echocardiographic finding	1
Mitral regurgitation	100
Severe mitral regurgitation	96
Moderate-to-severe mitral regurgitation	2
Moderate mitral regurgitation	2
Eccentric mosaic jet	78
Mitral leaflet flail	62

Results

The three most common reasons leading to mitral leaflet flail were spontaneous chord rupture (38%), myxomatous degeneration (23%), and combined spontaneous chord rupture and myxomatous degeneration (12%). Other etiologies included infective endocarditis, mitral annulus calcification, loose untethered chord, distorted mitral leaflet, papillary muscle rupture, and aortic dissection (Table 2).

Mitral leaflet flail was predominantly characterized by independent P_2 flail, accounting for 55% of the patient group. Entire posterior leaflet flail, $P_{2,3}$ flail, and independent A_2 flail were the next most common, representing 8%, 7%, and 7%, respectively. P_2 flail was often associated with prolapse of other segments of the mitral leaflet (Table 3).

Table 2. Etiologies of mitral leaflet flail.

Chord rupture	38
MD	23
Chord rupture + MD	12
Chord rupture + dilated mitral annulus	1
IE	2
MD + IE	2
Chord rupture + IE	1
Chord rupture + MD + IE	2
Mitral annulus calcification	4
Mitral annulus calcification + MD	1
Loose untethered chord	1
Distorted mitral leaflet	1
Papillary muscle rupture	5
Aortic dissection in Marfan's syndrome	1
Recurrent posterior mitral leaflet flail	1
Uncertain	5

MD — myxomatous degeneration; IE — infective endocarditis

Table 3. Anatomy of mitral leaflet flail.

Posterior mitral leaflet (entire) flail	8
Anterior mitral leaflet (entire) flail	5
Bi-leaflet flail	1
P_1 flail	2
P_2 flail	55
$P_{1,2}$ flail	1
$P_{2,3}$ flail	7
P_2 flail + A_2 prolapse	4
P_2 flail + P_1 prolapse	1
P_2 flail + P_1, A_1 prolapse	1
P_2 flail + $P_{1,3}$ prolapse	1
P_3 flail	4
A_2 flail	7
$A_{1,2}$ flail	1
$A_{2,3}$ flail	1
A_2 flail + P_3 prolapse	1

Table 4. Anatomic position of ruptured mitral chords.

P_1	1 (1.9%)
P_2	33 (61.1%)
$P_{2,3}$	7 (13.0%)
P_3	4 (7.4%)
Entire posterior mitral leaflet	1 (1.9%)
$A_{1,2}$	1 (1.9%)
$A_{1,2}$+P_3	1 (1.9%)
A_2	3 (5.6%)
$A_{2,3}$	1 (1.9%)
Entire anterior mitral leaflet	2 (3.7%)

Table 5. Surgical techniques for mitral leaflet flail.

Mitral valve repair	83
Port access	17
P_2 resection	52
P_3 resection	2
Pericardial augmentation of posterior mitral leaflet	1
Anterior commissure closure	1
Mitral ring	80
Cosgrove	40
Physio	39
Taylor	1
Artificial chord	43
Mitral valve replacement	17
Associated procedure	1
Coronary artery bypass	23
Tricuspid valve repair	14
Maze procedure	14
Aortic valve repair	1
Patent foramen ovale closure	4
Bentall operation	1

Chord rupture occurred in 54 patients, with 46 located at the posterior and 8 at the anterior mitral leaflet. The segments that were most commonly involved in mitral chord rupture were P_2, $P_{2,3}$, and P_3 with an incidence of 61.1%, 13.0% and 7.4%, respectively (Table 4).

Mitral valve repair was performed in 83 patients, and mitral valve replacement was carried out in 17 patients. Of the repair procedures, port access was employed in 17 patients. P_2 resection was conducted in 52 patients. A mitral prosthetic ring was inserted in the mitral position in 80 patients. Of them, Cosgrove was used in 40, Physio in 39, and Taylor in 1 patient, with a size of 32.6 ± 1.37 (range, 30–36) mm, 33.48 ± 3.30 (range, 28–40) mm, and 33 mm for the three prosthetic rings, respectively. Artificial chord was placed in 43 patients, with 3.31 ± 2.54 (range, 1–12) artificial chords per patient. The most frequent operations associated with the mitral procedures were coronary artery bypass, tricuspid valve repair, and Maze procedure (Table 5).

The most common risk factor for mitral valve replacement was papillary muscle rupture, which

Table 6. A comparison of echocardiographic evaluations.

Variable	Preoperation	Postoperation	P
Ejection fraction	62.04 ± 7.04	65.25 ± 8.71	0.0006
Left atrial diameter	4.8411 ± 0.7728	4.5177 ± 0.8962	0.0646
Left atrial area	32.1311 ± 8.7649	25.2566 ± 8.8875	0.0004
E-peak	1.28030 ± 0.33625	1.22364 ± 0.26575	0.6146
A-peak	0.63053 ± 0.22890	0.87400 ± 0.47277	0.0349
Mitral valve radius	1.0627 ± 0.2333	0.6400 ± 0.0834	0.0004
Regurgitant orifice area	61.743 ± 37.688	24.533 ± 2.065	0.1076
Peak pressure gradient		7.7706 ± 2.7558	
Mean pressure gradient		3.4535 ± 1.3227	

Table 7. Odds ratios and 95% confidence intervals of multivariate regression analysis of factors associated with mitral valve flail.

Variable	Odds ratio	95% confidence intervals	P
Patients' age	1.0282	0.9657–1.0948	0.3848
Gender	0.6540	0.1138–3.7593	0.6342
Symptom	0.1454	0.0107–1.9693	0.1470
Presence of chord rupture	0.4630	0.1067–2.0091	0.3038
Insertion of prosthetic ring	31.5874	3.7154–268.5520	0.0016
Number of artificial chord	0.7072	0.5079–0.9848	0.0403
Atrial fibrillation	0.5389	0.0672–4.3229	0.5606
Coronary artery disease/myocardial infarction	2.4791	0.3463–17.7468	0.3660
Pulmonary hypertension	17677.3876	–	0.9979
Tricuspid regurgitation	4.1665	0.2763–62.8270	0.3026
Infective endocarditis	0.5129	0.0549–4.7948	0.5583
Carotid stenosis	0.0537	0.0028–1.0214	0.0500
Patent foramen ovale	0.1272	0.0077–2.0970	0.1493

developed in 5 patients (29.4%), followed by severely dilated mitral annulus, extensive myxomatous degeneration, and extensive chord rupture, occurring in 4 (23.5%), 3 (17.6%), and 3 (17.6%) patients, respectively. Others were loose untethered chord, and aortic dissection in Marfan's syndrome, each occurring in 1 (5.9%) patient.

Post-bypass echocardiographic evaluation revealed that mitral regurgitation disappeared completely in 60 patients, trivial or mild regurgitation in 21 patients, and moderate regurgitation in 1 patient, excluding those patients whose information was unavailable.

There was no operative mortality. Postoperative outcome was good with regard to survival, symptomatic status, and postoperative left ventricular function. Reintervention due to recurrent mitral regurgitation was necessary in 3 patients, 12 days, 4 weeks, and 13 months, respectively, after the primary mitral valve repair. All three patients had had an extensive chord rupture for primary mitral valve repair. Two of them received a second mitral valve repair, the other had a mitral valve replacement, and all were doing well since then.

At a 12.10 ± 12.10 month follow-up (range, 0.7–48) by echocardiographic evaluation, left atrial area, A-peak, and mitral radius showed a significant decrease in comparison to the results of preoperation. The peak and mean pressure gradients across the mitral valve remained satisfactory (Table 6).

Multivariate regression analysis demonstrated that the development of mitral leaflet flail was significantly associated with the pertinent variables tested (Overall model fit: $\chi^2 = 24.8909$; df = 13; p = 0.0239), and correlated especially with insertion of the prosthetic ring, number of artificial chord, and presence of carotid stenosis (Table 7).

Discussion

Echocardiography remains the major diagnostic tool for the preoperative evaluation of mitral leaflet flail. Some patients remain asymptomatic until a chord rupture is disclosed by incidental echocardiographic evaluation. Their asymptomatic course after chord rupture may be associated with a more compliant left atrium and the impact of severe regurgitation on subvalvular apparatus along the natural course of mitral regurgitation prior to chord rupture [8]. In accordance with others [1], an eccentric mosaic flow jet was absent in some mitral leaflet flail patients of the present series. Instead, a smooth turquoise or blue stream, usually observed in mitral regurgitation caused by ischemic, hypertensive, or dilated cardiomyopathy, was present. The flail component could change the local laminar flow into strong turbulence and thus overcome the local mosaic pattern. Therefore, mosaic flow could occasionally be absent on echocardiography in patients with severe mitral regurgitation.

The etiologies of mitral leaflet flail have been a long-standing topic to be addressed. In myxomatous prolapsed mitral valve, breakdown of collagen and elastic tissue was noted [9]. In addition to affecting the mitral leaflets, myxomatous processes may also involve the mitral chord and papillary muscle [6]. In the spontaneously ruptured mitral chords, collagen types III and AB may be absent [10]. Considerable fibrosis or a sheath-like covering around the myxoid chord, particularly near their insertion into the leaflets, has been discovered [7]. Mechanical property studies showed that myxoid chords are more extensible, less stiff, weaker compared to the normal chords, and the failure strength is more likely to be compromised in the chord than in the leaflet [7]. Impaired mechanical properties due to collagen alterations and acid mucopolysaccharide accumulation in the mitral leaflets and chords may lead to spontaneous chord rupture. Age over 50 years, posterior leaflet thickness, male gender, and infective endocarditis involving anterior mitral leaflets were independent predictors of mitral chord rupture [8]. Moreover, collagen alterations were also found in floppy mitral valves in Marfan's syndrome [11].

Chord tissue strength plays an important role in the development of mitral leaflet flail. High leaflet thickness correlated significantly with surgery and the development of complications [12]. Myxomatous valve disease is the most common underlying cause of chord rupture [5]. In keeping with the previous report [5] on chord rupture as a common complication of myxomatous valve disease, 12 (12%) patients in the current series had an association of chord rupture and myxomatous valve disease. The flow direction impacting the mitral leaflets and the anatomical features of the mitral leaflets may account for the development of mitral chord rupture. The chords of the posterior mitral leaflet are thinner and more liable to myxomatous process [6]. The chords of the anterior mitral leaflet are large and thick, while those of the posterior are short and thin [12]. Therefore, the posterior mitral leaflet is more vulnerable to stress. In addition, chord rupture may alter the geometry of the left atrium. Grenadier et al. [13] found that the mean atrial dimension in a mitral valve prolapse with ruptured chords was 4.6 ± 1.1 (3.1–8) cm compared to 3.1 ± 0.8 (2.7–4.4) cm in a mitral valve prolapse without ruptured chords.

It was evident that previous or ongoing infective endocarditis and subvalvular ischemic damage resulting from myocardial ischemia may contribute to mitral chord rupture [5]. Valvular thickening or calcification due to vegetation healing is different from that due to rheumatic involvement, in that rheumatic changes considerably restrict the mobility and leaflet excursion amplitude, while the vegetations do not [14]. Two important findings of chord architecture by van der Bel-Kahn et al. [11] give a good explanation for infective endocarditis as an underlying cause of mitral leaflet flail. Chords fused in a chaotic pattern as an end result of fuse of ruptured chords, and marked deviations in branching and anchoring still within normal limit could lead to dysfunction, less support, and undue stress (wear and tear) of the mitral valve. According to this study, a loose untethered chord, distorted mitral leaflet, or aortic dissection in Marfan's syndrome could also be attributed to the development of mitral leaflet flail. The etiology of mitral leaflet flail was, however, undetermined in some patients [2, 5].

In patients with closed or unclosed secundum atrial septal defect, histological findings of the mitral leaflets were similar in that surface fibrosis was present without vascularization or myxomatous changes [5, 14]. This may explain the predictable patent foramen ovale in the development of mitral leaflet flail, as in this patient group. A flail mitral leaflet is associated with significant risk of developing heart failure, left ventricular dysfunction, atrial fibrillation, pulmonary hypertension [15], and tricuspid regurgitation [16].

Marwick et al. [17] reported that 8% (26/309) of their patients had immediate failure of mitral repair requiring further repair or replacement. The causes of immediate failure were proved to be left ventricular outflow tract obstruction, incomplete correction, and suture dehiscence. Late failure was noted in 5.5% (17/309) of the patients, resulting from progressive degenerative leaflet or chord disease, or suture dehiscence of the annular ring or the leaflet resection site. Late failure after mitral repair occurred predominantly due to progression of disease, particularly in patients with severe myxomatous or annular abnormalities. In this series, no incomplete correction or suture dehiscence was found in patients requiring reintervention.

Conclusions

Mitral leaflet flail may affect patients of any age, but is more often seen in males than in females, and more often in young patients than in the old. Mitral chord rupture was the leading cause for the development of mitral leaflet flail. Myxomatous degeneration, infective endocarditis, mitral annulus calcification, and papillary muscle rupture were the next most common, as has been described. A loose untethered chord, distorted mitral leaflet, or aortic dissection in Marfan's syndrome could also be attributed to the development of mitral leaflet flail. An increased incidence of mitral leaflet flail was closely related to the chords of the posterior leaflet and the middle scallop. Due to the progressive and disappointing prognosis based on observations in a patient population with asymptomatic mitral leaflet flail, surgery should be performed at an early stage [18]. The patients requiring a reintervention were likely to have a progressive degenerative process of the mitral leaflet.

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