Mitral valve prolapse in patients with coronary artery disease

Echocardiographic-angiographic correlation¹

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Echocardiography was performed in 25 consecutive patients with angina pectoris and angiographically demonstrable coronary artery disease. Left ventricular echograms detected late or pansystolic mitral valve bowing suggestive of mitral valve prolapse in 6/25 (24%). Left ventricular angiography showed prolapse of the posterior mitral leaflet in 15/25 (60%), including 5 detected by echocardiography. Significant triple vessel coronary disease was present in 11 of 15 patients with prolapsed mitral valve. In each of the latter a >90 per cent obstructive lesion was noted in at least one coronary artery: right coronary artery, 9 subjects (82%); left circumflex coronary artery, 5 patients (33%); and left anterior descending coronary artery, 4 patients (27%). Of 15 subjects with angiographic evidence of mitral valve prolapse, 13 had left ventricular asynergy-inferior or inferoposterior in 8 subjects (62%) and anterior or anteroapical in 5 subjects (38%). Eleven subjects had vectorcardiographic evidence of transmural myocardial infarction-inferior or inferoposterior in 9 (82%) and anteroapical in 2 (18%). A single subject with mitral valve prolapse had mild mitral regurgitation.

It is concluded that: (1) coexisting prolapse of the posterior mitral valve leaflet and coronary artery disease is usually associated with triple vessel obstructive lesions, (2) severe right coronary disease, inferior left ventricular wall asynergy, and inferior myocardial infarction are important angiographic and vectorcardiographic correlates, and (3) echocardiography will detect such mitral valve prolapse in only one-third of affected cases.

The association of mitral valve prolapse with obstructive coronary disease is recognised yet controversial (Davis *et al.*, 1971; Steelman *et al.*, 1971; Cheng, 1972; Gooch *et al.*, 1972; Liedtke *et al.*, 1973; Scampardonis *et al.*, 1973; Jeresaty, 1973, 1975; Aranda *et al.*, 1975; Gentzler *et al.*, 1975). Some investigators (Cheng, 1972) maintain that coronary artery disease can produce mitral ballooning by virtue of papillary muscle ischaemia or fibrosis. We report here a group of 25 patients with severe triple vessel coronary artery disease, in whom there was a high incidence (60%), of mitral valve prolapse. Interestingly, severe obstructive disease of the right coronary artery along with transmural infarction and asynergy of the inferior left ventricular wall dominated in these patients.

The vectorcardiographic, echographic, haemodynamic, and angiographic characteristics of subjects with advanced coronary artery disease who had prolapsed scallops of the posterior leaflet of the mitral valve will be described.

Subjects and methods

Twenty-five patients comprised the study group. There were 22 men and 3 women whose ages ranged from 35 to 65, with a mean of 53 years. All represented consecutive subjects who were found to have angiographic evidence of coronary artery disease.

Frank vectorcardiograms of 20 patients were available for study. They were analysed for transmural myocardial infarction and myocardial ischaemia according to criteria described by Benchimol (1973). The infarctions were classified as antero-

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septal, lateral, inferior, or true posterior. A QRS-T vector angle exceeding 70° was considered diagnostic of myocardial ischaemia.

Left ventricular echograms were obtained by means of an Ekoline 20 ultrasonoscope interfaced with an Electronics for Medicine DR-8 recorder. Echocardiograms were obtained with patients in the supine or left lateral position. A 2.25 MHz transducer focused at 7.5 cm was placed at the third or fourth intercostal space at the left sternal border and aimed perpendicular to the mitral valve. The interventricular septum, anterior and posterior mitral valve leaflets, and left ventricular posterior wall were simultaneously recorded on the echocardiographic tracing for detection of mitral valve prolapse in accordance with established criteria (DeMaria *et al.*, 1974).

After obtaining informed consent, right and left heart catheterisation along with selective coronary angiography in multiple projections was performed in the post-absorptive state. Intracardiac pressures were recorded on an Electronics for Medicine DR-12 oscilloscopic photographic recorder using P23Db Statham transducers and fluid-filled catheters. Cardiac output was determined by the dye dilution technique using indocyanine green. Biplane left ventriculography was performed in all patients in the right anterior oblique projection. Hypaque, 40 ml, was injected into the left ventricle at a rate of 26 to 30 ml/s using a Cordis II power injector. Angiographic images were recorded on 35 mm film

Table 1 *Vectorcardiographic, haemodynamic, and angiographic data for study group*

	No.	%
Total no. of patients with coronary artery disease	25	
Angiographic-mitral valve prolapse	15	60
Echographic-mitral valve prolapse	6	24
<i>Vectorcardiographic features</i>		
Normal	9	45
Transmural myocardial infarction	11	55
Inferior myocardial infarction	7	64
Posterior myocardial infarction	2	18
Anteroseptal myocardial infarction	2	18
Right bundle-branch block	1	
Left anterior hemiblock	2	10
QRS-T angle $> 70^\circ$	6	30
<i>Haemodynamic features</i>		
Cardiac index < 2.5 l/min per m^2	25	100
Left ventricular end-diastolic pressure > 12 mmHg	12	48
Poor left ventricular function	8	32
<i>Angiographic features</i>		
Normal left ventricular contraction	5	20
Left ventricular asynergy	20	80
Inferior and posterior wall	12	60
Anterior wall	8	40
Coronary artery disease ($> 75\%$ obstruction)	25	100
Triple vessel disease	16	64
Double vessel disease	2	8
Single vessel disease	7	28
Right coronary artery disease	22	88
Left anterior descending coronary artery disease	18	72
Left circumflex artery disease	17	68

Table 2 *Vectorcardiographic and angiographic features in 15 subjects with mitral valve prolapse*

	No.	%
<i>Vectorcardiographic features</i>		
Inferior wall myocardial infarction	7	47
True posterior wall myocardial infarction	2	13
Anteroseptal myocardial infarction	2	13
<i>Angiographic features</i>		
Prolapse of posteromedial scallops of posterior mitral leaflet	10	67
Prolapse of posteromedial and anterolateral or mid scallops	5	33
Mitral regurgitation	1	
Normal left ventricular contraction	2	13
Left ventricular asynergy	13	87
Inferior wall	7	54
Inferior and posterior wall	1	8
Anterior and apical	5	38
Left ventricular dilatation	5	33
Triple vessel coronary artery disease	11	73
Double vessel coronary artery disease	1	7
Single vessel coronary artery disease	3	20
$> 90\%$ Obstructive lesion—RCA	9	60
$> 90\%$ Obstructive lesion—LCx	5	33
$> 90\%$ Obstructive lesion—LAD	4	27

RCA, right coronary artery; LCx, left circumflex coronary artery; LAD, left anterior descending coronary artery.

at a speed of 45 frames/second. Care was taken to analyse only those ventriculograms obtained during stable sinus rhythm.

All angiograms were reviewed independently by at least two observers. Individual systolic frames of the ventriculograms were carefully studied. The mitral valve and the atrioventricular ring at the base of the opacified left ventricle as well as the posteromedial and anterolateral commissural areas were identified. A distinct convex bulge in the area of the posteromedial or anterolateral commissures suggested prolapse of the posteromedial or anterolateral scallops, respectively, and a central bulge was judged to be secondary to prolapse of the mid-scallop as described by others (Ranganathan *et al.*, 1970, 1973). Left ventricular contractility was assessed in a qualitative fashion. Regional wall motion was classified as follows: (1) Normal—the segment had synchronous and inward movement of good amplitude during systole. (2) Hypokinetic—a portion or all of a segment had inward movement judged qualitatively to be diminished in amplitude. (3) Akinetic—a portion or all of the segment had complete absence of wall motion. (4) Dyskinetic—a portion or all of the segment had paradoxical systolic outward motion.

Results

Of the 25 patients studied, 15 (60%) had angiographic and 6 (24%) had echographic evidence of posterior mitral valve leaflet prolapse. The vectorcardiographic and angiographic features for the

entire study group and those patients with mitral valve prolapse are summarised in Tables 1 and 2.

VECTORCARDIOGRAPHIC FEATURES

All patients were in sinus rhythm. Vectorcardiograms were normal in 9 patients (45%) and abnormal with evidence of transmural myocardial infarction in 11 (55%). Vectorcardiographic criteria for transmural infarction involving the inferior and posterior walls were noted in 9/20 (45%) and anteroapical wall in 2 (10%). An abnormal QRS-T angle ($>70^\circ$) suggestive of myocardial ischaemia was seen in 6/20 (30%) subjects. Right bundle-branch block was observed in one subject and left anterior hemiblock patterns in 2 patients. All 11 patients with vectorcardiographic diagnosis of myocardial infarction had angiographic evidence of mitral valve prolapse.

HAEMODYNAMIC FINDINGS

The cardiac index was <2.5 l/min per m^2 in all 25 patients. Left ventricular end-diastolic pressures were >12 mmHg in 12 (48%) subjects. Left ventricular function, estimated by analysis of dp/dt, tension time index, and ventricular power was considered poor in only 8 patients (32%).

ANGIOGRAPHIC FINDINGS

Mitral valve

Mitral valve prolapse was observed in 15 (60%) subjects. Isolated prolapse of the posteromedial scallops was seen in 10 patients (66%) (Fig. 1, 2) and combined anterolateral and posteromedial scallop prolapse in 5 patients (33%), (Fig. 3, 4). Of these, 3 patients showed features highly suggestive of mid-scallop prolapse. One patient had mild mitral regurgitation on the left ventriculogram. A single subject with echocardiographic evidence of

mitral valve prolapse did not have this finding on the angiogram.

Left ventricle

Left ventriculograms showed a normal pattern of contraction in 5 (20%) patients and ventricular asynergy in 20 (80%). Eight subjects (32%) had ventricular aneurysms which were distributed anatomically as follows: 5 patients, inferoposterior wall and 3 patients, anterior or anteroapical regions. Inferior wall dyskinesia was observed in 12 subjects of whom 2 had additional posterior wall asynergy. Anterior wall dyskinesia was observed in 8 patients, and 4 of these had apical involvement. A classical 'belle shoe' appearance was observed on 4 ventriculograms.

In this group of 15 patients with mitral valve prolapse, regional myocardial motion abnormalities and transmural infarction of the inferior left ventricular wall dominated. Eight subjects had inferior wall asynergy and one patient had combined inferior and posterior wall dyskinesia. Anterior and anteroapical asynergy was observed in 5 subjects and an identical number had left ventricular dilatation.

Coronary arteries

Selective coronary angiography showed advanced arteriographic obstruction of one or more major vessels in every patient. Significant obstruction of the right coronary artery was present in 22 patients (88%), of the left anterior descending artery in 18 patients (72%), and of the circumflex artery in 17 patients (68%). Of 15 patients with prolapse of the mitral valve, 11 (73%) had obstruction of all three major vessels, 3 patients (20%) had obstruction of two major vessels, and 1 patient had single vessel disease. Of 11 patients with triple vessel coronary

Fig 1 Left ventriculogram in right anterior oblique projection from a 63-year-old man with triple vessel coronary artery disease. There is isolated prolapse of posteromedial scallops of the posterior mitral leaflet. PMCS = posteromedial commissural scallops.

Fig. 2 (a) Left ventriculogram (left) and left ventricular echogram (right) of a 60-year-old man with coronary artery disease. Note prolapse of the posteromedial commissural scallops on the left ventriculogram and pansystolic prolapse of the posterior mitral valve on the echocardiogram. PMCS, posteromedial commissural scallops; PMV, posterior mitral valve leaflet; AMV, anterior mitral valve leaflet; IVS, interventricular septum; LV, left ventricle; MA, mitral area phonocardiogram; L II, lead II of electrocardiogram. (b) Coronary angiograms from this patient showing severe obstructive disease of the right and left anterior descending coronary arteries (arrows indicate lesions). RCA, right coronary artery; LCA, left coronary artery.

disease and prolapse of posterior mitral leaflet, a >90 per cent obstructive lesion of right coronary artery was seen in 9 patients (82%), of the circumflex coronary artery in 5 patients (46%), and of the left anterior descending coronary artery in 4 patients (37%).

Discussion

An association of mitral valve prolapse and left ventricular abnormalities, with or without involve-

ment of coronary arteries has been suggested (Steelman *et al.*, 1971; Cheng, 1972; Aranda *et al.*, 1975; Jeresaty, 1975). However, a definite relation between coronary artery disease and prolapse is not evident in some reviews of the papillary muscle-chordal-mitral valve complex. Jeresaty (Jeresaty, 1973) believes the association of two such common diseases to be coincidental rather than causative, since he saw only 4 instances of proven coronary artery disease in 45 patients with prolapse who

Fig. 3 Left ventriculogram (left) and left ventricular echogram (right) from a 59-year-old woman with occlusive disease of the right and left circumflex coronary arteries. The angiogram shows inferior wall asynergy with prolapse of the posteromedial commissural scallops (PMCS) and anterolateral commissural mitral scallops (ALCS). The echocardiogram shows mid-late systolic prolapse of the mitral valve leaflets. RV, right ventricle.

underwent coronary arteriography. Other authors (Davis *et al.*, 1971; Gooch *et al.*, 1972; Liedtke *et al.*, 1973; Scampardonis *et al.*, 1973; Gentzler *et al.*, 1975) have documented coronary artery disease in a small percentage (2 to 3%) of their patients with prolapsed mitral valve. We propose that in patients with coronary artery disease, ischaemia, infarction, or fibrosis of papillary muscles or their contiguous myocardium, together with left ventricular motion abnormality, results in dysfunction of the mitral valve apparatus and produces prolapsed mitral leaflets. In our series, a high incidence of prolapse of the posterior mitral leaflet was observed in patients who had severe triple vessel coronary disease. Posterior papillary muscle dysfunction arising as a consequence of right coronary artery and left circumflex obstructive lesions has been observed or suggested before (James, 1965; Estes *et al.*, 1966; Cheng, 1972). Cheng (1972) reported atherosclerotic disease of the right and left circumflex coronary arteries in 50 per cent and 17 per cent of his patients, respectively, who had angiographic evidence of the posterior mitral leaflet prolapse. Congenital absence of the left circumflex coronary artery AV branch, giving rise to segmental myocardial dysfunction, was noted by Gentzler *et al.* (1975) in 90 per cent of their patients who had abnormalities of the mitral valve apparatus and

non-ejection systolic clicks. None of their study group had significant occlusive disease involving the right coronary artery. It is noteworthy that the right coronary artery was the most frequently involved blood vessel in our series of subjects with prolapse of the posterior mitral valve. These patients also had angiographic evidence of inferior and inferoposterior asynergy along with vectorcardiographic evidence of healed inferior and inferoposterior transmural myocardial infarction. Findings reported herein are in accord with the recognised pattern of blood supply to the papillary muscles. The anterior papillary muscle receives its blood supply from branches of left anterior descending and circumflex arteries. The posterior papillary muscle derives its blood supply from branches of the right coronary and left circumflex arteries in 70 per cent, from right coronary artery alone in 20 per cent, and from the left circumflex artery in 10 per cent of cases (James, 1965; Estes *et al.*, 1966). While the anterior papillary muscle is supplied chiefly by the left anterior descending artery and to some extent by the left circumflex artery, the circulation to the posterior papillary muscle depends on coronary artery dominance. The posterior papillary muscle is almost exclusively supplied by the right coronary artery in the right dominant group. Severe obstructive coronary

Fig 4 Left ventriculogram (top) and left ventricular echogram (bottom) from a 59-year-old man with coronary artery disease. The angiogram shows prolapse of the anterolateral commissural scallops and posteromedial commissural scallops. There is no echocardiographic evidence of mitral valve prolapse.

disease, and especially involvement of the right coronary artery in the majority of our patients, appears to be the most important underlying factor for the genesis of posterior mitral leaflet prolapse.

Proper functioning of the papillary muscles is generally considered to be important for effective closing of the mitral valve, but papillary muscles *per se* play a minor role in producing efficient closure movements of mitral valve leaflets in a normally contracting ventricle (Tsakiris *et al.*, 1970). On the basis of anatomical and radiological studies it has been suggested that their contribution is twofold; firstly, tension exerted through the chordae tendineae at end-diastole draws the valve cusps toward a position of partial closure; secondly, early contraction of these muscles compensates for ventricular shortening during systole and thus prevents bulging of the valve leaflets into the atrium and associated mitral regurgitation (Shelburne, Rubinstein, and Gorlin, 1969; Tsakiris *et al.*, 1970). Infarction and asynergy of a portion of the left ventricle at the base of a papillary muscle may interfere with proper functioning of this

structure by means of a change in directional axis (Shelburne *et al.*, 1969). Paradoxical expansion of an inferior wall aneurysm may carry the base of the papillary muscle away from its normal position, thus changing the normal spatial three-dimensional alignment necessary for proper mitral valve closure.

Haemodynamic findings in the study group were suggestive of altered left ventricular performance. There is a wide spectrum of haemodynamic findings in various reported series of patients with mitral valve prolapse. Jeresaty (1971) described a constrictive pattern of left ventricular pressure curves in 5 of their 32 cases. Gulotta *et al.* (1974) reported poor left ventricular performance, while Scampardonis *et al.* (1973) described normal haemodynamic findings in the absence of severe mitral regurgitation. These disparate results can be explained by cause and effect relations between the myocardium, papillary muscles, chordae tendineae, and mitral valve leaflets. In the case of congenitally floppy mitral valves, the intrinsic abnormality of the leaflet and chordae would result in varying degrees of traction on associated segments of the myocar-

dium during ballooning, thereby producing non-uniform contraction abnormalities on left ventriculography. In most cases, however, prolapse and mitral insufficiency would be the cardinal angiographic finding. On the other hand, ischaemia, infarction, and asynergy of the papillary muscle base, in the setting of obstructive coronary artery disease would probably produce slackening or asynchrony of chordal tensing and resultant mitral valve prolapse. In such cases, the outstanding feature would be myocardial contraction disturbance during angiographic evaluation. Similar mechanisms may play a role in non-ischaemic cardiopathies, which produce myocardial dysfunction and occasional mitral insufficiency. A high incidence of severe triple vessel disease and obstructive lesions of the right coronary artery, together with asynergy and myocardial infarction of the inferior wall in the majority of our patients supports this thesis.

The rarity of mitral regurgitation in our patients contrasts sharply with angiographic documentation of mild to severe mitral insufficiency in most patients with prolapsed posterior mitral leaflet (Jeresaty, 1971; Scampardonis *et al.*, 1973; Ranganathan *et al.*, 1973; Lobstein *et al.*, 1973). The explanation for this variance is not entirely clear, but may be based on the following considerations. Firstly, prolapse of the middle scallop of the posterior mitral leaflet was infrequently observed in the present study. The middle scallop is usually the largest, and prolapse of this structure is considered the main factor responsible for mitral insufficiency. Secondly, selection of cases included in this study was based on angiographic findings while most of the other series were investigated because of clinical features (Scampardonis *et al.*, 1973; Ranganathan *et al.*, 1973; Lobstein *et al.*, 1973; Gulotta *et al.*, 1974) such as non-ejection systolic clicks and murmurs.

Interestingly enough, there was poor correlation between the cineangiographic and echocardiographic findings since only 6 of 15 patients showed echographic evidence of posterior mitral valve prolapse. These findings contrast with those of DeMaria *et al.* (1974) who showed echographic evidence of mitral valve prolapse in 23 of their 27 angiographically proven cases. We offer the following explanations for this apparent discrepancy. It is possible that mitral valve prolapse in the setting of coronary artery disease is occasionally absent in the basal state and may be provoked by a 'stress' on the left ventricle, such as angiography. In addition, the process itself may be dynamic and dependent on varying relations between myocardial oxygen demand and blood supply. In the latter

context, it should be pointed out that cineangiograms and echograms were not simultaneously recorded. Furthermore, prolapse of a single or all three scallops of the posterior mitral valve leaflet can be clearly defined on the left ventricular angiogram, while the echographic features of prolapse of individual scallops are not known at this time.

It is concluded that mitral valve prolapse is a common finding in subjects with triple vessel coronary artery disease and angiographic or vectorcardiographic evidence of inferior wall myocardial infarction. Possibly, such prolapse represents but a single stage in the evolution of mitral regurgitation secondary to papillary muscle dysfunction. Prospective angiographic and echographic study will be necessary in order to ascertain whether or not this is the case.

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