Prolapse of the Mitral Valve: Clinical and Cine-angiocardiographic Findings*

J. MICHAEL CRILEY, KENNETH B. LEWIS†, J. O'NEAL HUMPHRIES, AND
RICHARD S. ROSS

From the Cardiovascular Division of the Department of Medicine, and the Department of Radiology, the Johns Hopkins
University School of Medicine and Hospital, Baltimore, Maryland, U.S.A.

Mitral regurgitation can result from a variety of anatomical and functional abnormalities and can be the consequence of several disease processes. Clinical recognition of the ætiology is most often based on the history, while the functional anatomy of the lesion can occasionally be predicted by certain auscultatory findings.

This paper describes a unique anatomical type of mitral regurgitation, recognized cine-angiographically, which occurs in association with a murmur in the latter part of systole or marked accentuation of a soft holosystolic murmur in late systole. Correlations of the cine-angiograms with phonocardiograms have provided a functional anatomical basis for the late onset of the murmur as well as the systolic click which was present in 3 of the patients.

SUBJECTS AND METHODS

Five patients, ages 5 to 56, were studied because of the presence of a late systolic murmur (Table I). These patients were selected from a list of 79 patients on file in the Heart Sound Laboratory, who had systolic murmurs beginning after the onset of systole and extending to the second heart sound. Spectral and oscillographic phonocardiograms (McKusick, 1958), right and left heart catheterization, and selective 60-frame per second cine-angiography were performed on each patient. At the time of cine-angiography, correlations of pressures, phonocardiograms, and motion of intracardiac structures were made possible by the use of an electrocardiographic R wave marking device in the x-ray field (Ross, Criley, and Morgan, 1961). Intracardiac phono-

cardiograms obtained by an electromanometer* at the external catheter tip were recorded in all the patients.

CASE REPORTS

Case 1. J. M., a 39-year-old Caucasian man, had "growing pains" at the age of 9 but no clearly defined episode of rheumatic fever. At the age of 20 a murmur was heard during an induction physical examination, and he was accepted into the service only after repeated examinations indicated that the murmur was probably functional. He subsequently engaged in combat without any symptoms of heart disease. Because of slight exertional dyspnœa, fatigue, chest discomfort, and the presence of a murmur, he was referred for evaluation. His symptoms had begun insidiously 3 years before, 11 years after discharge from the Army. On examination the heart was not enlarged and the heart sounds were of normal quality. A grade 3/6 systolic murmur, beginning abruptly after a quiet interval in early systole, was heard maximally at the apex, but transmitted well to the left sternal border, base, and neck vessels. The electrocardiogram showed a wandering atrial pacemaker, diphasic T waves in lead II, inverted T waves in lead III, peaked T waves in leads V3–6, and no evidence of chamber hypertrophy. Chest radiography and fluoroscopy were normal. A phonocardiogram demonstrated low amplitude vibrations in early systole with a striking accentuation 0·12 sec. after the first sound and continuing to the second sound. Right and left heart catheterizations were performed, and the pressures in all chambers were normal. Left ventricular cine-angiograms in the left anterior oblique (LAO) and right anterior oblique (RAO) projections (Fig. 1) revealed mild mitral regurgitation and prolapse of the posterior leaflet of the mitral valve into the left atrium. Correlative timing studies (Table II) indicated minimal regurgitation beginning with valve closure and increasing in severity after completion of the valve prolapse.

TABLE I

CLINICAL AND GRAPHIC FINDINGS IN FIVE PATIENTS WITH PROLAPSE OF MITRAL VALVE

Case No.	Age	Sex	Aetiology	Symptoms	Electro-cardiogram	Phonocardiogram	Cine-angiocardiograms
1	39	M	Unknown	Mild exertional dyspnœa	Wandering atrial pacemaker; diphasic T in II	Crescendo apical murmur beginning softly after first sound, becoming abruptly louder in mid-systole and extending to second sound; no click	Systolic prolapse of posterior leaflet of mitral valve into left atrium; mild mitral incompetence increasing in late systole
2	31	M	Trauma (steering wheel injury)	None	Runs of bigeminy	Systolic click initiating late systolic murmur	Systolic prolapse of posterior leaflet of mitral valve into left atrium with moderate late systolic incompetence
3	56	F	Periarteritis nodosa	Exertional dyspnœa; later developed left heart failure	Normal	No click; high-pitched late systolic murmur well transmitted to base; as illness progressed, murmur became holosystolic	Systolic prolapse of posterior mitral leaflet into left atrium with moderate mitral incompetence
4	17	M	Unknown	None	Normal	Systolic click initiating a harsh late systolic murmur at apex	Systolic prolapse of posterior mitral leaflet into left atrium with moderate incompetence; enlarged left atrial appendage
5	5½	F	Marfan's syndrome	Disability due to skeletal deformities	Left atrial and ventricular hypertrophy	Multiple systolic clicks; musical apical late systolic murmur often initiated by click, (aortic diastolic murmur)	Systolic prolapse of mitral valve leaflets into left atrium; moderately severe mitral insufficiency; left ventricle and left atrium enlarged; aneurysmal dilatation of sinuses of Valsalva with mild aortic incompetence

The patient has been seen intermittently over the subsequent 4 years, and there has been no increase in symptoms. He has continued to work full time, and has required no cardiac medications.

Case 2. N.S., a 31-year-old Caucasian man, gave no history of rheumatic fever, and on physical examinations as a youth no mention was made of cardiac murmurs. At the age of 19 he joined the Marines, and no murmur was reported on the induction examination. One year later, he was in an automobile accident in which his companion was decapitated and the patient suffered a fractured skull and leg. The patient was not aware of any chest trauma at the time. A murmur was noted during his discharge examination from the Marines. He has never had any cardiac symptoms, but was referred for evaluation because of his heart murmur. The heart was not enlarged on examination, and the heart sounds were of normal quality. At the apex and at Erb's area a grade 3/6 high-pitched and slightly musical murmur was heard, beginning after a quiet interval following the first sound and extending to the second sound. The murmur was well heard in the axilla and back, but not at the base. The electrocardiogram had a normal axis and QRS duration, frequent premature ventricular contractions, and no evidence of ventricular hypertrophy. Chest radiography and fluoroscopy were normal. Phonocardiograms revealed a systolic click 0·12 sec. after the first sound, initiating a systolic murmur extending to the second sound (Fig. 2). Right and left heart catheterizations were performed, and pressures throughout the heart were normal. A systolic

click was recorded in the left ventricle, but the left atrium was not catheterized. Left ventricular cine-angiograms in the two oblique projections (Fig. 3 and 4) demonstrated aneurysmal dilatation and prolapse of the posterior leaflet of the mitral valve, with moderate mitral regurgitation. Timing studies (Table II) revealed a close correlation of the systolic click and the time of maximal prolapse of the valve leaflet into the atrium. Mitral regurgitation began shortly before the completion of valve prolapse, and continued throughout the remainder of systole.

Case 3. M.L., a 56-year-old Caucasian housewife, had a febrile illness 1½ years before our investigation, and a liver biopsy contained lesions characteristic of periarteritis nodosa. During her initial hospitalization with this illness, a soft systolic murmur was heard, but she had no cardiac symptoms. Eighteen months later, cardiac examination revealed a left ventricular heave, cardiac sounds of normal quality, and a third heart sound over the left præcordium. A high-pitched late systolic murmur was heard at the apex, which transmitted well to the axilla and posterior thorax. At the left sternal border and base, a harsh murmur, which was thought to be of aortic origin, was heard, and there was faint transmission to the carotid arteries. The electrocardiogram was normal, and cardiac fluoroscopy showed minimal generalized cardiomegaly. Phonocardiograms demonstrated a crescendo-decrescendo murmur beginning 0·12 to 0·16 sec. after the first sound and terminating with the second sound. The murmur had similar characteristics in the aortic area. Right and left heart
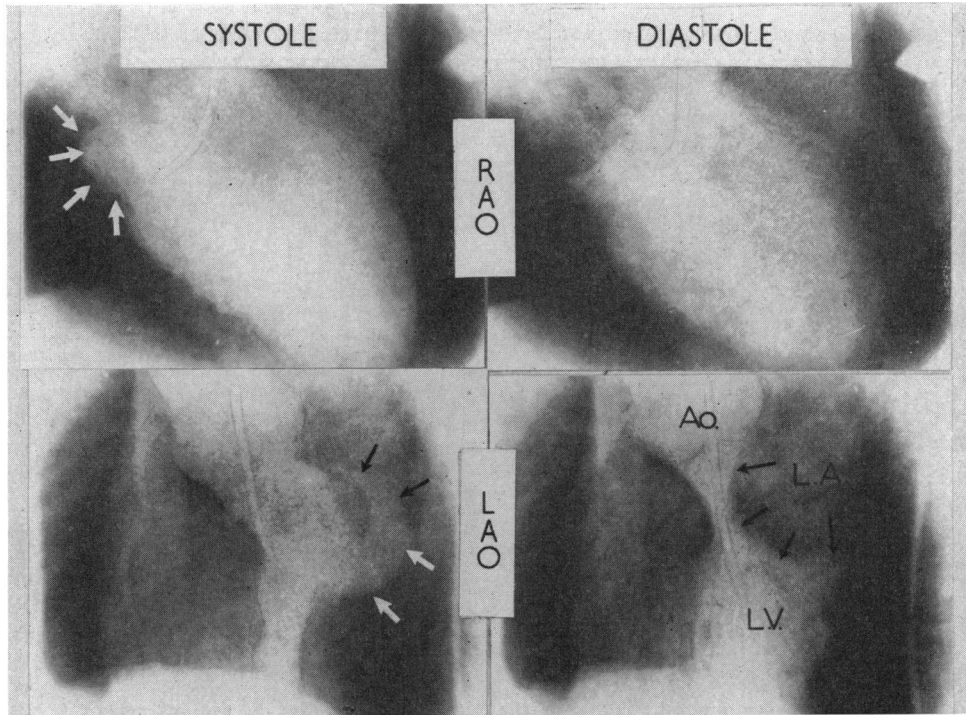
FIG. 1.—Case 1: Retrograde left ventricular cine-angiograms, right (RAO) and left (LAO) anterior oblique projections. *RAO, systole:* a rounded projection (arrows) of the left ventricular contrast silhouette protrudes across the lower portion of the atrio-ventricular ring into the left atrium. The sulcus of the atrio-ventricular ring is identified by the most rightward arrow. The left atrium is opacified by mitral regurgitation. *RAO, diastole:* the mitral valve has opened, and the prolapsed leaflet has pivoted forward into the left ventricle. *LAO, systole:* the projection occupies the postero-lateral rim of the atrio-ventricular ring, and is therefore the posterior (mural) leaflet of the mitral valve. *LAO, diastole:* the open mitral valve is seen as a filling defect which indents the outflow tract of the left ventricle (arrows). The prolapsed leaflet had emptied its contents into the left ventricle a few frames earlier. Note the "narrowing" of the left ventricular outflow tract which might be interpreted as "outflow obstruction" if the diastolic timing of this frame were not known.

catheterizations were performed and pressures were normal at rest. After injections of contrast medium, striking "v" waves appeared in the left atrial pressure pulse (resting "v" wave = 7 mm. Hg., after 1 injection of contrast medium = 25 mm. Hg, after 3 injections = 50 mm. Hg). Intracardiac phonocardiograms demonstrated the late systolic murmur in the left atrium, left ventricle, and aorta. Left ventricular cine-angiograms in both oblique projections revealed prolapse of a small portion of the posterior leaflet of the mitral valve with moderate mitral regurgitation. It was not possible to detect the time of onset of the regurgitant jet. Six months after these studies, she developed left ventricular failure, and the character of the murmur changed markedly. The murmur became less intense, holosystolic in timing, and was poorly heard at the base. Because of severe concurrent symptoms related to her systemic disease, cardiac surgery was not undertaken.

Case 4. J.T., a 17-year-old Caucasian schoolboy, had a cardiac murmur at birth, and never had symptoms suggestive of rheumatic fever. He led a normal life until he began to have infrequent dizzy spells at the age of 4, usually following severe exertion. On examination, he had a normal body habitus, the heart was not enlarged, and there was a systolic thrill at the apex. The heart sounds were normal in intensity, and a loud systolic click was heard at the apex, initiating a grade 4/6 murmur which terminated with the second sound. The electrocardiogram had a vertical axis, broad P waves, peaked T waves in V3–4, and slight S–T elevation in V5–6. Chest radiography revealed a normal heart size and contour. A systolic click 0·16 sec. after the first sound was seen on the phonocardiogram, and the murmur followed the click and extended to the second sound. During cardiac catheterization, the patient developed atrial fibrillation, but all pressures were within
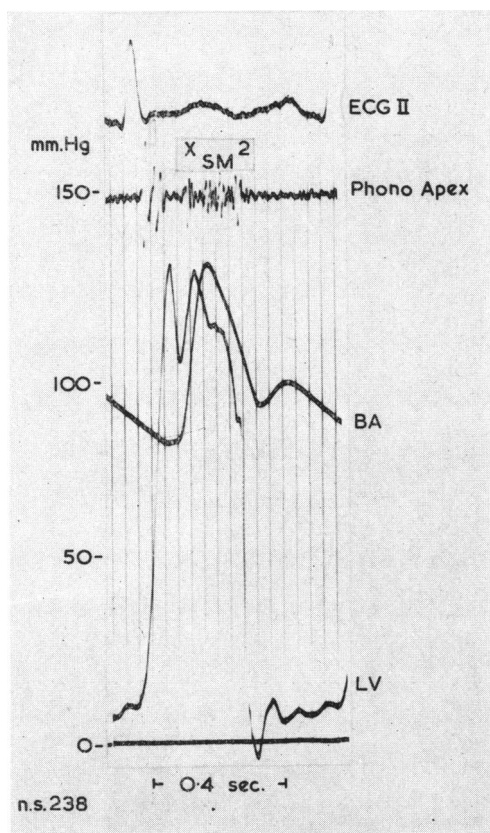
FIG. 2.—Case 2: Apical phonocardiogram with left ventricular and brachial artery pressures. The first sound is intact, and is followed by a click (x) and systolic murmur (SM) 130 msec. later (time lines = 40 msec.). There is no systolic gradient between the left ventricle and brachial artery, and the left ventricular diastolic pressure is normal.

normal limits and the "v" waves in the left atrium were not remarkable. Intracardiac phonocardiography in the left atrium detected a click 0·12 sec. after the first sound, and a systolic murmur (Fig. 5). During the course of the study, the murmur varied in timing from late systolic to holosystolic. Left ventriculography in the LAO and RAO projections (Fig. 6) demonstrated

an enlarged posterior mitral leaflet projecting into the left atrium during systole, and moderate mitral regurgitation. A left atriogram showed the prolapsing leaflet as a negative filling defect (Fig. 6a), and a minimally enlarged left atrium. Cine-angiographic timing studies (Table II) indicated a close correlation of the maximal systolic excursion of the deformed leaflet into the left atrium with the systolic click. The mitral regurgitation began shortly before the completion of prolapse, and continued throughout systole. The boy has been asymptomatic on somewhat restricted activities since the studies were performed.

Case 5. This 5½-year-old Caucasian girl was noted at birth to have extremely long fingers, and at 5 months of age was found to have ectopia lentis. A murmur was first detected at 1 year of age, at which time a diagnosis of Marfan's syndrome was established. Her exercise had been limited by poor vision and hyperextensible joints, but she had no cardiac symptoms. Examination revealed obvious skeletal evidence of Marfan's syndrome including moderate pectus excavatum. The heart was enlarged to the anterior axillary line, where a præcordial heave could be seen. A systolic thrill was palpable over the left præcordium. The heart sounds were of normal quality, and systolic clicks of variable timing were heard over the left præcordium. A more constant click was heard in mid-systole, followed by a grade 3/6 systolic murmur extending to the second sound. The murmur was heard in the axilla and base, but not at the base. A soft early diastolic murmur was heard along the left sternal border. The electrocardiogram revealed broad P waves, vertical axis, delayed præcordial transition, and T inversion in leads II, III, and aVF. Radiography revealed that the over-all heart size was increased, and the left atrium and ventricle were prominent. Increased aortic pulsations were seen on fluoroscopy. Several clicks in early and mid-systole were recorded, and a murmur beginning 0·2 to 0·24 sec. after the first sound was seen constantly. Retrograde left heart catheterization (performed by Dr. Richard D. Rowe) revealed increased left ventricular end-diastolic pressure (16 mm. Hg). A greatly enlarged and deformed mitral valve ballooned back into the left atrium on cine-angiography, and there was moderately severe mitral regurgitation. The aortic sinuses of Valsalva were dilated to twice normal size, and mild aortic regurgitation was seen by aortography. Intracardiac phonocardiography recorded a click 0·2 sec. after the

TABLE II

TIMING STUDIES OF VALVE ACTION IN PROLAPSE OF MITRAL VALVE

| Case No. | Phonocardiograph | | | Cine-angiograph | | | |
| | First heart sound | Click | Onset murmur | Mitral valve closure | Prolapse | | Onset regurgitation |
					Onset	Completion	
1	40	—	160	26	26	93	43
2	80	200	200	94	118	182	165
3	60	—	200	Technically inadequate for timing			
4	80	190	200	70	87	186	135
5	80	190	230	70	120	220	200

All times in msec. after the Q wave of the electrocardiogram
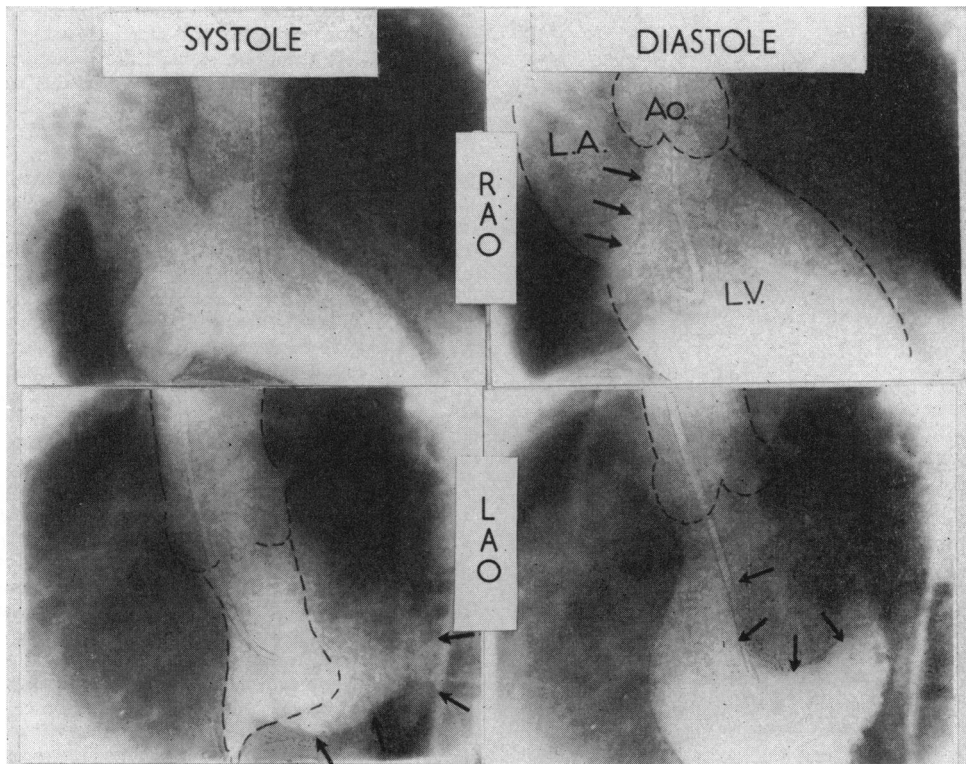
FIG. 3.—Case 2: Retrograde left ventricular cine-angiograms in RAO and LAO projections. *RAO, systole:* a sacular projection of the left ventricular silhouette into the left atrium is seen. The interpretation of this phenomenon is shown diagrammatically in Fig. 4. The left atrium is opacified by mitral regurgitation. *RAO, diastole:* the prolapsed leaflet has swung into the left ventricle, and is no longer visible. The arrows indicate the plane of the mitral valve in diastole. *LAO, systole:* the sacular prolapse occupies the posterolateral portion of the mitral valve. *LAO, diastole:* the orifice of the open mitral valve is indicated by arrows.

first sound in the left ventricle. The click coincided with the timing of the maximal excursion of the mitral valve into the left atrium (Table II).

SUMMARY OF STUDIES

Four of the five patients had clinical and hæmo-dynamic indications of mild mitral regurgitation with little or no cardiac enlargement, no evidence by. electrocardiography of chamber hypertrophy, and normal pressures at catheterization. The young girl with Marfan's syndrome (Case 5) had abnormalities of all of these features.

The cine-angiographic appearance of the mitral valve was similar in all the patients, and the absence of chamber enlargement in the first 4 patients was confirmed. The mitral valve was seen to open widely during diastole (Fig. 1, 3, and 6), producing a large filling defect in the opacified left ventricle, best seen in the LAO projection. With the onset of systole the non-opaque orifice of the valve was

obliterated as the leaflets came together. As systolic contraction progressed, a well-demarcated and smooth-walled projection from the left ventricular contrast shadow extended across the atrio-ventricular ring into the left atrium (Fig. 1, 3, and 6). In mid- to late systole, the contrast medium spread diffusely through the left atrium, producing a double density behind the more heavily opacified ventricular projection. The mitral regurgitation was slight or could not be detected in early systole, but became quite evident after 0·12 to 0·22 sec. (Table II).

As diastole began, the smooth-walled structure within the left atrium advanced rapidly towards the ventricle, pivoting on the atrio-ventricular ring. As the ring was traversed, the structure everted, poured its opaque contents into the left ventricle and thereafter did not displace or contain any contrast medium until the next systolic cycle. In 4 of the cases, the structure projected across the
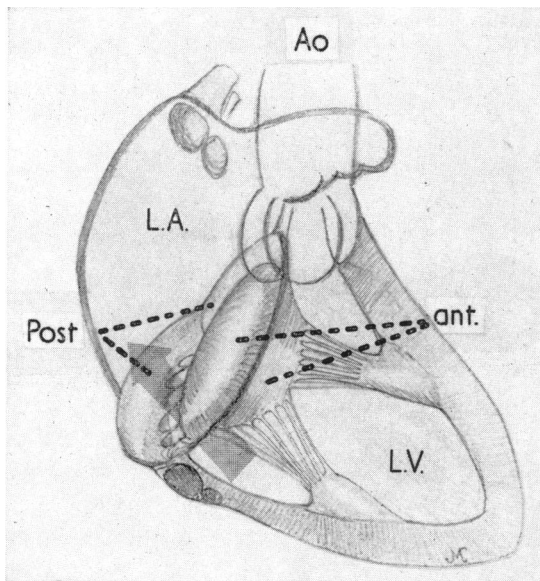
FIG. 4.—Diagrammatic representation of the systolic mitral valve prolapse seen in Case 2, RAO projection. The anterior leaflet is bowed toward the atrium in normal fashion, while the posterior leaflet has prolapsed into the atrium, allowing regurgitation (arrow) along the free margin of the leaflet.

postero-lateral or inferior margin of the atrio-ventricular ring and thus represented a deformed posterior (mural) leaflet of the mitral valve. In Case 5, the prolapsed structure was quite large, and may have been both leaflets or portions of both leaflets.

The systolic click which was demonstrated by chest wall and intracardiac phonocardiograms in 3 of the patients (Fig. 2 and 5), coincided with the timing of the maximum projection of the prolapsed valve structure into the left atrium (Table II). There was some variability in the timing of the clicks from one recording to another, but for purposes of comparison with the motion picture studies, the recording taken immediately before or after the cine-angiogram was utilized in the Table.

The physical characteristics of phonocardiographic registration of murmurs made timing of the onset of the murmurs less precise than that of the clicks. Similarly, it was more difficult to appreciate the exact onset of mitral regurgitation on the cine-angiogram. Despite these limitations, there was a fair correlation between the beginning of the murmur and the first appearance of contrast in the left atrium (Table II).

DISCUSSION

We believe that a systolic murmur of late onset and extending to the aortic closure sound, particu-
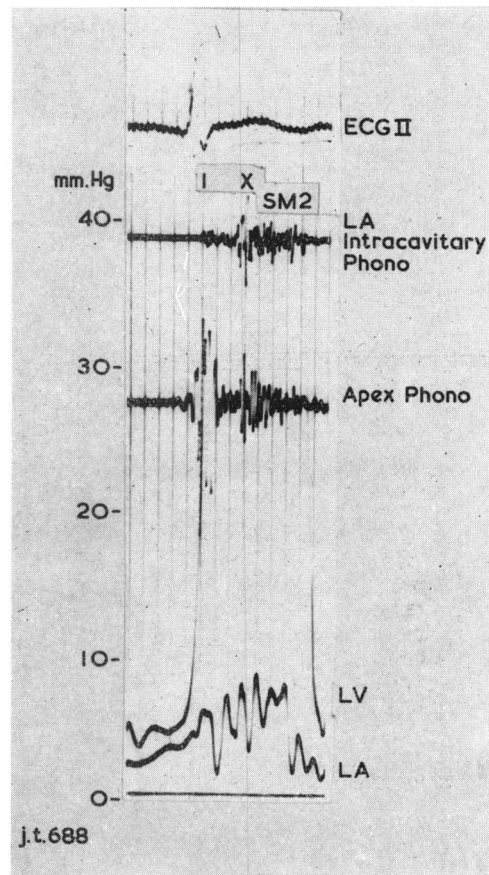

FIG. 5.—Case 4: Apical and intracavitary left atrial phonocardiogram, with left atrial and left ventricular pressures. The first sound is intact on the apical phonocardiogram. A click (x) is seen on both recordings, followed by a decrescendo systolic murmur (SM). The pressure recording reveals a low left atrial pressure. There was a small downward baseline shift in the left atrial pressure. Time lines = 40 msec.

Abbreviations used in figures:

LA = left atrium, LV = left ventricle, Ao = aorta, BA = brachial artery, RAO = right anterior oblique, LAO = left anterior oblique, post = posterior (mural) leaflet of the mitral valve, ant. = anterior (aortic) leaflet of the mitral valve, x = systolic click, SM = systolic murmur, 1 = first heart sound, 2 = second heart sound, Phono = phonocardiogram, ECG = electrocardiogram.

larly if preceded by a click, is suggestive if not diagnostic of prolapse of a portion of the mitral valve. Barlow and Bosman (1965) have reported 5 cases with a specific syndrome comprising an apical late systolic murmur, a non-ejection systolic click ("mid-late" in timing), an electrocardiogram compatible with a postero-inferior infarction, and cine-angiographic features identical to those reported here. However, Barlow's cases were selected
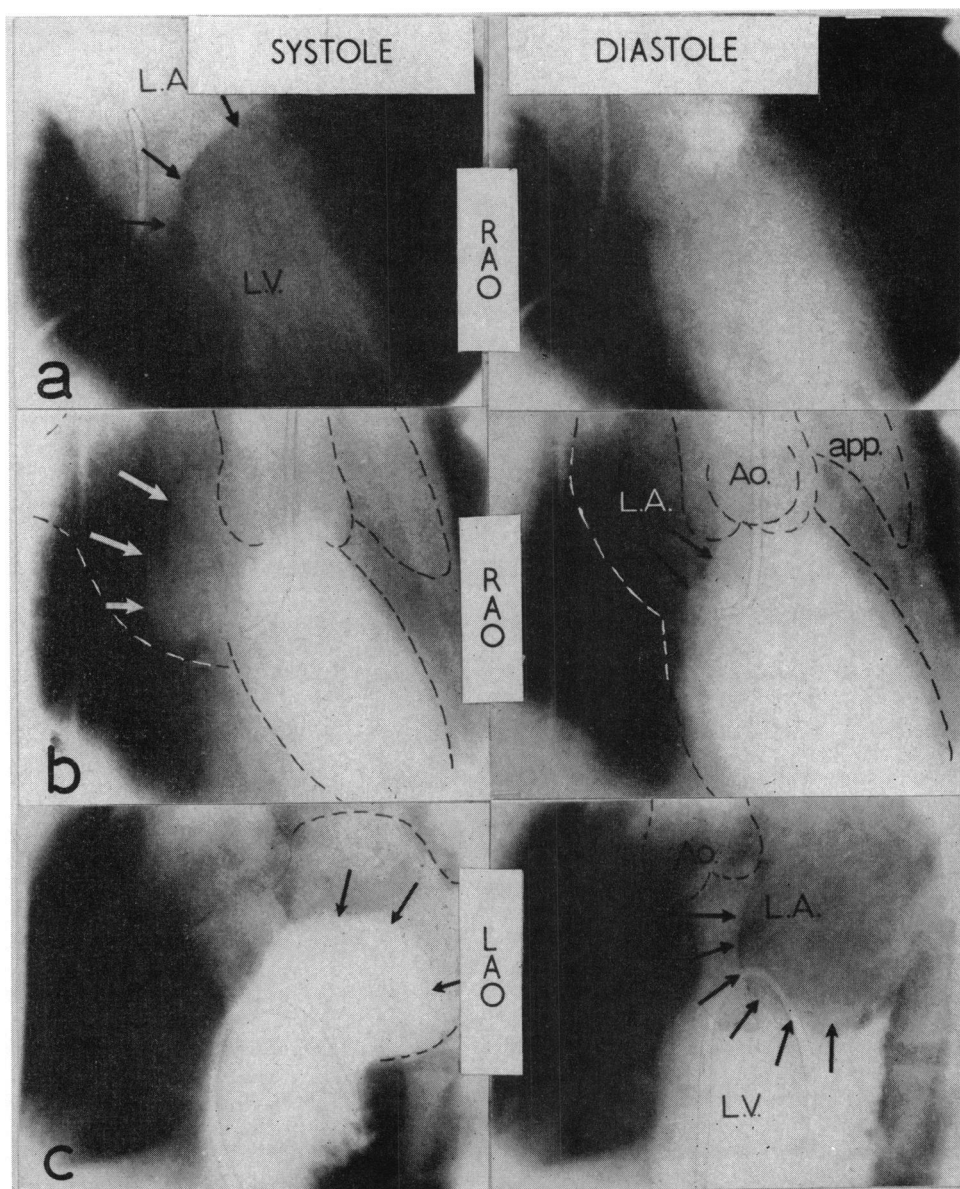
FIG. 6.—Case 4: Left heart cine-angiograms; (a) transseptal left atriogram, RAO, (b) retrograde left ventri-
culogram, RAO, (c) transseptal left ventriculogram, LAO. The prolapsed leaflet is seen as a non-opaque
convexity in the atrial injection (a), and is opacified by the left ventricular injection (b). The structure is not
seen in diastole on any of the injection studies.

from a group of 89 patients with similar phono-
cardiographic findings, some of whom did not
have obvious prolapse of the mitral valve, but did
have mobile leaflets that "billowed prominently".
The difference between billowing and prolapse may
merely be semantic or only a matter of degree,
with one condition merging into the other.

Segal and Likoff (1964) reported 8 patients with
late systolic murmurs due to Grade 2 regurgitation
confined to late systole. They described bulging
of the "septal" (anterior) leaflet of the mitral
valve with jetting of contrast medium into the
left atrium. An illustration (page 760, Fig. 4)
reveals an appearance similar to the cases reported

here. The cine-angiographic appearances of the cases reported by Tavel, Campbell, and Zimmer (1965) are also quite similar.

Other causes of late systolic murmurs have been described: coarctation of the aorta (Wells, Rappaport, and Sprague, 1949), mammary souffle (Tabatznik, Randall, and Hersch, 1960), hypertrophic subaortic stenosis (Bevegård, Jonsson, and Karlöf, 1962), and various benign non-valvular conditions (Humphries and McKusick, 1962a, b; Segal and Likoff, 1964). The first two conditions have obvious features which allow correct recognition of the cause of the murmur. Similarly, subaortic stenosis can often be suspected by the character of the arterial pulse. However, we believe that the murmur in this condition may well be due to mitral regurgitation beginning late in systole and not to late systolic obstruction of the outflow tract (Criley *et al.*, 1965). The benign condition responsible for clicks and late systolic murmurs (Humphries and McKusick, 1962a, b; Segal and Likoff, 1964) has not been clearly defined. In view of the evidence presented here that patients with prolapsed valves may have no symptoms, a normal heart size, and normal values at cardiac catheterization, a specific angiographic evaluation of mitral valve function may be necessary to rule out a valvular cause for the murmur.

In contrast to the uniformity of the clinical and cine-angiographic findings, the underlying causes of valve prolapse in the 5 cases varied widely. In none was rheumatic fever thought to be causative, though no aetiology was established in Cases 1 and 4. Case 5, the young girl with Marfan's syndrome, had widespread connective tissue disease and a grossly deformed aortic valve, and hence the mitral lesion was probably a result of the basic disease process. Segal and Likoff (1964) had one case of Marfan's syndrome in their series of patients with late systolic murmurs. The serious automobile accident was thought to be responsible for the lesion in Case 2, either through rupture of chordae tendineae or a portion of the free margin of the valve. Periarteritis nodosa could be responsible for the lesion in Case 3: lesions have been reported in the myocardium and papillary muscles in this disease (Askey, 1950).

Since none of the patients was significantly disabled by cardiac disease alone, surgery has not been indicated, and therefore anatomical examination of the valve has not been possible. The mitral regurgitation seen in these patients could result from either disease of the papillary muscle, chordae tendineae, the valve leaflets, or a combination of factors. Papillary muscle dysfunction following myocardial infarction has been responsible for

mitral regurgitation and a late systolic murmur in patients studied by Burch, De Pasquale, and Phillips (1963) and Phillips, Burch, and De Pasquale (1963). Disruption of the papillary muscle or a significant number of chordae usually leads to massive and catastrophic degrees of mitral regurgitation, but severance of only a few chordae might be expected to result in lesser degrees of incompetence. Chordal rupture is most often due to bacterial endocarditis (Osmundson, Callahan, and Edwards, 1961), but can occur as a result of trauma (Barber, 1944; McLaughlin *et al.*, 1964), or as a result of rheumatic fever. Abnormal laxity of the chordae has been described in Marfan's syndrome (McKusick, 1955; Raghib *et al.*, 1965).

Cine-angiographic evaluation does not provide sufficient detail to define chordal integrity, but aneurysmal bulging of the leaflets was present in all the patients studied in this report. This aneurysmal bulging of the leaflets may be the angiographic counterpart to the hoodlike or balloon deformity seen at necropsy in patients with ruptured chordae (Osmundson *et al.*, 1961; Edwards and Burchell, 1958; Bailey and Hickam, 1944). The "floppy valve syndrome", a result of myxomatous changes in the leaflet tissue in patients with and without stigmata of Marfan's syndrome, has been described (Read *et al.*, 1964), but cine-angiographic data on these patients have not been reported. It seems unlikely that rheumatic valvulitis could cause aneurysmal deformity, since scarring and retraction are the usual sequelae of rheumatism. Congenital abnormalities of the leaflets associated with endocardial cushion defects lead to deformity of the anterior leaflet, with ballooning of a portion of the valve into the septal defect during systole. This phenomenon has been noted on angiocardiograms by Baron *et al.* (1964) and Omeri *et al.* (1965). Cine-angiograms of these congenitally deformed valves are quite similar to the cases in this report: there is a projection of the left ventricular contrast shadow into the region of the right atrium, and this well-demarcated structure empties completely in early diastole. However, the presence of a large left-to-right shunt clearly distinguishes the two types of valve deformity.

The type of mitral valve dysfunction described in this report may be amenable to corrective surgery without the necessity of replacing the valve, since there is more than the normal amount of valve tissue. The aneurysmal bulging may be a result of loss of chordal support, and it is possible that the process will be self-perpetuating and the incompetence will increase with time. If these assumptions are correct, early surgical intervention would be indicated in patients with signs of progressive disability.

SUMMARY

A specific anatomical type of mitral regurgitation was recognized cine-angiographically in 5 patients with late systolic murmurs.

Prolapse of a portion of the mitral valve, usually the posterior leaflet, was responsible for the regurgitation in each case.

Correlations of cine-angiograms and phonocardiograms provided a functional anatomical basis for the auscultatory findings. (a) The systolic click (present in 3 patients) coincided with the time of maximal valve prolapse. (b) The late onset of the systolic murmur could be attributed to the initially competent valve becoming incompetent as the valve prolapse occurred.

The valve lesions, though anatomically similar, were caused by different disease processes. Rheumatic fever was not implicated in any of the cases.

Although the symptoms were mild in the reported cases, the long-term prognosis is not known.

REFERENCES

Askey, J. M. (1950). Spontaneous rupture of a papillary muscle of the heart: Review with eight additional cases. *Amer. J. Med.*, 9, 528.

Bailey, O. T., and Hickam, J. B. (1944). Rupture of mitral chordæ tendineæ: clinical and pathologic observations on seven cases in which there was no bacterial endocarditis. *Amer. Heart J.*, 28, 578.

Barber, H. (1944). The effects of trauma, direct and indirect, on the heart. *Quart. J. Med.*, 13, 137.

Barlow, J. B., and Bosman, C. K. (1965). Aneurysmal protrusion of the posterior leaflet of the mitral valve: an auscultatory—electrocardiographic syndrome. *Amer. Heart J.*, 71, 166.

Baron, M. G., Wolf, B. S., Steinfeld, L., and Van Mierop, L. H. S. (1964). Endocardial cushion defects: specific diagnosis by angiocardiography. *Amer. J. Cardiol.*, 13, 162.

Bevegård, S., Jonsson, B., and Karlöf, I. (1962). Low subvalvular aortic and pulmonic stenosis caused by asymmetrical hypertrophy and derangement of muscle bundles of the ventricular wall. *Acta med. scand.*, 172, 269.

Burch, G. E., De Pasquale, N. P., and Phillips, J. H. (1963). Clinical manifestations of papillary muscle dysfunction. *Arch. intern. Med.*, 112, 112.

Criley, J. M., Ross, R. S., Lewis, K. B., and White, R. I., Jr. (1965). Pressure gradients without obstruction—a new concept of "hypertrophic subaortic stenosis". *Circulation*, 32, 881.

Edwards, J. E., and Burchell, H. B. (1958). Endocardial and intimal lesions (jet impact) as possible sites of origin of murmurs. *Circulation*, 18, 946.

Humphries, J. O. (1963). Diagnosis of pure mitral regurgitation. In *The Theory and Practice of Auscultation*, ed. B. L. Segal. Davis, Philadelphia.

——, and McKusick, V. A. (1962a). The differentiation of organic and "innocent" systolic murmurs. *Progr. cardiovasc. Dis.*, 5, 152.

——, and —— (1962b). Murmur of late systole. (Abstract). *Circulation*, 26, 735.

McKusick, V. A. (1955). The cardiovascular aspects of Marfan's syndrome: a heritable disorder of connective tissue. *Circulation*, 11, 321.

—— (1958). *Cardiovascular Sound in Health and Disease.* Williams and Wilkins, Baltimore.

McLaughlin, J. S., Cowley, R. A., Smith, G., and Matheson, N. A. (1964). Mitral valve disease from blunt trauma. *J. thorac. cardiovasc. Surg.*, 48, 261.

Omeri, M. A., Bishop, M., Oakley, C., Bentall, H., and Cleland, W. P. (1965). The mitral valve in endocardial cushion defects. *Brit. Heart J.*, 27, 161.

Osmundson, P. J., Callahan, J. A., and Edwards, J. E. (1961). Ruptured mitral chordæ tendineæ. *Circulation*, 23, 42.

Phillips, J. H., Burch, G. E., and De Pasquale, N. P. (1963). The syndrome of papillary muscle dysfunction: its clinical recognition. *Ann. intern. Med.*, 59, 508.

Raghib, G., Jue, K. L., Anderson, R. C., and Edwards, J. E. (1965). Marfan's syndrome with mitral insufficiency. *Amer. J. Cardiol.*, 16, 127.

Read, R. C., Thal, A. P., Wolf, P. L., and Wendt, V. E. (1964). Symptomatic valvular myxomatous degeneration: floppy valve syndrome. (Abstract). *Circulation*, 30, Suppl. 3, p. 143.

Ross, R. S., and Criley, J. M. (1962). Contrast radiography in mitral regurgitation. *Progr. cardiovasc. Dis.*, 5, 195.

——, ——, and Morgan, R. H. (1961). Cineangiocardiography in mitral valve disease. *Trans. Ass. Amer. Phycns*, 124, 271.

Segal, B. L., and Likoff, W. (1964). Late systolic murmur of mitral regurgitation, *Amer. Heart J.*, 67, 757.

Tabatznik, B., Randall, T. W., and Hersch, C. (1960). The mammary souffle of pregnancy and lactation. *Circulation*, 22, 1069.

Tavel, M. E., Campbell, R. W., and Zimmer, J. F. (1965). Late systolic murmurs and mitral regurgitation. *Amer. J. Cardiol.*, 15, 719.

Wells, B. G., Rappaport, M. B., and Sprague, H. B. (1949). The sounds and murmurs in coarctation of the aorta: a study by auscultation and phonocardiography. *Amer. Heart J.*, 38, 69.

ADDENDUM

After this manuscript was submitted, a 23–year-old man with a history suggestive of recurrent pericarditis was studied in our laboratory. On clinical evaluation the patient had a normal heart size, a systolic click 0·1 second after the first sound, and no murmur, though a late systolic murmur had been heard previously. The electrocardiogram was normal. Pressures were normal in the right and left heart. Prolapse of the posterior leaflet of the mitral valve was seen on left ventricular cine-angiography, but there was no mitral regurgitation.