Late systolic click in non-obstructive cardiomyopathy

Edward N. Mercer¹, Robert L. Frye, and Emilio R. Giuliani

From Mayo Clinic and Mayo Foundation, Section of Medicine; Mayo Graduate School of Medicine, University of Minnesota, Rochester, Minnesota, U.S.A.

Two patients with seriously impaired left ventricular function, abnormal left ventricular conduction on the electrocardiogram, mitral regurgitation, and a very late systolic click are reported. Idiopathic non-obstructive cardiomyopathy seemed to be the cause of the left ventricular dysfunction in both cases. The mitral valve was anatomically normal at the time of operation in one patient, except for dilatation of the annulus, and the mitral regurgitation appeared to be secondary to left ventricular failure. The very late timing of the mitral systolic clicks in these two patients may be related to a large left ventricular end-diastolic volume and impaired left ventricular function, or to an abnormal sequence of excitation of the left ventricle. The timing of the late systolic click in these patients is in contrast to that in patients with mid systolic clicks, hearts of normal size, and little cardiac disability.

The genesis of mid systolic and late systolic clicks has been controversial. Some authors considered them to be extracardiac and of little significance (Gallavardin, 1913; Thompson and Levine, 1935; Johnston, 1938; Wolferth and Margolies, 1940; McKusick, 1958; Bleifer *et al.*, 1959). There is now abundant evidence that these clicks usually arise in the mitral valve apparatus (Reid, 1961; Barlow, 1965; Barlow *et al.*, 1963, 1968; Kesteloot and Van Houste, 1965; Ronan, Perloff, and Harvey, 1965; Tavel, Campbell, and Zimmer, 1965; Criley *et al.*, 1966; Hancock and Cohn, 1966; Leighton *et al.*, 1966; Leon *et al.*, 1966; Behar, Whalen, and McIntosh, 1967; Stannard *et al.*, 1967; Grossman *et al.*, 1968; Engle, 1969). Barlow and associates (1965, 1968) indicated that clicks of mitral origin might occur in early, middle, or late systole, and referred to them as 'nonejection systolic clicks'. Such systolic clicks have been described in association with rheumatic heart disease, Marfan's syndrome, ischaemic heart disease, congenital heart disease, trauma, mitral valve operations, and, most particularly, in the syndrome of the mid systolic click-late systolic murmur of mitral regurgitation (Barlow, 1965; Barlow *et al.*, 1963, 1968; Hancock and Cohn, 1966; Stannard *et al.*, 1967; Grossman *et al.*, 1968; Engle, 1969). Further, a nonejection click was found in 1 of 90 cases of

obstructive cardiomyopathy (Barlow *et al.*, 1968).

This report describes two patients in whom a very late, loud, non-ejection systolic click was found in the presence of non-obstructive cardiomyopathy with mitral regurgitation. Cardiac catheterization and angiocardiology were performed in both patients. Phonocardiograms were recorded on a three-channel Elema-Schönander Mingograf Cardirex Model 31B recorder with simultaneous lead II electrocardiographic and external carotid pulse tracings. Systolic time intervals were determined by the method of Weissler, Harris, and Schoenfeld (1968).

Report of cases

Case 1 A 50-year-old man was first seen in October 1968 for cardiac evaluation. He had been well until 8 months before admission, when paroxysmal nocturnal dyspnoea and moderate exertional dyspnoea developed abruptly. Symptoms of congestive heart failure persisted in spite of medical treatment.

He had had labile hypertension since age 17 years but it did not require therapy. At age 21 years he had had an illness characterized by arthralgia and malaise but without fever. An apical systolic murmur was heard at that time and a presumptive diagnosis of rheumatic fever was made. He was treated with aspirin and bed-rest for 3 months, after which he had no difficulties until the present illness. Periodic examinations to age 40 years had revealed no murmur or cardiac enlargement; he had had no further

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¹ Present address: The Montreal General Hospital, Montreal 109, Quebec, Canada.

examination until the present illness. There was no history of excessive alcohol intake and the family history was negative for cardiac disease.

On admission, the pulse rate was 80/min. and regular; the blood pressure was 158/94 mm. Hg. The ocular fundi showed mild hypertensive sclerosis. The jugular venous pressure was normal. The carotids had a brisk upstroke but decreased volume. The apical impulse was in the left sixth intercostal space in the anterior axillary line. The first heart sound was decreased; a prominent third sound was present at the apex. A pansystolic murmur (grade 2/6) at the apex was interrupted by a late systolic click. A variable late systolic 'honk' followed the systolic click. A few râles were heard at the lung bases. The liver was moderately enlarged. The results of the remainder of the examination were normal.

Fluoroscopy showed moderate to marked left ventricular and left atrial enlargement, moderate right ventricular enlargement, and no intracardiac calcification. The electrocardiogram showed left ventricular hypertrophy and conduction delay (Fig. 1).

A phonocardiogram, made 10 days after admission, showed the late systolic click, a pansystolic murmur, and the intermittent late systolic 'honk' or 'whoop' (Fig. 2). Measurement of systolic time intervals showed abbreviation of the left ventricular ejection time (Table 1). Right and retrograde left heart catheterization with left ventricular biplane angiography were performed. The haemodynamic findings are shown in Table 2. The angiocardiogram showed conspicuous reduction of left ventricular contraction, dilatation of the left ventricle, and mild mitral regurgitation. A diagnosis of non-obstructive cardiomyopathy was made and the patient was not offered surgical treatment. He was discharged, 16 days after admission, on a regimen of digitalis, low-sodium diet, and intermittent diuretic therapy.

Case 2 A 56-year-old woman was admitted to the hospital in January 1969 because of dyspnoea of 3 months' duration. She had been examined at the Mayo Clinic in 1965 because of malaise, weight loss, vague abdominal complaints, and palpitations; the findings had been essentially negative, except for left bundle-branch block on the electrocardiogram. No cardiac murmur was heard. In 1965 she had received electroshock therapy elsewhere for depression. She had been well otherwise until November 1968 when exertional dyspnoea, paroxysmal nocturnal dyspnoea, and oedema developed abruptly while she was on holiday at 9,000 feet. She improved on treatment with digitalis and diuretics but still had exertional dyspnoea. There was no history of rheumatic fever or excessive alcohol intake. The family history was negative for cardiac disease.

On admission she was thin but otherwise appeared well. The pulse rate was 110/min. and regular; the blood pressure was 110/70 mm. Hg. The jugular venous pressure was moderately increased with prominent A and V waves. The carotid pulses were brisk. The precordium was

FIG. 1 (Case 1) *Electrocardiogram showing left ventricular hypertrophy and left ventricular conduction delay (1 mV = 1 cm. deflection; recorded at 50 mm./sec.).*

hyperactive with a triple cardiac impulse in the left sixth intercostal space, 3 cm. lateral to the midclavicular line. There was a systolic thrill at the apex. The first heart sound was diminished. The second sound was soft but was preceded by a very loud click in late systole, which was maximal in the third left intercostal space in the mid-clavicular line. A loud third sound was present at the apex. There was a pansystolic murmur (grade 3/6) widely heard over the praecordium but maximal at the apex. The remainder of the physical examination gave normal results.

FIG. 2 (Case 1) *Phonocardiogram recorded in fourth left interspace along sternal border. Note pansystolic murmur (SM), very late systolic click (LSC), and normal relation between the two components of second heart sound (A₂, P₂). This patient had an intermittent late systolic 'honk'.*

Fluoroscopy showed small bilateral pleural effusions and obvious left ventricular enlargement. There was no valvular or coronary artery calcification. The electrocardiogram showed left bundle-branch block (Fig. 3).

Phonocardiography showed the late systolic click (Fig. 4 upper). Systolic time intervals were abnormal (Table 1), consistent with impaired left ventricular function (Weissler *et al.*, 1968). Right and retrograde left heart catheterization with left ventriculography were performed. The haemodynamic findings are shown in Table 2. The left ventriculogram showed poor contraction of the left ventricle and gross mitral regurgitation.

At open-heart operation, 2 weeks after admission, the heart was grossly enlarged. The ventricles appeared flabby and contracted poorly. The coronary arteries were grossly normal. The tricuspid valve was normal. The mitral valve appeared entirely normal except for conspicuous dilatation of the ring to a diameter of 6 cm. Mitral annuloplasty was carried out. The post-operative course was complicated by a cerebral embolus from which the patient recovered. After operation, the praecordium was much less active than previously. There was a late systolic murmur (grade 2/6) at the apex, and the loud, late systolic click was still present. Phonocardiography on the 13th post-operative day indicated the late click and normal splitting of the second sound (Fig. 4 lower). After administration of amyl nitrite by inhalation, the click softened considerably but did not alter its timing. The final diagnosis was idiopathic cardiomyopathy, and the patient was discharged 15 days after the operation.

Discussion

The course and clinical findings in these two patients were consistent with a diagnosis of idiopathic non-obstructive cardiomyopathy (Mattingly, 1961; Harvey, Segal, and Gurel, 1964; Goodwin, 1964, 1967). Both had mitral regurgitation (though this was mild in Case 1), probably secondary to left ventricular failure, and both had a very late systolic click. Since each patient also had abnormal ventricular conduction on the electrocardiogram, the possibility that the late click represented paradoxical splitting of the second heart sound was considered. Evidence indicating that the late systolic click was not the pulmonary closure sound consisted of the following: (1) in Case 1, the second heart sound appeared to contain two components with the second occurring later than the dicrotic notch of the external carotid pulse tracing; (2) in Case 2, normal splitting of the second heart sound was shown phonocardiographically; (3) measurement of Q-to-dicrotic notch intervals on aortic root and pulmonary artery pressure records obtained during cardiac catheterization indicated that pulmonary valve closure followed aortic valve closure in

TABLE 1 Summary of phonocardiographic data*

Measurement	Case 1	Case 2†
Heart rate (beats/min.)	73	109
QRS duration (sec.)	0.11	0.14
Electromechanical systole (Q to S ₂ , sec.)	0.371 (0.393 ± 0.028)	0.332 (0.331 ± 0.028)
Pre-ejection period (PEP, sec.)	0.122 (0.102 ± 0.026)	0.174 (0.089 ± 0.022)
Left ventricular ejection time (LVET, sec.)	0.249 (0.289 ± 0.020)	0.158 (0.244 ± 0.020)

* Numbers in parentheses indicate normal values (mean ± 2SD), according to sex and heart rate, from Weissler and associates (1968).

† Measurements made on preoperative phonocardiogram.

TABLE 2 Summary of haemodynamic data

Measurement	Case 1 (M—50 yr.)	Case 2* (F—56 yr.)
Cardiac index, Fick (l./min./m. ²)	1.8	1.4
Pressures (mm. Hg)		
Femoral artery	134/87	124/72
Left ventricle (systolic/end-diastolic)	117/23	102/20
Wedge		
Mean	23	29
V wave	34	47
Main pulmonary artery (systolic/diastolic)	46/20	59/30
Right ventricle (systolic/end-diastolic)	49/11	52/11
Right atrium (systolic/diastolic)	7/1	11/2

* Pulsus alternans during most of study.

FIG. 3 (Case 2) Electrocardiogram showing left bundle-branch block (1 mV = 1 cm. deflection; recorded at 50 mm./sec.).

both patients; and (4) the total duration of electromechanical systole (Q to S₂) was normal in both patients (Weissler *et al.*, 1968), indicating that aortic valve closure was not delayed.

The mechanism of mitral systolic clicks is unknown. It has been suggested that the click is due to a 'chordal snap' related to prolapse of a mitral valve leaflet, elongated chordae tendineae, or disturbed papillary muscle function (Reid, 1961; Barlow, 1965; Barlow *et al.*, 1963, 1968; Criley *et al.*, 1966; Hancock and Cohn, 1966). Anatomical studies of patients with the click syndrome are sparse. One patient reported to have a non-ejection click died suddenly and had a voluminous posterior mitral leaflet and elongated chordae tendineae at necropsy (Barlow *et al.*, 1968). Other patients appear to have large billowing mitral valve leaflets on cine-angiocardiology (Criley *et al.*, 1966; Behar *et al.*, 1967; Stannard *et al.*, 1967; Bittar and Sosa, 1968). In such cases the postulated chordal snap appears likely as the source of the click. The patient in the present report who underwent operation had no apparent anatomical abnormality of the mitral valve to account for the systolic click. Observations by Grossman and associates (1968) in patients with the mid systolic click syndrome suggested that the click and late mitral regurgitation were due to an abnormal bulging of the inferior aspect of the left ventricle, which allowed ballooning of the posterior mitral leaflet during systole. A similar mechanism might have been operative in our patients, but no abnormality of the inferior ventricular wall was identified on the left ventriculograms.

The systolic click in both our patients occurred very late in systole, being located 87 per cent of the distance from the Q wave to the aortic closure sound (A₂) in Case 1 and 83 per cent in Case 2. Most reported patients with non-ejection systolic clicks do not appear to have such a late timing of the click (Reid, 1961; Barlow, 1965; Barlow *et al.*, 1968; Kesteloot and Van Houte, 1965; Hancock and Cohn, 1966), though three patients reported (but not described in detail) by Barlow and associates (1968) had a click 85 per cent or more of the distance from Q to A₂. On the basis of the movement of non-ejection clicks with various manoeuvres, Barlow and associates (1965, 1968) concluded that ventricular end-diastolic volume and myocardial contractility were the major factors in the timing of systolic clicks. Thus, the very late timing in our two patients with severe cardiac disease and obvious enlargement of the left ventricle might be explained on this basis.

FIG. 4 (Case 2) *Phonocardiograms.* Upper, before operation, showing diminished first heart sound (S₁), pansystolic murmur (SM), late systolic click (LSC), and third heart sound (S₃). Lower, on 13th post-operative day: late systolic click was still present. Note normal relation between the two components of second heart sound (A₂, P₂). Loud protodiastolic gallop persisted after operation (S₃). Late systolic murmur not shown.

Another possible explanation of the late timing of systolic clicks that requires investigation is the possible influence of an abnormal sequence of excitation of the left ventricle. Both patients in the present report had electrocardiographic evidence of abnormal left ventricular conduction. The degree of mitral incompetence does not seem to be a factor in the late timing of the clicks because Case 1 had very little mitral incompetence and Case 2 had gross mitral incompetence.

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