THE PHONOCARDIOGRAPHY OF HEART MURMURS

PART II.—CLINICAL RESULTS AND DISCUSSION

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Received December 31, 1948

Papers by William Evans (1947) suggested that the phonocardiograph could aid the clinician in the elucidation of the following points: (1) the distinction between the systolic murmur found with organic heart disease and the systolic murmur found with no organic heart disease, referred to as an innocent murmur; (2) the murmurs found in mitral stenosis; (3) the distinction between aortic incompetence of rheumatic as opposed to that of syphilitic aetiology; and (4) the presence of unsuspected aortic diastolic murmurs in cases of hypertension.

SYSTOLIC MURMURS

One important problem in clinical cardiology is the investigation of systolic murmurs in the hope that the healthy youngster with a systolic murmur can be saved from some form of cardiac invalidism imposed by the medical profession.

Evans (1947) found that the systolic murmurs in organic heart disease, with the exception of those found in hypertension, heart block, and a few cases of aortic valvular disease if recorded from the mitral area (which are all unimportant from the above standpoint), occur early in electrical systole; whereas the systolic murmurs recorded in subjects without clinical heart disease—the “innocent” group—occur in mid or late electrical systole.

Evans used the S line, a line drawn through the end of the S wave of lead II of the electrocardiogram to touch the simultaneously recorded phonocardiogram to distinguish the two groups. A systolic murmur occurring at the S line was found in the organic group while a systolic murmur beginning some distance after the S line was found in the innocent group. In none of the innocent group was a diastolic murmur recorded.

To investigate this point two series of cases were collected clinically and checked by cardioscopy and electrocardiography.

Group I consisted of 57 cases of known congenital or valvular heart disease with systolic murmurs to auscultation and phonocardiography (see Fig. 3-6, 8A, B, and C, 10A, B, and C).

Group II consisted of 27 cases with obvious systolic murmurs but with no other evidence of disease. An obvious systolic murmur has been taken as one lasting an appreciable interval into systole between the first and second heart sounds and of not less than moderate intensity (Grade III, Levine, 1945), for it is this group of murmurs that presents a clinical difficulty as to whether organic disease is present or not. In four cases the systolic murmur was loud or very loud (Grade IV or V) and one of these suffered an undoubted attack of subacute bacterial endocarditis after the investigation—emphasizing that an organic lesion was present although careful cardiological investigation revealed no deviation from the normal other than a loud systolic murmur. Twenty-one of these cases (77 per cent.) were aged 30 or under. (See Fig. 7A, B, and C).

The phonocardiograph employed recorded a stethoscopic or logarithmic phonocardiogram with lead II electrocardiogram as reference tracing. (See Part I.) The time-marker on all the records is 0.2 seconds. Records are marked to show the

TABLE I
RELATION OF ONSET OF SYSTOLIC MURMURS TO S
LINE IN LEAD II ELECTROCARDIOGRAM

Timing	Valvular or congenital heart disease 57 cases		No diagnosed heart disease 27 cases	
After S ..	38	66.6%	27	100%
At S	9	15.7%	—	—
Doubtful ..	10	17.5%	—	—

FIG. 3.—Ventricular Septal Defect. Logarithmic phonocardiogram from site of maximal intensity of murmur—note that low frequencies in the first and second heart sounds are not recorded, and that the base line is very clear.

FIG. 4.—Aortic stenosis. A second heart sound was audible at the base and is recorded.

S line, the heart sounds I, II, III, and IV, systolic murmurs (S.M.), and diastolic murmurs (D.M.). Other lettering is explained under the appropriate figure. The site from which the record has been taken is indicated after the type of phonocardiogram shown (steth = stethoscopic, log = logarithmic).

It will be seen that in two-thirds of the organic cases the systolic murmur began after the S line, whereas only in 9 did it begin at the S line. A further analysis (Table II) of these 9 cases shows that a systolic murmur occurring at the S line can occur with most forms of valvular or congenital heart disease but wherever there were sufficient

cases to draw any conclusions it appears to be uncommon in any particular defect. (See Fig. 8A).

It would appear from this investigation that the systolic murmurs encountered in valvular and congenital heart disease cannot be differentiated from the systolic murmurs occurring with no recognizable heart disease by their relation to the S line of lead II of the electrocardiogram. For although in all the Group II cases the systolic murmur occurred after the S line, the same applied to at least 66 per cent of the cases in Group I.

It has been known for many years that mechanical and electrical systole in man and experimental

FIG. 5.—Pulmonary stenosis. No second heart sound was audible or is recorded. Record shows a low frequency event marked ?III ?IV which could be either a third heart sound because it occurs about 0.2 sec. after the second heart sound, or a fourth heart sound occurring as it does just after the P wave of the electrocardiogram, or a combination of both. The electrocardiogram cannot be used to differentiate these possibilities.

TABLE II
ANALYSIS OF RELATION OF ONSET OF THE SYSTOLIC MURMUR
TO THE CLINICAL DIAGNOSIS IN ORGANIC HEART DISEASE

Diagnosis	Site of record	No. of cases with S.M. at S line	No. of cases with S.M. after S line	No. of cases with doubtful onset of S.M.
Aortic incompetence	Base	3	12	3
Aortic stenosis ..	Base	1	1	0
Mitral stenosis ..	Apex	1	11	2
Combined rheumatic valvular lesions	Apex	1	5	2
Active rheumatic carditis	Apex	1	0	0
Auricular septal defect	Base	1	0	2
Ventricular septal defect	4th space left sternal edge	1	2	1
Pulmonary stenosis ..	Base	0	3	0
Fallot's tetralogy ..	Apex	0	2	0
Patent ductus arteriosus	Base	0	1	0
Lutembacher's syndrome	Apex	0	1	0
Total	57	9	38	10

animals are not simultaneous either in onset or in duration (Wiggers, 1944). Such asynchrony would provide the simplest explanation for the varying relation of systolic murmurs to the S line of the electrocardiogram. Thus in Fig. 4 the whole of the first heart sound occurs after the S line.

It will also be noted that it is a condition of the cases in Group II that they should have a normal electrocardiogram, whereas many cases in Group I had abnormal electrocardiograms often with a widened QRS interval. However, only 3 of the 9 cases with a systolic murmur at the S line had a widened QRS interval.

MITRAL STENOSIS

Evans (1947) found that when a systolic murmur was heard without a presystolic murmur in mitral stenosis, the murmur as recorded by phonocardiography started during the P-R period of lead II of the electrocardiogram in 33 out of 41 cases. In other words the murmur was really presystolic and not systolic in timing and due to auricular contraction. He also found that the systolic murmur never occurred later than the S line and that there was a mid-diastolic murmur in all of his 74 cases.

To test these points a consecutive series of 30 cases of mitral stenosis was investigated. (See Fig. 8A, B, and C.) In 17 of these cases a systolic murmur was recorded as it was heard. It never occurred

FIG. 6.—Atrial septal defect. Note splitting of the first and second heart sounds. This is not a good record as it shows “mush.”

during the P-R period of the electrocardiogram. In all 17 it occurred after the first heart sound. Its relation to the S line lead II electrocardiogram was as follows:

After the S line in	..	..	..	12
At the S line in	..	..	..	2
Exact onset doubtful in	..	..	..	3

In 15 of the series a presystolic murmur was heard, and in all 15 cases it was clearly seen on the record during the P-R period of the electrocardiogram. It was always separate from a systolic murmur if present and also differed from such a systolic murmur in that its mean frequency was considerably lower (See Fig. 8C.)

The position of the second heart sound in Fig. 8A and B has been determined by taking phonocardiographic records from the base of the heart where the second sound was clearly seen in these cases and transposing to the apical records. Apical and basal records were taken within a few minutes of one another. (Fig. 10A is a record from the base of the heart and Fig. 8A an apical record in a case of combined mitral stenosis and aortic incompetence.) The second heart sound is probably split in Fig. 8C.

It is my impression that the sole information which the phonocardiograph has added to that of auscultation in the cases of mitral stenosis in this series is that a mitral diastolic murmur occurs more frequently than it is heard. However, one cannot be certain of this unless the record shows a clear base line, and this was not always obtained.

Problems such as whether an opening snap of the mitral valve is always present in mitral stenosis, and the differentiation of this snap from a third heart sound (which may be of diagnostic importance in mitral stenosis) could not be investigated owing to the limitations imposed by the apparatus in having no other reference tracing than the electrocardiogram. Fig. 9A is an apical record from a case of mitral stenosis, with a linear phonocardiogram (apex cardiogram) as reference tracing in which a third heart sound is clearly indicated and in which no opening snap of the mitral valve is shown.

AORTIC INCOMPETENCE

Evans, in a series of 20 cases of aortic incompetence, found that 8 were clinically of syphilitic aetiology and 12 of probable rheumatic origin, although with no definite evidence of this after full cardiological investigation. After phonocardiography at the apex he considered that there was proof of rheumatic aetiology in 16 out of the 20 cases because of the presence of presystolic and mid-diastolic murmurs from added mitral stenosis.

To test this finding a series of 21 consecutive cases of aortic incompetence was investigated clinically (see Fig. 10A, B, and C); 11 were considered to be of rheumatic, 5 of syphilitic, and 5 of unknown aetiology.

Of the 11 rheumatic cases, 5 had definite evidence of mitral stenosis both to clinical and to phonocardiographic examination (See Fig. 10A and 8A taken from same patient.) In the remaining 6

FIG. 7.—“Innocent” systolic murmurs. Note that the relation of the systolic murmur to the S line does not differ from that found in organic heart disease.

In (B), note the auricular part of the first heart sound (a).

FIG. 8.—Mitral stenosis—apical recordings. Three patients.

- (A) Systolic murmur (S.M.) starting at the S line.
- (B) Systolic murmur starting well after the S line.
- (C) No systolic murmur.

A presystolic murmur (P.S.M.) is only shown in (C), auricular fibrillation being present in (A) and (B).

The opening snap of the mitral valve is probably shown at (c) in (A). Mid-diastolic murmur (M.D.M.).

FIG. 9.—Mitral stenosis. (A) Apical and (B) basal records of one patient. A loud pulmonary second sound was heard and the large amplitude of this sound in the logarithmic basal record is well seen.

cases there was no auscultatory or phonocardiographic evidence of mitral stenosis, although in 2 of these the apical records showed long aortic diastolic murmurs that might have obscured any mitral mid-diastolic murmurs present.

Of the remaining 10 cases in the series, none showed phonocardiographic evidence of mitral stenosis although 4 had long aortic diastolic murmurs recorded on the apical records, which might have obscured any mitral mid-diastolic murmurs present.

One case with aortic incompetence and subacute bacterial endocarditis, but of uncertain aetiology, in which no evidence of mitral stenosis had been heard or recorded by phonocardiography, died. Post-mortem, no enlargement of the left auricle was found; there was no evidence of rheumatic endocarditis or valvulitis, and microscopy did not elucidate the aetiological diagnosis.

In this series of cases of aortic incompetence no additional information to that found on clinical examination was given by phonocardiography.

UNSUSPECTED AORTIC DIASTOLIC MURMURS IN HYPERTENSION

Evans found aortic diastolic murmurs in 12 of a series of 43 hypertensive cases and in some cases of heart block. In order to test this finding a series of 20 cases of hypertension with loud or ringing aortic second sounds and diastolic blood pressures consistently over 100 mm. was investigated. In no case was a diastolic murmur heard clinically. The ringing quality as heard by auscultation showed itself as a musical second sound of no greater width than normal on phonocardiographic records taken from the aortic area, and no diastolic murmur was detected after the second sound in any case (See Fig. 11A and B.)

Evans in interpreting his records has stated that "at the end of the T wave (lead II electrocardiogram) the second sound starts." Such a relationship has not been observed by other users of the phonocardiogram (Orias and Braun-Menendez, 1939). It can be seen from Fig. 7B and 10B that

FIG. 10.—Aortic incompetence—basal recordings. Three patients. (A) and (B) are stethoscopic and (C) a logarithmic phonocardiogram.

FIG. 11. Hypertension—basal recordings. Two patients. Ringing aortic second sounds but no diastolic murmurs are present. A systolic gallop sound (S) is present in (A).

the T wave bears a sufficiently variable relationship to the second sound to make it valueless as an indication of the onset of the second heart sound. It is believed that Evans' records of hypertension can bear a different interpretation if this is taken into account.

SUMMARY AND CONCLUSIONS

An investigation was planned to test some of the phonocardiographic findings on heart murmurs announced by Evans (1947). In order to do this it became necessary to construct a new phonocardiograph whose characteristics are described in Part I.

No clear-cut distinction between the systolic murmurs found in valvular and congenital heart disease (57 cases) and those found in patients with no evidence of heart disease (27 cases) could be established by timing the onset of these murmurs against the S line of lead II of the electrocardiogram.

The systolic and presystolic murmurs in 30 cases of mitral stenosis were found to be clearly distinguishable from one another in timing and mean frequency, as they were on clinical auscultation.

No additional aetiological information to that collected clinically was found by a phonocardiographic examination of 21 cases of aortic incompetence.

In 20 cases of hypertension with a consistent diastolic blood pressure of over 100 mm. none was found with an aortic diastolic murmur.

For phonocardiography to be a useful aid in clinical cardiology it is necessary to use an instrument whose characteristics are known and satisfy certain basic considerations. The electrocardiogram alone is an unsatisfactory reference tracing for studying heart murmurs by phonocardiography as there is no strict co-relation between the electrical and mechanical events of the cardiac cycle.

Although the phonocardiographic investigations recorded in this article are of a negative nature it is felt that phonocardiography can help the clinician in the diagnosis of heart murmurs, and work on these lines is progressing.

It has been a great pleasure to work in close co-operation with the Research Department of the Cam-

bridge Instrument Company, England, to whom my grateful thanks are offered.

I wish to record my thanks to Professor Sir Lionel Whitby, Regius Professor of Physic at Cambridge, for much help and advice; to Dr. Leslie B. Cole of Addenbrooke's Hospital, Cambridge, for permission to use his

cases and for his enthusiasm and advice; and to Dr. William Evans for his generous advice and help.

This work was undertaken during the tenure of an Elmore research studentship at the University of Cambridge.

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