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Radiocardiography in Rheumatic Heart Disease and Its Value in Selection of Cases for Mitral Commissurotomy

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The use of surgery in the treatment of some forms of rheumatic valvular heart disease has made the accurate diagnosis of the site, type and grade of the cardiac lesion of great practical importance and not of mere academic interest.

In a trial to reach the proper assessment, the present series of cases were examined clinically, radiologically, electrocardiographically and by radiocardiography (1). Furthermore, to evaluate the aid that radiocardiography can offer, the results of radiocardiographic examination in some cases of mitral stenosis were correlated with the findings obtained during commissurotomy operations.

MATERIALS AND METHODS

The present report deals with the findings obtained in 76 patients, 60 males and 16 females. Their ages ranged between 9 and 62 years. From this group of patients, 64 had evidence of valvular lesion affecting one or more of the cardiac valves. The distribution of these cases was as follows: 34 pure mitral stenosis (MS), 3 pure mitral regurgitation (MR), 12 double mitral valve affection (DM), 1 pure aortic regurgitation (AR), 14 combined mitral and aortic valves affection (Tables I, II). The remaining 12 patients suffered from rheumatic fever (Table III).

For every patient a thorough clinical examination, electrocardiogram, x-ray (postero-anterior and oblique views) and radiocardiography were done. This latter test was performed with the patient lying comfortably on a couch. About 12 μc of human serum albumin tagged with I^{131} in ½ ml saline were injected rapidly in an antecubital vein using a wide bored needle. Radioactivity traveling through the heart chambers was detected by two well-shielded scintillation detectors. A flat field collimator with an aperture 3 inches in diameter was attached to one of the detectors and pointed towards the centre of the radiographic image of the the heart. To the other detector, a collimator having an aperture

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one inch wide was applied and centered just medial to the apex beat. The information collected by these probes was measured by two synchronized count rate meters with a time constant (TC) of one second, and recorded on a dual strip chart recorder moving at a rate of 12 inches per minute. The first detector with its connections were used to draw the common radiocardiographic tracing, whereas the second helped in the accurate definition of the peak of the L wave (2).

TABLE I

RADIOCARDIOGRAPHIC PATTERN IN RHEUMATIC MITRAL VALVE AFFECTION

Type and number of cases		*R wave*		*L wave*		*Total duration*	*PCT*	*MPCT*
		**A*	**B*	**C*	**D*			
Normals (120)	Mean	2.6	2.8	1.6	7.6	14.6	4.4	5.6
	Range	1.0–4.8	1.0– 4.8	0.6–4.0	3.2–12.8	9.0–21.0	2.6– 6.1	2.8– 8.5
MS (34)	Mean	4.5	5.8	2.6	13.8	26.7	8.4	10.2
	Range	2.4–8.0	1.8–11.6	0.8–4.2	6.0–16.0	14.2–48.4	3.6–17.2	4.5–24.0
Operated MS (9)	Mean	5.1	6.5	2.6	14.2	28.4	9.2	11.6
	Range	3.0–8.0	3.0–11.6	1.8–4.2	8.0–26.0	15.8–48.4	4.8–15.4	6.5–18.6
MR (3)	Mean	2.7	1.5	2.6	9.9	16.3	4.1	4.9
	Range	2.4–3.0	1.0– 2.0	2.2–3.0	7.0–12.0	12.6–20.0	3.2– 5.0	3.4– 6.4
DM (12)	Mean	3.7	4.0	2.3	10.8	20.8	6.3	8.3
	Range	1.4–6.0	1.6– 7.4	1.2–4.0	6.0–20.0	11.6–30.2	3.6–11.4	4.5–13.2
DM Predominant MR (9)	Mean	2.9	3.2	2.0	10.2	18.3	5.2	7.0
	Range	1.4–6.0	1.6– 4.8	1.2–2.8	6.0–20.0	11.6–30.2	3.6– 7.2	4.5–10.5
DM Predominant MS (3)	Mean	4.6	6.4	3.0	9.5	26.8	9.4	11.9
	Range	4.0–5.2	5.8– 7.4	1.4–4.0	11.0–16.0	24.0–31.4	8.0–11.4	11.0–13.2

All measurements are in seconds.
*A, B, C & D are shown in Fig. 1.
PCT: Peak to peak pulmonary circulation time.
MPCT: Mean pulmonary circulation time calculated by the method of Rosaia.

CALCULATIONS

A normal radiocardiogram is made of two waves, R & L, representing the right and left sides of the heart, respectively. In a common radiocardiographic tracing, R is higher in amplitude than L, which is longer in duration; since radioactivity is diluted into the pulmonary bed before reaching the left side of the heart. The ascending limb of each wave stands for filling, whereas the descending represents emptying of the corresponding cardiac chambers. This is why it was thought advisable to analyse the radiocardiographic tracings obtained in the present work by dividing each into four arbitrary segments A, B, C & D (Fig. 1) representing filling and emptying of the right and left sides of the heart, respectively. The dip in the curve (T) is caused by passage of radioactivity from beneath the detectors into the lesser circulation. Thus, the time interval between the peaks of R and L waves, made of segments B & C, represents roughly the pulmonary circulation time and is called the peak-to-peak pulmonary circulation time (PCT) (Fig. 1). According to Rosaia (3), a mean value which approximates remarkably the real mean pulmonary circulation time (MPCT) can

TABLE II

RADIOCARDIOGRAPHIC PATTERN IN RHEUMATIC AORTIC VALVE INVOLVEMENT

Diagnosis and number of cases		*R wave*		*L wave*		*Total duration*	*PCT*	*MPCT*
		**A*	**B*	**C*	**D*			
Normals (120)	Mean	2.6	2.8	1.6	7.6	14.6	4.4	5.6
	Range	1.0–4.8	1.0–4.8	0.6–4.0	3.2–12.8	9.0–21.0	2.6– 6.1	2.8– 8.5
AR (one)	—	2.6	2.2	3.4	13.8	22.0	5.5	6.8
MS & AS (one)	—	3.9	3.9	5.2	8.6	21.7	9.1	11.5
MS & AR (7)	Mean	3.2	3.8	1.8	10.0	18.8	5.6	7.1
	Range	1.4–5.0	1.8–4.4	0.7–2.7	5.4–14.0	10.9–24.4	2.5– 6.8	2.7– 8.7
DM & AR (4)	Mean	3.9	3.7	1.8	8.7	18.1	5.5	8.0
	Range	2.4–5.0	2.0–5.0	1.2–2.4	7.0–11.0	13.6–22.8	3.2– 6.8	4.5–11.1
DM & DA (2)	Mean	2.9	5.7	5.8	38.0	52.4	11.4	11.6
	Range	2.4, 3.4	4.2, 7.1	5.5, 6.0	17.0, 59.0	29.6, 75.0	10.2, 12.6	10.3, 12.8

*A, B, C & D are shown in Fig. 1.

be obtained by means of the following formula in the interval between minimum and maximum times of a common radiocardiographic curve:

$$MPCT = \frac{S_{ct}}{S_c}$$

Where S_{ct} is sum of product of concentrations for the times.
S_c is sum of concentrations.

RESULTS

Cases of mitral stenosis without radiological evidence of cardiac dilatation and showing no abnormality in ECG tracings and had normal radiocardiograms. In contradistinction, patients suffering from tight mitral stenosis with electrocardiographic signs of right ventricular hypertrophy and/or strain and radiological evidence of enlargement of left atrium and right ventricle, had abnormal radiocardiographic picture. The main abnormality was in the R wave, which was noticed to be longer in duration, specially its descending limb (segment B). In the very severe cases, the peak of the R wave was not sharp, taking the shape of

TABLE III

RADIOCARDIOGRAPHIC PATTERN IN PATIENTS HAVING RHEUMATIC FEVER WITH OR WITHOUT CARDITIS

Diagnosis and number of cases		*R wave*		*L wave*		*Total duration*	*PCT*	*MPCT*
		**A*	**B*	**C*	**D*			
Rheumatic fever (5)		2.0	2.5	1.6	5.0	11.1	4.1	4.9
Rheumatic carditis (4)		2.4	2.0	1.7	6.8	12.9	3.7	4.1
Rheumatic fever with old DM (3)		2.1	2.3	1.4	7.1	12.9	3.7	4.5
Rheumatic fever all cases (12)	Mean	2.2	2.2	1.6	6.5	12.5	3.9	5.1
	Range	1.4–3.4	1.6–3.4	0.7–2.2	4.0–8.0	10.0–15.4	2.5–4.6	2.7–6.6
Normals (31)	Mean	2.2	2.4	1.4	5.9	11.9	3.8	5.1
	Range	1.0–3.4	1.0–4.0	0.6–2.6	3.2–9.6	9.0–16.0	2.5–5.8	2.8–7.6

Both groups of subjects are of the same age group; being 9 to 19 years.
*A, B, C & D are illustrated in Fig. 1.

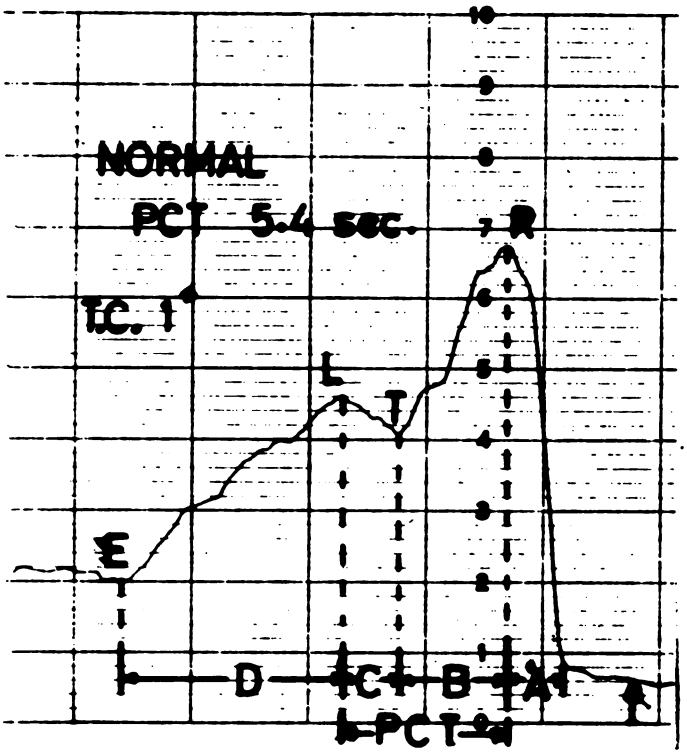

Fig. 1. Radiocardiogram of normal subject, aged 32 years, showing all component parts of the curve. R wave being made of the ascending limb (A) and descending limb (B). L wave made of the ascending part (C) and the descending part (D).
T = transitional zone between R & L waves.
E = end of tracing.
PCT = equals B + C; in this case it was 5.4 seconds.
T.C. = time constant of rate meter in seconds.

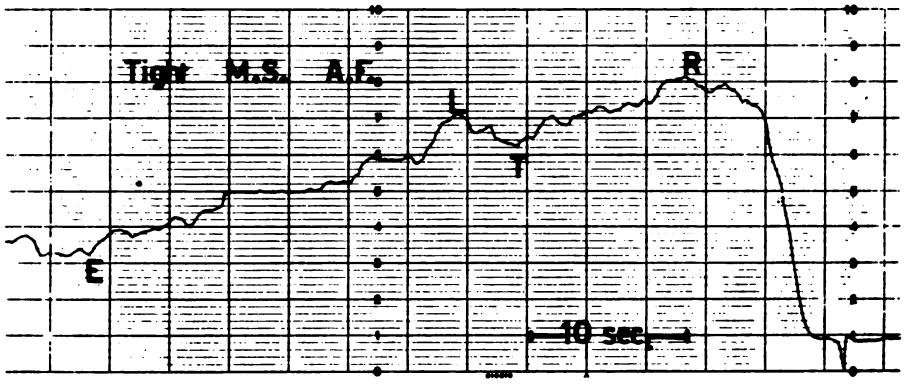

Fig. 2. Radiocardiographic tracing of a case of tight mitral stenosis with atrial fibrillation, before commissurotomy. There is marked prolongation in descending limb of R. PCT is 15.4 seconds.

a plateau rather than a peak (Fig. 2). The elongation of the descending limb of the R wave naturally led to prolongation of the PCT (Table I). The average PCT in the 34 cases of MS examined was 8.4 seconds (Normal—4.4 sec); with a range of 3.6 to 17.2 seconds (Normal—2.6-6.1 sec). In the same group of patients the average MPCT was calculated and amounted to 10.2 seconds, with a range of 4.5 to 24.0 seconds.

Figure 3 illustrates the radiocardiogram of one of the three patients having pure mitral incompetence included in the present series of cases. In these patients—in contrast to the normal—the L wave was higher in amplitude than the R wave. The PCT in these cases ranged between 3.2 and 5.0 seconds, with a mean of 4.1 ± 0.9 seconds (Mean ± 1 SD).

Similar to mitral stenosis, the main radiocardiographic abnormality in patients having double mitral valve affection was prolongation of the R wave, with consequent elongation of the PCT (Fig. 4). But, this effect was much less marked than in cases of pure MS, especially when patients having a predominant stenotic lesion were excluded (Table I). This is further supported by comparison of radiocardiograms of two patients having nearly equal cardiac shadows in postero-anterior x-ray films as measured by planimetry; one suffering from pure MS (Fig. 5), the other having DM (Fig. 6). The PCT in the first was 15.4 seconds (Fig. 2); while the patient who suffered from DM had a PCT of 5.6 seconds (Fig. 4). In patients having DM with predominant incompetence, the radiocardiographic curve tended to preserve its general configuration though appearing stretched out. In 2 of these 9 patients presenting with DM lesions the L wave was nearly of the same amplitude as R.

In the case of free aortic regurgitation studied, radiocardiography revealed

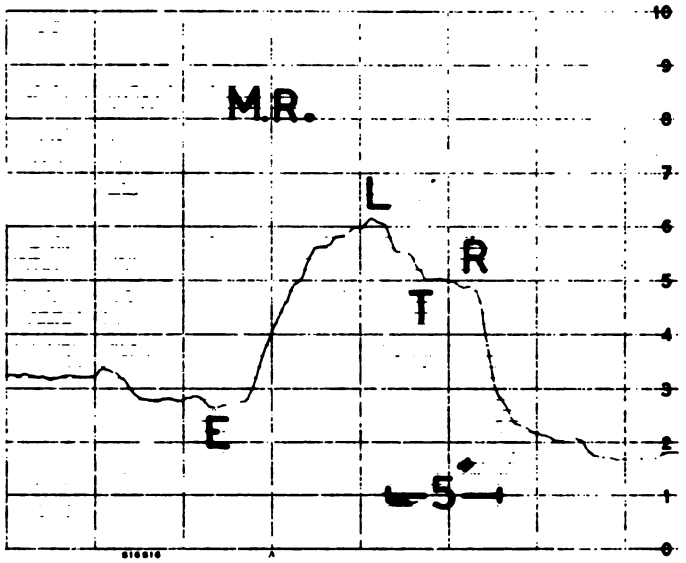

Fig. 3. Radiocardiogram of patient having pure mitral insufficiency. In contrast to normal, L is higher than R.

equal amplitude for both R & L waves, with a PCT of 5.6 seconds (Fig. 7).

It was noticed that in all patients presenting with a combined mitral and aortic valvular affection, the R wave was prolonged and L higher than normal. This can be clearly seen by comparing Fig. 8 with Fig. 1. Prolongation of the L wave was seen in the presence of cardiac dilatation, heart failure and/or aortic stenosis. The duration of the PCT was dependant on the predominant valvular lesion and on the presence of cardiac failure. The longest PCT recorded in combined mitral and aortic involvement was in cases showing predominant MS with double aortic valve lesions in the presence of cardiac failure (Table II).

Patients suffering from rheumatic fever, with or without carditis had a normal radiocardiographic pattern. This can be clearly seen from a comparison of the results obtained in the 12 patients who had rheumatic fever with the radiocardiographic pattern in 31 normal subjects of the same age group (Table III).

DISCUSSION

Radiocardiography was described in 1948 by Prinzmetal *et al* (1) to record graphically the passage of a radioactive bolus through the different cardiac chambers, thus giving direct information on the blood volumes and transport rates within the various chambers of the heart. Some years later, with the development of more sensitive equipment and availability of nondiffusible tracers, modifications were introduced into this technique by various groups of workers (4-7).

In pure mitral stenosis, radiocardiography revealed prolongation of the R wave, especially its descending limb (segment B) denoting delayed emptying of the right ventricle (8) and leading to elongation of PCT. The PCT in the 34

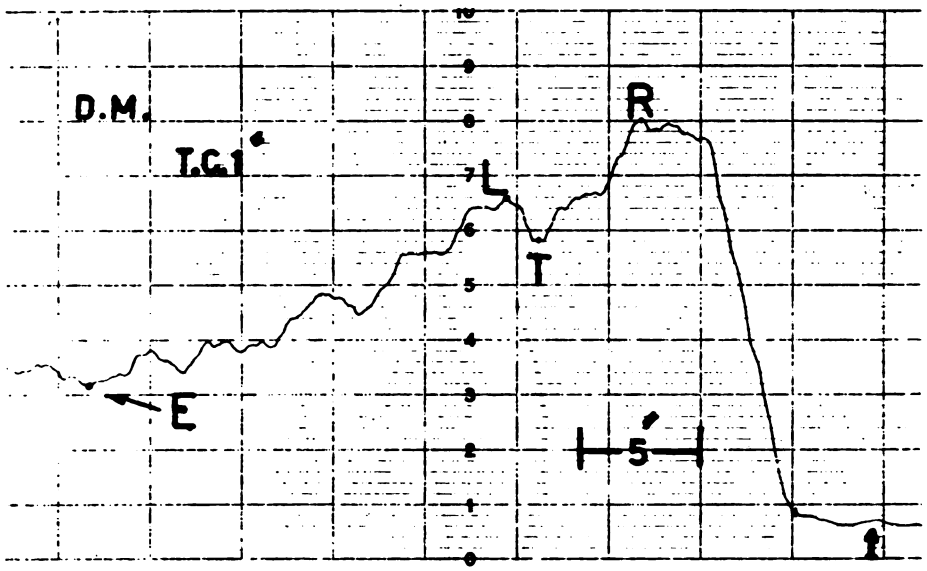

Fig. 4. Radiocardiographic curve of patient suffering from a double mitral lesion, with predominant regurgitation. PCT is 5.6 seconds.

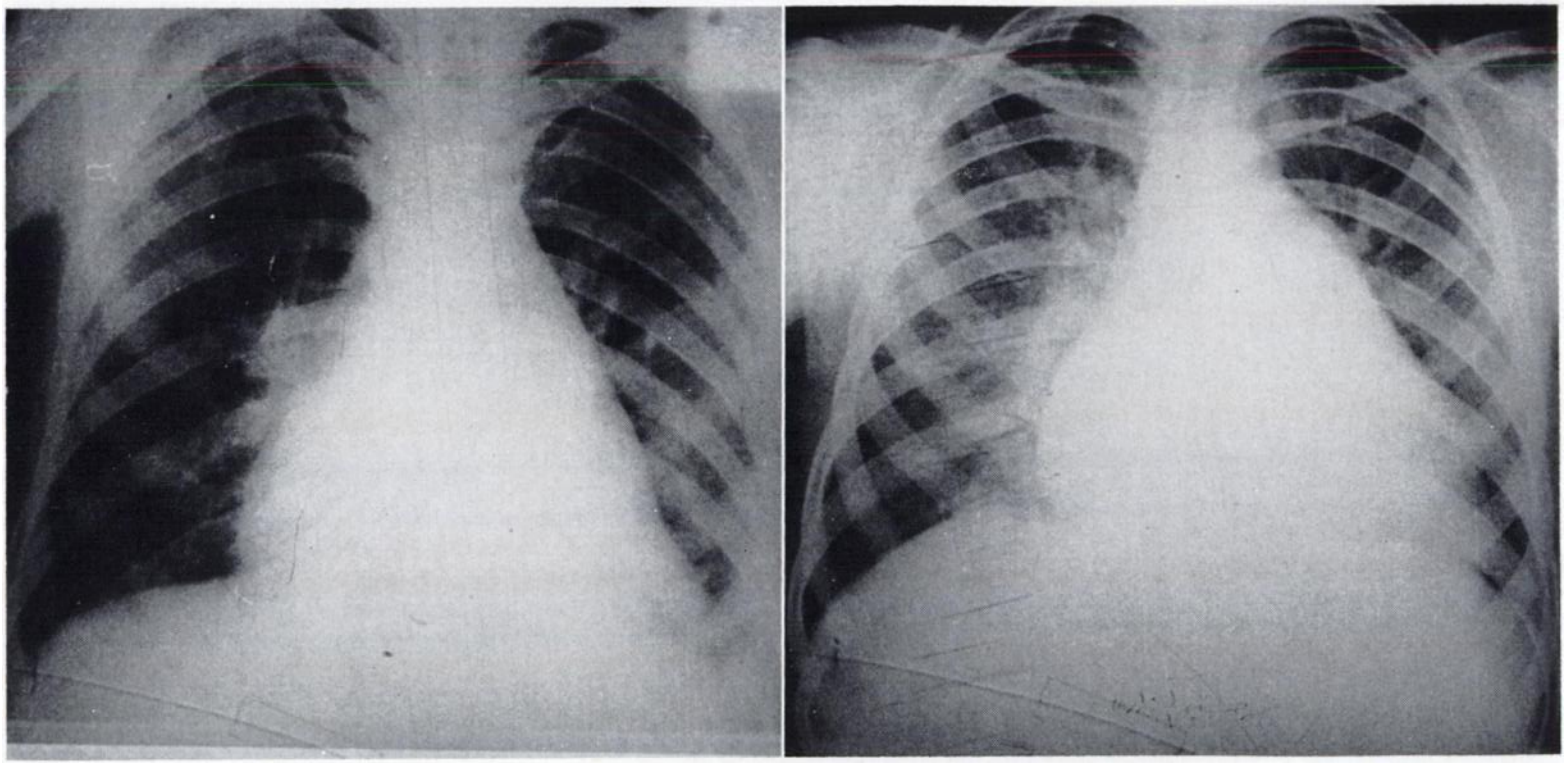

Fig. 5

Fig. 5. X-ray of tight mitral stenosis. Corresponding radiocardiogram is shown in Fig. 2.

Fig. 6

Fig. 6. X-ray of a case of DM. Cardiac shadow was nearly equal to that seen in Fig. 5, as measured by planimetry. His radiocardiogram is shown in Fig. 4.

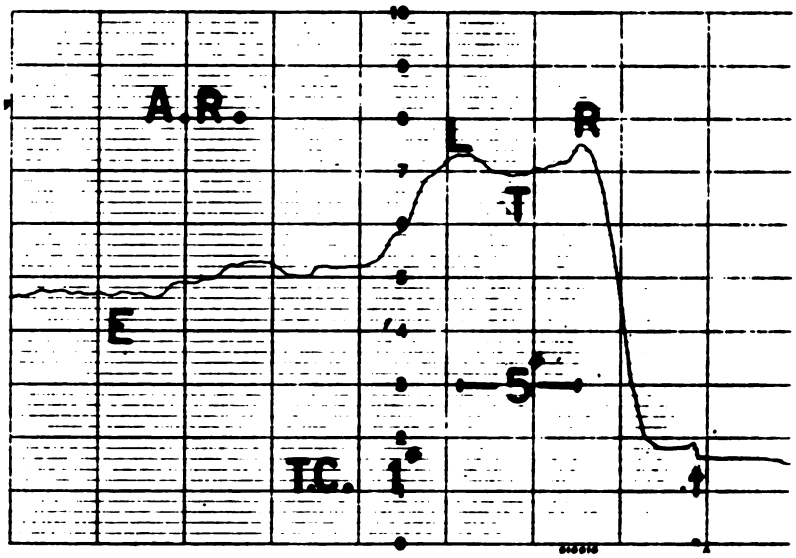

Fig. 7. Radiocardiogram of free aortic regurgitation. B.P. 140/40 mm of Hg. L is equal to R. The descent of L, specially in its early part, is very steep.

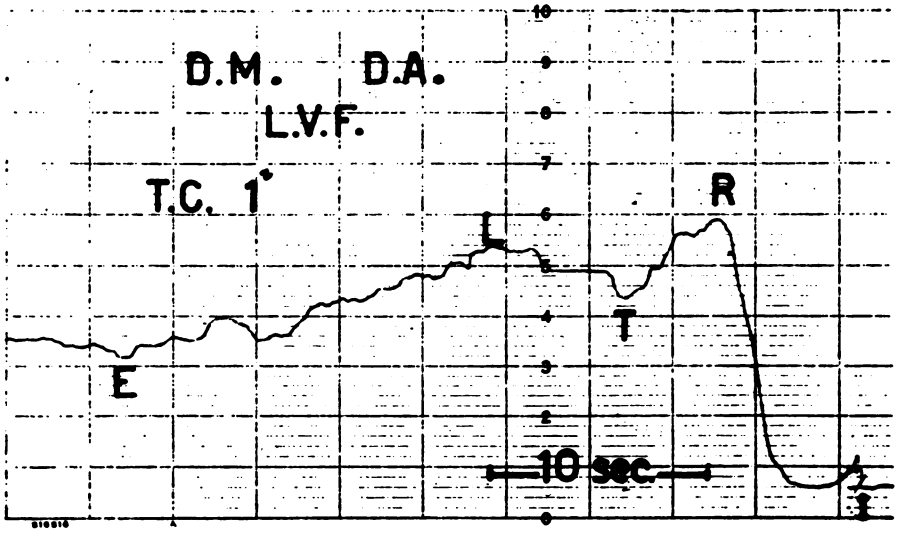

Fig. 8. Radiocardiogram of a case of DM & DA. L is high in amplitude and much prolonged, especially its descending limb. PCT is 10.2 seconds.

cases of MS included in this work ranged between 3.6 and 17.2 seconds, with an average of 8.4 seconds. In the same group of cases MPCT amounted to 10.2 seconds with a range of 4.5 to 24.0 seconds. This prolongation of PCT in mitral stenosis was similarly observed by various groups of workers in this field (9-12). In a study of 40 cases of MS, Pietila and Hakkila (11) found that peak-to-peak PCT ranged between 5.2 and 18.9 seconds; and that there was a highly significant correlation between PCT on one hand and both the relative radiologic heart size and the degree of impairment of physical performance on the other. This correlation was verified in the present work among cases having the same type of valvular lesion *i.e.*, MS. But, comparison of cases having identical cardiac shadows as measured by planimetry revealed that PCT was longer in pure MS than in cases suffering from a DM valve lesion, denoting that size of the heart could not be the main nor most important factor to explain prolongation of PCT. In their studies on the pulmonary circulation, Borden *et al* (13) reported that the mean circulation time was a function of the rate of blood flow and the intrathoracic blood volume. But, since various authors (9, 13, 14) found no significant increase in the intrathoracic blood volume in mitral stenosis, then the main factor controlling the duration of the PCT would naturally be the rate of blood flow in the lesser circulation. Thus, prolongation of the MPCT in MS would be due to diminution in the velocity of blood flow secondary to the increased pulmonary vascular resistance. This is supported by our finding in the present series of cases that prolongation of the circulation time in MS was caused by elongation of the descending limb of the R wave (segment B) (Table I & Fig. 2), denoting delayed emptying of the right heart. Therefore, it appears that the MPCT in cases of M.S. could give us an idea about the factors that cause or reflect the raised pulmonary vascular resistance, namely the width of the mitral orifice and the degree of pulmonary hypertension. The validity of this assumption can be proved from analysis of the radiocardiographic data obtained in nine cases of MS that were operated upon[1] (Table IV). From Table IV it can be seen that the more tight the stenosis, and the higher the pulmonary pressure, the more prolonged was the mean pulmonary circulation time. A further support to this conclusion can be obtained from a study of the radiocardiograms drawn before and after commissurotomy in five cases of pure MS that could be followed up (Fig. 2, 9). The PCT dropped significantly in the three cases in which the surgeon could widen the valve from just admitting the tip of a finger to a space that could allow three fingers or more. On the other hand, in the two cases where this valve width could not be achieved, the PCT did not change or even became a bit longer after the operation (Table IV).

The radiocardiographic pattern of patients having double mitral affection with predominant stenosis behaved in a similar way to cases of pure MS. In patients having significant MR the PCT was either normal or only slightly prolonged. This could be due to the relatively wider valve area, together with the lower level of pulmonary pressure usually met with in these cases of DM as compared to patients suffering from pure MS.

[1]Mitral commisurotomy operations were performed by Dr. S. El-Malah and Dr. A. Balbaa from the cardiopulmonary surgical unit of Cairo University.

In contrast to mitral stenosis where the main radiocardiographic abnormality was in the R wave, in both pure MR and AR the L wave was either equal or even higher in amplitude than the R wave. This was expected, since these lesions cause enlargement of the left side of the heart which would therefore occupy most of the field beneath the scintillation detector. The noticed difference between radiocardiographic findings in mitral stenosis and incompetence is against the work of Zacks, (15) who reported that mitral stenosis and insufficiency were indistinguishable radiocardiographically.

In the present study, it was noticed that in involvement of both mitral and aortic valves, R was prolonged and L higher in amplitude. The prolongation of the R wave could be explained by mitral affection with its consequences, namely pulmonary hypertension and right ventricular dilatation. The higher amplitude of L was most probably caused by the left-sided dilatation secondary to the aortic valve lesion. In this group of cases, the PCT was longest in patients having predominant MS and/or left ventricular failure. This could be a further

TABLE IV

CASES OF TIGHT MITRAL STENOSIS THAT WERE OPERATED UPON. DATA OBTAINED BEFORE, DURING AND AFTER OPERATION.

Pulmonary artery pressure assessed during operation	*Width of the valve in fingers*		*Assessment by surgeon*	*PCT in seconds*		*MPCT in seconds*	
	Before commissurotomy	*After*		*Before*	*After*	*Before*	*After*
+++	Tip	3	Good	11.6	—	15.0	—
*++	Tip	3	Good	15.4	13.4	18.6	15.2
†++	Tip	4.5	Very good	9.8	7.0	14.4	11.4
†++	Tip	4	Very good	9.0	7.4	12.5	7.8
++	Tip	2	Moderate	8.8	9.5	9.8	10.5
+++	More than tip	3	Good	8.4	—	10.5	—
++	More than tip	2.5	Moderate	8.2	—	9.5	—
+	More than tip	3	Good	6.5	—	7.9	—
Normal	1.5	2.5	Poor	4.8	5.4	6.5	6.3

* : This patient had a floating thrombus in the left atrium.

† : Both patients had palpable spleen before operation; after operation, the splenic enlargement disappeared.

proof for the importance of pulmonary hypertension in the pathogenesis of the prolongation of PCT.

The absence of radiocardiographic changes in rheumatic fever even in the presence of carditis, might be due to the counterbalancing effects of tachycardia that is known to cause shortening of the pulmonary circulation time (16).

SUMMARY

Radiocardiography has proved of great value in the diagnosis and assessment of rheumatic heart disease. From this study, based on 76 cases, the various patterns of radiocardiograms met with are described, analysed and criticised. The different valvular lesions were found to have characteristic radiocardiographic patterns, depending on the degree of lesion and the presence of hypertrophy and/or dilatation of the various cardiac chambers, together with the degree of pulmonary hypertension.

Special reference to the importance of radiocardiography in selection of cases for mitral commissurotomy is stressed, since this technique is easy and

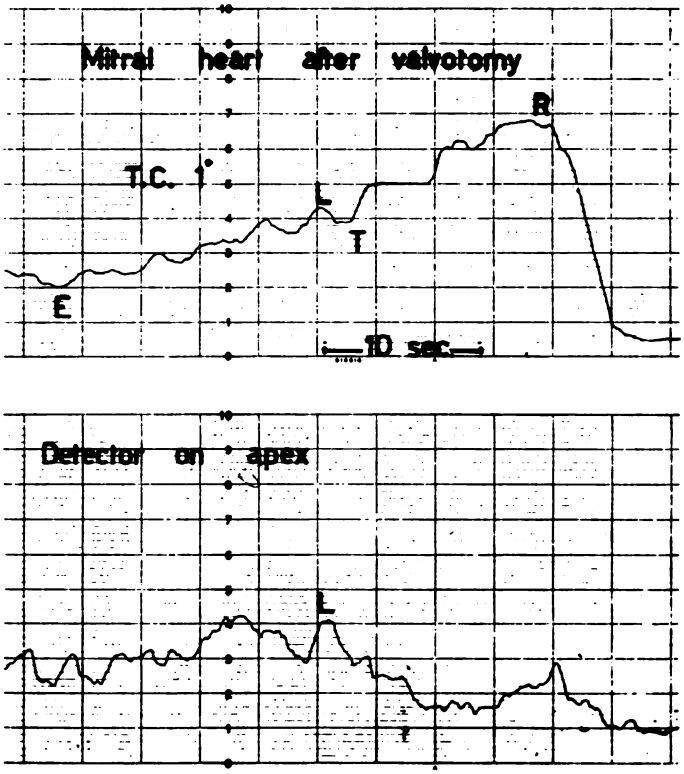

Fig. 9. Radiocardiogram of pure MS shown in Fig. 2 & 5, recorded after mitral commissurotomy. The PCT became 13.4 seconds. Lower tracing inscribed with detector over apex to define peak of L wave accurately.

readily gives an idea about the width of the mitral orifice as well as the degree of pulmonary artery pressure.

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