THE RIGHT PRÆCORDIAL LEAD

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Recent studies in clinical electrocardiography have indicated the desirability of taking multiple præcordial leads as a general routine practice. In their secondary supplementary report (1943) the Committee of the American Heart Association for the Standardization of Præcordial Leads stated that they believed that three is the least number of præcordial leads that can be regarded as satisfactory for general purposes. They suggested that those who wished to reduce the number of such leads to a minimum take leads from the C₁, C₃, and C₅ positions. All were urged to take additional leads whenever possible. Though a right præcordial lead, C₁, is recommended for general use, sufficient data have not yet been obtained on this lead either in regard to the range of normal or concerning its various abnormalities. Furthermore there is no agreement as to what is the best distal electrode for general use, a matter of considerable practical importance. The Wilson central terminal electrode, the right arm, the left leg, and the right scapula has each been preferred by different investigators.

In an attempt to gain further information on the right præcordial lead C₁ and to assess its value for general use we (1) have reviewed previous reports in which such a lead was employed; (2) have taken a series of electrocardiograms including this lead on patients without heart disease to determine the range of normal variations; and (3) have also noted characteristic alterations in CF₁ in certain cardiac conditions particularly posterior wall infarction, in which the use of this lead may be helpful.

Kossman and Johnson in 1935 reported on the normal variations in multiple præcordial leads. Their subjects were 30 medical students. They used the central terminal distal electrode and the right pectoral † position. With this lead V₁ they found: no Q wave; R, 1.0 to 9.6 mm.; S, 3.4 to 24 mm.; T from -4.0 to +5.6 mm. and RS (in-

trinsic inflection) 6.6 to 26.8 mm. An electro-negative T wave was found in 3 out of the 30 cases in V₁.

Wood and Seltzer (1939) examined the right pectoral lead using both the right arm and the left leg as sites for distal electrodes. In regard to the QRS complex they found S dominant in 75 per cent with the use of the right arm and 95 per cent when the proximal electrode was paired with the left leg. When the right arm was used the T wave remained upright, but when the left leg was used the T wave often became inverted. Thus in CF₁, T was inverted in 65 per cent of normal children and 56 per cent of normal adults. With progressive enlargement of the left ventricle they found the incidence of negative T waves fell from 58 per cent to nil in grade III enlargement. In other words if there was significant enlargement of the left ventricle T was upright. Hearts displaced by a high diaphragm to give left axis deviation in the standard leads did not act in the same way. Of twelve normal pregnant women with left axis deviation in the limb leads, ten had inverted T waves and two diphasic T waves in CF₁. These authors concluded that in the right pectoral lead (CF₁) one has a means of distinguishing left ventricular enlargement from displacement of the heart due to a high diaphragm. They indicated also that dominance of the right ventricle may be better ascertained in the right pectoral lead by the use of the left leg, rather than the right arm for the distal electrode. In the former an R taller than S was more certain of this interpretation. In cases of posterior myocardial infarction they stated they derived no help from the chest leads for the limb leads required no support and the chest leads had but little to give. Deeds and Barnes (1940), Shanno (1940), and Sigler (1944), have also described characteristics of lead CF₁. These are summarized in the Table.

Wilson and his associates in 1944 published

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† Right præcordial and right pectoral are used synonymously for the C₁ position in this paper.

TABLE
RIGHT PRÆCORDIAL LEAD CF₁

	Cases	P, mm		R,* mm		R absent	S, mm		T, mm		Percentage with negative T
		Minimum	Maximum	Minimum	Maximum		Minimum	Maximum	Minimum	Maximum	
Deeds and Barnes, 1940	100	-1.7	+0.5	0.2	9.8	—	6.0	35.0	-6.0	+6.7	—
Shanno, 1940	100	-2.0	+2.0	4.0	7.0	4.0	2.0	30.0	-6.0	+7.0	70
Sigler, 1944	100	-1.8	+0.6	0.2	10.0	—	4.0	35.0	-4.5	+5.5	51
Vesell and Shorr † ..	265	-2.8	+0.8	0.2	7.4	4.9	2.8	25.0	-4.6	+4.2	69
Wood and Seltzer, 1939	—	—	—	—	—	—	—	—	—	—	58

* Q was absent in all.

† RS-T was often elevated up to a maximum of 1.8 mm.

multiple præcordial lead electrocardiograms taken with the Wilson central terminal electrode in patients with myocardial infarction. The right pectoral lead V₁ was included; and they observed that with this lead in cases of high lateral, plain posterior and postero-lateral infarcts R and T of V₁ (and V₂) were unusually prominent. This was not so in postero-inferior infarction. In an article in 1946 he and his associates noted in the single case of high postero-lateral myocardial infarction that T waves became taller in leads from the right side of the præcordium.

The following is an analysis of the normal variations of the præcordial electrocardiogram taken in the right pectoral position CF₁. The subjects were 265 adults. There were two groups. In the first, all tracings were taken with the patient in the sitting position. This group consisted of 200 working men between the ages of 30 and 68 years, and only 11 were in the seventh decade. The majority were labourers; all were ambulant. No clinical evidence of heart disease was found in an ordinary history and physical examination and the routine four lead cardiogram (standard limb leads I, II, III, and CF₄) was normal by usual criteria.* In many a teleradiogram was taken and was normal. In the second group the cardiogram was taken with the patient in the recumbent position. The subjects were 65 men and women. They were patients in the hospital or office patients in private practice; their ages were from 20 to 58 years. As in the first group the heart was considered to be normal after an ordinary history, physical examination and four lead cardiogram. In the majority a cardiac fluoroscopy was done and was normal. In some the CF₁ lead was taken in both the recumbent and sitting position.

The cardiograph used was a string galvanometer,

* Criteria Committee of the New York Heart Association (1939), New York.

either the Cambridge mobile unit or Cambridge simplitol. The electrodes were the conventional ones, 3.5 × 6 cm., of german silver. A circular electrode 3 cm. in diameter was often used for the præcordial leads and was kept in place by an elastic rubber belt. The chest electrode was placed in the fourth intercostal space at the right margin of the sternum, and the distal electrode just above the left ankle. A suitable electrode paste was employed. Standardization of the string, 1 cm. for 1 mv., was made and recorded with each lead. Measurements recorded were usually the average of several deflections or segments. Frequently a magnifying lens was used.

In view of the fact that the normal variations in CF₁ revealed little or no difference in the two groups, they were considered as one group of 265 cases to include males and females, and sitting and recumbent positions. P ranged from -2.8 to +0.8 mm.; 88 per cent were negative, 9 per cent diphasic, and only 3 per cent positive; the average negative P was -1.3 mm.; the average positive T was +0.5 mm. Q, interpreted to mean an initial negative QRS deflection followed by a positive, R, deflection, was not observed in any of the 265. In 13 (5 per cent) there was (see Fig. 3) an absent R wave (i.e. monophasic negative QRS wave). In several other instances where the R wave was very small, about 0.2 mm., there were occasional complexes in the same tracings in which no R was visible also forming a monophasic negative QRS (S) complex. This monophasic negative wave, S, ranged from -4.5 to -17.0 mm. with an average of -10.8 mm. R ranged in amplitude from 0.2 to 7.4 mm. The average was 2 mm. Occasionally there was some slurring of R; this was usually in small deflections and was slight. S, ranged in amplitude from -2.0 to -25.0 mm. with an average of -13.2 mm. There was infrequent slurring and this was usually with waves of low voltage and was only slight. R¹, was

noted 46 times and ranged in amplitude from 1.0 to 7.5 mm. It was frequently slurred. QRS duration was the same as in CF_4 or in the limb leads; no noticeable difference was seen. RS-T segment was often elevated, up to 1.8 mm.; RS-T depression was not seen. T ranged from -4.6 to +4.2 mm.; it was negative in the majority of tracings, 183 of the 265, or 69 per cent: 46 were diphasic, +—; most of these were preponderantly negative. There were only 34 of the 265 (13 per cent) in which T was positive. Only 3 of the 37 females (8 per cent) had a positive T. In these three the amplitude of T was +4.0, +2.2 and +1.6 mm. with an angle alpha of +55°, +74° and +20°. In the whole series of 265 there were only 5 with T of +3 mm. or more; the average of the positive T waves was 1.8 mm.

In 15 cases in which T was negative with the patient in the sitting position a tracing was also taken, at the same time, with the patient in the recumbent position. In all 15 the T remained negative with little variation in depth. In 4 patients (2 male and 2 female) with a positive T in CF_1 in the recumbent position the tracing was also taken in the sitting position. In the latter position the T remained the same in two and in the other two was slightly reduced, from 1.2 to 1.0 mm. and from 1.6 to 1.2 mm.

The relationship of deviation of the electrical axis of QRS to negative T waves in CF_1 was examined. Axis deviation of QRS was expressed by angle alpha measured on a Dieuaidé chart. In the 265 cases angle alpha ranged from -35° to +115°. No correlation of T wave negativity with deviation of the electrical axis of QRS was noted, positive and negative waves were observed almost as frequently in the range of 0° to -35° as in that of +70° to +115°.

Tracings in which a Q wave was present in limb lead III were examined; there were 123. No correlation was noted with respect to T in CF_1 in that both negative and positive T waves were observed in this group. There were 11 of the series of 265 in which the Q III was prominent, 25 per cent. of the largest R in the three limb leads, with no S III, and without right axis deviation. Here also both negative and positive T waves were noted in CF_1 . In five, T in CF_1 was negative, in five diphasic, +—, and in one it was positive. Thus in normal subjects a negative T in CF_1 may occur with a prominent Q III. This is of significance in the light of the T wave findings with posterior wall infarction described later.

The effect of axis deviation on the RS deflection was the following: in 51 cases the angle alpha was between 0 and -35°. R averaged 1.4 mm. and S averaged 8.0 mm.; the relationship of R to S

varied considerably in this group, from 1 to 2 to 1 to 28, with the exception of one case in which R was larger than S and R : S was as 1 to 0.4. In the group (24) with angle alpha of +80° to +115° the average for R was 1.76 mm. and for S 12.0 mm. the ratio R to S ratio ranged from 1 : 2 to 1 : 18. Thus for the whole group of 265 normals, in the axis range most to the right (clockwise), R averaged 25 per cent larger and S 50 per cent deeper than in the axis range most to the left (counter-clockwise). There was only one tracing in the whole series of 265 where R was larger than S, $R = 3.2$, $S = -1.5$ mm. and angle alpha -17°.

There was some correlation between R and S in CF_1 and CF_4 . It has been pointed out that in normals R increases in amplitude as one goes from CF_1 to CF_4 or CF_6 and that S decreases. This was generally found to be so and R was larger in CF_4 than in CF_1 in all but 5 of the 265 cases; usually the difference in amplitude was considerable. In the 5 exceptions where R in CF_1 was larger it was 4.0, 4.8, 3.9, 4.8, and 4.7 mm., while R IV was 2.0, 3.0, 2.5, 3.6, and 3.0 mm. with angle alpha of +55°, +68°, +50°, +77°, +75° respectively. S was not infrequently larger in CF_4 than in CF_1 .

No correlation was noted between negative T waves in CF_1 and amplitude of T in CF_4 except that T in the latter was always positive while T in CF_1 was negative in 69 per cent.

Fifteen cases with the cardiographic pattern of left ventricular strain were examined. The pattern of left ventricular strain consisted of a tall R I, deep S III, depressed RS-T I (often RS-T II) and frequently inversion of T I and occasionally of T II. In all 15, T was upright in CF_1 except for one in which the T was diphasic, -4 and +1.0 mm. The average for T was +2.2 mm. These findings are largely in accord with those of Wood and Seltzer who found T wave negativity in CF_1 to be reduced in left ventricular enlargement and absent when the enlargement was marked. In the cases with the cardiographic pattern of left ventricular strain, enlargement of the left ventricle was practically always present. In this group R tended to be smaller than in normals; the average was 0.97 mm. compared with 2.0 mm. for the series of normals; in seven of the fifteen, $R = 0$ and R^1 was present three times. S in this group tended to be deeper than in the normal; the average was 18.4 mm. compared with 13.2 mm. for the normals.

CF_1 IN POSTERIOR WALL INFARCTION

A white woman, 64 years of age, for several years a private patient of one of the authors, was examined at his office on April 17, 1941. Her medical condition was essential hypertension and chronic osteo-

arthritis involving the joints of the arms, legs, feet, and spine. There was no chest pain related to effort, no mid-chest pain and no undue shortness of breath. Heart sounds normal; blood pressure, 168/110; lungs clear; liver not palpable, and no œdema of the lower extremities. Fluoroscopy revealed the heart to be of normal size, shape, and position; the thoracic aorta was somewhat tortuous. A cardiogram, taken with the patient recumbent, showed some left axis deviation; angle alpha was -15° . The tracing was within normal variations. The T waves in leads I, II, and IV were upright, 3.4, 2.0, and 5.4 mm. respectively. The RS-T segment was elevated, 0.5 mm. in lead I, and depressed 0.4 mm. in lead III. In lead CF_1 , P was -0.8 mm.; R, 0.4 to 0.8 mm.; S -6.5 mm.; RS-T, elevated 0.2 mm.; and T inverted, -0.5 to -0.8 mm. (Fig. 1). Four days later (April 21, 1941) while at home she suddenly developed severe prolonged substernal pain with the clinical picture of acute myocardial infarction. The cardiogram taken that day (Fig. 1) showed changes from the one taken four days before. RS-T in lead II became slightly elevated, with shouldering as it continued into the coved and inverted T wave. Lesser changes were present in leads I and III. CF_1 was not taken. Two days later, April 23, the second day of the acute attack, another cardiogram revealed progressive cardiographic changes in leads II and III characteristic of the pattern of recent posterior wall infarction. In CF_1 , T, which 6 days before was inverted, was now on the second day of the acute attack upright and of moderate amplitude, 2.8 mm., moderately tall for CF_1 . P remained unchanged while R became taller, 2.4 mm. compared with 0.4 to 0.8 mm. before the attack; S became slightly deeper, -8.0 mm. compared to -6.5 mm.; RS-T which was elevated 0.2 mm. prior to the attack was now depressed to 0.2 mm. below the isoelectric line. T remained upright in tracings taken ten days, 59 days and 136 days after the onset of the attack though gradually decreasing in amplitude; 2.5, 1.5, and 0.8 mm. respectively (Fig. 1). In this last tracing (136th day) T in lead II had become upright and was 0.8 to 1.0 mm. in amplitude.

Fourteen months later T in CF_1 again became inverted, 1.6 mm., R reduced to 0.0 to 0.2 mm., and RS-T isoelectric. The standard limb leads were similar to those taken before the attack with the exception of the presence of a small Q in lead II, 0.5 to 1.0 mm.; R I was slightly taller, R III correspondingly smaller; and T IV 2.5 mm. smaller. A cardiogram five years later (October 1947) revealed little change. A large Q wave was present in the augmented unipolar left leg lead.

Cardiograms including CF_1 were taken on another

patient before and after an attack of acute myocardial infarction (Fig. 2). Leads II and III after the attack were characteristic of the pattern of posterior wall infarction. In lead CF_1 , T which was negative before the attack became positive after the attack; R became taller.

These findings indicated that with acute posterior wall infarction certain changes occurred in lead CF_1 . The changes in the T wave in this lead were striking and it was thought they might be expressive of the specific cardiac lesion and helpful in diagnosis. Accordingly, electrocardiograms in cases with the clinical picture of recent myocardial infarction and with the electrocardiogram in the limb leads characteristic of the pattern of posterior wall infarction were examined. All had a prominent Q II and Q III with inverted T II and T III; none had right axis deviation. There were 35 cases; all were patients in the hospital; 31 males and 4 females; ages ranged from 41 to 78 years. The measurements in lead CF_1 were: P, -0.3 to -2.0 mm.; 3 were $+$; there were no positive P waves and none of unusual or abnormal configuration. Q waves were not present. R, 0.5 to 9.0 mm.; no absent R; the average was 3.9 mm. and taller than in the series of normals where the average was 2.0 mm. S, 0.0 to -19.2 mm.; average -8.2 mm. smaller than in the normal series where the average was -13.2 mm. R^1 was present twice; each 2.0 mm. QRS duration appeared unaltered. RS-T was depressed in 6; 0.2, 0.8, 1.0, 1.0, 1.5 and 1.5 mm. below the isoelectric base line; in two, J was the lowest point of the segment and the ascending limb of the T wave gradually rose from it. In nine, RS-T was elevated 0.2 to 1.8 mm. T was positive in all 35 cases and the range was from 1.0 to 9.0 mm. with an average of 3.1 mm. T was generally taller than in normals where the average positive T was 1.8 mm. and in only 5 of the 265 normals was T 3 mm. or taller. Negative T waves were not observed. The configuration and duration of the T did not appear abnormal.

Observations were not made on the duration of these changes in CF_1 in the 35 patients after their discharge from the hospital. However, in the first case described above the T wave changes were noted to last at least 4 months. In a cardiogram 14 months after the attack the T wave was again negative.

Thus it appears that lead CF_1 reflects changes in the posterior wall of the heart, exhibiting characteristic alterations with infarction of this area. The cardiographic changes are of opposite sense to those observed in the unipolar left leg lead in this condition, and may be contributed at least in part by the left leg component. R became taller and S

deeper. RS-T often was depressed below the base line. This did not occur in normals. The most striking alteration was in the T wave which was

positive in all such cases though in the normal T was positive in only 12 per cent and even less in females. This T wave alteration in CF_1 could be

FIG. 1.—Cardiograms of a patient who had acute myocardial infarction on April 21, 1941. Serial changes in the limb leads II and III of subsequent tracings conformed to the cardiographic pattern of posterior wall infarction. The cardiogram on the day of the attack, April 21, 1941, did not include CF_1 . In CF_1 , four days before the attack T was inverted, R small; two days after the attack, April 23, 1941, T was upright 2.8 mm.; gradually becoming smaller in the tracings on the tenth, fifty-ninth, and one hundred and thirty-sixth day after the attack. R was taller after the attack.

FIG. 2.—Cardiograms (A) before and (B) after attack of acute myocardial infarction. Serial changes in limb lead II and III and CF_4 conform to the cardiographic pattern of posterior wall infarction. In A lead CF_1 , $R=O$ and T is inverted; in B lead CF_1 , R is upright, 3.8 mm., and T is upright, 4 mm.

of use in the diagnosis of recent posterior myocardial infarction. It may be particularly helpful where changes in the limb leads especially lead II, are equivocal or absent and also in the evaluation of Q III. A negative T wave in CF_1 , which occurs in about 70 per cent of normal adult electrocardiograms, would, from the above, be important evidence against the presence of recent infarction of the posterior wall of the heart.

FIG. 3.—Cardiogram showing absent R in CF_1 ; also inversion of T. In 15 cases in the series without heart disease $R=O$ in CF_1 , frequently with inversion of the T in this lead.

SUMMARY AND CONCLUSION

Data on the right præcordial lead CF_1 have been reviewed. The characteristics of CF_1 in a group of 265 patients without heart disease have been described.

Variations of the T wave, in particular, in CF_1 are described in relation to changes in position of the patient, electrical axis of QRS, presence of a prominent Q III, and in left ventricular strain.

In two patients, CF₁ was taken before and after the occurrence of a posterior myocardial infarction and revealed the development of characteristic changes. These characteristic changes in CF₁ were found in each one of a series of 35 cases of recent myocardial infarction of the posterior wall. The use of lead CF₁ in the diagnosis of posterior wall infarction is discussed.

Usefulness of CF₁ has been indicated in (1) locating the side of bundle branch block, with CF₄ or CF₅ (Wilson); (2) evaluation of left ventricular enlargement, particularly from displacement by the

diaphragm; (3) possibly of right ventricular enlargement (Wood and Seltzer), and (4) in posterior wall infarction. It has also been used for better recording of auricular activity and by Ellis and Brown (1946) as an aid in the diagnosis of tricuspid insufficiency.

The information obtained from a right præcordial lead C 1, and in particular CF₁, described above, indicate it to be of sufficient value to recommend its regular use with other præcordial leads in routine electrocardiography for general purposes.

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