Clinical Observations with the Frank Precordial Lead System


Several new lead systems for electrocardiography and vectorcardiography have been proposed. Clinical evaluation of these systems is necessary to determine whether they yield useful information in addition to that furnished by conventional leads and whether the same information obtained from conventional leads appears in recognizable form in the new leads. This study is a step toward such an evaluation of one of the proposed lead systems.

There has been considerable effort to devise more adequate systems of electrode placement than those currently employed in electrocardiography. It is well known that many assumptions inherent in representing the body as simple geometric figures are only approximations and it is possible that eliminating the necessity for such assumptions may increase the usefulness of records of the heart's electric activity. It is also possible that an improved electrode system will permit satisfactory examination of electric activity in the heart with fewer leads than are now used in clinical electrocardiography. Evaluation of these possibilities requires clinical studies employing newly proposed electrode arrangements. This evaluation will not be complete without study of vectorcardiograms in which projections of electric activity are combined synchronously but it also appears worthwhile to investigate electrocardiograms from the new electrode systems. The latter studies may be expected to provide information concerning the form in which findings of known significance in conventional leads are reflected by the new systems. The present study was undertaken to obtain such information for the lead system proposed by Frank.

Materials and Methods

Ninety-one patients with normal electrocardiograms and 71 patients with a variety of etiologic types and electrocardiographic manifestations of heart disease were studied. Subjects with normal electrocardiograms were in the age range of 21 to 71 years and the patients with abnormal tracings varied in age between 29 and 78 years.

Electrocardiographic leads reflecting the horizontal (X), vertical (Y), and anteroposterior (Z) components of the heart's electric activity were recorded with the Frank electrode system. Electrodes were located on the neck, left leg, and thorax in the front and back midlines, right and left midaxillary lines, and at an angle of 45 degrees between the front midline and the left midaxillary line. All electrodes on the thorax were located at the level of the fifth intercostal space at the sternum. Resistor networks with components having the ratios recommended for this lead system and a range of values appropriate to the input impedance of the electrocardiograph were employed. The polarity of leads X and Y was comparable to leads I and aVr with upward deflections in X representing vectors directed to the left and upward deflections in Y indicating vectors directed downward. In lead Z upward deflections represented vectors directed posteriorly. A conventional electrocardiogram including standard leads, augmented unipolar limb leads, and precordial leads V, through V, was recorded immediately before or after Frank system leads were obtained. Serial electrocardiograms were available for most of the patients with heart disease. All leads were recorded consecutively at a paper speed of 25 mm. per second with a conventional electrocardiograph.

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The conventional leads and those obtained with the Frank system were inspected and described in terms commonly employed in electrocardiographic interpretation. Specific items of clinically useful information from the conventional tracings were listed and the presence or absence of each of these items in the Frank leads were noted. Lead X was examined for counterparts of information appearing in leads I, aV<sub>i</sub>, aV<sub>z</sub>, V<sub>1</sub>, V<sub>4</sub>, and lead Y for the counterparts of data in leads II, III, and aV<sub>r</sub>. Lead Z was examined for the counterparts of information in leads V<sub>5</sub> through V<sub>6</sub>. When an item of information in conventional leads did not have a recognizable counterpart in 1 lead from the Frank system, the other 2 leads from this system were examined for evidence of this specific information. It was recognized that counterparts of findings from a certain conventional lead would not always appear in the same Frank system lead. If all clinically useful information in conventional leads was reflected by the Frank system, however, recognizable counterparts of this data would be expected in 1 or more of the 3 leads. To provide another comparison of conventional and Frank system leads the electric axis of the QRS was calculated from the algebraic sum of maximal upward and downward deflections in leads I and aV<sub>r</sub> and from leads X and Y.

RESULTS

P waves. In all normal records obtained with the Frank system, P waves were upright or isoelectric in leads X and Y. Normal P waves in lead Z were upright in 11 records, diphasic in 7, and inverted in the remaining 67 records.

Five conventional electrocardiograms had P waves that were abnormal on the basis of duration or amplitude. All these records were from patients with mitral valve disease and all had roentgenographic evidence of left atrial enlargement. In each case P waves in lead X were qualitatively similar to those in lead I and waves in Y were similar to those in aV<sub>r</sub>. The polarity of P waves in the precordial leads of these subjects showed no consistent differences from that in normal records, but in lead Z of all of these records P waves were upright or diphasic with the major component upright. Since the majority of normal records showed inverted P waves in lead Z, these findings suggest that posteriorly directed vectors reflected by the Frank system may be helpful in recognizing left atrial enlargement. Study of a larger number of patients will be necessary to further evaluate this possibility.

QRS Complexes. The electric axis of the QRS calculated from leads I and aV<sub>r</sub> of normal records had an average of 31° and a range of −13 to +82°. A similar quantity calculated from X and Y of the Frank system had a narrower range, from 0 to 67°, with an average of 33°. The range of electric axis in all abnormal records obtained with the Frank system was greater than in conventional leads. The axis calculated from leads X and Y had a range of −171° to +154°, with an average of 20°, and that calculated from leads I and aV<sub>r</sub> had a range of −90 to +146, with an average of 25°.

The counterparts of most of the QRS abnormalities in conventional leads could be recognized in the Frank system leads. These findings cannot be quantitated, since the range of normal variations in leads obtained with the new system has not been established but the findings can be illustrated by selected examples. Figure 1A shows representative records from a normal subject for comparison with the abnormalities shown by other records in this and later figures. The records in figure 1B illustrate findings in patients with anterior and lateral myocardial infarction. The deep QS waves in V<sub>4</sub> through V<sub>6</sub> have their counterpart in lead Z, which does not show a Q wave. Normal Z leads always showed initial vectors directed anteriorly and represented by Q waves in lead Z. Nine records in this series showed evidence of old anterior infarction in the conventional electrocardiogram and 8 of these had no Q wave in the Z lead from the Frank system. One record from a patient with anterior infarction showed small Q waves in lead Z. The average amplitude of Q waves in lead Z in normal records was 0.25 mv, but the range was 0.05 to 0.75 and the small Q wave in the record of the patient with anterior infarction was comparable to the smaller ones present in some normal records. These findings seem to indicate that most, but not all, instances of anterior infarction recognizable in conventional pre-
cordial leads will be manifest in the Frank leads by initial vectors directed posteriorly.

Four records in this series showed evidence of lateral wall infarction manifest by abnormal Q waves in leads I, aV_L, and V_6. The X lead of 2 of these patients showed Q waves as illustrated by figure 1B. The records of the other 2 patients will be described in the section concerning QRS abnormalities in conventional tracings that did not have recognizable counterparts in the Frank leads.

Six records in this series showed evidence of old posterior wall infarction. All these records had Q waves in leads II, III, and aV_R and all showed similar Q waves in lead Y.

Two records in the series showed complete left bundle-branch block. In both records lead X had QRS complexes similar in form to those in lead I and complexes in aV_R were similar to those in Y. Lead Z showed initial Q waves and large R waves corresponding to R waves and deep S waves in leads V_1 through V_4. An example of these records is shown in figure 2A.

One conventional electrocardiogram showed complete right bundle-branch block. The Frank leads showed a wide S wave in lead X comparable to that in lead I and lead Z showed Q and R waves with a terminal S wave, which was not present in this lead in any normal records. This S wave appeared to be the counterpart of the large R' wave in V_1 and V_2 of the conventional tracing. These records are shown in figure 2B.
In 4 records there were QRS abnormalities in the conventional electrocardiogram, which did not appear to have recognizable counterparts in the Frank system leads. The records shown in figure 3 are examples of these findings. Figure 3A shows a conventional tracing with an R' wave in V₁ and V₂, which was interpreted as indicative of incomplete right bundle-branch block. Lead Z from this patient shows Q and R waves similar to those in normal records but there is no evidence of late excitation directed anteriorly. One other record in this series showed comparable findings.

Figure 3B shows a conventional tracing with Q waves in leads I and aV₃. These waves were considered to be the result of lateral wall infarction, since earlier serial tracings had shown ST-segment and T-wave changes of the type associated with the evolution of recent infarction. Lead X from this subject did not show Q waves and leads Y and Z were not recognizably different from these leads in some normal records. One other record in which evidence of lateral infarction in the conventional tracing was not recognizable in the Frank leads was encountered in this series.

**S-T Segments and T Waves.** The 91 normal records obtained with the Frank system showed upright T waves in lead X. T waves in lead Y were upright in 88 records and iso-
electric in the remaining 3. T waves in lead Z were inverted in 79, isoelectric in 9, and upright in 3 records. Among the 77 abnormal conventional electrocardiograms, 74 had significant ST-segment and T-wave abnormalities with easily recognizable counterparts in the Frank leads. These included displacement of the S-T segments and inversion or low voltage of T waves in leads I, aV_L, V_5, and V_6, which had their counterparts in lead X and similar findings in leads II, III, and aV_F with counterparts in lead Y. There were also records in which T-wave inversion in leads V_3 and V_4 had its counterpart in upright T waves in lead Z, since this lead showed inverted or diphasic waves in all but 3 normal records. An example of inverted T waves in anterior precordial leads reflected by upright T waves in Z is shown in figure 4A.

Seven conventional tracings had clinically significant T-wave findings without recognizable counterparts in the Frank system leads. These included the 3 normal records in which T waves were upright in lead Z and 4 records in which T-wave abnormalities in conventional leads were not recognizable in leads from the Frank system. Two of these records showed low or inverted T waves in V_1 through V_4 but T waves in lead Z were diphasic or inverted as in normal Z leads. One of these records is shown in figure 4B.
Another record showed low voltage of T waves in leads I, aVL, V5, and V6, while T waves in lead X were upright and had an amplitude comparable to that in most normal records. The other conventional tracing with significant T-wave findings that were not reflected in the Frank leads showed high peaked T waves in V2 through V4 suggestive of hyperkalemia. T waves in lead Z were inverted and had an amplitude comparable to that seen in many normal records.

**DISCUSSION**

The eventual purpose of new electrode systems is improvement in the detection of cardiac disease. In this study, most, but not all of the findings of known clinical significance in conventional leads appeared in recognizable form in the Frank system leads. Since the study concerned findings of demonstrated clinical importance that were obtained from leads now in common use, the failure of all these findings to be reflected by the new leads appears to be a serious shortcoming of the system.

It is still possible that the new lead system will provide information of clinical significance other than that now supplied by conventional leads. Evaluation of this possibility will require definition of the range of normal variation among records obtained with the Frank system. Correlation of presumed abnormal findings with the clinical course and autopsy findings in a large series of patients.

**FIG. 4.** A. Tracings in which T waves are inverted in V₁ through V₆. The counterpart of this finding is in lead Z which shows upright T waves. B. Tracings in which T waves are diphasic in leads V₃ and V₄. No counterpart of this finding could be recognized in Frank system leads.
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will also be necessary. Although the present study was not primarily concerned with the possibility of information in addition to that furnished by conventional leads, it yielded 2 supporting findings. One was the finding that left atrial enlargement resulted in atrial excitation vectors directed posteriorly to a greater degree than in normal records. Since the polarity of P waves in the precordial leads of these patients showed no consistent differences from that in normal records, it is suggestive evidence that the Frank system leads may be helpful in recognizing left atrial enlargement. Another finding that supports the possibility that the Frank system may provide information other than that furnished by conventional leads was the narrower range of the QRS axis in normal records obtained with this system. A similar finding has been reported with a lead system based on the work of McFee and Johnston. While not direct evidence, these findings are consistent with less distortion of the heart’s electric field by these systems. Since the range of QRS axis in abnormal records was not narrowed by the Frank system, these findings support the possibility that this system may decrease the range of some normal variations without necessarily obscuring abnormalities.

It should be emphasized that the present study of consecutively recorded electrocardiographic leads with the Frank electrode system is not equivalent to study of vectorcardiograms. In the latter records, projections of electric activity are combined synchronously to give certain data that cannot be derived from conventional electrocardiograms. In the further evaluation of the Frank electrode system, studies of vectorcardiograms will be necessary.

SUMMARY

Conventional 12-lead electrocardiograms and 3 leads from the electrode system devised by Frank were recorded on 91 subjects with normal conventional tracings and 77 patients with a variety of electrocardiographic abnormalities. Leads from the new electrode arrangement were examined for the counterparts of specific findings of known clinical significance in the conventional records. The majority but not all of these findings appeared in recognizable form in the Frank system leads. Since the study concerned findings of known significance, which were obtained from electrocardiographic leads now in common use, the failure of all of these findings to appear in the new leads appears to be a serious defect of the system.

SUMMARIO IN INTERLINGUA

Electrocardiogrammas a 12 derivationes conventional e a 3 derivationes ab le sistema de electrodos disveloppate per Frank esseva obtenite ab 91 subjectos con normal registra- tiones conventional e ab 77 patientes con un varietate de anormalitates electrocardiographic. Registrationes obtenite secundo le nove arrangiamento de electrodos esseva scrutinate pro correspondentias a phenomenos de cognoscite signification clinic in le electro- cardiogramma conventional. Le majoritate de iste phenomenos—ben que non omnes—esseva presente in forma recognoscibile in le registrationes obtenite secundo le sistema de Frank. Viste que le studio se concerneva con phenomenos de signification estabile in electrocardiogrammas per derivationes que es in uso commun al tempore presente, le facto que non omne ille phenomenos appareva in le registrationes effectuate per medio del nove derivationes indica un serie defecto del sistema.

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