The Extremity and Circumferential Chest Lead Electrocardiogram in Induced Acute Coronary Insufficiency

By Kenneth Chesky, M.D., Arthur M. Master, M.D., Harold S. Arai, M.D., and Leon Pordy, M.D.

The extremity and circumferential chest lead electrocardiogram (twenty-two leads) was studied in 8 patients with generalized coronary insufficiency induced by exercise. Over the right chest, posteriorly and laterally, there was noted RS-T elevation similar to but less pronounced than that occurring in lead aVR. These leads probably represent true or mixed cavity potentials. Standard leads revealed more marked RS-T alterations after exercise than did aV leads. In the left anterior chest leads, the greatest RS-T depression occurred in the left unipolar precordial leads representing the maximal voltage of the R wave—usually V₄ or V₅. The practical application of these findings is discussed in relation to routine two step exercise tests.

An electrophysiological investigation of induced acute coronary insufficiency was undertaken by means of the twenty-two lead electrocardiogram, i.e., three standard, three augmented “unipolar” extremity, and sixteen chest leads completely circumscribing the thorax. We wished to study the RS-T segment alterations in these various leads in order to determine those showing maximal changes and those most representative of coronary insufficiency. We also desired to relate the findings in individual leads to the chamber and also to the area of the myocardium involved, i.e., subendocardial or subepicardial regions. We desired also to determine the comparative value of the different leads for possible application to the two step exercise test. Conventionally, the standard bipolar leads (I, II, III) and unipolar chest lead V₄ are routinely employed for this procedure. However, the increasing popularity of the augmented “unipolar” extremity leads (aVR, aVL, aVF) and the six multiple unipolar precordial leads (V₁ through V₆) in clinical cardiology has prompted the question of any possible role of these newer leads in the interpretation of the exercise tolerance test.

Moreover, under certain circumstances, recording of leads taken circumferentially around the chest wall may be of value. In this study, we were anxious to determine whether or not there is any RS-T segment deviation in leads over the posterior and right side of the thoracic cage when there is RS-T segment depression after exercise in leads over the left anterior chest wall indicative of acute coronary insufficiency. We were particularly interested in a comparison of RS-T deviations in the right and posterior thoracic leads with those in lead aVR.

Eight patients with established coronary artery disease with normal resting electrocardiograms were selected for this study. In each instance, a control resting electrocardiogram was taken. This consisted of the three standard limb leads, “unipolar” extremity lead (aVR, aVL, aVF), and unipolar circumferential chest leads. The latter were taken as follows: the usual V₁ through V₆; V₇ (left posterior axillary line); V₈ (left midscapular line); V₉ (left paravertebral line); V₁₀ (right paravertebral line); V₁₁ (right midscapular line); V₁₂ (right posterior axillary line); V₁₃ (right midaxillary line); V₁₄ (right anterior axillary line); V₁₅ (right midclavicular line);* and lastly V₁₆ (midway between the conven-

* V₁ through V₁₆ being at the horizontal level of the fifth anterior intercostal space.
Table 1.—Extremity and Circumferential Chest Lead Electrocardiogram in Induced Acute Coronary Insufficiency

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Fig. 1. S. I., male, age 38. Angina pectoris for 1 year. Control twenty-two lead electrocardiogram—normal.

Fig. 2. S. I., male, age 38. Angina pectoris for 1 year. Twenty-two lead electrocardiogram after exercise discloses patterns of acute coronary insufficiency.
tional V₁ and V₉R). The Master two step exercise test³ was then performed. After exercise the electrocardiogram was taken immediately and an endeavor was made to take all the aforementioned leads again within two minutes or less during the induced acute coronary insufficiency. To facilitate the recording of all these leads after cessation of the exercise, chest electrodes were left at their respective points and connected by separate wires to a specially constructed selector box which in turn was connected to the exploring electrode of a single channel direct-writing electrocardiographic machine equipped with an instomatic device (Sanborn).

In all 8 cases the exercise tolerance test was positive (see table 1). The electrocardiographic changes observed were similar to alterations occurring during spontaneous attacks of acute coronary insufficiency. The deepest depression of the RS-T segment in the chest leads occurred either in unipolar lead V₄ or V₅ (table 1) and in each individual case, the greatest depression occurred in the chest lead with the maximal voltage of the R wave. Leads taken on the right side of the chest showed only minimal elevation, usually exhibiting qR, QR, Qr or QS patterns. Lead aVR in every case showed a significant elevation. These findings are illustrated by the following case. Figure 1 refers to a 38 year old male, S. I. (case 1, table 1), with a one year history of severe angina pectoris which led finally to cervicodorsal sympathectomy for attempted relief. The control resting twenty-two lead electrocardiogram is normal. Figure 2 demonstrates the patterns of acute coronary insufficiency in the twenty-two lead electrocardiogram after exercise. There is noted RS-T segment depression in leads I, II, III, aVF and V₄ through V₅ and RS-T segment elevation in lead aVR with minimal elevation in V₉R through V₁₂R. In all instances, the findings reverted to those of the control tracings within 10 minutes following cessation of exercise. In the cases studied, the electrocardiographic signs of acute coronary insufficiency were typically alterations of the RS-T segments with T wave abnormalities playing a relatively insignificant role.

**Discussion**

The electrocardiographic pattern obtained after exercise in patients with known coronary artery disease or myocardial injury, i.e., depression of the RS-T segment in routine "epicardial" leads, is due primarily to involvement of the cells in the subendocardial layers of the heart. In studies correlating electrocardiographic and anatomic findings in cases of acute coronary insufficiency Friedberg and Horn² and Master, Dack, Grishman, Field and Horn³ have demonstrated that the RS-T depressions found in this condition are associated with subendocardial necrosis. Injury to the subendocardial surface of the left ventricle induced experimentally resulted in elevation of the RS-T segment in leads from within the cavity of the left ventricle, while epicardial leads taken at the same time directly over the damaged subendocardial areas have shown RS-T segment depression.⁴,⁵,⁶ Wener, Scherlis, Sandberg, Master and Grishman⁷ in using esophageal leads, have shown that in patients with angina pectoris the depression recorded in standard and precordial leads immediately after exercise was regularly associated with elevation of the RS-T in the esophageal leads taken simultaneously at atrial levels reflecting left ventricular cavity potentials. Most pronounced depression of the RS-T segment was at times recorded in the lower esophageal electrocardiogram which reflected the posterior surfaces of the left ventricle.

Kisch⁸,⁹ has shown that if the right side of the heart is acutely damaged epicardially, the R-T segment is highly elevated in the right chest lead and is deeply depressed in the left chest lead. If the left side of the heart is acutely damaged epicardially, the opposite occurs in the chest leads, i.e., the R-T segment is elevated in the left chest lead and depressed in the right chest lead. In our series of cases, depression of the RS-T segment occurred over the left chest, therefore, we would expect elevation over the opposite side of the chest. The pattern usually obtained over the right side posteriorly was a qR, QR, Qr, or QS which probably represents either a true cavity or mixed cavity potential. The elevations seen
in leads from the right chest posteriorly and laterally are minimal because of the small voltage recorded at this distance from the heart and because vector relationships to the horizontal level selected may not be optimal to record maximal RS-T deviations. In our series of cases, lead aVR appeared similar to true or mixed cavity potentials and is probably similar to esophageal leads at the atrial level. In all instances, the RS-T elevations in aVR were much more pronounced than those observed over the right posterior and lateral chest leads.

The greatest RS-T depression was recorded in unipolar precordial leads over the left anterior chest reflecting the maximal voltage of the left ventricle, i.e., the unipolar precordial leads with the tallest and widest R wave, which is usually V₄ or V₅ depending upon the position of the heart within the thorax. The RS-T depressions seen maximally at V₄, V₅ or V₆ are similar to depressions seen in lower esophageal leads representing potentials from the posterior aspect of the left ventricle. In this study unipolar chest (V) leads were employed in preference to bipolar chest leads (CR, CL, or CF).

Although circumferential chest leads after exercise may furnish additional data concerning the electrophysical phenomena associated with acute coronary insufficiency, our studies indicate that a single unipolar precordial lead is adequate for routine diagnostic purposes. It must be emphasized that in taking one unipolar precordial lead during an exercise tolerance test, the position of the electrode must be over that area of the chest with a maximal voltage of the R wave, despite the presence or absence of an S wave, in order to obtain the maximal depression of the RS-T segment. Therefore, routinely all six precordial leads should be taken at rest, i.e., in the control, to determine the optimal placement of the precordial electrode in order not to miss localized induced coronary insufficiency.

Theoretically, in acute coronary insufficiency, RS-T segment alterations in extremity leads will be more marked in the customary bipolar standard leads I and II than in unipolar extremity leads (aVR, aVL and aVF) since the former will represent the RS-T depression in lead V₃ or VF minus any RS-T elevation in lead VR. This fact was substantiated in the cases studied (see table 1). Therefore the standard extremity leads are preferable to the aV leads in performing exercise tests for coronary insufficiency, despite the augmentation of potentials in the latter leads and regardless of the electrical axis of the heart.

It must be emphasized that the cases described above all showed generalized coronary insufficiency on effort because of underlying severe coronary artery disease. Hence, RS-T alterations were noted in many of the twenty-two leads selected for study with greatest deviations occurring most frequently in lead V₄ or V₅ and lead II, in that order.

**Conclusion**

1. Eight patients with angina pectoris due to coronary artery disease were studied. The electrocardiogram during a spontaneous episode of angina pectoris and also after exercise disclosed a classic picture of coronary insufficiency, i.e., RS-T alterations and T-wave inversions in the customary twelve leads (leads I, II, III, aVR, aVL, aVF, and V₁ through V₆).

2. In the same patients the two step exercise electrocardiogram was repeated with the chest electrode placed around the chest (V₁ through V₆ and V₃R through V₃R) and twenty-two leads were taken. RS-T depressions were found on the left side anteriorly and posteriorly. Over the right chest posteriorly and laterally there were qR, QR, Qr or QS patterns with elevation of the RS-T segment after exercise. Lead aVR in the cases of induced coronary insufficiency studied shows RS-T elevation in higher voltage than in unipolar chest leads taken posteriorly and to the right.

3. These findings corroborate the fact that if RS-T depressions are obtained over one area of the heart, then, according to the laws of electrophysics, RS-T elevations must be present elsewhere. The elevation over the right posterior and lateral aspect of the chest probably represent true or mixed cavity potentials.

4. The greatest RS-T depression is found in
unipolar precordial leads over the left anterior chest reflecting the maximal voltage of the R wave which is usually V₄ or V₅ depending on the position of the heart. Therefore, in selecting the position of the precordial electrode for the two step test, the lead recording the greatest voltage of the R wave should be chosen. Lead II is the best standard lead to employ.

5. The standard bipolar extremity leads show more marked RS-T deviation than the augmented "unipolar" extremity leads and are therefore preferable for the exercise tolerance test.

REFERENCES

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