RS-T Segment Displacement in Induced Coronary Insufficiency as Studied with Esophageal Leads

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Esophageal electrocardiograms are utilized as a means of studying the left ventricular cavity potentials in induced coronary insufficiency in patients with angina pectoris. Depressions of the RS-T segment recorded in precordial leads after exercise were consistently associated with simultaneously recorded RS-T elevations at the atrial level. These RS-T deviations are interpreted as indicating that in coronary insufficiency there are widespread changes involving the subendocardial aspect of the left ventricle. A circuit is described to enable the recording of better technical esophageal records despite interference due to extraneous low frequency potentials.

The Characteristic precordial electrocardiographic findings of acute coronary insufficiency consist of depression of the RS-T segment and flattening or inversion of the T waves. Autopsy studies have at times demonstrated subendocardial necrosis or infarction to be present in the myocardium of patients who had such an electrocardiographic pattern for varying periods prior to death.

The depressions of the RS-T segments after exercise and after the breathing of 10 per cent oxygen in patients with coronary sclerosis have been ascribed to anoxemia of the subendocardium. Numerous experiments involving the production of injury to the subendocardial surface of the left ventricle have resulted in elevation of the RS-T segments in leads recorded within the left ventricle and depression of the RS-T segment in epicardial leads recorded directly over the damaged areas.

Esophageal electrocardiograms recorded at the atrial levels have been shown to reflect left ventricular cavity potentials. Leads taken below this level usually record the potentials of the posterior and diaphragmatic surfaces of the left ventricle.

In this study, esophageal leads were used to investigate the nature of the RS-T segment displacement in induced coronary insufficiency. If the RS-T depression in the precordial leads is due to subendocardial changes, positive displacement of the RS-T segment should be recorded in those esophageal leads reflecting predominantly left ventricular cavity potentials.

Methods

The patients selected for this study had definite histories of angina pectoris and on prior occasions had positive responses after two-step exercise tests. In no patient was there a history or electrocardiographic evidence of a previous myocardial infarction. No patient had received digitalis for several months prior to this study. Following the recording of control electrocardiograms, including standard, Wilson unipolar extremity and precordial leads, and unipolar esophageal electrocardiograms, the patients performed the two-step exercise test with the electrodes still in place. Immediately upon the completion of the exercise and at frequent intervals thereafter, electrocardiograms were secured, the first esophageal lead being recorded within thirty seconds. To diminish the elapsed time in recording as many leads as possible, an instamatic control and external multiple-selector switch box were utilized.

The esophageal electrode employed in this study consists of an ordinary rubber tube containing a central core of 15 wires, each separately connected to external metal bands 1.75 cm. apart. This tube was introduced into the nasal cavity of the patient, and advanced until the tip, by fluoroscopic control, was selectively located 4 to 5 cm. below the diaphragm. Prior to exercise, esophageal electrocardiograms were recorded at each of the 15 levels repre-
resented by the metal bands. Simultaneously, two other electrocardiograms were recorded, usually V_1 and V_6 being selected.

After exercise the esophageal lead at that atrial level at which the control best represented left ventricular cavity potential was recorded. In addition, the esophageal lead reflecting the posterior or diaphragmatic surface of the heart was taken when conditions permitted. The amplitude of the individual tracings could be selectively varied by sensitivity controls, and these were utilized to allow maximum amplitude at all levels within the limits of respiratory excursions. The response to 1 mv. introduced into the circuit has been employed to permit comparison of the records taken at varying sensitivities, and this is recorded in each figure.

![Diagram of an electrocardiograph circuit](image)

**Fig. 1.** Electrical filter unit of the Technicon three channel cardiograph.

Esophageal electrocardiograms may be markedly distorted, or their recording made difficult, because of low frequency gastric, esophageal, and diaphragmatic potentials. These extraneous influences may at times be so pronounced as to make any detailed analysis of atrial and particularly ventricular complexes erroneous. In this study, a condenser-resistor arrangement was inserted between the electrode and the amplifier input (fig. 1). The condenser and resistor were so selected as to attenuate all frequencies of 1.5 cycles per second and less, while having negligible effect (5 per cent or less) on frequencies of more than 2.5 cycles per second. This device made it possible to obtain consistently adequate records at any esophageal level both before and after exercise. At the onset of this study, records were obtained with and without the presence of the filter in the circuit, and were found to be similar in detail and timing.

The electrocardiograph used throughout this study was a three channel direct writing Technicon Cardiograph. All records were inscribed at usual speed and double the normal speed to permit better analysis and timing.

## Results

Nine patients with angina pectoris performed the exercise test after control records had been obtained. Three of these patients had essentially normal records prior to exercise. In the remaining 6 cases, the resting records revealed diphasic to inverted T waves in the precordial and standard leads with slight depression of the RS-T segment. Immediately after exercise depression of the RS-T segment in the precordial leads (V_3 or V_5) was regularly associated with simultaneous elevation of the RS-T segment in the esophageal lead at the atrial level reflecting left ventricular cavity potentials (fig. 2). In each of the patients who, prior to exercise, demonstrated RS-T depressions precordially and minimal RS-T elevation at the atrial level showed a marked increase after exercise in the depression precordially and in the elevations recorded at the atrial level (fig. 3).

In three instances, significant depressions of the RS-T segments in the esophageal leads reflecting the posterior or diaphragmatic surface of the ventricle were recorded after exercise (fig. 4).

Inversion or flattening of the T waves in the precordial leads after exercise was usually associated with similar findings in the esophageal leads reflecting the posterior or diaphragmatic surface of the left ventricle. The T waves recorded at the atrial level were generally negative before exercise and became diphasic or positive following exercise. All electrocardiograms returned to the resting records within fifteen minutes.

Six control individuals with normal electrocardiograms, normal physical examination and no history of cardiac disturbance demonstrated no change in the precordial or esophageal leads after exercise.

### Discussion

The above observations indicate that RS-T segment depressions recorded in induced coronary insufficiency in the precordial leads and in the esophageal leads reflecting the posterior or diaphragmatic ventricular surface are regularly associated with RS-T segment elevations.
in the esophageal leads reflecting left ventricular cavity potential. Diagrams at the atrial level reflect left ventricular cavity potentials. Brown\textsuperscript{9} noted that "if

\begin{figure}
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\includegraphics[width=\textwidth]{fig2}
\caption{I. M.: 68 year old white man. Angina pectoris for six years. Resting standard and precordial leads normal. (In this and the following figures, the three leads were taken simultaneously and have been separated and remounted in the interest of saving space.) A. Resting control record. \textit{E}_9: Esophageal record taken at atrial level. Note intrinsic atrial deflection, \textit{Qr} ventricular deflection, and isoelectric RS-T segment. B. Immediately after exercise. RS-T depressed in \textit{V}_4 and elevated in \textit{E}_9. C. Ten minutes after exercise. Record has returned to resting state.}
\end{figure}

\begin{figure}
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\includegraphics[width=\textwidth]{fig3}
\end{figure}

The interpretation of the RS-T deviations as obtained in this study is dependent upon the demonstration that esophageal electrocardiographic interpretation is not reliable without prior testing and controls. An exploring electrode is placed against, or almost against, auricular musculature, then at the onset of the ventricular excitation it is
tapping the electropotential changes occurring in the ventricle under peculiar circumstances. It is connected to the internal surface of the ventricle by an electrolytic medium: the wall of the auricle and the auricular contents."

Esophageal patterns at the atrial level are essentially similar to those obtained by electrodes within the left ventricular cavity in animals.\(^{15,16}\) Other investigators\(^{17-19}\) have been in general agreement that esophageal leads at the atrial level reflect essentially left ventricular cavity potential. The patterns obtained at the atrial level were those of a QS or Q wave followed by a small R. Sodi-Pallares\(^{22}\) in a study of left heart catheterization in human subjects has found that the normal potential inside the left ventricular cavity is QS in configuration. This would further corroborate the fact that the potentials obtained at the atrial level reflect left ventricular cavity potentials.

Esophageal electrocardiograms recorded from the lower part of the esophagus usually reflect the potentials of the posterior surface of the left ventricle.\(^{10}\) Application of this fact has been made in the diagnosis of posterior myocardial infarctions.\(^{17,20-22}\)

In the actual selection of the control endocardial lead from the fifteen esophageal leads recorded, the most important criterion employed was the presence of a QS or Qr pattern with the initial inscription of the Q wave in the esophageal lead preceding or coinciding with the inscription of the initial ventricular deflection in V\(_1\) and V\(_6\). The tracing containing this complex usually revealed an intrinsic deflection of the P wave, but that the presence of such an intrinsic deflection is no constant criterion of endocardial potential was pointed out by Burchell\(^{20}\) who stated that "... Q and QR deflections characteristic of atrial levels may sometimes persist below the level where the P waves no longer show intrinsic deflections." Thus, the RS-T deviations in the electrocardiogram recorded at the atrial level are believed to be essentially similar to those recorded inside the left ventricle, while those at the lower esophageal levels reflect the potentials of the posterior and diaphragmatic surface of the left ventricle.

The significance of RS-T deviations has been the subject of many experimental studies. Experiments in animals have shown that damage to the epicardial surface produces positive displacement of the RS-T segment in epicardial leads and negative displacement in leads from the cardiac cavity.\(^5-8\) Trauma to the subendocardial surface, however, produced negative displacement over the circumscribed epicardial surface,\(^9\) and positive displacement in the car-

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**Fig. 4.** N. L.: 56 year old white man. Angina pectoris for two years. Resting standard and precordial leads reveal minimal depression of RS-T segments in Leads I, II, V\(_4\), V\(_5\) and V\(_6\); T diphasic in V\(_4\), V\(_5\) and V\(_6\). (All records taken at twice normal speed.) A. Resting control record. E\(_3\): Esophageal record taken at posterior surface, left ventricle. RS-T depressed prior to exercise in E\(_3\) and V\(_4\). B. Immediately after exercise. Increased RS-T depression in E\(_3\) and V\(_4\). C. Resting control record E\(_4\): Esophageal record taken at atrial level. RS-T isoelectric. D. Immediately after exercise. RS-T markedly elevated in E\(_3\) and depressed in V\(_4\).
diac cavity. Evidence in support of subendocardial damage giving rise to negative deviations of the RS-T segment in precordial leads is also derived from isolated cases of subendocardial infarction and the finding of subendocardial necrosis in acute coronary insufficiency. During intracardiac catheterization, contact of the electrode with the endocardium of the right or left ventricle can cause upward deviation of the RS-T segments in intracardiac leads. The failure of simultaneously recorded precordial leads to reveal RS-T deviations of either direction was usually interpreted as meaning that the extent of the injury must be very localized in distribution.

Under those circumstances in which the unipolar right arm lead reflects the potential variations of the endocardial surfaces and cavities of the two ventricles elevation of the RS-T segment in V6 has been reported in acute coronary insufficiency and in the induced hypoxemia test for coronary insufficiency. Similar results were obtained in this study. The elevations were interpreted as reflecting positivity of the ventricular cavity. A similar explanation has been given for the precordial elevation of the RS-T segment after hypoxemia tests in two patients with previous anterior wall infarction, the left ventricular cavity potential being tapped through the myocardial window.

The positive RS-T segment deviation at the atrial level recorded simultaneously with depressions of the RS-T segment in precordial and lower esophageal levels, as secured in this study, signifies widespread involvement of the subendocardium of the left ventricle.

In accord with the present concepts of the theory of the current of injury the results of this study would indicate that in induced coronary insufficiency there is predominant injury to the subendocardium.

**Summary**

1. The results of this study indicate that RS-T segment depressions recorded in induced coronary insufficiency in the precordial leads and in the esophageal leads reflecting posterior or diaphragmatic ventricular surface are regularly associated with RS-T segment elevations in the esophageal leads reflecting left ventricular cavity potential.

2. These observations strongly suggest that the electrocardiographic changes in coronary insufficiency are due to widespread involvement of the subendocardial aspect of the myocardium.

3. A circuit is described to minimize the interference due to excursion of the base line in esophageal electrocardiography.

**REFERENCES**


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13 Wilson, F. N., Johnston, F. D., and Hill, I. G. W.: The interpretation of the galvano curves obtained when one electrode is distant from the heart and the other near or in contact with the ventricular surface. Am. Heart J. 10: 176, 1934.


32 Sodi-Pallares, D.: Personal communication.
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