Postural ST-T Wave Changes in the Radioelectrocardiogram Simulating Myocardial Ischemia

By Alan B. Lachman, M.D., Herbert J. Semler, M.D., and Robert H. Gustafson, M.D.

It has been known for many years that changes in body position and posture will influence relative heart size and position, and consequently alter QRS, ST, and T-wave configuration and electrical axis of the standard electrocardiogram.

In the 1930’s Wood and Wofeath showed individuals having shortness of breath in the recumbent position who obtained relief by turning on their right side. They reported that symptoms subsided simultaneously with a shift in heart position, as shown by x-ray. Sigler showed a shift in the T-wave axis in the standard electrocardiogram in nine of 31 normal subjects when they moved from the dorsal recumbent to the standing position. Mayerson and Davis, using a tilt table, found frequent T-wave inversion and shift of the T-wave axis to the left in the electrocardiograms of 10 healthy subjects when they assumed the upright position.

Lopeschkin and Surawicz reviewed the criteria for true and false positive Master’s two-step exercise tests. In the electrocardiograms of 179 normal subjects with negative exercise tests, according to Master's criteria, there was a 3-per cent incidence of orthostatic T-wave changes after exercise upon assuming the upright position. In 25 subjects with a positive exercise test by Master’s criteria, but negative by the author’s criteria, 30.4 per cent showed orthostatic T-wave changes.

Studies on vasoregulatory asthenia by Holmgren and Strom, and later by Sandberg, showed ST-T depression during orthostatic testing. They attributed these changes to differences in heart position or increased sympathetic tone. They recommended using an orthostatic electrocardiographic test combined with an exercise-load test, in order to differentiate sympathicotonic from ischemic changes.

The development of radioelectrocardiography now enables investigators to study all the components of the electrocardiogram during any activities, and for as long a period of time as desired. Heretofore this was technically difficult with standard electrocardiography in which movement was restricted because of heavy connecting cables, and motion caused muscle-electrical potentials and a waving baseline, which greatly distorted the electrocardiogram.

The purpose of this study is to report ST-T changes in the radioelectrocardiograms of healthy persons, which are associated with changes in posture and position (orthostatic changes). It is also the intent of this study to attempt to find precordial electrode positions for the bipolar leads of the radioelectrocardiograph system, which will produce a minimum of orthostatic phenomena.

Material and Method

Radioelectrocardiograms were recorded in 676 healthy subjects between 5 and 77 years of age. Each subject had a normal clinical history, physical examination, and standard electrocardiogram.
Table 1

ST-T Changes in the Radioelectrocardiograms of 200 Healthy Subjects, Age 15 to 30 Years

<table>
<thead>
<tr>
<th>Category</th>
<th>Female No.</th>
<th>Male No.</th>
<th>Total No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>69 (69%)</td>
<td>69 (69%)</td>
<td>138 (69%)</td>
</tr>
<tr>
<td>Orthostatic</td>
<td>11 (11%)</td>
<td>21 (21%)</td>
<td>32 (16%)</td>
</tr>
<tr>
<td>J Junction</td>
<td>10 (10%)</td>
<td>6 (6%)</td>
<td>16 (8%)</td>
</tr>
<tr>
<td>Transient ST-T</td>
<td>10 (10%)</td>
<td>4 (4%)</td>
<td>14 (7%)</td>
</tr>
<tr>
<td>Total</td>
<td>100 (100%)</td>
<td>100 (100%)</td>
<td>200 (100%)</td>
</tr>
</tbody>
</table>

The subjects were monitored by the radioelectrocardiograph system (Telemedics RKG 100) as described by Bellet et al.\textsuperscript{10} and Hanson and Tabakin.\textsuperscript{11} A bipolar chest lead was used with the "remote electrode" over the manubrium and the "exploring electrode" over the sixth rib in the anterior axillary line (lead MV\textsubscript{5}). Tracings were taken in the supine, sitting, and standing positions; during a double Master's two-step test, at 1, 2, and 3 minutes; immediately after exercise, and at 1, 3, and 5 minutes later. Additional tracings were taken beyond 5 minutes, at 2-minute intervals, until the ST-T waves returned to the initial pattern and the heart rate was below 100.

Changes during and after exercise are considered significant if the following persist for a minimum period of 3 minutes: (1) ST segments have a descending slope with a depression of 1 mm, or greater; (2) J junctions have an ascending slope but are depressed 1 mm, or more below the level of the preceding PQ segment. Other observations of questionable significance are transient ST-T changes, multiple premature beats, and conduction defects. The criterion for orthostatic ST-T changes is that, when the subject changes from the supine to the sitting or standing position, the ST-T waves become negative, isoelectric, or biphasic within 3 minutes.

In addition, continuous 10-hour electrocardiography was carried out in 110 subjects with the technic initially described by Gilson, Holter, and Glasscock\textsuperscript{12} and subsequently modified by Norland and Semler.\textsuperscript{13}

Results

In order to reduce, as much as possible, latent coronary artery disease from the control group, 200 volunteer subjects, 15 to 30 years of age, equally divided between males and females, were evaluated for ST-T changes (table 1). Thirty-two subjects (16 per cent)
POSTURAL ST-T WAVE CHANGES

Figure 2

Twenty-three-year-old healthy white girl with orthostatic ST-T changes simulating myocardial ischemia during exercise test.

were found to have depressed ST segments and T-wave inversion within 30 seconds to 3 minutes after changing from the supine to the upright position. The ST-segment depression and T-wave inversion returned to the isoelectric level in 14 subjects during exercise; in the remaining 18 subjects they persisted during exercise as well as afterwards for as long as 7 minutes, and resembled the ST-T changes seen in myocardial ischemia. They were not associated with any subjective symptoms. The orthostatic ST-T changes persisted until the subjects returned to the supine position, at which time they reverted to the initial pattern. Since no other evidence of heart disease was present in these subjects, the orthostatic changes were regarded as "false-positive" responses simulating myocardial ischemia. Three subjects described below illustrate the type of orthostatic changes seen. Figure 1 shows the radielectrocardiogram of a 29-year-old healthy physician who inverted his T waves on shifting from the supine to the sitting and standing positions. These negative T waves persisted throughout and after exercise without symptoms and resembled changes of myocardial ischemia. The T waves became positive only after the subject again assumed the recumbent position. These orthostatic changes were also found in the 10-hour continuous electrocardiograms of the subject (fig. 1).

Similar findings are illustrated in figure 2 in a 23-year-old white woman.

T-wave inversion in a 29-year-old white woman upon change from the supine to standing position is shown in figure 3. The T waves became upright again on resuming the supine position.

Subsequent radioelectrocardiographic studies in a large portion of the same study population, with different electrode positions for the "remote electrode," demonstrated that many of the orthostatic ST-T changes could be eliminated. Orthostatic changes could be reduced to a minimum by shifting the "remote electrode" to the lateral third of the right clavicle, with the "exploring electrode" remaining over the sixth rib in the anterior axillary line (lead CV$_5$). These observations suggested that positioning the "remote electrode" near the right shoulder or arm reduces the incidence of orthostatic ST-T-wave phenomena. Figure 4 shows tracings of a 14-year-old boy...
old normal white girl with orthostatic changes in lead MV$_5$ which disappeared in lead CV$_5$.

Discussion

As with any new biologic test, methods of procedure and criteria for results of experiments must be established. In contrast to the precordial V leads of conventional electrocardiography, the radioelectrocardiograph system employs a bipolar lead. Where the electrodes are placed on the chest wall still varies among different investigators. There is no agreement on which precordial lead the bipolar system most closely represents, although most workers think that it is closely related to V$_5$ or V$_6$.

Several investigators have modified the criteria for a positive Master's two-step test and have subsequently found a very high (up to 30 per cent) incidence of "abnormal" ST-T changes in radioelectrocardiograms of presumably healthy subjects. Studies by Mattingly and Robb et al.,$^{14,15}$ indicate that ischemic ST depression of 0.5 mm. or greater in the electrocardiogram after exercise is indicative of significant coronary artery disease and a poor prognosis. In view of the great importance placed on ST-T changes as an indicator of the onset, course, and ultimate prognosis of coronary artery disease, one must be very careful in interpreting ST-T changes detected by radioelectrocardiography.

Using their own criteria, Bellet et al.$^{16}$ reported that 32 of 135 healthy subjects (24 per cent) had "definitely abnormal" radioelectrocardiograms during or after a bicycle exercise test. That is, they showed persistent ST-segment depression of 1 mm. or greater, with T-wave inversion during or after exercise. A bipolar lead system was used with the electrodes placed in the V$_{6R}$ and V$_6$ positions. Their studies demonstrated an incidence of abnormal radioelectrocardiograms in healthy persons below 40 years of age, in the bicycle exercise test, which was four times the incidence of abnormalities in the Master's two-step test.

In another study Bellet's group,$^{10}$ using the same electrode positions, found a decrease in T-wave amplitude, with sometimes complete T-wave flattening, in the radioelectrocardiograms of 68 of 127 normal subjects (54 per

**Figure 3**

Orthostatic ST-T changes in a 29-year-old white woman disappearing on resumption of supine position.
cent) during a Master’s two-step exercise test, and in 31 subjects (25 per cent) immediately after.

Rosenfeld and Master\(^{17}\) recently studied 140 consecutive patients referred for evaluation of “chest pain” or “cardiac status.” Using the radioelectrocardiogram with the bipolar leads in the V\(_{5R}\) and the V\(_{6}\) positions, they found “significant alterations” in the QRS, ST, or T waves in 16 cases.

The same authors\(^ {18}\) also studied 80 healthy persons and “selected” patients, using the same radioelectrocardiographic system and electrode positions. They found changes in the QRS voltage, RS-T segment, and T-wave direction in the standing radioelectrocardiogram, not present in the recumbent one. These were present in healthy subjects “as well as in patients with ischemic heart disease.”

Hinkle et al.\(^ {19}\) recently reported on 300 healthy subjects studied by continuous 10-hour electrocardiography, using bipolar electrodes in the V\(_{4R}\) and V\(_{6}\) positions. They found that nearly all subjects showed loss of T-wave amplitude upon changing from a sitting to standing position. These findings, along with other changes in the ST and T waves during normal daily activities, led Hinkle to conclude that “. . . changes in the ST segment and T wave vectors occur so frequently in people of all ages and both sexes, in association with ordinary activities and common physiologic states, that we believe it is hazardous to

Figure 4
Fourteen-year-old white girl with orthostatic ST-T changes detected in lead MV\(_ {5}\), manubrium V\(_ {5}\) (left), and not in lead CV\(_ {5}\), clavicle V\(_ {5}\) (right).
assume they necessarily indicate the presence of a pathologic process."

The results of the present study indicate that strict criteria for orthostatic ST-T changes need to be established. In addition, the placement of the electrodes of the bipolar lead system appears to be crucial. These studies have also demonstrated important differences, in many subjects, in the complexes of the radioelectrocardiogram compared with the standard precordial V leads. These differences have been corroborated by 10-hour continuous electrocardiograms with use of a technic similar to that used by Hinkle et al. Finally, the radioelectrocardiogram is recorded in the upright position as well as in the supine position, whereas the standard electrocardiogram is usually recorded only in the supine position. It is therefore advisable that before exercise radioelectrocardiography is performed, one should first take a radioelectrocardiogram in three positions—supine, sitting, and standing—to determine if there are postural effects that might simulate myocardial ischemia during exercise. Recognition of these factors should help eliminate some of the "false-positive" coronary ST-T changes in exercise tests, which may in reality be orthostatic changes.

**Summary**

Six hundred and seventy-six healthy subjects between 5 and 77 years of age have been studied by radioelectrocardiography. These subjects were studied before exercise, during a Master's two-step test, and after exercise. Orthostatic ST-T changes occurred in 32 of 200 subjects (16 per cent). The results indicate that the positioning of the bipolar chest leads is crucial in eliminating "abnormal" ST-T changes caused by changes in posture and position. Criteria for orthostatic ST-T changes have been presented. It is concluded that more rigid criteria for "definitely abnormal" ST-T changes during radioelectrocardiography should be developed, so that coronary artery disease will not be overdiagnosed, nor will significant ST-T changes be regarded as "normal variants" occurring with activity.

**Acknowledgment**

We wish to thank Mrs. Berniece Platt for her most valuable technical assistance.

**References**

How Medicine Became a Science

It was in the middle of the eighteenth century that Franklin took a hand in advancing the science of electricity. The properties of the Leyden jar had been described in 1746 and a report of it soon reached America. . . . Franklin then began a series of experiments in which he showed imagination and enterprise. Working entirely on his own initiative and without previous experience of scientific work, he showed qualities of a high intelligence. The letters in which he described the results of his researches were sent to Peter Collinson, a Quaker friend in London, and by him they were communicated to the Royal Society. Though at first the Royal Society paid little attention to them, it was not long before Franklin’s reputation in France compelled the Society to take more notice and soon they elected him a Fellow of the Society. Many of Franklin’s remarks on electricity have a modern ring because he was the originator of the terms “positive” and “negative,” and “plus” and “minus” as applied to electricity. He, more than anyone else at that time and for some time to come, appreciated the possibilities of the new power. In a letter which he wrote in 1751 occur the words—

“I forget whether I wrote to you, that I have melted brass pins and steel needles, inverted the poles of the magnetic needle, given a magnetism and polarity to needles that had none, and fired dry gunpowder by the electric spark. . . . There are no bounds (but what expense and labor give) to the force man may raise and use in the electrical way.”

It is clear that Franklin would have accepted the modern extensive use of electricity in medicine and in general without much surprise.—ZACHARY COPE, KT. Some Famous General Practitioners and other Medical Historical Essays. London, Pitman Medical Publishing Co., Ltd., 1961, p. 188.
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Circulation. 1965;31:557-563
doi: 10.1161/01.CIR.31.4.557

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