Editorial Comment

Upsloping ST Segments
Easy to Measure, Hard to Agree Upon

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In this issue of Circulation, Okin and coworkers present the results of an impressive project designed to demonstrate the effects of measuring ST segment amplitude at different times after the end of QRS on diagnostic accuracy of the exercise ECG for detection of ischemia. In all likelihood, this was prompted by a recent report critical of ST/HR types of analysis for improved detection of ischemia by Lachterman and coworkers. The background of this issue is the reasonable tendency of scientists and engineers to quantify an entity in terms of the strain provoked by a given degree of stress. When the subject is the heart, the relation is the amount of electrocardiographic abnormality provoked by a given degree of cardiac work. Heart rate is most often taken as the measure of cardiac stress to simplify the relation and bring it into workable terms. The measure of strain was taken to be the degree of depression of the ST segment, an indicator of the disparity between oxygen supply and demand of the working myocardium. The reasonableness of this concept has much to recommend it, and one would not have been surprised to find that this approach to interpretation of the exercise ECG yielded improved accuracy compared with conventional interpretation, but readers were surprised at the phenomenal accuracy of this method as found in early reports.

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The literature of cardiology contains many examples of new diagnostic procedures with greatly improved accuracy compared with conventional tests, and it is only after repeated trials at different institutions and on different patient populations that a balanced assessment of the new procedure is attained. What often slows the arrival at a mature assessment of a new method is failure to follow all the details of methodology in an attempt to replicate a new method in a different setting.

The opinions expressed in this editorial comment are not necessarily those of the editors or of the American Heart Association.

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Since exercise electrocardiography is so pragmatic, it should be clear to all who work in this field that any attempt to reproduce a new technology or diagnostic scoring method should reproduce not just what the other investigator understands to be the method's underlying principle, but every item and detail of the methodology; yet this need for precision in setting out to test the claims of others is not always honored. In examining the accuracy of the ST/HR concept, Lachterman and colleagues reviewed their extensive database of exercise ECG tests using measurements of the ST segment taken at its very beginning (the QRS-ST junction, or J point), although Kligfield et al have repeatedly stated that their measurements of ST amplitude were taken 60 msec after the J point (J+60). Lachterman's results with the ST/HR method were poor, and it is not surprising that the Kligfield group would examine the effects of measuring exercise ECGs at different times along the ST segment to see whether this might somehow explain the widely varying accuracy figures found by the two groups.

Okin and colleagues assembled a group of 50 asymptomatic, low-risk subjects as normal controls, 30 patients with clinical angina pectoris but without angiographic documentation, and 30 patients with angiographically proven significant coronary artery disease. This population was exercise tested by their own method, which involves not only highly specific ECG measurements but also a special exercise protocol with narrow work increments. They used a computerized ECG data acquisition system to evaluate ST/HR results first at their customary J+60-msec measurement point in each lead at the end of each exercise increment and at the peak of exercise. All the electrocardiographic data were stored and reanalyzed with addition ST amplitude measurements at J+0, J+20, J+40, and J+80 msec.

When this method was first introduced, all measurements and calculations were done by hand, and a single test analysis might take hours. The above investigations involved over 50,000 individual ST/HR calculations, obviously feasible only with computers. To this observer, such investigations represent optimal employment of contemporary technology.

Okin and coworkers found ST/HR test accuracy best when measurement was made at J+60 msec, slightly reduced when measured at J+40 or J+80.
msec, and worst at J+0 and J+20 msec. Best sensitivity, at J+60 msec, was 0.93, and worst, at J+0 msec, was 0.61 (essentially the same as so-called “standard criteria”). This one difference in ST segment measurement method largely explained the different accuracy results found by Froelicher’s2 and by Klugfield’s groups. There was another procedural difference, however. The former did not employ the gradual exercise staging found so necessary in calculating ST/HR slope by Klugfield et al. It is not possible to evaluate the effect of this variation, since the patient populations studied by the two groups are clearly different.

At first it was thought that ischemia was manifested only by flat or downsloping ST segment depressions, and indeed this was the standard definition given by the American Heart Association exercise working group in 1990.6 Yet, as early as 1968, it was recognized that there were differences of opinion about the significance of upsloping ST segments in the exercise ECG.7 Romano et al8 found that ischemia caused relative prolongation of the QT interval in exercise,8 producing additional alteration of the ST segment. In an early study comparing exercise ECG tests with coronary angiograms, Roitman et al9 categorized ischemic ST responses as “at least 0.1 mV of J point depression precipitated by exercise and disappearing with rest, combined with an ST segment having a negative (downsloping) or insignificant (flat≤1 mV/sec) rate of change.” Using this criterion, the authors found an unexpectedly high sensitivity (0.94) and specificity (0.93). By including ST segments that were not only flat but also upsloping up to +1 mV/sec, the authors were clearly including some degree of ST upslope in their ischemic category.

Kansal et al10 reported in 1976 that in patients with ST segment depression at rest, an additional 0.1 mV of flat, downsloping, or upsloping (≤1 mV/sec) ST depression identified those with angiographically significant coronary artery disease with good sensitivity (0.92) and specificity (0.75). Stuart and Ellestad,11 in a 6-year follow-up study, found that patients who had upsloping ST depression in their exercise tests had the same subsequent mortality rate (9%) as those with flat ST segment depression. However, patients with downsloping ST depression had an even higher mortality rate (13%). Subsequently, other investigators12,13,14 have reported that including ST responses that, although upsloping, are still 0.1–0.2 mV below the baseline at 60–80 msec after the J point, significantly increases test sensitivity without degrading specificity.

If one condenses that upsloping ST depression is sometimes a sign of ischemia, and not everyone does,6,15 then the point on the ST segment at which depression is measured becomes very important. Investigators who accept upsloping ST segments as ischemic caution against mistaking this for “junctional depression,” which is generally recognized as a normal response to exercise. The distinction lies in whether the ST segment returns to the baseline quickly (normal) or is still depressed equal to or greater than 0.1 mV at 60 or 80 msec after the J point (ischemic).10,12,13

Simoons and Block16 examined exercise ECG–ST segments at J+50, J+60, J+70, and J+80 msec and found that J+60 msec measurements gave the most accurate identification of exertional ischemia.

Rossi and colleagues17 implemented exercise ECG analysis on a general purpose scientific computer and examined ST segments, finding that amplitude measurement at J+60 msec gave the most accurate results. They found that ST depression equal to or greater than 0.8 mm, combined with an ST slope equal to or less than 1.2 mV/sec detected known coronary artery disease patients with a sensitivity of 0.92 and specificity of 0.94. Sievanen,18 at Tampere University in Finland, recently developed an exercise ECG analysis system employing ST/HR algorithms. He found that measurement of the depressed ST segment was most accurate at J+60 msec if the segment was upsloping, and that it mattered little where the measurement was made if the ST segment was flat or downsloping. Diamond et al19 have examined the exercise ECG test in order to determine the way the choice of interpretative criteria affects test accuracy. They showed how sensitivity and specificity of a test vary with changes of criteria thresholds. In the past, when only visual measurements were available, we could work only with relatively crude ST measurements. This is quite a contrast with the report above that the best accuracy resulted from an ST depression threshold of 0.8 mm!

One might summarize by stating that the time-honored and priceless scientific practice of testing new methods in different settings, on different patient populations, and by different investigators must always be done with meticulous attention to detail in replicating the method and analyzing the results. Clearly, the computer age has opened new horizons for analysis of all kinds of cardiovascular data, not least the exercise ECG. And if we can agree that “junctional ST depression” is normal and that downsloping ST depression heralds profound ischemia, then is it not easy to agree that everything in between may represent varying degrees of ischemia?

References


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