The Effect of Age on Mean Spatial QRS and T Vectors

By Ernst Simonson, M.D., and Ancel Keys, Ph.D.

The differentiation between normal and abnormal changes in conventional electrocardiography is substantially improved by consideration of normal age trends. For clinical application of spatial vectorcardiography, consideration of age trends is equally important. On the basis of statistical evaluation of magnitude, azimuth and elevation of mean spatial QRS and T vectors in 105 healthy young men and 178 healthy older men, upper and lower limits were determined for each age group. The age differences were highly significant for all items of vector analysis.

In a previous study,1 highly significant statistical differences in most conventional electrocardiographic items were found between a group of 157 normal men from 18 to 25 years and 233 men from 45 to 54 years. Consideration of age trends, of course, is as important for clinical application of spatial vectorcardiography as for conventional electrocardiography, and specific information appeared to be desirable.

The only study on changes of spatial QRS and T vectors with age is that by Abildskov,2 who compared the maximum instantaneous QRS and T vector projections in the frontal and sagittal planes between 75 young adults (from 22 to 33 years) and 114 older subjects (from 40 to 73 years). The group means in some of the items were considered to be significantly different, but no statistical evaluation of the mean differences between the two age groups was made. Furthermore, the vector projections on single planes are very sensitive to positional variation. Rotation in the sagittal plane will affect the magnitude and angles of the vector projections in the frontal plane and vice versa, and the instantaneous maximum vectors in the two planes are not identical due to phase differences. Determination of spatial vectors in terms of azimuth, elevation, and magnitude, from their projections in two planes or electronically by means of the stereovector electrocardiographic system,3 eliminates, at least theoretically, the effect of positional changes on magnitude, and also the direction is more precisely defined. Although the present methods of spatial-vector analysis fall somewhat short of this goal,4 spatial vector analysis permits a synthesis of information that cannot be readily obtained from the conventional interpretation of single leads, and it also drastically reduces the number of items to be analyzed.

Method and Subjects

Mean spatial QRS and T vectors were constructed from conventional leads by means of a mechanical analyzer.5 The data are given in terms of azimuth H° (left maxillary line O°; midline front +90°; midline back −90°; right maxillary line ±180°); elevation V° (angle between a vertical line through the hypothetical center and the vector (O° vertical down; 90° horizontal); vector magnitude (1 mm. = 0.1 mv.); and the angle between the mean spatial QRS and T vectors (d°).

A group of 105 young men from 18 to 28 years was compared with a group of 178 older men in the sixth decade. Both groups were found to be clinically healthy in a thorough clinical examination that included ballistocardiography, blood chemistry, and physiologic stress tests.

The group of older men was identical with that used in previous studies of the effect of age on the conventional electrocardiogram6 and the effect of relative body weight on mean spatial QRS and T vectors.6 This group has been examined annually over a period of eight years and, therefore, provides a much better selection of clinically normal subjects than would be possible in a single check-up.

The younger group is not identical with that used in the previous study.7 The selection of the younger group was made on the basis of only one examination, but the likelihood of latent cardiac pathology is, of course, much less than in an older age group.

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RESULTS AND DISCUSSIONS

Table 1 shows the group means (M) and standard deviations (σ), of the younger (Y) and older (O) age group, the mean differences (Δ) and their statistical significance, evaluated by means of the t-test. The differences in the standard deviations between the two groups were evaluated by means of the F-test. The mean group differences (Δ) of all seven items of spatial vector analysis have high statistical significance. As compared to the younger age group, both vectors are rotated more anteriorly in the older men (azimuth H° more positive) by about the same degree. The higher elevation (V°) of the QRS and the T vector in the older men corresponds to the shift to the left of the QRS and T axes with age in the conventional electrocardiogram, and also the greater elevation of the QRS vector than that of the T vector corresponds to a greater shift to the left of the Einthoven QRS axis than that of the T axis. Thus, highly significant age trends in adult population are apparent in the frontal plane of the limb leads as well as in the horizontal plane of the precordial leads.

The magnitude of the mean spatial QRS and the T vector is significantly smaller in the older men. This difference corresponds well with the lower amplitudes of R₂, T₃, ΣQRS and ΣT in the conventional electrocardiogram.

Without providing direct experimental proof, Olbrich and Woodford-Williams⁷ suggested that electrocardiographic age trends in single leads are due to anatomic changes in the thorax rather than to changes of the electric events in the heart. Positional factors are, indeed, of major importance for amplitudes in single leads, but are minimized in the determination of the magnitude of spatial vectors. Positional factors, therefore, cannot account for the large age differences of the spatial QRS and T vectors, and, on the basis of these results, it is also unlikely that they explain the decrease of the amplitudes with age in single leads. The distribution range of QRS-V°, T-V°, and T-da° is larger in the older men, as shown by the significantly larger standard deviation. The standard deviation of QRS-Mag is significantly smaller in the older age group, but this is explained by the smaller mean value. The variability coefficient, σ/M is identical (30 per cent) for both age groups. The greater variability between individuals in the elevation (V°) of the QRS and T vector is not due to a more heterogeneous composition of the older group, which consisted of “whitecollar workers.” If anything, the younger age group, consisting of students and soldiers, was more heterogeneous. The smaller magnitude and higher elevation of the mean spatial vectors in the older group is also reflected in the length and directions of the average maximum frontal and sagittal vector projections in Abildskov’s material.

<table>
<thead>
<tr>
<th>Group</th>
<th>QRS Vector</th>
<th>T Vector</th>
<th>da°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H°</td>
<td>V°</td>
<td>Mag. mm.</td>
</tr>
<tr>
<td>Y</td>
<td>-31.2</td>
<td>28.4</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>21.6</td>
<td>21.0</td>
<td>3.8</td>
</tr>
<tr>
<td>O</td>
<td>-22.2</td>
<td>54.2</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>21.4</td>
<td>26.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Δ Y-O</td>
<td>9.0</td>
<td>25.8</td>
<td>-2.6</td>
</tr>
<tr>
<td>t</td>
<td>3.42†</td>
<td>8.62†</td>
<td>-5.99†</td>
</tr>
<tr>
<td>F</td>
<td>1.027</td>
<td>1.551†</td>
<td>1.387*</td>
</tr>
</tbody>
</table>

* p = < 0.05
† p = < 0.01
‡ p = < 0.001

Table 1.—Mean values (M) and standard deviations (σ) of Magnitude (Mag.) and Directions (H° = azimuth, V° = elevation, da°, angle between QRS and T vectors) in a group of 105 young (Y) and 178 older (O) healthy men. The differences between the means (Δ) are evaluated by means of the t test, and the differences between the standard deviations by means of the F test.
Abildskov considered the magnitude of the frontal and sagittal T loop to be similar in the younger and older men, but the 20 to 30 per cent lower magnitude in his older group is in the same order as our results, and might well have been statistically significant.

In contrast to our results, Abildskov found the average orientation of the T vector farther posteriorly in the older men. No satisfactory explanation for this discrepancy can be given, but several factors might be involved. It is unlikely that the discrepancy is due to a different definition of spatial vectors: mean vectors in this study and instantaneous maximum vectors in Abildskov’s series. A high correlation between instantaneous maximum and mean vectors were found in a recent study. Of greater importance may be the different lead system, particularly since the location of the anteroposterior vector was determined by Abildskov from the sagittal plane projection and, in this study, from the horizontal plane projection, which appears to be more directly related to rotation around a vertical axis.

Table 2 shows the upper and lower limits for 95 per cent of the healthy male population as represented by the two age groups. The limits were calculated from the standard deviations, since the groups, particularly the younger group, are too small for analysis of possible skewness of distribution, and, therefore, the limits in table 2 have preliminary character. However, no major changes are expected in larger groups, and, in any case, the mean differences of table 1 are reliable. In the larger groups used for the evaluation of age trends in conventional electrocardiographic items, means and median gave identical results. It is of interest that the differences between the upper limits of the angles are larger than those between the lower limits.

The limits could be conceivably narrowed and improved by consideration of the correlations between the QRS and T vector.

A large literature is concerned with the correlation between the QRS complex and the T wave; Katz9 in his excellent review listed over 500 references as early as 1928. Due to the extreme sensitivity of single leads to positional variability, no consistent relationship could be established. The ventricular gradient, as another approach to this problem, was critically reviewed recently.11

In the older group there was a highly significant positive correlation for men with DA° < 45° (r = 0.35, t = 2.84, p = 0.01, N = 56) and for men with DA° from 45° to 65° (r = 0.51, t = 4.5, p = <0.001, N = 68), but not for those with DA° > 65° (r = 0.18, N = 54). The correlation for the total group of 178 men (r = .358) was of high statistical significance (p = <.001). The correlation between QRS-Mag and T-Mag was somewhat lower in the group of younger men (r = 0.228), but still statistically highly significant (p = 0.01).

The relationship between QRS-Mag and T-Mag can be expressed by the regression equations, calculated with the method of the least squares. The equations were T-Mag = 2.090 + 0.132 (QRS-Mag) for the older group, and T-Mag = 3.148 + 0.075 (QRS-Mag) for the younger group. The slope (0.132 and 0.075, respectively) was not significantly different in both groups. Although the correlation between QRS-Mag and T-Mag is statistically highly significant, it is too low to be used for individual prediction. In view of this situation, the ratio of the magnitude of the

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**Table 2.** Upper and Lower Normal Limits for 95 per cent of a Healthy Population of Young (Y) and Older (O) Adults

<table>
<thead>
<tr>
<th>Group</th>
<th>QRS Vector</th>
<th>T Vector</th>
<th>dA°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H°</td>
<td>V°</td>
<td>Mag. mm.</td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>+11.1</td>
<td>69.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Lower</td>
<td>-73.5</td>
<td>0.0</td>
<td>5.1</td>
</tr>
<tr>
<td>O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>+19.7</td>
<td>+105.2</td>
<td>16.9</td>
</tr>
<tr>
<td>Lower</td>
<td>-64.0</td>
<td>3.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>
QRS vector to that of the T vector (QRS-Mag; T-Mag) may be useful for evaluation of normality. It is essentially the same in the younger men (mean 3.28, S.D. ±1.14), and in the older men (mean 3.17, S.D. ±1.14), i.e., the decrease of the QRS vector magnitude with age parallels the decrease of the T vector magnitude.

There is good reason to believe that the electrocardiographic age trends in apparently healthy adult populations are related to the increasing arteriosclerosis of the coronary arteries. In Italian populations, the incidence of coronary artery disease as well as the electrocardiographic trends are much less pronounced. The mean group differences in electrocardiographic items between patients with an early phase of coronary artery disease (normal resting electrocardiogram, typical history of angina pectoris, abnormal exercise tolerance test) as compared to a healthy middle-aged population are in the direction of age trends in the same (Minnesota) population. From this point of view, the angle (dA°) between the mean spatial QRS and T vectors is of interest, since it increases in left ventricular strain or ischemia. It is, therefore, quite possible that the significantly larger angle dA° in the older men might be due to a mild degree of subclinical left ventricular ischemia.

**Summary**

Mean spatial QRS and T vectors, constructed from the conventional electrocardiogram, by means of a mechanical analyzer, were compared in 105 young healthy men from 18 to 28 years old and in 178 healthy older men in their sixth decade.

All items of vector analysis (magnitude, azimuth, elevation of the mean QRS and T vectors, and the angle between these vectors) showed highly significant differences between the group means.

In the older men, both the QRS and T vector were rotated more anteriorly (larger azimuth angle), and were more elevated, their magnitude was smaller, and the angle between the vectors was larger than in the younger men.

The range of interindividual variability was significantly larger in the older men for the angles of elevation of the QRS and the T vector.

Preliminary limits for 95 per cent of the healthy male population, corrected for age are calculated from the standard deviation.

**Summario in Interlingua**

Le median vectores spatial QRS e T, constriuite ab le electrocardiogramma conventional per medio de un analysator mechanic, esseva compara in 105 normal masculos inter 18 e 28 annos de etate e in 178 normal masculos in le sexte decennio de lor vita.

Omne elementos del analyse vectorial (magnitude, azimuth, elevation del median vectores QRS e T, e le angulo inter iste vectores) monstiva significativissime differentias inter le duo gruppos.

In le gruppo a etates plus avantage, le vectores QRS e T esseva ambes rotate plus anteriormente (con un plus grande angulo azimuthic) e plus elevate que in le gruppo del plus juvane subjectos. Le magnitude del vectores esseva reduce, e le angulo inter illos esseva plus grande.

In le gruppo a etates plus avantage le variabilitate interindividual del elevation del angulos del vectores QRS e T esseva significativamente plus extense.

Es presentate le limites preliminari, calculate ab le deviation standard e corrigite pro le factor del etate, que es valide pro 95 pro cento del normal population mascele.

**References**


EFFECT OF AGE ON MEAN SPATIAL QRS AND T VECTORS


Thirty-one patients were re-evaluated an average of 21 months following mitral commissurotomy for mitral stenosis. The usual methods of evaluation were used and, in addition, a standard exercise test that required the patient to walk for 10 minutes at 1.73 mph on a 10 per cent grade. A physical fitness index of over-all cardiorespiratory performance was determined from observations made during this test.

In reply to a questionnaire, 29 of 31 patients classified themselves as better and 7 reported relapses due to heart failure or manifestations of the postcommissurotomy syndrome. Twenty of the patients, have some persistent limitation, 15 required daytime periods of rest, and all but 4 still required some form of medication. The most common limiting symptom was exertional dyspnea for 19 patients and ease of fatigue for 15 patients. Prior to operation 17 of the 31 patients could do full-time work, but all but 3 of them had some limitation with exertion; following operation 24 patients could work full time, and 15 instead of 3 had no limitations with effort. Prior to the operation 11 patients were totally disabled; this was the case in only 3 following surgery. Following surgery the murmur of mitral stenosis never disappeared although it was often less intense. The frequency of mitral insufficiency as determined by auscultation increased from 13 to 15 patients after surgery whereas atrial fibrillation decreased from 16 to 11 patients.

Exercise tolerance tests were possible in 29 patients. Following operation 26 were able to walk 10 minutes in contrast to 21 preoperatively, normal respiratory efficiency was achieved by 10 in contrast with 7 prior to surgery, and a normal physical fitness index score was made by 15 patients as compared with 9 previously.

There was correlation of subjective improvement with objective evidence in only 55 per cent of the patients. The authors express the belief that for some patients the term "better" describes a change in attitude toward their disease and disability, rather than improvement in cardiorespiratory function. This change in attitude may result from many factors including the positive, enthusiastic approach of the surgeon and careful medical supervision. The increase in the mean physical fitness index in the group of patients reported here was hardly greater than that in a similar group of patients studied in the same laboratory and treated only by medical therapy. The problem of differentiating patients with myocardial insufficiency from those with mechanical block at the mitral valve makes evaluation of response to treatment difficult.

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