
Correlation between subjective and objective measures of correspondence between different systems of vectorcardiography

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For several years the vectorcardiographic loops obtained by different lead systems have been compared by a subjective method.^{1,2} The ideal correspondence was denoted by a rating of 10, whereas 0 denoted that the two loops showed no correspondence at all.

This method, although satisfactory in practice, has all the drawbacks of its subjective nature. This was the reason that we introduced objective measures for the differences between vectorcardiographic systems.^{3,4} These measures give the relative displacement of the points of the loop when the loop is transformed from one lead system to another. The calculation of the displacement can be made in an "isotropic" way (measure: D), if the prevailing directions of the heart vector are not taken into account, or in an "anisotropic" way (measure: δ), if allowance is made for the frequency of occurrence of different directions of the heart vector.

In our last paper⁴ the main problem was to study the relations of lead systems averaged over a fairly large number of subjects. It was pointed out, however, that

the agreement of the systems can also be evaluated for each individual separately. It is the purpose of this paper to investigate the correlation of different criteria for correspondence, using such individual data.

Material and method

The calculations to be described here were applied to the vector loops of 24 cardiac patients.

The three lead systems compared were those originated by Frank,⁵ McFee and Parungao,⁶ and Burger and associates.⁷ They will be referred to by the letters F, M, and B, respectively.

Subjective comparison. This was done in two ways. First, ratings for the correspondence between frontal and horizontal projections were given by the three authors separately and then averaged. Although the omission of the sagittal projection emphasizes the influence of the right-left vector component, later experience gives us the impression that the final result cannot be much in error because of this shortcoming.

A second, and principally better, com-

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parison was obtained by constructing three-dimensional vector loops from metal wire. A simple device, not to be described here, allowed this to be done with sufficient accuracy and in a relatively short time. Then, the correspondence of these wire figures was estimated and indicated by a rating, without consideration of the orthogonal projections. This method is essentially better than the first one, not only because all three orthogonal components of the heart vector are now equally weighed, but because the vectorcardiogram is essentially a three-dimensional curve. Although it *can* be described by orthogonal projections or by orthogonal components, it has a meaning in itself, apart from orthogonality or from any mathematical system used in displaying it. It is this consideration that induced us to replace the former comparison of projections, however easy it might be, by the comparison of spatial loops.

To increase the statistical evidence, the three ratings of the comparisons F-M, M-B, and B-F for each subject were averaged, accepting the loss of detail so introduced. Thus, for each subject the mutual correspondence of the three lead systems was indicated by two subjective criteria. The first (P) gives the correspondence of the two orthogonal projections; the second (S) gives the correspondence of the spatial loops.

Objective comparison. As mentioned above, the transformation of a vectorcardiographic loop from one system to another can be used to calculate the displacement of the end point of the heart vector in two different ways, yielding two different measures for the displacement, viz., D (isotropic) and δ (anisotropic).

In addition, there is a "true" distance of isophasic points of loops in two different lead systems. This distance was measured for 5 isophasic points on each pair of loops being compared. To obtain a relative measure (T) for the average true distance, the square root of the average squares of the five distances was divided by the average size of the loops:

$$T = \frac{\sqrt{\Sigma a^2/5}}{\sqrt{\bar{X}^2 + \bar{Y}^2 + \bar{Z}^2}}$$

Just as in the case of the subjective

measures, the objective measures for the correspondence of the three combinations F-M, M-B, and B-F were averaged.

For each pair-wise combination of the five quantities P, S, D, δ , and T a scattergram could be drawn containing 3×24 points. From this figure the correlation could be judged very roughly. All these figures will not be reproduced because a much better measure of their connection is given by the correlation coefficient r . We shall restrict ourselves to these coefficients without giving the regression equations. Since a correlation ($r \neq 0$) may be caused by chance, the (95 per cent) confidence limits must also be indicated.

Because of the limited number of cases the calculated r 's are not equidistant from their upper and lower confidence limits, so that the results may be represented in the form:

$$r = 0.46 (0.26 - 0.62).$$

Since S and P are measures for the agreement, but T, D, and δ for the difference, of two vectorcardiograms, negative r 's occur, meaning that an increase in the one quantity is accompanied by a decrease in the other.

Results and discussion

The first combination to be mentioned is δ -T (anisotropic-true). As could be expected, the values of these two objective measures of the difference of systems are almost equal. Their correlation coefficient $r = 1.00$. Therefore, we shall omit δ in the following considerations. Then, four quantities remain, viz., the two subjective measures P and S and the two objective ones T and D, giving six combinations.

In Fig. 1 the six correlation coefficients are shown. They can all be considered to be significant, although some of them are rather small. As could be expected, the isotropic measure D is less well correlated with the subjective measures S and P than is T, the "true" distance. Therefore, in further investigations we can rid ourselves of D in favor of T (or δ).

Comparing the correlations of S and P with the true difference T, we see that S is slightly better correlated with T than is P. This difference is not statistically significant. Still, the fact that the *mutual* cor-

relation between S and P deviates significantly from $r = 1.00$ indicates that there must be a real difference. The introduction

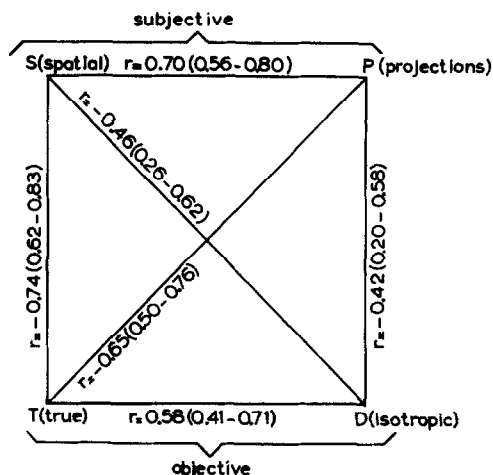


Fig. 1. Correlation coefficients between subjective and objective criteria for the correspondence and the difference, respectively, of the individual VCG loops in three lead systems. The numbers in parentheses give the range, corresponding to the standard error in the coefficient.

of the sagittal projection in the subjective comparison giving P would possibly further reduce this difference.

All in all, it does not appear to be worth while to construct wire loops in all cases for so little gain in correlation.

It might seem disappointing that the best correlation S-T between the "spatial wire loops" and the "true difference" does not score better than $r = 0.74$. But we must not forget that the aims of the subjective and of the objective methods are different. In the first one, criteria that are of diagnostic significance receive higher weight: attention is given to right or left preponderance, clockwise or counterclockwise inscription in the projections, etc. The objective methods, however, lead us to a result along a purely mathematical route, and, therefore, blindfolded. This is the price we have to pay for objectiveness.

Elaborating the relation S-T somewhat further, we have plotted the corresponding values of S and T in a scattergram (Fig. 2). It gives the regression, i.e., the average

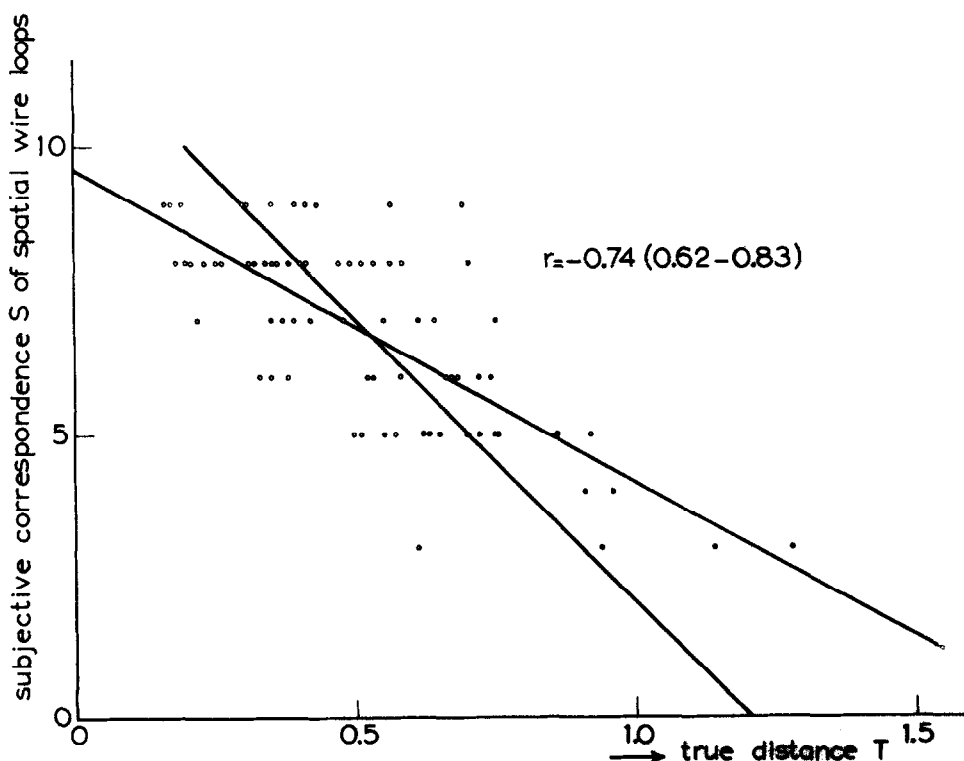


Fig. 2. Scattergram of the relation between the "relative average true distance" of isophasic points and the rating for the correspondence of spatial wire loops. The regression lines have a slope that can be considered to be satisfactory.

dependence of the one quantity on the other. That two lines are drawn is a consequence of the imperfect correlation ($r \neq -1$). But, taking a slope in between the slopes of the two lines, we see that a rating of 10 in the individual evaluation corresponds to a "relative average true distance" (T) of isophasic points of 0, as it should. A rating of 0 corresponds to a T of 1.3. Said otherwise, one unit in the range of individual ratings for the correspondence of spatial loops stands for a "relative average true distance" in position of corresponding points of 0.13 (13 per cent). This situation can be considered to be satisfactory.

Summary

The agreement between vectorcardiograms obtained by different lead systems may be judged by various subjective and objective methods.

To test the validity of these methods, the results were studied when they were applied to vectorcardiograms obtained by the lead systems of Frank, McFee and Burger. For each individual case the three vectorcardiograms were compared pair-wise from the loop-projections (P) as well as from spatial wire models (S), and the degree of *similarity* was evaluated subjectively and expressed by a rating between 0 and 10.

Objectively, the *difference* between the vectorcardiograms was given by the "relative average true distance" (T) between isophasic points on the loops, as well as by

the extent of the displacement brought about by a linear transformation designed to transform the one system into the other (δ). Correlations between P, S, T, and δ were calculated and were all found to be significant. T appeared to be interchangeable with δ ($r = 1.00$). Of the other correlations, the best one was between S and T (or δ) ($r = 0.74$), although the difference with P and T was only small. The regression coefficient proved to be plausible. For purposes of comparison of systems the use of wire models has only slight advantage over loop-projections.

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