The frontal plane QRS-T angle

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This editorial refers to ‘QRS-T angle as a predictor of sudden cardiac death in a middle-aged general population’ by A.L. Aro et al., on page 872

Availability of the limb leads of the 12-lead electrocardiogram (ECG) allows calculation of a mean QRS axis and a mean T axis, as is well known. These axes lie in the frontal plane of the body and can be used to calculate a very simple difference in angle between the two axes, namely the planar QRS-T axis. In contrast, it is possible to calculate the mean direction of ventricular activation in three-dimensional space. This is sometimes termed the orientation of the mean spatial QRS vector. Similarly, there is a mean spatial T vector and the science of vectorcardiography revolves around the study of spatial P, QRS, and T vectors as they vary throughout the cardiac cycle.1 Figure 1 shows a mean spatial QRS and T vector and their corresponding projections onto the frontal plane.

It should be noted that the frontal plane QRS-T angle is normally derived from the limb leads of the 12-lead ECG, i.e. the frontal plane leads, whereas Figure 1 shows how a mean spatial QRS vector and mean spatial T vector can be projected onto the frontal plane to provide a frontal plane QRS and T axis which may or may not be the same axes as calculated from frontal plane leads depending on how the spatial vectors were derived, as discussed later.

Over the years, there have been a number of publications suggesting that a wide spatial QRS-T angle in the ECG carries a poor prognosis. As summarized in the accompanying article by Aro et al.,2 more recent studies have indicated that an abnormally large QRS-T spatial angle predicts cardiac death in a clinical population and is a strong predictor of all-cause mortality in post-menopausal women. A wide spatial QRS-T angle also predicted cardiac death in a general population aged 55 years and above.3 Similarly, the frontal plane QRS-T angle also carries prognostic value in certain clinical situations such as shown by Pavri et al.4 in patients with non-ischaemic cardiomyopathy. Furthermore, Zhang et al.5 showed that the frontal plane QRS-T angle was a ‘suitable clinical substitute’ for spatial QRS-T angle with respect to risk prediction in the ARIC study.

However, there have not been many, if any, studies looking at the prognostic value of the frontal plane QRS-T angle in a middle-aged general population that has been followed for over 30 years, such as reported in the article by Aro et al.2 elsewhere in this issue. It should be noted that in some cases, the value of the QRS angle can be higher than that of the T angle and vice versa.

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versa. Aro et al. chose to take the absolute value of the difference between the two angles.

The normal limits of the frontal plane QRS-T angle are well known. For example, this writer published age- and sex-related normal limits some years ago. In young male individuals under 29 years of age, the normal range was from $-39$ to $71$° (i.e. a span of $110$°). In young women of the same age, the range was $-46$ to $59$° (i.e. a span of $105$°). In older male individuals over 50 years of age, the range was $-82$ to $40$° (i.e. $120$°). In older female individuals in the same age bracket, the range was $-89$ to $26$° (i.e. a range of $117$°). In their study, Aro et al. arbitrarily chose $100$° as a threshold for an abnormal planar QRS-T angle but it should be noted that they measured angles to the nearest $10$° so that if a planar QRS-T angle exceeded $100$° in their study, it had a minimum value of $110$°.

These frontal plane angles are easily calculated whereas a spatial QRS-T angle requires an additional electrocardiographic dimension to allow the mean spatial QRS vector to be derived, as does the mean spatial T vector. The angle between these two vectors is the spatial QRS-T vector (see Figure 1).

In order to do this, authors generally transform the 12-lead ECG into the three orthogonal XYZ lead ECG, from which the vectorcardiogram is derived, using equations that are best applied via computer techniques. With the use of these three XYZ leads, the spatial mean QRS and T vectors can be derived and hence the spatial QRS-T angle can be calculated. For those readers not familiar with the three orthogonal lead ECG, leads X, Y, and Z can very broadly be likened to leads I, aVF, and $-V_2$, which is why axes have been labelled in this way in Figure 1. Indeed, spatial mean QRS and T vectors could be calculated less accurately using I, aVF, and $V_2$, in which case their projections onto the frontal plane would produce planar QRS and T vectors very close to those derived directly from the limb leads.

It is clearly simpler for the practising physician to assess QRS-T in the frontal plane but on the other hand, with the widespread availability of automated ECG interpretation machines nowadays, a spatial QRS-T angle could easily be calculated and incorporated into the output measurements matrix.

Figure 1 has been designed deliberately to show that although there may be a large spatial QRS-T angle, it is theoretically feasible...
for the projections of the mean spatial QRS and T vectors onto the frontal plane to produce a narrow QRS-T frontal planar angle, which may be minimally different from the frontal QRS-T angle derived from limb leads. The spatial QRS-T angle therefore might be thought to be inherently different compared with the frontal planar QRS-T angle, though they were equivalent with respect to risk prediction in one study.\(^5\)

What does an abnormally wide planar QRS-T imply from an electrocardiographic standpoint? Aro et al. selected a value of \(\geq 100^\circ\) as being abnormal. This implies that, at one extreme, there could be an upright QRS in aVF (QRS axis \(= 90^\circ\) and an inverted T wave in the same lead (T axis \(\leq -10^\circ\) say). At the other extreme, if the QRS axis were to be at \(0^\circ\), then there would be an upright R wave in lead I and an inverted T wave in the same lead, e.g. T axis \(\geq 100^\circ\). Thus, the implication of the wide QRS-T angle in the frontal plane is that there must be a relatively flat or inverted T wave in the inferior lead aVF or the lateral lead I. It might therefore be argued at this point that wide QRS-T angle is not adding to the presence of a more basic T-wave abnormality in the inferior or lateral leads.

Aro et al. indicated that 212 individuals in their study, i.e. 2%, had a QRS-T angle \(\geq 100^\circ\). However, 0.7% (46) had a T-wave axis \(\geq 100^\circ\) implying T-wave inversion in lead I while 4.4% (509) had a T axis \(\leq -10^\circ\) suggesting T-wave inversion in aVF. Thus, many more individuals had abnormal T axes than abnormal QRS-T angles. This can be explained relatively easily with reference to Figure 2 where the QRS axis = \(-3^\circ\) and the T axis = \(-13^\circ\). In this example from a 44-year-old apparently healthy man, the T-wave changes could be regarded as non-specific because of the narrow QRS-T angle. The Minnesota Code recognized 50 years ago that T-wave inversion in the inferior lead aVF was not a codeable finding if the QRS in aVF was not mainly upright as in Figure 2 and the latest version of the code\(^8\) maintains this stance. The code completely ignores T-wave inversion in lead III. Aro et al. indicate that, in their study, the T axis was the main contributor to the risk associated with an abnormal QRS-T angle. It would have been interesting to compare those individuals with a T axis \(\leq -10^\circ\) and a normal QRS-T angle versus those with T axis \(\leq -10^\circ\) and an abnormal QRS-T angle. Furthermore, would there have been any difference in risk with QRS axis \(< T\) axis compared with QRS axis \(\geq T\) axis? This question might partially have been answered by noting that individuals with T axis \(\leq -10^\circ\) and those with T axis \(\geq 100^\circ\) treated separately still had an increased risk of an adverse outcome.

The message from Aro et al. is that a wide frontal plane QRS-T angle carries a considerably increased risk of sudden arrhythmic death and all-cause mortality but not of non-arrhythmic cardiac mortality. However, the authors stress that, in the main, this result is a reflection of an abnormal T axis, which reflects some of the argument above. Indeed, patients with an abnormal T axis \(\leq -10\) or \(\geq 100^\circ\) had an increased risk of arrhythmic death with a relative risk of 2.13, which is very similar to the relative risk of 2.26 associated with a wide QRS-T angle.

It could be argued that the limitations of the study such as (i) measuring angles to the nearest \(10^\circ\) and (ii) perhaps some uncertainty over an arrhythmic vs. non-arrhythmic death, even allowing for clearly specified definitions, could have influenced results in some way but the overall conclusion is in keeping with other studies, which suggests that these limitations did not have a significant effect on the overall result of the study.

The conclusion is that a simple check on QRS-T angle in the frontal plane provides a further indicator of cardiac risk, although with an abnormal angle having a prevalence of \(\sim 2\%\), at least in a general population, it may be of limited value to the clinician.

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**References**