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Research Article

View on the Clinical Value of QRS-T Angle

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Abstract: The QRS-T angle, as an index of non-invasive cardioelectric vector, is closely related to the change of heart structure and function. There are different methedologies to measure the QRS-T angle, which can be roughly dividedinto two types: plane angle and space angle. Studies show that the influence factors include two aspects of physiology and pathology of the angle, in pathological ways, the disease such as myocardial hypertrophy, myocardial ischemia, hypertension, ventricular arrhythmia has larger clinical significance. In recent years, the research on the risk stratification of the QRS-T angle on sudden death has made great progress, but there are still some disputes about whether the space angle can be replaced by the plane angle and the range of normal value and so on.

Keywords: QRS-T angle; Plane Angle; Space angle; The risk stratification on sudden death

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In 1920s, Mann initiated the concept of "Circulation", and vectorcardiogram appeared in the field of electrocardiography. Frank system, which appeared in 1950s, is widely used to measure ECG vector. Since 1934, the concept of "ventricular gradient" has appeared, which is the vector sum of spatial QRS-T angles. QRS-T angle, as a noninvasive vectorial index, can reflect the change of ventricular repolarization, and its relationship with cardiac structure and function is one of the hot spots in clinical electrocardiography. In recent years, with the in-depth study on the risk stratification and clinical significance of sudden cardiac death by noninvasive technology, people pay more and more attention to this angle. This paper reviews the recent research on QRS-T angle.

1 Basic concepts

There are two kinds of QRS-T angles. Spatial QRS-T angle and plane QRS-T angle.

Spatial QRS-T angle generally refers to the angle between the long axis of QRS complex space vector and the long axis of T wave space vector. It is characterized by "secondary T wave", that is, secondary repolarization heterogeneity. In the absence of active potential morphological heterogeneity, it highlights the repolarization abnormalities secondary to depolarization, including ventricular premature contraction, ventricular pacing, bundle branch block, etc. In this way, the QRS-T angle complements the ventricular gradient, and both can be used to fully assess depolarization abnormalities in patients with primary, secondary, or mixed disease.

The plane QRS-T angle refers to the angle between the maximum vector of QRS complex and the maximum vector of T wave.

2 Calculation method

Spatial QRS-T angle is an index of three-dimensional space, the calculation is complex, need professional software processing and enough knowledge of ECG vector. Three detection methods are introduced here.

2.1 Spatial peak QRS-T angle

That is to say, the degree of the angle between the space QRS and T vector is measured at the moment of maximum amplitude[1]. First of all, the starting point is generated between two points in a cardiac cycle, which are close in space but separated in time in the ECG vector loop. Secondly, the peaks of spatial QRS and t vectors are generated in QRS loop and T loop respectively, which are the farthest points from the starting point. The calculation of spatial QRS-T angle is defined by the normalized inner product of spatial QRS and T vector peak.

$$\text{SP QRS}-\text{T angle } = \arccos\frac{\text{QRSp}\times\text{Tp}}{|\text{QRSp}|\times|\text{Tp}|}$$

2.2 Spatial mean QRS-T angle

The spatial QRS-T angle can be regarded as the spatial "average" QRS-T angle for measurement. The spatial "average" QRS-T angle uses the average value of the spatial QRS vector in the QRS loop over time and the average value of the spatial T vector in the T loop over time[1]. This occurs when the "peak" and "average" vectors of the symmetric ring are equal.

$$\text{SM QRS}-\text{T angle}=\arccos\frac{\text{QRSm}\times\text{Tm}}{|\text{QRSm}|\times|\text{Tm}|}$$

The same equation can be expressed in several other ways:

$$\text{SM QRS}-\text{T angle}=\arccos\frac{\text{QRSx}\times\text{Tx}+\text{QRSy}\times\text{Ty}+\text{QRSz}\times\text{Tz}}{\sqrt{\text{QRSx}^2+\text{QRSy}^2+\text{QRSz}^2}\times\sqrt{\text{Tx}^2+\text{Ty}^2+\text{Tz}^2}}$$

$$\text{SM QRS}-\text{T angle} = \arccos\left(\frac{\left(\left[\int_{\text{Qbeg}}^{\text{J-p}}\text{V}_x\right]\times\left[\int_{\text{J-p}}^{\text{Tend}}\text{V}_x\right]\right)+\left(\left[\int_{\text{Qbeg}}^{\text{J-p}}\text{V}_y\right]\times\left[\int_{\text{J-p}}^{\text{Tend}}\text{V}_y\right]\right)+\left(\left[\int_{\text{Qbeg}}^{\text{J-p}}\text{V}_z\right]\times\left[\int_{\text{J-p}}^{\text{Tend}}\text{V}_z\right]\right)}{\sqrt{\left(\int_{\text{Qbeg}}^{\text{J-p}}|\text{V}_x|\right)^2+\left(\int_{\text{Qbeg}}^{\text{J-p}}|\text{V}_y|\right)^2+\left(\int_{\text{Qbeg}}^{\text{J-p}}|\text{V}_z|\right)^2} * \sqrt{\left(\int_{\text{J-p}}^{\text{Tend}}|\text{V}_x|\right)^2+\left(\int_{\text{J-p}}^{\text{Tend}}|\text{V}_y|\right)^2+\left(\int_{\text{J-p}}^{\text{Tend}}|\text{V}_z|\right)^2}}\right)$$

2.3 Spatial simple QRS-T angle

For those researchers who are not convenient to obtain records or convert XYZ leads, foreign researchers have developed a simplified method to calculate the spatial QRS-T angle by using AVF, V2, V5 and V6 leads. This method includes several steps: First, according to QRS net = ramp − | s / Q samp | the net value of QRS complex amplitude of each AVF, V2, V5 and V6 lead was calculated; Then T net = (+) t amp − (−) t amp | was used to measure the amplitudes of positive and negative T waves to calculate the net value of T wave; Then, according to the equation

$$\text{QRS}_{\text{sm}}=\left[\left(\text{QRS}_{\text{net}}\text{V}_6\right)^2+\left(\text{QRS}_{\text{net}}\text{aVF}\right)^2+\left(\text{QRS}_{\text{net}}\text{V}_2\right)^2\right]^{1/2}$$

$$\text{T}_{\text{sm}}=\left[\left(\text{T}_{\text{net}}\text{V}_5\right)^2+\left(\text{T}_{\text{net}}\text{aVF}\right)^2+\left(\text{T}_{\text{net}}\text{V}_2\right)^2\right]^{1/2}$$

The space size of QRS and t was calculated; Finally, the simple space QRS angle is calculated as follows.

$$\text{SS QRS}-\text{T angle}=\arccos\left(\frac{\left(\text{QRS}_{\text{net}}\text{V}_6\times\text{T}_{\text{net}}\text{V}_5\right)+\left(\text{QRS}_{\text{net}}\text{aVF}\times\text{T}_{\text{net}}\text{aVF}\right)+\left(\text{QRS}_{\text{net}}\text{V}_2\times\text{T}_{\text{net}}\text{V}_2\right)}{\text{QRS}_{\text{sm}}\times\text{T}_{\text{sm}}}\right)$$

Guldenring *et al* showed that: Compared with the matrix 12 lead ECG, the simplified ECG equipment based on limb leads I, II and precordial leads V1, V3, V6 can obtain high-quality spatial QRS-T angle, and the prediction results are similar[2].

2.4 Frontal QRS-T angle calculation

According to the principle of XYZ axis, the standard I lead of body surface electrocardiogram is the projection on X axis, and AVF lead is equivalent to the projection on Y axis. Therefore, the projection on X axis is represented by the height of R wave in I lead, and the projection on Y axis is represented by the height of R wave in AVF lead. A vertical line is made at the height point of R wave in two leads, and the intersection point of the two vertical lines is connected with the center point to obtain the frontal angle of R wave. Similarly, the vertical line of T-wave height can form the frontal angle of T-wave.On the frontal plane map, with 10 ° as the unit, each quadrant forms 9 sub angles of 0-90 °, set the first and fourth quadrants as negative values, and the second and third quadrants as positive values, then the absolute value of QRS-T angle can be obtained (using angle gauge).

3 Influencing factors of QRS-T angle

The QRS-T angle reflects the relationship between ventricular depolarization vector and ventricular repolarization vector. Therefore, all the factors that affect ventricular depolarization and repolarization can change the QRS-T angle. The factors that affect the angle of QRS-T are mainly physiological and pathological.

3.1 Physiological factors

Physiological factors include gender, age, body type, race and so on. At present, the QRS-T angle of female is smaller than that of male; In both sexes, the angle increases with age; The normal plane angle is less than the space angle.

3.2 Pathological factors

Pathological factors include myocardial hypertrophy, myocardial ischemia, hypertension, ventricular arrhythmia, etc. current studies show that various pathological changes lead to the increase of QRS-T angle.

3.2.1 Myocardial hypertrophy

In mild left ventricular hypertrophy, the direction of T-loop changed little; Severe left ventricular hypertrophy can affect the shape of action potential, such as prolonged QRS duration and change of T-loop direction. When the change of QRS loop is not obvious, the QRS-T angle increases, even opposite to QRS direction.

Tanriverdi *et al* studied the relationship between frontal QRS-T angle and non arytenoid status in 122 hypertensive patients without left ventricular hypertrophy[3]. Frontal QRS-T angle is an independent predictor of non arytenoid status in hypertensive patients without left ventricular hypertrophy. Cortez *et al* conducted a 10-year study involving 1053 patients with hypertrophic cardiomyopathy[4]. The spQRS-T angle (129.3 ± 26.4) ° and smQRS-T angle (121.8 ± 38.6) ° in patients with hypertrophic cardiomyopathy were significantly higher than those in the control group (30.5 ± 24.2) ° and (47.3 ± 27.6) ° ($P < 0.001$). It was also found that the combined application of body surface area, body mass index and spatial QRS-T angle in the diagnosis of left ventricular hypertrophy was better than the traditional ECG diagnostic criteria.

3.2.2 Myocardial ischemia

The long axis of QRS ring is almost parallel to or intersects with t ring at 45 degrees; In the case of myocardial ischemia, ventricular repolarization process is affected, not in the normal order, but from endocardial layer to epicardial layer, resulting in QRS-T angle increase, beyond 90 ° or even up to 180°. The results of a large sample study in China show that: 1The sensitivity and specificity of angle > 90 ° were the highest (76%, 74%).

3.2.3 Hypertension

Dern et alobserved the significance of average QRS complex vector and QSR-T angle in patients with hypertension after treatment through continuous ECG changes[5]. The results showed that during the treatment, the QRS-T angle decreased with the decrease of blood pressure. The continuous ECG changes including QRS-T angle may have great value in the diagnosis of hypertensive cardiac dysfunction.

3.2.4 Ventricular arrhythmia

Tran *et al* measured the spatial QRS-T angle in 117 patients undergoing Fontan palliative surgery, and concluded that the spatial QRS-T angle is an important independent predictor of ventricular arrhythmia[6].

3.2.5 Diabetes

Dawood *et al* showed that diabetes is an independent factor for the widening of spatial QRS-T angle in HIV infected people[7].

3.3 Others

Factors such as dialysis and laparoscopic surgery can also increase the QRS-T angle.

Poulikakosand other studies explored the relationship between ECG markers and major adverse cardiac events and mortality in hemodialysis patients, and found that the QRS-T angle was a significant predictor[8].

Dabrowski *et al* found that in healthy women undergoing laparoscopic surgery, intra-abdominal hypertension affected the relationship between cardiac depolarization and repolarization, and increased the spatial QRS-T angle[9].

Jing found that when the blood lead content increased by one unit, the probability of abnormal QRS-T angle increased by 34% in men and 4% in women, and suggested that the QRS-T angle deviation should be used to detect the risk of adverse cardiovascular events (such as arrhythmia) in people exposed to lead[10].

4 Prediction of death by QRS-T angle

This paper mainly summarizes the predictive effect of this angle on cardiac death and all-cause death.

4.1 Psychogenic death

Including sudden cardiac death and cardiovascular disease death.

4.1.1 Sudden cardiac death

Poulikakos and other studies found that the QRS-T angle in hemodialysis patients is a significant predictor of major adverse cardiac events and mortality[8]. Markus and other studies found that QRS-T angle has a significant value in predicting sudden death after acute coronary syndrome[11].

Many studies focused on the spatial QRS-T angle as an indicator of sudden cardiac death, and carried out one by one from low-risk level to high-risk level in different groups. They found that this angle is an effective and sensitive tool for the risk stratification of sudden cardiac death in the whole population and special population.

4.1.2 Cardiovascular death

As expected, many studies suggest that the widened QRS-T angle has a predictive effect on cardiovascular mortality. In the lower risk male population, the worsening cardiovascular mortality was accompanied by a wider QRS-T angle[12].

The study of voulgar et al indicates that spatial QRS-T angle is an advantageous predictor for future cardiovascular death by evaluating the potential heterogeneity of global and local ventricular function[13].

4.2 All cause death

Many studies on the correlation between total mortality and abnormal widened QRS-T angle have been followed up, and all of them are positive correlation. Compared with the patients with normal QRS-T angle, the risk of all-cause mortality in patients with cardiovascular disease and wide QRS-T angle is nearly three times higher[12]. Mayand other studies found that the increased QRS-T angle is a strong and independent long-term predictor of all-cause death in diabetic patients[14].

5 Outlook

As a noninvasive vectorial parameter of ECG, QRS-T angle has broad research prospects. But there are several problems that need our attention and consideration.

5.1 Can plane QRS-T angle replace space QRS-T angle

At present, there are two opposite views: One suggests that plane QRS-T angle and spatial QRS-T angle have almost the same predictive value for coronary heart disease events and all-cause mortality; The other suggests that the spatial mean QRS-T angle has more significant statistical diagnostic value in screening heart disease than the frontal QRS-T angle derived from ECG, the frontal QRS-T angle derived from vectorgraph, the left sagittal QRS-T angle and the horizontal QRS-T angle.

5.2 Which matrix model is the most suitable to transform the QRS-T angle

The QRS-T angle (sa-f) measured by the vectorgraph recorded by Frank's electrode position is the gold standard for measuring the QRS-T angle. However, the clinically available ECG must be multiplied by the synthetic vectorgraph through the matrix model, and the spatial QRS-T angle thus calculated is the estimated value of the QRS-T angle actually measured in Frank's system. The commonly used matrix models are frank vector graph synthesis model, kors vector graph synthesis model and anti-Dower vector graph synthesis model. At present, most researchers agree with the spatial angle (sa-k) calculated by kors model.

In recent years, some scholars have studied the Mason likar system. They think that the results of the average spatial QRS-T angle measured from the traditional standard system and the Mason likar (M-L) system are different, and the difference is (5-10) ° [15]. Another related study shows that compared with kors matrix, M-L vectorcardiogram based on 12 lead ECG data of M-L system provides more accurate prediction of spatial QRS-T angle[16].

5.3 The evaluation of normal value is not unified

For the spatial QRS-T angle, the upper limit is 105-110° for men and 73-90 ° for women. However, there are few studies on the plane QRS-T angle, and there are many opinions. The normal height range is 39-90 degrees. For this result, most scholars believe that the measurement of this angle should be stratified by age. Future research should first determine the normal range of QRS-T angle in different age groups, so as to provide a precise and effective reference for clinical practice; The choice of matrix model is closely related to the accuracy of this angle, so it is very important to determine and choose the optimal matrix model; Compared with the spatial angle, the calculation of the plane angle is simple and easy to measure. If it can replace the spatial angle through verification, it will provide the feasibility for the wide application of this angle in clinical practice.

6 Conclusion

A number of studies have shown that the QRS-T angle has a significant value in the risk stratification of various diseases, especially cardiovascular disease and sudden death, but this value has not been touched in clinical practice in China. We hope that the majority of ECG workers can recognize and verify the important role of QRS-T angle, so that this value can be widely used in clinic to play its due role.

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