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Cardiovascular diseases and frontal QRS-T angle

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SOUHRN

Rozdíl os komplexu QRS a vlny T (frontal QRS-T angle, fQRSTa) je elektrokardiografický parametr odrážející prostorový vztah mezi vektory depolarizace a repolarizace v srdci; určují jej úhly mezi vektory QRS a vlnou T ve frontální rovině. Širší fQRSTa je obecně spojován se zvýšenou komorovou ektopickou aktivitou, poruchou funkce levé komory a zvýšeným rizikem kardiovaskulárních onemocnění (KVO); podle několika studií je širší QRSTa spojen se zvýšeným rizikem rozvoje KVO včetně infarktu myokardu, srdečního selhání a náhlé srdeční smrti. Celkově lze z dostupných důkazů usuzovat, že fQRSTa je užitečný marker kardiovaskulárního rizika a může mít značný význam pro prevenci a léčbu KVO. Poznání vztahu mezi QRSTa a KVO si nicméně vyžádá další výzkum, který zároveň pomůže stanovit optimální využití tohoto ukazatele v klinické praxi.

Keywords:
Electrocardiogram
QRS-T angle
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ABSTRACT

The frontal QRS-T angle is an electrocardiographic measurement that reflects the spatial relationship between the depolarization and repolarization vectors in the heart. It is determined by the angles between the QRS and T wave vectors in the frontal plane. A wider QRS-T angle is associated with increased ventricular ectopic activity, impaired left ventricular function, and increased risk of cardiovascular diseases (CVDs). Several studies have suggested that a wider frontal QRS-T angle is associated with an increased risk of developing CVDs, including myocardial infarction, heart failure, and sudden cardiac death. Overall, the evidence suggests that the frontal QRS-T angle is a useful marker of CV risk and may have important clinical implications for the prevention and management of CVDs. However, further research is needed to fully understand the relationship between the QRS-T angle and CVD, and to determine the optimal use of this marker in clinical practice.

Introduction

Globally, heart disease kills most. In 2013, about 660,000 new myocardial infarctions (MI) with clinical symptoms (CMI) and 160,000 unintentionally found asymptomatic silent MIs (SMI) caused 14% of US fatalities.[1–3] Around 20% of new MIs were SMIs.[4,5] It was found that 45% of MIs in the Atherosclerosis Risk in Communities (ARIC) study were asymptomatic, or SMI.[6] Appropriate risk stratification equals appropriate resource allocation for cardiac devices. Electrocardiograms (ECGs) are affordable, noninvasive, rapid to produce, and quick to result in stratifying patients' risk for cardiac morbidity and death. Vector cardiography (VCG) has reemerged with digital ECG. VCG depicts heart vector movement as loops. The QRS loop is a reflection of depolarization, while the T loop is a reflection of repolarization. By using VCG, one may quantify the spatial QRS-T angle (sQRS-Ta) between depolarization and repolarization. A broad QRS-Ta is used to stratify cardiac risk.[7]

Abnormally broad spatial QRS-T angles are one of the strongest ECG indicators of aberrant repolarization and are predictive of cardiovascular diseases (CVDs) events and death. Nevertheless, computing the spatial QRS/T angle from the normal 12-lead ECG involves many steps, which limits its use. Nevertheless, the frontal plane QRS/T angle may be simply determined as the absolute magnitude of the difference between the QRS and T axes. SMI prediction by the spatial QRS/T angle and the easy-to-obtain frontal QRS/T angle are unknown.[8–13] As a result, the major goal of this review was to conduct a systematic evaluation of existing data.

Methods of measurement

Manipulation of the VCG may provide the sQRS-Ta. In brief, the VCG is either built from orthogonal Frank sQRS-Ta, may be assessed as a "peak" or "mean" angle (SP or SM QRS-Ta). Cortez and Schlegel address the differences between

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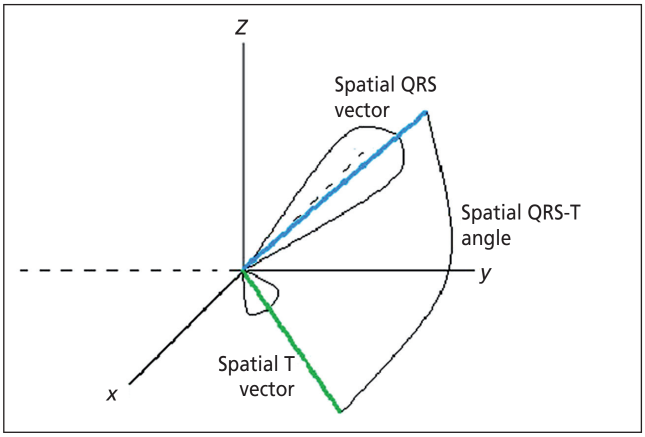

Fig. 1 – Spatial QRS-T angle is shown schematically. Other publication containing the figure in the manuscript include reference 7.

these two strategies briefly.[14] SP QRS-Ta measures QRS-Ta at maximal spatial QRS and T vector magnitude in a 3D loop. Sur et al. reported the SP QRS-Ta measurement at Tereshchenko's lab.[15] First, the starting point is midway between the two closest in space but distanced in time points on a vector cardiographic loop. Peak QRS and T vectors are furthest from QRS-loop and T-loop origins (Fig. 1).

SM QRS-Ta may be used to measure sQRS-Ta. SM QRS-Ta uses the mean spatial QRS vector and the mean spatial T vector. Peak and mean vectors are equivalent in symmetrical loops.[15]

Normal QRS-T angles can vary a little bit from source to source, but most of the time they are between –30 and +90 degrees. A positive QRS-T angle (between 0 and +90 degrees) means that the electrical vector of the T wave is pointing in the same general direction as the QRS complex. A negative QRS-T angle (between –30 and 0 degrees) means that the T wave is pointing in the opposite direction of the QRS complex. It's worth noting that the interpretation of the QRS-T angle should always be done in conjunction with other ECG findings and clinical information, as it's just one of many factors that can help diagnose and manage cardiac conditions.

Rautaharju et al.[16] determined the spatial QRS-T angle by using a 12-lead electrocardiogram (ECG) and analysing the electrical vectors in three dimensions. It is a more complex process that requires knowledge of vector mathematics and advanced ECG interpretation skills. However, there is a simple method to estimate the spatial QRS-T angle using a single-lead ECG. This method involves measuring the QRS axis and the T wave axis in the same lead and calculating the angle between them. To do this, you need to identify the lead with the highest R-wave amplitude (the lead with the tallest QRS complex) on the ECG. This lead is typically lead I or lead II.

Next, you need to measure the QRS axis in this lead. To do this, you should identify the most isoelectric (or nearly isoelectric) leads, which are the leads with the least amount of electrical activity during the QRS complex. Then, draw an imaginary line between the isoelectric leads on the ECG, which represents the QRS axis. The QRS axis is the direction of the electrical vector of the QRS complex. Once you have determined the QRS axis, measure the T wave axis in the same lead. The T-wave axis is the direction of the electrical vector of the T wave. It's important to note that the T-wave axis may not always be in the same direction as the QRS axis. Finally, to calculate the spatial QRS-T angle, subtract the QRS axis from the T wave axis. If the resulting value is positive, the angle is considered to be a positive angle (QRS and T waves are oriented in the same direction), and if it is negative, the angle is considered to be a negative angle (QRS and T waves are oriented in opposite directions).

QRSf and Tf are frontal projections of three-dimensional QRS and T vectors. Frontal QRS-Ta (fQRS-Ta) is the angle between QRSf and Tf vectors (Fig. 2). FQRS-T a is a 12-lead ECG's frontal QRS and T axis difference. If the difference exceeds 180°, the fQRS-Ta is 360° minus the absolute difference.[7]

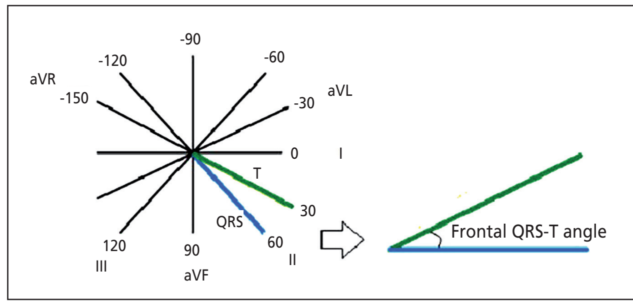

Fig. 2 – Planar frontal QRS-T angle measurement. Other publication containing the figure in the manuscript include reference 7.

fQRS-Ta versus sQRS-Ta

Many studies have compared frontal and sQRS-Ta techniques.[17] Cross-study comparison is difficult since each research has its own normal angles and population variation. SQRS-Ta predicts heart disease more reliably than fQRS-Ta, indicating better diagnostic value.

Since these indicators are praised more for their prognostic than diagnostic significance, numerous research has compared them. A research found that both frontal and spatial techniques were prognostic, although SQRS-Ta was more predictive for ventricular arrhythmias (VA) (a proxy for sudden cardiac death [SCD]) than fQRS-Ta in ischemic cardiomyopathy patients with ICDs.[18] Individuals with aberrant QRS-Ta had a higher risk of death and incident CHD, according to the ARIC trial of CVDs-free adults.[8] A research found that widening sQRS-Ta predicted total and cardiac death in 7052 CVD-free participants. FQRS-Ta was solely predictive in males, contrary to the ARIC research, which only found relevance in women. These two researches did not employ identical normal ranges for fQRS-Ta, a frequent problem in comparing studies on this issue.[10]

In healthies

The sQRS-T or fQRS-Ta varies by gender and age. From the frank lead system or modern digital ECG transformation technologies, normal ranges of sQRS-Ta vary. ARIC cohort of 5434 males aged 54 years reported a normal upper limit of 110°. This research capped women at 90.[19] Analysis of sQRS-Ta by age, gender, and digital ECG conversion technique is supported, as most approaches overestimate the resulting vector measurement. A cohort of older

Table 1 – Cornerstone studies on frontal QRS-T angle

Reference no.	Authors	Subjects	Numbers	Main theme
15	Topaloğlu et al.	Adrenal adenomas patients (NFAA)	58	The first research to link aberrant QRS-T angles to NFAA
16	Li et al.	Hypertensive patients	179	PHT patients showed greater f(QRS-T) angles than normotensives and HT patients
17	Tekin et al.	Patients with carbon monoxide (CO) poisoning	212	In CO poisoning patients, the frontal QRS-T angle may identify myocardial damage early
18	Gungoren et al.	Anemic subjects	66	Hemoglobin independently predicted frontal QRS-T angle
19	Işık et al.	Coronary slow flow patients	200	Frontal QRS-T angle increases TIMI-frame count. CSF patients had greater frontal QRS-T angles.
20	Kurisu et al.	Patients with LV diastolic function	128	Without considerable perfusion abnormalities, the frontal QRS-T angle was linked with LV diastolic function.
21	Jiang et al.	Patients with long QT syndrome	144	Drug-induced long QT syndrome is assessed by the QTc, not the frontal QRS-T angle
22	Kurisu et al.	Patients with advanced chronic kidney disease (CKD)	220	In advanced CKD patients, broad QRS-T angle is related with LV remodeling such increased LVEDV or lower LVEF
23	Gunduz et al.	COVID-19 patients	327	A large fQRS angle >90° predicted in-hospital mortality and mechanical ventilation in COVID-19 patients
24	Kuyumcu et al.	Patients with coronary artery bypass graft surgery	180	POAF develops with high f(QRS-T) angle. POAF may indicate f(QRS-T) angle.
25	Eyuboglu et al.	Patients with acute-onset AF	179	Amiodarone may drastically alter frontal plane QRS-T angle. Frontal plane QRS-T angle may be determined from automated ECG recordings to monitor intravenous amiodarone dosing.
27	Dogan et al.	Patients with ST segment elevation myocardial infarction	340	In STEMI patients, the fQRST angle is an independent predictor of coronary atherosclerotic load
28	Erdogan et al.	Patients with non-ST elevation myocardial infarction	269	f(QRS-T) predicts SYNTAX score to determine early invasive strategy in NSTEMI patients
29	Dindas et al.	Patients with non-ST elevation myocardial infarction	210	The Selvester QRS score and f(QRS-T), two simple ECG measures, predict post-PCI SF in non-STEMI patients
30	Han et al.	Patients with ST segment elevation myocardial infarction	592	QRS distortion and fQRS-T angles improve STEMI prognosis, particularly when coupled

adults free of CVD at the outset of the research reported 39° for women and 81° for males as normal upperlimits.[18]

Sudden cardiac death

Kors et al. examined the sQRS-Ta in low-risk and high-risk groups and discovered an alarming connection with CV mortality and SCD. This research also found a 5.6 hazard ratio for SCD in individuals with an aberrant sQRS-Ta.[20] A research of 277 dialysis patients found a hazard ratio of 4.5 in individuals with an excessively broad QRS-Ta. The sQRS-Ta has a better predictive value in high-risk groups for CV mortality.[21] The biggest research to ask this topic included 10,957 middle-aged Finns. A fQRS-Ta greater than 100° tripled the risk of SCD in this cohort. Patients were initially screened for CVD risk. Also in this study, the power of the QRS-Ta to predict SCD was found to be limited.[22]

Ventricular arrhythmias

Widening QRS-T predicts VA. Borleffs et al.[18] studied 412 high-risk individuals with implanted ICDs to determine initial suitable treatment. An aberrant spatial QRS-Ta had a statistically significant adjusted hazard ratio of 7.3.

Cardiovascular mortality

In a study involving 7052 individuals without CVD, a 14-year increased risk of mortality was found with an increased QRS-Ta (men > 135°, women > 120°).[20] fQRS-Ta predicts overall death, but not CV mortality. This study also showed that the wide fQRS-Ta (men >95°, women >43°) increased mortality more in men than women. Another study of 10,957 people discovered that having a large fQRS-Ta (>100°, undifferentiated by gender) did not raise the risk of non-arrhythmic CVD.[22]

All-cause mortality

The FQRS-Ta predicts all-cause mortality in a diverse population. The Finnish CHD cohort seems to be the biggest research looking at this subject. A broadened (>100°) fQRS-Ta produced a hazard ratio of 1.8 for overall mortality in this

Table 2 – QRS-T angle in clinical situations

	Impacts	Limitations
Sudden cardiac death	A wider QRS-T angle indicates greater heterogeneity in ventricular repolarization, which is associated with an increased risk of ventricular arrhythmias and SCD. Clinicians can use the QRS-T angle to identify individuals who are at a higher risk of SCD and who may benefit from closer monitoring, lifestyle modifications, or pharmacologic interventions. For example, individuals with a wide QRS-T angle may benefit from an implantable cardiover-ter-defibrillator (ICD) to reduce the risk of SCD.	The QRS-T angle is influenced by various factors, such as age, sex, and heart rate, which can affect its accuracy as a predictor of SCD. The QRS-T angle is only one of several ECG markers that can predict SCD, and it may not be the most reliable. While the QRS-T angle can help identify individuals at risk for SCD, it does not provide information about the underlying cause of SCD, such as coronary artery disease or arrhythmia.
Ventricular tachycardia	A wider QRS-T angle is associated with an increased risk of ventricular tachycardia (VT), a rapid heart rhythm that originates in the ventricles of the heart. The impacts of the QRS-T angle on VT are significant and can affect patient management and outcomes.The wider the QRS-T angle, the greater the risk of VT, as it indicates greater heterogeneity in ventricular repolarization, which can predispose individuals to the development of VT.	The QRS-T angle is influenced by various factors, such as age, sex, and heart rate, which can affect its accuracy as a predictor of VT. The QRS-T angle is only one of several ECG markers that can predict VT, and it may not be the most reliable. The QRS-T angle may not provide information about the underlying cause of VT, such as coronary artery disease or genetic mutations. The QRS-T angle is a static measurement of ventricular repolarization and does not take into account dynamic changes that may occur over time. Therefore, repeated ECGs may be necessary to provide a more accurate assessment of an individual's risk of VT.

Table 3 – QRS-T angle in clinical situations

	Impacts	Limitations
Cardiovascular mortality	A wider QRS-T angle is associated with an increased risk of cardiovascular mortality. The impacts of the QRS-T angle on cardiovascular mortality are significant and can affect patient management and outcomes. A wider QRS-T angle is associated with an increased risk of cardiovascular disease. The wider the QRS-T angle, the greater the risk of cardiovascular mortality, as it indicates greater heterogeneity in ventricular repolarization, which can predispose individuals to the development of these conditions.	The QRS-T angle is that it is influenced by various factors, such as age, sex, and heart rate, which can affect its accuracy as a predictor of cardiovascular mortality. Additionally, the QRS-T angle may not accurately predict the risk of cardiovascular mortality in certain populations, such as those with pre-existing conditions like heart failure or atrial fibrillation. The QRS-T angle is that it does not provide information about the underlying cause of cardiovascular disease. The QRS-T angle is a static measurement of ventricular repolarization and does not take into account dynamic changes that may occur over time. Therefore, repeated ECGs may be necessary to provide a more accurate assessment of an individual's risk of cardiovascular mortality.
All-cause mortality	A wider QRS-T angle is associated with an increased risk of overall mortality, which includes cardiovascular and non-cardiovascular causes of death. A wider QRS-T angle is associated with an increased risk of all-cause mortality, independent of other cardiovascular risk factors such as age, sex, smoking, hypertension, and diabetes. The wider the QRS-T angle, the greater the risk of overall mortality.	One limitation is that the QRS-T angle is only a single measurement of ventricular repolarization and does not take into account other factors that may contribute to overall mortality risk. Another limitation of the QRS-T angle is that it may not accurately predict overall mortality risk in certain populations. The QRS-T angle may be affected by various factors, such as age, sex, and heart rate, which can affect its accuracy as a predictor of overall mortality risk.

research of the general population.[22] The DEFINITE study found no association between non-ischemic cardiomyopathy and fQRS-T for mortality. To highlight study variation, this research classified abnormal as more than 90° and did not stratify by gender.[20] Tables 2 and 3 show the impact and limitations of the QRS-T angle in different clinical situations.

Recent studies

Lau et al.[23] discovered that the great arteries TGA patients with higher fQRS-Ta following atrial switch surgery had poorer RV mechanics. Narrow QRS-Ta (135 degrees), QRS length, and cQT interval predict cardiac resynchronization therapy (CRT) responsiveness in heart failure patients. FQRS-Ta predicts CRT response independently.[24] Topaloglu et al.[25] initially studied an aberrant QRS-Ta and nonfunctional adrenal adenomas (NFAA). A considerable majority of patients had an aberrant QRS-Ta, which was linked to hypertension but not left ventricular hypertrophy.

The fQRS-Ta, a noninvasive marker of cardiac conduction dysfunction, was greater in individuals with PHT than in normotensives. Our results support the concept that ventricular repolarization abnormalities occur early in essential hypertension.[26] FQRS-Ta, a simple and affordable metric determined from 12-lead surface electrocardiography, may be utilized to assess myocardial damage in carbon monoxide (CO) poisoning patients.[27]

Hemoglobin level can predict fQRS-Ta.[28] FQRS-Ta and TIMI-frame count are correlated. CSF increases the fQRS--Ta.[29] Kurisu et al.[30] linked the fQRS-Ta to LV diastolic performance in the absence of perfusion abnormalities. The fQRS-Ta cannot replace the QTc in drug-induced long QT syndrome. Jiang et al.[31] agree that human QT interval measurements should be undertaken notwithstanding machine results.

Wide QRS-Ta is related with LV remodeling in advanced chronic kidney disease (CKD) patients, such as increased LV end-diastolic volume (LVEDV) or lower LV ejection fraction (LVEF), according to Kurisu et al.[32] In COVID-19 patients, a broad fQRSa >90° predicted mortality.[33] High levels of fQRS-Ta are linked to the development of postoperative atrial fibrillation (POAF). The fQRS-Ta can be a possible sign of POAF.[34] Amiodarone affects fQRS-Ta. FQRS-Ta may be readily determined from automated ECG recordings and used to monitor intravenous amiodarone medication.[35] fQRSTa, readily determined from automated ECG recordings, may indicate early AF recurrence following amiodarone cardioversion.[36]

fQRSTa predicts atherosclerosis in STEMI patients.[37] F(QRS-T) may predict SYNTAX score to determine early invasive approach in non-ST elevation myocardial infarction (NSTEMI) patients.[38] Selvester QRS score and f(QRS-T), easy-to-calculate ECG measures, predict post-percutaneous coronary intervention (post-PCI) slow flow in non-STEMI patients.[39,40] When coupled, G3I and fQRS-Ta improve STEMI prognosis. These results assist physicians select high-risk individuals for extensive therapy.[41] Percutaneous chronic total occlusion (CTO) revascularization repolarized the ventricle. FQRS-Ta reduced after CTO PCI during 6-month follow-up.[42]

Athletes have a larger fQRS-Ta than healthy people. Protein supplements (PS) users and non-users didn't vary much.[43] Surface electrocardiography readily measures fQRS-Ta. This research shows for the first time that severe chronic obstructive pulmonary disease (COPD) patients have a considerably elevated fQRS-Ta.[44] QRS-Ta predicts survival and is related with advanced amyloid illness.[45] Asarcikli et al. found that fQRSTa increases from dippers to non-dippers to reverse dippers. The fQRSTa helps identify and stratify hypertensive individuals.[46]

Tascanov et al.[47] showed that propofol enhanced colonoscopy patients' fQRS-Ta. Since a prolonged fQRS-Ta is linked to VA, it may be prudent to monitor propofol patients undergoing colonoscopies. The fQRS-Ta may be a significant ECG parameter in psychiatric patients.[48] Right ventricular in acute pulmonary embolism overload affects fQRS-Ta. Changing fQRS-Ta may indicate effective thrombolysis.[49] Histopathological investigations suggest ICD leads may induce fibrosis and scar tissue. Fibrosis and scar tissue did not change the fQRS-Ta, suggesting they have little clinical value.[50] In type 2 diabetes mellitus (DM) patients with CVD, empagliflozin narrows the fQRSTa.[51]

Discussion

A wider QRS-T angle is associated with an increased risk of CVDs and mortality. The impacts of the QRS-T angle on CV mortality are significant and can affect patient management and outcomes. Studies have shown that a wider QRS-T angle is associated with an increased risk of CVDs, including coronary artery disease, heart failure, and SCD. The wider the QRS-T angle, the greater the risk of CV mortality, as it indicates greater heterogeneity in ventricular repolarization, which can predispose individuals to the development of these conditions. Clinicians can use the QRS-T angle to identify individuals who are at a higher risk of CVDs and mortality and who may benefit from closer monitoring, pharmacologic interventions, or lifestyle modifications. For example, individuals with a wide QRS-T angle may benefit from statin therapy to lower cholesterol levels or blood pressure-lowering medications to reduce the risk of CV events.

Aside from its effects on clinical care, the QRS-T angle can also have important effects on research. Studies that use the QRS-T angle to find people with a high risk of CVDs and death can help find new therapeutic targets and help make prevention strategies that work better. Overall, the QRS-T angle is a useful way to measure CV risk and can have a big effect on how a patient is treated and how well they do, especially when it comes to the risk of CV death. But it should be used together with other clinical information and diagnostic tests to get a full picture of a person's CV risk profile.

The QRS-T angle is a good way to measure the risk of CVDs and death, but it has some limitations that should be taken into account when interpreting the results. One problem with the QRS-T angle is that it can be affected by things like age, sex, and heart rate, which can make it less accurate as a predictor of CV death. For example, a wider QRS-T angle may be observed in younger individuals, which can lead to false positive results. Additionally, the QRS-T angle may not accurately predict the risk of CV mortality in certain populations, such as those with preexisting conditions like heart failure or atrial fibrillation. Another limitation of the QRS-T angle is that it does not provide information about the underlying cause of CVDs. Therefore, additional diagnostic tests may be needed to determine the underlying cause and inform appropriate treatment.

Also, the QRS-T angle is a static way to measure ventricular repolarization, which means that it doesn't take into account changes that may happen over time. So a person may need to have more than one ECG to get a more accurate picture of their risk of dying from CV causes. Finally, the QRS-T angle is only one of several ECG markers that can predict CV mortality, and it may not be the most reliable marker in all cases. Other markers, like the QT interval, ST segment changes, and T-wave alternans, have also been shown to help predict CV mortality in certain populations. In conclusion, the QRS-T angle is a useful way to measure the risk of death from cardiovascular disease, but it should be used with other clinical information and diagnostic tests to get a full picture of a person's CV risk profile. Clinicians should also be aware of the limitations of the QRS-T angle when interpreting results and making decisions about treatment.

Even though it can't always predict SCD, it can give important information about the risk of CVDs and change how patients are treated and how well they do. Studies have shown that a higher QRS-T angle is linked to a higher risk of SCD and other bad cardiovascular events. When there is more heterogeneity in ventricular repolarization, which is shown by a wider QRS-T angle, the risk of ventricular arrhythmias and sudden cardiac death (SCD) goes up. Clinicians can use the QRS-T angle to find people who are more likely to have SCD and could benefit from closer monitoring, changes to their lifestyle, or medication. For example, people with a wide QRS-T angle may benefit from an implantable cardioverter-defibrillator (ICD) to lower their risk of SCD. Aside from its effects on clinical care, the QRS-T angle can also have important effects on research. Studies that use the QRS-T angle to find people who are at high risk of SCD can help find new therapeutic targets and help make prevention strategies that work better.

Overall, the QRS-T angle is a useful way to measure CV risk and can have a big effect on how patients are treated and how well they do. But it should be used together with other clinical information and diagnostic tests to get a full picture of a person's CV risk profile.

While the QRS-T angle can provide valuable information about the risk of CVDs, it has some limitations in predicting SCD. First of all, the QRS-T angle is affected by things like age, sex, and heart rate, which can change how well it can predict SCD. For example, the QRS-T angle may be wider in younger individuals, which can lead to false positive results. Secondly, the QRS-T angle is only one of several ECG markers that can predict SCD, and it may not be the most reliable. Other markers, such as the QT interval and T-wave alternans, have been shown to be better predictors of SCD in some studies. Finally, while the QRS-T angle can help identify individuals at risk for SCD, it does not provide information about the underlying cause of SCD, such as coronary artery disease or arrhythmia. Therefore additional tests may be needed to determine the cause and inform the appropriate treatment. In summary, the QRS-T angle is a useful tool in assessing CV risk, but it has limitations in predicting SCD and should be used in conjunction with other clinical information and diagnostic tests.

Confounding variables are variables that can affect the relationship between the independent and dependent variables in a study. They can distort the true relationship between variables, leading to incorrect conclusions. In research, it's important to identify and control for confounding variables to accurately assess the effect of the independent variable on the dependent variable. The QRS-T angle is a measure of the electrical activity of the heart, calculated as the angle between the QRS complex (a group of three waves on an electrocardiogram that represent the electrical activation of the ventricles) and the T wave (the wave that represents the electrical recovery of the ventricles). The QRS-T angle is used in clinical practice to assess the risk of cardiac events and to monitor the effect of treatments.

Even though the QRS-T angle is not a confounding variable by itself, it can be affected by other variables that can act as confounding variables in studies that look at the relationship between the QRS-T angle and other variables. For example, factors like age, sex, and medical history can affect the QRS-T angle and also be linked to the outcome variable of interest. So, when looking at the relationship between the QRS-T angle and clinical outcomes, it's important to control for potential confounding variables to accurately measure the effect of the QRS-T angle on the outcomes of interest.

Conclusion

Significant evidence has gathered over the last decade for the utility of the QRS-T angle metric in predicting unfavorable cardiac outcomes. A wider QRS-T angle increases ventricular ectopic activity, left ventricular dysfunction, and CVDs risk. Numerous studies have linked a larger frontal QRS-T angle to CVDs, including myocardial infarction, heart failure, and SCD. The evidence implies that the frontal QRS-T angle is a valuable predictor of CV risk and may have substantial clinical implications for CVDs prevention and therapy. However, further research is needed to properly understand the QRS-T angle and CV illness and determine the best clinical usage of this measure.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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References

1. Thygesen K, Alpert JS, White HD; on behalf of the Joint ESC/ACCF/AHA/WHF Task Force for the Redefinition of Myocardial Infarction. Universal definition of myocardial infarction. Circulation 2007;116:2634–2653.
2. Thygesen K, Alpert JS, Jaffe AS, et al. The writing group on behalf of the Joint ESC/ACCF/AHA/WHF Task Force for the Universal Definition of Myocardial Infarction. Third universal definition of myocardial infarction. Circulation 2012;126:2020–2035.
3. Mozaffarian D, Benjamin EJ, Go AS, et al. American Heart Association Statistics Committee; Stroke Statistics Subcommittee. Heart disease and stroke statistics – 2016 update. A report from the American Heart Association. Circulation 2016;133:e255–e269.
4. Schelbert EB, Cao JJ, Sigurdsson S, et al. Prevalence and prognosis of unrecognized myocardial infarction determined by cardiac magnetic resonance in older adults. JAMA 2012;308:890–896.
5. de Torbal A, Boersma E, Kors JA, et al. Incidence of recognized and unrecognized myocardial infarction in men and women aged 55 and older: the Rotterdam Study. Eur Heart J 2006;27:729–736.
6. Zhang ZM, Rautaharju PM, Prineas RJ, et al. Race and sex differences in the incidence and prognostic significance of silent myocardial infarction in the Atherosclerosis Risk in Communities (ARIC) study. Circulation 2016;133:2141–2148.
7. Oehler A, Feldman T, Henrikson CA, Tereshchenko LG. QRS-T angle: a review. Ann Noninvasive Electrocardiol 2014;19:534–542.
8. Zhang ZM, Prineas RJ, Case D, et al. For the ARIC Research Group: comparison of the prognostic significance of the

electrocardiographic QRS/tangles in predicting incident coronary heart disease and total mortality (from the Atherosclerosis Risk in Communities study). Am J Cardiol 2007;100:844–849.

9. Jogu HR, O'Neal WT, Broughton ST, et al. Frontal QRS-T angle and the risk of atrial fibrillation in the elderly. Ann Noninvasive Electrocardiol 2017;22:e12388.
10. Whang W, Shimbo D, Levitan EB, et al. Relations between QRSlT angle, cardiac risk factors, and mortality in the third National Health and Nutrition Examination Survey (NHANES III). Am J Cardiol 2012;109:981–987.
11. Zhang ZM, Rautaharju PM, Prineas RJ, et al. Usefulness of electrocardiographic QRS/T angles with versus without bundle branch blocks to predict heart failure (from the Atherosclerosis Risk in Communities study). Am J Cardiol 2014;114:412–418.
12. Strauss DG, Mewton N, Verrier RL, et al. Screening entire health system ECG databases to identify patients at increased risk of death. Circ Arrhythm Electrophysiol 2013;6:1156–1162.
13. Zhang X, Zhu Q, Zhu L, et al. Spatial/frontal QRS/T angle predicts all-cause mortality and cardiac mortality: a meta--analysis. PLoS One 2015;10:e0136174.
14. Cortez DL, Schlegel TT. When deriving the spatial QRS-T angle from the 12-lead electrocardiogram, which transform is more Frank: Regression or inverse Dower? J Electrocardiol 2010;43:302–309.
15. Sur S, Han L, Tereshchenko LG. Comparison of sum absolute QRST integral, and temporal variability in depolarization and repolarization, measured by dynamic vector cardiography approach, in healthy men and women. PLoS One 2013;8:e57175.
16. Rautaharju PM, Prineas RJ, Zhang ZM. A simple procedure for estimation of the spatial QRS/T angle from the standard 12--lead electrocardiogram. J Electrocardiol 2007;40:300–304.
17. Brown RA, Schlegel TT. Diagnostic utility of the spatial versus individual planar QRS-T angles in cardiac disease detection (STAFF Symposium). J Electrocardiol 2011;44:404–409.
18. Borleffs CJ, Scherptong RW, Man SC, et al. Predicting ventricular arrhythmias in patients with ischemic heart disease: clinical application of the ECG-derived QRS-Tangle. Circ Arrhythm Electrophysiol 2009;2:548–554
19. Rautaharju PM, Prineas RJ, Wood J, et al. Electrocardiographic predictors of new-onset heart failure in men and in women free of coronary heart disease (from the Atherosclerosis in Communities [ARIC] Study). Am J Cardiol 2007;100:1437–1441.
20. Kors JA, Kardys I, van der Meer IM, et al. Spatial QRS-T angle as a risk indicator of cardiac death in an elderly population. J Electrocardiol 2003;36(Suppl):113–114.
21. de Bie MK, Koopman MG, Gaasbeek A, et al. Incremental prognostic value of an abnormal baseline spatial QRS-T angle in chronic dialysis patients. Europace 2013;15:290–296.
22. Aro AL, Huikuri HV, Tikkanen JT, et al. QRS-T angle as a predictor of sudden cardiac death in a middle-aged general population. Europace 2012;14:872–876.
23. Lau LY, So EK, Chow PC, Cheung YF. Frontal QRS-T angle and ventricular mechanics in congenital heart disease. Heart Vessels 2020;35:1299–1306.
24. Gündüz R, Usalp S. Predictive value of frontal QRS-T angle after cardiac resynchronization therapy. J Electrocardiol 2021;68:24–29.
25. Topaloğlu O, Çimci M. The frontal QRS-T angle in patients with incidentally discovered nonfunctional adrenal adenomas. Eur Rev Med Pharmacol Sci 2021;25:3028–3037.
26. Bağcı A, Aksoy F. The frontal plane QRS-T angle may affect our perspective on prehypertension: A prospective study. Clin Exp Hypertens 2021;43:402–407.
27. Tekin YK, Tekin G, Nur N, Korkmaz İ, Yurtbay S. Frontal QRS-T angle as a predictive marker for myocardial damage in acute carbon monoxide poisoning. Hum Exp Toxicol 2021;40:583–592.
28. Gungoren F, Tanriverdi Z, Besli F, et al. Effect of anemia on the frontal QRS-T angle. Minerva Cardiol Angiol 2021;69:36–42.
29. Işık F, Aslan B, Çap M, et al. The relationship between coronary slow-flow and frontal QRS-T angle. J Electrocardiol 2021;66:43–47.
30. Kurisu S, Nitta K, Ikenaga H, et al. Frontal QRS-T angle and left ventricular diastolic function assessed by ECG-gated SPECT in the absence of significant perfusion abnormality. Heart Vessels 2020;35:1095–1101.
31. Jiang E, Raubenheimer JE, Isbister GK, et al. Machine read frontal QRS-T angle and QTc is no substitute for manual measurement of QTc in pro-arrhythmic drug overdose. J Electrocardiol 2021;65:151–156.
32. Kurisu S, Nitta K, Watanabe N, et al. Associations of frontal QRS-T angle with left ventricular volume and function derived from ECG-gated SPECT in patients with advanced chronic kidney disease. Ann Nucl Med 2021;35:662–668.
33. Gunduz R, Yildiz BS, Ozgur S, et al. Frontal QRS/T angle can predict mortality in COVID-19 patients. Am J Emerg Med 2022;58:66–72.
34. Kuyumcu MS, Uysal D, Özbay MB, et al. Frontal plane QRS-T angle may be a predictor for post-coronary artery bypass graft surgery atrial fibrillation. Rev Assoc Med Bras 2020;66:1673–1678.
35. Eyuboglu M. Frontal plane QRS-T angle in the monitoring of intravenous amiodarone infusion for pharmacological cardioversion of acute atrial fibrillation. J Clin Pharm Ther 2021;46:731–737.
36. Eyuboglu M, Celik A. Frontal plane QRS-T angle predicts early recurrence of acute atrial fibrillation after successful pharmacological cardioversion with intravenous amiodarone. J Clin Pharm Ther 2021;46:1750–1756.
37. Dogan A, Kahraman S. Frontal QRS-T angle predicts coronary atherosclerotic burden in patients with ST segment elevation myocardial infarction. J Electrocardiol 2020;58:155–159.
38. Erdogan G, Yontar OC, Yenercag M, et al. Frontal QRS-T angle predicts syntax score in patients with non-ST elevation myocardial infarction. J Electrocardiol 2020;61:86–91.
39. Dindas F, Koyuncu I, Candan O, et al. Predictive role of Frontal QRS-T angle and Selvester QRS Score in determining angiographic slow flow phenomenon following percutaneous coronary intervention in patients with Non-ST elevation myocardial infarction. J Electrocardiol 2021;69:20–26.
40. Aşkın L, Aşkın HŞ. ST Segment Yükselmeli Miyokard Enfarktüsü Hastalarında Serum Prokalsitonin Düzeyleri ve Selvester QRS Skoru Arasındaki İlişki. MN Kardiyoloji 2018;25:52–59.
41. Han X, Chen Z, Wang Y, et al. Prognostic significance of QRS distortion and frontal QRS-T angle in patients with ST--elevation myocardial infarction. Int J Cardiol 2021;345:1–6.
42. Uzun F, Güner A, Demir AR, et al. Improvement of the frontal QRS-T angle after successful percutaneous coronary revascularization in patients with chronic total occlusion. Coron Artery Dis 2020;31:716–721.
43. Usalp S, Kemal H, Cerit L, Duygu H. Do sporting activities and using protein supplements change the frontal QRS-T angle? Minerva Cardiol Angiol 2021;69:244–250.
44. Hocanli I, Tanriverdi Z, Kabak M, et al. The relationship between frontal QRS-T angle and the severity of newly diagnosed chronic obstructive pulmonary disease. Int J Clin Pract 2021;75:e14500.
45. Medvedovsky AT, Pollak A, Shuvy M, Gotsman I. Prognostic significance of the frontal QRS-T angle in patients with AL cardiac amyloidosis. J Electrocardiol 2020;59:122–125.
46. Asarcikli LD, Hayiroglu Mİ, Osken A, et al. Frontal QRS-T angle may predict reverse dipping pattern in masked hypertensives. Clin Exp Hypertens 2022;44:2043892.
47. Tascanov MB, Tanriverdi Z, Gungoren F, et al. The effect of propofol on frontal QRS-T angle in patients undergoing

elective colonoscopy procedure. J Clin Pharm Ther 2020;45:185–190.

48. Tekin A, Tanrıverdi Z, Kapıcı Y, et al. Comparison of frontal QRS-T angle in patients with schizophrenia and healthy volunteers. J Psychiatr Res 2022;149:76–82.

49. Şahan E, Aydemir S. Evaluation of thrombolytic treatment effect on frontal plane QRS-T angle in patients with acute pulmonary embolism: A novel marker of successful thrombolysis. Herz 2021;46:187–190.

50. Başyiğit F, Balcı KG. Effect of implantable cardioverter defibrillator implantation on frontal QRS-T angle. Eur Rev Med Pharmacol Sci 2022;26:1839–1845.

51. Eyuboglu M, Celik A. Empagliflozin has favourable effect on frontal plane QRS-T angle in diabetic patients with cardiovascular disease. J Clin Pharm Ther 2022;47:1783–1788.