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ORIGINAL ARTICLE

ELECTROCARDIOGRAPHIC CHANGES AND CLINICAL IMPORTANCE OF THE FRONTAL QRS-T ANGLE IN OPEN-HEART SURGERY

Abstract

Introduction: The frontal QRS-T angle reflects the difference between ventricular depolarization and repolarization and is a marker of electrical remodeling. This study evaluates changes in the frontal QRS-T angle before and after open-heart surgery, especially in the geriatric population. It examines its association with left ventricular ejection fraction, cardiopulmonary bypass time, and aortic cross-clamp time.

Materials and Method: A retrospective analysis of 88 adult patients undergoing open-heart surgery was conducted. Preoperative and postoperative electrocardiographic data were compared, and frontal QRS-T angles were analyzed. Statistical analysis included paired t-tests and generalized linear modeling to identify factors influencing changes in the frontal QRS-T angle.

Results: After surgery, a significant increase in ventricular rate ($p<0.001$) was observed, accompanied by significant reductions in QRS duration ($p=0.024$) and QT interval ($p=0.011$). Higher preoperative left ventricular ejection fraction values were inversely associated with postoperative changes in the frontal QRS-T angle (odds ratio: 0.980; $p=0.017$).

Conclusion: Open-heart surgery leads to significant changes in ventricular conduction and repolarization, which are reflected in alterations in the frontal QRS-T angle. The preoperative frontal QRS-T angle emerged as a robust predictor of postoperative electrical remodeling dynamics. Higher preoperative left ventricular ejection fraction is associated with less pronounced postoperative changes in the frontal QRS-T angle, highlighting its importance in predicting postoperative electrical remodeling. Particularly in elderly patients, the frontal QRS-T angle may serve as a practical marker for perioperative risk stratification. The frontal QRS-T angle may be valuable for perioperative risk assessment, particularly in elderly patients. Further large-scale studies must validate these findings and explore the underlying mechanisms.

Keywords: Aged; Electrocardiography; Cardiopulmonary Bypass; Stroke Volume.

INTRODUCTION

The spatial QRS-T angle, which indicates myocardial repolarization, represents the vectorial difference between ventricular depolarization and repolarization. Accurate measurement of this parameter requires sophisticated computational software. However, the frontal QRS-T (FQRST) angle, which also reflects the vectorial concordance between ventricular depolarization and repolarization and is more commonly used in clinical practice, can be automatically calculated using modern electrocardiography devices and has been shown to strongly correlate with the spatial QRS-T angle (1,2). The FQRST angle is the absolute difference between the QRS and T wave axes and is recognized as a marker of disrupted ventricular electrical activity. Numerous studies have demonstrated that a widened FQRST angle is significantly associated with increased cardiovascular mortality, all-cause mortality, and risk of arrhythmia. For instance, an enlarged FQRST angle has been linked to atrial fibrillation, postoperative complications, and sudden cardiac death (3). Furthermore, its prognostic significance has been validated in patients undergoing myocardial revascularization or cardiac valve surgery (4-6).

Recently, there has been a growing focus on the potential of pharmacological and surgical interventions to improve the FQRST angle. For example, certain pharmacotherapeutic agents have been shown to narrow a widened FQRST angle, positively influencing cardiac repolarization and reducing the risk of sudden cardiac death. Moreover, the association between an abnormal FQRST angle and complications such as postoperative atrial fibrillation has been demonstrated, highlighting its importance for predicting clinical outcomes following surgery (1,5,7).

This study aimed to evaluate changes in the FQRST angle before and after open-heart surgery and to analyze its relationship with parameters such as left ventricular ejection fraction (LVEF), cardiopulmonary bypass (CPB) duration, and aortic X-clamp time. Due to the limited number of studies conducted on this subject, particularly in elderly patients, it also aimed to investigate the prognostic value of the FQRST angle for postoperative risk stratification and patient follow-up.

MATERIALS AND METHOD

Ethical Considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and the Good Clinical Practice guidelines. Approval was obtained from the local ethics committee (approval No. 2024/660). All patients provided written informed consent for the use of their clinical and surgical data. Additionally, the surgeons performing the procedures granted permission to include the surgical data they generated. These surgeons also waived their right to be acknowledged as coauthors of this article.

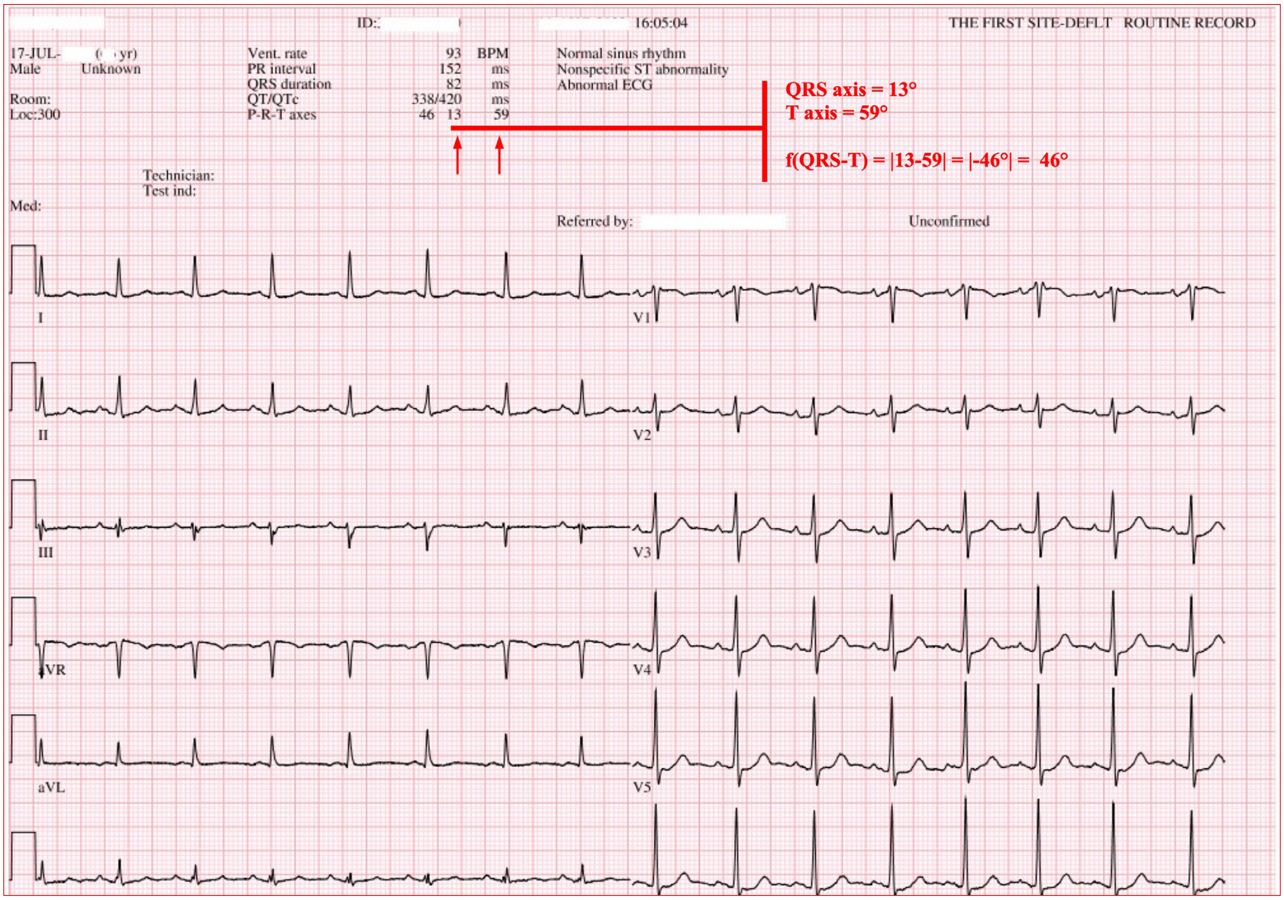
Population and Samples

A retrospective analysis of 600 patients undergoing open-heart surgery between March 2017 and March 2024 was performed. The electrocardiograms (ECGs) of 88 consecutive adult patients were analyzed. Specifically, preoperative ECGs were compared with ECGs obtained on the morning of postoperative day one. Patients with missing preoperative or postoperative ECGs and patients under the age of 18 years were excluded. Demographic, ECG, and echocardiographic data were collected from the patients' medical files and electronic databases.

ECG Measurements

The FQRST angle was calculated as the absolute difference between the QRS and T wave axes derived automatically from the ECG machine (Figure 1). The aim of using the QRS and T wave axes derived from the machine was to eliminate

Figure 1. Illustration of Frontal QRS-T Angle Calculation Method



measurement subjectivity. If the FQRST angle exceeded 180°, the value was subtracted from 360.

Statistical Analysis

Continuous variables were expressed as means and standard deviations, while categorical variables were expressed as frequencies and percentages. Preoperative and postoperative electrocardiographic indices, such as the QT interval, QTc interval, and FQRST angle, were compared using paired t-tests. To identify factors related to changes in the FQRST angle, a generalized linear model (GLM) was employed, in which the FQRST angle change was analyzed using a gamma distribution with a log-link function. Odds ratios with 95% confidence intervals (CIs) were calculated. Values of $p<0.05$ were considered statistically significant. All analyses were performed using IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA).

RESULTS

The demographic and clinical characteristics of the study cohort are summarized in Table 1. The mean age of the patients was 66.32± 9.11 years. Female patients accounted for 34.09% of the study population. The mean body mass index was 28.27±3.98 kg/m², corresponding to an average body surface area was 1.86. The mean LVEF was

51.01±8.78, indicating that most patients had preserved to mildly reduced cardiac function. These baseline characteristics reflected a population at moderate cardiovascular risk, typical of patients undergoing cardiac surgery.

The differences between preoperative and postoperative ECG parameters are detailed in Table 2. A statistically significant increase was observed in the postoperative ventricular rate (VR; mean difference: −16.28, 95% CI: −21.18 to −11.38; p<0.001). This elevation was likely due to heightened sympathetic activation or autonomic dysregulation during recovery. In contrast, reductions in QRS duration (mean difference: 3.011, 95% CI: 0.406 to 5.617; p=0.024) and the QT interval (mean difference: 14.489, 95% CI: 3.434 to 25.543; p = 0.011) were noted postoperatively, suggesting improved ventricular conduction and reduced repolarization heterogeneity.

The mean preoperative frontal QRS-T angle was 60.48± 50.61, while the postoperative value was 60.88 ± 49.89, showing no statistically significant difference (p=0.959). In the generalized linear model used to identify factors related to changes in the FQRST angle, the dependent variable, FQRST angle change, was modeled with a gamma distribution and a log-link function. The variables included in the analysis—based on their clinical relevance and the related literature—were the procedure at hospital admission, total CPB time, aortic X-clamp time, and preoperative LVEF. As

Table 1. Baseline Characteristics and Perioperative Metrics of the Study Cohort

Parameters	(n=88)
Age	66.32±9.11
Female, n (%)	30 (34.09%)
Body Mass Index, kg/m^2	28.27±3.98
Ischemic etiology	44 (50.00%)
Hypertension	54 (61.4%)
Diabetes mellitus	39 (44.3%)
Dyslipidemia	40 (45.5%)
Smoking	39 (44.3%)
Total Cardiopulmonary Bypass time (min)	109.89±31.02
Aortic X-clamp time (min)	76.38±25.08
Left Ventricle Ejection Fraction (%)	51.01±8.78

Table 2. Comparison of Pre- and Postoperative ECG Parameters in Open Heart Surgery

Parameters	Preoperative	Postoperative	P value
Frontal QRS-T angle (°)	60.48±50.61	60.88±49.89	0.959
Frontal QRS-T angle (°) (Age>65)	60.62±52.41	64.36±51.63	0.690
Ventricular rate (bpm)	75.59±15.59	91.88±15.71	**<0.001***
P wave axis (°)	41.99±40.13	42.71±47.53	0.915
R wave axis (°)	19.22±47.06	16.50±41.33	0.538
T wave axis (°)	48.57±77.13	52.15±75.18	0.762
PR interval, ms	166.14±35.57	164.19±48.07	0.715
QRS duration, ms	94.03±16.74	91.02±16.26	**0.024***
QT interval, ms	393.43±37.60	378.94±40.02	**0.011***
QTc interval, ms	422.33±59.87	415.44±77.80	0.440
Tp-e interval, ms	422.24±59.87	415.35±77.79	0.440
Tp-e/QT ratio	1.077±0.15	1.101±0.19	0.351
Tp-e/QTc ratio	0.999±0.00	0.999±0.00	0.285

shown in Table 3 and Figure 2, only the preoperative LVEF was found to be significantly associated with changes in the FQRST angle, showing an inverse relationship (odds ratio: 0.980, 95% CI: 0.964 to 0.996; p=0.017), thus suggesting that higher preoperative LVEF values were associated with less pronounced postoperative changes in the FQRST angle.

In a subgroup analysis of patients over 65 years old, the mean preoperative FQRST angle was 60.62±52.41, while the postoperative mean value was 64.36±51.63. The mean change in the FQRST angle was +3.73, indicating substantial interpatient variability in postoperative cardiac remodeling. The generalized linear model analysis for the ≥65 age subgroup demonstrated that preoperative FQRST angle was significantly associated with postoperative FQRST angle (β=0.2881, p=0.048). However, LVEF did not exhibit a statistically significant effect in this age group (β=0.0992, p=0.906). This suggests that factors other than LVEF may play a more significant role in postoperative electrical remodeling in elderly

Table 3. Analysis of Surgical and Cardiac Parameters Associated with the Frontal QRS-T Angle

	OR (95% CI)	p-value
Procedure (reference: CABG only)		
Valve Replacement alone	1.573 (0.866 – 2.859)	.137
Complex Procedure	0.762 (0.437 – 1.330)	.339
Total Cardiopulmonary bypass time	1.003 (0.995 – 1.011)	.490
Aortic X-clamp time	1.002 (0.990 – 1.014)	.718
Left Ventricle Ejection Fraction (%)	0.980 (0.964 – 0.996)	**.017***

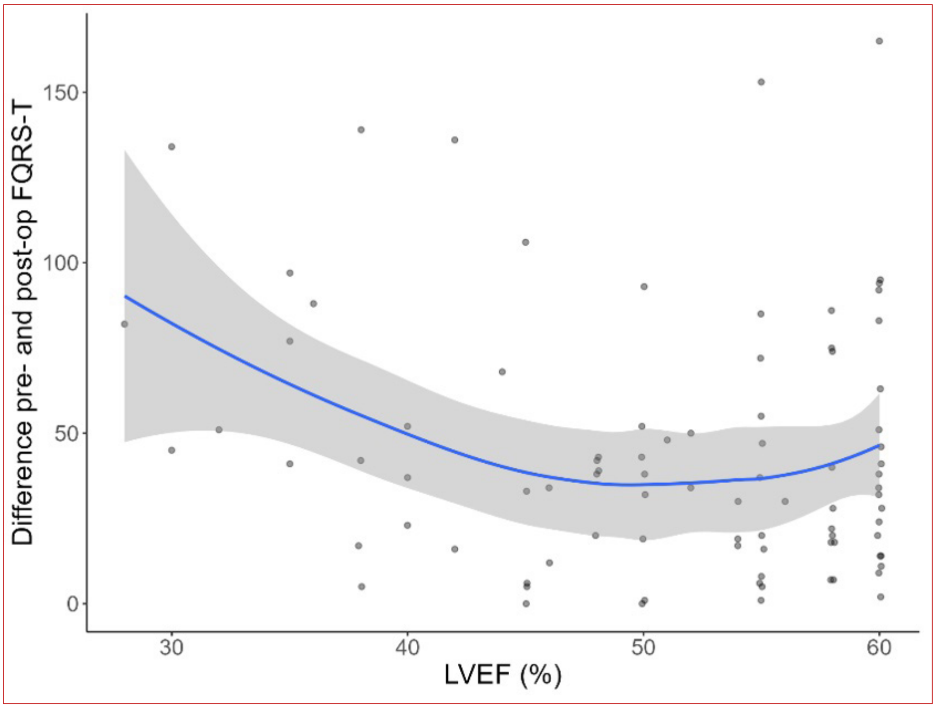


Figure 2. Relationship Between Left Ventricle Ejection Fraction (LVEF) (%) and Differences in Pre- and Postoperative Frontal QRS-T Angles

patients. The scatter plot in Figure 3 illustrates the relationship between LVEF and the difference in preoperative and postoperative FQRST angles, but it does not show a meaningful trend.

In subgroup analyses based on surgical procedures, patients undergoing complex procedures exhibited the highest mean preoperative FQRST angles (79.25±50.66), followed by those undergoing coronary artery bypass grafting (CABG) (58.46±49.79) and valve replacement (52.00±55.38). Postoperatively, complex procedures also demonstrated the highest FQRST angles (81.92±60.38), whereas CABG and valve replacement groups showed lower values (58.26±45.22 and 53.36±62.64, respectively). However, paired t-tests revealed no significant changes in FQRST angles between preoperative and postoperative measurements across all subgroups: CABG ($p=0.98$), valve replacement ($p=0.95$), and complex procedures ($p=0.87$) (Table 4). A GLM analysis demonstrated that the preoperative FQRST angle was a significant predictor of postoperative FQRST angle changes ($\beta=-0.6674$, $p<0.001$). This indicates that higher preoperative FQRST angles are associated with less pronounced postoperative changes. Importantly, the type of surgical procedure (CABG, valve replacement, or complex procedure) did not significantly influence

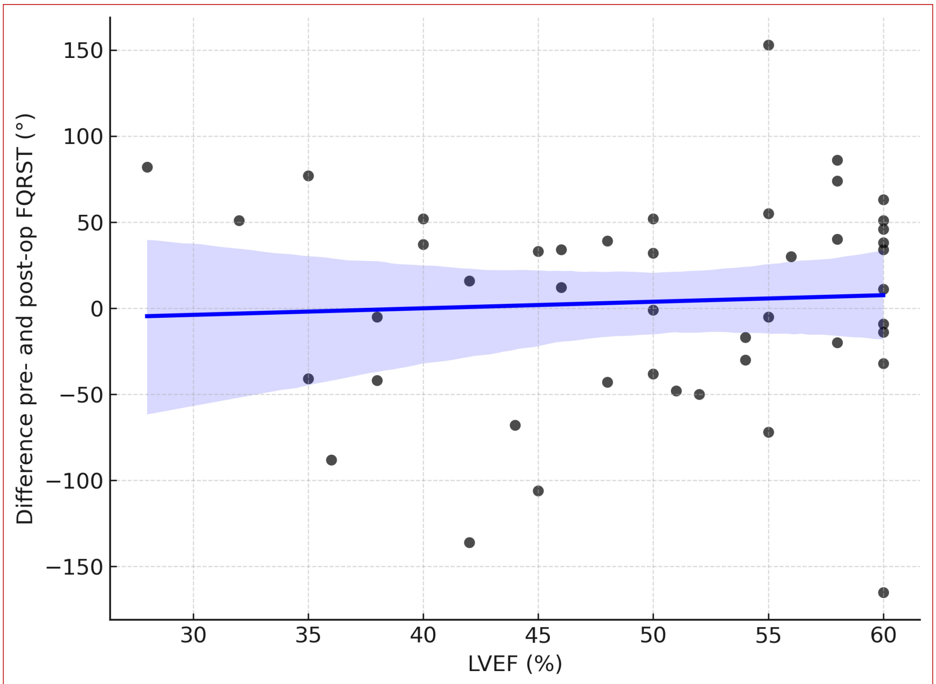
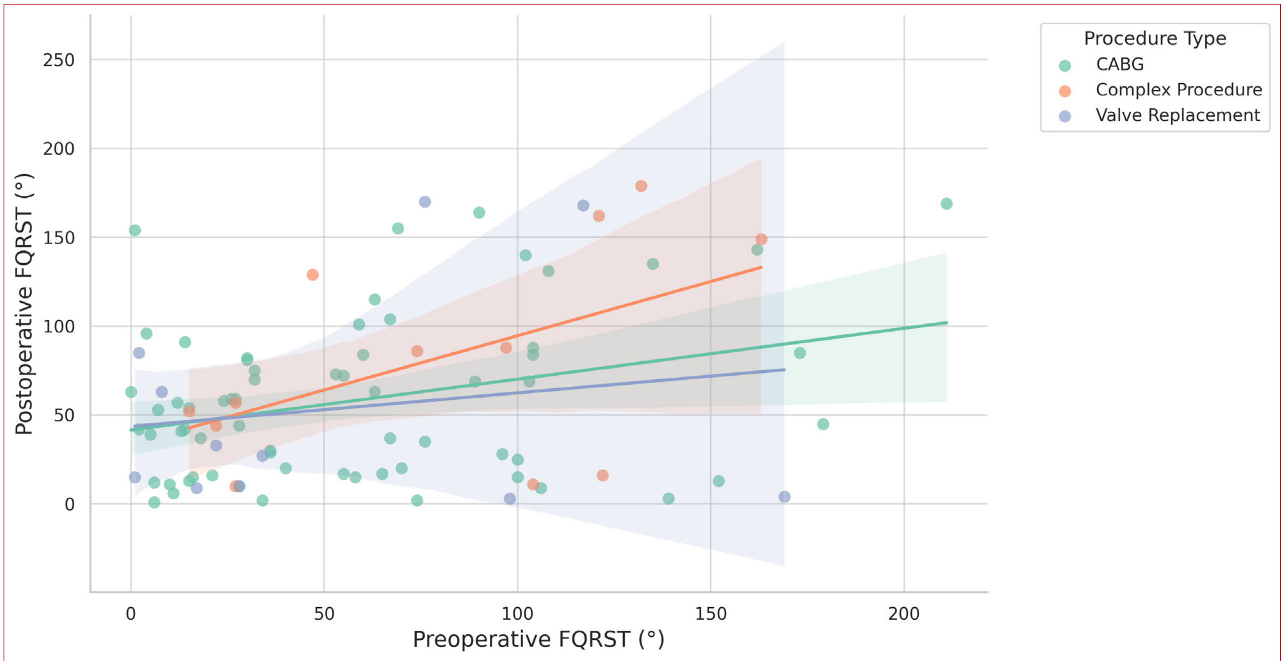


Figure 3. Relationship Between Left Ventricle Ejection Fraction (LVEF) (%) and Difference in Pre- and Postoperative Frontal QRS-T Angles (Age>65)

Table 4. Preoperative and postoperative Frontal QRS-T angles by procedure

Procedure	n	Preoperative	Postoperative	P value
CABG	65	58.46±49.79	58.26±45.22	0.98
Valve Replacement	11	52.00±55.38	53.36±62.64	0.95
Complex Procedure	12	79.25±50.66	81.92±60.38	0.87

Figure 4. Subgroup Analysis of the Frontal QRS-T Angles by Procedure (CABG: Coronary Artery Bypass Grafting)



this relationship (p=0.811), suggesting that preoperative electrical characteristics primarily drive postoperative remodeling. Figure 4 illustrates these findings, showing consistent trends across surgical subgroups, with a clear inverse relationship between preoperative FQRST angle and postoperative changes, irrespective of the procedure type. This emphasizes the potential role of preoperative electrical characteristics as dominant factors in predicting postoperative remodeling outcomes.

DISCUSSION

This study investigated the relationship between preoperative and postoperative ECG parameters and clinical outcomes in cardiac surgery patients. Our findings are consistent with previous studies showing that cardiac surgery leads to significant electrical remodeling, as evidenced by changes in ventricular conduction and repolarization processes (1,4,7). Specifically, the observed postoperative reductions in QRS duration and the QT interval suggest improved ventricular conduction and decreased repolarization heterogeneity. These findings provide valuable insights into how cardiac surgery may influence the electrical substrate and arrhythmic risk.

Aging is associated with structural and electrical remodeling of the heart, including myocardial fibrosis, conduction system disease, and increased arrhythmic vulnerability. Our findings indicate significant postoperative ventricular conduction and repolarization changes in geriatric patients following cardiac surgery. Age-related vascular changes, such as increased arterial stiffness, reduced nitric oxide bioavailability, and endothelial dysfunction, contribute to impaired myocardial perfusion and increased cardiovascular vulnerability. These changes are often compounded by comorbidities such as hypertension, diabetes, and chronic kidney disease, which are more prevalent in elderly populations. Consequently, postoperative cardiac outcomes in geriatric patients are significantly influenced by intrinsic myocardial changes and systemic vascular aging processes that compromise overall cardiovascular resilience (8).

In line with prior reports (1,7,9), the marked increase in the VR observed postoperatively reflects increased sympathetic activation and autonomic dysregulation during recovery. In older adults, this increase may indicate heightened postoperative sympathetic activation combined with age-related autonomic dysfunction. The reduced QRS duration and QT interval suggest improved myocardial conduction and repolarization, although age-related myocardial stiffness may modulate these effects. The observed QRS duration and QT interval changes are noteworthy, as they suggest a potential reduction in arrhythmic vulnerability. Similar findings have been reported in the context of other cardiac interventions, highlighting the dynamic nature of electrical remodeling (1,4,7).

The prognostic significance of the FQRST angle has been well documented (1,2,6). To the best of our knowledge, this study is one of the first to investigate the relationship between these factors and clinical outcomes in patients undergoing cardiac surgery, where the majority of the study population consists of geriatric individuals. A wide QRS-T angle has consistently been linked to adverse cardiovascular outcomes, including ventricular arrhythmia and sudden cardiac death (10). The inverse relationship between the preoperative LVEF and postoperative changes in the FQRST angle observed in this study highlights the protective role of preserved cardiac function against adverse electrical remodeling.

Subgroup analyses demonstrated that complex procedures had the highest preoperative and postoperative FQRST angles compared to CABG and valve replacement. Despite this, no significant pre-to-postoperative changes in FQRST angles were observed across subgroups, suggesting that procedural type alone does not independently drive substantial electrical remodeling. Generalized linear model analysis revealed that preoperative FQRST angle was a robust predictor of postoperative values, with higher preoperative angles associated with attenuated postoperative changes. Notably, the type of surgical intervention did not significantly influence this relationship, emphasizing the preeminence of intrinsic preoperative electrical characteristics in shaping postoperative remodeling. These findings highlight the prognostic utility of the FQRST angle in assessing perioperative electrical remodeling dynamics. Future investigations should focus on elucidating the mechanistic underpinnings of this relationship, particularly in complex procedures, to refine risk stratification and improve personalized cardiac care.

Although paired t-tests revealed no significant difference in mean preoperative and postoperative FQRST angles, the GLM analysis demonstrated a significant relationship between the preoperative FQRST angle and its postoperative changes. This discrepancy highlights the strength of GLM in identifying predictive relationships and variability at the individual level, which comparisons of groups may not capture means. The findings suggest that while the overall mean FQRST angle remained stable, individual factors, particularly preoperative electrical characteristics, played a significant role in determining postoperative electrical remodeling.

In a subgroup analysis of patients aged ≥65 years, we observed that preoperative FQRST angle remained a significant predictor of postoperative changes in FQRST angle. However, LVEF did not exhibit a statistically significant association with FQRST angle changes. As shown in Figure 3, there was no meaningful relationship between LVEF and the degree of electrical remodeling, suggesting that other factors may play a more prominent role in geriatric patients. This association appears to be particularly relevant to geriatric patients, in whom age-related structural and functional changes may amplify the clinical implications of electrical remodeling. A previous study on primary percutaneous coronary interventions has also identified the FQRST angle as a strong predictor of mortality (11).

Although the Tp-e/QT and Tp-e/QTc ratios have been proposed as electrocardiographic markers of ventricular repolarization heterogeneity and arrhythmic risk (12), no significant differences were observed in these parameters before and after surgery in our study. This may be attributed to the differing etiologies and mechanisms of arrhythmogenesis in surgical and trauma populations.

The observed postoperative improvements in ventricular conduction are likely related to enhanced myocardial function following surgical intervention. Similar findings have been reported in populations undergoing myocardial revascularization or valve surgery, with the postoperative changes in the FQRST angle linked to reduced arrhythmic vulnerability (4). Both these findings and our results underscore the prognostic value of the FQRST angle and its potential to be used for perioperative risk stratification. The significant association between the preoperative LVEF and changes in the FQRST angle highlights the importance of baseline cardiac function as a determinant of postoperative electrical remodeling. However, the subgroup analysis of patients aged ≥65 years revealed that LVEF may not independently predict postoperative electrical remodeling in this age group. This finding suggests that other age-related structural or functional changes might be more significant in modulating postoperative electrical remodeling. Geriatric patients with impaired baseline cardiac function may require closer perioperative monitoring and targeted interventions to mitigate arrhythmic complications during recovery. The potential of dynamic ECG changes, such as alterations in the FQRST angle, to be used as biomarkers for predicting arrhythmic risk and cardiac dysfunction warrants further investigation in comprehensive studies (1,4,6).

This study has certain limitations that should be acknowledged. Its retrospective and single-center design inherently limits the generalizability of the findings. Moreover, although sufficient for early postoperative analyses, the relatively small sample size may not provide adequate statistical power to detect more nuanced associations or subgroup differences. Additionally, the absence of mid- and long-term follow-up data restricted the ability to evaluate the prognostic value of observed ECG changes, such as FQRST angle alterations, to arrhythmic events and clinical outcomes. Furthermore, the study population primarily consisted of patients with preserved or mildly reduced left ventricular ejection fraction (LVEF). This may have influenced the extent and generalizability of the observed electrical remodeling. Furthermore, this study did not evaluate key cardiovascular parameters such as left ventricular end-diastolic volume or left atrial diameter, which are known to influence electrical remodeling due to data limitations. The potential role of these parameters warrants further investigation in future studies.

Future studies should address these limitations by including larger and more diverse patient populations, focusing on geriatric subgroups. Incorporating advanced imaging techniques, biomarker analyses, and additional clinical variables would enable a deeper understanding of postoperative electrical remodeling mechanisms. Additionally, future research should explore the impact of different surgical procedures on long-term outcomes, such as mortality and arrhythmic events, to further delineate the role of electrical remodeling in perioperative risk stratification. Longitudinal studies with extended follow-up periods are essential to elucidate the interaction between structural and electrical remodeling and its long-term clinical implications, particularly in high-risk surgical populations.

CONCLUSION

This study highlights the dynamic nature of early postoperative electrical remodeling following cardiac surgery, with changes in the FQRST angle reflecting significant alterations in ventricular conduction and repolarization. Preoperative LVEF was identified as a key predictor of these changes; however, in elderly patients, additional age-related structural and functional factors may influence the remodeling process, emphasizing its multifactorial complexity. The findings underscore the value of the FQRST angle as a biomarker for perioperative risk stratification and the need for further validation in larger cohorts with long-term follow-up to better understand its prognostic implications.

Ethics approval and consent to participate: The study was approved by the Local Ethical Committee. The ethics approval date and number is 17.12.2024-2024/660.

Consent for publication: The author has read and approved the final version of the manuscript .

Availability of data and materials: The data and materials are available upon reasonable request.

Conflict of Interest: The authors declare that they have no competing interests.

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Authors' Contributions: AO is the first and corresponding author.
AO: All stages, including conceptualization, investigation, literature search, analysis, interpretation, writing, editing, final draft review, and critical review, were carried out by the author.

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REFERENCES

1. Macfarlane PW. The frontal plane QRS-T angle. Europace. 2012;14(6):773-5. doi: 10.1093/europace/eus057
2. Askin L, Tanriverdi O, Poyraz F. Cardiovascular diseases and frontal QRS-T angle. Cor Vasa. 2023;65:749-56. doi: 10.33678/cor.2023.030
3. 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(8):e0136174. doi: 10.1371/journal.pone.0136174
4. Lazzeroni D, Bini M, Camaiora U, et al. Prognostic value of frontal QRS-T angle in patients undergoing myocardial revascularization or cardiac valve surgery. J Electrocardiol. 2018;51(6):967-72. doi: 10.1016/j.jelectrocard.2018.08.028
5. Kuyumcu MS, Uysal D, Özbay MB, Aydın O, İbrişim E. Frontal plane QRS-T angle may be a predictor for post-coronary artery bypass graft surgery atrial fibrillation. Rev Assoc Med Bras (1992). 2020;66:1673-8. doi: 10.1590/1806-9282.66.12.1673
6. Sakhnova TA, Blinova EV, Dotsenko YuV, Uskach TM, Drozdov DV. Detection of left ventricular systolic dysfunction in patients with ischemic heart disease using spatial and frontal QRS-T angles of the electrocardiogram. Terapevticheskii Arkhiv (Ter. Arkh.). 2024;96(4):337–41. doi: 10.26442/00403660.2024.04.202695
7. Durak H, Çetin M, Ergül E, et al. Relationship Between Frontal QRS-T Angle and Ascending Aortic Dilatation: A Cross Sectional Study. Turkiye Klinikleri J Cardiovasc Sci. 2024;36(1):11-20. doi: 10.5336/cardiosci.2024-102540
8. Koc M, Kutsal A. Vascular aging. Turk J Geriatr. 2015;18(2):156-61.
9. Bernard F, Denault A, Babin D, et al. Diastolic dysfunction is predictive of difficult weaning from cardiopulmonary bypass. Anesth Analg. 2001;92(2):291-8. doi: 10.1097/00000539-200102000-00002
10. 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(6):872-6. doi: 10.1093/europace/eur393
11. Colluoglu T, Tanriverdi Z, Unal B, Ozcan EE, Dursun H, Kaya D. The role of baseline and post-procedural frontal plane QRS-T angles for cardiac risk assessment in patients with acute STEMI. Ann Noninvasive Electrocardiol. 2018;23:e12558. doi: 10.1111/anec.12558
12. Gupta P, Patel C, Patel H, et al. T(p-e)/QT ratio as an index of arrhythmogenesis. J Electrocardiol. 2008;41:567-74. doi: 10.1016/j.jelectrocard.2008.07.016