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Evaluation of Tp-e / QT Ratio as a Predictor of Hospital Course in Patients with Decompensated Heart Failure

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Abstract

Background: Heart failure [HF] is a clinical syndrome characterized by breathlessness, fatigue, ankle swelling, and signs such as peripheral edema, pulmonary crackles, and elevated jugular venous pressure.

The aim of the work: This work aimed to assess the utility of the Tp-e/QT ratio as a prognostic marker for the clinical course of cases hospitalized with decompensated HF.

Patients and Methods: This prospective observational research included 100 patients diagnosed with HF with diminished ejection fraction [EF], defined as a left ventricular EF below 40%.

Results: Tp-e intervals, Tp-e/QTc and Tp-e/QT ratios were significantly elevated in cases who developed arrhythmias. These electrocardiographic parameters were also significantly elevated in cases whose hospital stay exceeded one week.

Conclusion: Non-survivors exhibited elevated rates of valvular heart disease, diminished EF, elevated LDL titres, and elevated QTc, QT interval, Tp-e, and Tp-e/QT ratios. Careful monitoring of these parameters, particularly ECG markers [Tp-e/QT] and hemodynamic status, could be vital for effective risk stratification and optimizing treatment strategies in cases with HF.

Keywords: Tp-e / QT Ratio;' Hospital Course; Decompensated; Heart Failure.

INTRODUCTION

Heart failure [HF] is a clinical syndrome characterized by structural or functional cardiac dysfunction, resulting in diminished cardiac output and elevated intracardiac pressures, and commonly presenting with dyspnea, fatigue, ankle swelling, peripheral edema, pulmonary crackles, and elevated jugular venous pressure [1].

The clinical presentation of HF cases is varied, with many symptoms being non-specific. Typical features of congestive HF [CHF] include exercise intolerance, dyspnea, fatigue, and ankle swelling, along with manifestations related to the underlying disease process. Nevertheless, diagnosing HF based solely on these clinical signs and symptoms frequently falls short, particularly in elderly, female, or obese populations [2].

Myocardial damage from multiple origins underlies HF development, commonly including hypertension, ischemic heart disease, and diabetes mellitus. Less frequent causes comprise valvular disorders, myocarditis, cardiomyopathies, infections, systemic toxic exposures, and cardiotoxic medications [3].

HF is categorized into three types: diminished [HFrEF], preserved [HFpEF], and mildly diminished [HFmrEF] ejection fraction. In a healthy heart, the left ventricular ejection fraction [LVEF] measures the proportion of blood ejected from the left ventricle with each contraction and ranges from 52% to 72% in men and 54% to 74% in women. An LVEF of 40% or below is considered indicative of HFrEF. In the United States, approximately 50% of HF cases are attributed to cases with HFrEF [4].

The elevated in hospital admissions for decompensated HF [DHF] has paralleled the growing prevalence of chronic HF [CHF]. Beyond the direct costs of hospitalization, the substantial morbidity and mortality in DHF contribute significantly to the financial challenges faced by healthcare systems [5].

Depolarization of the ventricular myocardium initiates from the endocardial surface and progresses toward the epicardium, followed by ventricular repolarization. During repolarization, a temporal dispersion exists between the endocardial and epicardial layers. The Tp-e interval, defined as the time from the peak to the end of the T wave, reflects transmural ventricular repolarization [6].

Both the Tp-e interval and its ratio to the QT interval have been linked to arrhythmic conditions across various cardiac pathologies and are recognized as markers indicating elevated risk for sudden cardiac death [7].

The twelve-lead electro-cardiogram [ECG] is a fundamental diagnostic tool routinely employed in clinical practice and is recommended for all cases suspected of having HF.

In cases of acute HF [AHF], the ECG primarily serves to identify underlying causes like acute myocardial infarction or tachyarrhythmia and bradyarrhythmias. A completely normal ECG makes the presence of HF, particularly with systolic dysfunction, unlikely [8].

This research aimed to evaluate the prognostic significance of the Tp-e/QT ratio in predicting the clinical course of cases hospitalized with DHF.

PATIENTS AND METHODS

Research Design and Patients:

This prospective observational research was carried out on 100 cases of HFrEF defined as LVEF < 40%. This research was carried out over three months at the Cardiology Departments of Al-Azhar University Hospitals and Ahmed Maher Teaching Hospital in Egypt.

Inclusion criteria:

Eligible participants were adults over 18 years old diagnosed with HFrEF, defined by a LVEF of 40% or less.

Exclusion criteria included cases that refused to provide informed consent, those with HFpEF, severe pulmonary hypertension, atrial fibrillation, or if their ECGs were of insufficient quality for interpretation. Other exclusion criteria encompassed the presence of pacemakers, bundle branch block, conditions associated with QT interval prolongation like electrolyte abnormalities, intake of QT-prolonging drugs, recent myocardial infarction, QRS duration longer than 120 milliseconds, and severe chronic kidney disease [creatinine clearance ≤ 30 ml/min/1.73 m²].

All enrolled participants underwent a thorough and systematic evaluation, beginning with a detailed medical history that encompassed demographic information, overall health status, the presence of comorbidities, and risk factors for coronary artery disease [CAD].

Additionally, symptoms suggestive of cardiac conditions were carefully documented, along with an assessment of the patient's physical activity titres and capacity for daily living.

A comprehensive clinical examination followed, which included vital signs like blood pressure, heart rate [HR], oxygen saturation [SpO_2], respiratory rate, and body temperature. The general physical examination covered key observations, including overall appearance, JVP, presence of peripheral edema, cyanosis, clubbing of the fingers, cachexia, and ascites.

A focused cardiac examination was also performed. Diagnostic investigations included a resting 12-lead ECG and a series of baseline laboratory tests like complete blood count, lipid profile [including triglycerides and low-density lipoprotein], renal function tests, glycated hemoglobin [HbA1c] for glycemic control, and electrolytes including sodium, potassium, magnesium, and calcium. Finally, all subjects underwent echocardiographic evaluation to assess cardiac structure and function.

Resting 12-lead ECG:

Upon admission, all patients underwent a standard 12-lead ECGs, which included the limb leads [I, II, III, aVR, aVL, aVF] and the precordial leads [V1 through V6]. ECG tracings were recorded at a standardized paper speed of 25 mm/sec and a calibration of 1 mV per 10 mm, with measurements taken during periods of sinus rhythm.

The Tp-e interval was defined as the duration from the peak of the T wave to its return to the isoelectric baseline. Lead V5 was primarily used for this measurement; however, if the T wave amplitude in V5 was less than 1.5 mm, leads V4 and V6 were used alternatively, and the mean value from these leads was considered representative.

The QT interval was estimated from the beginning of the QRS complex to the end of the T wave. To correct for HR variability, the QT interval was adjusted using Bazett's formula [QTc=QT ÷ √RR interval].

Similarly, the Tp-e interval was also corrected for HR using the same approach, yielding the corrected Tp-e interval [Tp-e-c] [9].

In healthy adults, the upper normal limits for the Tp-e interval and its HR-corrected counterpart [Tp-e-c] are set at 90 milliseconds and 100 milliseconds, respectively. These benchmark values hold clinical importance because prolonged Tp-e intervals have been associated with a heightened risk of arrhythmias in everyday clinical settings [10].

To ensure standardization, all ECG measurements were performed using digital calipers on high-resolution screen images, with magnification to enhance accuracy. Measurements were taken from the same cardiac cycle and lead whenever possible to ensure consistency.

All ECGs were interpreted independently by two trained cardiologists who were blinded to the patients' clinical data and outcomes.

To assess inter-observer reliability, a random sample of 30 ECGs was selected and analyzed by both observers. The inter-observer agreement was excellent, with an intraclass correlation coefficient [ICC] of 0.91 for Tp-e interval and 0.93 for QT interval measurements.

Echocardiography:

TTE in parasternal long axis view & apical view as regards ejection fraction, resting wall motions & global function. Echocardiography provides essential insights into ventricular remodeling, functional recovery, LV volumes and dimensions, regional wall motion abnormalities, and potential complications arising from CAD. Ejection fraction [EF] was calculated using either M-mode or the modified Simpson's method, based on the formula:

$EF = \left(\frac{EDV-ESV}{EDV}\right) \times 100$, where EDV represents the end-diastolic volume and ESV denotes the end-systolic volume.

Ethical approval:

The entire research protocol underwent a thorough review and subsequently received formal approval from the local ethics committee affiliated with the Faculty of Medicine at Al-Azhar University. This ethical endorsement ensured that the research adhered to established standards for the protection of human subjects. Before their inclusion in the research, every participant was given a detailed and comprehensive explanation regarding the objectives, scope, and specific methodologies of the research.

Statistical analysis:

The data were carefully analyzed using the SPSS software package [version 22.0, IBM/SPSS Inc., Chicago, IL], a widely accepted tool for statistical evaluation. Quantitative variables were described using measures like mean values along with their standard deviations [± SD] to reflect data spread. Qualitative variables were summarized through frequency counts and percentages to illustrate their distribution across the sample. To examine the relationships between categorical variables, the Chi-Square test was applied to determine if any statistically significant associations existed. Additionally, correlation analysis was conducted to assess the strength and direction of the relationship between continuous variables. All statistical tests were two-tailed, with a significance threshold set at $p < 0.05$, indicating a standard level of confidence in the results.

RESULTS

Survivors and non-survivors were comparable in terms of age, sex, BMI, and the prevalence of smoking, HTN, DM, CKD, dyslipidemia, history of HF hospitalization, and clinical presentations including dyspnea, orthopnea, dizziness, fatigue, and PND. The prevalence of IHD was significantly elevated in survivors. Conversely, non-survivors had a significantly greater prevalence of valvular heart disease [VHD], NYHA class IV, and peripheral swelling, with swelling-related clinical features also more frequent in this group (**Table 1).**

Non-survivors exhibited significantly diminished systolic and diastolic blood pressures, accompanied by a markedly elevated heart rate as opposed to survivors. Most laboratory parameters were similar between the groups, except low-density lipoprotein [LDL], which was significantly elevated in non-survivors. Additionally, the table shows that non-survivors had elevated considerably QT interval, QTc, Tp-e interval, and the Tp-e/QT and Tp-e/QTc ratios (**Table 2).**

Echocardiographic findings were broadly comparable between survivors and non-survivors, except for ejection fraction, which was significantly diminished, and the E/A ratio, which was significantly elevated in non-survivors. The administration of vasopressors and inotropes was substantially more frequent among non-survivors. Conversely, survivors demonstrated significantly greater use of loop diuretics, ACEIs, MRAs, and SGL2Is. Severe tricuspid regurgitation and severe mitral regurgitation were substantially more prevalent in non-survivors, whereas other valvular lesions were comparable in type or severity between the groups (**Table 3).**

Pneumonia was significantly more prevalent among non-survivors as opposed to survivors. The prevalence of cardiomegaly, lung congestion, and pleural effusion was comparable between groups. Incidence of AF and VT was significantly elevated in non-survivors. Moreover, arrhythmic events on ECG follow-up, ICU admission, need for MV, and hospital stays longer than one week were all significantly elevated in non-survivors (**Table 4).**

Tp-e, Tp-e/QT ratio, and Tp-e/QTc ratio were significantly elevated in cases presenting with arrhythmia. These parameters were also markedly elevated in cases with prolonged hospital stay exceeding one week (**Table 5).**

Duration of stay, EF, QTC, Tp-e/QTC ratio, and ventilation were independent predictors for mortality [P value <0.05], while admission, DBP, SBP, E/A ratio, HR, LDL, NHYA class, QT interval, Tp-e/QT ratio, and Tp-e were not (**Table 6).**

Table [1]: Comparison of the demographic data, clinical history, and clinical presentation according to survival.

Variables		Survivors [n= 75]	Non-survivors [n= 25]	P value
Age [Years]		59.16 ± 8.10	60.28 ± 6.49	0.532
Sex	Males	48 [64%]	16 [64%]	1
	Females	27 [36%]	9 [36%]	
BMI [Kg/m²]		29.61 ± 3.94	28.61 ± 3.99	0.279
Clinical history				
Smoking		44 [58.7%]	13 [52%]	0.560
Hypertension		47 [62.7%]	17 [68%]	0.630
DM		38 [50.7%]	13 [52%]	0.908
CKD		25 [33.3%]	6 [24%]	0.382
Dyslipidemia		33 [44%]	11 [44%]	1
History of hospitalization due to heart failure		45 [60%]	15 [60%]	1
IHD		65 [86.7%]	17 [68%]	0.035*
Valvular heart disease		5 [6.7%]	6 [24%]	0.016*
Dilated cardiomyopathy		5 [6.7%]	2 [8%]	0.821
Clinical presentation				
NYHA classification	NYHA class 3	47 [62.7%]	9[36%]	0.020*
	NYHA class 4	28 [37.3%]	16[64%]	
Dyspnea		75 [100%]	25 [100%]	1
Orthopnea		51 [68%]	20 [80%]	0.252
Dizziness		31 [41.3%]	13 [52%]	0.352
Swelling		43 [57.3%]	21 [84%]	0.016*
Fatigue		48 [64%]	16 [64%]	1
PND		56 [74.7%]	21 [84%]	0.337

BMI body mass index. NYHA New York Heart Association, PND paroxysmal nocturnal dyspnea *: statistically significant [p< 0.05]

Table [2]: Comparison of the vital signs and laboratory findings according to survival

Variables		Survivors [n= 75]	Non-survivors [n= 25]	P value
SBP [mmHg]		123.13 ± 20.92	94.60 ± 12.82	< 0.001*
DBP [mmHg]		74.07 ± 11.62	60 ± 6.45	< 0.001*
HR [B/min]		87.76 ± 17.37	102.76 ± 14.76	< 0.001*
Spo2 [%]		92.22 ± 10.10	91.68 ± 4.95	0.797
Laboratory findings				
HGB [gm/dl]		11.91 ± 1.49	11.98 ± 1.39	0.841
Platelets [x10³/ul]		246.13 ± 86.23	237.84 ± 70.25	0.665
WBCs [x10³/ul]		9.66 ± 7.88	11.72 ± 6.21	0.239
Creatinine [mg/dl]		0.96 ± 0.34	1.04 ± 0.37	0.289
Urea [mg/dl]		23.83 ± 12.47	29.56 ± 26	0.143
Uric acid [mg/dl]		10.32 ± 3.62	11.28 ± 3.93	0.263
Na [mmol/L]		135.33 ± 14.89	132.07 ± 25.19	0.434
K [mmol/L]		4.37 ± 0.70	4.44 ± 0.64	0.670
ALT [U/L]		50.90 ± 124.27	55.16 ± 67.75	0.871
AST [U/L]		55.2 ± 120.16	57.08 ± 63.74	0.941
GFR [ml/min/1.73 m²]		71.55 ± 18.63	81.48 ± 31.07	0.057
Cholesterol [mg/dl]		203.56 ± 22.49	207.68 ± 35.65	0.500
LDL [mg/dl]		152.17 ± 22.87	165.45 ± 22.13	0.013*
HDL [mg/dl]		43.99 ± 9	41.97 ± 8.20	0.324
TGs [mg/dl]		198.21 ± 57.54	206.68 ± 79.35	0.565
HBA1c		6.69 ± 1.27	6.81 ± 1.36	0.678
Mg [mg/dl]		1.98 ± 0.19	2.01 ± 0.19	0.454
Ca [mg/dl]		9.41 ± 0.84	9.71 ± 0.91	0.129
ECG findings				
Rhythm	Sinus	64 [85.3%]	14 [56%]	0.002*
	Sinus+ PVCs	11 [14.7%]	11 [44%]	
P wave duration[ms]		95.79 ± 16.04	98.36 ± 15.11	0.483
PR interval[ms]		150.63 ± 31.29	157.52 ± 41.99	0.385
QRS duration[ms]		97.68 ± 16.10	100.84 ± 16.47	0.400
QT interval[ms]		379.81 ± 37.46	404.8 ± 16.73	0.002*
QTC[ms]		461.31 ± 50.56	526.04 ± 32.85	< 0.001*
Tpe[ms]		89.41 ± 17.34	117.96 ± 8.92	< 0.001*
Tp-e / QT ratio		0.24 ± 0.04	0.29 ± 0.02	< 0.001*
Tp-e / QTc ratio		0.19 ± 0.04	0.23 ± 0.05	< 0.001*

DPB diastolic blood pressure, HR heart rate, SPB systolic blood pressure, Spo2 oxygen saturation. *: statistically significant [p< 0.05], ALT alanine transaminase, AST aspartate aminotransferase, Ca calcium, GFR glomerular filtration rate, HBA1c hemoglobin A1c, HGB hemoglobin, HDL high density lipoprotein, K potassium, LDL low density lipoprotein, Mg magenesium, Na sodium, TGs triglycerides, WBCs white blood cells. PVCs premature ventricular contractions, Tp-e Twave peak to end of the Twave.

Table [3]: Comparison of the echocardiographic findings, drug treatment, and valve affection according to survival

Variables		Survivors [n= 75]	Non-survivors [n= 25]	P value
EF %		33.29 ± 4.69	27.36 ± 4.29	< 0.001*
LAD [mm]		40.39 ± 6.86	43.33 ± 8.33	0.082
EDD [mm]		59.96 ± 7.63	59.30 ± 8.16	0.715
ESD [mm]		48 ± 9.08	49.57 ± 9.38	0.459
EDV [ml]		179.65 ± 54.61	175.66 ± 56.88	0.755
ESV [ml]		120.64 ± 41.08	129.03 ± 47.74	0.398
E/A ratio		1.67 ± 1.13	2.32 ± 1.49	0.024*
TAPSE [mm]		16.36 ± 3.39	15.98 ± 3.26	0.629
Drug treatment				
Antiplatelets		67 [89.3%]	24 [96%]	0.313
Statins		65 [86.7%]	25 [100%]	0.054
Loop diuretics		74 [98.7%]	21 [84%]	0.004*
Vasopressors/inotropes		13 [17.3%]	24 [96%]	< 0.001*
Beta blockers		44 [58.7%]	10 [40%]	0.105
ACEIs		48 [64%]	6 [24%]	0.001*
MRA		61 [81.3%]	11 [44%]	< 0.001*
SGL2I		59 [78.7%]	2 [8%]	< 0.001*
Amiodarone		26 [34.7%]	9 [36%]	0.904
Digoxin		14 [18.7%]	5 [20%]	0.883
Anticoagulant		64 [85.3%]	24 [96%]	0.155
Valve affection				
Aortic stenosis	No	74 [98.7%]	24 [96%]	0.409
	Mild stenosis	1 [1.3%]	1 [4%]	0.409
Mitral stenosis	No mitral stenosis	73 [97.3%]	24 [96%]	0.584
	Mild stenosis	1 [1.3%]	0 [0%]	0.562
	Moderate stenosis	1 [1.3%]	0 [0%]	0.562
	Severe stenosis	0 [0%]	1 [4%]	0.082
Aortic regurge	No aortic regurge	63[85.1%]	23 [92%]	0.178
	Mild regurge	6 [8.1%]	2 [8%]	0.902
	Moderate regurge	3 [4.1%]	0 [0%]	0.310
	Severe regurge	2 [2.7%]	0 [0%]	0.440
Tricuspid regurge	No tricuspid regurge	16 [21.3%]	1 [4%]	0.064
	Mild regurge	25 [33.3%]	7 [28%]	0.260
	Moderate regurge	18 [24%]	7 [28%]	0.305
	Severe regurge	16 [21.3%]	10 [40%]	0.039*
Mitral regurge	No mitral regurge	5 [6.7%]	2 [8%]	0.558
	Mild regurge	37 [49.3%]	8 [32%]	0.046*
	Moderate regurge	21 [28%]	6 [24%]	0.304
	Severe regurge	12 [16%]	9 [36%]	0.033*

*: statistically significant [p< 0.05], EDD end diastolic diameter, ESD end systolic diameter, EDV end diastolic volume, ESV end systolic volume, E/A ratio E wave velocity of mitral inflow/ A wave velocity of mitral inflow, EF ejection fraction, TAPSE tricuspid annular plane systolic excursion. ACEI angiotensin converting enzyme inhibitors, MRA mineralocorticoid antagonist, SGL2I sodium glucose cotransporter-2 inhibitor.

Table [4]: Comparison of the radiological findings, ECG findings at follow up and the follow up and outcomes according to the survival

Variables		Survivors [n= 75]	Non-survivors [n= 25]	P value
Cardiomegaly		52 [69.3%]	13 [52%]	0.116
Pneumonia		13 [17.3%]	17 [68%]	< 0.001*
Lung congestion		18 [24%]	7 [28%]	0.689
Pleural effusion		55 [73.3%]	18 [72%]	0.897
ECG findings at follow up				
Atrial fibrillation		20 [26.7%]	11 [44%]	0.037*
Non-sustained VT		3 [4%]	0 [0%]	0.310
Sinus rhythm		32 [42.7%]	1 [4%]	< 0.001*
Sinus rhythm + PVCs		19 [25.3%]	6 [24%]	0.550
Ventricular fibrillation		0 [0%]	1 [4%]	0.302
Ventricular tachycardia		1 [1.3%]	6 [24%]	0.026*
Follow-up and outcomes				
Malignant arrhythmic event on ECG follow up		44 [58.7%]	24 [96%]	0.001*
Admission	Ward	22 [29.3%]	1 [4%]	0.009*
	ICU	53 [70.7%]	24 [96%]	
Need for MV		10 [13.3%]	23 [92%]	< 0.001*
Duration of hospital stay	≤ 1 week	40 [53.3%]	3 [12%]	< 0.001*
	> 1 week	35 [46.7%]	22 [88%]	

*: statistically significant [p< 0.05], PVCs premature ventricular contractions, VT ventricular tachycardia.

Table [5]: Comparison of Tp-e, Tp-e / QT ratio and Tp-e / QTc ratio according to arrhythmic events and according to length of hospital stay

Variables	Absent [n= 32]	Present [n= 68]	P value
Tp-e[ms]	81.31 ± 14.44	103.72 ± 18.14	< 0.001*
Tp-e / QT ratio	0.21 ± 0.03	0.27 ± 0.04	< 0.001*
Tp-e / QTc ratio	0.18 ± 0.03	0.21 ± 0.03	< 0.001*
Length of hospital stay	≤ 1 week [n= 43]	> 1 week [n= 57]	P value
Tp-e[ms]	85.67 ± 15.48	104.75 ± 19.11	< 0.001*
Tp-e / QT ratio	0.22 ± 0.04	0.27 ± 0.04	< 0.001*
Tp-e / QTc ratio	0.19 ± 0.03	0.23 ± 0.04	< 0.001*

*: statistically significant [p< 0.05], Twave peak to Twave end.

Table [6]: Multivariate regression for prediction of mortality

Independent variables	Coefficient	Std. Error	P value
Admission	0.02080	0.05904	0.725
DBP	0.001731	0.004794	0.719
SBP	-0.004660	0.002692	0.087
Duration of stay	-0.03650	0.009010	<0.001*
E/A ratio	-0.009092	0.02151	0.673
EF	-0.01733	0.005556	0.002*
HR	0.001855	0.002332	0.428
LDL	0.001239	0.001075	0.252
NYHA class	-0.05108	0.05132	0.322
QT interval	0.002493	0.003360	0.460
QTC	-0.006913	0.003266	0.037*
TP-e/QT ratio	4.1845	4.8618	0.391
TP-e/QTC ratio	-17.9995	7.5817	0.019*
TP-e	0.03383	0.01835	0.068
Ventilation	0.3302	0.06930	<0.001*

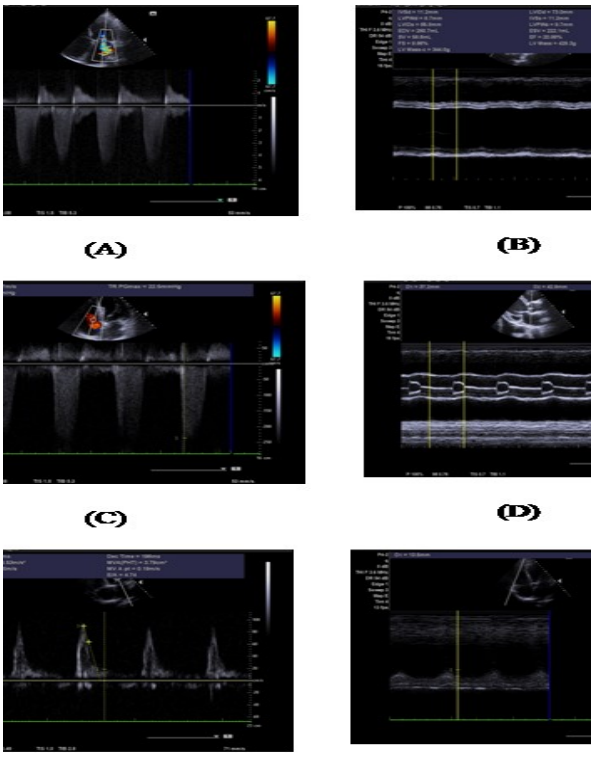
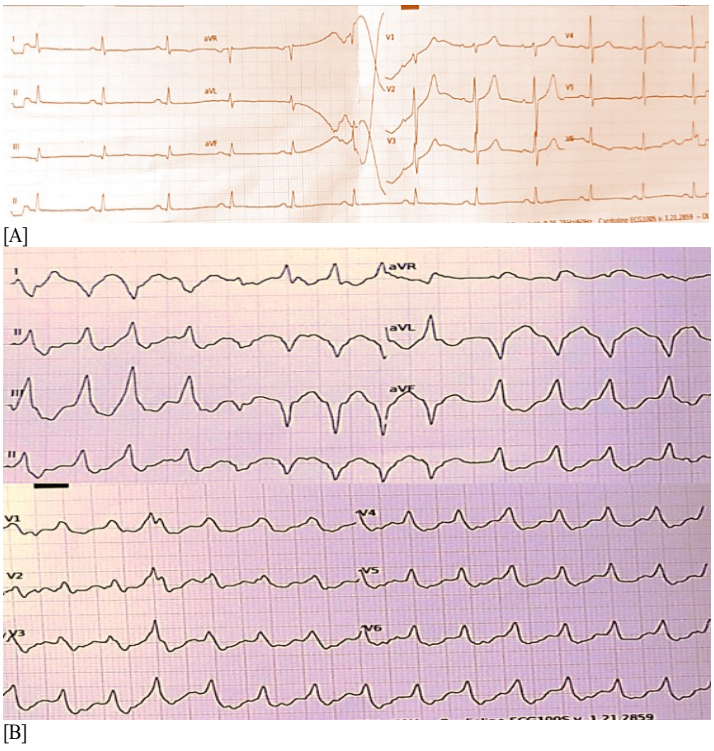


Figure [1]: Echocardiographic images from patient study [A] CWD across MV, [B] M-mode measurement of LV EF%, [C] CWD across TV , [D] M-mode across aorta and LA, [E] PWD across MV, [F] TAPSE.



[A]

[B]

Figure [2]: ECG on admission: [A] 12 lead ECG showed sinus rhythm, normal axis, HR 75b/m, inverted T-wave in LI, aVL, V5, V6. [B] 12 lead ECG showed, wide complex regular tachycardia, right axis deviation, AV dissociation, capture beat, fusion beat, and positive concordance in precordial leads.

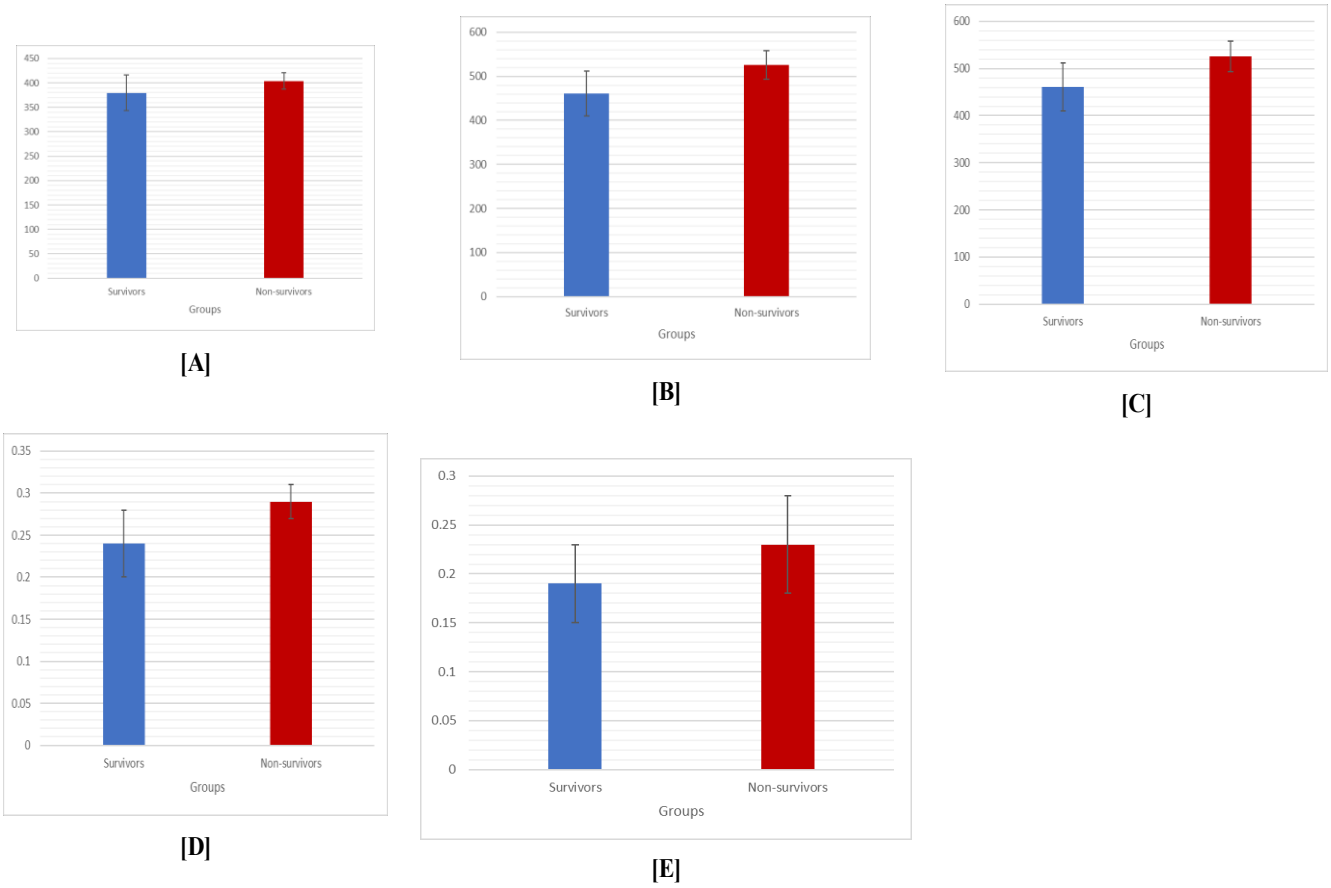


Figure [3]: Comparison of ventricular repolarization parameters [A] QT interval, [B] QTc, [C] Tp-e interval, [D] Tp-e/QT ratio, and [E] Tp-e/QTc ratio] according to survival status.

DISCUSSION

The novelty of our research lies in establishing the Tp-e/QT ratio as a practical and powerful prognostic indicator in acute HFrEF. Whereas previous studies recognized the arrhythmogenic significance of a prolonged Tp-e interval [11]. Our work is among the first to compare these ECG markers with clinical outcomes in HF directly. We emphasize in the manuscript that this finding provides a new avenue for risk stratification: patients with elevated Tp-e/QT ratios on admission should be flagged for closer monitoring and aggressive management, as our data suggest they are more likely to experience complications or mortality. This sharper focus on Tp-e/QT's prognostic role distinguishes our research from earlier research and adds novel insight to the field of HF risk assessment.

HF is a complex condition that presents with common symptoms like tiredness, shortness of breath, and swelling in the limbs, alongside noticeable signs like raised neck vein pressure, abnormal lung sounds, and fluid buildup in the extremities. This syndrome develops due to underlying problems with the heart structure or function, which result in elevated pressure inside the heart chambers or diminished ability of the heart to pump enough blood, either during rest or physical activity [12].

In this research, the prevalence of VHD was significantly elevated in the non-survivors. In addition, VHD prevalence was markedly greater among non-survivors. Corroborating these findings, Hibino and colleagues conducted a thorough analysis of global mortality trends associated with VHD, emphasizing disparities between middle- and high-income countries. Utilizing mortality data from the World Health Organization Mortality Database spanning from 2000 to 2019, their investigation examined VHD and its principal subtypes, including rheumatic valvular disease, infective endocarditis, aortic stenosis, and mitral regurgitation. Their investigation revealed that VHD remains one of the leading contributors to cardiovascular mortality worldwide [13].

In the present research, the prevalence of New York Heart Association [NYHA] class 4 and swelling were significantly elevated in the non-survivors. Corroborating our results, Ahmed and co-authors investigated the relationship between NYHA functional classes and clinical outcomes in ambulatory cases with chronic CHF and preserved ejection fraction [EF > 45%]. This retrospective follow-up research included 988 participants from the Digitalis Investigation Group trial. The all-cause mortality rates observed across NYHA classes I through IV were 14.3%, 21.3%, 35.9%, and 58.3%, respectively, demonstrating a significant trend [p for trend < 0.001]. Notably, mortality among cases classified as NYHA III and IV [37.2%] was significantly elevated as opposed to those in NYHA classes I and II [19.5%] [p<0.001] [14].

In the current research, non-survivors had significantly diminished systolic and diastolic blood pressure, while their HR was elevated more than that of survivors. This result echoes the work of Adamopoulos and co-authors, who explored the prognostic impact of LVEF and MAP on short-term mortality in the EFICA cohort cases. Their analysis of 581 AHFS admissions across 60 CCU/ICUs revealed that declines in both LVEF and MAP independently heightened mortality risk. The odds ratios were OR=1.27, 1.30, and 2.84; the 95% confidence intervals were 1.05–1.53, 1.15–1.48, and 1.64–4.93; and the p-values were 0.012, <0.0001, and 0.0002, respectively. Importantly, a significant LVEF–

MAP interaction was observed [p < 0.0001], indicating that diminished LVEF markedly elevated risk when MAP was ≤ 90 mmHg [OR=2.73; 95% CI=1.23–5.98; p=0.01], while this association was not significant for MAP values above this threshold [15].

Moreover, Ho and co-authors assessed the association between baseline HR and both fatal and nonfatal outcomes over 20 years. Their cohort comprised 4,058 FHS participants [mean age 55 years; 56% female]. Utilizing Cox proportional hazards models adjusted for clinical risk factors and physical activity, baseline HR was significantly associated with cardiovascular disease, HF, all-cause mortality, and cardiovascular mortality. Specifically, HR=1.15, 1.32, 1.17, and 1.18; 95%, CI=1.07–1.24, 1.18–1.48, 1.11–1.24, and 1.04–1.33; and p= 0.0002, <0.0001, <0.0001, and 0.01, respectively. These findings highlight a stronger link between elevated baseline HR and the risk of HF, alongside elevated mortality risks [16].

In the current research, LDL titres were significantly elevated among non-survivors. This finding contrasts with **Araújo and co-authors,** who examined biochemical markers of nutritional status in cardiac cachexia and identified factors linked to poor prognosis. Their cohort included 94 ambulatory cases, 38 cachectic [defined by ≥7.5% weight loss], and 56 non-cachectic. The authors reported that diminished total cholesterol titres were consistently associated with elevated mortality in cases with established HF [17].

Data on the influence of LDL-c in HF and whether a paradox akin to that observed in other contexts exists are sparse. While LDL-c diminishing is widely recommended to reduce CVD risk, especially among cases classified as high or very high risk, the applicability and clear benefit of such aggressive lipid management in those who have already developed HF remain uncertain. Consequently, definitive data supporting the advantages of implementing stringent LDL-c targets in high-risk individuals with established HF are still lacking [18]. For instance, some research suggests that elevated LDL titres correlate with an elevated risk of cardiovascular disease, while others indicate that diminished LDL titres may correlate with worse outcomes in HF cases, potentially due to malnutrition or cachexia commonly observed in this cohort [19].

This research revealed that non-survivors exhibited marked elevations in QT interval, QTc, Tp-e, and both Tp-e/QT and Tp-e/QTc ratios, highlighting their potential role as indicators of poor prognosis. This aligns with Piccirillo and co-authors, who aimed to identify ECG markers based on short-term temporal repolarization dispersion to stratify decompensated CHF cases at high mortality risk. They analyzed variables from 5-minute ECG recordings via mobile monitoring, including RR, QTe, QTp, and Tp-e, calculating mean, SD, and normalized index. Among 101 cases, 25 [25%] died in-hospital. As opposed to survivors, deceased cases exhibited significantly elevated QTeSD, Tp-e mean, Tp-eSD, and QTeVN [all p < 0.05] [20].

In the current research, QT interval, Tp-e, QTc, Tp-e / QT, and Tp-e / QTc ratios were statistically notably elevated in the cases with prolonged length of stay [> 1 week]. Similarly, Piccirillo and co-authors studied 139 cases hospitalized for acutely decompensating CHF. They found that cases with hospital stays longer than one week exhibited elevated short-term repolarization variability, specifically in Tp-eSD and Tp-eVN. Multivariable Cox regression analysis identified Tp-eVN as a significant risk factor for prolonged hospitalization [p<0.05]. These observations indicate that elevated temporal dispersion of repolarization, as indicated by Tp-e variability, is associated with more extended hospital stays [20].

In the present research, non-survivors exhibited a statistically significant diminished in EF and a statistically significant elevated in the E/A ratio. Numerous cohort investigations have shown that mortality is diminished in HFpEF as opposed to HFrEF [21, 22]. Along the same lines, the research by **Tribouilloy and colleagues** exhibited that diminished EF had an elevated in-hospital mortality rate as opposed to preserved one [8.2% vs. 2.7%, p=0.002] [23].

In the present research, vasopressor and inotrope utilization were significantly greater among non-survivors. This observation is consistent with the retrospective analysis by Jentzer and co-authors, who evaluated consecutive adult admissions to a tertiary care CICU between 2007 and 2015. Their findings demonstrated a strong association between elevated peak vasopressor/inotrope use and elevated hospital mortality [24]. Our findings align with recent literature demonstrating the prognostic relevance of ventricular repolarization parameters across diverse clinical settings. **Dal and Eraybar** [25] found that a diminished Tp-e/QTc ratio was significantly associated with 90-day mortality, while an elevated ratio predicted recurrent unstable angina. Additionally, **Rath *et al.*** [26] demonstrated that a prolonged Tp-e interval predicted arrhythmia recurrence in cases with idiopathic ventricular fibrillation and early repolarization syndrome. **Baytugan and Mağden** [27] reported that patients with ADPKD exhibited significantly elevated Tp-e, QTc, Tp-e/QT, and Tp-e/QTc ratios as opposed to controls

Conclusions: Several clinical, laboratory, and ECG parameters are significantly associated with mortality and adverse outcomes in HF cases. Non-survivors exhibited elevated rates of VHD, diminished ejection fraction, elevated LDL titres, and elevated QT interval, Tp-e, QTc, and Tp-e/QT ratios. Additionally, the need for vasopressors/ inotropes, ICU admission, and mechanical ventilation was significantly greater among non-survivors, while survivors were more likely to receive loop diuretics, ACEIs, MRAs, and SGLT2 inhibitors. These results suggest that careful monitoring of these parameters, particularly ECG markers [Tp-e/QT] and hemodynamic status, is essential for effective risk stratification and optimizing treatment strategies for cases with HF.

Recommendations: Consistent follow-up and careful monitoring of ECG measurements should be integrated into the routine management of HF cases to aid in recognizing those at greater risk as early as possible. Closer monitoring of non-survivor-associated risk factors, like VHD, low ejection fraction, and elevated LDL titres, may lead to better patient outcomes through early intervention. To improve survival rates, suitable cases should emphasize pharmaceutical therapy, including the use of loop diuretics, ACEIs, MRAs, and SGLT2 inhibitors. Future research should investigate the effect of continuous long-term monitoring of ECG indicators on predicting arrhythmic episodes and overall prognosis.

Limitations: This research has several limitations. The short follow-up period limits assessment of long-term outcomes and progression of HF complications. Conducted within a single institution and involving a limited number of participants, this study's outcomes should be interpreted with caution. The restricted sample size may reduce the robustness of statistical analyses, while the single-center design may limit the applicability of the results to diverse or larger populations. Potential confounding factors, like medication adherence, treatment variations, and comorbidities, may have influenced the results.

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REFERENCES

1. Bozkurt B, Coats AJS, Tsutsui H, Abdelhamid CM, Adamopoulos S, Albert N, et al. Universal definition and classification of heart failure: a report of the Heart Failure Society of America, Heart Failure Association of the European Society of Cardiology, Japanese Heart Failure Society and Writing Committee of the Universal Definition of Heart Failure: Endorsed by the Canadian Heart Failure Society, Heart Failure Association of India, Cardiac Society of Australia and New Zealand, and Chinese Heart Failure Association. Eur J Heart Fail. 2021; 23:352-80, doi: 10.1002/ejhf.2115.

2. Watson RD, Gibbs CR, Lip GY. ABC of heart failure. Clinical features and complications. BMJ. 2000 Jan 22; 320[7229]:236-9, doi: 10.1136/bmj.320.7229.236.

3. Kemp CD, Conte JV. The pathophysiology of heart failure. Cardiovasc Pathol. 2012 Sep-Oct; 21[5]:365-71, doi: 10.1016/j.carpath.2011.11.007.

4. Bloom MW, Greenberg B, Jaarsma T, Januzzi JL, Lam CSP, Maggioni AP, et al. Heart failure with diminished ejection fraction. Nat Rev Dis Primers. 2017; 3: 17058, doi: 10.1038/nrdp.2017.58.

5. Felker GM, Adams KF, Jr., Konstam MA, O'Connor CM, Gheorghiade M. The problem of decompensated heart failure: nomenclature, classification, and risk stratification. Am Heart J. 2003; 145:S18-25, doi: 10.1067/mhj.2003.150.

6. Kongstad O, Xia Y, Liang Y, Hertervig E, Ljungström E, Olsson B, et al. Epicardial and endocardial dispersion of ventricular repolarization. A study of monophasic action potential mapping in healthy pigs. Scand Cardiovasc J. 2005; 39:342-7, doi: 10.1080/14017430500188744.

7. Porthan K, Viitasalo M, Toivonen L, Havulinna AS, Jula A, Tikkanen JT, et al. Predictive value of electrocardiographic T-wave morphology parameters and T-wave peak to T-wave end interval for sudden cardiac death in the general population. Circ Arrhythm Electrophysiol. 2013; 6:690-6, doi: 10.1161/CIRCEP.113.000356.

8. Dickstein K, Cohen-Solal A, Filippatos G, McMurray JJ, Ponikowski P, Poole-Wilson PA, et al. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: the Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC [HFA] and endorsed by the European Society of Intensive Care Medicine [ESICM]. Eur Heart J. 2008; 29:2388-442, doi: 10.1093/eurheartj/ehn309.

9. Hnatkova K, Toman O, Šišáková M, Smetana P, Huster KM, Barthel P, et al. Sex and race differences in J-Tend, J-Tpeak, and Tpeak-Tend intervals. Sci Rep. 2019 Dec 27; 9[1]:19880, doi: 10.1038/s41598-019-56328-8.

10. Koca H, Koç M. What is the Normal value of Tpe interval and corrected Tpe interval? Acta Medica. 2020; 51:10-5, doi: 10.32552/2020.ActaMedica.493.

11. Gupta P, Patel C, Patel H, Narayanaswamy S, Malhotra B, Green JT, Yan GX. T[p-e]/QT ratio as an index of arrhythmogenesis. J Electrocardiol. 2008 Nov-Dec; 41[6]:567-74, doi: 10.1016/j.jelectrocard.2008.07.016.

12. Arrigo M, Jessup M, Mullens W, Reza N, Shah AM, Sliwa K, Mebazaa A. Acute heart failure. Nat Rev Dis Primers. 2020 Mar 5; 6[1]:16, doi: 10.1038/s41572-020-0151-7.

13. Hibino M, Ueyama HA, Halkos ME, Grubb KJ, Verma R, Majeed A, et al. Valvular Heart Disease-Related Mortality Between Middle- and High-Income Countries During 2000 to 2019. JACC Adv. 2024 Aug 28; 3[12]:101133, doi: 10.1016/j.jacadv.2024.101133.

14. Ahmed A, Aronow WS, Fleg JL. Higher New York Heart Association classes and increased mortality and hospitalization in patients with heart failure and preserved left ventricular function. Am Heart J. 2006 Feb; 151[2]:444-50, doi: 10.1016/j.ahj.2005.03.066.

15. Adamopoulos C, Zannad F, Fay R, Mebazaa A, Cohen-Solal A, Guize L, Juillière Y, Alla F. Ejection fraction and blood pressure are important and interactive predictors of 4-week mortality in severe acute heart failure. Eur J Heart Fail. 2007 Sep; 9[9]:935-41, doi: 10.1016/j.ejheart.2007.06.001.

16. Ho JE, Larson MG, Ghorbani A, Cheng S, Coglianese EE, Vasan RS, Wang TJ. Long-term cardiovascular risks associated with an elevated heart rate: the Framingham Heart Study. J Am Heart Assoc. 2014 May 8; 3 [3]: e000668, doi: 10.1161/JAHA.113.000668.

17. Araújo JP, Lourenço P, Rocha-Gonçalves F, Ferreira A, Bettencourt P. Nutritional markers and prognosis in cardiac cachexia. Int J Cardiol. 2011 Feb 3; 146 [3]:359-63, doi: 10.1016/j.ijcard.2009.07.042.

18. Mach F, Baigent C, Catapano AL, Koskinas KC, Casula M, Badimon L, et al. 2019 ESC/EAS Guidelines for the management of dyslipidaemias: lipid modification to reduce cardiovascular risk. Eur Heart J. 2020; 41:111-88, doi: 10.1093/eurheartj/ehz455.

19. Gandedkar NH, Liou EJ. The immediate effect of alternate rapid maxillary expansions and constrictions on the alveolus: a retrospective cone beam computed tomography study. Prog Orthod. 2018 Oct 15; 19[1]:40, doi: 10.1186/s40510-018-0237-x.

20. Piccirillo G, Moscucci F, Mariani MV, Di Iorio C, Fabietti M, Mastropietri F, et al. Hospital mortality in decompensated heart failure. A pilot study. J Electrocardiol. 2020 Jul-Aug; 61:147-152, doi: 10.1016/j.jelectrocard.2020.05.006.

21. Dunlay SM, Redfield MM, Weston SA, Therneau TM, Hall Long K, Shah ND, Roger VL. Hospitalizations after heart failure diagnosis a community perspective. J Am Coll Cardiol. 2009 Oct 27; 54[18]:1695-702, doi: 10.1016/j.jacc.2009.08.019.

22. Gottdiener JS, McClelland RL, Marshall R, Shemanski L, Furberg CD, Kitzman DW, et al. Outcome of congestive heart failure in elderly persons: influence of left ventricular systolic function. The Cardiovascular Health Study. Ann Intern Med. 2002 Oct 15; 137[8]:631-9, doi: 10.7326/0003-4819-137-8-200210150-00006.

23. Tribouilloy C, Rusinaru D, Leborgne L, Mahjoub H, Szymanski C, Houpe D, Béguin M, Peltier M. In-hospital mortality and prognostic factors in patients admitted for new-onset heart failure with preserved or reduced ejection fraction: a prospective observational study. Arch Cardiovasc Dis. 2008 Apr; 101[4]:226-34, doi: 10.1016/s1875-2136[08]73697-0.

24. Jentzer JC, Wiley B, Bennett C, Murphree DH, Keegan MT, Kashani KB, Bell MR, Barsness GW. Temporal Trends and Clinical Outcomes Associated with Vasopressor and Inotrope Use in The Cardiac Intensive Care Unit. Shock. 2020 Apr; 53[4]:452-459, doi: 10.1097/SHK.0000000000001390.

25. Dal E, Eraybar S. Prognostic significance of the Tpe/Qtc ratio in predicting major adverse cardiac events in acute STEMI patients. Sci Rep. 2025 Jul 12; 15[1]:25259, doi: 10.1038/s41598-025-11353-8.

26. Rath B, Wolfes J, Ellermann C, Güner F, Wegner F, Köbe J, Reinke F, Lange PS, Frommeyer G, Eckardt L. T_{peak}-T_{end} interval predicts arrhythmia recurrence in idiopathic ventricular fibrillation and early repolarization syndrome. Clin Res Cardiol. 2025 Apr 14, doi: 10.1007/s00392-025-02648-x.

27. Baytugan NZ, Mağden K. Evaluation of QTc Interval, Tp-e Interval, Tp-e/QT Ratio and Tp-e/QTc Ratio in Patients with Autosomal Dominant Polycystic Kidney Disease. Turk Kardiyol Dern Ars. 2025 Jul; 53[5]:328-335. English, doi: 10.5543/tkda.2025.53768.