Heart & Lung 56 (2022) 86–90

Contents lists available at ScienceDirect

Heart & Lung

journal homepage: www.heartandlung.com

A single-center retrospective study on the incidence and clinical significance of the electrocardiographic "Triangular QRS-ST-T Waveform" pattern***

Ariyon Schreiber[a,*], Kim Inciong[b], Wilbur Ji[a], Justin S. Bauzon[b], Omar Al-Taweel[c], Keaton Nasser[c], Binna Chokshi[c], Jimmy Diep[c], Chowdhury H. Ahsan[c]

[a] Department of Internal Medicine, Kirk Kerkorian School of Medicine at the University of Nevada Las Vegas (UNLV), Las Vegas, NV
[b] Kirk Kerkorian School of Medicine at UNLV, Las Vegas, Nevada
[c] Department of Cardiology, Kirk Kerkorian School of Medicine at UNLV, Las Vegas, Nevada

ARTICLE INFO

Article History:
Received 30 March 2022
Revised 16 June 2022
Accepted 20 June 2022
Available online 6 July 2022

Keywords:
Abnormal ECG waveform
ST-segment elevation hyperacute myocardial infarction
Hyperacute STEMI
Hemodynamic instability

ABSTRACT

Background: The triangular QRS-ST-T waveform is a rare presentation of ST-segment elevation acute myocardial infarction associated with a poor in-hospital prognosis.
Objective: To evaluate the incidence and clinical implications of the QRS-ST-T waveform pattern.
Methods: Clinical data from non-pregnant adult patients who presented as STEMI activations at a single institution between 2017 and 2021 were reviewed. Patients who met electrocardiographic criteria for triangular QRS-ST-T waveform — a giant wave from the fusion of the QRS complex, the ST-segment, and the T-wave — were included in the study.
Results: There were 417 STEMI activations, eight (1.9%) of which fulfilled the criteria for the triangular QRS-ST-T waveform pattern on electrocardiography. Coronary angiography was performed in five of these patients, four of whom demonstrated a significant lesion to the left anterior descending artery. Three patients did not undergo angiography secondary to hemodynamic instability. Seven of the patients in our study experienced cardiogenic shock requiring vasopressor, inotropic, and/or mechanical support. Only two patients survived to discharge; one was successfully bridged to coronary artery bypass grafting via intra-aortic balloon pump, while the other underwent a staged percutaneous coronary intervention.
Conclusions: The triangular QRS-ST-T waveform pattern is a rare ECG finding that may indicate hyper-acute STEMI and is an ominous sign of impending hemodynamic instability. Patients who survived received prompt aggressive therapeutic management.

Introduction

The triangular QRS-ST-T waveform (TW) is a rare form of ST-segment elevation myocardial infarction (STEMI) that typically manifests in the hyper-acute phase of myocardial infarction.[1] It is an ominous sign of impending hemodynamic instability.[1] This specific electrocardiographic (ECG) pattern has been associated with an increased likelihood of left main coronary artery involvement, ventricular fibrillation, cardiogenic shock, and death during hospitalization when compared with other forms of ST-segment elevation ECG patterns.[1-3] This study aims to describe the clinical presentation, management, and clinical outcomes of this rare electrocardiographic phenomenon.

Methods

After obtaining institutional review board approval from University Medical Center of Southern Nevada, all patients aged 18 years and older who presented as a STEMI activation at a single medical center between January 2017 to December 2021, were identified using our institution's prospectively-maintained STEMI patient registry. Two reviewers applied strict inclusion criteria to the ECG data of all patients who underwent STEMI activation to identify patients with the TW pattern (Fig. 1; Supplementary Figure 1). The TW pattern is defined as:

1) a giant R-wave with an amplitude of $\geq$ 1 mV;

* Conflicts of Interest: The authors declare no conflicts of interest.
** Funding: This research did not receive any specific grant from funding agencies in public, commercial, or not-for-profit sectors.
* Corresponding author.
E-mail address: Ariyon.Schreiber@unlv.edu (A. Schreiber).

https://doi.org/10.1016/j.hrtlng.2022.06.018

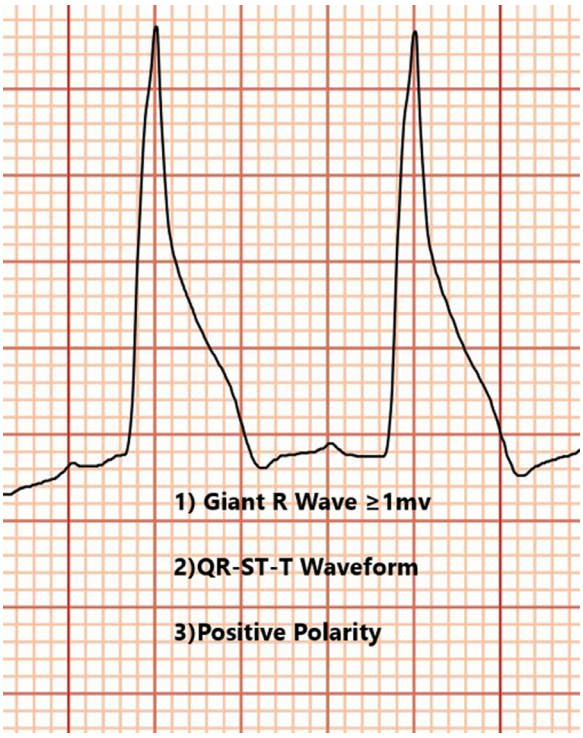

Fig. 1. Characteristics of the triangular QRS-ST-T waveform. TW consists of an R-wave with an amplitude of >1 mV, an ST-segment that steeply slopes down, and the fusion of the QRS- and T-wave.

2) a QRS complex fused with the ST-segment and the T-wave, forming a characteristic 'triangular' morphology;
3) a positive polarity that indicates the region of ischemia.[1]

Patients were excluded if they were pregnant, demonstrated signs of complete bundle branch block, or had paced ventricular rhythm. Institutional STEMI activation criteria included new ST elevation at the J point in at least 2 contiguous leads of >2 mm in men or >1.5 mm in women in leads V2-V3 and/or >1 mm in other contiguous chest leads or the limb leads. Abstracted data included demographics, disease presentation, ECG findings, initial management, hospitalization course, morbidity, and mortality. Descriptive statistics and incidence of the ekg finding were performed.

Results

Initial presentation

Among the 417 patients who underwent STEMI activation between January 2017 and December 2021, a total of eight patients presented with the TW pattern on ECG (Table 1). All eight patients were male. The mean age was 66 years, with a range between 54 and 78 years. Medical histories included previous myocardial infarction (n= 2), hyperthyroidism (n= 2), chronic obstructive pulmonary disease (n= 1), and malignancy (n= 2). Six patients endorsed tobacco use. Most patients (n= 6) presented to the emergency department with symptoms of progressive or sudden onset chest pain, half of whom (n = 3) were in cardiac arrest by the time of arrival. Two patients were given cardiopulmonary resuscitative compressions while en route to the emergency facility. Other reported symptoms included bilateral lower extremity weakness (n= 1), dyspnea (n= 1), and abdominal pain (n= 1). Six patients presented after March 2020, all of whom tested negative for COVID-19.

All patients displayed the TW pattern on admission ECG. Two patients experienced a junctional rhythm; three were found to have intraventricular conduction delays. The areas of ischemia on ECG that contained the TW pattern were classified as anterior (n= 3), anterolateral (n= 3), and inferior (n= 2).

Table 1
Characteristics of the triangular QRS-ST-T waveform study population.

Population	
Number of patients	8
Age (years), mean ± SD	66.3 ± 11.4
Male, n (%)	8 (100)
Body mass index (kg/m^2), mean ± SD	28.1 ± 4.4
Hospital outcomes	
Length of stay (days), mean ± SD	4.6 ± 2.5
Mortality, n (%)	6 (75)
COVID-19 status at admission (positive, negative, never tested)	0, 5, 3
Medical history, n (%)	
Previous acute myocardial infarction	2 (25.0)
Previous stroke	0 (0)
Hypertension	3 (37.5)
Hyperlipidemia	3 (37.5)
Family history of coronary artery disease	0 (0)
Diabetes mellitus type 2	2 (25.0)
Hypothyroidism	2 (25.0)
Chronic obstructive pulmonary disease	0 (0)
Chronic kidney disease	2 (25.0)
History of malignancy	2 (25.0)
Social and behavioral characteristics, n (%)	
Tobacco use	6 (75.0)
History of drug abuse	0 (0)

Cardiac interventions

Table 2 summarizes the interventional findings of the study population. Five patients underwent coronary angiography for acute MI. Out of these five patients, four were found to have significant culprit lesions in the left anterior descending artery (LAD), with stenosis ranging between 90 and 95%. Four patients successfully received percutaneous coronary intervention (PCI).

On angiography, Patient 2 was found to have proximal LAD in-stent thrombosis secondary to medication noncompliance and luminal irregularities, which required PCI and placement of a drug-eluting stent. Patient 3 successfully underwent emergent coronary angiography and was found to have chronic total occlusion of the mid-right coronary artery (RCA) in addition to 95% stenosis of the mid LAD. In addition, Patient 3 underwent emergent PCI of the culprit RCA with staged PCI of the LAD three days later. Patient 5 also underwent successful emergent coronary angiography, which showed high-grade ostial stenosis of the LAD, mid-LAD, distal left circumflex, and proximal RCA. This patient received an intra-aortic balloon pump, which served as a bridge for coronary artery bypass grafting (left internal thoracic artery graft to the mid-LAD and second graft between the aorta and second obtuse marginal branch using the saphenous). Patient 6 was found to have a mid-LAD chronic total occlusion without collaterals and mid-left circumflex subtotal occlusion. This was treated via PCI of the left circumflex. Patient 7 was found to have 80% stenosis of the mid-LAD; however, due to emergent surgical intervention for concurrent bowel necrosis, PCI was delayed to a later date during the index of hospitalization.

Morbidity & mortality

Hemodynamic instability was a common finding (Table 3). Seven patients met hemodynamic criteria for cardiogenic shock, all of whom required vasopressors during their hospital course. Five underwent transthoracic echocardiogram: two were found to have preserved to mildly reduced ejection fractions (EF), two had moderately reduced EF, and one had a severely reduced EF.

Table 2
Initial cardiac evaluation of patients with ST-segment elevated acute myocardial infarction showing the triangular QRS-ST-T waveform.

Patient	**Age (years)**	**Sex**	**Ethnicity**	**Troponin Peak (ng/mL)**	**Cardiogenic Shock**	History of Acute Myocardial Infarction	Location of Acute Infarction on ECG (Leads)	Ejection Fraction (%)	Echocardiogram Findings	Percutaneous Catheterization Findings (% Stenosis)
#1	72	Male	Cacasian	207,480	Yes	No	Anterior (V1-V3)	>65	Moderate concentric LVH, normal LV systolic function	**
#2	83	Male	Caucasian	43,213	Yes	Yes	Anterior (V1-V3)	25–30	Severely reduced LVSF, elevated RVSP, mild to moderate MR	pLAD stent thrombosis, LMCA with luminal irregularities, no significant disease
#3	48	Male	Hispanic	96,980	No	No	Inferior (II, III, aVF)	>50	*Borderline concentric LVH	Total occlusion of mRCA, mLAD stenosis (95)
#4	75	Male	Hispanic	146	Yes	Yes	Anterior (aVR)	—	—	**
#5	62	Male	Caucasian	37,367	Yes	No	Anterolateral (V3-V6)	20–25	Severely reduced LVSF, mild concentric LVH, severe anterior wall hypokinesis	LAD with high-grade ostial stenosis, mLAD stenosis (95), dLCx stenosis (80), pRCA stenosis (50)
#6	69	Male	Caucasian	63,947	Yes	No	Inferior (II, III, aVF)	<20	Mild concentric LVH, mild MR, mild AR	Total occlusion of mLAD without collaterals, subtotal occlusion of mLCx (TIMI 2)
#7	71	Male	Hisapnic	454	Yes	No	Anterolateral (V3-V6)	50–55	Moderate concentric LVH, moderate aortic sclerosis without stenosis, trace pericardial effusion	mLAD stenosis (80)
#8	50	Male	Caucasian	24	Yes	No	Anterolateral (V4-V6)	—	—	**

Abbreviations: AR, aortic regurgitation; dLCx, distal left circumflex; LAD, left anterior descending artery; LCx, Left circumflex; LMCA, Left main coronary artery; LV, left ventricle; LVH, left ventricular hypertrophy; LVSF, left ventricular systolic function; mLAD, mid-left anterior descending artery; MR, mitral regurgitation; mRCA, mid-right coronary artery; pLAD, proximal left anterior descending; pRCA, proximal right coronary artery; RVSP, right ventricular systolic pressure; TIMI, thrombolysis in myocardial infarction score.
*Study was technically difficult due to body habitus.
**Patient demise prior to catheterization.

Table 3
Post-operative outcomes of patients with ST-segment elevation acute myocardial infarction showing triangular QRS-ST-T waveform who underwent cardiac intervention.

Patient	Age (Years)	Sex	Catheterization Intervention	IABP	CABG	Mortality	Cardiac Rhythm on ECG Prior to Demise
#1	72	Male	—	No	No	Yes	PEA
#2	83	Male	PCI: Coronary 2.50×22.00 mm stent (Resolute Onyx)	No	No	Yes	—
#3	48	Male	Emergent PCI of the RCA, staged PCI of the LAD three days later	No	No	No	—
#4	75	Male	—	No	No	Yes	PEA
#5	62	Male	IABP as a bridge to CABG	Yes	Yes	No	—
#6	69	Male	PCI x2 to the LCx	No	No	Yes	PEA
#7	71	Male	—	No	No	Yes	PEA
#8	50	Male	—	No	No	Yes	VT

Abbreviations: CABG, coronary artery bypass grafting; LAD, left anterior descending artery; LCx, left circumflex; IABP, intra-aortic balloon pump; PCI, percutaneous coronary intervention; PEA, pulseless electrical activity; RCA, right coronary artery; VT, ventricular tachycardia.

There were six mortalities in total within our patient population. Of the six, four patients expired during hospitalization while two expired soon after hospital discharge. Patient 4 experienced significant bradycardia and profound hypotension, which required intravenous atropine and dopamine. He had multiple, prolonged episodes of pulseless electrical activity (PEA) that did not resolve despite maximum medical therapy. Patient 6 presented with ventricular fibrillation that required three rounds of defibrillation and one dose of epinephrine. Despite the return of spontaneous circulation, he suffered from persistent acidemia, hypotension, and renal failure leading to PEA and death. Patient 7 had two intraoperative episodes of ventricular fibrillation that initially resolved with cardioversion but recurred postoperatively. He received defibrillation and was treated with amiodarone drip but clinically decompensated before succumbing to PEA and death. Patient 8 presented with ventricular tachycardia and cardiogenic shock that did not improve despite maximal medical interventions, leading to patient's demise within 24 h of admission. Of the two patients discharged to hospice care, one (Patient 1) was transitioned to comfort care due to poor inpatient prognosis, while the other (Patient 2) was discovered to have worsening end-stage COPD despite maximal medical management.

Only two patients in the present series survived. Patient 3 successfully underwent emergent PCI and was discharged three days following an unremarkable hospital course post-catheterization. The second patient who survived (Patient 5) also recovered shortly after surgery with an unremarkable postoperative course, leading to his discharge five days later.

Discussion

Since its first characterization by Eckmecki et al. in 1961, several case reports and series in clinical settings have been described, the largest study to date performed by Cipriani et al. that included 5 patients with the TW pattern.[1–5] In the present series, we identified eight cases of the TW pattern after retrospective review of clinical data from all patients who underwent STEMI activation at a single institution over a five-year period. Our findings reveal an incidence of 1.9% (8/417), which is comparable to one recent prospective study 1.3% (5/367).[1] The TW pattern has a predilection for overweight men with a smoking history; a majority of patients were found to have significant lesions affecting the branches of the left coronary artery.[1-4] The TW pattern in our study appears to be associated with higher rates of mortality (75%) than previous reports.[1] All patients who presented with ECG TW pattern met the criteria for cardiogenic shock, requiring vasopressor therapy. For reasons not well understood, three-quarters of our patients presented following the initial declaration of the COVID-19 pandemic by the World Health Organization.

It is suspected that the TW morphology is the result of massive areas of ischemic burden.[2] Eckmecki and colleagues noted a positive correlation between augmented R-waves and the histochemically-derived extent of myocardial necrosis. Madias et al. postulated that in the setting of myocardial ischemia, an atypical propagation of the ventricular activation secondary to regional ischemic injury may result in a regional block.[6] This leads to prolonged conduction as the electrical current travels over the ischemic area, resulting in a direct increase in R-wave duration and amplitude.[7]

Notably, interventions that significantly impacted survival appeared to be related to early and aggressive therapeutic intervention. All patients with TW pattern who did not receive emergent angiography expired. Patients who survived to discharge received early management with emergent angiography followed by aggressive therapeutic intervention, as seen in Patients 3 and 5. Based on the above findings, we recommend that patients who present with the TW pattern receive prompt and aggressive therapeutic intervention to maximize their chances of survival.

This study is restricted by its retrospective nature, which can lead to potential selection biases. The small study population from a single institution limits the generalizability of our findings. One way that this can be addressed is by generating a study that spans multiple centers over a longer period of time. Larger case series and retrospective studies are needed to elucidate this rare subset of STEMI to better understand appropriate management and associated clinical outcomes.

Conclusions

The TW pattern is a rare ECG finding of hyper-acute myocardial infarction associated with an increase risk of cardiogenic shock and hemodynamic instability. There are high rates of mortality associated with the TW pattern consistent with previous studies. Patients should receive prompt therapeutic interventions upon discovery of the TW pattern, which may enhance the opportunity for a better clinical course and outcomes.

Declaration of Competing Interest

The authors declare no conflicts of interest.

Acknowledgments

language help, writing assistance / proof-reading

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.hrtlng.2022.06.018.

References

1 Cipriani A, D'Amico G, Brunello G, et al. The electrocardiographic "triangular QRS-ST-T waveform" pattern in patients with ST-segment elevation myocardial infarction: incidence, pathophysiology and clinical implications. *J Electrocardiol*. 2018;51(1):8–14. https://doi.org/10.1016/j.jelectrocard.2017.08.023.
2 Ekmekci A, Toyoshima H, Kwoczynski JK, Nagaya T, Prinzmetal M. Angina pectoris. V. Giant R and receding S wave in myocardial ischemia and certain nonischemic

conditions. *Am J Cardiol*. 1961 Apr;7:521–532. https://doi.org/10.1016/0002-9149(61)90510-0. PMID: 13726265.
3 V Ruiz Pizarro, Palacios-Rubio J, MÁ Cobos-Gil. Lettertothe editor:is"triangular QRS-ST-T waveform" aleft main total occlusion marker? *J Electrocardiol*. 2018 May-Jun;51(3):378. https://doi.org/10.1016/j.jelectrocard.2018.03.004. Epub 2018 Mar 14. PMID: 29779526.
4 Joki T, Nikus K, Laukkanen J. The electrocardiographic 'triangular QRS-ST-T wave-form' pattern: a marker of severe haemodynamic compromise in Takotsubo syn-drome-a case report. *Eur Heart J Case Rep*. 2020 Apr 25;4(3):1–6. https://doi.org/10.1093/ehjcr/ytaa076. PMID: 32617505; PMCID: PMC7319850.
5 Jaiswal A.K., Shah S. Shark Fin Electrocardiogram: a Deadly Electrocardiogram Pat-tern in ST-Elevation Myocardial Infarction (STEMI). Cureus. 2021 Jun 28;13(6):e15989. doi: 10.7759/cureus.15989. PMID: 34336480; PMCID: PMC8317974.
6 Madias JE, Krikelis EN. Transient giant R waves in the early phase of acute myocar-dial infarction: association with ventricular fibrillation. *Clin Cardiol*. 1981 Nov-Dec;4(6):339–349. https://doi.org/10.1002/clc.4960040606. PMID: 7326885.
7 David D, Naito M, Michelson E. Intramyocardial conduction: a major determinant of R-wave amplitude during acute myocardial ischemia. *Circulation*. 1982;65(1):161–167. https://doi.org/10.1161/01.cir.65.1.161. PMID: 7053277.