JOURNAL OF CARDIOVASCULAR DISEASE VOL.2 NO.2 APRIL 2014
ISSN: 2330-4596 (Print) / 2330-460X (Online) http://www.researchpub.org/journal/jcvd/jcvd.html

Deep T-Wave Inversions: Cardiac Ischemia or Memory?

Kairav Vakil, MD*; Sheiphali Gandhi, MD; Kashan Syed Abidi, MD; Venkat Tholakanahalli, MD, FHRS; Alok Sharma, MD; Marina Zakharova, MD; Richard Madlon-Kay, MD

Abstract

Cardiac memory is a unique phenomenon of electrical remodeling characterized by marked diffuse T-wave inversions (TWI) that can mimic severe myocardial ischemia. When misinterpreted, these often lead to unnecessary diagnostic investigations or therapeutic interventions. We report a case of an elderly female with a history of coronary artery disease that presented with diarrhea, and was incidentally found to have marked TWI following episodes of altered ventricular conduction. Although these findings were concerning for severe myocardial ischemia or an acute intra-cranial event, in the context of the patient's clinical scenario, were highly suggestive of cardiac memory. Understanding these mechanisms of altered ventricular conduction and being familiar with such a pathologic entity is important for clinicians to prevent unnecessary testing, expert consultations, or inpatient admissions all of which can have financial and/or crucial clinical implications.

Keywords — T-wave memory; cardiac memory; myocardial ischemia

Cite this article as: Vakil K, Gandhi S, Abidi KS, et al. Deep T-Wave Inversions: Cardiac Ischemia or Memory? JCvD 2014: in press

I. Introduction

Cardiac memory is a unique phenomenon of electrical remodeling seen after periods of altered ventricular conduction wherein the T-wave direction during 'memory', i.e. during periods after altered depolarization, is similar to that of the QRS complex during periods of abnormal depolarization. Although it appears to be a relatively benign pathophysiologic finding, T-wave inversions (TWI) due to cardiac memory may lead to unnecessary testing and treatment, when misinterpreted. We report a case of 'cardiac memory' in a patient with deep diffuse TWI that raised concerns for and could have been potentially misinterpreted for an underlying acute cardiac or intracranial event.

Received on 22 January 2014
From the Division of Cardiology (**KV, KSA, VT, AS, RMK**) and Internal Medicine (**SG**, **MZ**), University of Minnesota, Minneapolis, MN, USA
All authors reports no conflicts of interest.
*Correspondence to Dr. Kairav Vakil: vakil012@umn.edu
420 Delaware Street SE, Mayo Mail Code 508, Minneapolis, MN 55455
Phone: 612-656-2451; Fax: 612-626-4411

II. Our Experience

An 87-year-old was admitted after three-days of black-tarry diarrhea. She denied having chest pain, dyspnea, or pre-syncopal symptoms. Her past history included paroxysmal atrial fibrillation (AF), intermittent complete heart block treated with a dual chamber pacemaker, and a right coronary artery stent placed 3-years prior for unstable angina. An adenosine nuclear stress test, performed a month prior to admission for dyspnea, was negative for ischemia. Physical examination revealed an elderly female in no distress with a BP of 100/60 mm Hg and HR of 65 bpm. Cardiac, pulmonary, and neurologic examination was normal. Significant labs included hemoglobin of 9.1 gm% (decreased from 12.3 gm% 2-months prior) and INR of 2.5. The initial 12-lead ECG (**Figure 1A**) showed sequential atrio-ventricular (AV) pacing with a paced AV-delay of 280 msec with expected repolarization changes.

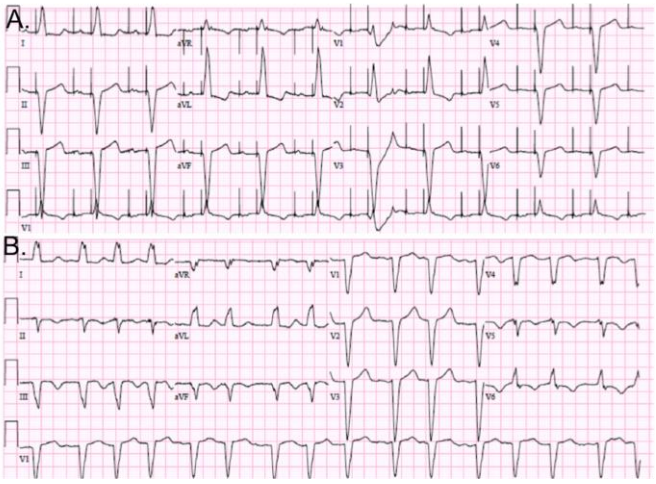

Fig. 1. (A) Electrocardiogram on day-1 showing sequential atrio-ventricular pacing, prolonged set AV-delay (280 msec), and left-bundle-branch block (LBBB) morphology from right ventricular pacing (B) Electrocardiogram on day-4 showing atrial fibrillation with rate-related LBBB with concordant infero-lateral T-wave changes

On day four of her hospitalization, she had an episode of AF with rate-related LBBB (seen on prior ECGs) with concordant T-waves changes in the inferior-lateral leads (**Figure 1B**). A subsequent ECG 2-hours later showed an atrial-paced rhythm with native QRS conduction, ventricular pacing spikes (pseudo-fusion), and diffuse, deep TWI (**Figure 2**) that were highly concerning for acute myocardial ischemia.

The patient continued to deny having any cardiac symptoms. An echocardiogram demonstrated normal left ventricular (LV) systolic function with no wall-motion abnormality. Stable troponin-I elevations (μg/L) at 0.043, 0.035, and 0.037 (lab ref: 0.000-0.034) were noted over the next 24-hours.

At this point, the internal medicine team sought cardiology consultation, and a diagnosis of T-wave memory or cardiac memory was made. The troponin elevations were thought to be non-specific and likely secondary to hemodynamic stress from anemia and AF in a patient with known coronary artery disease. In view of her gastrointestinal bleeding, she was managed expectantly. No further work-up for ischemia was performed as these changes were thought to be non-pathologic. The patient did well through the remainder of her hospital course and had complete resolution of these profound ECG changes at discharge. There were no reported cardiac events at a 3-month clinic follow-up visit.

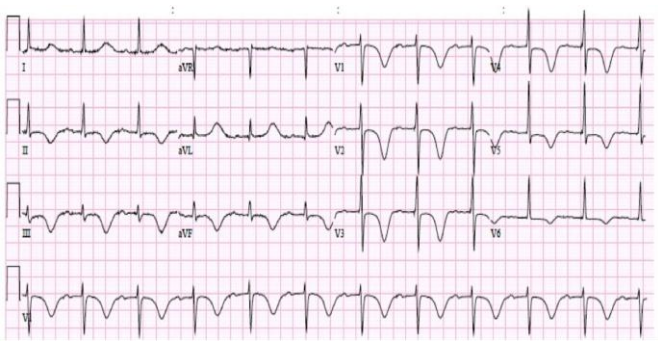

Fig. 2. Electrocardiogram showing atrial paced rhythm, normal QRS, and marked diffuse T-wave inversions. Note that the intrinsic PR-interval co-incidentally happens to be the same as the set paced AV-delay leading to non-capture (pseudo fusion) of the ventricular pacing spike and a resultant normal QRS morphology

III. Discussion

The patient's ECG findings caused understandable concern in her physicians, as these were suggestive of severe myocardial ischemia, myocarditis, or an acute intra-cranial pathology. However, given the absence of symptoms suggestive of myocardial ischemia, recent negative stress test, normal echocardiogram, non-specific pattern of minimal troponin elevation, and a normal neurological exam, these diffuse TWI were concluded to be consistent with 'cardiac or T-wave memory'. A prompt and accurate clinical diagnosis in this patient prevented further un-warranted diagnostic testing.

This phenomenon of altered T-wave polarity (originally referred to as 'post-tachycardia T-wave changes') was described in patients with ventricular tachyarrhythmias as early as 1940's, but Rosenbaum et al. first coined the term 'cardiac or T-wave memory' in 1982.[1] Such T-wave findings are occasionally seen following periods of altered ventricular conduction such as with ventricular pacing, ventricular arrhythmias, intermittent bundle-branch block, or ventricular pre-excitation.[1-4] Given that these findings can mimic life-threatening conditions, they frequently tend to be associated with unnecessary work-up and diagnostic interventions.[5,6] In the patient described, the absence of clinical findings suggesting any alternative diagnoses and the classic appearance of TWI in the setting of recent pacing and LBBB clinched the diagnosis of cardiac memory without the need for additional work-up.

Pathophysiology of cardiac memory

Cardiac memory is an adaptation of electrical pathways to external stimuli manifested as TWI following periods of abnormal ventricular activation. Interestingly, the duration of the altered T-wave polarity is frequently related to the duration of altered ventricular conduction and accordingly may be short- or long-term. The cellular mechanisms underlying this phenomenon are complex and uncertain, and largely beyond the scope of this discussion. However, herein we briefly review the basic pathophysiologic concepts and factors that contribute to its development.

The movement of sodium, potassium, and calcium ions across the cell membrane via ion channels and gap junctions creates gradients necessary to regulate ventricular repolarization, which normally occurs from epicardium to endocardium. Current observations suggest that altered ventricular activation, such as with pacing, causes a disproportionate change in the action potential duration in the early- (mild prolongation) versus late-activated (significant prolongation) regions of the myocardium. This results in increased transmural repolarization gradients in the ventricle that seem to serve as the current electrophysiological basis for cardiac memory.[7]

Although various mechanisms for the development of cardiac memory have been described, three mechanisms appear to be of key importance - (a) transient reduction in the intensity of outward K-current following altered activation,[8] (b) angiotensin-II receptor mediated signaling that regulates I_{to} by regulating K-channels,[9] and (c) presence of mechanical strain in the late-activated region of the ventricle during altered conduction which causes marked prolongation of action potential leading to increased repolarization gradients.[10]

Clinical implications of cardiac memory

Significant clinical implications of cardiac memory per se are rare, although it has been shown to have detrimental electrical consequences on the heart. Life-threatening ventricular arrhythmias like torsade de pointes, although rare, have been previously described.[11,12] In addition to arrhythmias, the underlying pathophysiology of altered conduction and repolarization instability has shown to predispose to adverse mechanical remodeling in the human heart.[7,13,14]

Recent studies suggest that this electrical remodeling precedes structural remodeling.[7,10] Clinically adverse outcomes related to this phenomenon have been reported in the MADIT-II and DAVID trials, wherein ventricular pacing was associated with an increased rate of heart failure hospitalizations and cardiac mortality. Lastly, it should be

important to note that patients that manifest 'cardiac memory' also tend to respond differently to antiarrhythmic therapy.[15]

Myocardial ischemia versus cardiac memory

When TWI present in the setting of abnormal ventricular activation, especially ventricular pacing, the diagnosis of cardiac memory must always be considered. However, caution is advised as diffuse ischemic TWI of the magnitude as seen in our patient, are likely to represent an acute intra-cranial event or acute ischemia from severe proximal three-vessel or left main coronary artery disease. These diagnoses should especially be considered in the presence of concomitant ST segment changes.[16]

A few electrocardiographic clues have recently been suggested to aid clinicians in distinguishing cardiac memory from ischemia. Reportedly, the combination of (a) positive T in aVL, (b) positive or isoelectric T in lead-I, and (c) maximal voltage of TWI in precordial leads > lead III – has been shown to be 92% sensitive and 100% specific for cardiac memory.[17] However, in the absence of a classic clinical scenario, other clinical correlates such as symptoms, echocardiography, and serial cardiac enzymes should remain the cornerstone of clinical assessment.

IV. Clinical Perspective

This report demonstrates a case of diffuse TWI that, although concerning for cardiac ischemia, are typical electrocardiographic manifestations of cardiac memory. Although occasionally seen in the cardiac electrophysiology catheterization laboratory after episodes of pacing or bundle branch blocks that alter normal ventricular depolarization, these T-wave findings are seldom caught on ECG in the emergency department, in-hospital, and outpatient settings. Despite their relatively benign nature, these marked ECG changes can lead to significant concerns amongst clinicians unfamiliar with such an electrocardiographic entity. As such, understanding these mechanisms of altered ventricular conduction and being familiar with such a pathologic entity is important for clinicians, especially internists, family medicine, and emergency department physicians to prevent unnecessary work-up and treatments - all of which can have significant financial and/or crucial clinical implications.

References

[1] Rosenbaum MB, Blanco HH, Elizari MV, Lazzari JO, Davidenko JM. Electrotonic modulation of the T wave and cardiac memory. The American journal of cardiology 1982;50:213-22.
[2] Kalbfleisch SJ, Sousa J, el-Atassi R, Calkins H, Langberg J, Morady F. Repolarization abnormalities after catheter ablation of accessory atrioventricular connections with radiofrequency current. Journal of the American College of Cardiology 1991;18:1761-6.
[3] Rosenbaum MB, Elizari MV, Lazzari JO, Halpern MS, Nau GJ, Levi RJ. The mechanism of intermittent bundle branch block: relationship to prolonged recovery, hypopolarization and spontaneous diastolic depolarization. Chest 1973;63:666-77.
[4] Kernohan RJ. Post-paroxysmal tachycardia syndrome. British heart journal 1969;31:803-6.
[5] Chen-Scarabelli C, Scarabelli TM. T-wave inversion: cardiac memory or myocardial ischemia? The American journal of emergency medicine 2009;27:898 e1-4.
[6] Sovari AA, Farokhi F. When the heart remembers. The American journal of emergency medicine 2007;25:831-3.
[7] Jeyaraj D, Ashwath M, Rosenbaum DS. Pathophysiology and clinical implications of cardiac memory. Pacing and clinical electrophysiology : PACE 2010;33:346-52.
[8] del Balzo U, Rosen MR. T wave changes persisting after ventricular pacing in canine heart are altered by 4-aminopyridine but not by lidocaine. Implications with respect to phenomenon of cardiac 'memory'. Circulation 1992;85:1464-72.
[9] Ricard P, Danilo P, Jr., Cohen IS, Burkhoff D, Rosen MR. A role for the renin-angiotensin system in the evolution of cardiac memory. J Cardiovasc Electrophysiol 1999;10:545-51.
[10] Jeyaraj D, Wilson LD, Zhong J, et al. Mechanoelectrical feedback as novel mechanism of cardiac electrical remodeling. Circulation 2007;115:3145-55.
[11] Medina-Ravell VA, Lankipalli RS, Yan GX, et al. Effect of epicardial or biventricular pacing to prolong QT interval and increase transmural dispersion of repolarization: does resynchronization therapy pose a risk for patients predisposed to long QT or torsade de pointes? Circulation 2003;107:740-6.
[12] Haverkamp W, Hordt M, Breithardt G, Borggrefe M. Torsade de pointes secondary to d,l-sotalol after catheter ablation of incessant atrioventricular reentrant tachycardia--evidence for a significant contribution of the "cardiac memory". Clinical cardiology 1998;21:55-8.
[13] Wecke L, Rubulis A, Lundahl G, Rosen MR, Bergfeldt L. Right ventricular pacing-induced electrophysiological remodeling in the human heart and its relationship to cardiac memory. Heart rhythm : the official journal of the Heart Rhythm Society 2007;4:1477-86.
[14] Geelen P, Brugada J, Andries E, Brugada P. Ventricular fibrillation and sudden death after radiofrequency catheter ablation of the atrioventricular junction. Pacing and clinical electrophysiology : PACE 1997;20:343-8.
[15] Plotnikov AN, Shvilkin A, Xiong W, et al. Interactions between antiarrhythmic drugs and cardiac memory. Cardiovascular research 2001;50:335-44.
[16] Tan NS, Goodman SG, Yan RT, et al. Comparative prognostic value of T-wave inversion and ST-segment depression on the admission electrocardiogram in non-ST-segment elevation acute coronary syndromes. American heart journal 2013;166:290-7.
[17] Shvilkin A, Ho KK, Rosen MR, Josephson ME. T-vector direction differentiates postpacing from ischemic T-wave inversion in precordial leads. Circulation 2005;111:969-74.