JACC: CASE REPORTS VOL. 3, NO. 2, 2021

CASE REPORT

BEGINNER

CLINICAL CASE

A Tragic Case of Wearable Cardioverter-Defibrillator Failure

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ABSTRACT

The American College of Cardiology/American Heart Association guidelines recommend a wearable cardioverter defibrillator (WCD) for certain conditions or scenarios. WCD is felt to provide adequate protection against ventricular arrhythmias. This case highlights failure of a WCD to detect and deliver life-saving therapy and the need for improved detection algorithms. (**Level of Difficulty: Beginner.**) (J Am Coll Cardiol Case Rep 2021;3:322–6) © 2021 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A wearable cardioverter defibrillator (WCD) is designed to protect patients from sudden cardiac death. American College of Cardiology/American Heart Association guidelines recommend the use of a WCD in patients with a low ejection fraction post myocardial infarction before permanent implantable cardioverter defibrillator (ICD) implantation (1). In addition, a WCD can also be considered when an ICD is extracted, and the patient is waiting for reimplantation (1). Available literature reports a sensitivity of 97% for detection of ventricular tachycardia (VT) and 100% for ventricular fibrillation (VF), with a specificity of 100% for both (2–4). Here, we report a case of WCD failure to accurately detect VF and consequent failure to deliver life-saving shock therapy.

LEARNING OBJECTIVES

- To understand the WCD detection algorithm.
- To educate clinicians and patients of the possibility of the WCD to fail to detect and deliver life-saving therapy despite proper use.

HISTORY OF PRESENTATION

A 63-year-old man with ischemic cardiomyopathy (ejection fraction 20%), status/post (s/p) cardiac resynchronization therapy-defibrillator with history of appropriate defibrillator shocks for VT/VF on amiodarone and mexiletine, presented with shortness of breath, cough, and hypoxia. His examination was notable for low-grade fever, blood pressure of 104/50 mm Hg, heart rate of 88 beats/min, and oxygen saturation of 88% on room air but alert and oriented with midline sternotomy scar that was well-healed. ICD pocket was nontender in left upper chest. Regular rate and rhythm with no murmurs, rubs, or gallops, but prominent rhonchi over right posterior lung fields, crackles at the left posterior base, and wheezing. His right stump was nontender without ulcerations and no edema in the left lower extremity.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received May 15, 2020; revised manuscript received November 2, 2020, accepted December 22, 2020.

ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2020.12.016

PAST MEDICAL HISTORY

In addition to his cardiomyopathy, the patient also had coronary artery disease s/p 2-vessel coronary artery bypass grafting, peripheral arterial disease s/p right below-the-knee amputation, chronic obstructive pulmonary disease, chronic kidney disease stage III, and metabolic syndrome.

DIFFERENTIAL DIAGNOSIS

Initial differential included multilobar pneumonia, viral illness, and/or chronic obstructive pulmonary disease versus heart failure exacerbation.

INVESTIGATIONS

Chest radiograph was remarkable for multilobar airspace disease. Cultures were obtained, and the patient was started empirically on antibiotics. Blood cultures quickly grew *Streptococcus pneumoniae* and *Staphylococcus epidermidis*. Transesophageal echocardiogram was performed to exclude endocarditis, which was significant for approximately 1 cm lead vegetation (Figure 1).

MANAGEMENT

After consultation with infectious disease service, the patient underwent successful device and laser lead extraction. In line with current American College of Cardiology/American Heart Association guidelines, the patient was discharged with a WCD (LifeVest 4000, ZOLL, Pittsburgh, Pennsylvania) model for secondary prevention with plans for reimplantation after completion of antibiotics and clearance of bacteremia on surveillance cultures. The VT and VF rate thresholds were set at 150 and 200 beats/min, respectively. The response time for therapy was set at 60 s for VT and 25 s for VF.

The evening after discharge, the patient developed sustained VT at approximately 150 beats/min that lasted for approximately 3 min and eventually degenerated into VF that lasted for approximately 15 min before terminating into asystole.

DISCUSSION

Review of the patient's WCD rhythm strips showed that at 8:24 PM the device alarms went off, and the patient appropriately pressed the response buttons to delay the shock (Figure 2). The noisy signal appeared to have been detected as high VT/VF rate by the device.

Coincidentally at 8:26 PM, the device detected true VT appropriately but stopped after approximately 48 s of detection due to the rate being at times faster, at the edge or below the detection threshold of 150 beats/min (Figure 3). Time to detection of VT was approximately 10 s. The treatment in the VT range occurs after 60 s, but in this case, the heart rate as detected by the device did not stay at or above the detection threshold long enough to be treated.

At 8:29 PM, approximately 3 min into sustained VT, the rhythm accelerates and degenerates into coarse VF (Figure 4A). VF was detected for a total of 62 s before underdetection (Figure 4B). VF was detected as VT by the device, as rate was varying at approximately 150 beats/min.

However, the QRS complex amplitude and frequency varied, and the fundamental frequency (or dominant frequency) appeared unstable. Because of the autogain-like feature, the device seemed to have recognized only the dominant frequency or the higher amplitude QRS signals at a frequency of approximately 2.17 Hz, which is equivalent to 130 beats/min and ignored the finer VF. This is below the detection threshold for therapy for both VT (2.5 Hz = 150 beats/min) and VF (approximately 3.33 Hz = 200 beats/min). The variation between coarse and fine VF was not detected by the WCD (Figure 5).

The WCD uses the TruVector detection algorithm that was developed and validated by ZOLL LifeVest (2). The detection algorithm uses a combination of the following:

ABBREVIATIONS AND ACRONYMS

FFT = fast Fourier transformation

ICD = implantable cardioverter defibrillator

s/p = status post

VF = ventricular fibrillation

VT = ventricular tachycardia

WCD = wearable cardioverter defibrillator

FIGURE 1 Transesophageal Echocardiogram With Approximately 1-cm Lead Vegetation

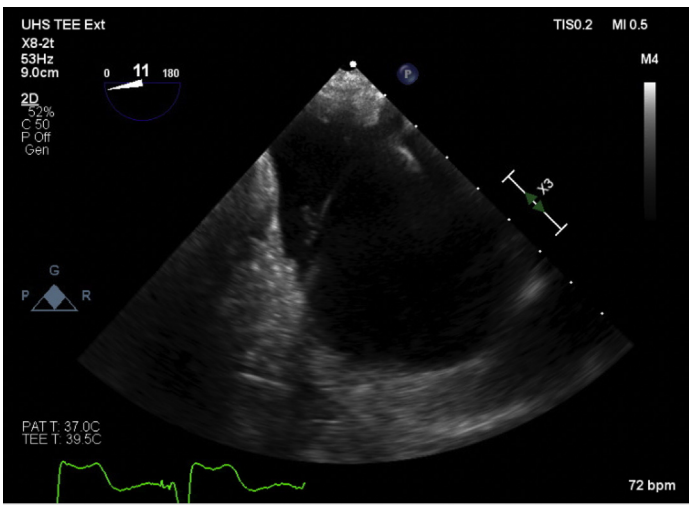
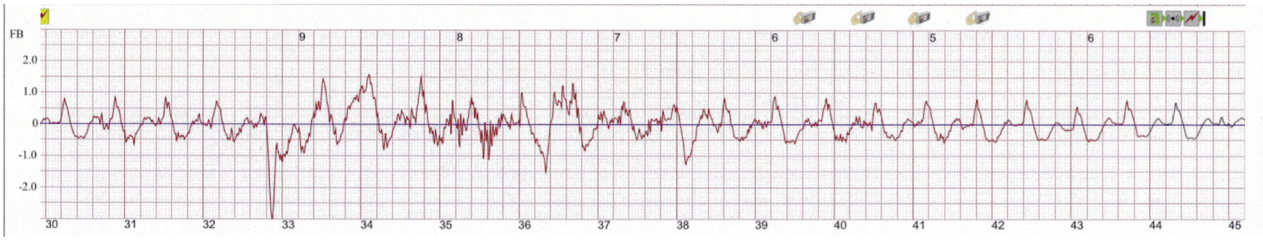


FIGURE 2 Artifact Detected as VT by WCD



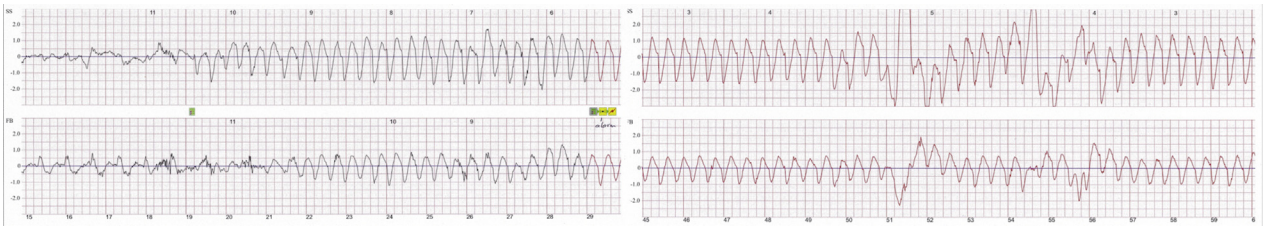
Red tracing symbolizes detection of arrhythmia by the device and alarms going off. **Black tracing** denotes intrinsic rhythm as determine by the device. FB = front to back vectors; VT = ventricular tachycardia; WCD = wearable cardioverter-defibrillator.

1. Heart rate (using a 4-electrode and 2-lead system positioned circumferentially at the level of the xiphoid process, front to back and side to side).
2. Morphology analysis (based on the baseline template of the patient's vectorcardiogram). Failure to match the real-time vectorcardiogram with the baseline morphology templates suggests that a treatable arrhythmia exists. If a match occurs, then the device simply continues to monitor the patient.
3. Fast Fourier transformation (FFT), which decomposes an analog waveform into its frequency components to be able to determine the fundamental or dominant frequency indicative of the heart rate. FFT analysis often provides the best indication of heart rate and is best for detection of heart rate in VF due to its sinusoidal characteristics.
4. Advanced arrhythmia discrimination, which discriminates electrocardiogram patterns caused by physiological arrhythmias from patterns caused by nonphysiological signals to determine treatable arrhythmias.

The TruVector algorithm applies logical weight based on comparing leads, signal quality, and historic rate values to determine the best inputs to accurately monitor the patient's heart rate. If there is interference or poor contact of the electrode with the skin, then less diagnostic weight is applied to these inputs, and other factors are used to determine the presence or absence of an arrhythmia. Aborting the shock by using response buttons lowers the confidence of the device to detect that arrhythmia (2).

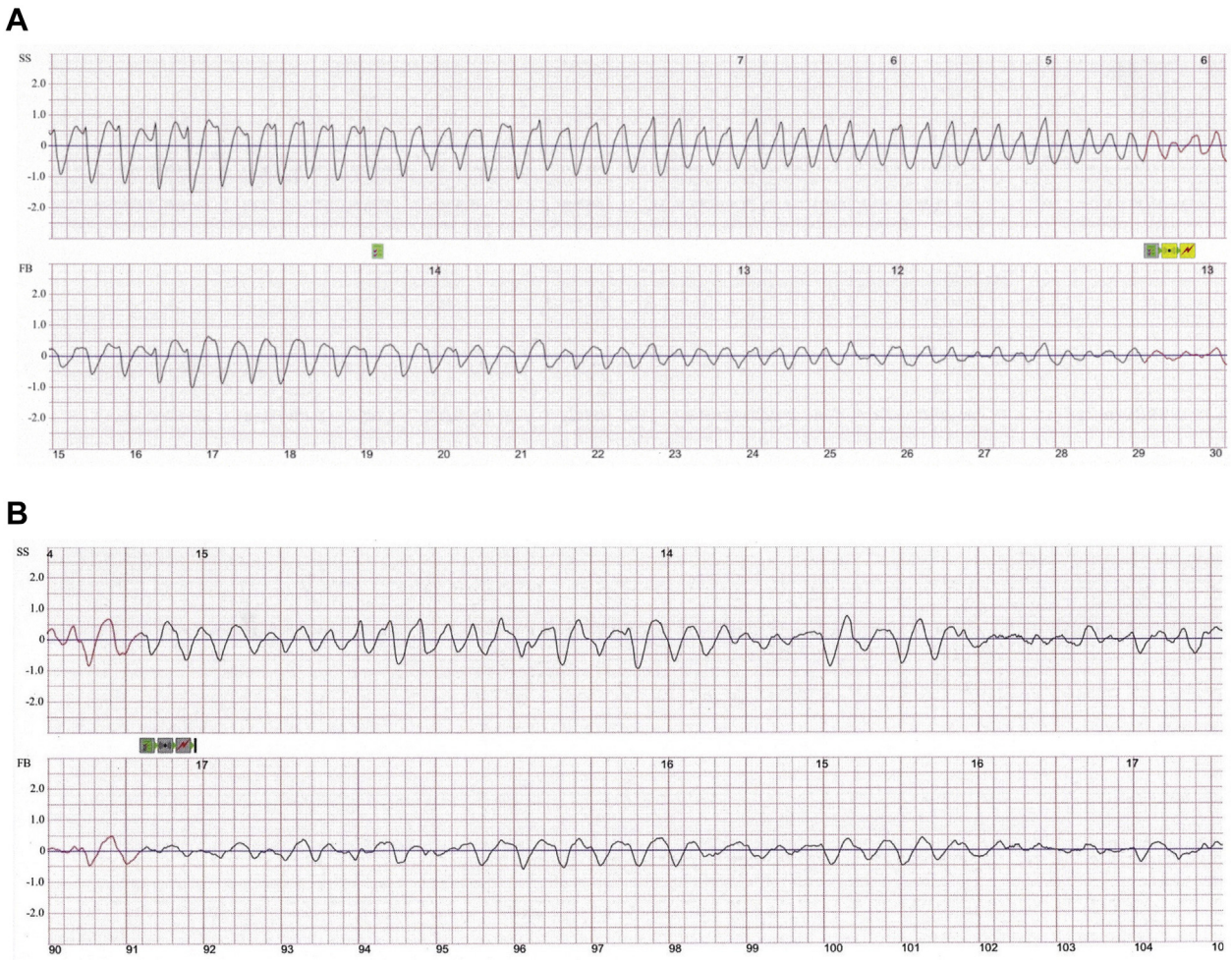
In our case, the patient first had an inappropriate detection that led to use of response buttons, which could have affected the confidence of the rhythm subsequently being detected. At 8:26 PM the patient went into true VT and the device detected it; however, the rate hovered around 150 beats/min and fell out of detection. Although the VT was sustained, it was not detected again until 8:29 PM, when the rhythm degenerated into VF. However, the device detected the VF as VT with rate again hovering around 150 beats/min as detected by the device. Both heart rate and morphology are required by the device to detect an arrhythmia. Although

FIGURE 3 Onset of Sustained VT



FB = front to back vectors; SS = side to side vectors; VT = ventricular tachycardia.

FIGURE 4 Under Detection of VF



(A) Deterioration of ventricular tachycardia (VT) into coarse ventricular fibrillation (VF). **(B)** Underdetection of VF. FB = front to back vectors; SS = side to side vectors.

morphology was different since the device rate was determined to be lower than 150 beats/min, the device did not shock. Here the algorithm used FFT rather than direct heart rate detectors. The individual heart rate detectors were worse, as they function better with sharp peaks. The FFT determined the HR to be <150 beats/min. The unstable rate led to a delay in detection, and eventually the "best" rate (detected during the coarse VF) was determined to be below the threshold.

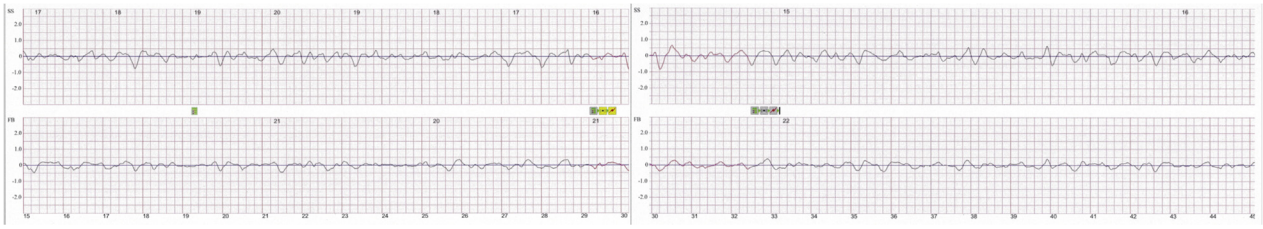
FOLLOW-UP

Unfortunately, the WCD failed to deliver a shock, culminating in the patient's death.

CONCLUSIONS

This is a tragic case of borderline VT deteriorating into coarse and fine VF that led to WCD failure to deliver life-saving therapy. WCD does have a role in the prevention of ventricular arrhythmias and is certainly a tool that is used in practice. However, physicians need to be aware that the WCD specificity for VF detection may not be 100%, and patients should be educated on this rare possibility of failure to detect. This case highlights the need for better or revised algorithms for arrhythmia detection to tackle these kinds of scenarios that are currently being missed.

FIGURE 5 Coarse and Fine VF



FB = front to back vectors; SS = side to side vectors; VF = ventricular fibrillation.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

Dr. Panday has served as a consultant for Biotronik; and is a member of the Speakers Bureau of Bristol Myers Squibb, Janssen, Pfizer, and Sanofi. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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REFERENCES

1. Al-Khatib SM, Stevenson WG, Ackerman MJ, et al. 2017 AHA/ACC/HRS guideline for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: A report of the American College of Cardiology/American Heart Association Task Force on clinical practices guidelines and the Heart Rhythm Society. J Am Coll Cardiol 2018; 72:e91–220.

2. LifeVest® TruVector™ Arrhythmia Detection Algorithm. Available at: https://zolllifevest.showpad.com/share/FMNGa93oNlBeP6FTMoRi4/0. Accessed May 11, 2020.

3. ZOLL LifeVest®. FDA Operator Manual. Available at: https://www.accessdata.fda.gov/cdrh_docs/pdf/P010030S056d.pdf. Accessed May 11, 2020.

4. ZOLL LifeVest®. Physician Brochure. Available at: https://ohiopa.com/aws/OAPA/asset_manager/get_file/81823/20c0019revh_physician_brochure.pdf. Accessed May 11, 2020.

KEY WORDS TruVector detection algorithm, ventricular fibrillation, ventricular tachycardia, wearable cardioverter defibrillator