Repetitive ineffective shock delivery with max 6 joules of a wearable defibrillator during ventricular fibrillation with lethal consequences

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Introduction

Despite the high rate of sudden death after myocardial infarction among patients with a low ejection fraction, implantable cardioverter-defibrillators (ICD) are contraindicated until 40–90 days after myocardial infarction.[1,2] To fill this potentially dangerous gap, the wearable defibrillator is an available option. Wearable defibrillators have been shown to reduce mortality in patients with a recent myocardial infarction and a left ventricular ejection fraction of 35% or less.[3–6]

Case report

A 67-year-old, single male patient with no pre-existing medical conditions was admitted to the hospital and immediately transferred to the catheterization lab under continuous cardiopulmonary resuscitation including external defibrillation for ventricular fibrillation (VF). After return of sinus rhythm, an acute anterior myocardial infarction (ST-segment elevation myocardial infarction) was diagnosed and immediate coronary revascularization of the culprit lesion was performed using the T and small protrusion technique (percutaneous coronary intervention of the left anterior descending and D1 arteries) (Figure 1). After 3 weeks of hospitalization, including initial therapeutic cooling (target temperature of 34°C for 24 hours) and invasive ventilation during the first week, a severely reduced left ventricular ejection fraction of 24% was diagnosed by echocardiography. Nineteen days after primary percutaneous coronary intervention, a second-look coronary angiography was performed using optical coherence tomography for intravascular imaging. Owing to slight underexpansion of the proximal part of the left anterior descending stent, a post-dilatation was performed. A residual 70%–80% stenosis of the medial circumflex artery and the proximal right coronary artery was left natively for the time being. The discharge electrocardiogram (ECG) showed complete left bundle branch block (Figure 2). The patient was discharged with optimal medical treatment for heart failure owing to ischemic cardiomyopathy and a wearable defibrillator (LifeVest®; ZOLL, Chelmsford, MA) was fitted after regular in-hospital patient training provided by the company. Within the first week after discharge, the patient contacted our department because he was having much trouble with the wearable cardioverter-defibrillator (WCD), which led to further outpatient training by the company within 48 hours of the complaint. Subsequently, WCD wear times of >22 hours per day were continuously documented.

Six weeks later, another planned coronary angiography was performed, which showed a hemodynamically relevant stenosis of the proximal right coronary artery (fractional flow reserve 0.77), which was also treated with drug-eluting stents. The circumflex artery was left unchanged owing to the small vessel caliber. The wearable defibrillator was extended for a further 8 weeks.

Four days before a planned final outpatient cardiology visit to determine whether or not an ICD was indicated, the patient called the hotline of the company that distributed the wearable defibrillator to report a gel leak from the vest. As a data transmission had failed, the patient was advised to promptly go to the hospital owing to a possible previous treatment of the vest. The patient refused ambulance transport and told the hotline that his neighbor would take him to the hospital. A day later, follow-up calls to the patient, the patient's brother, the patient's neighbor, and the hospital were unsuccessful. Sixteen hours after the patient's first contact with the hotline, he died at home.

Retrospective analysis of the vest's data showed a primary effective treatment for VF, which correctly resulted in gel leakage from the vest (Figure 3). The technical report furthermore revealed a high impedance 15 hours after this initial treatment, which triggered an acoustic request to reapply gel. This warning is repeated every 13 minutes until the problem is resolved, the battery is empty, or the battery is

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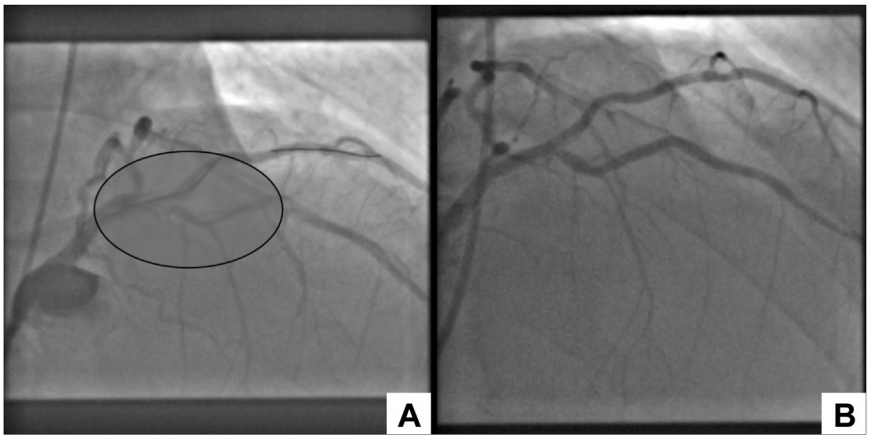

Figure 1 **A:** Coronary angiography with subtotal occlusion of left anterior descending (LAD) and D1 arteries with intravascular thrombus. **B:** Coronary angiography after percutaneous coronary intervention and drug-eluting stent implantation in LAD and D1.

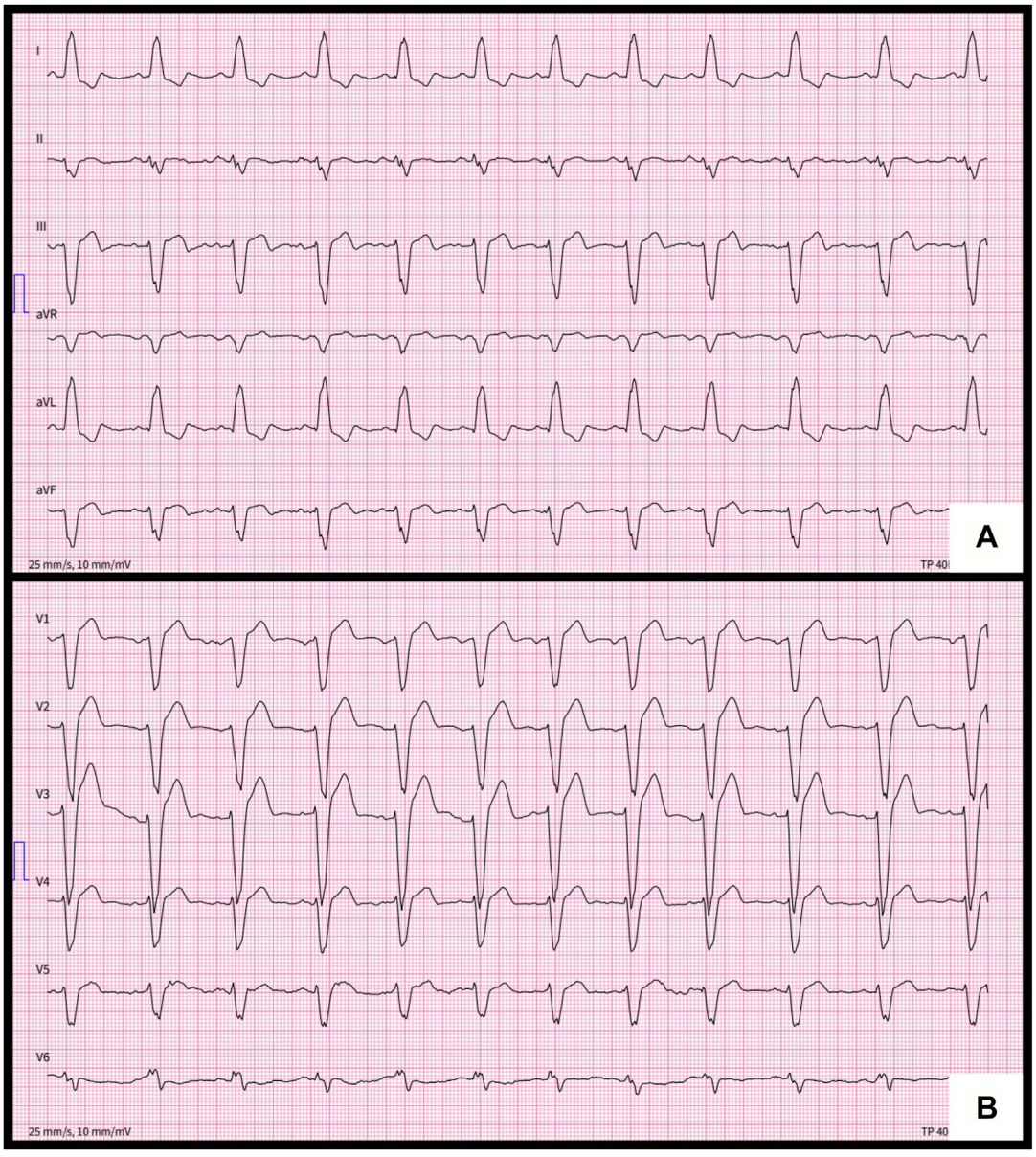

Figure 2 **A, B:** Electrocardiogram at discharge showing a sinus rhythm 69 beats/min, left axis deviation, and complete left bundle branch block.

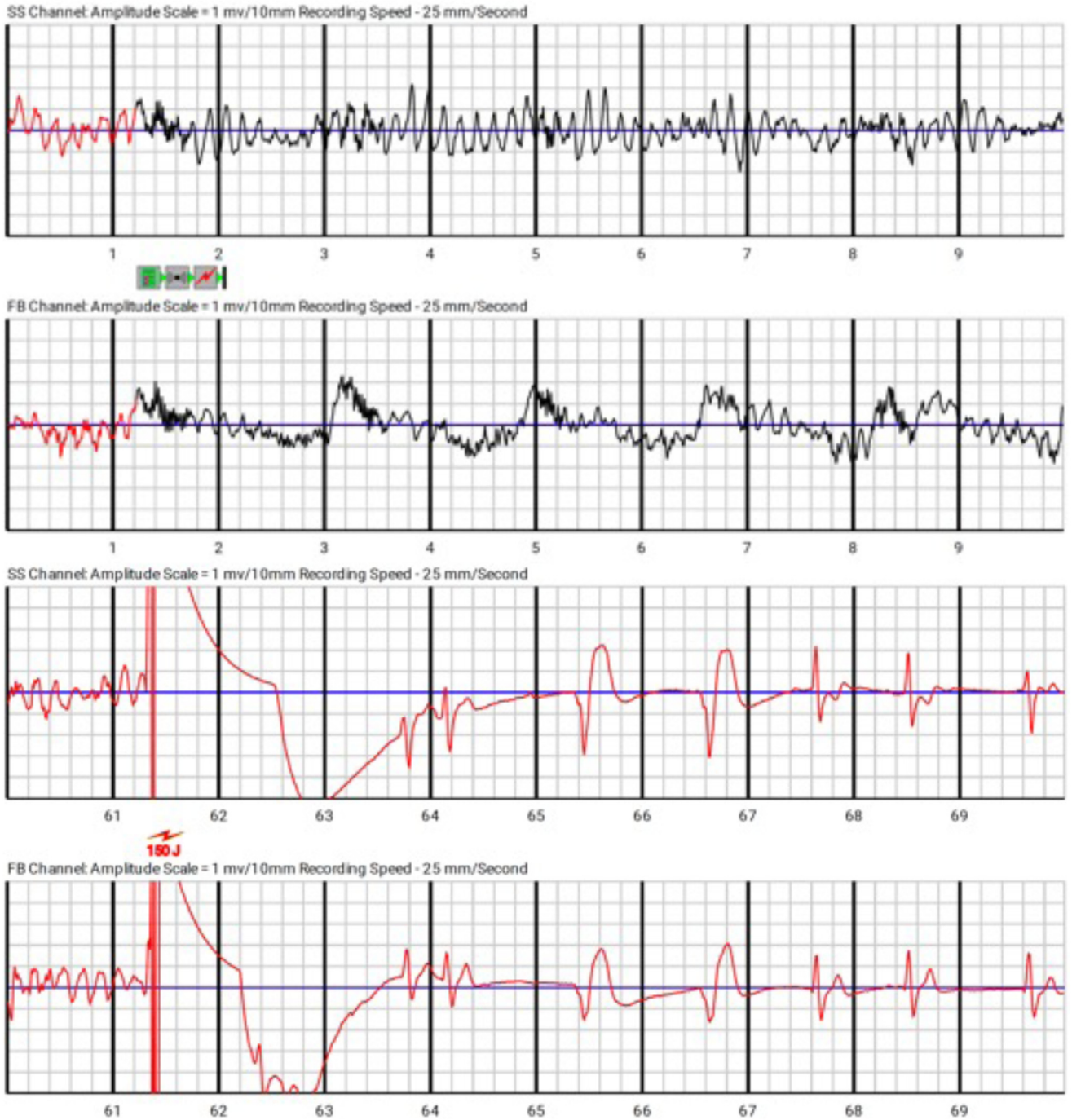

Figure 3 Ventricular tachycardia: rate 150 beats/min (60-second response time); therapy 5 × 150 J. Ventricular fibrillation: rate 200 beats/min (25-second response time); therapy 5 × 150 J. Duration 100 seconds, time to first shock: 31 seconds.

disconnected, resulting in a total system shutdown. In this particular case, the alarm was repeated for 14 hours, interrupted by several battery disconnections by the patient. Exactly 1 minute after the last alarm, VF recurred owing to an R-on-T phenomenon, which was again correctly detected by the vest. Subsequently, 5 shocks of 4–6 joules were delivered, all of which were ineffective (Figure 4), resulting in monitored sudden cardiac death. The patient died 3 days before the planned final outpatient appointment to re-evaluate the cardiac function and consider the indication of a cardiac resynchronization therapy-defibrillator.

Discussion

To our knowledge, this is the first reported case of a WCD with ineffective shock treatment due to low energy output.

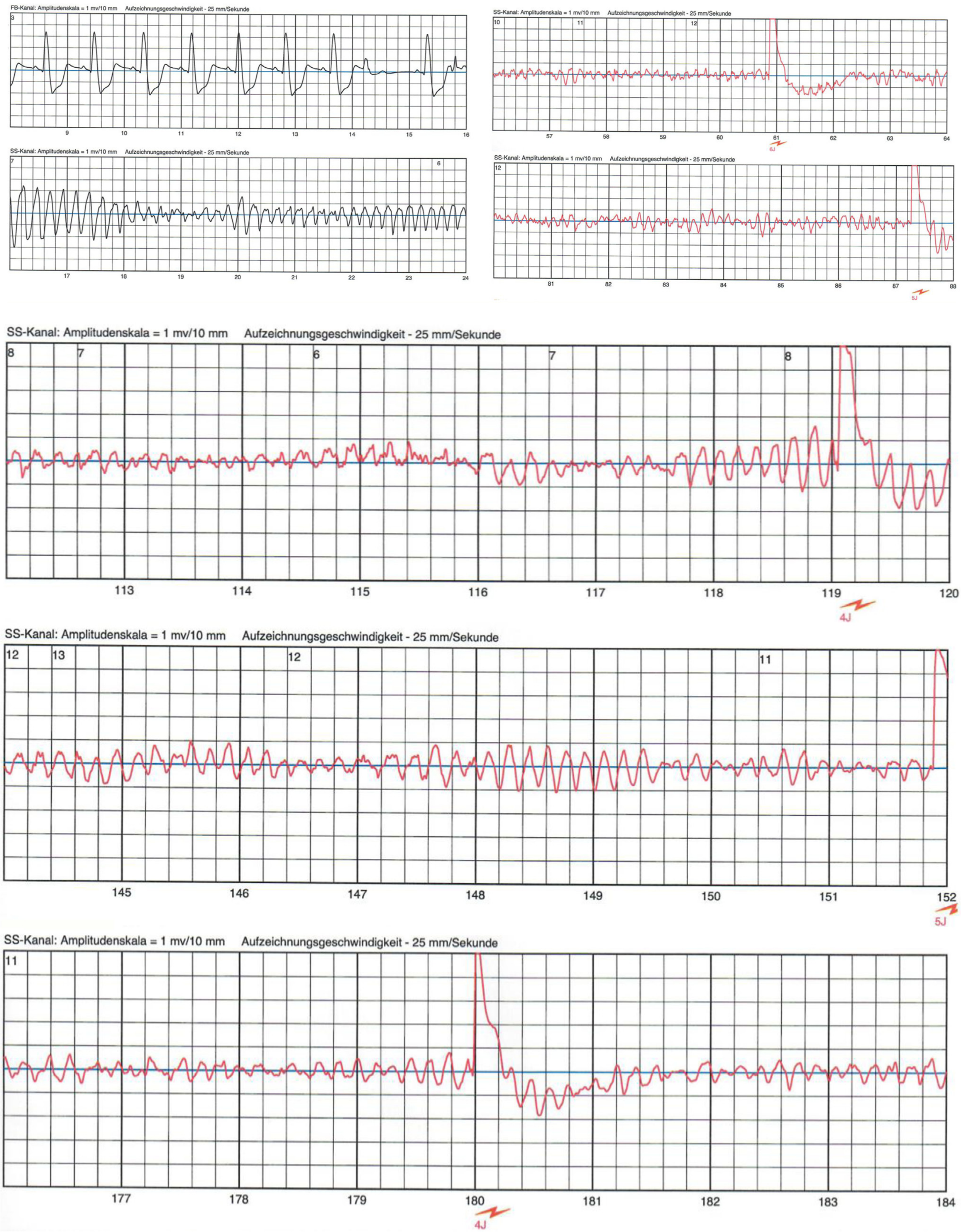

Figure 4 Ventricular tachycardia: rate 150 beats/min (60-second response time); therapy 5 × 150 J. Ventricular fibrillation: rate 200 beats/min (25-second response time); therapy 5 × 150 J. Duration 195 seconds, time to first shock: 31 seconds.

The technical software function of the WCD was in good order in this particular case, since the detection of the VF and the treatment were performed adequately and promptly, as programmed. Since electrotechnically the current is directly proportional to the energy produced—if the voltage is constant—it is well explicable that a large increase in impedance leads to an inversely proportional reduction in current and, therefore, energy. As soon as the gel dries on the skin, which starts after 1 hour, the impedance begins to rise, eventually leading to ineffective shock delivery despite a full battery. Bridging the time to stationary monitoring is achieved by applying fresh gel and is strongly recommended. Alternative skin impedance–reducing substances such as shower gel, shampoo, or ultrasound gel will also work.

The WCD is a semiautomatic device and its proper functioning depends on the patient's interaction. It is therefore essential to critically reflect on the patient's cognitive abilities and compliance before prescribing. It is confirmed that despite double and intensive primary training of the patient and further verbal feedback by telephone after the first shock, it was not enough to save the patient's life.

Nevertheless, future patient safety will improve as patients' understanding of their underlying condition improves. We therefore proposed the idea of sending the ECG of a life-saving shock to the patient's private e-mail address, in addition to the acoustic signals from the vest and the telephone calls from the company's hotline. The visualization of a survived sudden cardiac death could have a major impact on a patient's understanding and therefore action.

An ICD would probably have prevented this particular event, which occurred 171 days after the myocardial infarction. This time span seems long and is due to, among other factors, the 2-stage revascularization strategy, which is a reasonable approach according to recent evidence in patients with ST-segment elevation myocardial infarction and multivessel disease.[7] In addition, supporting the idea of an extended time span of the WCD along with the PROLONG trial, we aimed to avoid untimely ICD implantation, while allowing left ventricular reverse remodeling during intensified medical heart failure therapy in cooperation with the revascularization therapy.[8]

Conclusion

The time to hospital admission after gel leakage is critical. As soon as the gel dries on the skin, which starts after 1 hour, the impedance begins to rise, eventually leading to ineffective shock delivery despite a full battery. Patients, paramedics, nurses, and physicians need to be aware that a wearable defibrillator should be considered as a single-shot device, not designated for repeated therapy delivery, even if the battery life is acceptable. As a consequence, in routine clinical practice, eg, in the emergency department, a patient suspected of having received a shock from a WCD should be monitored directly with an ECG and recurrent ventricular tachycardia/fibrillation should be treated with an external defibrillator, and the WCD should not be relied upon for further treatment.

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