

SPOTLIGHT

“Carryover phenomenon” in subcutaneous implantable cardioverter-defibrillator: Residual energy caused early shock to subsequent ventricular tachycardia

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A 67-year-old man with dilated cardiomyopathy, low left ventricular ejection fraction (17%), and chronic heart failure with New York Heart Association functional classification II despite optimal medical therapy was referred to our hospital. Asymptomatic non-sustained ventricular tachycardia (VT) was observed but was infrequent. Other medical history of the patient included atrial fibrillation and postoperative transcatheter mitral valve repair (MitraClip®, Abbott Vascular, IL, USA) for severe mitral regurgitation. The patient had no history of sustained VT and bradycardia requiring pacing therapy; thus, he underwent subcutaneous implantable cardioverter-defibrillator (S-ICD) implantation surgery for primary prevention. S-ICD (S-ICD®, Boston Scientific, Marlborough, MA, USA) surgery was successfully performed; however, heart failure worsened because of intraoperative infusion for hypotension caused by general anesthesia. The conditional shock zone was 190 beats per minute (bpm), the shock zone was 250 bpm, and there were no problems with sensing.

Three days after implantation, a shock was delivered to the VT. There were two VTs within a short period. The first VT (VT1) was 214 bpm and spontaneously terminated 12 s later. The subsequent VT (VT2; following approximately 2 min after VT1) was 231 bpm, sustained for 9 s, and shock was delivered (Figure 1). The shock terminated VT2; however, the interval between the initiation of VT2 and the shock was short. The patient was asymptomatic both during VT1 and VT2, and conscious during the shock to VT2. We immediately performed an interrogation. The VT1 cycle length met the

conditional shock zone, and a shock charge was initiated; however, the shock was aborted because VT1 spontaneously terminated (Figure 2). In VT2, after SMART charge was activated, charge for shock was initiated, and shock was finally delivered, followed by approximately 2.4 s of charge time (Figure 3). We interpreted this phenomenon as the first charge during VT1 remaining in the capacitor of the S-ICD and carried over for VT2. We changed the detection rate (the conditional shock zone setting from 190 to 220 bpm) to bail out and monitored the electrocardiogram (ECG) carefully, prescribed amiodarone 200 mg/day, and continued optimal medical therapy for heart failure, after which the patient was discharged. After 10 months, the patient had neither syncope, ventricular high-rate episodes, nor shocks.

The charge time from 0 to 80 J is clearly stated in the Boston S-ICD user's manual as 10 s or less in the state of BOL (refers to the beginning of life). However, in the present case, the charge time in VT2 was approximately 2.4 s and was short (Figure 3).

This early shock was interpreted as that the first charge during VT1 carried over to VT2. To the best of our knowledge, very few reports have focused on the short charge time caused by high residual energy on the capacitor after previously aborted shocks, including both transvenous ICD and S-ICD. Advanced ICD Troubleshooting Part II was the only report on the short charge time caused by residual energy¹; however, the short charge time was not considered the main theme and a clinical problem. Herein, we present a case of early shock caused by residual energy, and the patient remains conscious during shock.

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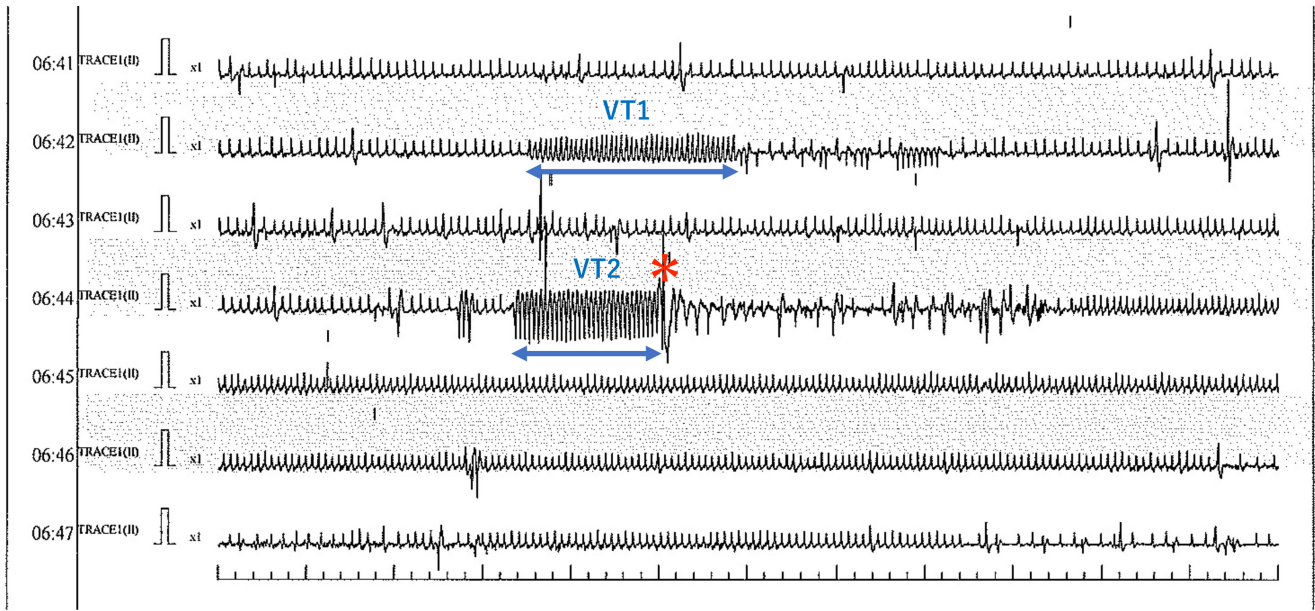


FIGURE 1 Two VTs were captured by monitor ECG. The first VT (VT1) was 214bpm and terminated spontaneously 12s later. The second VT (VT2), following 2 min after VT1, was 231bpm, sustained for 9 s, and shock was delivered (red asterisk). ECG, electrocardiogram; VT, ventricular tachycardia

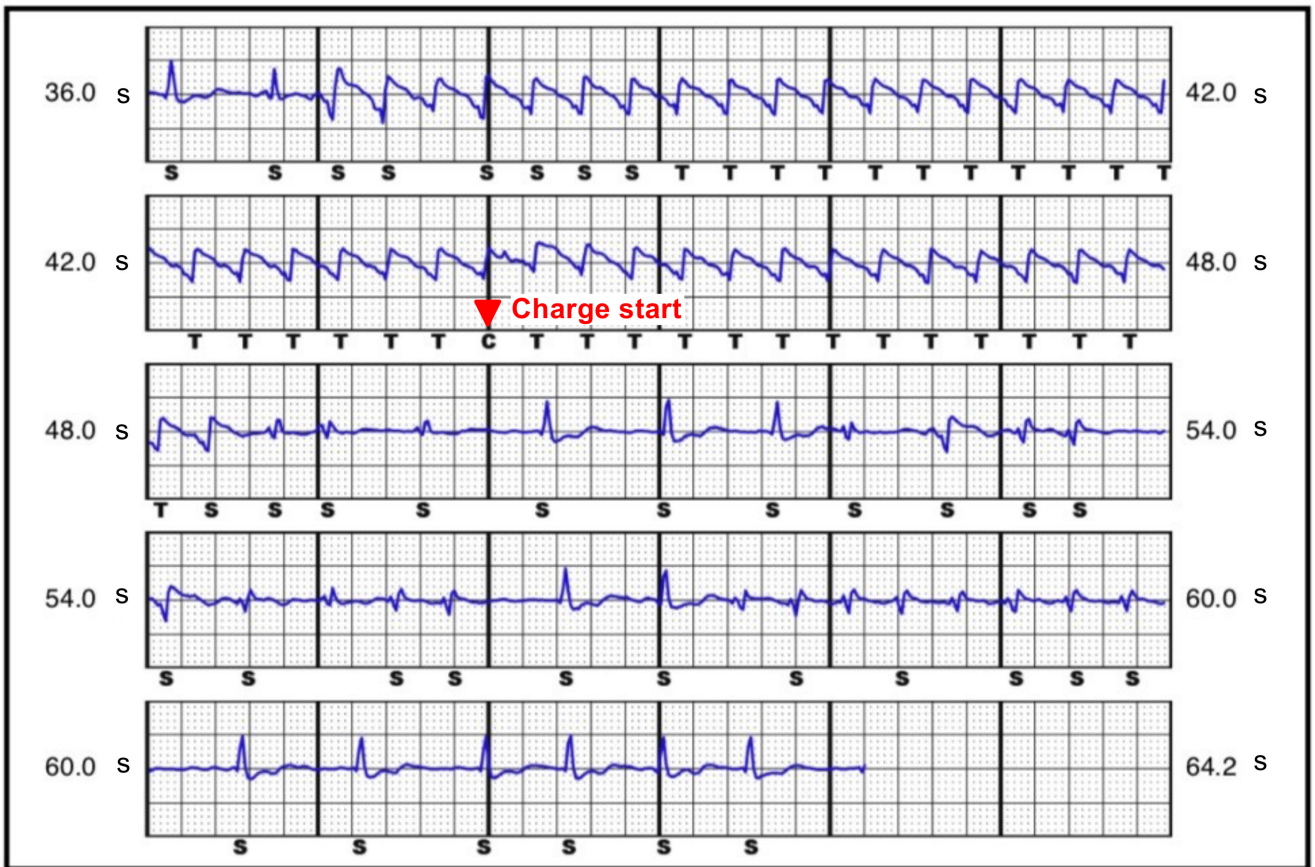


FIGURE 2 Intracardiac ECG shows initiation of charge for shock (red triangle). The charge was started and automatically charged up to the maximum of 80J. From there, re-confirmation period was started, and 24 consecutive intervals longer than the conditional shock zone plus 40ms have been met (abort criterion) because of spontaneous termination of VT1. ECG, electrocardiogram; VT, ventricular tachycardia

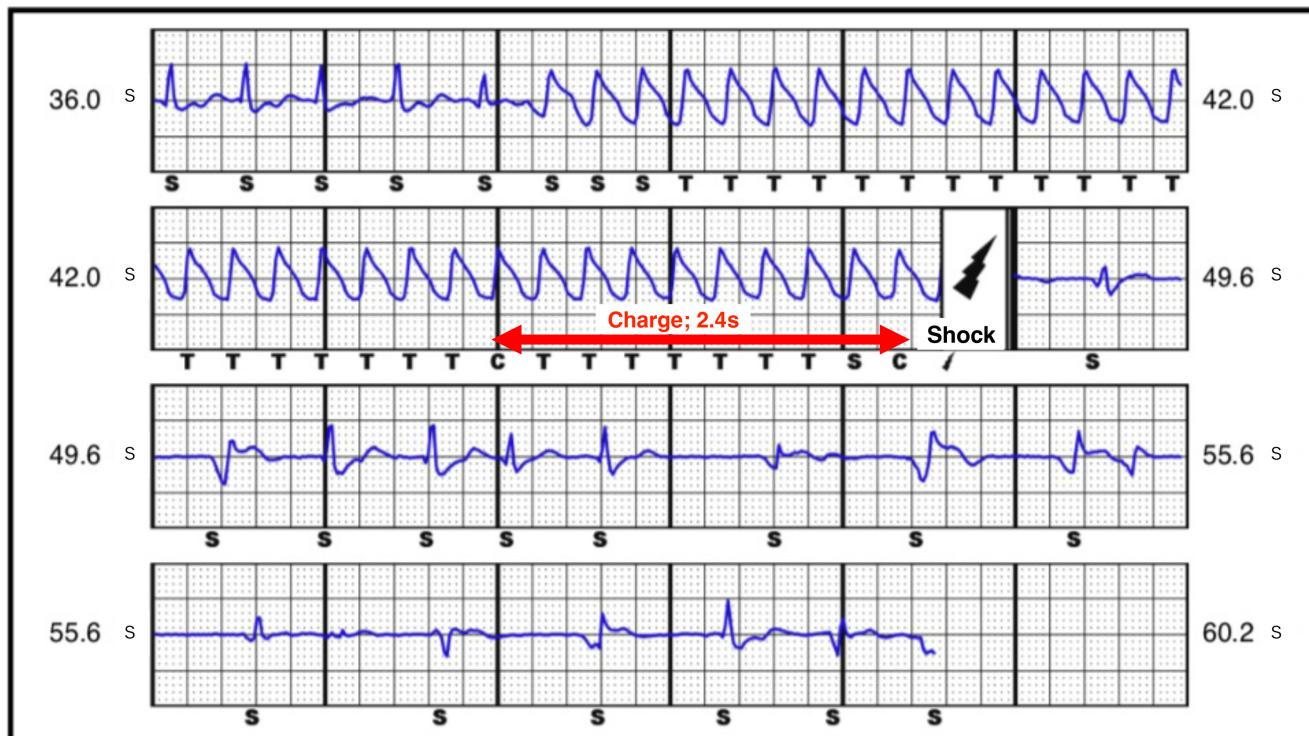


FIGURE 3 Intracardiac ECG shows that the S-ICD shock terminated VT2 with short charge time (approximately 2.4 s; red arrow between the first “C” and second “C.” this is not a pure charge time because the second “C” does not mean complete charge, but the discharge criteria have been met. Therefore, the actual charge time was even shorter than this). ECG, electrocardiogram; S-ICD, subcutaneous implantable cardioverter-defibrillator; VT, ventricular tachycardia

Possible countermeasures to this phenomenon were as follows: (1) device setting and indication for S-ICD, (2) medication (antiarrhythmic drug), (3) optimal medical therapy for heart failure, and (4) catheter ablation (CA) for VT.

For this patient, because the past non-sustained VT rate was 150 bpm and he had a severely low left ventricular ejection fraction, the original conditional shock zone setting was 190 bpm. However, VT1 (214 bpm) caused capacitor charging and self-termination; thus, this phenomenon occurred. “Carryover phenomenon” can also occur in transvenous ICD. However, the number of intervals to detect is programmable in transvenous ICD, while it is non-programmable in S-ICD. Moreover, the SMART charge function can be reset, but cannot be activated manually. Because the limited measures to avoid the “Carryover phenomenon” may lead to more clinical problems in S-ICD, in cases where non-sustained VTs occur frequently, the indication for S-ICD surgery should be considered carefully.

A previous study on high-rate cut-off (220 bpm) shock-only programming in primary prevention patients with reduced left ventricular ejection fraction reported a low rate of discharge, and a possibility of safety during a long-term follow-up.² It cannot be determined whether VT2 which was documented after surgery was non-sustained or sustained VT because of the early shock of S-ICD. In terms of secondary prevention, HRS/EHRA/APHRS/LAHRs recommends setting the VT detection rate at 10–20 bpm lower than the documented VT rate. Of the VTs observed after surgery, VT1 (214 bpm) was spontaneously terminated. Because ICD shock was

delivered to VT2 (231 bpm), the modified conditional shock zone was set 10 bpm lower than the VT2 rate (220 bpm) according to the recommendation. This is also valid as evidence for primary prevention.

Anti-tachycardia pacing (ATP) with transvenous ICD is known to be an effective tool for terminating VTs,³ however, in this present case, there was no history of sustained VT before the operation, and non-sustained VT was infrequent. Because the “Carryover phenomenon” was no longer observed by the countermeasures described in the discussion section, we decided not to change to transvenous ICD in this present case. In cases where the “Carryover phenomenon” is unavoidable in the S-ICD despite various countermeasures, changing to a transvenous ICD with delayed therapy and ATP function is one of the treatment options.

S-ICD is incapable of monitoring arrhythmias with a slower rate than the conditional shock zone setting. However, in this present case, all the documented VTs that were slower than the modified conditional shock zone setting were terminated spontaneously. Furthermore, there was no history of syncope, hence the indication of implantable loop recorder (ILR) in Japan was not met at this time. Because there is no difference between S-ICD and transvenous ICD in terms of preventing sudden cardiac death in the literature,⁴ we decided to observe the patient without an additional monitoring device. In case of syncope in the future, the addition of an ILR or a change to a transvenous ICD should be considered.

CA was not performed because the VTs were pleomorphic in the present case. Finally, we changed the detection rate, started

prescribing amiodarone, and continued optimal medical therapy for heart failure.

In summary, we presented a case of early S-ICD shock due to a carryover of previously charged energy. Depending on the interval with the preceding event, an early shock may occur for the subsequent event. Especially, in cases where non-sustained VTs occur frequently, the indication for S-ICD surgery should be considered carefully.

CONFLICT OF INTEREST

The authors declare no conflict of interests for this article.

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