DEVICE ROUND

Failure of an Implantable Cardioverter Defibrillator to Terminate Ventricular Tachycardia: Why?

LETIZIA CONTI, M.D., NAM TRAN, M.D., HARAN BURRI, M.D.,
and MARC ZIMMERMANN, M.D.
From the Cardiovascular Department, Hôpital de la Tour, Meyrin-Geneva, Switzerland

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Case Report

A 69-year-old man with a history of coronary artery bypass grafting for severe three-vessel coronary artery disease underwent the implantation of a cardioverter defibrillator with cardiac resynchronization (CRT-D) for reduced left ventricular ejection fraction (LVEF) (EF 25%) associated with clinical signs of heart failure (New York Heart Association class III) in December 2005. A three-chamber implantable cardioverter defibrillator (ICD) (Insync Sentry 7298, Medtronic Inc., Minneapolis, MN, USA) was implanted and the improvement of heart failure occurred during the following months despite the development of permanent atrial fibrillation in October 2006. The device was programmed with a ventricular tachycardia (VT) zone of 171–188 beats/min (350–320 ms) and a ventricular fibrillation (VF) zone of 188–500 beats/min (320–120 ms). The counter for VT detection was set at 16 intervals and for VF at 12/16. In the VT zone, the programmed therapy consisted in two antitachycardia pacing protocols (burst and ramp +; three sequences each) followed by cardioversion with 35 J. In the VF zone, therapy consisted of defibrillation at 35 J. Criteria for supraventricular tachycardia discrimination were activated because of persistent atrial fibrillation; pacing mode was VVIR 70–120 beats/min; sequential biventricular pacing was programmed with left ventricular preexcitation of 20 ms. The patient was not taking any antiarryhthmic medication except for β-blockers.

In February 2009, the patient was admitted to the hospital for bronchopneumonia. On day 5, he experienced two successive internal shocks with malaise but without loss of consciousness. Shortly thereafter, he complained of palpitations, severe shortness of breath, sweating, and malaise. Pulse rate was 173 beats/min and blood pressure 70/45 mmHg. An electrocardiogram (ECG) was performed (Fig. 1) and the patient was rapidly transferred to the intensive care unit where external cardioversion (150 J, biphasic) promptly restored sinus rhythm. Interrogation of the device revealed that the first shock was adequate, applied for a regular rapid VT at a cycle length of 310 ms (194 beats/min). This first shock also converted atrial fibrillation into sinus rhythm. The second shock was applied for a rapid regular VT at a cycle length of 320 ms (188 beats/min). Why was the third VT shown of Figure 1 not correctly treated by the device?

The first explanation could be the rate programmed in the VT zone. However, the clinical VT was slightly faster (173 beats/min or 345 ms) than the lower limit for delivering therapy in the VT zone (171 beats/min or 350 ms).

Interrogation of the device showed that the third episode of VT was initially regular (cycle length 340 ms or 176 beats/min); the second burst applied during VT transformed the regular VT into an irregular VT with cycle length alternans (310 ms alternating with 380 ms, Fig. 2). This cycle length alternans prevented the arrhythmia from fulfilling the programmed criteria for intervention [300 ms classified as VF; 380 ms classified as ventricular sense (VS); impossibility to obtain 12/16 VF cycles, Fig. 2B]. Immediately after device interrogation, parameters were reprogrammed in order to avoid underdetection (VT detection set at 154–188 beats/min or 390–320 ms) and follow-up was uneventful.

Discussion

Sustained monomorphic VTs related to reentrant circuits are usually stable, at least after the first 4 seconds, but some irregularities in cycle length have been observed in 10 to 20% of cases.[1] The cause of cycle length irregularities during monomorphic VT is unclear, but cycle length alternans as in this report may be related to the presence of two different exit sites in the reentry circuit[2] or to double wave reentry.[3] In the present case, cycle length alternans was not spontaneous

Address for reprints: Marc Zimmermann, M.D., Cardiovascular Department, 1 Av. J.-D. Maillard, Hôpital de la Tour, CH-1217 Meyrin-Geneva, Switzerland. Fax: 41 22 785-18-63; e-mail: zimmermann.family@bluewin.ch

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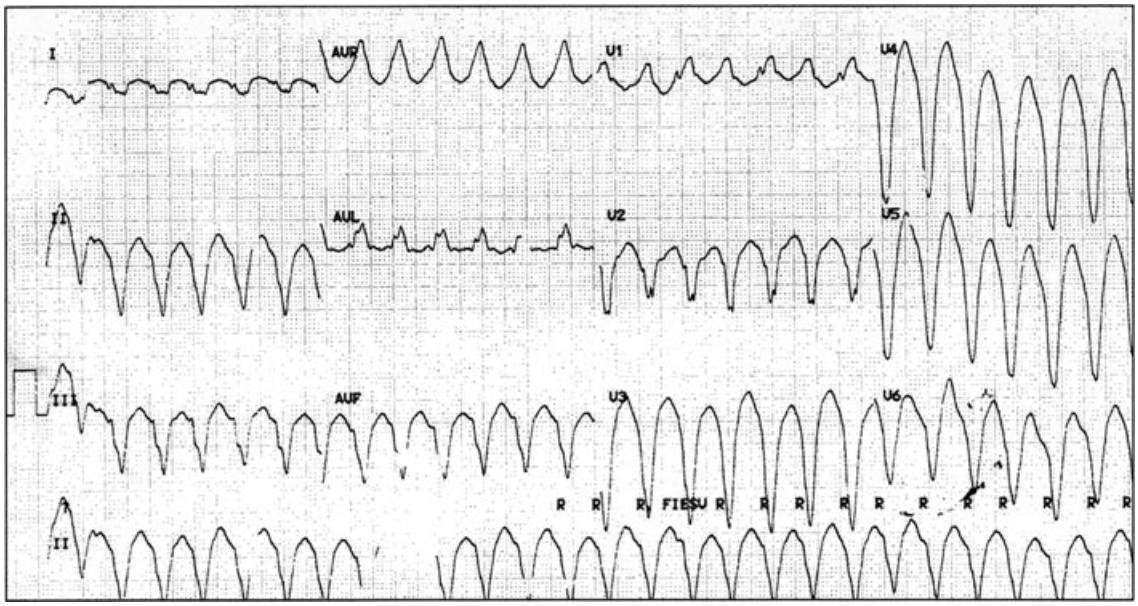

Figure 1. *Clinical tachycardia: broad complex tachycardia, at a rate of 173 beats/min, with a QS pattern from V2 to V6, an atypical right bundle branch pattern in V1, an R wave in aVR with an electrical axis at -100°. According to usual ECG criteria the tachycardia is ventricular in origin. QRS morphology and cycle length alternans are best appreciated in lead V1.*

but was induced by burst pacing during a regular monomorphic VT, possibly because rapid pacing favored alternating exit sites in the reentry circuit. Antiarrhythmic drugs may also influence RR stability during VT but in the present report, the patient was not taking any antiarrhythmic agent apart from β-blockers.

Underdetection of irregular VTs may be disastrous because adequate therapy may be delayed or even withheld.[4] Studies such as Primary Prevention Parameters Evaluation Study (PREPARE)[6] advocate for programming zones with relatively short intervals for VT treatment in patients with primary prevention, in order to avoid inappropriate shocks. However, our case illustrates the importance of also programming a monitoring zone to detect slower VTs in these patients. Rate limits for VT detection and treatment should be carefully programmed (or reprogrammed) in order to avoid alternans in the detection as in the present case and the VT detection interval should be set at least 40–50 ms longer than the slowest predicted VT.[5] Programming the stability criterion may also influence underdetection of VT when RR irregularities are present and special attention should be paid when this parameter is programmed in patients with irregular VTs. Stability criterion of 50–60 ms combined with 12–14 RR intervals is able to detect over 90% of irregular VTs[1] but exceptions to this rule may exist[6,7] as shown in the present case. Supra-ventricular tachycardia (SVT) discrimination algorithms may sometimes lead to underdetection of VT [e.g., VT with 1:1 retrograde conduction and long ventriculoatrial (VA) intervals mimicking SVT]. However, this was not an issue in the present case with VA dissociation. Our report also illustrates how an ICD can miss an arrhythmia with obvious VA dissociation, due to the rate criterion not being met.

Medtronic devices require a prespecified number of consecutive intervals (16 in our patient) to fall within the VT zone in order for VT to be detected. Thus a single longer interval will reset the counter to zero. Would a device from another manufacturer have correctly identified VT in our patient with the same programmed zones? Boston Scientific devices (Boston Scientific, Natick, MA, USA) require that three consecutive fast intervals be detected in order to initiate analysis, with a "sliding window" probabilistic counter that functions during a predefined duration for tachycardia detection.[8] As three consecutive fast intervals were not detected in our patient, VT would not have been identified. St. Jude devices (St. Jude Medical, Sylmar, CA, USA) on the other hand use a binning system in which VT counters keep on incrementing as long as five sinus intervals are not detected (this may be programmed between three and seven intervals). A fast interval will be binned as VT if the average of the current and three last intervals is shorter than the VT interval.[8] In our patient, this average would be 340 ms (i.e., mean

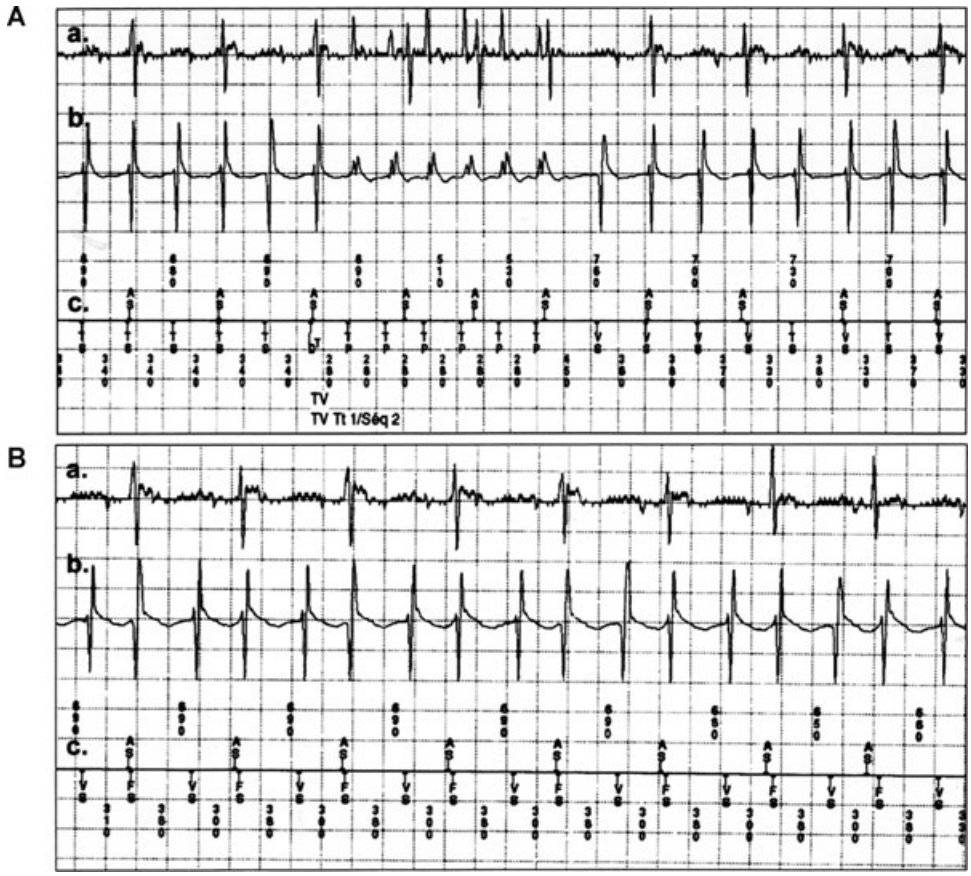

Figure 2. *(A): Intracardiac recordings and markers during the third episode of VT. (a) Recording from the atrium showing normal sinus rhythm at a rate of 78 beats/min. (b) Recording from the right ventricle showing (on the left) a regular VT (cycle length 340 ms), transformed by burst pacing into an irregular VT (on the right) with cycle length alternans (330–370/380 ms). (c) Markers (TS for tachycardia sense; VS for ventricular sense; TP for tachycardia pacing). (B) Intracardiac recordings and markers during the third episode of VT. (a) Recording from the atrium showing normal sinus rhythm at a rate of 78 beats/min. (b) Recording from the right ventricle showing an irregular VT with cycle length alternans (300–380 ms). (c) Markers (VS for ventricular sense; FS for fibrillation sense).*

of 300–380 to 300–380 ms), which is shorter that the programmed VT interval of 350 ms. Thus VT would have been detected, despite every second interval falling out of the VT zone.

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