Undetected ventricular fibrillation in a single-chamber implantable cardioverter-defibrillator: When the far-field channel sees more than the intraventricular channel

Milena Kubickova, MD,[*] Pavel Cervinka, MD, PhD, FESC, FSCAI,[*] Andreas Kucher, MSc, PhD,[†] Zdenek Nastoupil,[‡] Roland X. Stroobandt, MD, PhD, FHRS[§]

From the [*]Department of Cardiology, Masaryk Hospital, Usti nad Labem, Czech Republic, [†]Biotronik, Berlin, Germany, [‡]Biotronik, Prague, Czech Republic, and [§]Ghent University Hospital, Heart Center, Ghent, Belgium.

Introduction

Implantable cardioverter-defibrillators (ICDs) represent the treatment of choice for the prevention of sudden cardiac death. Low signal amplitudes are occasionally encountered during placement of ICDs. ICD implant guidelines state that the amplitude of the sinus rhythm R-wave recorded from the ventricular electrogram should be higher than 5 mV. If no sufficient R signal amplitude can be found despite several attempts of repositioning the ICD lead, an induction of ventricular fibrillation (VF) is useful to ensure that the ICD will sense, detect, and defibrillate VF.

Case report

A 51-year-old woman with prior anterior myocardial infarction, apical and septal dyskinesis, a left ventricular ejection fraction of 26%, and NYHA class III symptoms received an ICD device (Itrevia 7 VR-T DX; Biotronik SE & Co KG, Berlin, Germany).[1] The implanted ICD lead (Linox Smart ProMRI DX S 65/15; Biotronik SE & Co KG) has a pentapolar design, which also enables atrial sensing via the 2 floating atrial sensing rings.[2]

Lead positioning was difficult, as no sufficient R-wave amplitude could be measured. Several repositionings of the ICD lead were tried in the right ventricular (RV) apex and on the septal wall. Maximum signal amplitudes between 2.9 and 3.6 mV were found in a low septal position, as shown in Figure 1. Induction of VF was performed by shock-on-T to check the VF sensitivity in the presence of very low signal amplitudes. VF was clearly displayed on the electrocardiogram monitor, but no automatic VF detection could be fulfilled. Since no automatic ICD shock is to be expected under these circumstances, a manually initiated ICD emergency shock at 40 joules was delivered in order to terminate VF. The manually recorded real-time electrogram (EGM) is shown in Figure 2.

Two major questions may arise:

1. Is the missed VF detection caused by too-small signal amplitudes?
2. Why is the tachycardia rate faster in the far-field EGM (FF-EGM) than in the right ventricle?

Discussion

The RV signal amplitude during sinus rhythm was indeed very low (2.9–3.6 mV) and was thus below the minimum requirement of at least 5 mV. Signal amplitudes became even less after VF induction. In Figure 2A there is definitely ventricular undersensing. Comparing the VF signals with the calibration bar in front of the EGM tracing indicates that signal amplitudes are probably below 0.8 mV, the default minimum sensing threshold of the device. There are no ventricular sense markers in Figure 2A. Thus, the lower rate interval can time out, and a ventricular pace event is released after 1500 ms (VVI 40). VF detection becomes impossible owing to subthreshold signal amplitudes.

In Figure 2B, the sensitivity of the ICD becomes sufficient to detect all intraventricular signals. Interestingly, the rate of tachycardia in the FF-EGM appears to be faster than in the RV channel. The FF channel suggests ventricular fibrillation. The intraventricular intervals, however, are in a range between 294 and 368 ms and are therefore longer than the temporarily programmed VF intervention interval of 270 ms for defibrillation threshold testing. In the present case we can only speculate because a single-chamber ICD does not provide left ventricular (LV) electrograms, as would be available in an ICD with resynchronization therapy (cardiac resynchronization therapy defibrillator; CRT-D). The observations of dissimilar ventricular tachycardia (VT) rhythms

KEYWORDS Implantable cardioverter-defibrillator; Ventricular tachycardia; Ventricular fibrillation; Left ventricular sensing; Dissimilar ventricular rhythms (Heart Rhythm Case Reports 2016;2:321–323)

Andreas Kucher and Zdenek Nastoupil are employees of Biotronik, Berlin, Germany. **Address reprints and correspondence:** Dr Roland X. Stroobandt Acacialaan 45 B- 8400 Ostend Belgium E-mail address: roland@stroobandt.com.

http://dx.doi.org/10.1016/j.hrcr.2016.03.009

KEY TEACHING POINTS

- Dissimilar ventricular rhythms have been observed in cardiac resynchronization implantable cardioverter-defibrillators (ICDs) in the presence of a left ventricular lead. The same arrhythmic phenomenon may also occur in patients with a single- or dual-chamber ICD in the absence of a left ventricular lead.
- Electrograms (EGMs) recorded from pace/sense electrodes (or "near-field" EGMs) show bipolar signals from the local area in the near vicinity of the electrode position. In contrast, the far-field EGM recording from the shocking electrodes (right ventricular coil vs can), integrating a much larger area of myocardium, provide a more global visualization of electrical activity, which includes both right and left ventricular deflections. The far-field EGM becomes of special importance and is of clinical relevance for the diagnosis of dissimilar ventricular rhythms even if the far-field channel is not used for automatic detection.
- Right ventricular rates slower than the left ventricular rate may lead to nondetection and lack of ICD therapy during a life-threatening ventricular tachycardia. Repositioning of the ICD lead and a renewed ventricular fibrillation induction may be helpful measures.

(dissociated RV and LV rhythms) and the implications for ICD detection were described by Barold et al.[3]

Our observation may be due to the presence of dissimilar ventricular rhythms, recorded by a single-chamber ICD. The fast VF rhythm shown in the FF channel can be explained if we assume that there was VF in the left ventricle and a VT in the right ventricle. The exact reason for dissimilar ventricular rhythms is still unclear. Interventricular conduction block may be invoked to explain the long RR intervals in the RV-EGM in the presence of a faster rate in the FF-EGM. The RV lead tip may have been partially protected by local scar tissue (entrance block), whereas the fast VT involved the LV and most of the RV apart from the RV electrode tip. The relatively regular shorter-cycle-length atrial EGMs as recorded by the floating electrodes are probably due to retrograde atrial activation from the slower VT in the right ventricle.

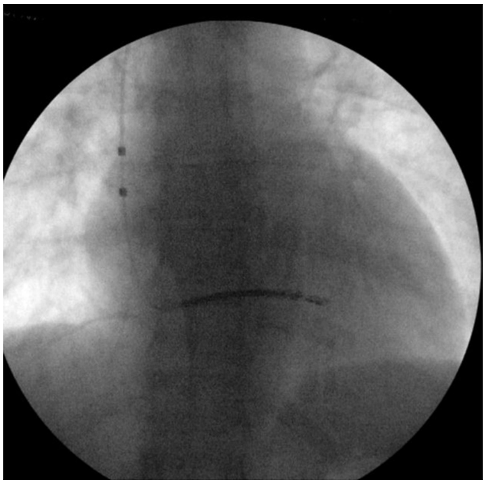

Figure 1 Fluoroscopic anterior-posterior view of the lead position.

After repositioning of the lead in another low septal area, a signal amplitude ranging from 4.9 to 7.1 mV was obtained. A renewed VF induction was performed 2 days after the implantation procedure with a programmed minimum sensing threshold of 0.8 mV. The second VF sensing test was successful and VF detection could be fulfilled after 8/12 without undetected ventricular events.

In summary, the situation that led to an undetected VF may be 2-fold. Firstly, low-amplitude and subthreshold VF signals resulted in undersensing. Secondly, the RV rate was too slow and far below the programmed VF zone owing to dissimilar ventricular rhythms, as presented in this case.

Similar observations were already made by Josephson[4] and described as atypical VF. The surface electrocardiogram presented classic VF; however, the bulk of the heart demonstrated regular discrete ventricular activity. Fragmented, asynchronous activity was only seen in the area of the large infarction in the left ventricle.

The present case also bears similarities to a well-documented case report by Yunoki et al.[5] In that report, both the FF-EGM and the external defibrillator recordings present VF-like electrical activity. This VF, however, remained undetected because RR intervals on the RV-EGM stayed prolonged at 400 ms (150 beats/minute) for the duration of the episode, well below the programmed tachycardia intervention rate.

Other published case reports described failure of VF detection because of too-long RR intervals but in the presence of VF-like signal morphologies in the FF-EGM, despite large R signal amplitudes during sinus rhythm.[6–8] The possible presence of "dissimilar VT rhythms" was, however, not taken into account and discussed in these articles. The availability of an LV-EGM with CRT-D devices renders the diagnosis of dissimilar VT rhythms less problematic, as is the case with single- or dual-chamber ICDs.

Clinical implications and conclusion

Dissimilar ventricular rhythms during VT have been observed in both directions: LV rate faster than RV, and RV rate faster than LV. As long as the RV delivers the shortest intervals, ICD detection and therapy delivery is guaranteed. ICD detection may fail under worst-case conditions if the LV rate is faster than the RV. Both repositioning of the ICD lead and reinduction of VF might be appropriate measures. If the unit is not equipped with a DF-4 lead, interchanging the RV and LV lead plugs could be an option in a CRT-D device to permit VF detection from the

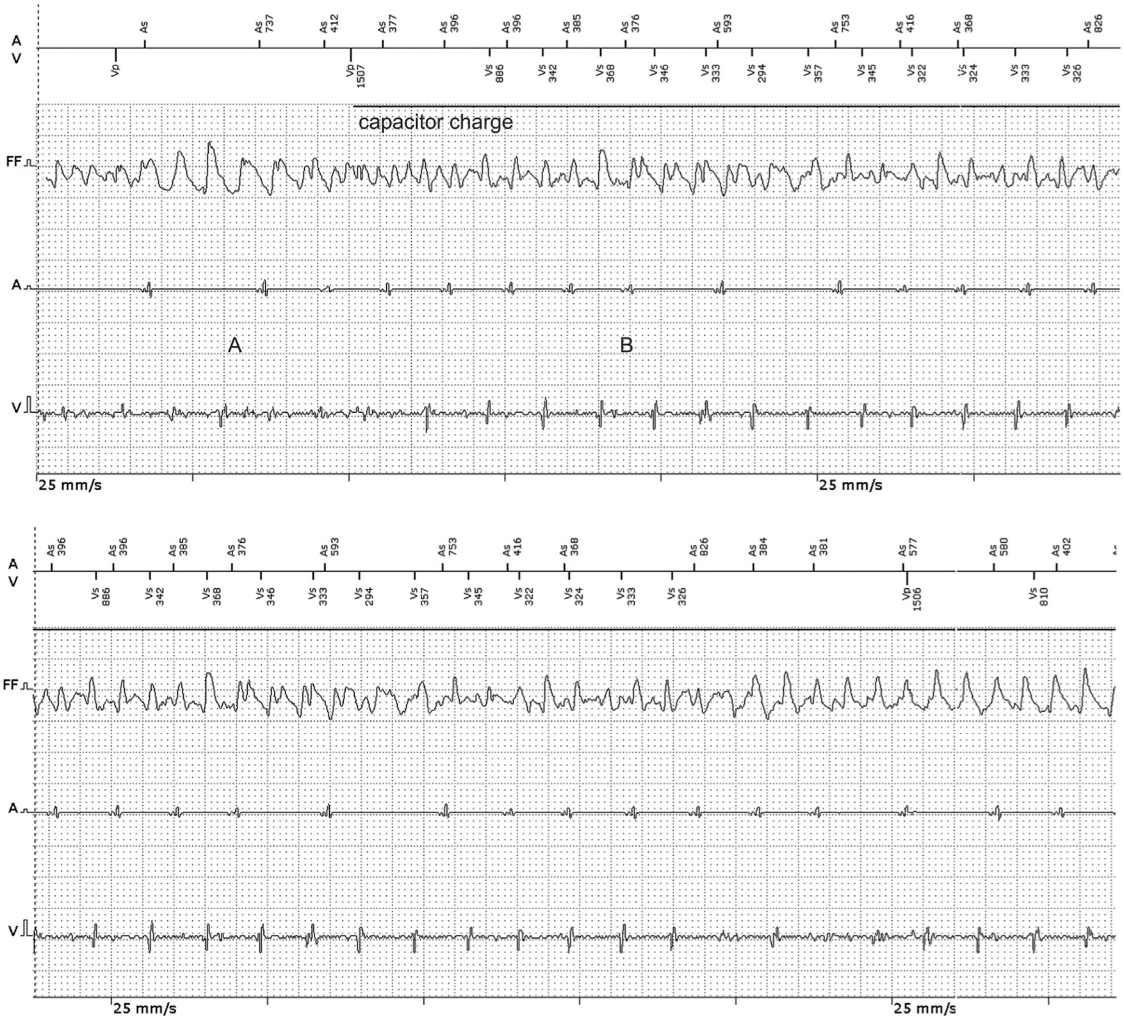

Figure 2 Ventricular undersensing and tachycardia rate in right ventricle below the ventricular fibrillation intervention rate in a patient with an Itrevia 7 VR-T DX device. The marker channels are on top (A = atrial, V = right ventricular). The electrogram channels are below the marker channels (far-field [FF], A, and V). **A:** Ventricular undersensing because of signal amplitudes below the minimum sensing threshold of 0.8 mV. Ventricular undersensing led to ventricular pacing at the lower rate interval of 1500 ms. **B:** RR intervals vary from 294 to 368 ms. The rate of the tachycardia shown in the FF channel is faster than the rate in the right ventricular channel.

left side. The presence of dissimilar ventricular rhythms in a single- or dual-chamber ICD remains a critical issue that could possibly be solved by introduction of a suitable hemodynamic sensor in future ICDs.

A VF induction has luckily been performed, which is no longer a standard procedure. Without induced VF, dissimilar rhythms would never have been discovered as the root cause. Understanding the origin of underdetection is of the utmost importance in order to avoid dramatic consequences at the occurrence of spontaneous tachyarrhythmias.

Acknowledgment

We are grateful for the support by Biotronik SE & Co KG, Berlin, Germany.

References

1. Technical manual. Itrevia 5/7 ProMRI, 403737 Revision: B (2014-11-19). Available at: ⟨http://manuallibrary.biotronik.com/manuals/home⟩. Accessed November 19, 2014.
2. Technical manual. Linox Smart ProMRI S DX, 408242 Revision: D (2014- 12-14). Available at: ⟨https://www.biotronik.com/wps/wcm/connect/int_web/emanuals/emanuals/⟩. Accessed December 14, 2014.
3. Barold SS, Kucher A, Nägele H, et al. Dissimilar ventricular rhythms: implications for ICD therapy. Heart Rhythm 2013;10(4):510–516.
4. Josephson ME. Clinical Cardiac Electrophysiology – Techniques and Interpretations, In: Third edition. Philadelphia: Lippincott Williams & Wilkins; 2002:487–495.
5. Yunoki K, Nishii N, Morita H, et al. Anti-tachycardia pacing degenerated fast ventricular tachycardia into undetectable life-threatening tachyarrhythmia in a patient with non-ischemic dilated cardiomyopathy. J Cardiol Cases 2010;2:e159–e162.
6. Bastian D. Underdetection of ventricular fibrillation despite ICD testing and high sinus R wave. Herzschr Elektrophys 2013;24:131–135.
7. Antolinos-Pérez MJ, García-Alberola A, Redondo-Bermejo B, Valdés-Chávarri M. Failure to detect ventricular fibrillation in a patient with an implantable cardioverter-defibrillator [Letters to the editor]. Rev Esp Cardiol 2006;59(5):515–518.
8. Chin A, Healey JS, Ribas CS, Girish M, Nair GM. Delayed AICD therapy and cardiac arrest resulting from undersensing of ventricular fibrillation in a subject with hypertrophic cardiomyopathy – a case report. Indian Pacing Electrophysiol J 2015;15:121–124.