CASE REPORT

Unusual cause for an increase of the sensing integrity counter in a patient with inappropriate implantable cardioverter-defibrillator therapy

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We describe the case of a patient who presented with multiple implantable cardioverter-defibrillator (ICD) shock discharges 12 months after device implantation. Upon device interrogation, intermittent oversensing of electrical noise and potential ICD lead failure were suggested by a significant increase in the sensing integrity counter (SIC), a cumulative count of very short ventricular sensed intervals. Analysis of stored episodes, however, revealed that inappropriate ICD therapy had been caused by intermittent T-wave oversensing (TWO), and that the increase of the SIC resulted from the coincidence of TWO and premature ventricular complexes (PVCs). T-wave oversensing resolved and the SIC did not increase any more during follow-up after adjustment of ventricular sensitivity. The coincidence of TWO and PVCs should therefore be considered as an uncommon cause for short ventricular sensed intervals in ICD patients presenting with a suspect increase in the SIC.

KEYWORDS
Implantable-cardioverter defibrillator; Oversensing; Inappropriate therapy; Sensing integrity counter

Case report

A 69-year-old man presented for regular follow-up 12 months after prophylactic implantation of a dual-chamber implantable cardioverter-defibrillator (ICD) (Medtronic EnTrust™, Medtronic Inc. Minneapolis, MN, USA). Underlying cardiac diseases were ischaemic cardiomyopathy with a left ventricular ejection fraction of 30% and sick sinus syndrome with a history of paroxysmal atrial fibrillation. At presentation, the patient reported that he had experienced multiple shock discharges several weeks earlier, and that, 4 weeks ago, these events had triggered an unscheduled follow-up at another institution, where the ICD had been interrogated. Thereafter, the device had delivered one additional shock. The patient denied loss of consciousness, and there was no evidence of myocardial ischaemia or cardiac decompensation. At presentation, the patient reported that he had experienced multiple shock discharges several weeks earlier, and that, 4 weeks ago, these events had triggered an unscheduled follow-up at another institution, where the ICD had been interrogated. Thereafter, the device had delivered one additional shock. The patient denied loss of consciousness, and there was no evidence of myocardial ischaemia or cardiac decompensation. The surface ECG showed, similar to prior recordings, an atrial paced rhythm with first-degree atrioventricular block and right bundle branch block.

Several device alerts were noticed upon interrogation. The sensing integrity counter (SIC), which cumulatively counts short (120–130 ms) V–V intervals and thereby typically indicates intermittent oversensing of electrical noise, had increased to 3471 since last interrogation.

Furthermore, all therapies including shocks had been delivered without success for one VT/VF episode. Last, patient activity had progressively decreased during the last months to currently <2 h per day. The device had been programmed to AAIR → DDDR pacing at a rate of 50–120 bpm, with two ventricular tachyarrhythmia detection zones (VT >158 bpm, VF >231 bpm). In both detection windows, anti-tachy pacing (ATP) and shock therapy were active (ATP during charging in the VF zone). Ventricular sensitivity was programmed to the nominal value of 0.3 mV.

The episode counter showed that 8 VT, 117 non-sustained VT, and no AF/AT episodes had been detected since the last device interrogation. One high-voltage shock and multiple ATP sequences had been delivered. Analysis of stored data also revealed that 5 VF, 65 VT, and 621 non-sustained VT episodes had been documented at the previous follow-up 4 weeks earlier. Also, 12 shocks had been delivered in the corresponding time interval. Some of these older episodes could be retrieved from the device memory. Of note, no reprogramming and no additional diagnostic or therapeutic procedures had been performed during the follow-up at the other institution.

At the present follow-up, analysis of stored episode data revealed intermittent T-wave oversensing (TWO). Furthermore, combined occurrence of TWO and premature ventricular complexes (PVCs) was found to cause short V–V intervals.
Figure 1  Detection of short V–V intervals (FS) due to the coincidence of TWO and PVCs. The upper panel shows an episode strip with bipolar atrial (EGM1) and ventricular (EGM2) electrograms and marker annotations below. One of the two short V–V intervals (↓) is shorter than 140 ms, thus resulting in an increase in the short interval counter. The interval plot in the lower panel illustrates the high incidence of short V–V intervals during 2:1 occurrence of PVC (−165 to 150 s).

Figure 2  Changes in the true bipolar ventricular electrogram ($V_{\text{tip}}/V_{\text{ring}}$) during the follow-up. Real-time electrograms were acquired during atrial stimulation (90 bpm). Note the prolongation of the time interval between R-wave (negative peak) and T-wave (negative peak) and the progressive increase in T-wave amplitude. Far-field signals from the paced atrium superimpose the last part of the T-wave.

intervals (Figure 1), thereby explaining the significant increase in the SIC as well as the inappropriate detection of VF. Analysis of lead trend data and acute measurements of the sensed R-wave amplitude (19 mV) and ventricular pacing impedance (584 $\Omega$) provided no evidence of dysfunction of the implanted ICD lead (Medtronic model 6947). Comparison of ventricular electrograms, recorded 3 days, 3 months and 12 months post-implant, revealed discrete changes in the RT-interval and T-wave amplitude over time (Figure 2).

To prevent additional episodes of TWO, ventricular sensitivity was reprogrammed to 0.6 mV after ensuring that appropriate VF detection had intra-operatively been tested with a sensitivity of 1.2 mV. Four weeks later, the SIC had not increased any more, and no more atrial or ventricular episodes had been detected by the device.

Discussion

Inappropriate ICD therapy occurs in 15–20% of the patients and is the most common device-related complication in this population. Inappropriate device therapy may cause pain, psychological distress, and potentially fatal pro-arrhythmia. Lead failure is one potential cause for inappropriate ICD therapy. An insulation defect or a conductor fracture within the pace-sense circuit can produce electrical noise, and oversensing of these high-frequency signals can result in inappropriate detection of VT/VF and unnecessary ICD therapy. If the structural lead defect is incomplete at first, the electrical integrity may be lost only for brief moments, and short episodes of oversensing...
will occur only sporadically.\textsuperscript{3} If this is the case, lead failure will not necessarily be manifest by inappropriate therapy, and is unlikely to be detected by single measurements of lead impedance and pace-sense performance. The SIC can also detect these brief episodes of noise oversensing and may thereby enhance the early detection of lead failure.\textsuperscript{3,4} The algorithm continuously counts the number of short V–V intervals (120 and 130 ms) that are typically seen during oversensing of electrical noise. An increment in the total SIC to more than 300 events since the last follow-up is commonly considered as an indicator of system dysfunction.\textsuperscript{3,6,7} In a recent analysis, however, we found that a notable increase in the SIC may also occur in a significant proportion of patients with integrated bipolar ICD leads that provide no evidence of structural dysfunction.\textsuperscript{3} It has been shown earlier that integrated bipolar leads are more susceptible than true bipolar electrodes for oversensing of P- and T-waves\textsuperscript{8} and diaphragmatic potentials.\textsuperscript{9} In our prior analysis, we were only able to speculate whether the inappropriate increase of the SIC had been caused by oversensing of cardiac or diaphragmatic potentials. With the present case, we identify the coincidence of TWO and PVC as the underlying cause for a significant increase in the SIC. No evidence of a lead defect was found, and the SIC did not increase any more after ventricular sensitivity was adjusted and TWO resolved. Our patient had an ICD lead for true bipolar sensing, but the same complication could just as easily affect patients with integrated bipolar sensing electrodes, where T-waves are even more likely to be oversensed. Thus, intermittent TWO should be considered in all patients presenting with an increase of the SIC and no additional evidence for lead failure or electrical noise due to other causes.

Prior studies showed that TWO is a common cause of inappropriate device therapy.\textsuperscript{8} Implantable cardioverter-defibrillator devices have to ensure reliable detection of low-amplitude VF and at the same time avoid oversensing. To reduce the likelihood of TWO, most ICDs automatically adjust sensitivity in relation to the amplitude of the preceding R-wave.\textsuperscript{10} In Medtronic devices, sensitivity is adjusted after each sensed ventricular event to an initial starting value that is related to the R-wave amplitude and the programmed sensitivity. Sensitivity then decreases exponentially until the programmed (maximum) sensitivity value is reached. Therefore, ventricular sensitivity and the consecutive risk for TWO is higher if the time interval between R- and T-wave is longer. In our patient, the occurrence of intermittent TWO was related to a progressive prolongation of the RT-interval and an increase in T-wave amplitude. Considering the algorithm for auto-adjusted sensitivity, both changes probably contributed to the development of TWO in the present case.

Several reversible causes have been associated with the occurrence of TWO (e.g. hyperglycaemia, hyperkalaemia, and use of QT-prolonging drugs). In our patient, we excluded that TWO and the underlying electrographic changes were related to any of these causes. T-wave oversensing and the associated complications resolved after reprogramming ventricular sensitivity from 0.3 to 0.6 mV. Reliable detection of VF always has to be ensured when reprogramming sensitivity to higher values. In the present case, reprogramming was safe because adequate detection had been tested intraoperatively with a sensitivity of 1.2 mV. Furthermore, the sensed R-wave had constantly been $\geq 10$ mV during the follow-up. In the presence of a such a relatively large R-wave amplitude, changes in programmed sensitivity are known to alter substantially the entire auto-adjusting sensitivity curve.\textsuperscript{10}

The device had been interrogated at another institution after the delivery of 12 shock discharges, but no corrective action had been taken to prevent additional inappropriate therapies. This suggests that inappropriate device therapy and the underlying cause had not been identified. Earlier re-programming of ventricular sensitivity could have prevented TWO and inappropriate therapy in our patient.

In summary, this case illustrates several problems that may be encountered during the ICD follow-up. First, the coincidence of TWO and PVC is identified as an uncommon cause of short V–V intervals and a resulting increase in the SIC. Second, we found that slow and progressive changes in the ventricular electrogram may cause TWO and inappropriate ICD therapy late after device implantation. Last, our findings suggest that tailored programming of ventricular sensitivity should be considered to prevent TWO.

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\section*{References}


