

ICD Arrhythmia Detection and Discrimination: Are We There Yet?

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Editorial Comment

Implantable cardioverter defibrillator (ICD) therapy is beneficial to patients who have experienced life-threatening ventricular arrhythmias (secondary prevention) and those at risk for ventricular arrhythmias due to the presence of structural heart disease (primary prevention).¹⁻⁵ The DAVID trial suggested that dual-chamber ICDs programmed to “force” ventricular pacing result in an increase in morbidity and mortality.⁶ The increased costs and added complexity of dual-chamber ICDs, along with results from DAVID and other trials, have led to the recommendation that, in the absence of a pacing indication, single-chamber ICDs should be implanted and programmed to permit intrinsic ventricular activation and avoid right ventricular pacing.⁷

ICD technology has evolved to allow more accurate rhythm detection to avoid inappropriate shocks. There are, however, differences in the sensitivity and specificity of ventricular tachycardia (VT) detection dependent on the specific device programming, the type of device (single vs dual chamber), and the clinical arrhythmia. Furthermore, expectations related to the ability of the device to detect and provide therapy are different, dependent on the clinical arrhythmia. For example, ICD detection of ventricular fibrillation (VF) must have high sensitivity, as the consequences of underdetection are potentially fatal.⁸ In contrast, detection algorithms for ventricular tachycardia (VT) must balance the risks of underdetection with the painful, psychologically troubling, and potentially proarrhythmic consequences of inappropriate therapy.⁹⁻¹⁷ A highly sensitive detection algorithm is appropriate for faster tachycardias because the risks of underdetection are high and the probability of rate-zone overlap with supraventricular tachycardia (SVT) is low. On the other hand, a highly specific algorithm is appropriate for hemodynamically stable, slower VT because the risks of underdetection are low and the probability of rate-zone overlap with SVT is high.

Historically, when tiered-therapy ICDs detected VT by rate criteria only, inappropriate therapy for SVT occurred in 45% of patients.⁸ The problem of inappropriate therapy was greater for tiered-therapy ICDs because the probability of rate overlap between the target VT and SVT was greater. Pacing therapies delivered during SVT could potentially induce VT; or could induce atrial fibrillation, which in turn could be sensed as VT and treated with pacing, reinitiating VT.

Therefore, tiered-therapy ICDs needed to include detection-enhancement algorithms to discriminate VT from SVT.

Morphology algorithms, which discriminate between VT and SVT based on electrogram (EGM) morphology, provide an alternative method for discriminating between SVT and VT that is independent of correct classification of one or a few of the most recent intervals. Morphology algorithms were not applied in early ICDs because the required calculations exceeded the capability of the devices’ microprocessors. As device technology has improved, morphology algorithms for rhythm discrimination have been implemented by most device manufacturers in both single- and dual-chamber ICDs.¹⁸⁻²²

Dual-chamber detection algorithms improve tachycardia discrimination by analyzing the relation between atrial and ventricular activity. Aside from making sense intuitively, dual-chamber detection has been reported to be superior to single-chamber detection by some, but not all, recent clinical trials.²³⁻²⁹ The recently published Detect SVT trial was a randomized study of 400 patients comparing the ability of single-versus dual-chamber ICDs to discriminate SVT from VT.³⁰ Inappropriate detection of SVT occurred in 46.5% of patients in the single-chamber group versus 32.3% in the dual-chamber group. Moreover, dual-chamber devices resulted in a 50% overall reduction in inappropriate detection. The clinical consequence of improved rejection of SVT episodes that met ventricular rate-based detection was a 46% reduction in the odds of inappropriate therapies in the dual-chamber versus single-chamber group.

However, as previously stated, dual-chamber ICDs are not indicated in patients without a pacing indication and may result in undue morbidity and mortality. Therefore, it seems logical that what is needed are single-chamber ICDs that are as good or better than current dual-chamber devices in differentiating SVT from VT. Over the years, single-chamber algorithms that analyze QRS morphology to discriminate SVT from VT have been developed to reduce the incidence of inappropriate therapy without compromising device safety. Despite evolution of these algorithms, inappropriate device therapy for SVT continues to be an obstacle of ICD therapy. The incidence of inappropriate therapy in the current era ranges from 12% to 29%. In the DEFINITE trial, single-chamber ICDs were programmed to VVI pacing at 40 bpm with a single-tachycardia detection window programmed to a lower rate of 180–200 bpm.³¹ Despite the use of a single-tachycardia detection zone, inappropriate shocks for SVT occurred in 47 of 227 patients and accounted for 86 (55%) of the total 156 shocks that were delivered.³² In SCD-HeFT, despite conservative programming settings, 82 (32%) of the 259 patients received inappropriate shocks.³³ Clearly, a single-chamber algorithm that accurately discriminates SVT from VT is a desirable goal. The question to be answered by

Klein et al. in their study³⁴ is whether we have achieved this goal yet.

In this issue of the *Journal of Cardiovascular Electrophysiology*, Klein et al.³⁴ report the results of the Worldwide Application of Marquis VR Enhancements (WAVE) study, a nonrandomized prospective study of a new ventricular electrogram morphology discrimination algorithm operating as the sole discriminator to differentiate SVT from VT or VF in a single-chamber ICD. In this large multicenter study, 1,122 patients underwent implantation of a Medtronic Marquis™ VR (Medtronic, Minneapolis, MN, USA) single-chamber ICD for primary and secondary (54%) prevention of sudden cardiac death and had this novel Wavelet Dynamic Discrimination algorithm programmed on and other discrimination enhancements like interval stability and rate onset programmed off. The programmed parameters for Wavelet™ included a Match Threshold of 70% and a RV coil-can EGM source.

The algorithm works by comparing automatically collected rhythm templates when the patient is presumably in normal rhythm and not during tachycardia, ectopy, or VT/VF to a tachycardia occurring above the programmed detection cutoff. When three or more of the last eight beats exceed the programmed match threshold, Wavelet criterion is satisfied and the VT detection and resultant therapy are withheld, assuming the rate-based or time-based overrides are not met.

After an average of more than 5 months of follow-up, 2,235 episodes of sustained tachycardia occurred: 1,350 episodes (in 192 patients) deemed VT and 885 episodes (in 174 patients) deemed SVT. Of these episodes, only two-thirds (1,496) were within the range of cycle lengths where the Wavelet criterion could apply. Of the episodes deemed VT where Wavelet was applied, the algorithm correctly labeled 762 (98.6%) of the 772 episodes in 110 of 115 patients. The occurrence of inappropriate therapies was reduced in 78.2% (549 of the 724) episodes in 119 of 168 patients where Wavelet was applied. The reason the algorithm inappropriately labeled VT episodes as SVT a little over 20% of the time, was mostly due to EGM morphology differences during tachycardia compared to the template taken mostly in normal sinus rhythm.

The results of this trial are noteworthy and the authors need to be commended for their work in reporting the results of this large, multicenter, international trial that set out to answer an important and appropriate clinical question. The WAVE algorithm employed in this trial did prove to be a highly sensitive algorithm, but, unfortunately, not nearly as specific. As mentioned, a highly specific algorithm is important for slow VT because the risks of underdetection are low and the probability of rate-zone overlap with SVT is high. Based on the rate cutoffs that were utilized, this algorithm was evaluated within the confines of limited cycle lengths and did not test the ability of the algorithm to discriminate between slow SVT and slow VT. This is an important clinical consideration for patients receiving antiarrhythmic medications—especially amiodarone—who may experience slow VT.

A second concern about the Wavelet algorithm is the employment of the ventricular electrogram morphology during normal sinus rhythm to base future SVT versus VT discrimination. This methodology assumes that the template obtained during sinus rhythm is constant and that the VT electrogram is always significantly different from the template EGM. Other potential difficulties with this and other morphology-based

algorithms include template misalignment, electrogram maturation, and postshock electrogram distortion.

Furthermore, there are issues with the study design that make the derived data of decreased applicability in a “real-world” patient population. Concern about selection bias is raised because this is a nonrandomized study. The incidence of SVT in this patient population was 15.5% (174 out of 1,122 patients), which is lower than that found in many other trials where the SVT incidence approaches 40%. Klein et al. programmed off all other detection algorithms (e.g., onset, rate stability, etc.) other than the wavelet algorithm being studied. Whereas this may have made the data interpretation simpler, it is unlikely clinicians would program these algorithms off in “real” life. Finally, the study protocol only allowed for programming the RV coil-can as the EGM source. However, as morphology detection algorithms have robust programming capabilities, the results of evaluating different EGM sources in this large patient population may have proved interesting. For instance, in the 18% of patients with a right or left bundle branch block, changing their EGM source may have improved the poor detection specificity from 54.1%.

New and innovative methods of rhythm discrimination are needed. In a recent report, Saba and colleagues³⁵ described a new dual-chamber ICD algorithm to discriminate between SVT and VT based on the response of the arrhythmia to simultaneous atrial and ventricular antitachycardia pacing (ATP), combining arrhythmia discrimination and therapy. ATP terminated 55% of the episodes of SVT and 41% of the episodes of VT. Of those arrhythmias that were not terminated, the discrimination algorithm correctly classified 24/24 episodes as VT and 85/91 as SVT. These results are striking and provocative, but will require further investigation in a large patient population to define the clinical utility of this technique and its incremental improvement in detection.

Detection algorithms for VT have evolved and will continue to improve. Single-chamber devices with algorithms with both high sensitivity and specificity for differentiation of SVT from VT are inevitably looming on the horizon. It is possible that if currently available algorithms (stability, onset, morphology, etc.) are tested with algorithms using morphology discrimination in a large, “real-world” patient population, the results may be even better. We may not have yet solved the arrhythmia discrimination problem; however, Klein et al.³⁴ have shown us where we need to be going.

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