

Discrimination Algorithms and Arrhythmia Detection

CHAPTER 16

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Introduction

Since the commercial release of the first generation of implantable cardioverter defibrillators (ICDs), remarkable technologic advances have enhanced their efficacy and safety and improved the accuracy of arrhythmia detection algorithms. The introduction of dual chamber devices was an important milestone that incorporated additional atrial information into discrimination algorithms, while offering dual chamber pacing. Nevertheless, despite these developments, inappropriate therapy for supraventricular tachyarrhythmias (SVT) remains a major limitation of contemporary ICDs, with 7% to 27%^{1,2} of implanted patients receiving inadequate therapies.

In this chapter, we review current detection algorithms included in modern single and dual chamber devices developed by the various

manufacturers and describe particularities and performance issues. In so doing, the following definitions pertaining to tachycardia detection will be adopted (Table 16.1 on following page): true positive (TP), false positive (FP), true negative (TN), and false negative (FN).

MEDTRONIC DEVICES

Single Chamber ICDs

Single chamber ICDs from Medtronic currently incorporate four elements into detection algorithms: (1) RR interval analysis; (2) RR onset; (3) RR regularity or stability; and (4) Ventricular electrogram (VEGM) morphology.

RR Interval Analysis

The RR interval analysis is the first and simplest criterion used to classify high ventricular

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Device Classification		Physician Classification	
VT	VT (TP)	SVT (FP)	
SVT	VT (FN)	SVT (TN)	

Table 16.1 Tachycardia Detection. Abbreviations: FN, false negative; FP, false positive; SVT, supraventricular tachycardia; TN, true negative; TP, true positive; VT, ventricular tachycardia.

rates according to the cycle length of each programmed zone. It provides the highest sensitivity for detecting true VT but does not distinguish VT from SVT with a high ventricular rate that overlaps with VT/VF zones. Counting algorithms based on RR interval analyses are similar in single and dual chamber devices and consist of two counters with three programmable rate detection zones: VF, VT, and fast VT (FVT).

The VF counter nominally requires that 18 of the last 24 intervals be shorter than the fibrillation detection interval (FDI), the latter indicating the “window size.” This counter relies on a “sliding window” principle; as long as intervals are binned within this window, an interval that meets the FDI threshold will increment the counter by one whereas a sinus or a VT interval will “freeze” the counter (Fig 16.1).

The VT counter nominally requires 16 consecutive RR intervals that fall within the tachycardia detection interval (TDI) but are greater than or equal to the FDI. The emphasis on consecutive intervals may be useful in rejecting variable rates during rapidly conducted AF. Thus, an interval meeting the VT threshold will increment the counter, whereas a slower interval will reset the counter to 0; of note, an interval binned in the VF zone will neither increase nor reset the counter.³

To avoid delays in detecting tachyarrhythmias with overlapping rates between VT and VF zones, a combined count feature was added that is automatically enabled when a VT zone is programmed On. This count is triggered when at least 6 RR intervals are in the VF zone. It increments if VF or VT counters increment and decrements if the VT counter is reset or if the VF counter decrements.³ Detection occurs when the sum of the VT and VF counters reaches a value of 7/6 multiplied by the programmed number of intervals needed to detect VF (rounded down). The nature of subsequent delivered therapy is based on the last 8 intervals: if all fall within the VT zone, VT therapy is delivered; if any fall within the VF zone,

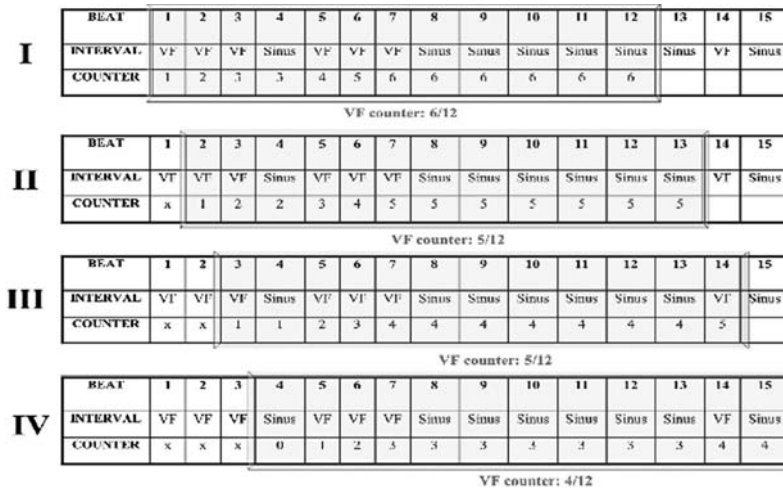


Fig 16.1 The sliding window principle: a window progressively slides beat by beat from I to IV. Shown are the numbered beats, intervals binned, and the VF zone counter (in this example set to 9/12). (Reproduced from Mansour and Khairy.³)

VF therapy (or FVT therapy, see following) will be triggered.

The third programmable rate zone is the fast VT (FVT) zone, which is intended to allow therapies while avoiding unnecessary shocks.⁴ If the fast tachycardia interval (FTI) is less than FDI, the FVT zone becomes a subset of the VF counter (FVT via VF). For FVT via the VF zone, FVT therapy is delivered if *all* of the last 8 intervals are in the FVT zone. If not, VF therapy is delivered. If the FTI is greater than FDI, FVT intervals are considered in the VT counter (FVT via VT). FVT therapy is delivered if *any* of the last 8 intervals are in the VF or FVT zone, otherwise VT therapy is provided.

RR Onset

“RR onset” relies on sudden ventricular rate changes to discriminate VT from sinus tachycardia (ST) of progressive onset. This feature is nonspecific for ventricular arrhythmias, because atrial tachycardia that conducts 1:1 may exhibit a similar pattern, and may miss detection of VT that initiates during ongoing ST. “RR onset” is functional only in single chamber ICDs (until EnTrust) and is exclusively applicable for initial detection. The onset algorithm is based upon a rolling counter that uses the 8 most recent intervals. “Sudden onset” is declared if the average of the 4 most recent intervals is less than the average of the previous 4 intervals, multiplied by the programmed onset percentage (nominally set to 81%). Once this occurs, the VT counter is activated. This criterion only pertains to the VT counter.

RR Stability

This feature is used to discriminate monomorphic, presumably regular, VT from rapidly conducted atrial fibrillation (AF) with an irregular cycle length. It may prevent detection of unstable VT such as polymorphic forms. Conversely, it may misclassify a supraventricular arrhythmia with 2:1 conduction block, such as atrial flutter (Aflutter), or a rapidly conducted AF with a pseudoregular ventricular pattern.

The algorithm operates with a rolling counter, which uses the 4 most recent intervals. When the VT counter reaches 3, if the current interval varies from *any* of the previous 3 by more than the programmed value, the rhythm is considered unstable and the VT counter is reset to zero. The “stability interval” nominal value is set to 50 ms. Of note, the VT counter requires consecutive intervals to fall within the programmed zone, thus providing a complementary feature to the stability criterion. It is the only discriminator that applies to both initial and redetection periods.

Wavelet Dynamic Discrimination Criterion

“Wavelet” (or morphology) criterion is used to classify rapid rhythms as SVT if the arrhythmia template is similar to that recorded during baseline rhythms. SVT with aberrancy is a well-recognized source of misclassification. To minimize this drawback, the morphology is analyzed after the fourth fast beat and withholds detection when at least 3 of the last 8 complexes match the stored template. Morphology analysis continues until insufficient normal beats are recognized (and VT detection occurs) or until the heart rate slows out of the detection zone. This comparison is expressed as a percent-match score that reflects the degree of similarity of sinus and tachycardia electrograms.

Nominally, beats with match scores < 70% are classified as ventricular in origin. The 70% value (programmable feature) is based on results of a previous, retrospective, postprocessing analysis of electrograms recorded during electrophysiologic study² and was subsequently confirmed to be a reasonable cutoff with high specificity, without compromising sensitivity.^{5,6}

The morphology algorithm

The morphology algorithm functions as follows:

1. The “wavelet transform” of the composite baseline-rhythm template electrogram is constructed as shown in Fig 16.2 on the following page and stored;