# Discrimination of Ventricular Tachycardia from Ventricular Fibrillation by Morphologic Analysis of Electrograms

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## Abstract

*To determine whether ventricular tachycardia (VT) and ventricular fibrillation (VF) can be discriminated by time-domain analysis, correlation waveform analysis (CWA) was performed using bipolar (1 cm, 1-500 Hz) intracardiac electrograms of 12 consecutive patients during sinus rhythm (SR) and induced monomorphic VT and VF. Using a "best fit" template-signal alignment, CWA separated SR from 10/12 VTs (83%) and 12/12 VFs (100%), respectively. The individual variances for VT and VF were significantly different (F test, $p < 0.0001$), and a threshold midway between the average variance in VT and VF was a successful discriminant in 11/12 cases (92%). These results suggest that time-domain analysis can discriminate VT and VF from SR, and the magnitude of the variance in VT and VF can be used to distinguish VT from VF.*

## 1 Introduction

Pacing-cardioverter-defibrillators are capable of providing "ramp" therapy including antitachycardia pacing, low- and high-energy cardioversion, or defibrillation for sustained ventricular tachycardia (VT) and ventricular fibrillation (VF). Appropriate therapy, however, is dependent upon correct identification of VT and VF.

Currently available, implantable devices utilize a combination of rate and a variation of amplitude distribution analysis (probability density function) to distinguish VF from SR. It has been demonstrated, however, that this algorithm is not capable of reliably detecting VT.

Morphologic analysis of intracardiac electrograms using correlation waveform analysis (CWA) has been demonstrated to be effective in discriminating normal sinus rhythm (SR) from VT, paroxysmal bundle branch block of supraventricular origin, and retrograde atrial activation [1, 2, 3, 4]. Whether VF can be distinguished from SR and VT with a similar time-domain analysis has not been determined.

## 2 Methods

Twelve consecutive patients were evaluated while undergoing routine cardiac electrophysiology studies. Distal bipolar (1-500 Hz) intraventricular electrograms were recorded from an electrode catheter positioned in the right ventricular apex during SR, monomorphic VT induced by programmed electrical stimulation, and VF induced by programmed stimulation or alternating current.

Ventricular electrograms were recorded on FM magnetic tape and digitized subsequently on a PC at a sampling rate of 1,000 Hz. The programs for digitizing and waveform analysis were written in C and assembly language.

A digital differentiator was used to detect each of the individual intracardiac electrograms. A template was created from a 15 s passage of SR for CWA of subsequent 15-30 s passages of SR, VT, and VF. A patient- specific window was chosen during creation of the sinus rhythm template to include depolarization only and to exclude the potentially confounding repolarizion injury current caused by the acute placement of the electrode catheters. This window size was imposed on all subsequently analyzed electrograms.

The template was aligned with the trigger point of the electrogram under analysis, and then shifted a maximum of 10 ms in both directions in order to maximize the alignment of the two waveforms. The magnitude of the variance of cycle-to-cycle CWA was then used as a discriminant function for VT and VF.



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# 3 Experimental Results

Table 1 summarizes the results for all 12 patients. The types of electrograms analyzed are illustrated in Figures 1 and 2.

The window sizes of the analyzed electrograms ranged from 52-106 ms. Mean correlation coefficient separated SR from VT in 10/12 patients (83%) and SR from VF in all 12 patients (100%). The range (and means) for standard deviation (s) were 0.004-0.049 (0.013) for SR, 0.007-0.177 (0.059) for VT, and 0.092-0.718 (0.414) for VF.

For each of the 12 patients, the individual variances for VT and VF were significantly different (F test, $p < 0.0001$). A threshold midway between the average variance in VT and VF, respectively, was a successful discriminant in 11/12 patients (92%).

| | SR | | VT | | VF | |
|---|---|---|---|---|---|---|
| # | mean | sd | mean | sd | mean | sd |
| 1 | .986 | .008 | .852 | .115 | .714 | .221 |
| 2 | .987 | .006 | .836 | .072 | .355 | .348 |
| 3 | .995 | .003 | -.108 | .097 | .499 | .382 |
| 4 | .970 | .003 | .848 | .017 | .405 | .453 |
| 5 | .980 | .006 | .882 | .041 | .429 | .493 |
| 6 | .962 | .020 | .641 | .047 | .625 | .408 |
| 7 | .995 | .002 | .925 | .007 | .650 | .433 |
| 8 | .990 | .021 | .969 | .013 | .347 | .432 |
| 9 | .984 | .011 | .868 | .022 | .228 | .490 |
| 10 | .977 | .049 | .960 | .018 | .881 | .092 |
| 11 | .959 | .024 | .040 | .177 | .162 | .499 |
| 12 | .996 | .003 | .870 | .087 | .313 | .718 |

*Table 1: Results of Correlation Waveform Analysis for Discriminating Ventricular Tachycardia from Ventricular Fibrillation.*

# 4 Discussion

The efficacy of implantable electrical devices such as pacing-cardioverter- defibrillators is dependent upon accurate identification of rapid ventricular tachyarrhythmias such as monomorphic VT and VF. The primary method for tachycardia detection by implantable devices has been based upon timing information derived from rate, including an abrupt increase in heart rate, detection of a rate which exceeds an arbitrary minimum, and observation of a stable RR interval during the tachycardia. Such algorithms lack specificity for VT and VF recognition, however [5, 6].

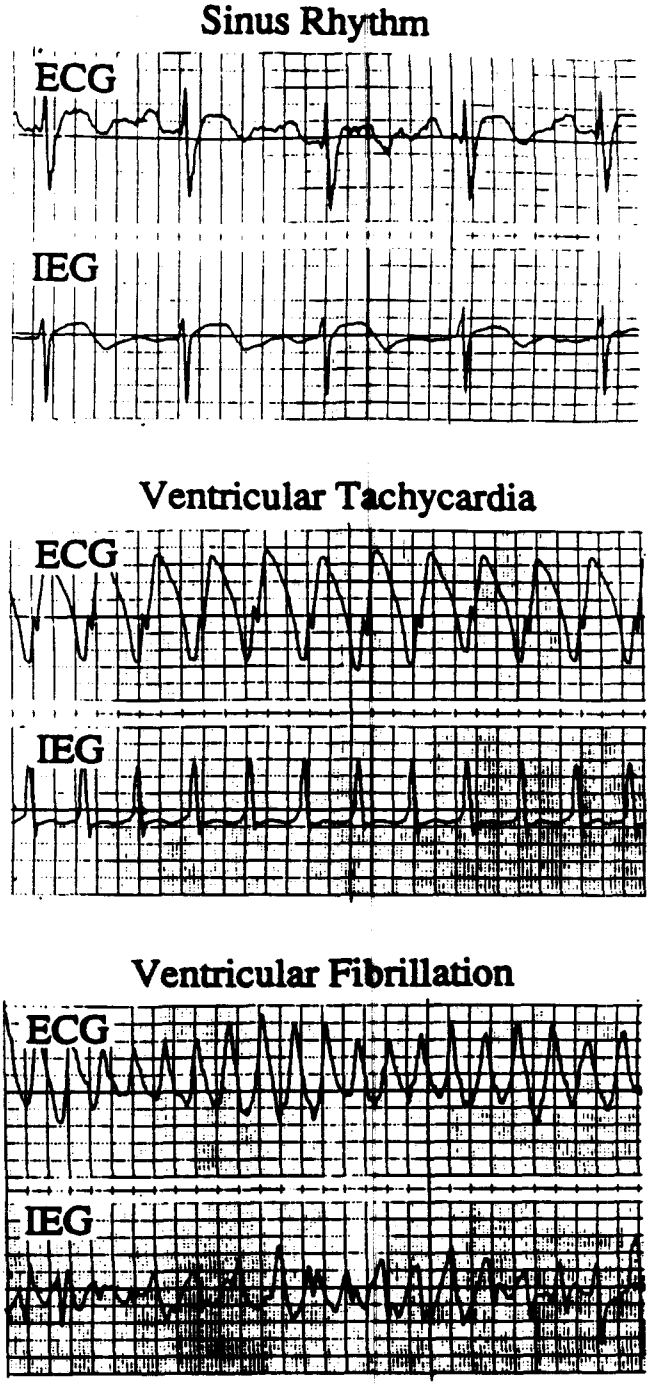


*Figure 1. Examples of the surface electrocardiographic (ECG) and distal bipolar intraventricular electrograms (IEG) of patient No. 11 during sinus rhythm (SR), monomorphic ventricular tachycardia (VT), and ventricular fibrillation (VF). The difference in mean CC from CWA of SR (.959) differentiated it from VT (.040) and VF (.162). The variance of VT $(.177)^2$ differentiated it from VF $(.499)^2$.*

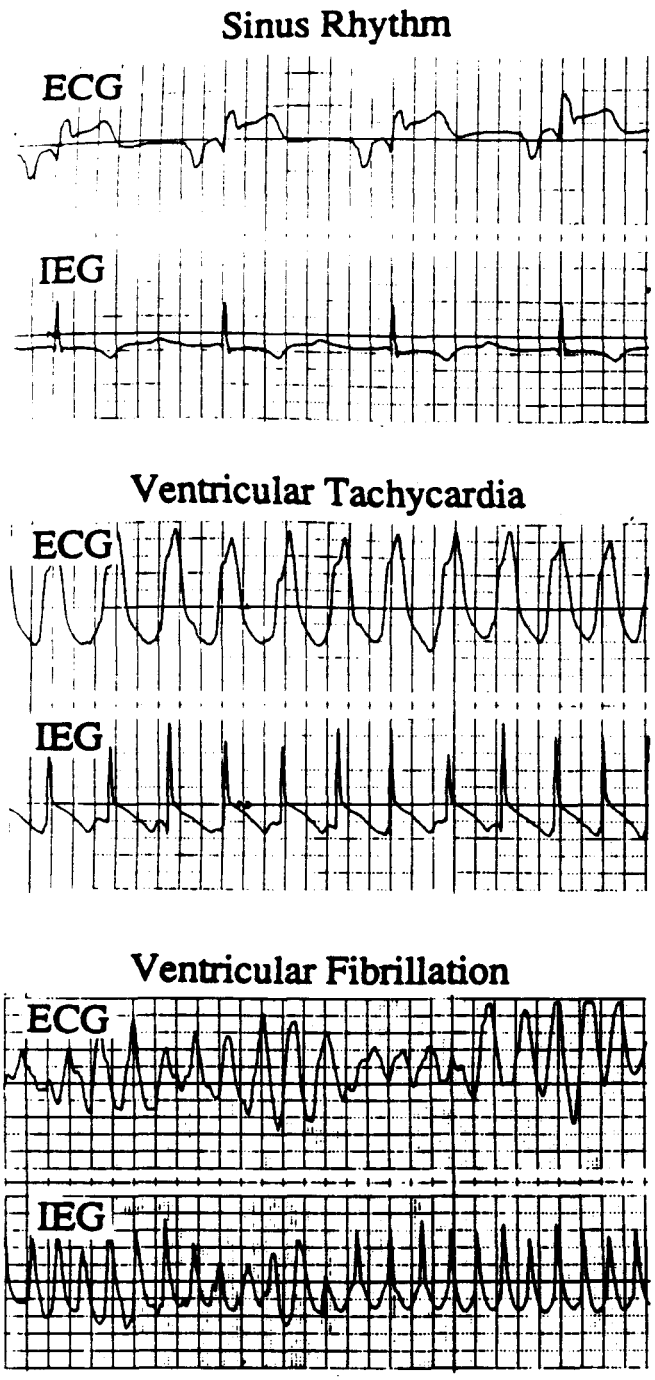


*Figure 2. Examples of the electrograms of patient No. 10 during SR, VT and VF. The difference in mean CC from CWA of SR (.977) differentiated it from VT (.960) and VF (.881). The variance of VT $(.018)^2$ and VF $(.092)^2$ were similar, however. Discrimination between these two tachyarrhythmias was not possible using this criterion. The abbreviations are similar to those of Figure 1.*

Both time-domain and frequency-domain analysis have been proposed for VT and VF detection [1, 2, 3, 4, 7]. Only one method–probability density function–has been incoporporated into an implantable device for VF detection. However, it has had limited applicability for patients who experience both recurrent VT and VF. In many cases, the activity peak of VT determined by this method of amplitude distribution analysis may occur at amplitude zero, resulting in failure to detect VT [8].

Previous studies have demonstrated the efficacy of correlation waveform analysis in detecting VT when compared to other proposed time- and frequency-domain analyses of individual bipolar intraventricular electrograms. The results of the present study suggest a similar time-domain analysis of intraventricular bipolar electrograms may also be useful in discriminating VF from SR as well as from more organized and more stable monomorphic VT. Although the values of CWA of VT and VF may be similar, this study has demonstrated that the variances of the correlation coefficient of VT are significantly different from those of VF. The magnitude of the variance in VT and VF appears to be useful in distinguishing these two ventricular tachyarrhythmias.

CWA has been utilized in previous studies of other arrhythmias as a "gold standard" against which other methods of time-domain analysis have been compared. Although CWA has potential advantages of being independent of electrogram amplitude and baseline fluctuations, its incorporation in currently available, implantable microprocessors is impractical because of its computational demands. Further work will be necessary to determine whether other, less computationally demanding time-domain methods [9] will be similarly effective in the detection and discrimination of VT and VF.

## Acknowledgments

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