DIAGNOSTIC METHODS

ARRHYTHMIA

Computer detection of atrioventricular dissociation from surface electrocardiograms during wide QRS complex tachycardias

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ABSTRACT Differentiation of wide QRS complex tachycardias on surface electrocardiograms is difficult for physicians and computers due in part to their inability to identify atrial activity, specifically atrioventricular (AV) dissociation. We studied 20 examples of AV associated rhythms and 17 examples of AV dissociated ventricular tachycardia. We applied an algorithm consisting of substraction of a mean beat from each individual beat in leads II and V1 to generate remainder electrocardiograms. The remainder electrocardiograms were visually inspected for the presence of P wave candidates and then autocorrelated. AV dissociated P wave candidates were evident on visual inspection of remainder electrocardiograms in none of 20 AV associated and 15 of 17 AV dissociated rhythms. Atrial cycle length and the presence of AV dissociation were automatically detected by applying a peak selection algorithm to the autocorrelation function. AV association was detected in all 20 AV associated rhythms and AV dissociation was detected for 11 of 17 AV dissociated rhythms (sensitivity 65%, specificity 100%, positive and negative predictive accuracy 100%, 77%). The correlation coefficient of detected vs true atrial cycle length for the 11 correctly detected AV dissociated rhythms was \( r = .98 \). Visual inspection of the remainder electrocardiograms along with the original electrocardiogram may increase the ease with which human readers can identify the presence of AV dissociation and thus diagnose ventricular tachycardia. Computer diagnosis of wide QRS complex tachycardias should be significantly improved by use of this algorithm.


DETECTION of atrial activity is the most significant limiting factor of the accuracy of current algorithms for diagnosis of arrhythmias by computer. The reason for this is that on the surface electrocardiogram, atrial activity is often represented by small amplitude waves that may be buried in QRS complexes or T waves. Of particular clinical significance is the detection of atrial activity, specifically atrioventricular (AV) dissociation, during a wide QRS complex tachycardia. While occasional instances of supraventricular tachycardias with AV dissociation have been reported, AV dissociation during a wide QRS complex tachycardia is considered virtually diagnostic for ventricular tachycardia.2 Wellens et al.3 found that approximately half of ventricular tachycardias are AV dissociated and fewer than one-third had a 1:1 ventriculoatrial conduction ratio. The percentage of AV dissociated ventricular tachycardias increases somewhat when the ventricular rate exceeds 200 beats/min.

Historically, arrhythmia algorithms have determined atrial activity by searching the isoelectric region between the end of the T wave and the beginning of the following QRS complex for P wave candidates.4–19 P waves have been found by a variety of approaches, such as slope measurement,4–16 difference functions,17,18 and matched filters.19 Some algorithms for interpretation of arrhythmias assume any detected P wave candidate a valid P wave, while in others additional criteria must be fulfilled (e.g., those relating to expected P wave width, slope, and PR interval) to validate a P wave candidate. All of these methods of P wave detection depend on detectable P waves occurring between the end of the T wave and the beginning of the following QRS complex. Such methods are unlikely to be reliable at rapid ventricular rates since little
or no isoelectric region is present between the end of the T wave and the beginning of the following QRS complex.

Stark et al. reported a method for the detection of AV dissociated P waves that involves taking the average of several consecutive QRST segments to generate a template. The template is then lined up and subtracted from each individual beat. The AV dissociated P waves can then be detected on the remaining signal. Unfortunately, no results with this method have been reported. Additional studies have used similar algorithms involving calculations of a template and subtraction to identify changes in the morphology of the QRS complex.

Recent studies of two widely used computerized electrocardiographic analysis systems have shown poor or no ability to diagnose ventricular tachycardia. In both cases failure was attributed to the inability of the systems to detect P waves, and neither system attempts to identify AV dissociation.

Differentiation of wide QRS complex tachycardias is difficult for the physician as well as for the computer. It has been suggested that based on the surface electrocardiogram, expert electrocardiographers can be certain of the diagnosis in only 50% of cases. Physicians also attribute this to the difficulty with detecting atrial activity. To accurately assess atrial activity, intra-atrial electrodes and esophageal leads have been used.

We present a method that detects AV dissociation by looking for a series of P waves that may appear looking for a series of P waves that may appear at the end of the RR interval instead of attempting to detect individual P waves. Our method involves subtracting a mean beat from surface leads to generate a remainder electrocardiogram. The remainder electrocardiogram is visually inspected for P wave candidates and autocorrelated. The output of the autocorrelation function is then used to automatically detect the presence of AV dissociation and the atrial cycle length for AV dissociated rhythms.

Methods

The data base for this study consisted of electrocardiograms from two sources. The first was analog tape recordings from the electrophysiology laboratory and included both surface leads and simultaneous intra-atrial electrograms. The second source was a commercial computerized electrocardiogram system (Marquette Electronics; Milwaukee, WI) that provided standard 12-lead electrocardiograms in digital form. Each data source provided 10 sec rhythm strips. Both leads II and V1 were analyzed, except in six cases in which lead II was unavailable. In all cases, the diagnosis of ventricular tachycardia was confirmed in the electrophysiology laboratory by standard criteria. Other rhythm diagnoses were determined in the electrophysiology laboratory or with the use of standard electrocardiographic criteria.

For each rhythm, the presence or absence of AV dissociation and true atrial cycle length were determined from simultaneous intra-atrial recordings (when available) or from surface leads. For the purposes of this study we use the term AV dissociation to mean the presence of P waves at a rate slower than the ventricular rate. While not technically correct, we refer in this report to rhythms with intact ventriculoatrial conduction but conduction ratios greater than or equal to 2:1 as AV dissociated rhythms (one of 17 rhythms). This is because the algorithm cannot currently distinguish such rhythms from those that are truly AV dissociated and the implication of both types of atrial activity for the differential diagnosis of wide QRS complex tachycardias is the same. In addition, the detection of AV dissociation by our algorithm requires that P waves be present and therefore rhythms with atrial fibrillation were excluded from the analysis. Unstable rhythms such as polymorphic tachycardias were also excluded. Computer processing was done with a Masscomp MCS-563 system (Massachusetts Computer; Littleton, MA).

Preprocessing. Data from the electrophysiology laboratory were played back from analog tape through an antialiasing filter with a cutoff frequency of 500 Hz and then digitized at 1200 Hz. The waveform was then low-pass filtered at 60 Hz. Data from the commercial electrocardiogram system had been digitized at 250 Hz, filtered, and compressed for the commercial system, and were decompressed and transferred to our computer.

When long strips of data were available (i.e., from the electrophysiology laboratory), 10 sec strips of data without premature ventricular complexes, fusion beats, or amplifier saturation were obtained. No special attempt was made to avoid otherwise noisy electrocardiograms. Each beat in the 10 sec rhythm strip was classified as either a dominant or anomalous beat. Beats that contained QRS complexes of the most common morphology for the rhythm strip were defined as dominant beats. Premature ventricular beats, fusion beats, or beats that saturated the amplifiers were defined as anomalous beats.

Fiducial points were marked for both dominant and anomalous beats and a baseline wander correction was applied. The baseline correction algorithm calculated the mean of successive 2 beat intervals and subtracted the linear trend. Fiducial point marking and beat classification were done by hand for electrophysiology laboratory data. The commercial electrocardiogram system automatically determined fiducial points and classified beats as part of its routine processing. These data were obtained in digital form along with the rhythm strips.

Mean beat and remainder electrocardiogram calculation. The mean ventricular cycle length for each rhythm strip was calculated by averaging the intervals between the fiducial points of consecutive dominant beats. For each beat in the 10 sec rhythm, a beat window was defined as a segment of the rhythm strip equal in length to the mean ventricular cycle length with the fiducial point at its center. A mean beat was generated for leads II and V1 by averaging every dominant beat window. The mean beat was then lined up against all beat windows in the 10 sec strip and subtracted to generate remainder electrocardiograms.

We reasoned that some anomalous beats may be capture beats with fusion and would therefore be preceded by P waves. It would be desirable in these cases to zero the QRS complex of the anomalous beats to prevent their large remnants from contributing to the autocorrelation function (see below), while attempting to preserve the P waves that occur before them. We therefore zeroed only the part of the beat windows containing anomalous beats beginning at 120 msec before the fiducial points and ending at the end of the window. The earlier part of the window was retained with the appropriate segment of the mean beat subtracted from it.

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After subtraction, the data from the electrophysiology laboratory were reduced to 240 Hz for further processing, while the commercial electrocardiogram data were kept at 250 Hz. The remainder electrocardiograms were smoothed by taking the mean of five consecutive data points as the value for the center point. The subtraction process was found to subtract between 71% and 97% of the original signal. Remainder electrocardiograms were examined subjectively and autocorrelated.

**Autocorrelation.** The autocorrelation function gives a measure of similarity of a signal and the same signal shifted in time. The value of the autocorrelation function at each time shift of interest equals the sum of data points in the product of the original signal and the shifted signal (figure 1). The autocorrelation function of a periodic signal will have a peak at the cycle length of the repetitive waveform. This feature makes the autocorrelation function useful for detecting the periodicity of a signal in noise.25

After subtraction of the mean beat, the remainder electrocardiogram will contain signals that are not synchronous with the QRS complexes, such as AV dissociated P waves, muscle artifacts, and noise in addition to the beat to beat fluctuations of QRST morphology. If the atrial activity is periodic and AV dissociated, the autocorrelation of the remainder electrocardiogram will contain a peak at the atrial cycle length and multiples of the cycle length. A suitable peak selection algorithm may then automatically detect the atrial cycle length.

Autocorrelation was performed on two consecutive 1024-point segments of the remainder electrocardiogram giving a resolution of one sample period of from 0 to 2.5 sec.26 The autocorrelations were then averaged and a peak detection algorithm (see below) was applied.

**Computer detection of AV dissociation.** Autocorrelation functions for leads II and V1 were processed separately. Since AV dissociated P waves were expected to have a cycle length longer than the ventricular cycle length and shorter than 1200 msec, only this portion of the autocorrelation function was examined. A peak selection algorithm applied slope and amplitude criteria to the maximum of the examined portion of the autocorrelation function. Values for the slope and amplitude criteria were chosen empirically to avoid falsely identifying AV associated rhythms as AV dissociated rhythms. If the criteria were met, the cycle length at the maximum of the autocorrelation function was identified as the "detected cycle length." If the maximum did not meet the criteria, the rhythm was identified as AV associated and the computer processing was complete.

If a detected cycle length was identified, the computer continued processing to determine whether this cycle length was different from the ventricular cycle length. If the detected cycle length was within an allowable error of the true ventricular cycle length then the computer identified the rhythm as AV associated and the detected cycle length as the ventricular cycle length. Otherwise, the rhythm was identified as AV dissociated and the detected cycle length was identified as the detected atrial cycle length. The allowable error for detected cycle length was chosen

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**FIGURE 1.** The autocorrelation of a rectangular wave with a 500 msec cycle length. The autocorrelation function has three time shifts marked on it that correspond to each of the three panels above it. A. The original signal and the signal with a time shift of 0 msec below it. The autocorrelation function is calculated by multiplying the value of the signal by the value of the shifted signal for each data point and summing the results. The autocorrelation of a time shift of 0 always equals the maximum of the autocorrelation function since the signal is identical to itself at that time. (In A, large values within the rectangular waves of the original signal are multiplied by large values within the rectangular waves of the shifted signal, while data points with a small value are multiplied by small values in the shifted signal. The result is a large sum.) B. The original signal and the signal with a shift of 250 msec. The rectangular waves no longer overlap and the autocorrelation at this time shift will be small, since large values within the rectangular waves are now multiplied by small values within the shifted signal. C. The original signal and the signal with a shift of 500 msec. The rectangular waves line up again at this time shift, producing a peak in the autocorrelation function.
as the standard deviation of RR intervals of consecutive dominant beats plus 8 msec. Thus, the greater the variation in RR intervals, the greater the allowable error.

A peak detected at a cycle length different from the ventricular cycle length is likely to represent a meaningful waveform, specifically AV dissociated P waves. By contrast, a peak detected at the ventricular cycle length is most likely to represent artifacts from subtraction of QRS complexes and T waves.

The results of applying the peak selection algorithm to data from the two leads were output by the computer and compared. If AV dissociation was found in either lead, the rhythm was considered AV dissociated with the corresponding detected atrial cycle length. If both leads were detected as AV associated, the rhythm was considered AV associated.

**Results**

The database for this study consisted of 37 rhythms. Of these rhythms, 20 were recorded in the electrophysiology laboratory and the remaining 17 were routinely recorded by the commercial computerized electrocardiogram system. The true presence or absence of AV dissociation and the true atrial cycle length were determined from simultaneously recorded intra-atrial electrograms (20 rhythms, 12 associated and eight dissociated) or from surface leads (17 rhythms, nine associated and eight dissociated). Both leads II and V1 were analyzed (31 rhythms), except when lead II was unavailable (six rhythms). All rhythms obtained from the computerized electrocardiogram system were first analyzed by the Marquette 12SL system. None of the rhythms was called AV dissociated by their algorithm.

Twenty of the 37 rhythms analyzed were AV associated. Eleven of the 20 were wide QRS tachycardias (ventricular tachycardias with intact ventriculoatrial conduction, three; assorted supraventricular tachycardias, eight). The ventricular cycle length of the AV associated tachycardias ranged from 552 to 272 msec (mean ± SD 432 ± 98 msec). The remaining nine of the 20 AV associated rhythms were narrow QRS rhythms (sinus rhythm, seven; supraventricular tachycardia, two).

Seventeen of the 37 rhythms analyzed were AV dissociated. All 17 were ventricular tachycardias with cycle lengths ranging from 628 to 192 msec (399 ± 117 msec). The mean cycle lengths of the AV associated and AV dissociated tachycardias were not significantly different (p = .21).

**Computer detection of AV dissociation.** The computer correctly identified all 20 AV associated rhythms and 11 of the 17 AV dissociated rhythms (six of eight from the electrophysiology laboratory and five of nine from the commercial system) and incorrectly identified six of the latter as AV associated. This algorithm for detection of AV dissociation therefore had a sensitivity of 65% and a specificity of 100% for this data set. The algorithm had a positive predictive value of 100% and a negative predictive value of 77%. Of the 11 correctly identified AV dissociated rhythms, the detected atrial cycle length was within 20 msec of the true atrial cycle length in all but one rhythm in which the detected atrial cycle length was 77 msec less than the true cycle length. The correlation coefficient of the true vs detected atrial cycle length was r = .98. Of the 11 correctly identified AV dissociated rhythms, atrial cycle length was detected in all analyzed leads (6/11 rhythms) or in one of the two leads (1/11 rhythms in lead V1, 4/11 rhythms in lead II). For all rhythms in which AV dissociation was found in both analyzed leads, the atrial cycle lengths detected in leads V1 and II were identical.

**Remainder electrocardiograms.** Visual inspection of remainder electrocardiograms was performed. Major features of the remainder electrocardiograms from AV associated rhythms usually occurred coincident with the most prominent features of the original electrocardiograms, namely QRS complexes and T waves (figure 2). Thus, prominent features often recurred at regular intervals equal to the ventricular cycle length. Of the 20 remainder electrocardiograms from AV associated rhythms, visible features recurring at the ventricular cycle length were evident in all analyzed leads (15/20 rhythms), in one of two leads (4/20 rhythms), or in neither lead (1/20 rhythms). There were no prominent features that recurred at an interval other than the ventricular cycle length in any of the 20 remainder electrocardiograms from AV associated rhythms.

Major features of the remainder electrocardiograms of the AV dissociated rhythms often recurred coincident with the most prominent features of the original electrocardiogram, as they did for AV associated rhythms, and thus they also often recurred at regular intervals equal to the ventricular cycle length. Of the 17 AV dissociated rhythms, visible features recurring at the ventricular cycle length were evident in remainder electrocardiograms of all analyzed leads (4/17 rhythms), in one of the two leads (6/17 rhythms), or in neither lead (7/17 rhythms). However, in addition to features recurring at the ventricular cycle length, 15 of the 17 remainder electrocardiograms for AV dissociated rhythms also had prominent features that recurred at a cycle length different than the ventricular cycle length (figure 3). In each case, these features were coincident with atrial activity as assessed by simultaneous intra-atrial electrograms or from surface leads and were therefore labeled P wave candidates. P wave candidates were evident in all analyzed leads (13/17 rhythms).
rhythms), in one of the two leads (2/17 rhythms), or in neither lead (2/17 rhythms). When P wave candidates were visible in a given remainder electrocardiogram, most but not all true P waves had a corresponding P wave candidate and some P wave candidates were visible in only one lead (figures 4 and 5).

**Autocorrelation function.** Plots of the autocorrelation functions of remainder electrocardiograms were varied in shape. Allowable error used to determine how far a peak could be from the mean ventricular cycle length and still be labeled as such ranged from 16 to 104 msec (33 ± 18 msec). Remainder electrocardiograms with major features recurring at the ventricular cycle length usually produced autocorrelation functions with peaks at the ventricular cycle length and multiples of the cycle length. Signals with substantial 60 cycle noise or with very little amplitude in the remainder electrocardiogram produced plots that showed little correlation and no clear peaks (figure 6). Some remainder electrocardiograms that contained wide deflections with no repetitive patterns produced autocorrelation plots with small peaks at many different intervals. Remainder electrocardiograms with P wave candidates usually produced autocorrelation plots with peaks at the cycle length of the P wave candidates and multiples of the cycle length (figures 7 and 8), thus allowing detection of AV dissociation.

**Description of errors.** The computer incorrectly identified six of the AV dissociated rhythms as AV associated. For two of these rhythms only lead V1 was available for study. Three additional rhythms, one with frequent anomalous beats, had the true atrial cycle length as the maximum of the autocorrelation function but the peak failed the amplitude criteria.

The final AV dissociated rhythm that was incorrectly identified by the computer had a true atrial cycle length that was only 5 msec different than the true ventricular cycle length, thus making detection of AV dissociation with a cutoff of more than 8 msec in allowable error impossible. The computer correctly identified the atrial cycle length. In addition, P wave candidates were visible in the remainder electrocardiogram.

**Discussion**

The computer correctly identified all of the 20 AV associated rhythms and 11 of the 17 AV dissociated rhythms. This is comparable to the reported success of human electrocardiographers and superior to currently available computer algorithms. For the 11 correctly identified AV dissociated rhythms, a close correlation was found between detected and true atrial cycle lengths. Of the 17 AV dissociated rhythms, P wave candidates were evident by visual inspection of the remainder electrocardiogram.

For two undetected AV dissociated rhythms and the one that was detected with an incorrect atrial cycle...
FIGURE 3. Leads II and V₁ and their respective remainder electrocardiograms (RE) from a patient with ventricular tachycardia. True atrial (ACL) and ventricular (VCL) cycle lengths are given in msec. Both remainder electrocardiograms show prominent P wave candidates (P). It is easily verified by the reader of the electrocardiogram that these P wave candidates correspond to P waves in the original signal. While the presence of AV dissociation may be diagnosed in this rhythm with the use of surface leads alone, the display of remainder electrocardiograms along with the original rhythms makes the presence of AV dissociation easily observable.

FIGURE 4. Leads II and V₁ and their respective remainder electrocardiograms (RE) from a patient with ventricular tachycardia. Atrial electrograms (AE) show the presence of AV dissociation. True atrial (ACL) and ventricular (VCL) cycle lengths are given in msec. On the remainder electrocardiograms, the repetitive features occurring simultaneously with the atrial electrogram (A) are termed P wave candidates (P). The remainder electrocardiogram from lead V₁ demonstrates two P wave candidate morphologies consistent with sinus P waves and two premature atrial complexes (PAC).
length only lead $V_1$ was available for analysis. Lead $V_1$ is a good choice for visual inspection of the remainder electrocardiogram since P waves tend to be large compared with the QRS complex, but it may not be the best choice for analysis by autocorrelation because the P waves are biphasic. The biphasic P waves cause negative and positive peaks in the autocorrelation function and reduce the amplitude of the peak of the detected atrial cycle length. Of the 11 correctly detected AV dissociated rhythms, seven were detected in lead $V_1$ and 10 were in lead II. It might be possible to take advantage of the large P waves in lead $V_1$ by integrating the remainder electrocardiogram to get P waves that are only positive in excursion. Use of a different choice of leads, such as the magnitude of the Frank lead system or lead I or III, might also be considered.

Three of the six errors occurred when the peak of the autocorrelation function was at the atrial cycle length but did not pass the amplitude criterion. Lowering the amplitude criterion would decrease the specificity of the algorithm. This situation might be improved by implementing some signal conditioning before or after subtraction. Any type of signal conditioning that decreases the energy of noise in the remainder electrocardiogram relative to the energy of the P waves will cause the peak at the detected atrial cycle length to be larger. This might be accomplished by variety of methods, such as use of a different low-pass filter for the original signal, bandpass filtering of the remainder electrocardiogram, or use of different smoothing algorithms for the remainder electrocardiogram.

The final undetected AV dissociated rhythm had a true ventricular cycle length 5 msec less than the true

![FIGURE 5](http://circ.ahajournals.org/)

**FIGURE 5.** Leads II and $V_1$ and their respective remainder electrocardiograms (RE) from a patient with ventricular tachycardia. Atrial electrograms (AE) show the presence of AV dissociation. True atrial (ACL) and ventricular (VCL) cycle lengths are given in msec. Most, but not all, atrial electrograms (A) have P wave candidates (P) that can be visually detected on the remainder electrocardiograms in lead II despite substantial baseline wander and a short ventricular cycle length.

![FIGURE 6](http://circ.ahajournals.org/)

**FIGURE 6.** Autocorrelation function of the remainder electrocardiogram of lead II of the AV associated rhythm shown in figure 2. The ventricular cycle length (VCL) is marked in msec. The autocorrelation plot shows no peaks meeting slope and amplitude criteria and the rhythm is detected as AV associated.
atrial cycle length and 12 msec less than the detected cycle length. The P waves were easily recognizable on the remainder electrocardiogram and the computer-detected cycle length represented the true atrial cycle length. However, the allowable error was larger than 12 msec and the rhythm was called AV associated. The problem of the detection of AV dissociation in those rhythms in which the atrial and ventricular cycle lengths are either close to each other or multiples of each other is an interesting one. We made some assumptions about the rhythms we could diagnose by choosing to use the methods of mean beat calculation and autocorrelation. The rhythms were required to have a relatively constant QRS morphology, PP interval, P wave morphology, and variable PR intervals if the rhythm was to be detected as AV dissociated. In addition, the atrial and ventricular cycle lengths had to be more than an allowable error apart. Rhythms such as those with close atrial and ventricular cycle lengths (e.g., isorhythmic AV dissociation) and rhythms with Wenckebach conduction, multiform atrial tachycardia, and atrial fibrillation are examples of rhythms that do not comply with these assumptions.

The results presented in this report were obtained with a study data set and it remains to be seen whether results from a future test set will be as good. Further investigation must be done with a much larger data set to rigorously test the specificity of this algorithm. If it proves to be capable of accurately detecting AV dissociation, then processing should continue after detection of AV dissociation to detection of individual P waves in the remainder electrocardiograms. The technique of mean beat subtraction might also be applied to detection of single AV dissociated beats during otherwise normal rhythms. Similar computer algorithms might detect second- and third-degree AV block.

The algorithm for detection of AV dissociation presented here is not intended as a stand-alone system but should be used as a software module that may be added to existing arrhythmia interpretation systems. By obtaining half of our data from a commercially available electrocardiogram system, we have shown that it is possible to use the automatic preprocessing from such a system as input to our algorithm with successful results.

Although ventricular tachycardia appears on a very small percentage of the 12-lead electrocardiograms recorded, when it is recorded it is usually in an acutely ill patient requiring immediate therapy. While intravenous verapamil is the current drug of choice for therapy for paroxysmal supraventricular tachycardia with functional or preexisting bundle branch block, administration of this drug to patients with ventricular tachycardia most often results in failure to convert the tachycardia combined with negative inotropy and thus, the risk of hemodynamic collapse. The availability of an algorithm for detection of AV dissociation (both for inspection of the remainder electrocardiogram and the final computer interpretation) in an emergency room or

FIGURE 7. Autocorrelation function of the remainder electrocardiogram of lead V1 of the AV dissociated rhythm shown in figure 4. The large peak was detected by the computer and labeled as the detected atrial cycle length (ACL) equal to 708 msec. True atrial cycle length was 700 msec. A significant peak was also detected at twice the atrial cycle length.

FIGURE 8. Autocorrelation function of the remainder electrogram of lead II of the AV dissociated rhythm in figure 5. The plot shows large peaks at the detected atrial cycle length (ACL) and multiples of the atrial cycle length.
coronary care setting could be of significant benefit, especially when house staff, nurses, or other nonexpert electrocardiographers are called upon to make the diagnosis. Improvements in the algorithm and addition of other diagnostic criteria relating to QRS morphology may improve sensitivity. Extension of the algorithm to coronary care monitors or ambulatory monitors in addition to 12-lead electrocardiograms may be feasible. Whether this algorithm will improve upon the ability of expert electrocardiographers to detect AV dissociation remains to be determined.

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