Can Paroxysmal Atrial Fibrillation Be Predicted?

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Abstract

Atrial fibrillation is an ECG rhythm with a significant mortality due to stroke. The objective of this study was to detect those patients most likely to develop atrial fibrillation, and to identify ECGs closest to the onset of fibrillation. Our hypothesis was that patients with atrial fibrillation would have atrial ectopy, and the frequency of this activity would increase prior to onset of fibrillation. From a learning set of one hundred 30 min ECGs from 50 patients, 25 without atrial fibrillation (normal) and 25 who subsequently developed atrial fibrillation, an algorithm was developed to detect the presence of ectopic beats using R-R interval data. In the learning set, 37/50 abnormal and 34/50 normal patients were identified, giving a potential screening accuracy of 71%. As a prediction test to detect the ECGs closest to atrial fibrillation, 19/25 were correctly identified. For the test set, a total of 29/50 were correctly assigned to the normal and fibrillation groups (reference 20010430.191646 entrant 11), and a 39/50 score obtained in predicting the onset of atrial fibrillation (reference 20010430.194799 entrant 11).

1. Introduction

Atrial fibrillation (AF) is the most commonly occurring arrhythmia, and its prevalence increases with age [1]. It is uncommon below the age of 50 years, but around 5% of those over 65 have the condition [2]. The risk of stroke, resulting from thrombus formation in the heart's poorly contracting chambers, is increased fivefold in patients with AF, and the risk of death is almost doubled [3,4]. Despite these risks there is evidence that atrial fibrillation is undetected in up to 40% of patients [5,6,7]. The ability to predict the onset of AF would allow treatment to prevent the arrhythmia developing. Pharmacological or electrical treatments are available, but there are no reliable validated methods for predicting the onset of paroxysmal AF (PAF). 12-lead ECG, signal-averaged P-wave morphology, RR interval dynamics and atrial ectopy have all been studied as possible predictors of the onset of PAF. The aim of this study was to assess the ability of a computer algorithm to automatically i) screen subjects for PAF and ii) predict the onset of PAF, from the ECG. Our hypothesis was that patients with atrial fibrillation would have atrial ectopy, and the frequency of ectopics would increase prior to the onset of fibrillation.

2. Method

2.1. PAF data

Data were provided for the 2001 Computers in Cardiology Challenge from PhysioNet. The learning dataset comprised 2-lead ECGs from 25 subjects with no PAF (normal) and 25 patients with PAF. Two 30-minute ECG sections were provided for each subject. In the case of PAF patients, one section was at least 45 minutes distant in time from AF (although short episodes of AF were observed in this section for some of the subjects), and the remaining section immediately preceded the onset of AF (Figure 1). Similarly, the test dataset comprised two 30-minute ECGs from 50 subjects for which the diagnosis (normal or PAF) was unknown to us.

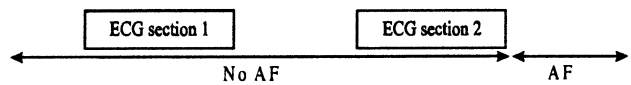

Figure 1. Schematic of patient dataset. Two 30-minute ECG sections, one distant from AF and one immediately preceding AF were available.

2.2. Detection of atrial ectopic beats

Beat-by-beat RR intervals from a single ECG lead (ECG0) were generated by an automatic QRS detector which used a threshold on the differential of the lead signal to locate R waves in each beat.

An algorithm was developed to detect and categorise ectopic beats. Ectopic beats were detected by identifying

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Computers in Cardiology 2001;28:121-124.

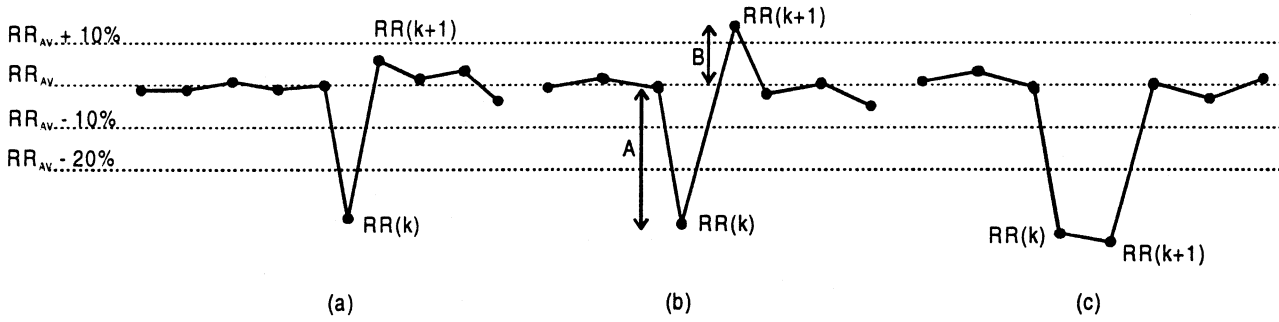

Figure 2. Illustration of the thresholds used in the algorithm and three RR series containing possible ectopic beats: (a) atrial ectopic beat is detected, (b) ventricular or atrial ectopic beat is detected depending on the ratio B/A, and (c) atrial or artifactual ectopic detected dependent on the sum of RR(k) and RR(k+1).

short RR intervals relative to the average RR (RR_{AV}) of the surrounding beats. If the RR interval of a beat fell below the moving average of RR less 20%, a suspected ectopic beat was detected.

Ectopic beats were characterised automatically according to the change in the RR interval in the beat following the suspected ectopic. Atrial ectopics are usually followed by a beat with sinus RR interval, since the SA node is reset by propagation across the right atria. Thus, an ectopic beat (beat k) directly followed by a beat (beat k+1) falling within $RR_{AV} \pm$ 10% was characterised as atrial in origin (Figure 2a). This condition alone was not sufficient to detect all atrial ectopics. Ventricular ectopics are followed by a beat with long RR (compensatory pause) if propagation fails to reset the SA node. In this case the SA node fires, but does not propagate to the ventricles. Therefore, ventricular ectopics were characterised as those in which the change in RR of beat k+1 from RR_{AV} exceeded 30% of the change in RR of beat k from RR_{AV} (Figure 2b). If the sum of the RR of the ectopic beat and the RR of the following beat fell within $RR_{AV} \pm$ 10%, then this detection was ignored since it was indicative of incorrect detection of the T wave as an R wave or due to noise (Figure 2c). All further conditions were classified as atrial ectopics.

The total number of atrial and ventricular ectopic beats in each 30-minute ECG were recorded. Figure 3 illustrates the algorithm used for the detection, classification and recording of ectopic beats.

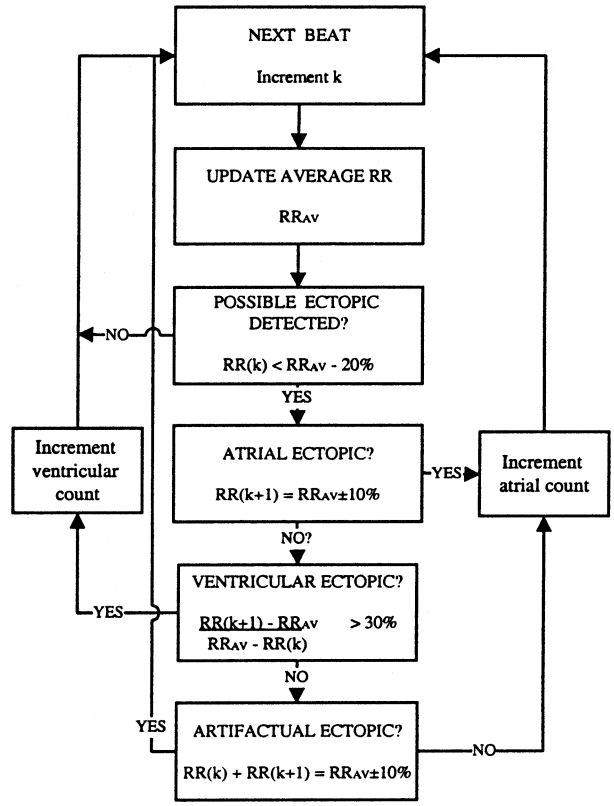

Figure 3. Flow chart of the algorithm to detect, characterise and count ectopic beats.

2.3. Screening for PAF

Two screening criteria were investigated. PAF patients were identified as:

a) those with an atrial ectopic count greater than zero,
b) those with atrial *and* ventricular ectopic counts greater than zero.

The ECG section closest to the onset of AF was used for the screening analysis in the learning dataset.

2.4. Prediction of PAF

From the two ECG sections for each subject, the recording with the greatest number of atrial ectopic beats

was assumed to be the recording closest to the onset of AF. If there were an equal number of atrial ectopics detected in each ECG section, the section with the greatest ventricular ectopic count determined the section closest to the onset of AF.

3. Results

3.1. Ectopic beats

Figure 4 shows histograms of the atrial and ventricular ectopic beats detected by the algorithm for each recording of the learning set. 31 recordings in the normal group had zero detected atrial ectopics, and 19 recordings had zero detected ventricular ectopics. There were 3 recordings in which the ventricular count was zero, and the atrial count was non-zero (but less than 3) in this group. In the PAF group there were 37 recordings with detected atrial ectopics and 48 with detected ventricular ectopic beats. All those with atrial ectopics also had ventricular ectopics.

3.2. Screening for PAF

Classifying those recordings with an atrial ectopic count greater than zero resulted in the correct classification of 37/50 PAF patients and 31/50 normal subjects from the learning dataset.

Classifying those recordings with both atrial and ventricular ectopic counts greater than zero, correct classification of normal subjects was improved to 34/50, and the classification of PAF patients was unchanged giving a potential screening accuracy of 71%. For the test dataset, a total of 29/50 were correctly classified (reference 20010430.191646 entrant 11).

3.3. Prediction of PAF

In the learning dataset, the mean number of atrial ectopic beats detected in the first ECG section was 15 with a range of 0 to 126 beats. In the section closest to the onset of AF the mean number of atrial ectopics was 45 with a range 0 to 508. In this dataset 19/25 were correctly identified as the ECG sections immediately preceding AF.

In the test dataset, the algorithm achieved a score of 39/50 (reference 20010430.194799 entrant 11). With the subtraction of the 25 normal patients, this was equivalent to 14/25 correctly identified ECG sections immediately preceding AF.

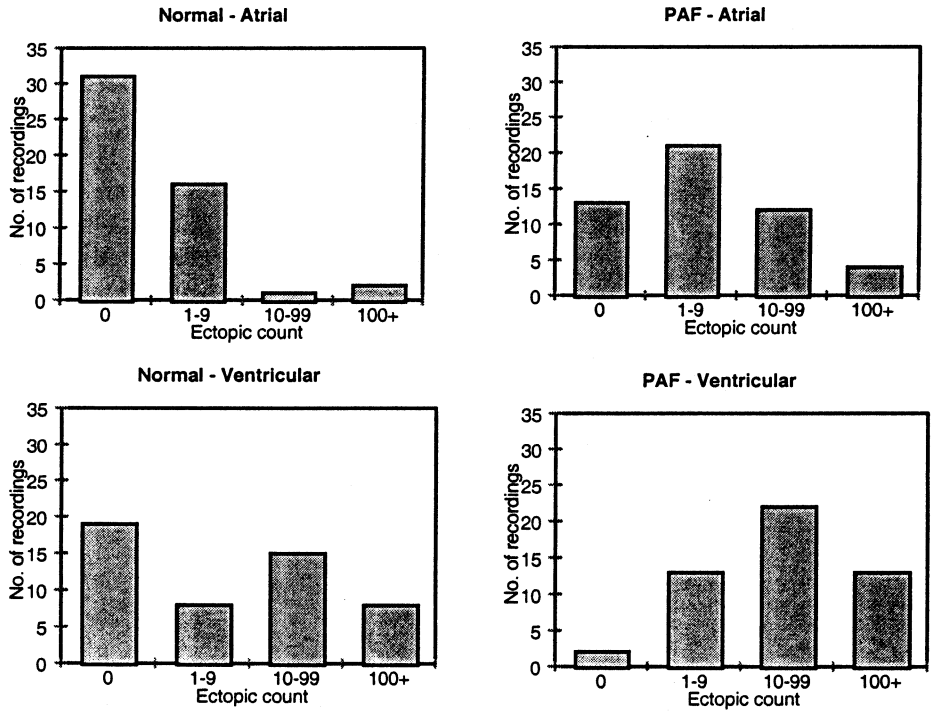

Figure 4. The number of recordings for ranges of the number of atrial and ventricular ectopic beats detected for the learning dataset.

4. Discussion and conclusions

Our hypothesis was that PAF patients may be detected by the presence of atrial ectopic beats, and that the onset of PAF could be predicted by an increase in the number of atrial ectopic beats. We have presented an algorithm to automate the detection and classification of ectopic beats from single lead ECG data. We achieved a screening accuracy of 71% for the learning dataset, which fell to less than 60% for the test dataset. We achieved a prediction accuracy of 76% for the learning dataset, which fell to 56% for the test dataset.

Since in the PAF group there were a large number of recordings with zero detected atrial ectopics and very few with zero detected ventricular ectopics, it is probable that some atrial ectopic beats were classified as ventricular. No attempt was made to optimise the thresholds used in the algorithm and some reduction in misclassification could be achieved by optimising the thresholds. In addition, we made no attempt to check the automatic QRS detector. Improvements in QRS detection might have increased the accuracy of the screening and prediction tests.

Our results are consistent with reports that have shown there is no consistency in the mode of onset of AF, both across a population and within subjects, which confounds the ability of a single simple algorithm to detect the onset of AF in all cases [8].

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