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Automatic detection of end QRS notching or slurring

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Abstract

The purpose of this study was to define criteria suited to automated detection of end QRS notching and slurring and to evaluate their accuracy. One hundred resting 12 lead ECGs from young adult men, split randomly into equal training and test sets, were examined independently by two reviewers for the presence of such notching or slurring. Consensus was reached by re-examination. Logic was added to the Glasgow resting ECG program to automate the detection of the phenomenon. After training, the automated detection had a sensitivity (SE) of 92.1% and a specificity (SP) of 96.6%. For the test set, SE was 90.5%, SP 96.5%. Two populations of healthy subjects – one Caucasian, one Nigerian – were analysed using the automated method. The prevalence of notching/slurring with peak/onset amplitude respectively ≥ 0.1 mV in two contiguous inferolateral leads was 23% and 29% respectively. In conclusion, the detection of end QRS notching or slurring can be automated with a high degree of accuracy.

Keywords: Early repolarization; Automated ECG; Racial differences

Introduction

In the last few years, there has been renewed interest in the significance of end QRS notching or slurring. This is one of the characteristics of early repolarization (ER) [1]. It has been reported that the presence of a notch or slur in the downslope of the R wave together with a horizontal/descending ST segment is a risk factor for cardiovascular mortality [2,3]. However, there is no clear definition of this morphology and there has been considerable variety in reporting this feature visually. If standard definitions for notching and slurring could be found that are acceptable to all concerned, then they could be incorporated into criteria for diagnostic analysis.

ECGs are commonly reported using computer programs. The aim of this study was to determine if end QRS notching and slurring could be detected using automated methods, and to assess the accuracy of such automated detection of this end R wave phenomenon by comparing manual and computer detection for a set of ECGs.

Methods

One hundred resting 12 lead ECGs from young adult men (mean age 24.8 ± 3.2 years) were split randomly into equal training and test sets. These were a subset of ECGs from a dataset of 1496 apparently healthy Caucasians (859 males and 637 females with an age range of 18–82 years) collected in the West of Scotland in the 1980s, recorded using a locally designed and built electrocardiograph that recorded 8 seconds of data, with a sampling rate of 500 samples/sec. The subgroup of young adult men was chosen as the prevalence of end QRS notching and slurring is known to be higher in this section of the population [4]. The waveforms for the training set were examined independently by two reviewers for the presence of end QRS notches and slurs (Fig. 1). The tracings used for the review were the average beats for each of the 12 leads. The reviewers marked the leads on the paper printout with an 'N' or 'S' for notch or slur respectively where appropriate.

The protocol involved marking all notches and slurs in leads II, III, aVF, V4, V5 and V6 unless they were considered too small (as defined later) to be of any significance. A notch was defined as a reversal of slope distinguishable to the eye, and a slur as a change of QRS slope on the terminal component of an R wave. Where reviewers differed initially, consensus was reached by re-examination.

As a starting point for automating detection, preliminary definitions were set to describe the morphologies in question. While it is common to report notches in automated ECG reports, this is not true of slurs. The definitions were based on ECG wave measurement standards [5] and on the criteria used in recent studies [1,3,6].

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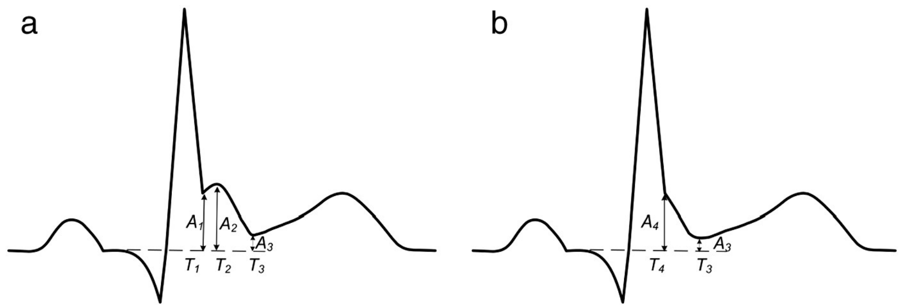

Fig. 1. Measurements of amplitudes (A) and sample numbers (T) for a QRS end notch (1a) or slur (1b).

Various points on the notches and slurs were chosen to be measured (Fig. 1). The following requirements were stipulated: the last component of the QRS complex was an R wave; the R wave duration was greater than 40 msec; the notch or slur was on the downward slope of the R wave; the start of the notch or slur was more than 10 msec from the end point of the complex; the notch amplitude A2 or slur amplitude A4 (Fig. 1) had a minimum allowed amplitude of 0.05 mV and maximum of 0.5 mV.

The preliminary definitions for notching and slurring were implemented in the wave measurement module of the Glasgow resting ECG program [7]. There is considerable debate in the current literature about the definition of QRS end. The conventional QRS end, i.e. ST onset, is used in the program and is determined from the spatial velocity over all leads and from changes in slopes and amplitudes for each lead. The current method of identifying a notch by finding changes in slope was used and the additional measurements were stored.

New logic was added to identify and measure a slur at the end of the R wave. The point of inflection was determined by using the same method as is used to identify a delta wave in the WPW pattern, namely finding the inflection point (IP) on the curve (Fig. 2) which minimises the sum of the areas between the curve and the two straight lines drawn from the point of inflection – one connecting to the start of the slope and the other to the end of the slope. The angle of the slope had to be above a minimum value to qualify as a slur.

The category of notch or slur for each lead was output from the program for analysis along with the slope of the ST segment and the ST amplitude at the QRS end point. The slope of a line between the QRS end and the point at 3/8th of the ST-T segment is used as a measurement of ST slope. A slope $\leq 10°$ was defined as horizontal or downward sloping.

The manual and automated categorizations were compared and basic statistics obtained, using Excel and IBM SPSS Statistics, for the ECGs in the training set. The classification and comparison were subsequently carried out on the test set.

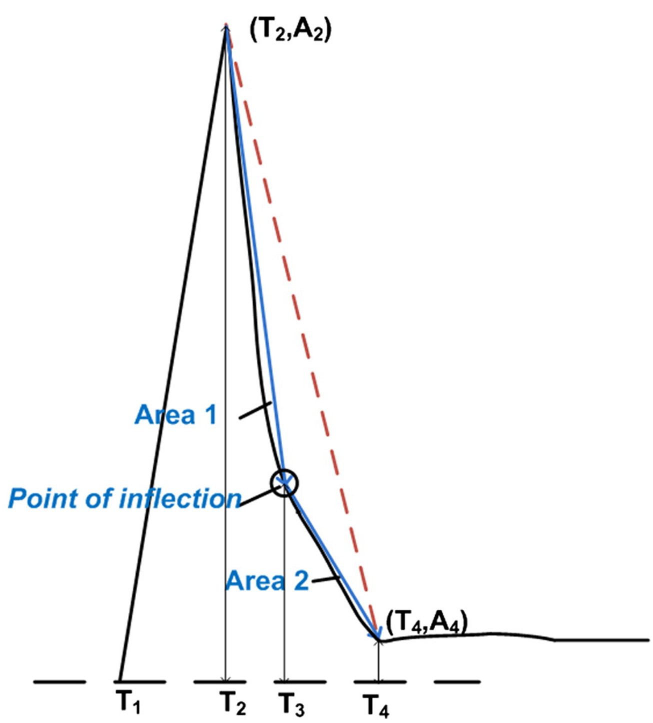

Fig. 2. Finding the point of inflection. The method used is to find the inflection point on the curve which minimises the sum of the areas (area 1 + area 2) between the curve and the two straight lines drawn from the point of inflection – one connecting to the start of the slope (T_2,A_2) and the other to the end of the slope (T_4,A_4).