A Study on the Applicability of Non-Linear Analysis of P-wave Duration Over Time to Predict Atrial Fibrillation Onset

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Abstract – Analysis of P-wave duration from the ECG has been widely used to predict the onset of atrial fibrillation (AF). Given the low amplitude of P-waves, this index has been mainly computed by using signal-averaging algorithms, thus discarding the clinically relevant information from its time course. This work presents an alternative based on a non-linear approach, the central tendency measure, to quantify the P-wave duration evolution over time.

I. INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in clinical practice [1]. Although AF is not lethal, it may lead to serious complications, significant morbidity and mortality. Much effort has been made to develop tools for evaluating predisposition to the disease, and for early diagnosis and tailored treatments. In this context, P-wave from the ECG has been widely analysed. Its duration is generally accepted as the most reliable marker of atrial conduction, and its prolongation has been associated with a history of AF, development of AF after bypass surgery and progression of paroxysmal to persistent AF [1].

Given the relatively low amplitude of P-waves, previous works have used signal-averaging techniques to obtain a P-wave template, from which duration is estimated [2]. Hence, to date not much attention has been paid to the P-wave duration evolution over time. However, because transition of sinus rhythm to AF is often associated with alterations of the atrial electrophysiological properties [3], this work focuses on estimating the P-wave duration time course by means of the central tendency measure (CTM). The use of this non-linear index seems to be appropriate, given that mechanisms involved in cardiovascular regulation interact with each other in a far-from-linear way [4].

II. METHODS

The 2 hours preceding the longest AF episode were extracted from Holter ECG recordings of forty-six patients (mean age 61.1 ± 12.8 years), suffering from intermittent self-terminating AF episodes (i.e., paroxysmal AF). In order to assess the CTM ability in following P-wave duration over time, the interval under study was divided into two 1 hour-length segments. The first set comprised the hour immediately before AF onset and the second set comprised those segments 1 hour away from the episode. For lead V1 of each segment, P-wave was detected and delineated making use of an algorithm based on the phasor transform [5]. Then, duration of each P-wave was computed as the distance between its offset and onset. Time course of P-wave duration in each 1 hour-length segment was quantified using CTM. This index estimates the degree of variability in a time series [6]. It is based on the plots of the first-order differences and is calculated by counting the points that fall within a circle of radius ρ around the origin and dividing it by the total number of points.

III. RESULTS

Using the optimum threshold provided by a receiver operating characteristic (ROC) curve, 85% and 78% of the segments close to AF and far from AF, respectively, were correctly identified with CTM. In addition, segments close to AF (0.787±0.177) presented lower CTM values than those distant from AF (0.916±0.070), both groups being statistically distinguishable (p<0.001, Kruskal-Wallis test).

IV. DISCUSSION AND CONCLUSION

Obtained results suggest a higher variability in the P-wave duration when AF onset approximates. This finding is in agreement with previous works, which have revealed that this variability in atrial activations is due to the overlapped result of the slowed conduction velocity and the decreased cell refractory periods in the atria [3].

On the other hand, the ability provided by CTM for distinguishing between segments close to AF and distant from AF is similar or even higher than those reported by the P-wave duration computed from signal-averaging techniques [3]. This suggests that CTM might be a clinically useful early risk predictor of AF onset.

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