Available online at www.sciencedirect.com

ScienceDirect

Journal of Electrocardiology xx (2016) xxx – xxx

JOURNAL OF Electrocardiology

www.jecgonline.com

Measurement of T wave variability in body surface ECG

Mathias Baumert, PhD*

School of Electrical and Electronic Engineering, The University of Adelaide, Australia

Abstract Lability in the ventricular repolarization process has been associated with an increased risk of experiencing ventricular tachycardia or fibrillation. A number of risk predictors have been devised that quantify beat-to-beat variability in the T wave morphology of body surface ECG. Initial studies have suggested that measurement of T wave variability may yield important prognostics markers of cardiac mortality, but approaches and experimental designs vary. The aim of this contribution is to provide an overview of existing techniques as well as discuss some of the methodical considerations.
© 2016 Elsevier Inc. All rights reserved.

Keywords: T wave variability; Repolarization; ECG

Introduction

Spatiotemporal lability in the ventricular repolarization process has been associated with an increased risk of experiencing ventricular tachycardia or fibrillation (VT/VF). There has been a long-standing interest in utilizing body surface ECG to quantify repolarization lability due to its non-invasiveness, wide availability and simplicity of use. The most prominent repolarization dynamics features of interest are microvolt T wave alternans and beat-to-beat QT interval variability [1]. While the former quantifies one particular phenomenon of T wave variability that typically occurs at higher heart rates and is therefore not easily measurable in ambulatory ECG, the latter does not consider the change in morphology of the T wave, but aims at quantifying beat-to-beat dynamics in the global repolarization duration instead [2]. In an attempt to overcome restrictions associated with each of the two concepts, efforts have been made to develop more general descriptors of the overall beat-to-beat variability in the T wave morphology (T wave variability, TWV). A number of initial studies have suggested that TWV may yield important prognostics markers of cardiac mortality [3,4], but available evidence is limited for various reasons. Among these reasons, methods for TWV quantification vary and a comprehensive evaluation of existing techniques is lacking. While a systematic study of TWV methodologies that have reported in the literature is beyond the scope of this contribution, it aims to provide an overview of available techniques as well as discuss some of the technical considerations.

Data acquisition and pre-processing

Different ECG sources/lead systems have been used for TWV analysis, partly owing to the availability of ECG recordings and/or limitations of data acquisition systems. Given that the heart vector moves in 3-dimensional space as a function of time, multilead assessment would be generally desirable, capturing the tempo-spatial repolarization characteristics.

Single lead far-field electrograms of implantable cardioverter defibrillators have been utilized to study TWV changes before the onset of VT/VF [4]. The vector magnitude ECG of orthogonal leads has been used for TWV analysis [3]. Repolarization variability has also been studied in the vector cardiogram (VCG), obtained by transforming standard 12-lead ECG using well-known matrices or by applying singular value decomposition. In the former case, orientation with respect to a Cartesian reference system is preserved, but correct electrode placement is crucial, while the latter provides strictly orthogonal decomposition of the cardiac vector, but without reference to traditional frontal, transverse and sagittal planes. Beat-to-beat changes in T loop morphology or orientation have been exploited to obtain measures of repolarization variability [5].

Pre-processing of ECG, including removal of baseline wander and high frequency noise, is typically carried out using band pass filters. Although filter settings can have significant effects on the T wave morphology, by either

* School of Electrical and Electronic Engineering, The University of Adelaide, Adelaide, SA 5005, Australia.
E-mail address: mathias.baumert@adelaide.edu.au

http://dx.doi.org/10.1016/j.jelectrocard.2016.07.014
0022-0736/© 2016 Elsevier Inc. All rights reserved.

compromising the isoelectric line and/or unnecessarily allowing for high frequency noise, no systematic evaluation of its effects on TWV has been carried out, despite the existence of a large number of studies on the effects of baseline removal on ST-T wave morphology [6]. No dedicated analyses of sampling rates requirements with respect to TWV analysis have been proposed, but 500 Hz or higher would be generally considered sufficient [7,8].

Delineation of fiducial waves

While automated detection of QRS complexes is achievable under most circumstances with readily available algorithms, delineation of the repolarization end is generally more challenging. Automated identification of the 'exact' T wave end may not be critical, considering that repolarization signal energy is low at the T wave end and presumably, its beat-to-beat variability too. Likewise, identification of the T wave start is challenging and the ST-T segment is commonly analyzed instead.

Dealing with artifacts and noise

Artifacts and noise can seriously compromise TWV estimation. As the anticipated beat-to-beat changes in T wave morphology are small it is necessary to exclude artifacts from TWV analysis and continuously monitor signal quality. A robust framework for handling these issues is a necessary prerequisite for robust TWV measurement. A basic approach would include a post-processing stage where 'abnormal' beats are excluded based on the identification of statistical outliers. A critical issue is to determine whether 'abnormal' beats are contaminated by artifacts or whether they in fact reflect genuine abnormal repolarization patterns, perhaps highly relevant to the assessment of VT/VF risk.

Another important confounder of TWV is cardiac axis rotation due to respiration. As respiratory signals are not commonly recorded along with ECG, respiration may be obtained indirectly, by exploiting its modulation of the QRS complex. Once beat-to-beat time series of respiration have been extracted, multivariate autoregressive models could be employed to decompose power distributions of T wave variability related to respiration and/or other sources, e.g., heart period. This modeling approach has been successfully employed for QT interval variability [9,10]. In VCG, respiration artifacts cause rotation of the vector loops that can be attenuated by a set of matrix operations [11]. It should be noted that these corrections make certain assumptions about the data (e.g., wide-sense stationarity in case of the autoregressive models) that may not always be met in practice.

Measures of T wave variability

A basic TWV descriptor that has been reported in the literature quantifies the difference between maximum and minimum deflection of the T wave over a number of beats and takes the average pair-wise beat-to-beat difference in T wave amplitude [4]. In a similar, more robust approach the T waves of electrograms are ensemble-averaged pair-wise and the root-mean-square of differences of consecutive pair-averages is used to measure non-alternans TWV [12]. A template-based approach has been devised, where the T wave of the current heartbeat is compared to a template T wave and cross-correlation is calculated and average cross-correlation across a sequence of beats is used to quantify TWV [13]. While the template beat helps to improve the signal-to-noise ratio, it does not take into consideration the temporal changes in T wave duration. To address this issue, dynamic time warping has been utilized. Consecutive pairs of beats are compared by the length of warping path and he beat-to-beat distance time series is subjected to Fourier transform to measure variability in the frequency band of interest [14]. Following a more flexible approach, the template, imposed on a so-called warping grid, is warped in 2 dimensions, minimizing the Euclidean distance between current beat and template (Fig. 1) [15]. T wave features of interest can be labeled on the template beat and change over time tracked by measuring the relative changes in the feature.

Couderc et al. [3] introduced a TWV measure where the ST-T interval of the vector magnitude ECG is divided into a number of segments and the average amplitude is computed for each segment. The standard deviation of average amplitudes is computed over a sequence of heart beats and that segment with the highest standard deviation defines TWV (Fig. 2). In a modification, the percentage of alternans pattern has been incorporated in the TWV analysis as a weighting factor.

Aside from T wave morphology features obtained in the time domain, power spectrum characterization of TWV has been proposed, where an ensemble of T waves is subjected to 2-dimensional Discrete Fourier Transform [16] (Fig. 3). Filter bank decomposition of T waves has been applied to measure T wave morphology variability across frequency ranges between consecutive pairs of beats [17].

Acar et al. [18] proposed a set of measures for VCG that can be computed for a single heartbeat and hence, a beat-to-beat time series could be constructed to measure TWV [19]. A commonly used repolarization descriptor is the angle between depolarization wave and repolarization vector, the 'total cosine R-to-T'. Alternatively, point-by-point distances of T loops with respect to a template loop [19] or variability in T peaks length can be analyzed [20]. More recently, variability between pairs of average T wave vectors has been measured [21]. Rizas et al. [22] investigated low frequency power of beat-to-beat changes in the T vector in polar coordinates.

Other considerations

Virtually all methods for TWV assessment have a number of parameters that need to be set, at the very least specifying the number of heartbeats included in the calculation, all of which warrant systematic investigation. Good reproducibility of TWV metrics is critical to clinically usefulness and

Download English Version:

https://daneshyari.com/en/article/5615526

Download Persian Version:

https://daneshyari.com/article/5615526

Daneshyari.com