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EDITORIAL

Measuring ventricular repolarisation dynamics from ambulatory electrocardiography as non-invasive cardiac risk indices

Medición de la dinámica de repolarización ventricular mediante electrocardiografía ambulatoria, como índices de riesgo cardiaco no invasivos

Ventricular repolarisation instabilities are known to be closely related to the development of arrhythmias.[1] Thus, different measurements of the ventricular repolarisation phase of the electrocardiogram (ECG) have been proposed as risk indices, in order to help therapeutic decisions, according to the risk of suffering malignant arrhythmias and sudden cardiac death (SCD).[1,2]

Relevant information characterising ventricular repolarisation can be found in some ECG features, such as the time intervals between the ECG waves or the waves' amplitudes and shapes. Some of these measurements, such as the QT interval, the QTc (same interval, but corrected to take into account its natural variation with the heart rhythm) or the Tp-e (interval from T-wave peak to T-wave end) can be measured manually by a cardiologist on the ECG tracing, with the help of a ruler, or using a computer to magnify the tracing on digitised recordings.

Ventricular repolarisation can also be characterised by other features not directly available by visual inspection of the ECG tracings. Moreover, the variation over time of the repolarisation features, and their spatial distribution have been shown to convey useful information on the physiology of repolarization.[1] Of particular interest is the response of these features to changes in heart rate (HR). These indices, usually driven by electrophysiological observations, must be obtained by computerised methods, where signal processing plays a crucial role.[1]

In the current issue of *Revista Clínica Española*, Demirtaş et al.[3] assessed in an interesting case-control study the values of some repolarisation indices quantifying repolarisation dispersion in patients with coeliac disease (CD). In particular, Tp-e interval and the ratios Tp-e/QT and Tp-e/QTc were manually measured from the 12-lead ECG in 38 patients with CD and 38 age- and sex-matched controls. Their results showed significantly higher values of the three indices in the CD patients with respect to the control population, suggesting that CD might be associated with an increase in ventricular repolarisation dispersion. Interestingly, the Tp-e/QTc ratio also showed a significant positive correlation with the duration of CD and the erythrocyte sedimentation rate.

From these data, together with the fact that increased prevalence of cardiac dysfunction, such as idiopathic congestive heart failure and myocarditis, have been observed in CD,[4,5] authors suggest that patients with CD would have an increased incidence of ventricular arrhythmia.[3] An important limitation of the study is the lack of follow-up in the CD population, which would have enabled it to be established whether differences in repolarisation features are indeed related to an increased risk of arrhythmic events.

The study presents repolarisation dispersion indices as instantaneous measurements. However, it is well known that repolarisation features on the ECG are quite dependent on the HR, which introduces an extra ingredient of inter-patient variability if not taken into account. Although there are some corrections for HR, such as the well-known Bazett formula, to get the HR-corrected QTc,[6,7] these corrections do not account for the inter-patient differences in the HR dependence of the repolarisation. Moreover, correction formulae do not consider the fact that the QT interval does not depend on the last RR interval alone, but also on the RR intervals of the preceding beats (typically, those

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of the previous 2–3 min). This phenomenon, termed QT/RR memory or hysteresis, has been shown to be relevant for risk stratification.[7] In this editorial comment we aim to recall some recent results showing the potential value of the dynamic analysis of the repolarisation parameters.

One simple way to take those effects into account without the need for designing a specific protocol is by analysing 24-h Holter recordings. Since a Holter recording typically includes a wide range of HR, including periods with stationary HR as well as abrupt accelerations and decelerations of HR, computerised analysis of Holter recordings can be used to achieve good characterisation of the repolarisation dynamics.

Non-linear models including memory have been proposed[8] to characterise the memory of different ECG parameters with respect to the HR in the previous beats. Results have shown that the duration and profile of the QT dependence with HR (QT/RR hysteresis) is highly individual-dependent while, on average, RR intervals of the past 150 beats (approximately 2.5 min) are required to accurately model the QT response.[8,9] The residual of the model, i.e. the portion of QT variation that cannot be explained by the model, was also a significant risk stratifier in patients under amiodarone.[8] The Tp-e was also shown to be dependent on the previous RR intervals, but with a shorter memory than the QT interval.[9]

The relative amount of change in the Tpe (measured in different stable conditions) with respect to the change in the RR interval (denoted as $\Delta\alpha$) has been related to the dispersion of action potential duration restitution slopes in the ventricular cells.[9] This non-invasive parameter, measurable in regular ambulatory recordings, has been shown to discriminate between SCD victims during the four-year follow-up from survivors in a population of chronic heart failure (CHF) patients,[10] and to be predictive of arrhythmic risk induced by sotalol.[11] Interestingly, $\Delta\alpha$ was also able to identify differentially the CHF patients predisposed to death from the progression of the disease (pump failure death [PFD]): while values of $\Delta\alpha$ in the higher range where predictive of SCD, values of $\Delta\alpha$ in the lower range were suggestive of PFD.[12]

In a recent work, we hypothesised that increased dispersion of repolarisation restitution should be better reflected in the overall morphology of the T-wave and its variation with HR. A novel index called T-wave morphology restitution (TMR) was quantified by measuring the T-wave morphological variation between two T waves that were representative of different HR, and normalised by per RR increment. In the previously cited CHF population, TMR was significantly higher in SCD victims than in the remaining patients, with Cox analysis revealing that increased TMR was strongly associated with SCD, independently of other clinical and ECG-derived variables. However, no association was found between this index and PFD.[13]

The research described in the previous paragraphs was performed as a collaborative effort between clinical and engineering research groups. We believe that these types of collaborations will be crucial in years to come to make advances in the management of clinical decisions based on non-invasive data.

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