QRS Slopes for Potassium and Calcium Monitoring in End-Stage Renal Disease Patients

Hassaan A Bukhari1,2,3, Pablo Laguna1,4, Mark Potse2,3, Carlos Sánchez1,4, Esther Pueyo1,4

1 I3A, University of Zaragoza, IIS Aragón, Zaragoza, Spain
2 Univ. Bordeaux, IMB, UMR 5251, Talence, France
3 Carmen Team, Inria Bordeaux – Sud-Ouest
4 CIBER en Bioingeniería, Biomateriales y Nanomedicina, Spain

Background and aim: Non-invasive estimation of serum potassium, [K⁺], and calcium, [Ca²⁺], are of major importance to prevent ventricular arrhythmias and sudden cardiac death, but current ambulatory estimation methods are limited. In this study, we present a QRS slopes-based analysis to detect and quantify electrolyte abnormalities in end-stage renal disease (ESRD) patients.

Methods: We applied principal component analysis onto 12-lead electrocardiograms (ECGs) of 29 ESRD patients undergoing hemodialysis (HD). Over the first principal component, we analyzed two-minute segments at the end of each HD hour and we computed a mean warped QRS complex (MWQRS) representing an optimal average of QRS complexes in time and amplitude. We calculated the upward (QRSUS) and downward (QRSDS) slope of the MWQRS and we quantified the slope change with respect to the end of HD session (ΔQRSUS and ΔQRSDS). We assessed the relationship between QRS slope changes and variations in [K⁺], [Ca²⁺] and R-R interval duration (RR) by computing Pearson correlation coefficient ρ.

Results: ΔQRSUS and ΔQRSDS significantly increased and decreased, respectively, during HD in association with decreasing [K⁺] and increasing [Ca²⁺]. The median ρ of ΔQRSUS and ΔQRSDS with Δ[K⁺] were −0.84 and 0.88, respectively. Corresponding ρ values with Δ[Ca²⁺] were 0.78 and −0.91. ΔRR presented non-monotonic patterns along HD, with corresponding ρ values for ΔQRSUS and ΔQRSDS being −0.13 and 0.19. High inter-individual variability in these relationships was found. The quantified QRS slope changes in ESRD patients were related to both amplitude and duration changes in the QRS complex during HD.

Conclusions: Changes in QRS slopes are strongly related to variations in [K⁺] and [Ca²⁺] levels during HD in ESRD patients. These results stimulate further studies to monitor ionic concentrations based on ECG depolarization in the search for ion-specific markers.