# Characterization of T wave changes by Lyapunov Exponents in Chronic Kidney Disease Patients

Sabarathinam Srinivasan, Hassaan A. Bukhari, Pablo Laguna, Carlos Sánchez, Esther Pueyo

I3A, University of Zaragoza, IIS Aragón, Zaragoza, Spain

**Background and aim:** Chronic kidney disease (CKD) affects more than 10% of the world population. CKD patients present impaired potassium homeostasis, which increases the risk of ventricular arrhythmias. Non-invasive estimation of serum potassium, $[K^+]$, before the patient experiences serious effects is of major importance. Current methods for $[K^+]$ estimation are limited. We investigated changes in maximum Lyapunov exponent (MLE) of T-waves in the electrocardiogram (ECG) and assessed the relationship with $[K^+]$.

**Methods:** ECGs of twelve CKD patients undergoing hemodialysis (HD) were processed and T-waves in one-minute windows were extracted for each hour during the HD session. ECGs were additionally calculated from simulated transmural ventricular fibers. The MLE was calculated based on Rosenstein algorithm. $[K^+]$ was measured at different time points during HD and simulated from 3 to 7 mmol/l in the modeled ventricular fibers.

**Results:** In CKD patients, MLE took higher values at the beginning and end of the HD session, corresponding to the lowest and highest $[K^+]$ values. However, the pattern of such relationships depended highly on the characteristics of each patient. The MLE-$[K^+]$ relationship and its variability was reproduced in the simulations (Fig. 1). The high inter-individual variability in T-wave morphology could be explained by differences in transmural heterogeneities, with 10% variations in the proportion of midmyocardial cells leading to changes larger than 45% in MLE.

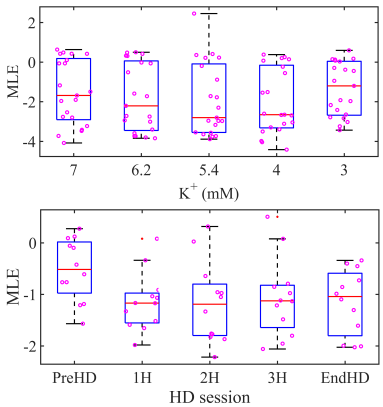


Fig. 1. MLE vs $K^+$ for 21 simulated cases (top) and vs HD session times for 12 patients (bottom). Each purple dot represents one simulated fiber or patient.

**Conclusions:** Changes in MLE calculated from T-waves of the ECG have the potential to be used as indicators of $[K^+]$ variations in CKD patients, but the associated inter-individual variability should be taken into account, especially under hyper- and hypokalemic conditions.