X JORNADA DE JÓVENES INVESTIGADORES DEL I3A

Estimation of potassium levels using QRS slopes in chronic kidney disease patients

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Introduction

Chronic kidney disease (CKD) affects 11-13 % of the world population.

CKD patients commonly present with hyperkalemia (elevated blood potassium cocentration), which increases risk for ventricular arrhythmias and sudden cardiac death [1-5].

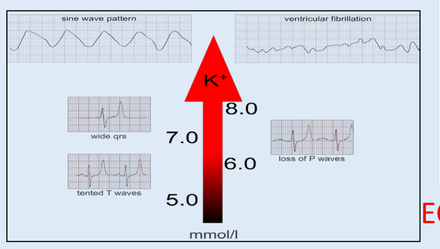
Blood tests allow to quantify potassium (K+) but this is not feasible for ambulatory monitoring.

Electrocardiogram (electrical activity of heart i.e. ECG) estimation of [K⁺] at home would facilitate hyperkalemia detection in a timely manner.

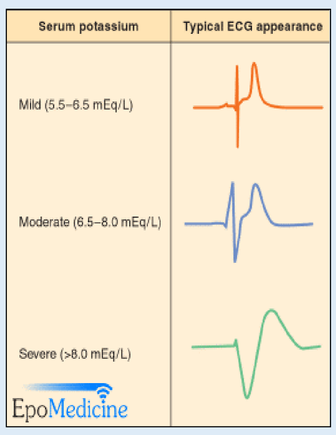
Previous attempts have been proposed to estimate [K⁺] by only ECG repolarization (T wave) markers.

In this study, we estimated $[\boldsymbol{K}^+]$ by quantifying upward ($\boldsymbol{I_{US}}$) and downward ($\boldsymbol{I_{DS}}$) slopes of QRS complex (electrical activation of ventricles) during and after hemodialysis (HD) in CKD patients.

Hemodialysis Session at Hospital



Characteristics of Hyperkalemia[11]

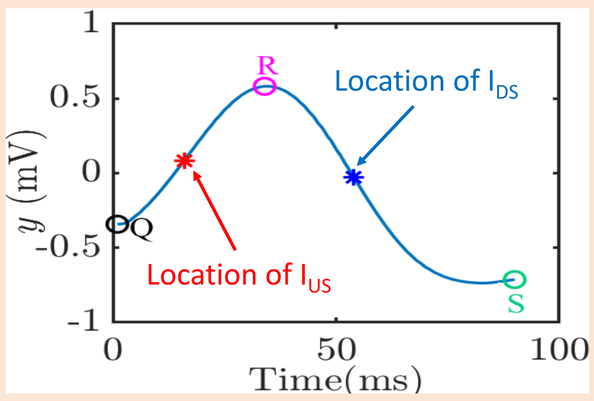


ECG variations[12] with [K⁺]

Methods and Materials

QRS slopes characterization:

- Location of QRS onset, peak and end
- $\boldsymbol{I_{US}}$ calculated as maximum gradient from QRS onset to QRS peak [8-9]
- $\boldsymbol{I_{DS}}$ calculated as minimum gradient from QRS peak to QRS end [8-9]



QRS complex from a patient's ECG at the start of HD (h_0)

- $\boldsymbol{\Delta I_{US}}$ and $\boldsymbol{\Delta I_{DS}}$ quantified as change in QRS slopes with respect to the end of the HD session ($\boldsymbol{h_4}$).

Potassium estimation:

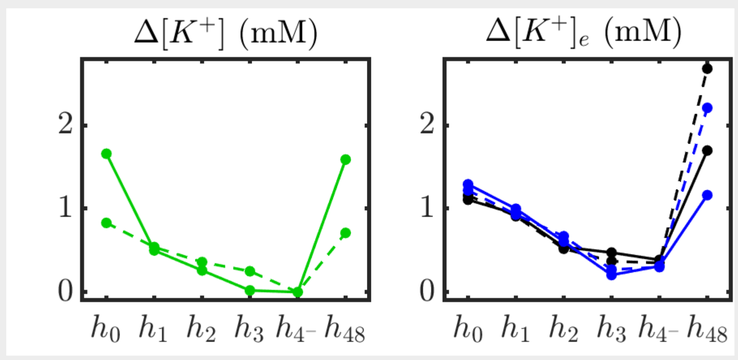
- Univariable estimators defined as:

$$\boldsymbol{\Delta[K^+]^{US}} = \beta_0^{US} + \beta_1^{US}\boldsymbol{\Delta I_{US}},$$
$$\boldsymbol{\Delta[K^+]^{DS}} = \beta_0^{DS} + \beta_1^{DS}\boldsymbol{\Delta I_{DS}}.$$

- Leave-one-out cross-validation used to evaluate the performance of $[\boldsymbol{\Delta K^+}]$ estimation.
- Estimation performed individually for each patient.

Results and Discussion

- QRS slope-based markers significantly varied with varying $[\boldsymbol{\Delta K^+}]$ during and after HD, with median Spearman correlation of -0.75 and -0.81 for $\boldsymbol{\Delta I_{US}}$ and $\boldsymbol{\Delta I_{DS}}$.
- Good agreement was found between actual and estimated $[\boldsymbol{\Delta K^+}]$, with average error -0.26mM and -0.20mM for $\boldsymbol{\Delta I_{US}}$ and $\boldsymbol{\Delta I_{DS}}$.



Mean and median of $[\boldsymbol{\Delta K^+}]$ measured in blood and $\boldsymbol{\Delta[K^+]_e}$ estimated

- A wide range of patterns was obtained for the investigated relationships, using computational modeling and simulation [10].

Conclusions

QRS slopes vary with potassium in ECGs of CKD patients.

QRS slope-based estimators allow non-invasive quantification of $[\boldsymbol{K^+}]$ changes.

Characterization of ECG depolarization, in addition to ECG repolarization, could improve monitoring of hypokalemia and hyperkalemia and prediction of arrhythmic events.

Methods and Materials

Study Population and Data Analysis:

- 29 CKD patients from Hospital Clinico Universitario de Zaragoza (HCUZ).
- 48-hour 12-lead ECGs, 1 kHz sampling frequency.
- Acquisition started 5 minutes before the HD treatment onset and lasted for 48 hours.

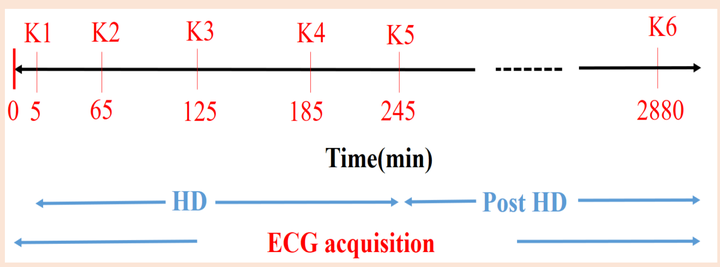
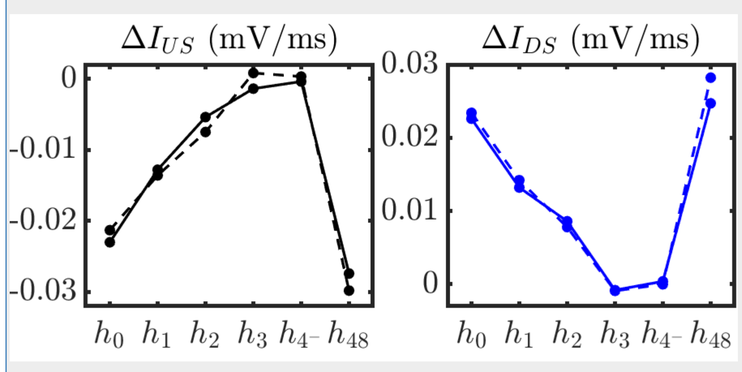


Diagram of the study protocol. h_0 to h_{48} are the time points (in minutes) for blood sample extraction.

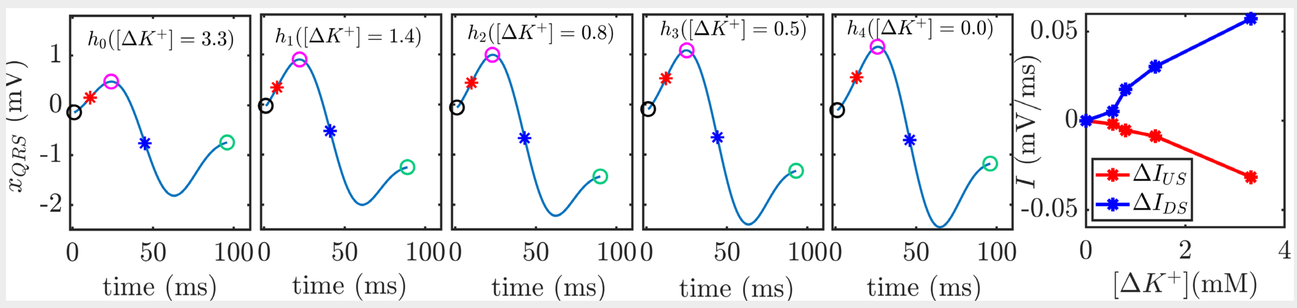
- ECG pre-processing [6] and wavelet-based delineation [7].
- First principal component used to enhance the QRS complex energy and improve delineation.

Results and Discussion

- Potassium elevation was associated with a reduction in the absolute magnitude of upward ($\boldsymbol{I_{US}}$) and downward slope ($\boldsymbol{I_{DS}}$).



Mean and median of $\boldsymbol{\Delta I_{US}}$ and $\boldsymbol{\Delta I_{US}}$ in 29 ESRD patients



QRS complexes and QRS slopes variations during HD with $[\boldsymbol{\Delta K^+}]$ for a patient.
Location of Q, R and S waves were marked by black, purple and green circles, respectively.
Red and blue asterisks show the locations associated with $\boldsymbol{I_{US}}$ and $\boldsymbol{I_{DS}}$ in the QRS complex, respectively.

Acknowledgements

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