COMPARISON OF DIFFERENT APPROACHES TO POTASSIUM MODELLING DURING HAEMODIALYSIS

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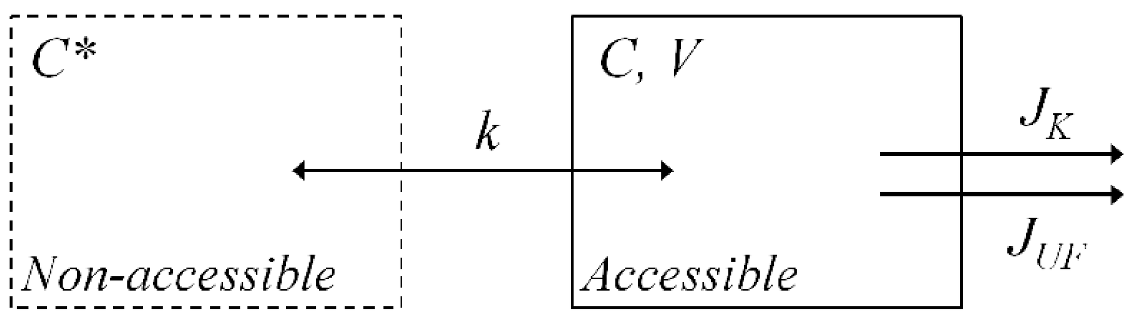
OBJECTIVES

- The regulation of potassium (*K*) is especially important in haemodialysis (*HD*), as disequilibrium in potassium levels may lead to life-threatening arrhythmic complications.
- The aim of this study was to compare two different types of single-solute kinetic models to *HD* data coming from two dialysis centres to describe the transport of potassium during water removal.
- The parameters and output of the models were compared across model types and cohorts, to assess the feasibility of each approach to describe the removal of potassium.

METHODS

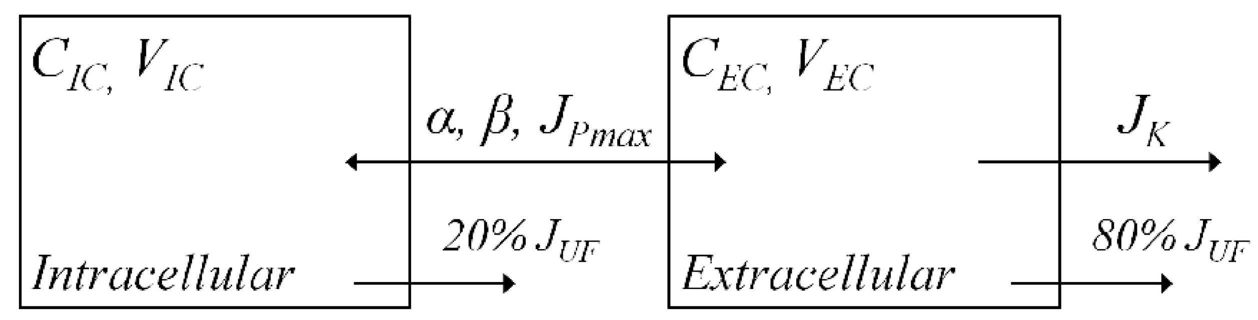
- HD patients from two cohorts, L-cohort (n=22, 16 females) and S-cohort (n=8, 6 females) with similar age (median 67 and 69 years, respectively) and body weight before first HD session (71 ± 16 kg and 72 ± 12 kg) underwent consecutive HD sessions, 3 and 2, with longer pre-dialytic interval and more fluid overload prior to the first session (average fluid removed: 2.3 ± 0.8 L and 2.2 ± 0.9 L).
- The models were a pseudo-one compartment (*p1*) model and a two compartment (*2c*) model. An overview of the structure of the two models is presented in Figures 1 and 2. A set of optimal parameters was estimated for each model: mass transfer coefficient (*k*) and the accessible compartment initial volume (V_0) for *p1*, and Na/K ATPase pump rate (J_{Pmax}) for *2c* .



$$\frac{d(C \cdot V)}{dt} = k\left(C^* - C\right) - J_K$$

Figure 1. Pseudo-one compartment model.

- Potassium is distributed across theoretical accessible (*AC*) and non-accessible (*NAC*) compartments, with concentration *C* and *C** respectively.
- Transport of *K* occurs passively following the concentration gradient.
- *NAC* is assumed to be large enough that its volume and *K* content are constant during *HD*.
- J_{UF} and J_K are the flows of water and potassium removal, respectively.



$$\frac{d(C_{EC} \cdot V_{EC})}{dt} = \alpha\left(C_{IC} - C_{EC}\right) - \beta \cdot J_{P\max} - J_K$$

Figure 2. Two compartment model.

- Compartments represent the sum of extra- and intracellular spaces, both described by volume (*V*) and *K* concentration (*C*).
- Transport of K: passive and active components (ATPase pump), respectively first and second right-hand terms in the equation above.
- Volume in both compartments decreases linearly during water removal, proportionally to a constant fraction of the total ultrafiltration.
- α is the passive transport coefficient (calculated for steady-state) and β is a sigmoidal scaling function that depends on C_{EC}.

RESULTS

Both models reproduced accurately the changes measured in serum potassium concentration during water removal, for each session in both cohorts. The relative error of the simulation was significantly lower for *p1* in both sessions ($p < 0.05$, Table 1), but errors were small and the results qualitatively similar. The parameters of the *p1* model were similar in each session of the HD cycle, and no difference was found between the cohorts (Table 1). The maximum pump rate (J_{Pmax}) estimated in the *2c* model was higher for the patients in L-cohort ($p < 0.05$).

Table 1. Parameters of the models for each *HD* session. Values were estimated minimizing the relative root mean squared error (*RMSE*) i.e. the deviation of the simulated values from the data. Mean ± standard deviation. * $p < 0.05$ vs. *2c*. & $p < 0.05$ vs. L-cohort.

	L-cohort			S-cohort	
	HD1	HD2	HD3	HD1	HD2
K (L/min)	0.15 ± 0.12	0.18 ± 0.09	0.15 ± 0.09	0.12 ± 0.06	0.13 ± 0.05
V_0 *(L)*	15.4 ± 7.6	16.9 ± 8.4	18.8 ± 12.1	15.9 ± 6.3	16.6 ± 5.2
J_{Pmax} *(mmol/min)*	4.7 ± 2.7	7.5 ± 7.1	3.5 ± 2.3	2.1 ± 0.9&	2.7 ± 1.2&
RMSE p1 (%)	2.3 ± 1.8*	2.5 ± 1.6*	2.8 ± 1.5*	1.3 ± 0.6*	2.2 ± 1.2*
RMSE 2c (%)	3.7 ± 1.7	3.7 ± 2.2	4.2 ± 1.9	1.9 ± 0.8	3.2 ± 1.3

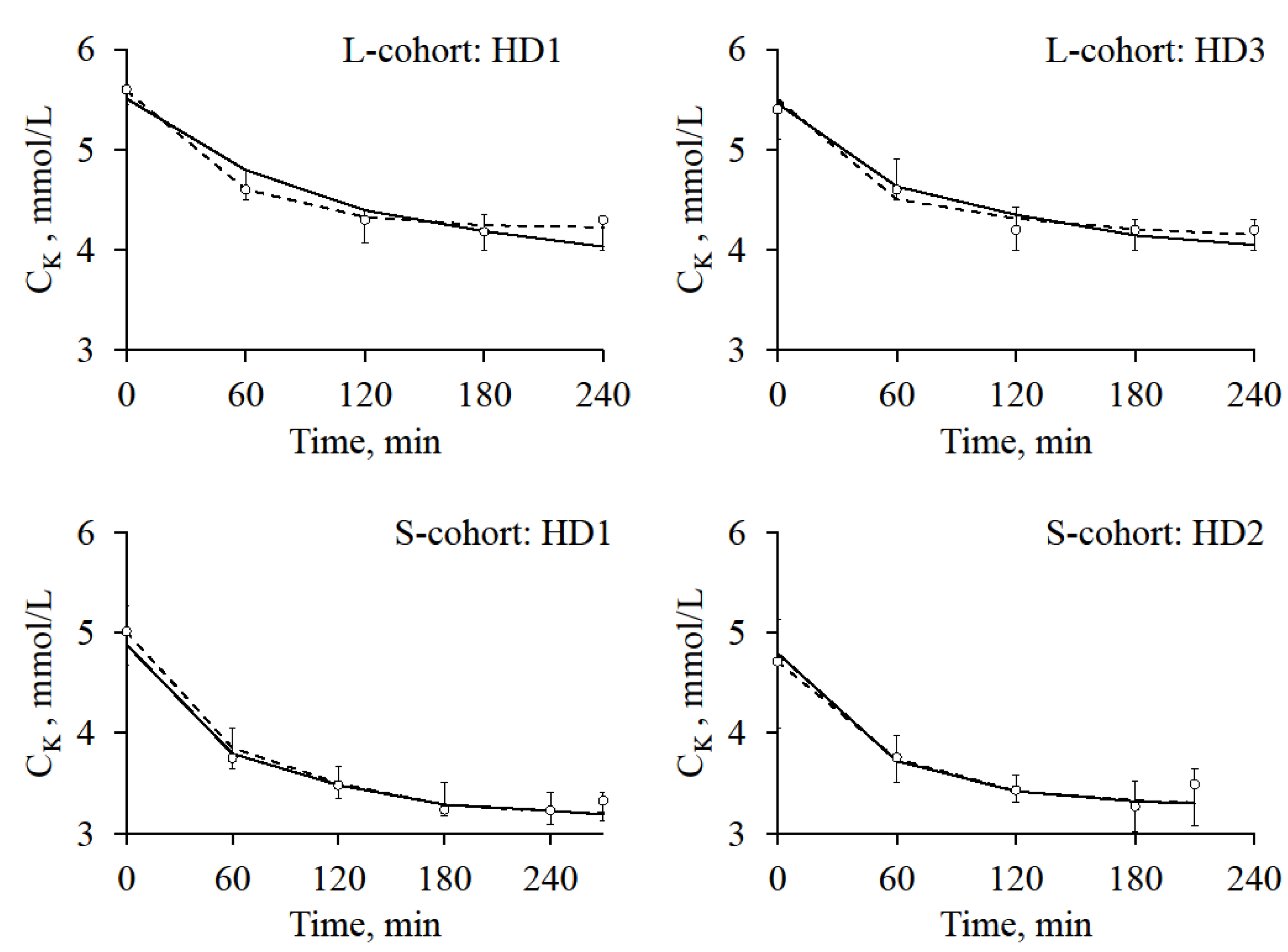


Figure 3. Median values of potassium concentration (C_K) simulated by the two models for the first and the last session of each cohort. Dotted line: *p1*, continuous line: *2c*. Circles: plasma concentration data (Median ± quartiles).

CONCLUSIONS

Both models are characterized by low complexity and require estimation of only few parameters, making them applicable in a clinical context to predict potassium removal by HD. In both models, the parameters were relatively independent of the fluid status of the patients, but the lower scattering of the parameters of the *p1* model, and the slightly lower error with *p1*, makes it a possibly more robust choice for practical applications.

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