## Engineering Design of Robust Ultrafiltration Profiles in Hemodialysis<sup>#</sup>

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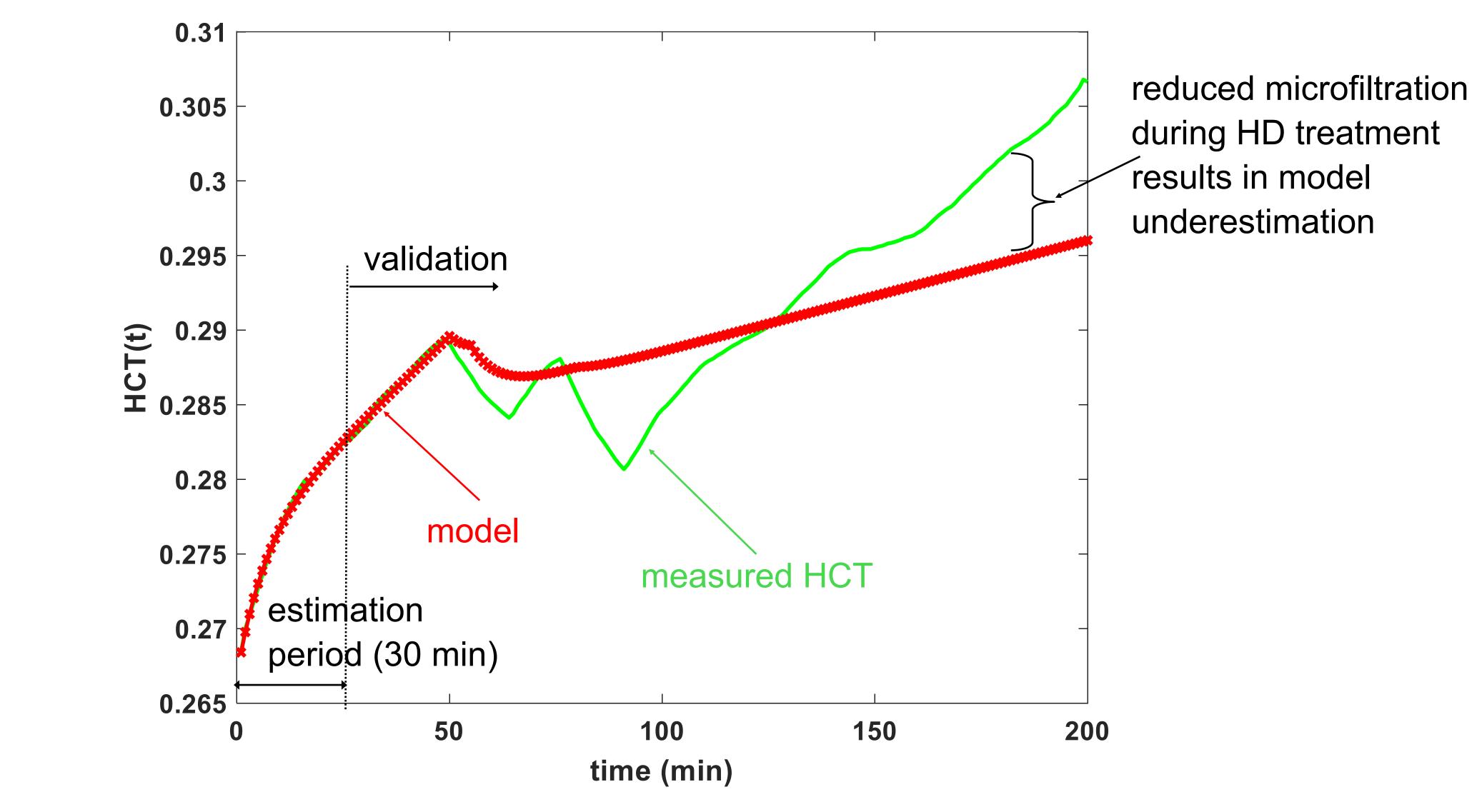
#### Objective

To design individualized robust ultrafiltration rate (UFR) profiles to remove desired volume in a fixed time based on a patient's fluid volume model that includes parameter uncertainty, critical hematocrit profile, and to minimize maximal UFR.

#### Background

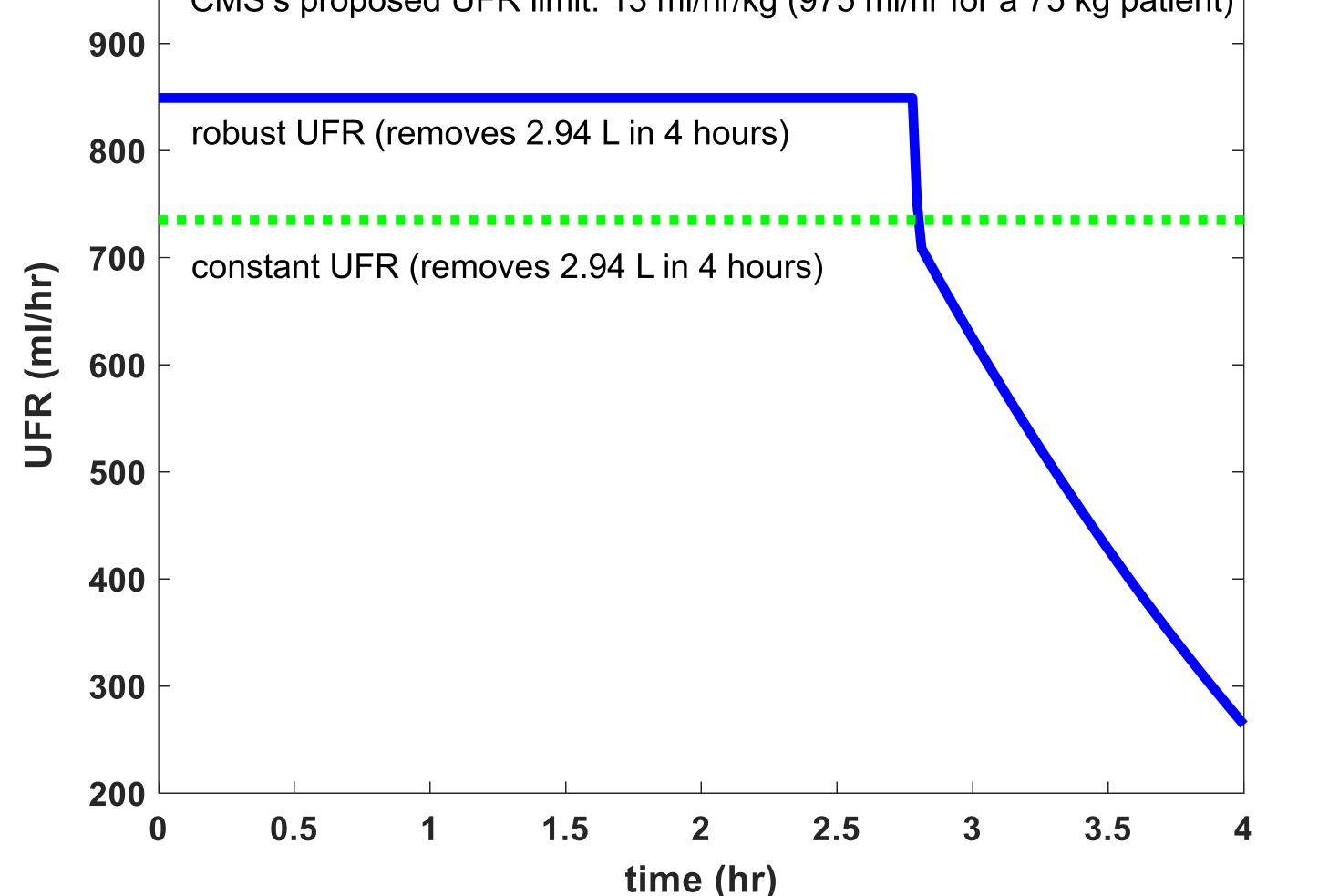
- Fluid management remains a major challenge of hemodialysis (HD) care, with serious implications for morbidity and mortality.
- Fluid management is typically guided by blood pressure and

Individualized model estimation: First 30 minutes of HD treatment are used for model parameter estimation.





# 1000 CMS's proposed UFR limit: 13 ml/hr/kg (975 ml/hr for a 75 kg patient) 900



- online HCT measurements (Crit-line).
- The application of a constant critical hematocrit (HCT) limit to guide fluid removal is controversial and has yet to contribute to improved treatment outcomes.
- Ultrafiltration quality measures are currently being discussed by the Centers for Medicare and Medicaid Services, e.g., ultrafiltration rate (UFR) limit of 13 ml/hg/kg.
- Hard UFR limits can conflict with target volume removal; Fluid overload is strongly associated with adverse outcomes.
  Fluid volume models are imprecise; Microfiltration is often reduced during HD resulting in mismatch between actual HCT and model estimation.

## Methods

Fluid Volume Model: Intravascular and interstitial pools with flows governed by Starling forces, nonlinear microfiltration and lymphatic flows, and ultrafiltration. Fixed parameters.

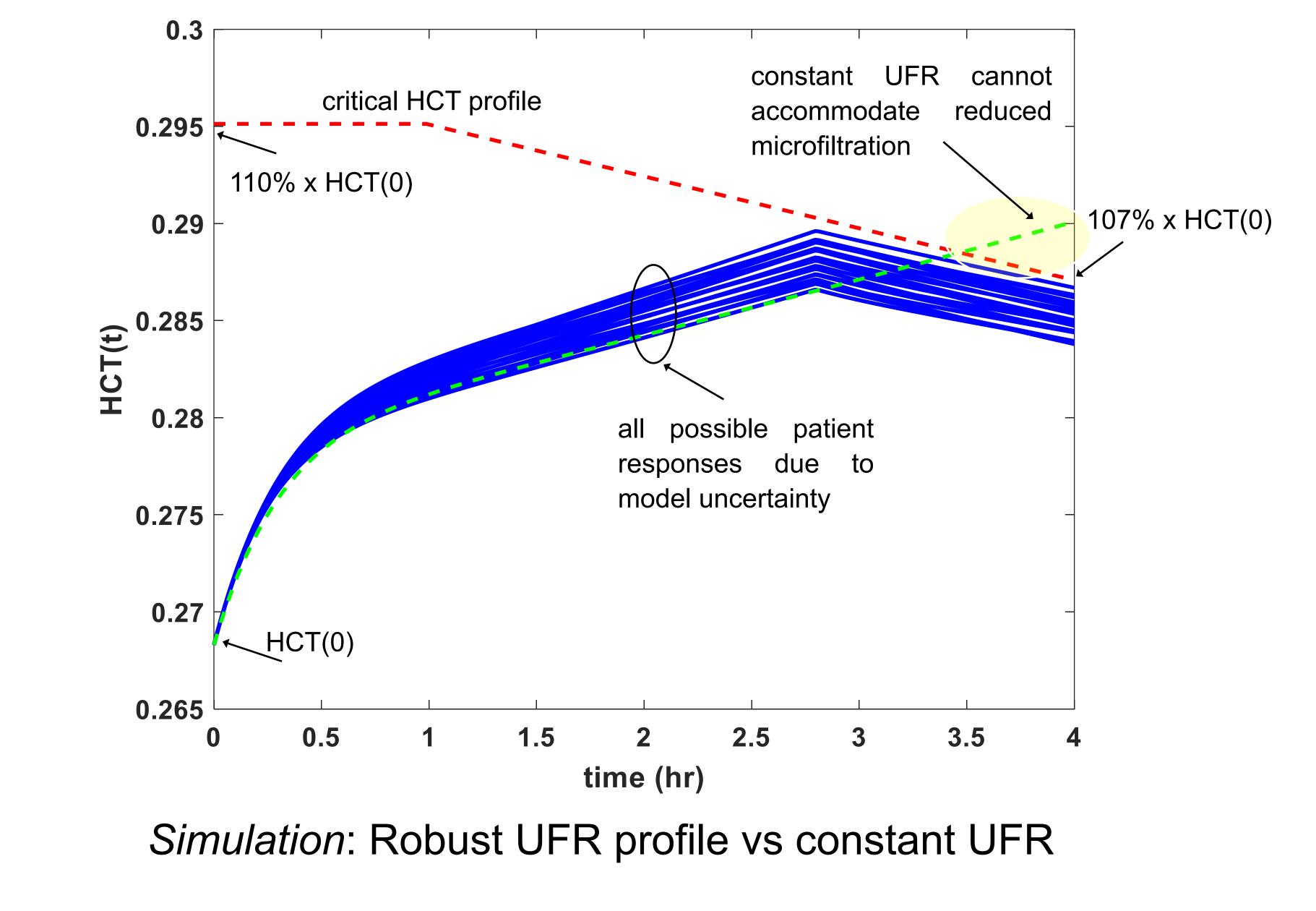
microfiltration, not modelled, results in model underestimation of HCT.

<u>Model uncertainty</u>: Accounts for imprecise model, parameter estimation errors, noisy measurements, and varying filtration during HD

 Model parameters are assigned uncertainty range; here it is ±5% of estimated values.

Individualized Robust UFR Profile Design: Linear optimization formulation to minimize maximal UFR, meet target volume removal and critical HCT profile constraints for the *uncertain* patient model:

- Remove 2,94 L in 4 hours,
- UFR < 13 ml/hr/kg (975 ml/hr for a 75 kg patient), and</li>
- Critical HCT < 110% of initial HCT then drops to 107% of initial value (based on clinical observations over several HD treatments for this



## Conclusions

A new model-based method was developed for the design of individualized, robust UFR profile that accounts for patient's model uncertainty, critical HCT profile, and maximal UFR limit.