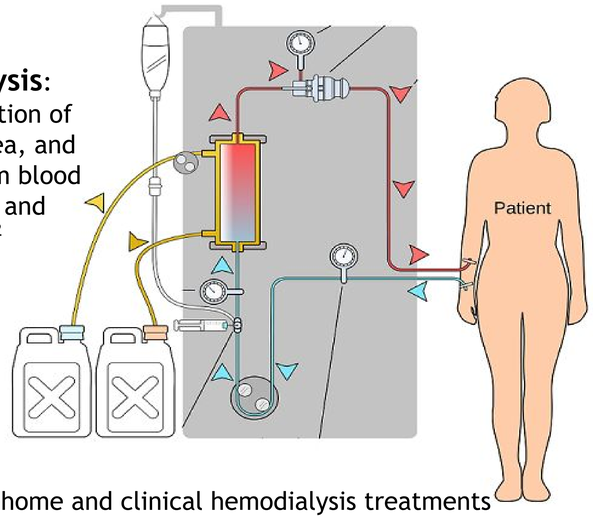
Cost-Effective Dialysis

Eleanor Kwik, Muyuan Li, Marissa Morales, Dhrisya Raman, Anthonia Raphael-Chieke
Departments of Chemical Engineering and Biomedical Engineering, Carnegie Mellon University

Introduction

Hemodialysis: External filtration of creatinine, urea, and free water from blood by diffusion and osmosis[2]



Problem: At-home and clinical hemodialysis treatments are expensive
- 370,000 average patients per year[1]
- Cost ≤ $72,000 for 2010[3]
- Major utilities include water and electricity[3]

Our goal: Analyze the potential solutions to minimize cost of utilities for hemodialysis

Hemodialysis efficacy is defined by:
- URR: Urea Reduction Ratio ≥ 65%[2]
- Kt/V: Must be ≥ 1.3[2]

Important terms:
- Ultrafiltration (UF): Removes excess water and sodium
- BUN: Blood Urea Nitrogen [=] mg/dL

Methods

- **Simulink Simulation**: Assessment of efficacy of proposed cost-effective changes to hemodialysis machine

- **Hemodialysis Machine Prototype:** Physical model of proposed modifications to assess filtration efficacy
  - Test strips measure: BUN, protein, ketones, glucose, pH, etc
    - **Dialysate**: NaCl, KCl, $MgCl_2$, $CaCl_2$, bicarbonate, glucose
    - **Blood**: Dialysate + Urea

Results

Simulink Simulation: Established a model that plots the responses of tuning individual variables to obtain desired results of URR above 65% and Kt/V above 1.3

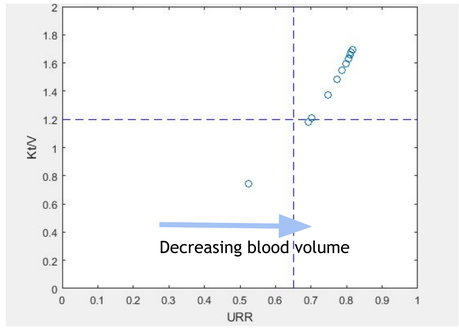


Figure 1: System response to varying blood volume from model

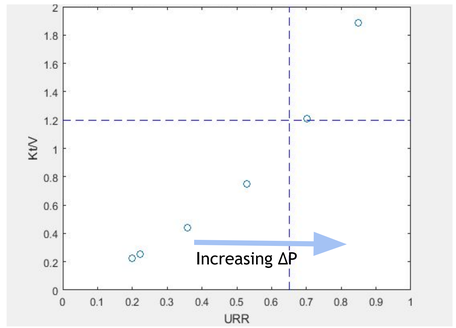


Figure 2: System response to varying tuning pressure difference from model

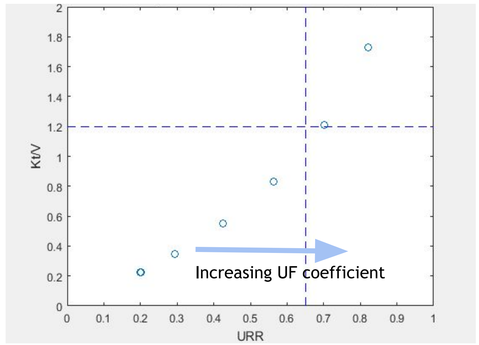


Figure 3: System response to varying the ultrafiltration coefficient from model

- **Simulink simulation indicates dialysis efficacy criteria were only satisfied when**
  - Pressure difference > 20 mmHg
  - Ultrafiltration coefficient > 10 mL/min/mmHg
- Blood volume of 500 and 1000 mL do not satisfy efficacy criteria

Hemodialysis Machine Prototype: A physical setup was realized to compare efficacy of proposed hemodialysis modification to an unmodified model primarily through evaluation of BUN reduction

- **Testing with hemodialysis machine prototype resulted in:**
  - BUN decrease by 20-40 mg/dL
  - Indicates effective filtration

- **Complications:**
  - 2 L crossed from dialysate to blood side
  - 0.15 L either leaked or remained in the dialyzer

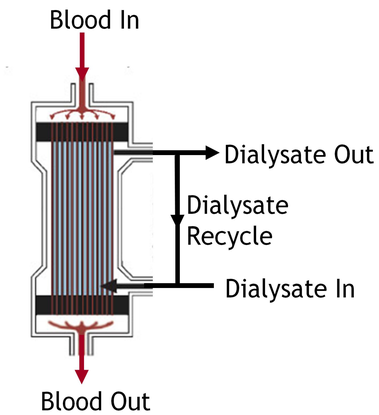


Figure 4: Diagram of prototype with dialyzer and hemodialysis recycle modification

Conclusions

Simulink Simulation:
- Energy requirements can be decreased through:
  - Addition of dialysate recycle loop
  - Increased dialyzer pressure difference

Hemodialysis Machine Prototype:
- Dialysate solution leaking across dialyzer into blood side
  - Prevents evaluation of dialysate volume saved with addition of recycle
  - Reevaluation with new dialyzers needed

Future Work

- Optimization analysis to determine parameters for hemodialysis prototype
  - Blood flow rate, dialysate flow rate, dialyzer surface area, and pore size
- Modify hemodialysis machine
  - Run with optimized parameters
- Compare the results of the hemodialysis machine vs hemodialysis machine prototype
  - Analyze causes of differences
- Determine if there is a need for additional technology on the dialysate recycle line
  - Additional filter, degassing, or purge fraction

Acknowledgments

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References

1. "Kidney Disease Statistics for the United States." *The National Institute of Diabetes and Digestive and Kidney Diseases*. NIH, n.d. Web.
2. "Treatment Methods for Kidney Failure: Hemodialysis." *The National Institute of Diabetes and Digestive and Kidney Diseases*. NIH, June 2004. Web.
3. Deno, Terri. "Pricing and Costs of Dialysis Equipment and Supplies Choose the Least Expensive Dialysis Equipment Manufacturer for Your Needs." *Business.com*. Business.com Media, Inc., 2 Oct. 2010. Web