Cost-Effective Dialysis
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Introduction

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

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

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

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

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, MgCl₂, CaCl₂, 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

- Decreasing blood volume
- Increasing ΔP
- Increasing UF coefficient

Figure 1: System response to varying blood volume from model
Figure 2: System response to varying pressure difference from model
Figure 3: System response to varying the ultrafiltration coefficient from model

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

- 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

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

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References