Team F13: High-Flux Hemofiltration System for Toxin and Solute Removal

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Introduction

Clinical Problem

Our goal is to determine a more efficient method to **eliminate non-dialyzable toxins** in patients with acute poisoning to **increase patient survival** and **improve quality of life.**

Current Standard of Care

Traditional single-filter hemofiltration systems are limited by **low blood flow rates (0.1–0.5 L/min)**[1] and instability during rapid solute clearance, resulting in **inefficient toxin removal.**

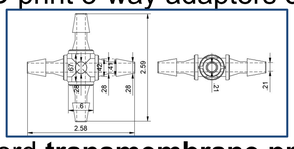
Objective

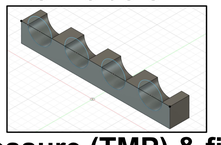
Our project aims to develop a high-flux (4-5 L/min), high-efficiency **ECMO-hemodialysis hybrid system.**

Methods

System Design & Assembly (Fig. 1 & Table 2)

1. Assemble 12-filter hemofiltration system (**4 L/min** flow rate & **1 L/min** effluent/replacement fluid rate).
   i. 3D print 3-way adapters & filter holders:

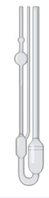




2. Record **transmembrane pressure (TMP) & filter pressure (ΔP Filter)** with the following solutions:
   i. Saline at 7 mg/dL **creatinine (model toxin).**
   ii. **Blood viscosity mimic** at 7 mg/dL creatinine.

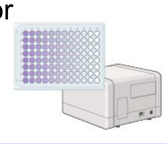
Blood Viscosity Mimic Preparation (Table 1)

1. Develop various [**Water:Glycerin:Xanthan Gum:Starch**] compositions → Run viscosity tests.
2. Identify composition with closest viscosity to blood (3.5-5.5 cP)[2].



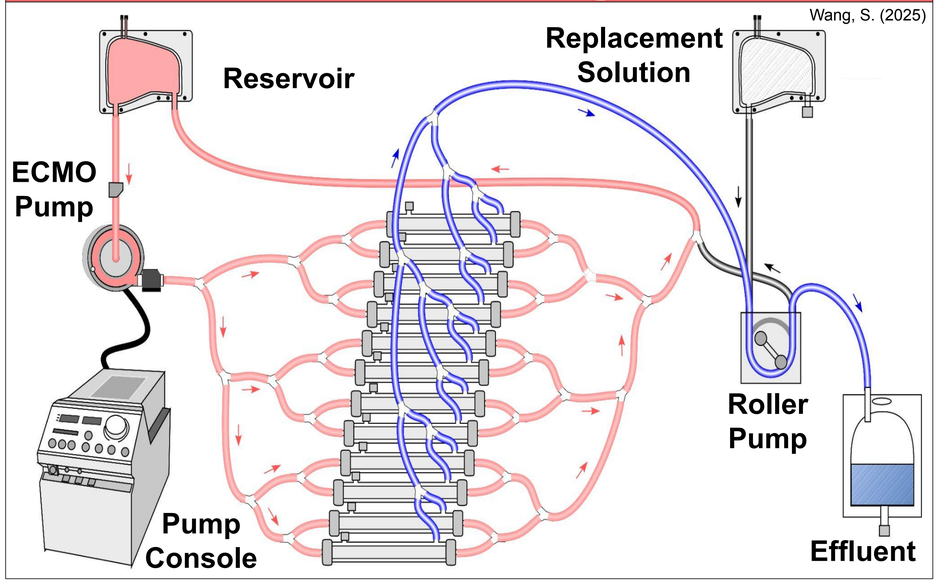
Creatinine Filtration Testing (Fig. 2 & 3)

1. Samples **before/after filtration** tested for creatinine using Diazyme assay kit[3], for water and blood mimic trials.*



*Healthy levels are 0.7 to 1.3 mg/dL[4].

Final Design



Results & Conclusions

Viscosity Testing

Table 1. Viscosity data results for various compositions of water, glycerin, xanthan gum (XG), and starch for blood mimic development.

Water: Glycerin:XG: Starch	t (s)	η (cP)
79.99:20:0.005:0.005	154	2.495
73.32:26.67:0.007:0.007	195	3.160
69.9985:30:0.0075:00.075	221	3.581
66.65:33:0.0083:0.0083	**275**	**4.456**
59.98:40:0.01:0.01	397	6.434

(Viscometer)

★ **Key Point:** Composition of **66.7% Water, 33% Glycerin, 0.01% XG, and 0.01% Starch** is within blood viscosity range (3.5-5.5 cP).

Pressure Testing

Pressure Differential Data

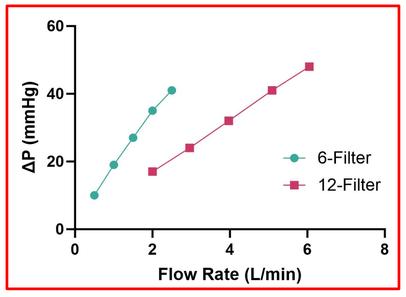


Figure 1. ΔP Filter at 10% effluent flow for water systems with 6 and 12 filters, shown versus total system flow rate.

Table 2. Average TMP and ΔP Filter readings for water and blood-mimic solutions over time (70 seconds).

Solution in 12-Filter System	Average TMP (mmHg)	Average ΔP Filter (mmHg)
Water	37	64
Blood Mimic	50	105

$$\Delta P = Filter\ Pressure - Return\ Pressure$$

$$TMP = \frac{(Filter\ Pressure + Return\ Pressure)}{2} - Effluent\ Pressure$$

★ **Key Point:** Increasing the viscosity of the solution in our system increases both TMP and ΔP Filter, but the system remains below max TMP threshold (600 mmHg[5]).

Results & Conclusions

Creatinine Concentration Over Time (Saline)

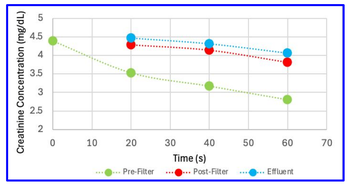


Figure 2. Creatinine concentration change over 60 sec. in a **12-filter saline system** (pre-, post-filtration, effluent samples). Shows a **13.22% decrease** from initial (t=0) to final post-filter concentration.*

Creatinine Concentration Over Time (Mimic)

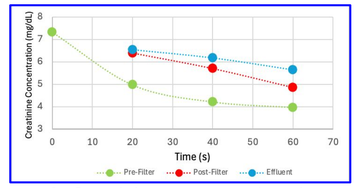


Figure 3. Creatinine concentration change over 60 sec. in a **12-filter blood mimic system** (pre-, post-filtration, effluent samples). Shows a **33.54% decrease** from initial (t=0) to final post-filter concentration.*

* Reflects "patient" toxin reduction

★ **Key Point:** Filtration efficacy is maintained at high flux → Creatinine concentrations decrease over time in the saline & blood mimic trials.

Bioethical Considerations

1. Ensure the appropriate **risk and benefit assessment** and protection of **informed consent** during trials.
2. Drastic improvements in **survival** & **recovery in high-risk patients** will transform standard of care.
3. We want to ensure **access** and **equity** for clinicians and patients of all demographics.

Future Work

1. Test with sheep or pig blood.
   → Integrate **pre-replacement fluid** to prevent clotting and pressure build-up.
2. Test with a **non-dialyzable** model toxin.
3. Clinical testing to measure **safety and efficacy.**
   → Shorten tubing to minimize blood removed from patient (currently about 2.5 L).
4. Commercialization.

References

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