Dimensions and Dynamics in Pediatric Continuous Renal Replacement Therapy

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Introduction

- Continuous renal replacement therapy (CRRT) is commonly utilized in the intensive care unit for management of kidney dysfunction.
- Blood flows are traditionally calculated based on patient body surface area, but few studies have investigated the underlying fluid dynamics of these circuits.
- Without understanding the fluid dynamics, there is a gap in our understanding of safe and effective dialysis treatments.
- This gap has also stunted our growth in advancing extracorporeal devices for the pediatric population.
- In this study, we sought to describe the fluid dynamics in a cohort of pediatric patients.

Methods and Materials

- This retrospective review included 22 children, aged 0-26 years, previously admitted to the University of Iowa Stead Family Children's Hospital Neonatal or Pediatric Intensive Care Unit for CRRT only (filter sizes HF20, M60, and HF1000, IRB 202212339).
- Patient body surface area (BSA) at CRRT start and average blood flow between 24-48 hours post-CRRT start were collected
- Similar data was collected for pressure drop and access, filter, effluent, return, and transmembrane pressures.
- Patients who remained on CRRT for prolonged periods account for multiple data points as BSA, average blood flow and pressure data were collected every 30 days.
- Linear regression models were used to investigate blood flow and BSA as predictors of CRRT pressures.
- Correlation coefficients were used to measure the relationship between blood flow/ BSA and CRRT pressures in each filter size.

Discussion

Blood flow was significantly associated with patient BSA ($p < 0.001$) flow and pressure drop ($p < 0.001$). Blood flow was also significantly associated with filter pressure in the M60 filter ($p < 0.001$) and trended toward significance in the HF20 Filter ($p = 0.112$).

These data suggest that patient blood flow drives CRRT pod pressures and has created a standardized approach for choosing CRRT circuits by BSA and blood flow. These data may also point to important characteristics for pediatric extracorporeal device developers to consider when designing pediatric specific devices in the future.

Limitations of this study include sample size and lack of prior research studies in this topic. Patients on ECMO and CRRT were excluded from the study, limiting sample size. Future work includes expanding this study to evaluate dynamics of CRRT and ECMO to guide further development of extracorporeal devices in the pediatric population.

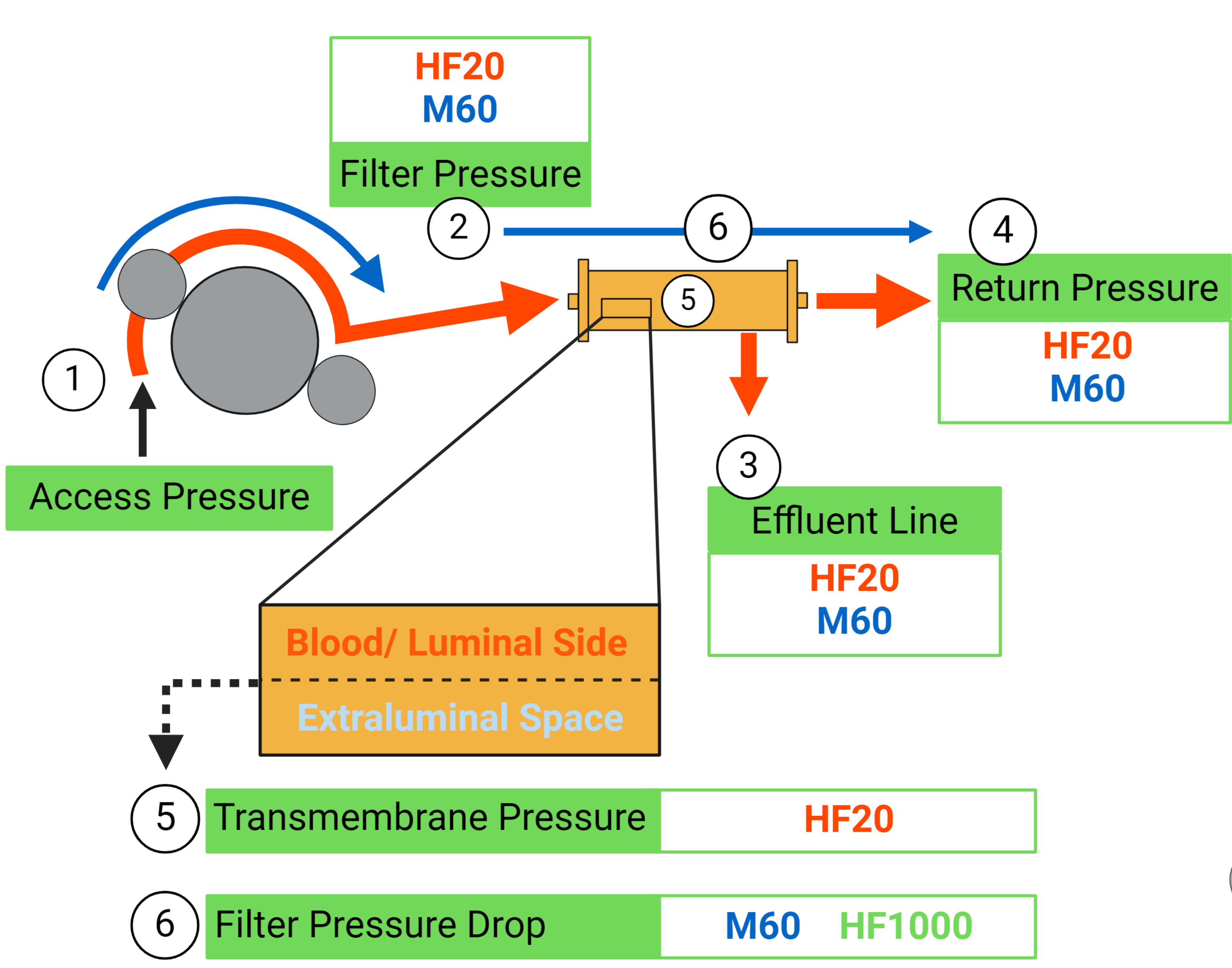
Results and Conclusions

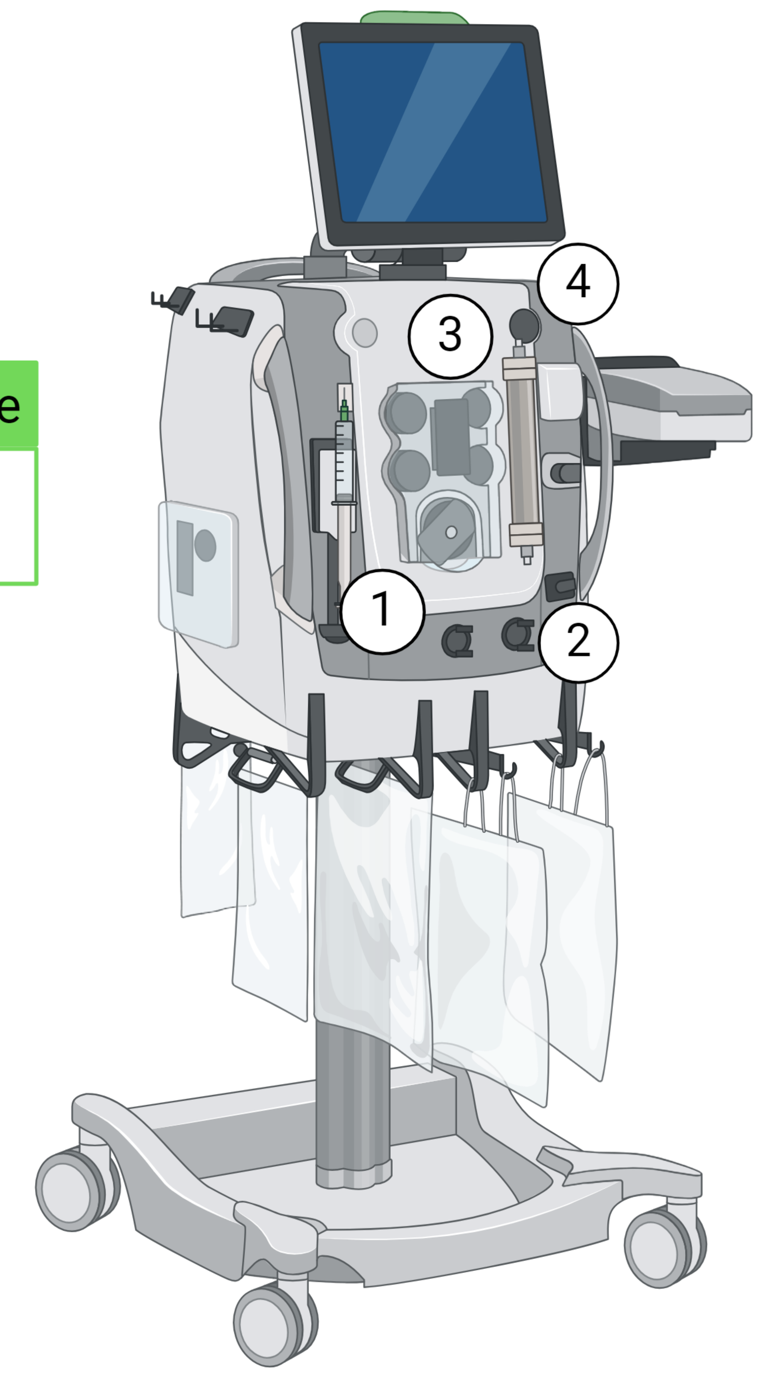
Predictive Analysis by Blood Flow	Std. Error	95% CI	R Squared	p-Value
BSA	16.29	53.36 – 121.30	0.5897	**< 0.001**
1. Access Pressure	0.34	-0.27 – 1.14	0.0765	0.213
2. Filter Pressure	0.16	-0.18 – 0.48	0.0421	0.359
3. Effluent Pressure	0.18	-0.42 – 0.34	0.0002	0.838
4. Return Pressure	0.13	-0.32 – 0.21	0.0090	0.665
5. Transmembrane Pressure	0.08	-0.07 – 0.25	0.0576	0.282
6. Pressure Drop	0.05	0.10 – 0.32	0.4573	**< 0.001**
Filter Pressure of HF20	0.63	-0.47 – 3.05	0.5065	0.112
Filter Pressure of M60	0.12	0.41 – 0.98	0.8568	**0.001**
Filter Pressure of HF1000	0.44	-0.68 – 1.47	0.1185	0.404

HF20 Filter

	Acess Pressure	Filter Pressure	Effluent Pressure	Return Pressure	Transmembrane Pressure	Pressure Drop	Blood Flow	BSA
Acess Pressure	1.00	-0.27	-0.21	-0.37	-0.23	0.21	-0.02	-0.53
Filter Pressure	-0.27	1.00	0.80	0.88	0.50	0.29	0.71	0.89
Effluent Pressure	-0.21	0.80	1.00	0.89	-0.05	-0.07	0.17	0.83
Return Pressure	-0.37	0.88	0.89	1.00	0.36	-0.19	0.40	0.87
Transmembrane Pressure	-0.23	0.50	-0.05	0.36	1.00	0.21	0.83	0.33
Pressure Drop	0.21	0.29	-0.07	-0.19	0.21	1.00	0.62	0.10
Blood Flow	-0.02	0.71	0.17	0.40	0.83	0.62	1.00	0.42
BSA	-0.53	0.89	0.83	0.87	0.33	0.10	0.42	1.00

1.0 0.5 0 -0.5 -1.0





M60 Filter

	Acess Pressure	Filter Pressure	Effluent Pressure	Return Pressure	Transmembrane Pressure	Pressure Drop	Blood Flow	BSA
Acess Pressure	1.00	0.47	0.37	0.18	-0.28	0.69	0.59	-0.43
Filter Pressure	0.47	1.00	0.81	0.91	-0.24	0.91	0.93	0.22
Effluent Pressure	0.37	0.81	1.00	0.88	-0.74	0.60	0.81	-0.10
Return Pressure	0.18	0.91	0.88	1.00	-0.37	0.65	0.76	0.18
Transmembrane Pressure	-0.28	-0.24	-0.74	-0.37	1.00	-0.07	-0.38	0.52
Pressure Drop	0.69	0.91	0.60	0.65	-0.07	1.00	0.92	0.18
Blood Flow	0.59	0.93	0.81	0.76	-0.38	0.92	1.00	0.16
BSA	-0.43	0.22	-0.10	0.18	0.52	0.18	0.16	1.00

1.0 0.5 0 -0.5 -1.0

HF1000 Filter

	Acess Pressure	Filter Pressure	Effluent Pressure	Return Pressure	Transmembrane Pressure	Pressure Drop	Blood Flow	BSA
Acess Pressure	1.00	-0.36	-0.33	-0.59	-0.07	0.14	0.56	-0.31
Filter Pressure	-0.36	1.00	0.91	0.93	-0.39	0.73	0.34	0.40
Effluent Pressure	-0.33	0.91	1.00	0.93	-0.72	0.47	0.16	0.01
Return Pressure	-0.59	0.93	0.93	1.00	-0.45	0.44	-0.02	0.26
Transmembrane Pressure	-0.07	-0.39	-0.72	-0.45	1.00	0.02	-0.01	0.65
Pressure Drop	0.14	0.73	0.47	0.44	0.02	1.00	0.84	0.63
Blood Flow	0.56	0.34	0.16	-0.02	-0.01	0.84	1.00	0.36
BSA	-0.31	0.40	0.01	0.26	0.65	0.63	0.36	1.00

1.0 0.5 0 -0.5 -1.0

Key Findings:

Larger body surface area (BSA) is significantly associated with **higher blood flow**
Smaller filters with lower blood flows (< 110 mL/min) **more closely predict filter pressures**
Blood flow and BSA are more correlated with **pre-filter pressures in smaller filter circuits**
Blood flow and BSA are more correlated with **post-filter pressures in larger filter circuits**