Design of Blood Warmer Medical Device

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INTRODUCTION: Multiphysics simulations were performed for designing the blood warmer accessory of a dialysis machine. This work deals with the design and development project of the blood warmer and explains in detail the electro-thermo-fluid simulations aspect of the blood warmer used in a dialysis machine. Blood Warmer is an accessory in dialysis machine intended to deliver the blood or fluids before to transfusion to a human body at 37° C which is the set temperature.

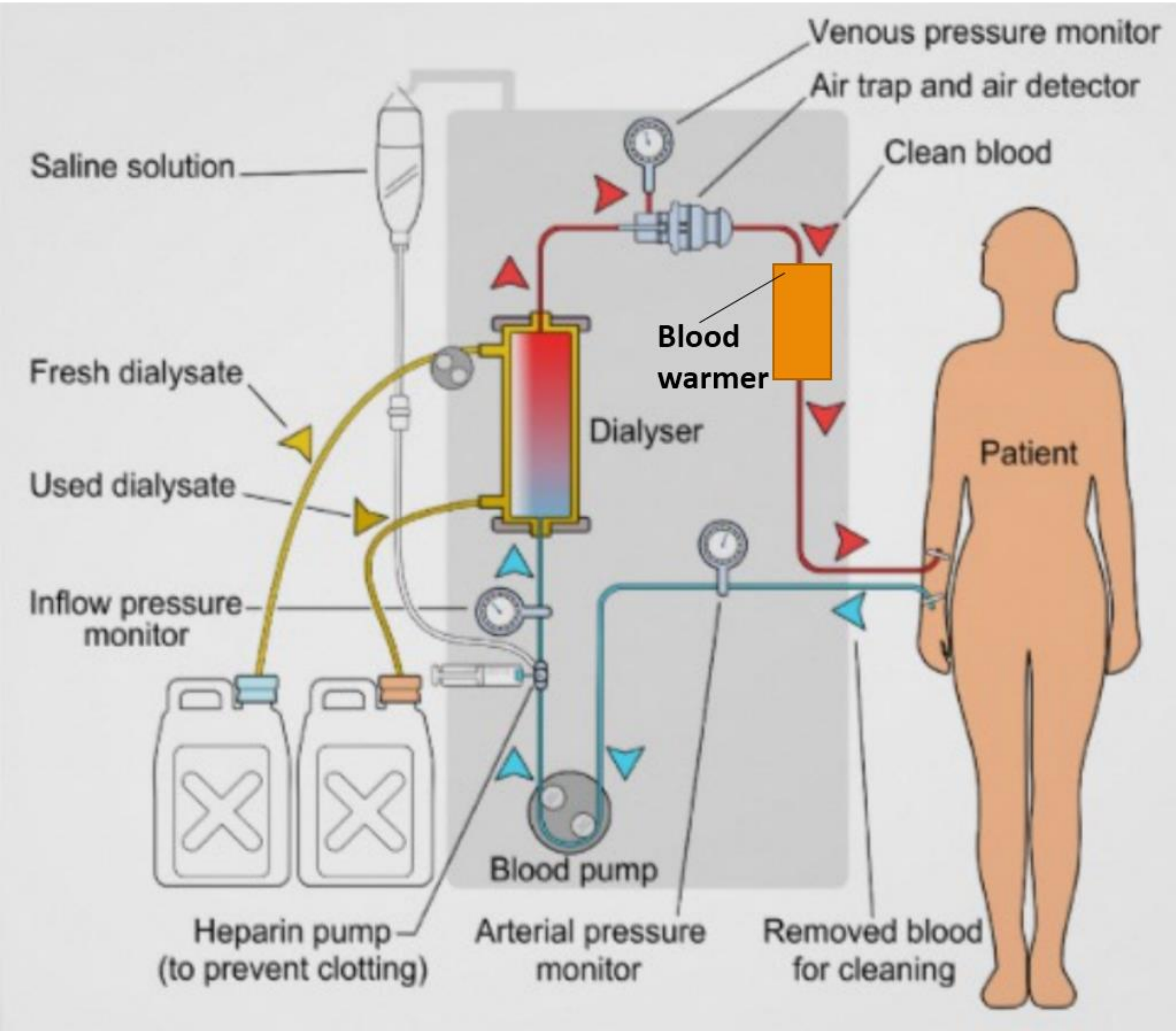

Figure 1. Blood warmer unit in a dialysis machine.

COMPUTATIONAL METHODS:

The multiphysics simulations were performed to determine the power input required for 8 different flow rates to reach a desired set temperature of 37.6 ° C from the inlet temperature of 30 ° C.

The range of flow rates used in the simulation are 100,150,200,250,300,350,400 and 450 ml/min.

By varying the power input applied on the heating coils of heater plates, the power required to achieve the desired set temperature was determined. A convective heat transfer coefficient of 10W/m^2.K was assumed considering that the heating unit is placed in an enclosure.

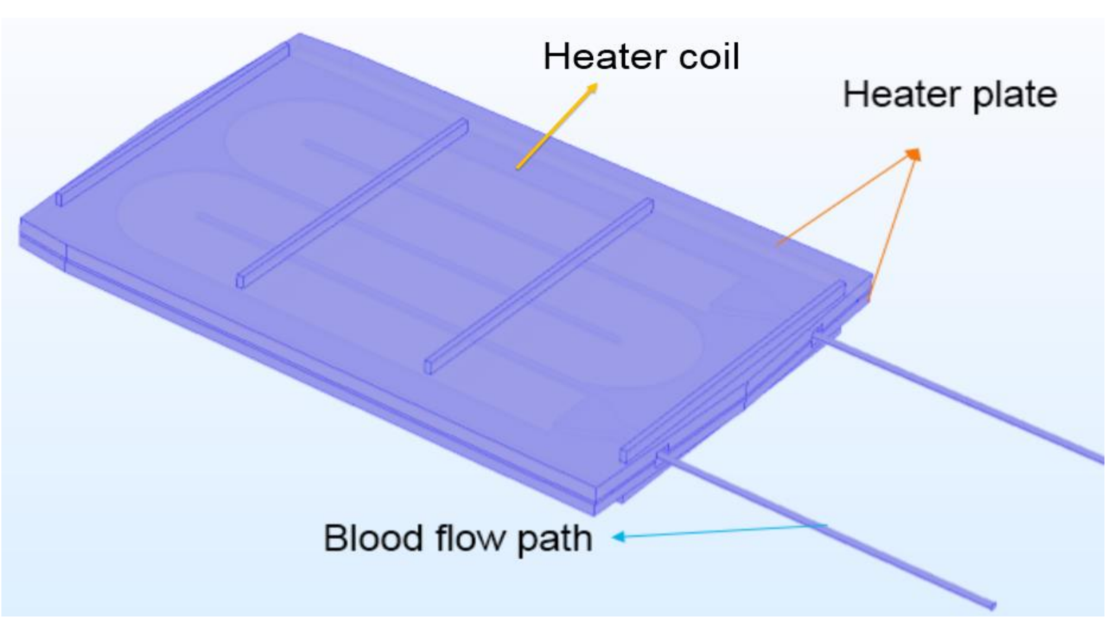

Figure 2. Blood warmer assembly

Component /Material	Property	Values	Unit
Fluid/Water	Specific heat	4181.8	J/kg*K
	Density	1000	Kg/m^3
	Dynamic viscosity	1.002	Pa-s x 10-3
	Kinematic viscosity	1.004	(m2/s) x 10-6
	Thermal conductivity	0.58	W/(m.K)
Blood flow path/ Polyethylene	Specific heat	1800	J/kg*K
	Density	1500	Kg/m^3
	Thermal conductivity	0.209	W/(m.K)
Heater plate/ Aluminum	Specific heat	956	J/kg*K
	Density	2699	Kg/m^3
	Thermal conductivity	165	W/(m.K)

Table 1. Material data

RESULTS:. There is a linear directly proportional relationship between the mass flow rate and heat energy required.

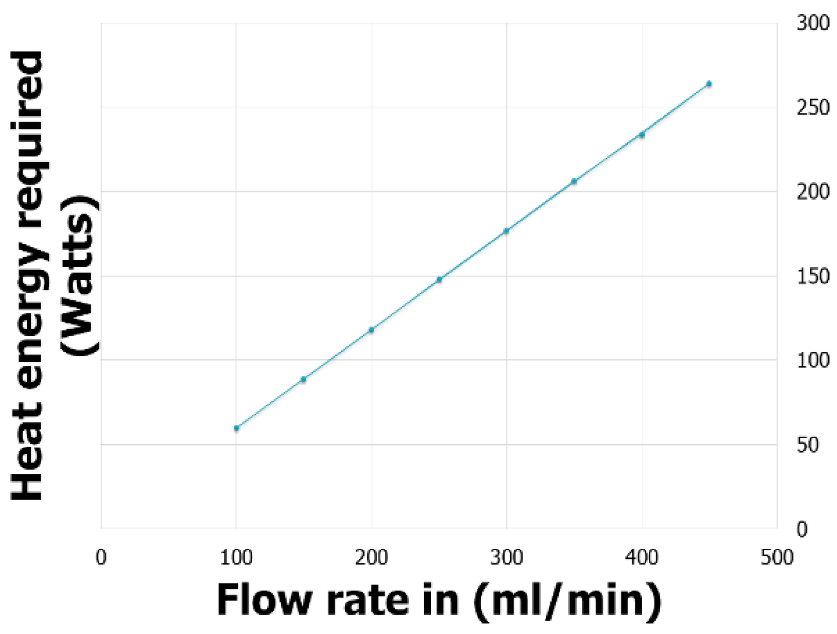

Figure 3. Title of the figure

Sl. No.	Mass Flow rate (ml/min)	Heat energy required(W)
1	100	60
2	150	89
3	200	118
4	250	148
5	300	177
6	350	206
7	400	234
8	450	264

Table 2. Title of the figure

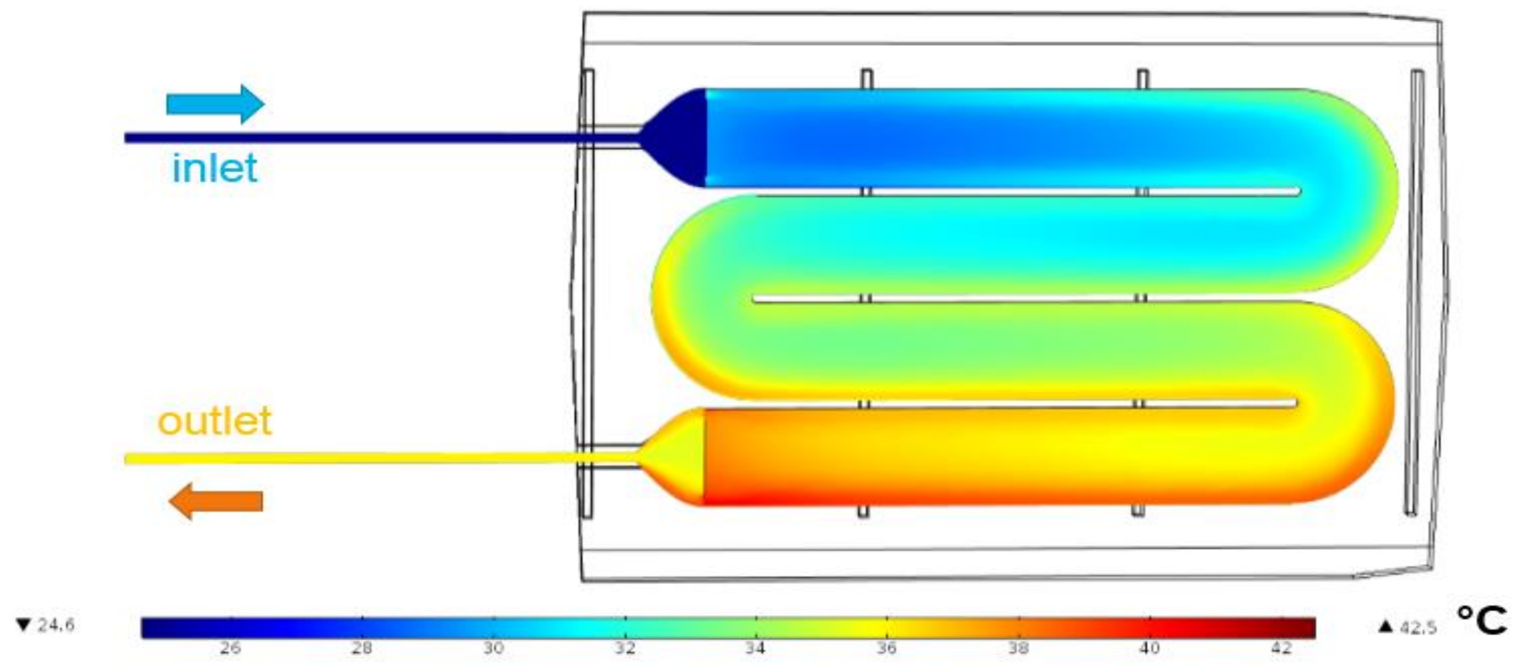

Figure 4. The spatial thermal distribution of the blood flow path

The temperature of the fluid increases along the blood flow passage. The temperature distribution is higher in the exit region of the blood warmer and lower at the entry region of the blood warmer.

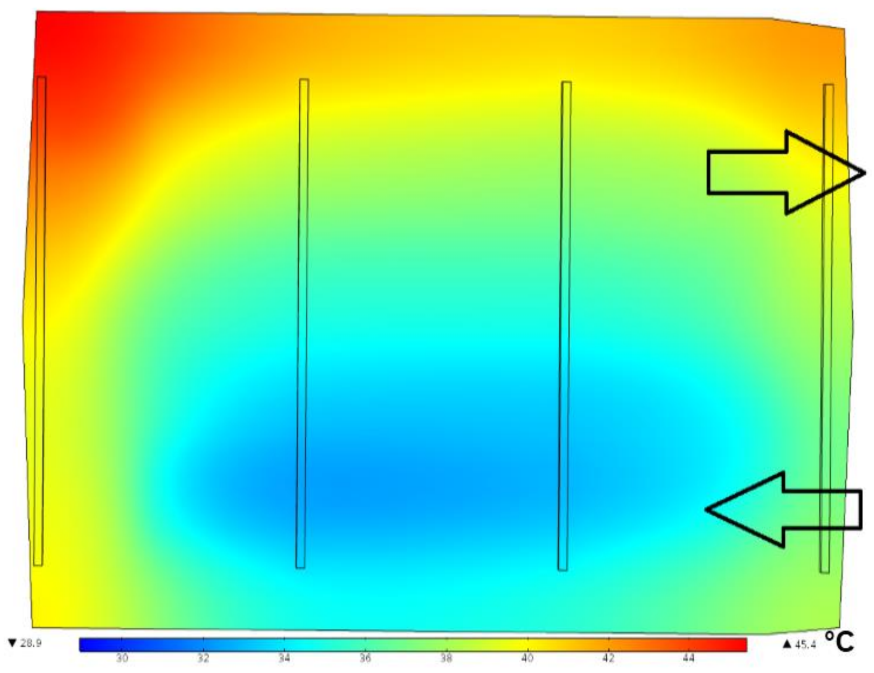

Figure 5. Temperature distribution in the heater plate

CONCLUSIONS: Based on the simulation results, the heat energy required at different flow rates to heat the blood to 37° C was obtained. This information was useful for the further developments in the product design cycle.

There is a linear relationship between the flow rate and heat energy required.

The temperature gradient is observed across flow passage as it gets heated up.

The correlation between testing and multiphysics simulation results was good. The multiphysics simulations results were used for creating the control algorithms.

The product development process has been shortened in the concept and prototyping phase by effectively using multiphysics simulations.

The heat transfer reports generated by using COMSOL® were submitted as supporting documents for regulatory purposes and successfully moved to manufacturing stage.