Memorandum

To: Dr. Trevas

From: William Merritt (Team 23)

Date: November 18, 2016

Re: Individual Analysis: Maintaining Fluid Temperature in an *in vitro* Model

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Introduction:

The purpose of this memo is to prove that it is feasible to maintain a physiologically relevant fluid temperature throughout an *in vitro* vascular model.

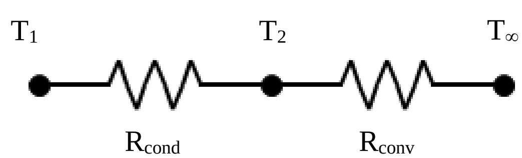
Problem:

Our *in vitro* model's purpose is to imitate a biological vascular system so that experiments can be performed and refined before being performed in a living subject. In order for the model to be effective in its purpose, it must be as physiologically relevant as possible.

There are many important variables to consider when creating a physiologically relevant model, but one of the most vital variables our team must consider is the temperature of the fluid in our model. Many fluids behave differently with changes in temperature. In order to ensure that our model is relevant, we need to prove that fluids throughout our entire model are within a physiologically relevant range.

Approach:

Since we do not have a working model to test, the temperature drop of the fluid in our model must be estimated mathematically. Heat loss can be estimated by creating a thermal resistance network (Figure 1) to model the system and using it to calculate total thermal resistance.



The thermal resistance due to conduction through the vessel can be found using Equation 1, where k is the conduction coefficient of the model material, L is the length of the vasculature, r_2 is the outer radius of the vasculature, and r_1 is the inner radius of the vasculature.

$$R_{cond} = \left(\ln\frac{r_2}{r_1}\right)/(2\pi kL) \quad (1)$$

The thermal resistance due to free convection from the vessel to the ambient air can be found using Equation 2, where h is the convection coefficient of air, L is the length of the vasculature, and r_2 is the outer radius of the vasculature.

$$R_{conv} = 1/(2h\pi r_2 L) \quad (2)$$

Since the thermal resistors are in series, they can be summed to find the total equivalent thermal resistance of the system. Using the parameters defined in Table 1, it is possible to calculate the total equivalent thermal resistance of the system.

Table 1: Parameters for Equation 1

Parameter	**Value**
k_{glass}	$1.05 \frac{W}{m \cdot K}$
h_{air}	$10 \frac{W}{m^2 \cdot K}$
L	0.127 m
r_2	2.01 mm
r_1	1.50 mm
T_1	37 °C
T_∞	25 °C

R_{eq}= 65.84 K/W

Once the total resistance has been found, this value along with the temperatures from Table 1 can be used to find heat loss in Equation 3.

$$q = (T_1 - T_\infty)/R_{eq} \quad (3)$$

q= 182.3 mW

Once we have a value for heat loss, we can use this to find the temperature drop of the fluid in the model using Equation 2, where c_p is the specific heat of the fluid, V is volume of the fluid, and ρ is density of the fluid. These parameters are quantified in Table 2.

$$q = c_p \cdot V \cdot \rho \cdot (T_1 - T_2) \quad (4)$$

Table 2: Parameters for Equation 2

Parameter	**Value**
c_p	$2.43 \frac{kJ}{kg \cdot K}$
ρ	ρ= $1.26 \frac{g}{cm^3}$
V	8.98×10^{-7} m^3
T_1	37 °C

T_2= 36.94 °C

This equation shows that there is very little temperature drop in the fluid as it flows through the system.

Conclusion:

The result of this estimation is very promising. Since there is minimal temperature drop in the fluid as it flows through the model, insulation of the model is likely unnecessary. This allows the model design to be simplified and allows for better visualization of flows within the model.

Since the model has not been developed, assumptions had to be made for several factors. Glass was chosen as the vessel material as a conservative estimate because glass conducts heat better than the polymers being considered. Glycerin was chosen as the fluid for the model because it has a lower specific heat than water so it doesn't take as much heat to change its temperature. Due to these assumptions, this is a conservative estimate, so the measured temperature drop in the system will likely be smaller than calculated.

This estimation can be easily proved empirically when the model is created by measuring the temperature as it flows both in and out of the model.