
The Effect of Temperature on the Pressure Drops Across 25 and 40 Micron Arterial Line Filters

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Abstract

The purpose of this *in vitro* study was to quantify the effect of temperature on the pressure drop, ΔP , across 25 and 40 micron arterial line filters. The pressure drop for each micron size filter was found to significantly increase ($P < .01$) with decreasing blood temperature when measured at a constant blood flow ($\dot{Q} = 5$ LPM) and a hematocrit of 35%. Protein electrophoresis, hematology analysis, and testing for cryoglobulins indicated that blood clot formation or cryoprecipitates did not contribute to the measured pressure drop. During the conduct of extracorporeal circulation knowledge of pressure drop versus blood temperature is useful to the perfusionist in accounting for temperature effects when reading the pressure at the arterial filter inlet.

Before deciding to bypass an arterial filter because of a high inlet pressure reading the perfusionist should consider the effect of temperature.

Introduction

The pressure drop across a filter, ΔP , is defined as the fluid pressure on the inlet side of the filter, P_1 , minus the fluid pressure on the outlet side of the filter, P_2 .

$$\Delta P = P_1 - P_2$$

The pressure drop across a filter is a function of the fluid viscosity, fluid flow, and design of the filter. According to Poiseuille's law, during constant, non-turbulent fluid flow with a fixed filter design, the pressure drop is proportional to the fluid viscosity.

Blood is a non-Newtonian fluid with a viscosity that fluctuates in response to changes in temperature, hematocrit, and protein concentration.¹ During extracorporeal circulation the pressure drop across an arterial filter will fluctuate with changes in hematocrit, blood flow, protein concentration, and temperature. The pressure drop will increase if the arterial filter media becomes partially occluded due to the formation of a blood clot or the aggregation of blood components (such as cryoprecipitates).

During extracorporeal circulation the perfusionist can use arterial filter pressure drop readings in an effort to ascertain if the filter media has become occluded.

The purpose of this study was to investigate the relationship between temperature change and arterial filter pressure drop changes. With an understanding of this relationship the perfusionist will be better able to manage the use of arterial line filters.

Materials and Methods

The 25 and 40 micron arterial filters were constructed using polyester filter media of 25 and 40 microns (nominal) respectively. The 25 and 40 mi-

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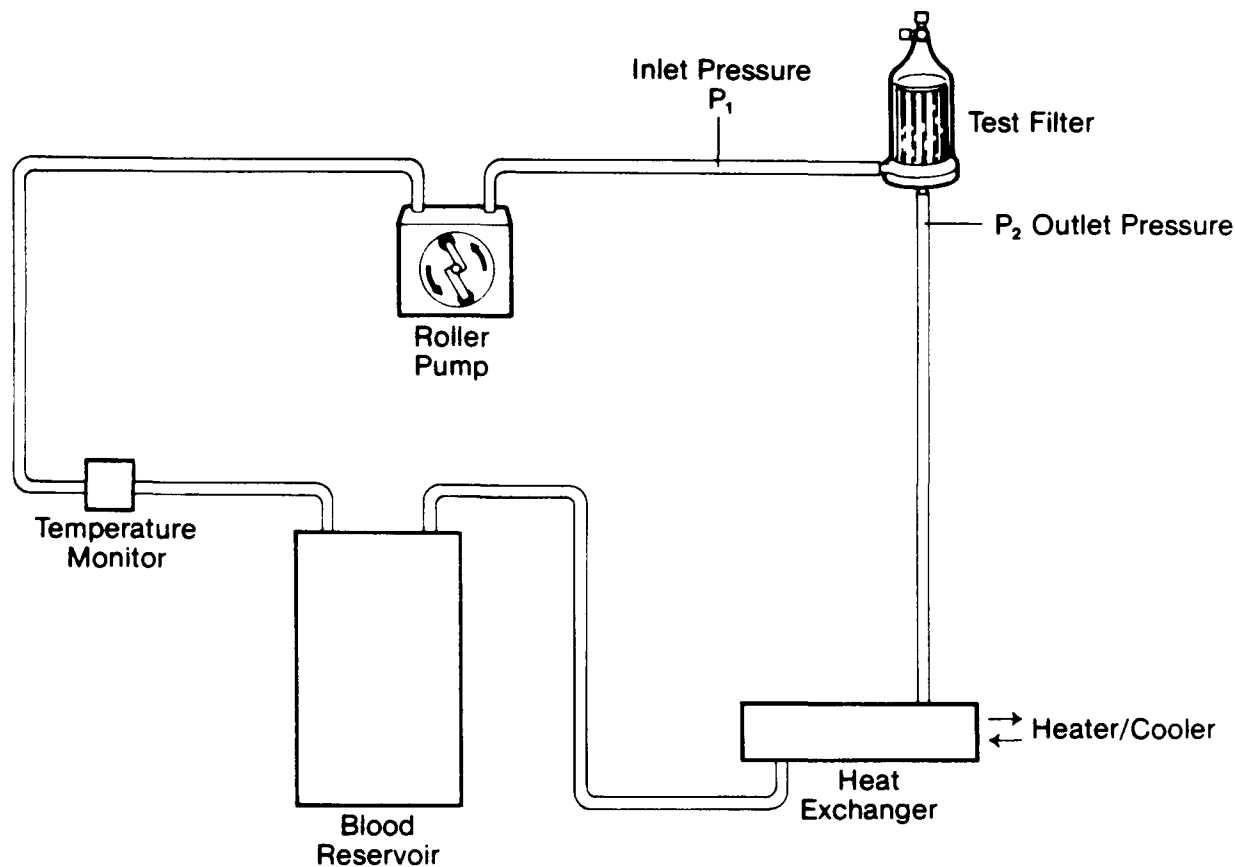


FIGURE 1. In Vitro Circuit.

cron elements were assembled utilizing identical housings to eliminate the effect of filter design.

The *in vitro* circuit used in the study is shown in Figure 1. The circuit utilized a Sarns Miniprime Heat Exchanger,^a a Cincinnati Sub Zero Heater/Cooler,^b an Extracorporeal Blood Reservoir,^c a Yellow Springs In Line Temperature Probe and Monitor,^d a Sarns 5000 Roller Pump,^e Hewlett-Packard Pressure Transducer,^e and Tygon S-50 HL Tubing.^f The roller pump occlusion was set to allow a 1 cm/minute decrease in a 24 cm column of blood. The roller pump was calibrated at 15 °C through 40°C with the filter outlet pressure, P_2 , equal to 100 mmHg. The effect of temperature on roller pump flow was accounted for by altering the roller pump RPM setting during pressure drop measurements.

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^b Cincinnati Sub Zero Product, Inc., Cincinnati, OH 45206

^c Extracorporeal Medical Specialties, Inc., King of Prussia, PA 19406

^d Yellow Springs Instrument Company, Yellow Springs, OH 45387

^e Hewlett-Packard, Waltham, MA 02154

^f Norton Medical Products, Akron, OH 44309

Canine blood having a hematocrit of 35% was used to prime and debubble the *in vitro* circuit. The following conditions were then established: blood flow, $Q = 5.0$ LPM; temperature, $T = 40^\circ\text{C}$; outlet pressure, $P_2 = 100$ mmHg; and hematocrit = 35%. Activated clotting times were maintained above 500 seconds.

At equilibrium, three inlet and outlet pressures, P_1 and P_2 , were measured and recorded at five minute intervals. The heater/cooler was then adjusted to decrease the blood temperature by ten degrees centigrade. Three 25 micron and three 40 micron arterial filters were studied.

Prior to each individual filter evaluation (at 40°C) a hematology scan was performed. In addition, a blood protein electrophoresis and cryoglobulin analysis were performed. Post-test (at 5°C) hematology, protein electrophoresis and cryoglobulin analysis were performed for each filter.

A two-way analysis of covariance was performed for the two filter groups to test for a sig-

TABLE 1
25 and 40 Micron Mean Pressure Drops at
Selected Temperatures

	Temperature	Mean ΔP	Standard Deviation
25 Micron Filter	40°C	25.0	1.6
	30°C	28.2	3.2
	20°C	31.4	3.7
	10°C	34.6	4.3
	5°C	36.7	4.5
40 Micron Filter	40°C	22.5	2.1
	30°C	23.9	1.6
	20°C	24.1	2.0
	10°C	26.3	1.9
	5°C	27.7	2.0

nificant temperature effect on pressure drop within groups. A similar analysis was performed to test for a significant difference in measured pressure drop between filter groups.

Results

Table 1 shows the mean (N = 9) pressure drop measurements, ΔP , at the corresponding temperature for the 25 micron and 40 micron filters.

Figure 2 graphs the linear regression curves for pressure drop as a function of temperature.

The pressure drops for both the 25 and 40 micron filters were found to significantly increase ($P < .01$) with decreasing temperature. The pressure drop with temperature was significantly higher ($P < .001$) for the 25 micron filter compared with the 40 micron filter.

Table 2 shows the baseline and post-test hematology, protein electrophoresis, and cryoglobulin results for the 25 micron filter. Since there were no significant differences between baseline and post-test values for the 25 micron filter, the analysis was not repeated for the 40 micron filter.

Discussion

For the 25 micron filter the pressure drop increased from 25.0 mmHg at $T = 40^\circ\text{C}$ to 36.7 mmHg at $T = 5^\circ\text{C}$, a significant ($P < .01$) change of 47%. For the 40 micron filter the pressure drop increased from 22.5 mmHg at 40°C to 27.7 mmHg at $T = 5^\circ\text{C}$, a significant ($P < .01$) change of 23%.

The pressure drop versus temperature plots for the 25 and 40 micron filters show the best fit to a straight line (correlation coefficient = 0.96 for

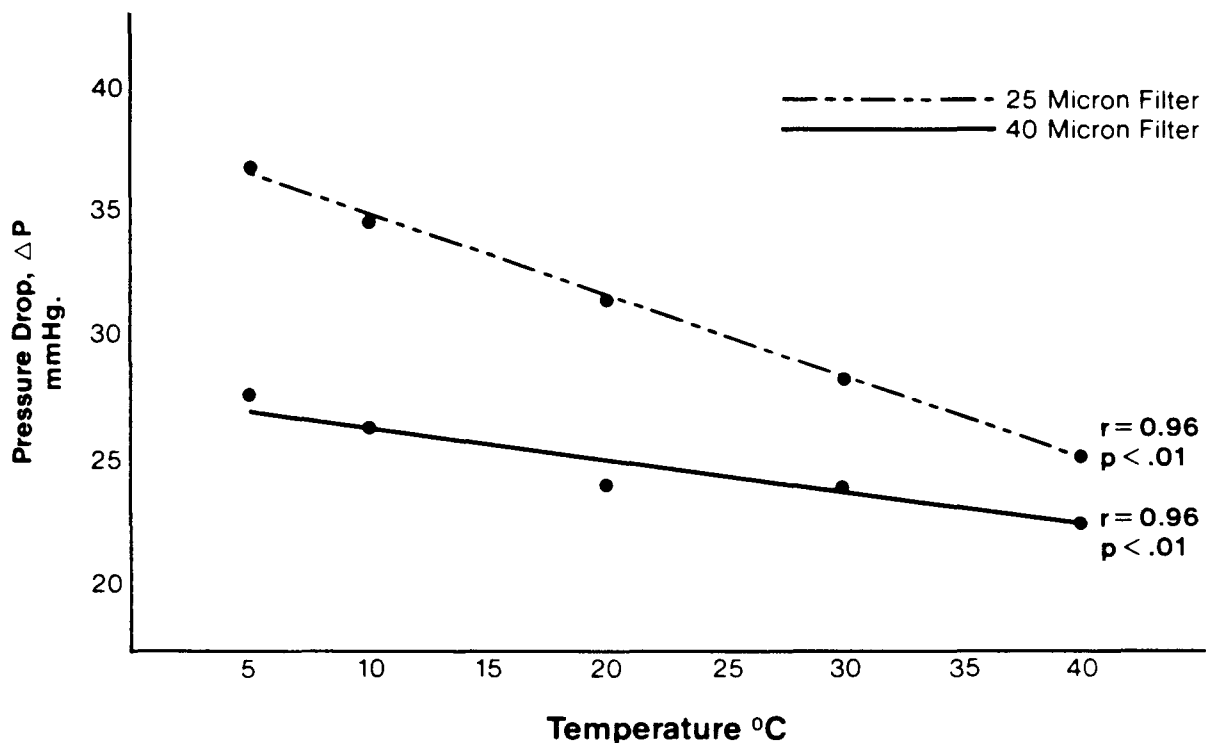


FIGURE 2. 25 and 40 Micron Filter Linear Regression Curves for Pressure Drop Versus Temperature.

TABLE 2
Selected Hematology Data 25 Micron Filter

	WBC	RBC	Hgb	Hct	Protein Electrophoresis Albumin	Cryoglobulin
Filter 001	14.7	4.81	11.6	34.6	5.0	NEG
Filter 002	15.5	5.12	12.2	36.9	5.1	NEG
Filter 003	16.9	5.13	12.3	36.7	5.5	NEG
Filter 001	15.9	4.81	11.5	34.8	4.6	NEG
Filter 002	15.7	5.12	12.4	36.6	5.0	NEG
Filter 003	16.0	5.07	12.2	36.7	5.5	NEG

each filter). Since the hematology data did not indicate the formation of a blood clot and in the absence of cryoglobulin, the increasing pressure drop with decreasing temperature may be assumed to be a result of viscosity changes in the blood.

It has been suggested by Chenoweth (personal communication) that the presence of cryoglobulins or other cryoprecipitates may cause the pressure drop across an arterial filter to increase as the cryoprecipitates aggregate on the filter media and occlude the pores. The canine blood used in this study did not test positive for cryoglobulin so the effect of cryoglobulins on arterial filter pressure drop was not quantifiable in this study.

Since the perfusionist should use the pressure drop across an arterial filter to gauge whether the filter media has become occluded, the perfusionist needs to understand how hematocrit, blood flow, and temperature affect blood viscosity and thereby pressure drop.^{1,2}

This *in vitro* study has shown that for the 25 and 40 micron (with fixed filter design) arterial filters the pressure drop increases linearly with decreasing temperature. Before deciding to bypass an arterial filter because of an alarming increase in the pressure drop reading the perfusionist should account for the contribution of blood flow, arterial line length and diameter, arterial cannula size and placement, hematocrit, and blood temperature.

Further research is needed to quantitate the effect of cryoprecipitates to understand whether patients with cryoglobulinemia are at risk using an arterial filter.

References

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