PRESSURE DROP EVALUATION IN ARTERIAL BLOOD FILTERS

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Abstract. *Cardiopulmonary bypass with extracorporeal blood oxygenation has become one of the most frequently performed classes of procedures worldwide.Cerebral damages after cardiac operations have been widely recognized since the early days of open-heart surgery and it happens because emboli are introduced into the patient's arteries. These emboli may be thrombi, cellular aggregates or bubbles. Interposition of a filter in the arterial line of the extracorporeal circuit has been one of the proposed methods for avoiding cerebral damage during a cardiopulmonary bypass.An arterial blood filter has a screen filter, with a porosity of 40 µm, for the removal of microemboli and can also be used to eliminate air present in the extracorporeal circuit. The presence of the screen filter will induce a resistance to the blood flow. This resistance can be described in terms of pressure drop across the arterial blood filter and its level must be kept below a threshold value otherwise red blood cells will be damaged. The aim of this work is to evaluate the pressure drop across arterial blood filters produced in Brazil. A test bench was developed and several solutions of water and glycerin have been used as working fluids. Finally the pressure drop was analyzed considering the flow rate and fluid viscosity.*

Keywords. *Blood filter, Hemolysis, Pressure Drop*

1. Introduction

Cardiopulmonar bypass (CPB) with extracorporeal blood oxygenation has become one of the most frequently performed classes of procedures worldwide. Improvement in extracorporeal oxygenation technology, surgical technique and postoperative medical management have decreased the mortality rate of cardiac operations (Schwarz et all., 1992). CPB may introduce emboli into the patient's arteries (Mitchell et all., 1996). These emboli may be thrombi, cellular aggregates, bubbles air, as well as pieces of plastic (Waaben et al., 1994). Cerebral damage after cardiac operations with CPB has been widely recognized since the early day of open heart surgery (Aris et all., 1986). This damage may occur due to an inefficient local oxygenation caused by the blood flow interruption.

Interposition of a filter in the arterial line of the extracorporeal circuit has been one of the proposed methods for avoid cerebral damage during CPB (Aris et all., 1986). The use of these filters has increased in the last years. A good arterial filter has the following characteristics (Souza e Elias, 1995):

- Operate with a maximum flow rate of 6 l/min,
- Low resistance to the flow,
- Should not damage blood cells,
- Have a low priming volume,
- Must be used in the elimination of the air present in the extracorporeal circuit.

Accordingly Mueller et all. (1999), three reasons seem to justify the systematic use of arterial line filters.

- They are excellent gross bubble traps,
- There is an increasing evidence that membrane oxygenators are associated with significant reduction, but not complete elimination, of microbubbles delivered to the patient,
- And finally, their wide use suggests that there is a little adverse effect from their use.

The use of an arterial line filter has also some disadvantages. A pressure gradient can be built up across the filter necessitating a switch to an external bypass line. There is also a risk for air embolism because air trapped in the filter during initial filling may be ejected later into the patient. Finally line filters may damage blood elements. Although the foci of thrombus formation and embolization in the arterial filter were recognized, no quantitative information about rate, size and amount of emboli shed from the filter, nor about the interrelationship of trapping of emboli in the arterial filter and thrombi formed and emboli shed from arterial filter is available (Dewanjee et all., 1992). One parameter associated with red blood cells damage is the pressure drop across the filter. Accordingly the literature, there is a threshold value of 100 mmHg, below this value hemolysis is not representative.

The aim of this work in to evaluate the pressure drop across arterial blood filters produced in Brazil. A test bench was developed and several solutions of water and glycerin have been used as working fluids. Finally the pressure drop was analyzed considering the flow rate and fluid viscosity.

2. Materials and Methods

2.1. The blood filter

The filters studied are used in cardiopulmonary bypass procedures. Both filters are made of acrylic and polyester is used in the filtering element. The filtering element has a porosity of 40 μm. The filters inlet and outlet connectors have a diameter of 9,5 mm and are made of reinforced acrylic. Both filters are projected to be used in adult patients and can be operated with a maximum flow rate of 6 liters per minute. The filters have a bypass line that can be used in situations where the filtering element pores are closed and another line is used to eliminate air trapped by the filter. Figure 1 shows a schematic view of one of the tested filters, its elements and how it works. In figures 1 and 2, blue arrows are used to indicate unfiltered blood while red arrows indicate filtered blood.

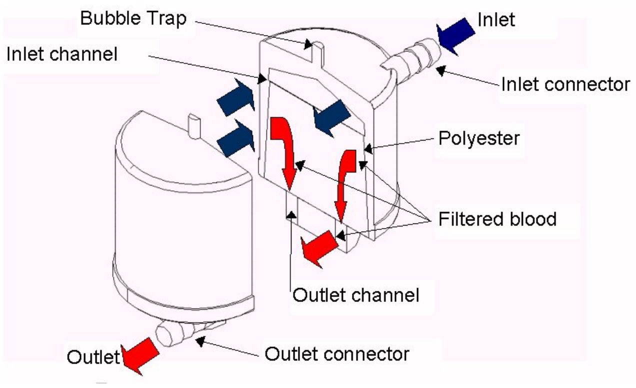

Figure 1. Schematic view of the filter

Figure 2 shows a schematic view of the second filter. Blood flows through the inlet connector, located at the upper part of the filter, and describes a descending helical movement while it flows along the inlet channel. During this helical movement the blood flows through the filtering element, polyester, reaches the outlet channel and flows in direction of the outlet connector, located at the bottom of the filter.

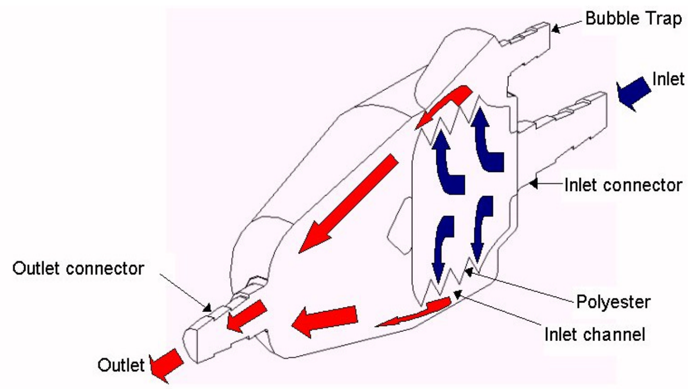

Figure 2 – Schematic view of the filter

Blood flows through the inlet connector and at the inner part of the polyester the blood flow is divided axially while the blood flows through the filtering element. The filtered blood, indicated by the red arrows, reaches the inlet channel and flows in the direction of the outlet connector passing through a big empty chamber.

2.2. The flow circuit

A test bench was assembled in order to reproduce the flow condition observed during a cardiopulmonary bypass. Figure 3 depicts schematically the test circuit.

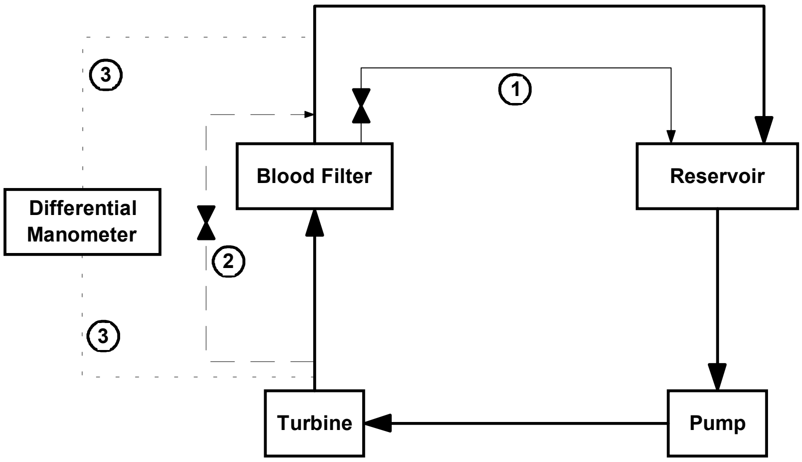

Figure 3 – Schematic view of the test circuit

Working fluid was pumped through the turbine and blood filter returning to the circuit reservoir. Line 1 represents the bubble trap and was used during the circuit filling up. Pressure drop across the filter was monitored by a differential manometer, indicated by the lines 3. Flow rate was monitored by a turbine flow meter and the pump rotating speed was controlled changing the excitation voltage of a brushless motor. All elements were connected using PVC flexible tubes.

The pressure drop was measured changing the flow rate and reading the differential pressure in the manometer. The flow rate varies in a range of 1,5 until 4,5 l/min, in an increment of 0,5 l/min. Tests were performed in a non-pulsatile condition and solutions of water and glycerin, with concentration of 0, 20 and 40%, in mass were used as working fluids. The glycerin concentration variation has the finality to evaluate the influence of the viscosity in the pressure drop.

3. Results and Discussion

Pressure drop was evaluated in two different filters. Figure 4 shows the results for the first tested filter.

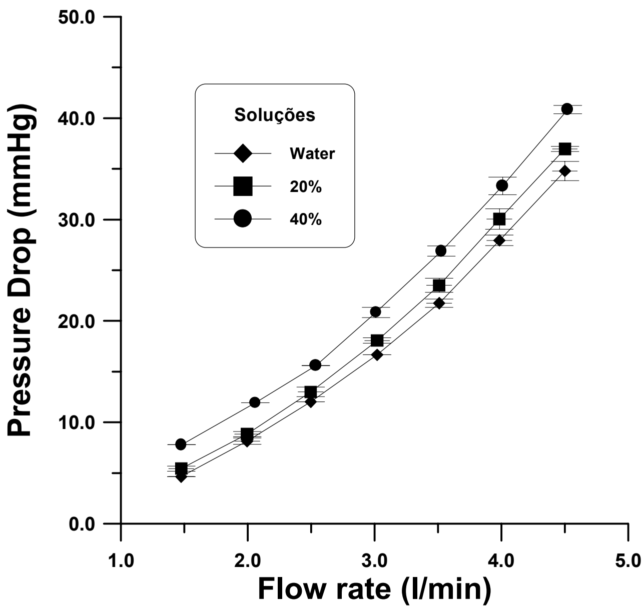

Figure 4 – Pressure drop across the first filter

The results for the second filter are shown below.

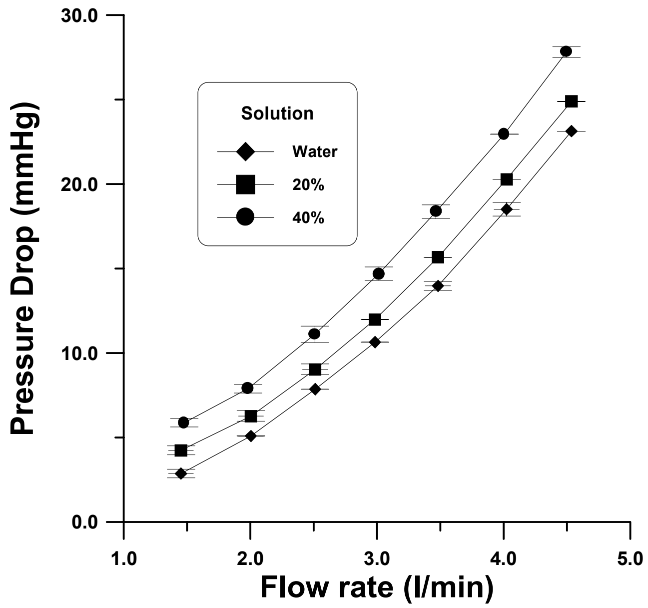

Figure 5 – Pressure drop across the second filter

The results show that the pressure drop tends to increase with the flow rate. The pressure drop increases with the working fluid viscosity because, higher is the viscosity more difficult is the flow across the filter. Both filters differ with respect to the geometry but the results exhibit the same pattern. The maximum pressure drop observed was 41 mmHg which is below the threshold value of 100 mmHg. From this point of view is possible to say that both filters have a low potential to damage blood cells.

4. Conclusions

A test bench was developed and several solutions of water and glycerin have been used as working fluids. Finally the pressure drop was analyzed considering the flow rate and fluid viscosity. Despite the fact that both filters have a completely different geometry the results presents the same pattern. The results shown that both filters have a low hemolitic potential.

5. Acknowledgement

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