A Comparative Study of Five Filtered Cardiotomy Reservoirs

Peter J. Swanney
The Christ Hospital
Department of Cardiac Surgery
Cincinnati, OH

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Abstract

Five commercially available cardiotomy reservoirs (CR) were tested to determine:

a) Gaseous microemboli removal efficiency
b) Manufacturer contaminant levels
c) Blood hold-up volume

The gaseous microemboli were detected by a doppler type ultrasonic detector. Manufacturer contaminant levels were counted by flushing each CR with filtered water and collecting the contaminants on a filter paper. This was then examined under a light microscope and size and counts were taken. The blood hold-up volume was determined by finding the difference in volume in a cylinder between flowing through the CR and bypassing it.

The Intersept and BST-1 CR were found to be significantly more efficient at removing the gaseous microemboli. All the CR had a large number of contaminants which included a particle count range from 10-278 greater than 100 microns. The Intersept CR had less hold-up volume then the others.

Introduction

The deleterious effects of cardiotomy suction are well known. Gaseous microemboli removal is affected by the pore size of the filter, amount of air aspirated, the time the blood is held up in the CR, and the volume of blood held up in the CR.[1,2] The gaseous microemboli that are not removed may be passed to the patient via the extracorporeal circuit and produce tissue damage.[3-6] The cardiotomy suction system is the largest source of solid microemboli.[7] Filtration has been shown to decrease the tissue damage from these particles.[8-12]

The need for pre-bypass filters to remove manufacturer contaminant particles has been described.[13-15] This paper shows the need to preflush the CR and filter the priming solution.

On occasion a CR needs to filter and defoam blood at flow rates equal to systemic blood flow so that this blood can be returned to the oxygenation circuit and hence to the patient. This study compares the blood hold-up volume for the different CR.

Methods and Materials

Five commercially available filtered CR were evaluated. These were:

1) Bentley BCR3500[a]
2) Extracorporeal INTERSEPT[b]
3) SciMed BST-1[c]
4) Shiley CARDFPLS[d]
5) Travenol 5M1471[e]

Table 1 shows the CR filter sizes and materials.

The test circuit, Figure 1, for the gaseous microemboli study consisted of a Sarns pump[f], Cobe Optiflo II bubble oxygenator[g], and a TM-8 Microbubble Activity

Direct communications to: Peter J. Swanney, Cardiac Surgery, Terre Haute Regional Hospital, 601 Hospital Lane, Terre Haute, IN 47802

a American Bentley, Irvine, CA 92714
b Extracorporeal Inc., King of Prussia, PA 19406
c SciMed Life Systems, Inc., Minneapolis, MN 55441
d Shiley Inc., Irvine, CA 92714
e Omnis Surgical Inc., Deerfield, IL 60015
f Sarns Inc., Ann Arbor, MI 48103
g Cobe Laboratories, Lakewood, CO 80215

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Table 1

FILTERED CR	BCR3500	INTERSEPT	BST-1	CARDFPLS	5M1471
Capacity ml	2800	2600	2800	2400	2000
Filter size microns	20	20	20	20	20
Filter material	polypropylene	polyester	polyester	polyester	polyester
Outer sock	nylon	polyester	polyester	polyester	polyester

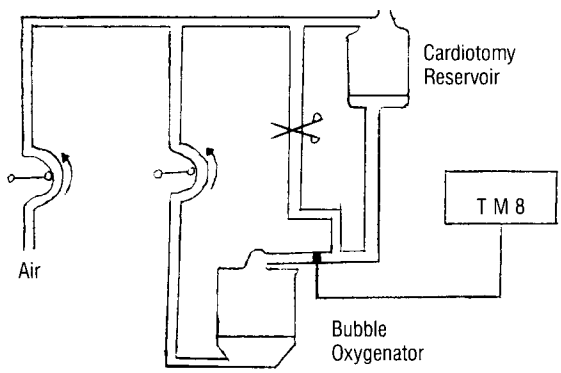

Figure 1: Gaseous Microemboli Circuit.

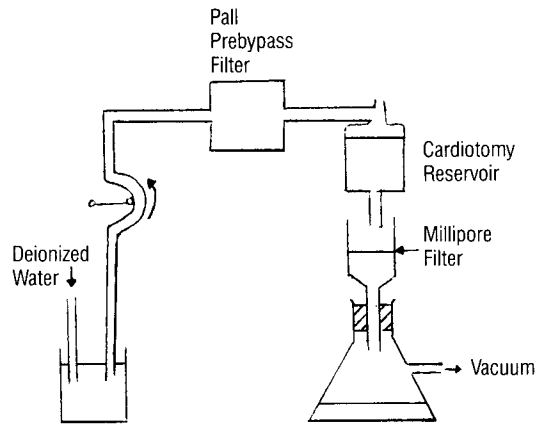

Figure 2: Manufacturer Contaminant Levels Circuit.

Monitor[h]. The circuit was primed with Lactated Ringers solution. The bubble oxygenator was used as a source of bubble free fluid and as a reservoir to allow for changes in circuit volume. A flow of 1L/min of fluid bypassing the CR was first used to obtain a microemboli free circuit which was confirmed by the zero reading on the TM-8 Microbubble Activity Monitor. When this fluid was pumped through the CR a Hoffman clamp was used in the outlet tubing to maintain a level of 100 ml in the CR. Gaseous microemboli counts were taken at the 20 microns and greater level from the TM8 counter. The counts were found to be so low that 2L/min of air was also pumped into the CR at the same time as the 1L/min of fluid. Counts were then taken for ten, one minute sample times for five of each different CR.

The circuit, Figure 2, for the manufacture contaminant levels consisted of a Pall 0.2 micron prebypass filter,[i] PVC tubing and a stainless steel collection jar containing a 0.8 micron Millipore[j] filter. Clean water was obtained by pumping deionized water with a Sarns pump through the Pall filter and testing the filtered water for contaminants by scanning the Millipore filter paper under a light microscope. The microscope had a graduated graticule from which counts were taken in the 10-24 microns, 25-49 microns, 50-100 microns, and greater than 100 microns size ranges. The clean water was found to be free from contaminants. This water was then pumped into a CR to the top of the volume scale. After one minute this water was then slowly released through the Millipore filter. The Millipore filter was then placed in a plastic cover and allowed to dry before counts and photographs were taken. Five of each CR were tested.

The blood hold-up volume circuit consisted of a Sarns pump, PVC tubing and a one liter graduated cylinder. The circuit was primed with human blood diluted to a hematocrit of 35% so as to simulate a normal bypass. The change in volume in the cylinder due to flowing through the CR and bypassing it was recorded at the 2,3 and 4L/minute flow rates for two of each CR.

Results

Table 2 shows the gaseous microemboli counts for the 5 CRs. Analysis of variance by the Scheffe test, at a p value less than 0.01 showed the BST-1 and Intersept were significantly better than the other three and the 5M1471 was significantly worse than the other four.

h Technique Laboratories Ltd., Hants, England
i Pall Biomedical Products, Glen Cove, NY 11542
j Millipore Filters, Medford, MA 01730

Table 2

Gaseous Microemboli Counts/Min Greater than 20 Microns

	Mean	±	1.S.D.	Significant Differences*
BCR3500	44.4	±	12.4	B
INTERSEPT	4.2	±	3.9	A
BST-1	3.2	±	2.7	A
CARDFPLS	40.0	±	36.0	B
5M1471	115.3	±	60.4	C

A flow rate of 1L/min of Lactated Ringer + 2L/min of Air
n=5
*Same letter means no significant difference.
Different letter designates significant difference at p less than 0.01

Table 3

Contamination n=5

Size microns		10-24	25-49	50-100	> 100
5M1471	mean	102.4	46	33.6	64.4
	range	42-206	24-67	20-62	40-117
CARDFPLS		50.6	27.4	23.8	70.8
		19-76	17-34	19-33	39-100
BCR3500		129	40.2	19.8	41.8
		75-199	16-25	7-34	10-80
BST-1		242.4	78.8	57.8	66
		167-308	65-92	40-70	63-85
INTERSEPT		123.2	59.8	70.8	200.8
		79-163	53-72	49-96	138-278

Table 4

Hold-up in ml With Human Blood

Hct=35
Mean of 2
S.D. for each count= ±50ml

Flow rate in Liters/Minute	2	3	4
BCR3500	350	420	590
INTERSEPT	150	210	280
BST-1	330	400	480
CARDFPLS	410	570	630
5M1471	250	360	390

Table 3 shows the particle contamination counts. In each particle contamination range the CRs were compared by pairs using the Least Square Means analysis of variance at a p value less than 0.05. The CARDFPLS and BCR 3500 were significantly better than the BST-1 over the three lower size ranges and the Intersept over the three higher size ranges. The reason for the larger counts at greater than 100 microns than 50-100 microns is that fibers were detected on the Millipore filter and these were all greater than 100 microns in length. Photographs were taken of the larger particles, these showed fibers (Figures 3-6), excess moulding material (Figures 7 and 8), plastic particle (Figure 9), and some antifoam sponge (Figure 10).

The hold-up volume, Table 4, is seen to increase with flow rate. The Intersept CR has the least hold-up over all the flow rates.

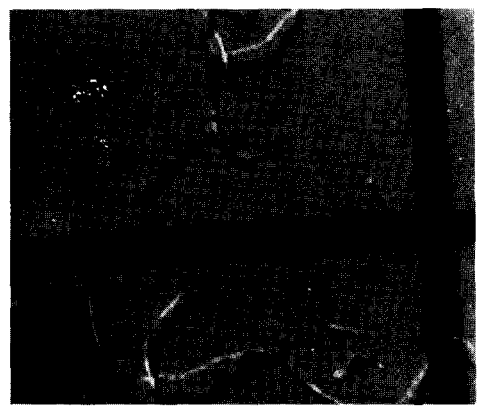

Figure 3: Intersept Magnification X40

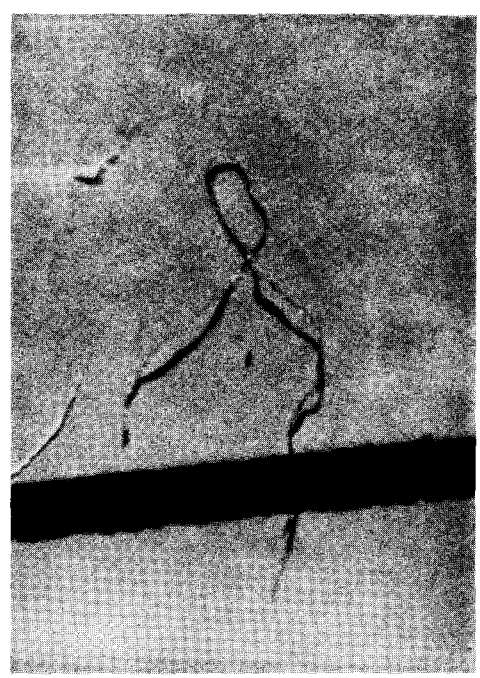

Figure 4: Intersept Magnification X40

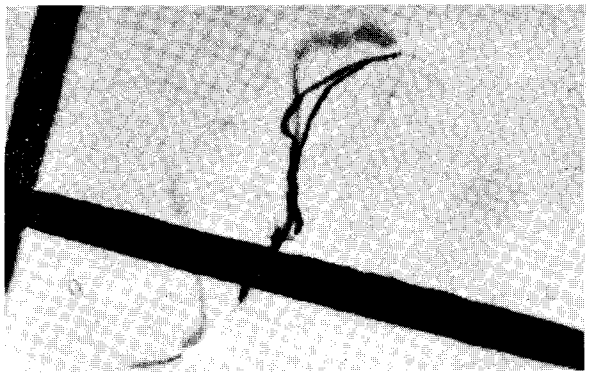

Figure 5: BCR3500 Magnification X40

Figure 6: BCR3500 Magnification X40

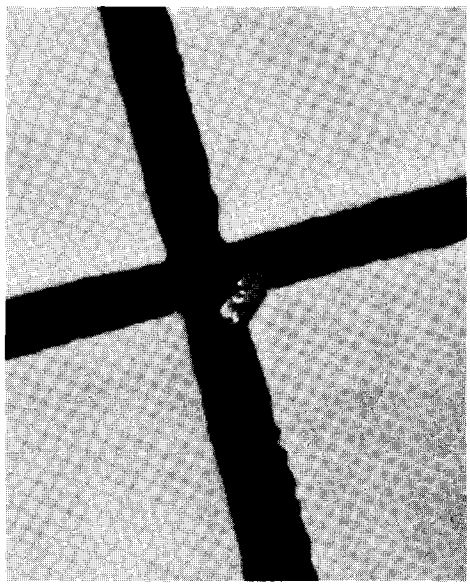

Figure 7: CARDFPLS Magnification X40

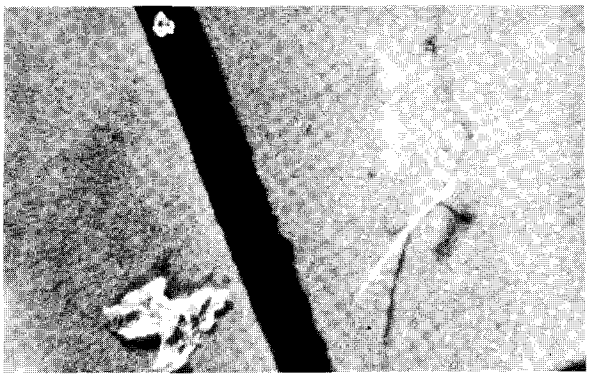

Figure 8: 5M1471 Magnification X40

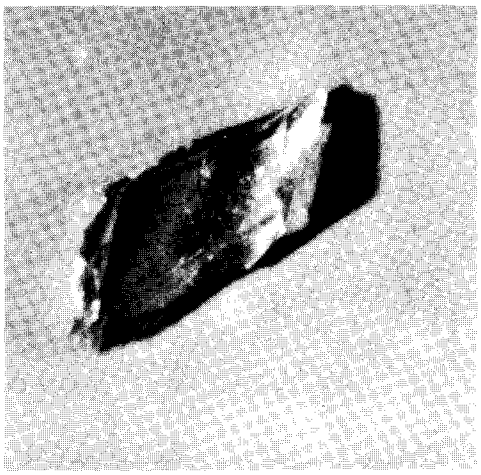

Figure 9: BST-1 Magnification X40

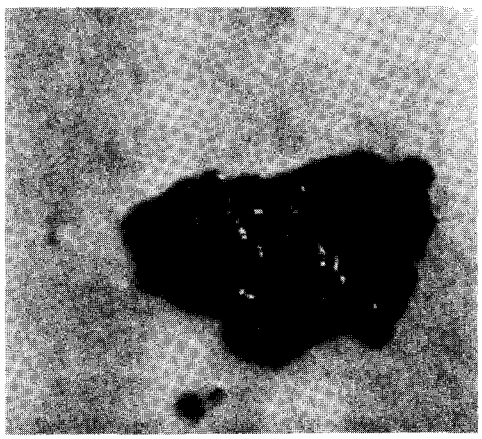

Figure 10: Intersept Magnification X100

Discussion

The reason for studying these CRs was that 20 micron filtered CRs have been shown to be superior for gaseous and particulate microemboli removal compared to other sizes.[1,2,16] There is an increase in arterial line gaseous microemboli counts when the blood from a CR is returned to the oxygenator.[16] The importance of removing these gaseous microemboli is that they are

mostly nitrogen which is relatively insoluble in blood and, as such, is more likely to cause tissue damage.[17]

The various methods of gaseous microemboli detection have been reviewed.[18] While the TM8 Microbubble Activity Monitor is not perfect, a comparison study helps to reduce the errors of gaseous microemboli detection. The first fluid tried in this study was human blood, but the range in the gaseous microemboli production was so large that Lactated Ringers solution was used and repeatable results were obtained.

The large amount of manufacturer particle contamination could be washed from the CR into the oxygenator and hence to the patient. One method of reducing this particulate contamination would be to add the priming solution through the CR, and to recirculate the priming solution through the CR and then recirculate the prime through a prebypass filter. One explanation for detecting 20 micron particles distal to the filter is that the filters are not 100% efficient, also the manufacture may not wash the CR after final assembly. The excess moulding material was identified as such by personal communication with a manufacturer.

There was a large difference in hold-up volume between the different CR. When going on bypass with suction alone or when adding large amounts of donor blood in emergency situations, this blood has to be filtered efficiently and returned to the patient as quickly as possible; consequently, a minimal hold-up volume is advantageous.

Conclusion

The Intersept and BST-1 are the most efficient at gaseous microemboli removal, and the Intersept have the least hold-up volume. The CARDFPLS and BCR3500 have the least manufacturer particulate contamination. Just as the oxygenator and circuit are flushed through a prebypass filter, this study shows the need to include the CR in this prebypass filtration.

Acknowledgment

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