Particulate Removal Efficiency in Arterial Screen Filters

R. J. Massimino, G. T. Stearns, J. D. Gough, R. Dyer, and J. Martin, Jr.
Department of Cardiovascular and Thoracic Surgery
Rhode Island Hospital
Providence, Rhode Island

Abstract

Six types of commercially available arterial screen filters ranging from 20 to 40 microns pore size were evaluated for their efficiency in removing particulate matter. Five filters of each of these six commercial types were tested, for a total of thirty filters.

Three sizes of polystryene microspheres ranging from 25 to 53 microns in diameter were used to simulate particulate contamination. For each determination, approximately 124,000 microspheres were introduced proximal to each filter in a circuit flowing at 6L/min.

An ultrasonic microemboli detector was positioned distal to each filter to monitor the presence of microspheres.

Filtration efficiency ranged from 20.6% to 99.6% with 25 micron spheres, 13.9% to 99.5% with 35 micron spheres, and 94.4% to 99.4% with 53 micron spheres.

Introduction

Microemboli have long been incriminated as a cause of multi-organ dysfunction during and after cardiopulmonary bypass.[1-4] Several sources of emboli can be cited: platelet aggregation induced by contact with foreign surfaces,[5] cellular aggregation and gaseous microemboli generation by bubble oxygenators,[6-9] fat and solid debris from unfiltered cardiotomy suction,[10] particulate matter from disposable devices,[11] etc.

More recently, significant differences in subclinical changes in brain morphology as reflected by computed tomographic scans have been seen when comparing 20 and 40 micron arterial filters during cardiac surgery. Their results suggested that microbubbles and microaggregates of more than 20 microns in size may be responsible for these changes.[12]

These findings indicate strongly that arterial filtration is an essential part of an extracorporeal circuit. There are presently seven commercially available arterial filters ranging from 20–40 microns pore size. This study deals specifically with the comparative efficiencies of commercially available screen filters with respect to particulate emboli removal.

Methods and Materials

Six types of commercially available arterial screen filters were evaluated. These filters were: 1) Bentley AF-10[a]—25 microns; 2) Delta BTF-37[b]—37 microns; 3) Extracorporeal Intersept[c]—

Direct communications to: Ronald J. Massimino, 106 Moorefield St., Providence, RI 02909.

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[a] Bentley Laboratories, Irvine, CA 92714.
[b] Delta Medical, Costa Mesa, CA 92626.
[c] Extracorporeal Medical Specialties, King of Prussia, PA 19406.

20 microns; 4) Pall Ultipor[d]—40 microns; 5) Shiley SAF-20[e]—20 microns; 6) Shiley SAF-40[e]—40 microns.

Five filters of each of these six types were tested (e.g., five Bentley, five Delta, etc.). Unfortunately, we were not able to test the Harvey H-625[f] since it was communicated to us by the manufacturer's representative that they could not provide five filters on a complimentary basis for the purpose of this evaluation.

The test circuit consisted of a Bentley BCR-3500 cardiotomy reservoir,[a] an Extracorporeal Intersept cardiotomy filter and pre-bypass filter,[c] a Travenol compliant reservoir bag,[g] a Cobe Stockert modular pump,[h] a protected calibrated aneroid manometer, and ancillary tubing and connectors (Figure 1).

A Micropure 1100[j] microcontaminant detection system was used to count particles downstream to the filters. The threshold voltage was set to monitor contaminant activity ≥ 20 microns. The methodology for detection and analysis has been previously reported.[13]

Three diameters of polystryene microspheres[i] were used: 25.2 ± 2.1 microns, 35.5 ± 2.5 microns, and 53.8 ± 3.6 microns. A calibrated syringe was used to inject approximately 124,000 microspheres for each test. To determine the reproducibility of counting spheres in the fluid stream, 10 injections of approximately 124,000 spheres of each size microsphere were made with subsequent recording by the Micropure detection system. The average variance from the mean of the 10 injections was 4.3% for the 25 micron spheres, 1.1% for the 35 micron spheres, and 1.2% for the 53 micron spheres.

The five filters of each type were tested consecutively and separately. The circuit was primed with 0.9% normal saline and the filters were primed according to manufacturer's instructions. A flow rate of 6L/min. was maintained for all phases of calibration and testing.

Prior to the testing of a five filter series, baseline counts were obtained by injecting microspheres with the arterial filter bypassed. Three injections of each size microsphere were made and the average used as baseline count. To preclude the possibility of recounting microspheres that had been injected and counted by the detection chamber, a 5 micron pre-bypass filter was utilized to trap the microspheres (See Figure 1). Reliability of this filter had been verified previously by placing a detection chamber downstream.

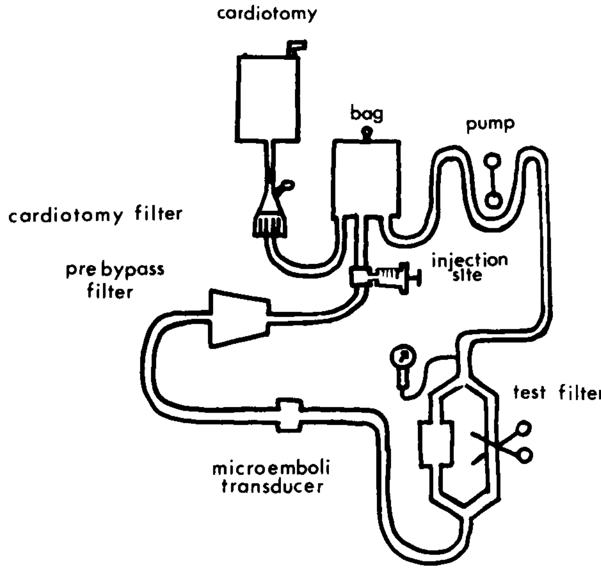

FIGURE 1. Diagram of test circuit for filter evaluations.

All microsphere injections were made proximal to the compliant reservoir bag, thus assuring a more even distribution of microspheres before entering the arterial filter. Simultaneous with the beginning of each injection, monitoring of microspheres began distal to the filter and continued until microspheres were no longer counted. Prior to each microsphere injection, zero activity distal to the arterial filter was verified. Filters were not purged at any time during this evaluation, except for priming and debubbling. Pressure gradients were monitored continuously for each filter.

Four injections of each size microsphere were made and subsequent activity was recorded downstream to the filter. The four microsphere counts were averaged and subtracted from the baseline. This difference was then divided by the baseline count to obtain the percentage of microspheres removed by the filter. Each filter was then ascribed an efficiency rating for each microsphere

[d] Pall Biomedical Products, Glen Cove, NY 11542.
[e] Shiley Laboratories, Irvine, CA 92714.
[f] C. R. Bard, Santa Ana, CA 92705.
[g] Travenol Laboratories, Deerfield, IL 60015.
[h] Cobe Laboratories, Englewood, CO 80215.
[i] 3 M Company, St. Paul, MN 55144
[j] Micropure, Greenville, RI 02828

TABLE 1
Individual and Average Removal Percentages with 25 Micron Spheres

Filter #	Intersept	SAF-20	25 Micron Spheres % Removal AF-10	BTF-37	Ultipor	SAF-40
1	99.5	96.7	76.9	24.4	49.2	27.1
2	99.6	97.6	76.9	28.2	60.2	32.8
3	100.0	95.6	88.4	0.0	74.2	22.5
4	99.7	98.8	78.8	22.9	31.0	46.7
5	99.3	95.7	94.2	27.5	46.1	6.4
Average	99.6 ± .3	96.9 ± 1.0	83.0 ± 8.0	20.6 ± 11.7	52.1 ± 16.2	27.1 ± 14.7

size, which is the percent removal of microspheres during one pass through the filter.

Results

Filter efficiencies with the 25 micron spheres ranged from 20.6% to 99.6% (Table 1). Efficiency with the 35 micron spheres ranged from 13.9% to 99.5% (Table 2). Efficiency with the 53 micron spheres ranged from 94.4% to 99.4% (Table 3).

Overall, the Extracorporeal Intersept was the most effective for the removal of all 3 sizes of microspheres. The least effective for the removal of 53 and 35 micron spheres was the Shiley SAF-40. However, the Delta BTF-37 was the least effective in removing 25 micron spheres.

It was also noted that the Extracorporeal Intersept group had the least deviation from the percent removal average in all size ranges. The greatest amount of variation occurred within the Pall Ultipor group.

Discussion

As expected, efficiency was directly related to filter pore size. Removal rates were higher with the smaller pore sizes for all microspheres. It was interesting to note that the 37–40 micron filters did not approach higher removal rates in the 53 micron size range. One would certainly expect better efficiency since the pore size of these filters was well below the microsphere size.

Questionable results were derived in two of the three micron sizes with the Pall Ultipor.[d] It would appear from the results that the overall efficiency of this filter was better at 25 microns than at 35 microns. Since the filter population studied was small and only four data points were obtained for each size range, a statistical analysis between these two groups would not be reliable. Our impression was that since there was such a large standard deviation in both groups, there may not be any significance to the disparity in results.

As mentioned earlier, polystryene microspheres were used to simulate particulate material. This difference in composition may be a factor in a realistic comparison to circulating particulate emboli in terms of the respective abilities to pass through filter media. However, we feel that the positive advantages, such as uniformity in density and size, qualify them as a reliable substitute.

These results suggest that 20 micron screen fil-

TABLE 2
Individual and Average Removal Percentages with 35 Micron Spheres

Filter #	Intersept	SAF-20	35 Micron Spheres % Removal AF-10	BTF-37	Ultipor	SAF-40
1	99.8	98.7	96.0	54.1	22.8	15.1
2	99.9	98.6	94.3	43.1	24.9	17.4
3	99.6	97.8	95.0	58.9	52.9	10.0
4	98.7	98.5	98.7	59.0	24.6	8.3
5	99.6	99.6	95.6	54.8	18.4	18.5
Average	99.5 ± .48	98.6 ± .64	95.9 ± 1.7	54.0 ± 6.5	28.7 ± 13.8	13.9 ± 4.5

TABLE 3
Individual and Average Removal Percentages with 53 Micron Spheres

Filter #	Intersept	SAF-20	53 Micron Spheres % Removal AF-10	BTF-37	Ultipor	SAF-40
1	99.9	99.1	98.2	98.6	96.3	98.9
2	99.7	99.7	98.9	96.4	96.6	98.4
3	99.7	98.9	97.7	96.6	98.3	96.9
4	99.8	98.2	98.4	96.6	97.9	91.4
5	99.2	97.9	99.2	97.8	98.0	86.2
Average	99.4 ± .4	98.8 ± .7	98.5 ± .6	97.2 ± 1.0	97.4 ± .9	94.4 ± 5.5

tration affords the best protection against particulate contamination.

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