Adhesion of ^{111}Indium-Labeled Platelets to the Defoamers of Two Types of Bentley BOS-10 Oxygenators

A. F. Hope; A. du P. Heyns M.B., Ch.B., D.T.M., H., L. F. Path, S.A., D.M.; M. G. Lötter, Ph.D., J. M. Meyer, M.B. Ch.B., M.Med.

Blood Platelet Research Unit of the
South African Medical Research Council
Medical Faculty, University of the
Orange Free State, Bloemfontein

Abstract

^{111}Indium-labelled autologus blood platelets administered to patients preoperatively can be traced in the components of the extracorporeal circuit by gamma camera scintillation imaging. Quantitative assessments can be made of platelet/biomaterial adhesion.

It was thus possible to compare the ratio of adherent platelets on the defoaming systems of two types of Bentley BOS-10 oxygenators. The results indicated that more platelets adhered to the areas of the defoamer where gas bubbles burst than to areas such as the gaseous micro-emboli inhibitor sponge through which all the bubbles had to pass in the later types of BOS-10 oxygenator. In both types the pattern of platelet adhesion to the defoamer layers was comparable and was not influenced by bypass time. Gamma camera images of the oxygenators showed that most platelet adhesion took place in areas of blood/gas to biomaterial interfaces. Tubing circuits and cannulae displayed negligible ^{111}Indium activity on their surfaces, while the oxygenators held a mean of 8.5% of the activity administered to the patients. This technique could be applied to study platelet interaction with various extracorporeal circuits and oxygenators and may help to clarify the role of cardiopulmonary bypass (CPB) in thrombocytopoenia during heart surgery cases.

Introduction

Damage to the living cellular elements of the blood is ever present in even the most carefully designed and operated CPB equipment.

It is accepted that CPB is associated with a 30–50% decrease in the preoperative blood platelet count. This is due to hemodilution, platelet aggregation induced by heparin and protamine, activation of platelets and consumption of platelets in disseminated intravascular coagulation.[1] The greatest fall in platelet count is usually evident within the first five minutes of CPB.

Autologous platelets labeled with ^{111}Indium oxine^{++}, a 2.8 day half-life radionuclide, emit sufficient gamma radiation to allow quantitative scintographic detection of platelet distribution *in vivo*.[2–4] By exploiting this new technology we have studied the kinetics and sites of sequestration of ^{111}In-labeled platelets during CPB.[5] We could account for 27% of the total of 34% platelets lost in the perioperative period (whole body ^{111}In-radioactivity regarded as 100%). The drained extracorporeal circuit contained a total of

Correspondence: Mr. A. F. Hope, Department of Cardiothoracic Surgery, Faculty of Medicine, University of the Orange Free State, P.O. Box 339, Bloemfontein, 9300, South Africa. Submitted at Amsect's 19th International Conference, March 1981.

†† In-Cloride (Radiochemical Centre, Amersham, U.K.)

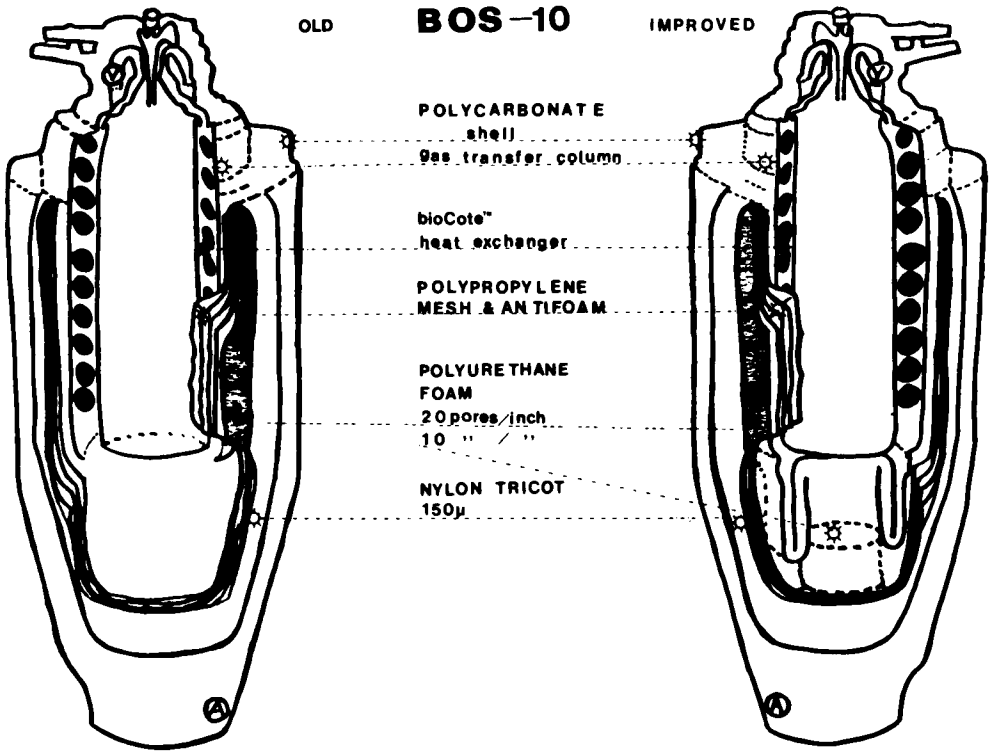

FIGURE 1. Line drawing of oxygenators with a biomaterial list.

11% while the oxygenator alone accounted for sequestration of 9% of the administered radioactive platelets.

We now report on the distribution of labeled platelets in the defoamers of the older model BOS-10 oxygenators compared to that in the improved BOS-10 oxygenators. We also wanted to establish whether the introduction of an expanded gas transfer column and a polyurethane sponge, with 10 pores per inch, in the blood foam flow path of the improved model of the BOS-10 oxygenator alters the platelet adhesion pattern in the defoaming mesh layers in distal blood flow path (Figure I).

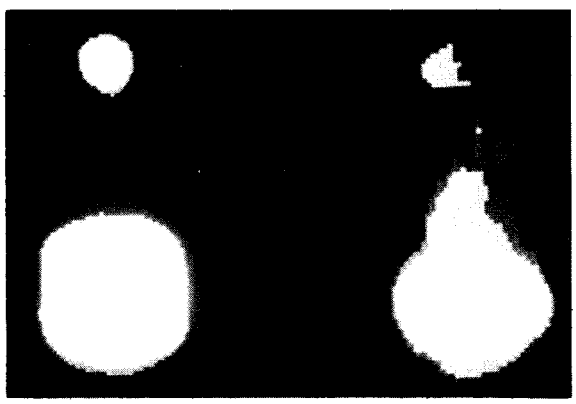

FIGURE 2. Two scintillation images of the upright oxygenators: old (left) and improved (right).

Materials and Methods

All the patients agreed to partake in this study approved by the Ethical Committee of the Provincial Administration and the University of the Orange Free State. All seven patients were white males. Two had surgery for mitral valve repair and replacement and the others had coronary artery bypass surgery. The duration of the CPB ranged from 45 to 167 minutes.

A Sarns Model 5000 pump console was equipped with a custom packed tubing circuit*, a Bentley BOS-10 bubble oxygenator, a Bentley cardiotomy reservoir with a 27 μ cardiotomy filter. The CPB circuit was primed with 2 to 2.5 liters of Plasmalyte B** to which was added 3000 i.u. heparin per liter, 1 g cephalosporin and the autologous red cells remaining from

* Baxter Ltd., Fenwal.
** Bentley Laboratories, Santa Ana, California.

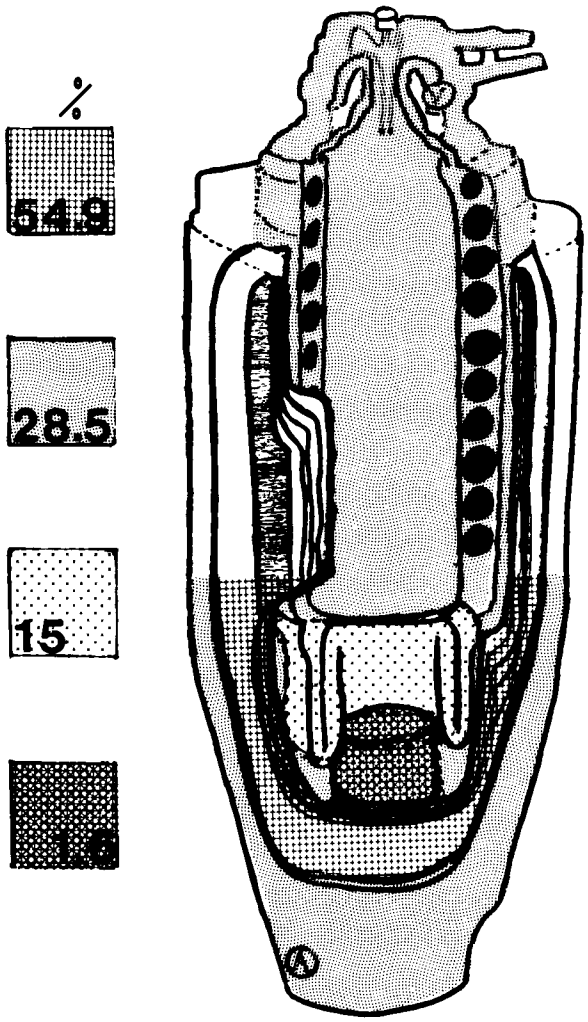

FIGURE 3. ^{111}In-platelet distribution in an improved BOS 10 oxygenator. A profile scan of the individual components is illustrated.

the 450 ml of blood used for the platelet labeling procedure.[6] Blood flow rate during CPB was 2.4 liter per minute per m^2 of body surface area. The latter varied from 1.75 m^2 to 2.1 m^2. Gas-to-blood flow ratios were limited to the minimum consistent with adequate gas exchange and were about 0.8/l. Hypothermia to 28°C was used in all 7 cases. The CPB circuit was drained of blood after bypass, and the individual components were imaged and radioactivity quantitated with a scintillation camera and a profile scanner. In all cases correction for radionuclide decay, radioactive background and divergent radiation was done with a computer. Details of the procedures are given elsewhere.[4,5]

Autologous platelets obtained from 450 ml of the patient's blood were labeled with ^{111}In-oxine and administered about 17 hours prior to surgery. The labelling method has been described elsewhere.[5]

Results

Scintillation camera images of the distribution of labeled platelets in both models of oxygenators were similar. The overall distribution of labeled platelets in an improved model BOS-10 oxygenator is illustrated in Figure III. It is apparent that some platelets adhere to the gas-exchange column, but that the major site of accumulation is on the defoaming mesh/sponge layers in the blood-foam contact areas.

The results obtained in the two types of oxygenators are given in Table I. Radioactivity of the components of the defoamers is expressed relative to the 100% assigned to the complete defoaming system of the oxy-

TABLE I

Percentage Distribution of Adherent In-III Oxine Platelets to the Defoaming System of the Bentley BOS 10 Bubble Oxygenator

	BOS 10				Improved BOS 10 With Expanded Gas Transfer Column and Gaseous Micro-Emboli Inhibitor Plug.				
Layer	Patient 1	Patient 2	Patient 3	Mean	Mean	Patient 4	Patient 5	Patient 6	Patient 7
MI Inhibitor	—	—	—	—	4,35 ± 1,6	6,6	4	4	2,8
A	45	51	47	47,7 ± 3,1	47,6 ± 10,9	32,8	52	47	58,5
B	19	24	25	22,7 ± 5,6	14,9 ± 5,6	7,8	17	21	13,6
C	7	6	7	6,7 ± 0,6	6,1 ± 0,7	6,1	6	7	5,2
D	8	3	4	5 ± 2,7	5,5 ± 1,0	6,3	6	4	5,5
E	7	5	6	6 ± 1,0	7,4 ± 5,0	14,9	5	5	4,5
F	14	11	11	12 ± 1,7	14,3 ± 7,5	15,4	10	12	9,9
Bypass Time (Minutes)	55	105	112			167	45	105	166

genators. The accumulation of ^{111}In-radioactivity in the defoamer layers, designated A to F from the inner to the outer layers, is compared.

Little radioactivity was found in the gaseous micro-emboli inhibitor (M) compared to the two most active inner siliconized polypropylene mesh defoamer layers (A and B). Bypass time did not influence the platelet distribution in the oxygenators.

Discussion

It is evident that the introduction of the expanded gas transfer column and the micro-emboli inhibitor does not markedly influence the adhesion pattern of platelets in the improved Bentley BOS-10 oxygenator defoamers.

Platelet interaction with bio-material is greatly enhanced by the presence of a gas/blood interface.[6-9] Our study indicates that platelets are activated mainly at the site of a blood/gas bubble interface and that some of these activated platelets adhere to bio-materials when contact with the bubble is lost. This occurs in the gas-exchange column where smaller bubbles coalesce near the top of the column. Platelet adhesion also occurs after the blood foam has passed through the microemboli inhibitor when the bubbles burst against the defoamer and outer wall of the gas-exchange column.

This interaction of platelets with bio-materials is important since it may be the cause of the transient qualitative platelet defect demonstrable during bubble oxygenation.[6,10,11] This may be an important cause of postoperative bleeding.

Conclusion

Modifications to the original BOS-10 model oxygenator designed to limit excessive gaseous microemboli and to enhance oxygenation do not alter the pattern of platelet adhesion to the defoamer layers. Bypass time ranging from 45 to 167 minutes did not influence platelet adhesion patterns. The finding that platelets adhere mainly to the coarse inner polypropylene mesh layers and less to the finer 150 μm nylon filter in oxygenators during short and long bypass periods, suggests that there is no significant platelet embolization from these layers.

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