TITLE: ALTERATION OF RED CELL DEFORMABILITY DURING EXTRACORPOREAL BYPASS: MEMBRANE OXYGENATOR VERSUS BUBBLE OXYGENATOR

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Introduction: Red cell deformability - the ability of the red cell to change its form - is an important factor for normal microcirculation. This is because the diameter of the red cell is greater than the calibre of small capillaries. It has been shown that red cell deformability is significantly impaired by extracorporeal bypass with a bubble oxygenator (1). The purpose of this study was to investigate whether or not there was a difference in red cell deformability when using a membrane oxygenator as opposed to a bubble oxygenator during coronary artery bypass graft surgery.

Method: This study was approved by the institutional Human Subjects Committee and an informed consent was obtained. A total of 30 patients participated in this study. The patients received midazolam 4 mg p.o. as a premedication the morning of their surgery. Anesthesia was induced and maintained with a high dose of fentanyl and 100% oxygen. During extracorporeal bypass, either a bubble oxygenator (BOS-10S, Bentley) (B-group) or a hollow fiber membrane oxygenator (CM-5, Bentley) (M-group) was used with non-blood prime in a random fashion. Moderate hypothermia was induced during bypass. Gas flow to blood flow ratio was 1.5:1 for the bubble oxygenator and 1:1 for the membrane oxygenator, respectively. Arterial blood was sampled 5 min before bypass (after heparinization), 5 min after the institution of bypass, every 30 min thereafter during bypass, and at 1 hour after bypass. Measurements were made for gas tensions and pH, hematocrit (Hct) and red cell filtration rate (RFR) as an index of red cell deformability. RFR was measured as follows: from 10 ml of each blood sample a 20% red cell suspension in normal saline was prepared using a standard method. From this 20% suspension 500 µl was allowed to pass by gravity through a 5µm nuclepore polycarbonate filter (Nuclepore Corp., CA) and the time required for this was measured with a stopwatch. This was repeated twice and the values were averaged. RFR µl/sec was then calculated as 500µl divided by time (sec). Those patients who had bypass times longer than 120 min were analyzed. Statistical analysis was made using ANOVA followed by Dunnett's test to compare values between the B-group and M-group, with p value less than 0.05 considered significant.

Results: Eight patients in the B-group (age 61.8±3.8 years, mean ± SE, weight 90.3±4.4 kg) and 14 patients in the M-group (age 61.5±2.2 years, weight 83.9±6.8 kg) experienced bypass time longer than 2 hours. There were no significant differences in age and weight between the two groups. PaO_2, $PaCO_2$ and pH values did not differ from each other in all corresponding measurements (Table 1). Hct was significantly lower at the beginning of bypass in the M-group as compared to the B-group (Table 1). RFR before bypass was 77.9 ± 4.1 µl/sec (mean ± SE) in the B-group and 76.8 ± 3.6 µl/sec in the M-group, respectively. After the start of bypass, RFR (% control) was significantly higher in all measurements in the M-group as compared to the B-group (Fig 1).

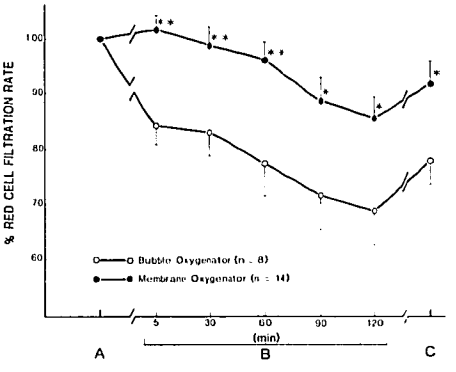
Discussion: RFR is the most widely used method for measuring red cell deformability because of its relative simplicity and reproducibility (2). Hypoxia and acidosis may impair red cell deformability. However, in these groups of patients $Pa0_2$ and pH were all within normal limits, and there were no significant differences between the B-group and the M-group. The lower Hct in the M-group at the beginning of bypass was thought to be due to the larger prime volume that was required for the membrane oxygenator. In the membrane oxygenator there is no direct contact between gas and blood. On the other hand, the bubble oxygenator creates a huge blood-gas interface, which will cause significant blood damage. It is generally believed that the differences between the two types of oxygenators in terms of blood damage is relatively insignificant for short bypass times (<2 hours). This study, however, revealed that RFR became significantly lower in the B-group even shortly after the beginning of bypass. Impaired red cell deformability during bypass may contribute to organ dysfunction, thereby increasing morbidity. In summary, this study shows that the hollow fiber membrane oxygenator is superior to the bubble oxygenator in maintaining red cell deformability during extracorporeal bypass.

Table 1

BUBBLE OXYGENATOR

	before	5'	30'	60'	90'	120'	After
pH	7.43 ± .02	7.51 ± .02	7.48 ± .02	7.47 ± .01	7.49 ± .02	7.48 ± .02	7.39 ± .02
pO_2 (mmHg)	301 ± 41	356 ± 26	397 ± 27	365 ± 27	277 ± 47	289 ± 20	261 ± 47
pCO_2 (mmHg)	35.8 ± 1.5	33.6 ± 1.2	34.3 ± 1.1	34.6 ± 1.4	31.3 ± 2.1	30.8 ± 1.5	38.4 ± 1.4
Hct	37.6 ± 1.6	25.3 ± 1.0	25.7 ± 0.8	25.9 ± 1.1	25.8 ± 1.6	26.0 ± 1.1	27.9 ± 1.5
HOLLOW FIBER MEMBRANE OXYGENATOR							
pH	7.42 ± .01	7.49 ± .01	7.48 ± .01	7.49 ± .02	7.49 ± .02	7.46 ± .03	7.41 ± .02
pO_2 (mmHg)	342 ± 38	408 ± 23	388 ± 48	299 ± 29	241 ± 44	370 ± 63	274 ± 40
pCO_2 (mmHg)	35.3 ± 1.9	31.6 ± 1.5	33.5 ± 1.3	32.1 ± 1.3	30.4 ± 1.5	34.5 ± 3.5	36.1 ± 1.1
Hct	37.4 ± 1.5	21.0 ± 1.0*	21.7 ± 1.0*	24.3 ± 1.1	22.8 ± 2.0	24.5 ± 0.9	29.0 ± 1.4

Fig 1



A: 5 min before bypass; B: during bypass; C: 1 hour after bypass

*p <0.05; **p <0.01 as compared between two groups

References:

1) Hirayama T, et al: Change in red cell deformability associated with anesthesia and cardiopulmonary bypass in open-heart surgery. Scan J Thorac Cardiovasc Surg 19:257-262, 1985.

2) Dormandy JA: Red cell deformability. Eur-Neurol 22: Suppl 1, 23-29, 1983