Transient Hypoxemia Upon Initiation of Cardiopulmonary Bypass

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ABSTRACT

A review of 38 consecutive coronary artery bypass perfusions was undertaken with the goal to determine the efficiency of oxygenation with the BOS-10 oxygenator. In reviewing these 38 cases, six (16%) showed surprisingly low initial arterial oxygen tension (PaO_2 56–70 torr). These six patients required active remedial measures to correct this deficit which was corrected within 10 minutes of continued perfusion. In addition, there were five more patients (13%) with initial PaO_2 70–100 torr, or a total of eleven (29%) of the 38 cases with less than optimal PaO_2. All of the initial blood gases were drawn after stabilization of perfusion flows and pressures, discontinuation of patient ventilation, and the initiation of moderate hypothermia (30°C). No explanation could be found for this transient hypoxemia which appeared to correlate only with a higher hematocrit in patients with the lowest oxygen tensions.

It has been observed that, on occasion, an unacceptably low arterial oxygen tension (PaO_2) develops during the initial phase of routine perfusion. This observation prompted a review of the last 38 consecutive coronary artery bypass perfusions done in this institution. The review has shown that eleven (28.9%) of the cases done with the BOS-10* oxygenator had PaO_2's less than 100 torr. An attempt was therefore made to delineate the factors involved and to try to isolate the problem. Realizing fully that at a PaO_2 of 70 torr, the hemoglobin is still well saturated, and probably is not detrimental to the anesthetized patient, six patients (16%) had truly depressed oxygenation with PaO_2 56–70 torr and in these six patients, arterial desaturation could become a factor in successful perfusion.

METHODS

The BOS-10 oxygenator was used in all 38 consecutive coronary bypass patients, in series with a Sarns** roller pump. The oxygenating gas composition is regulated by a manifold arrangement of 100% oxygen and 100% carbon dioxide, allowing versatility in composition from 100% O_2 to 12% CO_2, 88% O_2. Hypothermia is maintained by a Sarns** Dual Cooler/Heater, and all blood gas determinations are done on an IL213 Blood Gas Analyzer.***

The perfusion was initiated slowly with a calculated blood flow of 2.0–2.25L/min/m^2B.S.A. and a gas flow twice that of the blood flow, thus achieving a Q gas:Q blood ratio of 2:1. The prime is asanguineous, consisting of Plasmalyte-148**** with a pH of

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* Bentley Labs, Irvine, California.
** Sarns, Inc., Ann Arbor, Michigan.
*** Instrumentation Labs, Lexington, Massachusetts.
**** Travenol Labs, Deerfield, Illinois.

7.4 and 12.5 grams of human serum albumin. Stabilization of blood flow rates and arterial pressures was achieved 2 to 3 minutes into the perfusion. At this point in time, the patient is on total bypass and ventilation by the anesthesiologist is stopped. Moderate hypothermia of 30°C perfusion temperature is immediately employed when commencing bypass. Five minutes after stabilization, or eight minutes into the perfusion, the initial PaO_2 is routinely drawn, unless indicated earlier by very dark arterial blood. The initial blood sample with temperature correction is analyzed for PaO_2, $PaCO_2$, pH and hematocrit and the results are returned to the perfusionist. The necessary adjustments in blood gas parameters are then made by the perfusionist.

In the presence of relative arterial hypoxemia ($PaO_2 < 100$ torr), the perfusionist increases the gas:blood flow ratio (from 2:1 to 3:1) and increases blood flow to potentially improve tissue oxygenation. The anesthesiologist initiates ventilation and further operative manipulation is delayed until oxygenation improves. Such improvement has occurred in each case within 10 minutes of initiating perfusion.

RESULTS

The patient population of 38 perfusions was divided into three groups according to their initial PaO_2. Group I, consisting of 27 patients (71%) had initial PaO_2 of 100 torr. The five patients (13%) comprising Group II had initial PaO_2 70–100 torr, and Group III contained the six patients (16%) with initial PaO_2 56–70 torr. All statistical evaluations were conducted using Student's "t" test. Table 1 displays the mean values and standard errors of all measured parameters.

As can be noted in Table 1, there is no significant difference between groups with respect to pump index, $PaCO_2$, pH, gas and blood flows. However, there is a significant difference between these groups with respect to PaO_2 and hematocrit. As regards PaO_2, Groups II and III are significantly lower than Group I. As regards mean hematocrit, Group III is significantly different from Groups I and II. The mean hematocrit of Group I is not significantly different from that of Group II. Thus 16% of patients (Group III) had both the lowest PaO_2 and the highest hematocrit.

Table 1: Comparing the Average Values of the Measured Parameters in the Three Groups Studied

	N	Pump Index*	Qg:Qb**	PaO_2	$PaCO_2$	pH	HCT
Group I	27	2.2 ±.03	1.96 ±.01	200.6 ±10.8	31.3 ±1.1	7.49 ±.01	26 ±.63
Group II	5	1.99 ±.36	2.09 ±.16	91.9*** ±3.1	30.26 ±2.9	7.49 ±.03	26.8 ±1.8
Group III	6	1.90 ±.01	1.965 ±.04	61.6*** ±2.9	33.78 ±1.68	7.44 ±.03	31.3*** ±.87

* Pump Index = Total Blood Flow/B.S.A.
** Qg:Qb = gas to blood flow ratio
*** $p < .01$ when compared to Group I

DISCUSSION

It has long been accepted practice that a blood flow of 2.25 liters per minute per square meter of body surface area (Pump Index) is an adequate perfusion rate for total bypass.[1,2] In our perfusion protocol, an index of 2.2 is a goal, not an "iron clad" limit. Once this range is reached, other parameters such as mean arterial pressure, central venous pressure and body temperature will influence the optimal perfusion rate. During this initiation of bypass, the O_2 is set at the pre-determined value of 2.0 liters of gas × suspected blood flow (2.2 liters/min/m^2), which results in a Qgas:Qblood of 2:1 as a mean. In association with this, it has been our observation that most patients will show a deficit in $PaCO_2$ if not corrected, so initially a flow of 150 cc/min of CO_2 is mixed in. This typically results in about a 1.5% admixture of CO_2 to O_2 and quite predictably gives us physiologically good $PaCO_2$ values.

It has been suggested that a delay in handling blood samples may be responsible for artificially low PaO_2's. However, as the blood gases are performed immediately on the premises, it has been quite easy to dispel this thought. The mean PaO_2 prior to bypass for these 38 patients was 156 ± 28 with a range from 128 to 184 torr, and therefore the patients have not been desaturated prior to operation. This high incidence of relative arterial hypoxemia must be related in some way to the oxygenator system (the BOS-10) we are employing, but we have been unable to find any published discussion of the problem and continue to see it periodically appear. The higher hematocrit in Group III patients may contribute to poorer oxygenation in this group, but why this is so cannot be answered by the company manufacturing the oxygenator. The fact is the problem has been resolved by corrective measures after about 10 minutes of continued perfusion.

CONCLUSION

Thirty-eight consecutive coronary revascularization cases operated on at the Baystate Medical Center have all been supported with the BOS-10 oxygenator, with essentially good performance characteristics. However, in our experience we have seen 29% of these units that, at least initially, did not perform as expected.

In all of these eleven patients with $PaO_2 < 100$ torr, none suffered any detrimental effects due to transient hypoxemia. Immediate measures to increase the arterial PaO_2 corrected the hypoxemia within 10 minutes as confirmed by blood gases.

What this is due to has not been revealed by this study. The only parameter measured which correlated with the lowest oxygen tensions was the hematocrit which was higher in patients with the lowest PaO_2. It is sincerely hoped that others using this oxygenator, or perhaps a different one, will comment on this subject in future publications.

REFERENCES

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