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## Hypoxemia during Cardiopulmonary Bypass

BARRY F. BASS, M.B., CH.B. (CAPE TOWN)\*

The commercial disposable bubble oxygenator for open-heart surgery has found wide application since its introduction in 1957.<sup>1</sup>

In 1966, DeWalt *et al.*<sup>2</sup> introduced the Temptrol † disposable blood oxygenator, which has been routinely used for all patients undergoing open-heart surgery during the past 18 months in this hospital. It has provided full oxygenation during cardiopulmonary bypass, elimination of carbon dioxide without destruction of blood elements, and the capacity for lowering or raising blood temperature in minimal time.

During January 1971, three patients undergoing open-heart surgery developed noticeable hypoxemia while on bypass. The most recent case is described below.

## REPORT OF A CASE

A 62-year-old man weighing 83 kg was scheduled for myocardial revascularization by saphenous vein bypass graft of the right posterior coronary artery. He had angina which had been steadily increasing in severity for 13 years.

Premedication consisted of morphine, 9 mg, and atropine, 0.5 mg. Induction of anesthesia with thiopental, 150 mg, and succinylcholine, 100 mg, to facilitate intubation was uneventful. Anesthesia was maintained with nitrous oxide and oxygen in a 50 per cent mixture. Morphine and *d*-tubocurarine were given in increments as needed. Electrocardiogram, central venous pressure, arterial pressure, blood gases, rectal and esophageal temperatures, serum electrolytes and urinary output were continually monitored.

Cannulation and the proximal vein-to-aorta anastomosis proceeded smoothly. The patient was then placed on cardiopulmonary bypass for the distal anastomosis. A Sarns console with the Temptrol disposable blood oxygenator was used. Venous return, after going onto total bypass, was good, and a flow rate of 60 ml/kg (4,980 ml/

\* Assistant Professor, Department of Anesthesiology, University of Texas Medical School at San Antonio, San Antonio, Texas.

† Bentley Laboratories, Santa Ana, California.

TABLE 1. Blood Gases during Surgery for Coronary Revascularization with Total Cardiopulmonary Bypass Using the Temptrol Disposable Bubble Oxygenator

	F <sub>I</sub> O <sub>2</sub> %	P <sub>a</sub> CO <sub>2</sub> torr	P <sub>a</sub> O <sub>2</sub> torr	pH	Base Excess
Postintubation	0.5	34	235	7.40	-3
Chest open	0.5	31	151	7.40	-5
Aorta-to-graft anastomosis	0.5	17	144	7.56	-5
On bypass	0.97	32	54	7.38	-5
	0.97	38	59	7.35	-4
	0.97	36	28	7.35	-4
	0.97	36	45	7.37	-4
Partial bypass	0.97	38	247	7.31	-7
Chest closed	0.5	36	186	7.36	-4
Recovery Room on Emerson ventilator	0.94	39	252	7.36	-3

min) was maintained. Oxygen, 97 per cent, and carbon dioxide, 3 per cent, were passed through the oxygenator at a flow of 15 l/min. It was noticed that blood in the arterial line was dark in color. A sample of arterial blood was immediately drawn for gas analysis.

The patient was cooled to 29 C and the flow of 60 ml/kg kept constant. Blood gases were drawn every ten minutes while the patient was on bypass (table 1). Persistent hypoxemia was noted. During this period the pupils remained constricted, urinary output was copious, but marked hemoglobinuria was observed. Sodium bicarbonate, 200 mEq, and Mannitol, 200 g, were given over a period of two hours to facilitate excretion of free hemoglobin. Bypass lasted an hour and 21 minutes. The patient was rewarmed to a rectal temperature of 37 C and taken off total bypass. The heart took over satisfactorily, and perfusion was discontinued. The patient did well postoperatively and showed no signs of any cerebral damage. The hemoglobinuria gradually decreased over three days. The patient was discharged from the hospital two weeks postoperatively.

After the operation the oxygenator was disassembled and the filter found to be free of any debris or mechanical defect. The Carbogen tank was checked for accuracy with a Beckman oxygen analyzer.

#### DISCUSSION

The Temptrol disposable bubble oxygenator has been well described elsewhere.<sup>2</sup> The oxygen flow necessary to obtain good oxygenation has been in the range of 2 to 5 l/1,000 ml blood, depending on blood gases and visual monitoring of the arterial line. A recent survey of 150 patients during use of the Temptrol oxygenator has shown it to have good oxy-

genating efficiency and minimal priming volumes, and to cause little damage to blood elements by the fine nylon filters (tricot fabric), which have a pore size between 1/24 and 1/32 per mm.<sup>3</sup>

Kessler *et al.*<sup>4</sup> recently stressed the danger in the formation of bubble microemboli, when the rate of oxygen flow is excessive in ratio to blood flow. In this respect there exist the possibility of mechanical failure of the oxygenator, and the dangers of excessive destruction of blood elements<sup>5</sup> and microemboli outflow, with the hazard of cerebral damage.<sup>6</sup>

In the case described, no evident gross cause for the poor oxygenation could be identified. Flows to the patient and venous return were good. Tissue perfusion, as judged by urinary output and the absence of severe metabolic acidosis during and after bypass, was adequate. Microscopic examination of the oxygenator filter, unfortunately, was not done.

Since this incident, several Temptrol oxygenators with the same lot number as the three oxygenators that malfunctioned have been used, with no further episodes of hypoxemia. Filters from three oxygenators have been subjected to microscopic examination for excessive collection of debris, and stained for fibrin. No evidence of excessive fibrin collection has been found.

We feel that the main cause of the hypoxia during cardiopulmonary bypass was an intrinsic defect in the bubble oxygenator.

This defect in the oxygen diffuser has been recognized by Bentley Laboratories, which instituted diffuser inspection by an optical comparator of all adult oxygenators (Q-100) from lots 254 to 276 (serial 37878 to 42803).<sup>7</sup> The oxygenators have also been spectrophotometrically examined, and no evidence of contamination by foreign materials, other than a small amount of polyvinyl chloride (since eliminated from the manufacturing process) was found.<sup>8</sup> This material in small amounts cannot account for the hypoxemia. The manufacturer has recalled all oxygenators in the suspect lots.

Shortly before the presently-reported incidents, Bentley Laboratories, Inc., had modified the design of the oxygen dispersion cone. It is conceivable, though there is no evidence for this, that this change, coupled with unusual operational factors, including mismatched perfusion rate and oxygen flow rate, could result in reduced oxygenation such as apparently occurred in fewer than 1 per cent of more than 8,000 cases in which Temptrol was used during the past two to three months.<sup>8</sup> Bentley Laboratories, Inc., has reverted to the previous design of the dispersion cone, which

has proved to be of excellent quality in more than 30,000 cases in which the Temptrol oxygenator has been used.<sup>8</sup>

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#### Paraphernalia

**MOBILE INTENSIVE CARE** Medical emergencies result in 700,000 deaths annually. Some deaths could be prevented if communities improved their response systems. Improvements should include better communication, instruction of the public in resuscitation, training of ambulance personnel, and well designed and equipped ambulances. Facilities for intensive life support during transit should be provided in ambulances. Their design should permit physicians and attendants to carry out resuscitation procedures. Ambulance design and equipment are discussed in detail, and reference is made to recent national recommendations on the subject. Proper planning and the addition of portable equipment convert an ambulance into a Mobile Intensive Care Unit. (Safar, P., Esposito, G., and Benson, D. M.: *Ambulance Design and Equipment for Mobile Intensive Care*, *Arch. Surg.* 102: 163-171 (Mar.) 1971.)