A TOROIDAL FLOW MEMBRANE OXYGENATOR: FOUR DAY PARTIAL BYPASS IN DOGS

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A MEMBRANE OXYGENATOR has been developed in which gas transfer is augmented by convective mixing produced in torsionally oscillating toroidal membrane chambers (tubular dimethyl silicone rubber, 0.25 inch diameter, 5 mil wall). Gas transfer rates with blood of 200 cc. $O_2/m^2/min.$ and 100 cc. $CO_2/m^2/min.$ were obtained *in vitro* (1) and in dogs (2). Following these early experiments, tests were undertaken to study the feasibility of extracorporeal oxygenation with this system for periods of 2 to 5 days in unanesthetized dogs.

METHODS AND RESULTS

The purpose of this phase of the study was to detect any physiologic or hematologic changes produced by an apparatus which had already been proven to be an effective oxygenator. Prolonged bypass, without gas transfer, through a heavy walled (60 mils), but otherwise similar, system of toroidal chambers was studied with awake, air breathing dogs. In the first series the dogs were maintained on femoral arteriovenous bypass for periods ranging from 8 hr. to 5 days at flow rates of 500 to 700 ml./min. The bypass circuit included only the oxygenator system and an electromagnetic flowmeter in the return line. Heparin was continuously infused at 0.2 to 0.3 mg./kg./hr. to maintain the clotting time at 20 to 30 min. Ampicillin was given prophylactically, and intravenous diazepam (vallium) and pentobarbital were given occasionally for light sedation. The dogs were allowed to move about, eat, and drink as desired. No blood was administered. After bypass was discontinued, the dogs were observed until killing one week later.

Periods of up to 5 days of partial arteriovenous bypass were well tolerated. Daily analyses showed no significant changes in plasma hemoglobin value, white blood cells, platelets, blood urea nitrogen, lactate, hematocrit level, or blood gases. Blood pressure, pulse, respiratory rate, temperature, and neurologic status were similarly stable. Postmortem gross and microscopic examination showed occasional small pulmonary emboli.

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A venovenous bypass circuit without reservoirs was devised, which allowed high flows to be maintained in the conscious dog. Venous blood was drained from the inferior vena cava through a femoral cannula, to the roller pump, which was controlled by a pressure cut-off switch in the suction line. From the pump the blood flowed through the oxygenator and the electromagnetic flowmeter and was returned to the dog via the jugular vein. To assure an adequate supply of blood a partially occlusive balloon was placed in the inferior vena cava above the diaphragm, diverting venous blood from the splanchnic and renal circulations to the femoral cannula; inferior vena cava pressure was continuously monitored. Flows of 800 to 1000 ml./min. were maintained in dogs weighing 20 kg. for up to 8 hr. with stable hemodynamics and blood gases and with plasma hemoglobin levels under 15 mg.%.

DISCUSSION

Prolonged partial bypass of flows adequate to support respiration (3) through an oscillating toroidal flow oxygenator of proven gas transfer capacity can be regularly achieved without significant deleterious effects on normal dogs.

With this oxygenator a heparin dose of 0.2 to 0.3 mg./kg./hr. was sufficient to prevent clotting without causing bleeding. This represents one-fifth to one-tenth the heparin requirements reported for other membrane oxygenators.

The next phase of this work is investigation of the effects of prolonged partial bypass with oxygenation in hypoxic dogs.

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