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9-4 A HIGH SHEAR STRESS ANNULAR MEMBRANE OXYGENATOR WITH TANGENTIAL FLOW

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PROBLEM. All present membrane oxygenators may be divided into two types: a) oxygenators with laminar blood flow, b) oxygenators with secondary flows. The oxygenators with laminar flow are limited to gas transfer rates of 20 - 30 $ccO_2/min/m^2$ membrane because of the diffusion of the gases in the blood layers.
Some increase in transfer can be accomplished by recirculation of the blood. In oxygenators with secondary flows the gas exchange can be enhanced up to the limits of permeability of 40μ thick silicone membranes. Bartlett and Drinker have shown that secondary flows can be achieved by oscilatory motion of a cylinder on which membrane tubes are wound. By introducing high shear rates in the thin blood layer of a Couette Oxygenator, Overcash and Keller demonstrated that cell rotation leads to augmentation of gas exchange. We have developed an oxygenator which combines cell rotation with recirculation (fig. 1.)

METHOD. Two membrane sheets with a total surface area of 0.03 m^2 are mounted over a smooth horizontal cylinder. Blood streams circumferentially in thin layers between the membranes and the cylinder surface. The turning cylinder introduces shear rates in the blood layers, which in turn determine the hydro-dynamic stability of film and membrane position. We were able to reach velocities of 1 m/sec at layerthicknesses between 50 and 300μ (this corresponds to average shear rates of $0.3*10^4$ - $2*10^4$/sec.). At the top and bottom of the cylinder is a strong mixing of the blood. Recirculation is introduced (fig. 1) by the layer moving upwards. The net flow through the oxygenator is determined by means of a rollerpump. A discoxygenator was used as deoxygenator through which a gasmixture of 95 % N_2 and 5 % CO_2 is blown. With the membrane lung a gasmixture of 95 % O_2 and 5 % CO_2 is used. The oxygen saturation of the blood before and after the membrane lung is continuously measured with a Philips Hb-Oximeter. At several fixed net flow rates the saturation increase in the oxygenator is measured as a function of the cylinder rotation rate. Typical results are shown in fig. 2.

DISCUSSION. The data presented indicates that enhancement of the O_2 - transfer can be realized by increasing the speed of the cylinder. Values of 120 $ccO_2/min/m^2$ have been reached. This value is a factor of 5 greater than that of commercial membrane oxygenators operating under comparable conditions. It is not clear as yet how much of the enhancement is accomplished by cell rotation, by recirculation of the blood or by thinning of the blood layers. We note here that the max. capacity of the membrane used is approximately 272 $ccO_2/min/m^2/atm.$ which implies that almost 50 % of the pO_2 difference between the gas atmosphere and the blood is needed for transfer of O_2 through the membranes. In the device presented here only one side of the blood layer has contact with membrane.

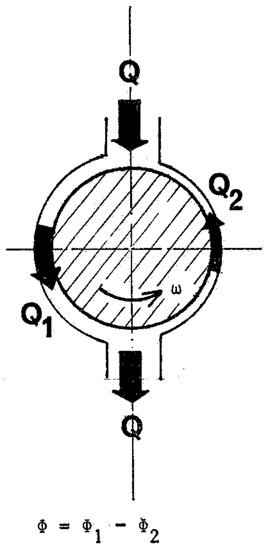

Fig.1
Schematic of the oxygenator

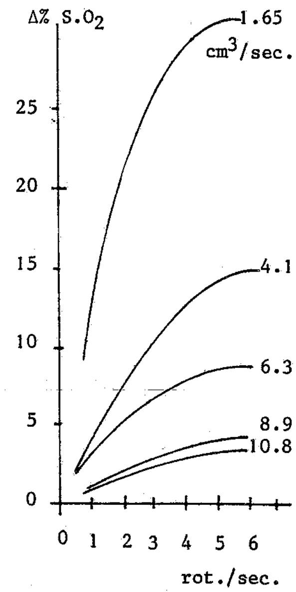

Fig.2
Saturation increase across the oxygenator versus cylinder rotation rate

Thus the efficiency can be increased by using better membranes and inserting a membrane on the cylinder. Using this concept we believe that it may be possible to construct a membrane oxygenator for total bypass with a membrane area of less than 1 square meter.

References:
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