Prolonged Extracorporeal Circulation for Respiratory Support

by

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INTRODUCTION

Many cases have now been managed to demonstrate that prolonged extracorporeal oxygenation by means of a membrane oxygenator for acute respiratory insufficiency is now clinically possible. [1,2,3,4,5].

The successful treatment of a patient by prolonged extracorporeal oxygenation is discussed.

THE PATIENT

A grossly obese woman (105 kg) aged 26 years was admitted to this hospital following an appendectomy five days before.

Admission was due to what was diagnosed as a massive pulmonary embolism. On admission she had a PaO_2 of 29 with a PCO_2 29 and a pH of 7.52.

Maximum ventilatory support was undertaken along with conventional therapy. Over the next 12 hours she deteriorated further. Her PaO_2 which had risen to 70 began to fall again to 30 mmHg.

It was then felt that she probably had a staphylococcal pneumonia secondary to a viral infection.

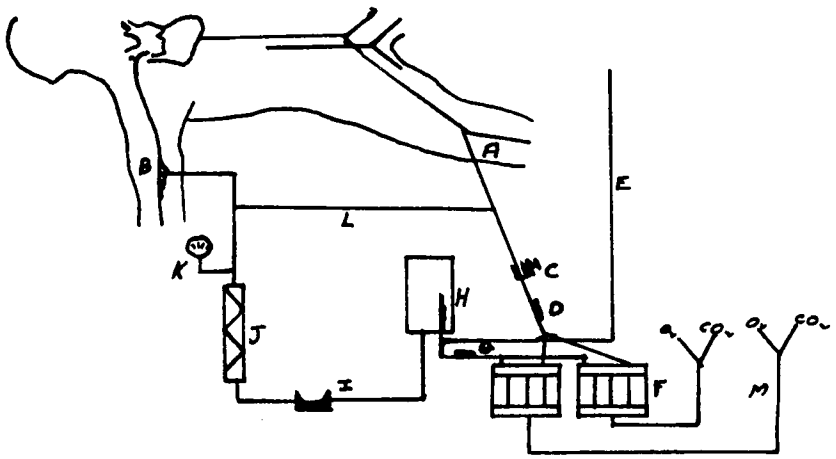
Eventually despite 100% oxygen in the inspired gases and a positive and inspired pressure of 10 cm of water the PO_2 reached 46 mmHg.

It was obvious clinically that the patient was not responding to treatment and as it was considered that death was likely within a few hours a decision was made to place the patient on a membrane oxygenator.

THE EXTRACORPOREAL CIRCUIT

The perfusion circuit was similar to that first described by Baffes and later modified by Carlson for open heart surgery.

Tubing throughout the circuit was P.V.C. except for the pump segment which was ⅛" walled silicone rubber. Venous blood from the bifurcated cannulation of the femoral vein was introduced by gravity to two 3M Lande Edwards membrane oxygenators, placed in parallel near floor level. A 750 ml. plastic disposable reservoir was placed approximately 20 cms. above the membranes and approximately 50 cms. below the patient to receive oxygenated blood from the oxygenators. Oxygenated blood from the reservoir was pumped with a Pemco roller pump.



The Perfusion Circuit

A. Venous cannulation.
B. Arterial cannulation.
C. Laboratory gate clamp.
D. Venous sampling.
E. Priming line.
F. Lande'-Edwards oxygenator.
G. Arterial sample.
H. Reservoir bag.
I. Roller pump.
J. Heat exchanger.
K. Pressure gauge.
L. Recirculation line.
M. Divided O_2 and CO_2 lines.

A Sarns torpedo type heat exchanger to the patient's bifurcated cannulation of the axillary artery was used. Priming and fluid replacement was directly into the reservoir bag. Sample points were placed in the venous line and between the oxygenators and reservoir bag for venous and arterial blood samples. Simple gate clamps were placed on the venous line and on the bifurcated arterial line to the distally cannulated axillary artery.

Illustrated in Figure 2 is the pump-membrane unit as used.

TECHNIQUE OF CANNULATION

The right axillary artery was exposed under local anaesthesia and a metal cannula of 6 mm. was introduced.

A Y-connector was used to divert part of the oxygenated blood into the distal right arm by another metal cannula of 3 mm., the flow of blood being controlled by a simple gate clamp.

The right femoral vein was cannulated with a 36 french gauge Argyle cannula which was positioned as close to the right atrium as possible.

A second Y-connector was used to receive blood from the distal femoral vein, venous return being by gravity.

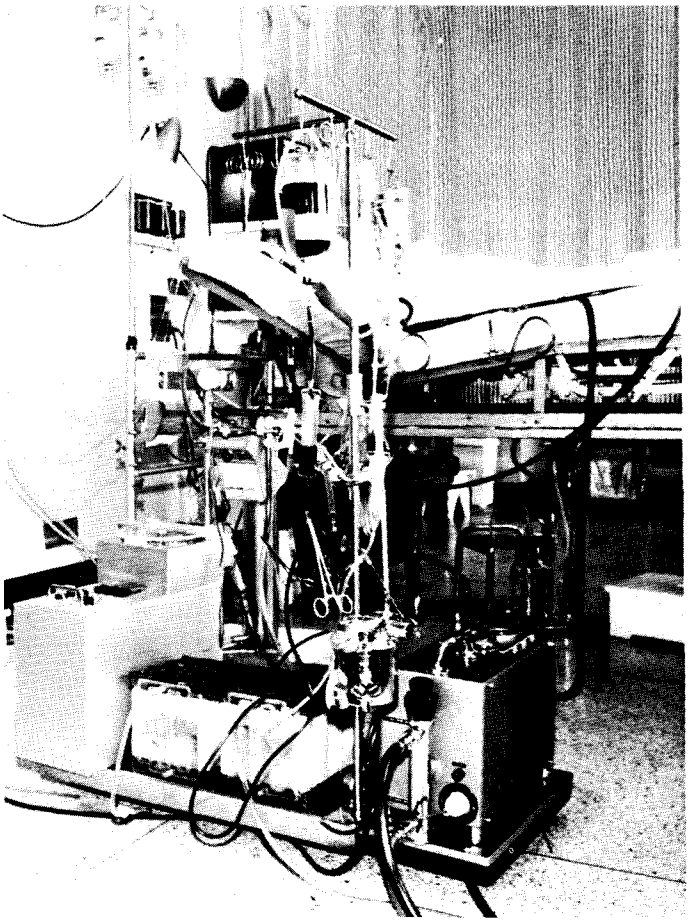
MANAGEMENT OF THE PERFUSION

An arterial blood flow of 2.5 - 3.0 litres per min. produced a PaO_2 of 50 mmHg in comparison with a PO_2 of 105 mmHg to 150 mmHg in the blood leaving the oxygenator. Throughout the perfusion this flow produced a normal blood pressure.

The left radial artery was cannulated percutaneously for monitoring and was also used as a source of arterial blood sampling. Right atrial pressure was obtained via a right subclavian catheter.

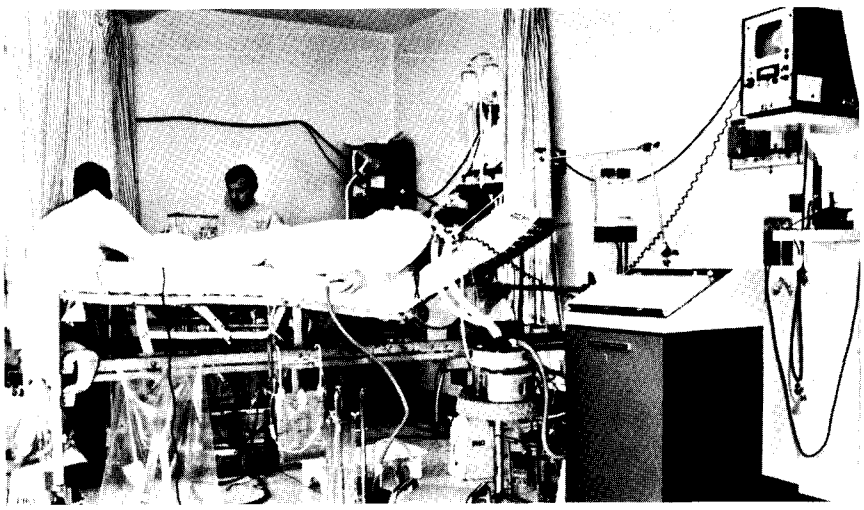
Both atrial pressures were kept at near normal values by the use of a simple gate clamp across the venous drainage line.

As the procedure was carried out in an intensive care room a system of venous drainage by gravity was used in an effort to simplify the technique. This necessitated the patient's bed being raised from the floor by 12" blocks.



The pump-membrane system

Elevation of the Bed



This system provided a totally adequate venous drainage throughout the entire perfusion.

Humidified oxygen was independently supplied to each membrane oxygenator at the rate of 6 litres per min. to each membrane, CO_2 was added to the gas flow as indicated by blood-gas determinations.

At one hour intervals the total blood flow was passed through each membrane separately for a period of 3 minutes to prevent the establishment of selective blood pathways.

The arterial blood reservoir used was the Edwards Laboratories reservoir of 750 ml capacity. A reservoir level was predetermined and transfusions were given directly into the reservoir to maintain a stable circulation volume.

Respiratory Support

During the course of the perfusion whole blood or electrolyte solutions with potassium chloride supplements were added as required, the haematocrit being kept at approximately 30%. The maintenance of the circulating volume was complicated by a consistent blood loss due to a persistent oozing from the site of cannulation. At the completion of the 93 hour perfusion a total of 60 units of whole blood and 23 litres of plasmalyte (Travenol) had been used.

The patient was heparinised initially with 20,000 units and continuous heparinisation of 30 units per kilogram per hour was delivered through a constant infusion pump. A malfunction of this pump forced a change to intermittent heparinisation depending on the clotting time which was performed at hourly intervals.[6]

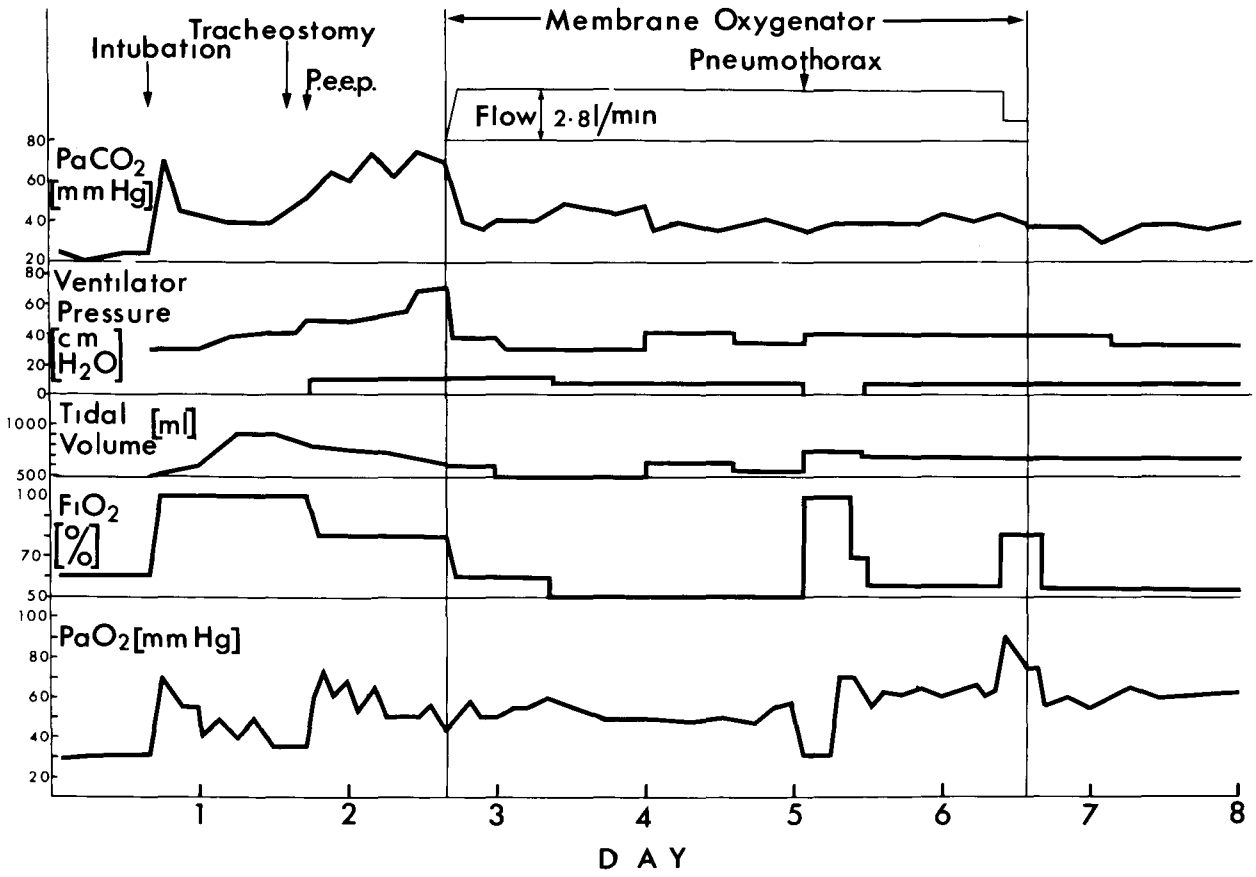
A Sarns heat exchanger was used throughout to maintain a constant temperature of 37° C.

Arterial line pressure was monitored at all times as the periodic restlessness of the patient could have endangered the positioning of the arterial cannulae.

RESPIRATORY COURSE

Following the institution of partial supportive bypasss it was found that the PO_2 in the blood leaving the oxygenator varied between 105 to 150 mmHg.

Over the course of the first 20 hours of perfusion it was possible to maintain an arterial PO_2 in the patient's radial artery of approximately 50 mmHg while at the same time reducing the inhaled oxygen concentration from 100% to 50% while reducing the positive end expiratory pressure from 10 to 5 cm. of water, with a peak ventilator setting of approximately 35 cm. of water which represented a reduction from 70 cm. of water.



The respiratory course

The PCO_2 was varying in the range from 40-50 mmHg.

After two days of bypass during which her state remained steady there was a fairly rapid deterioration in which her PO_2 fell. This fall was found to be associated with a left sided pneumothorax.

Following drainage of the pleural cavity the patient again began to improve. By the fourth day it was possible to achieve a PO_2 of 88 mmHg when the inspired concentration was increased to 80% for short periods.

The inflationary pressure was now 30 cm of water with a P.E.E.P. of 8 cm. of water; at 93 hours of bypass the pump was stopped and the patient was ventilated with 80% oxygen.

Initially the arterial PO_2 was 60 mmHg but this rose rapidly over the next hour to 75 mmHg, then declined over the next hours to approximately 55 mmHg.

Over the next three days it was possible to reduce the inspired concentration of oxygen maintaining the PO_2 in the range of 60 mmHg and until four days after the end of bypass the arterial PO_2 was 65 mmHg on 40% oxygen.

CONVALESCENCE

Improvement of the pulmonary function was progressive, assisted ventilation being discontinued 16 days after the finish of bypass and the tracheostomy tube was removed 26 days from the end of bypass.

After a convalescence complicated by a major unsuspected gastro-intestinal haemorrhage which caused a prolonged period of hypotension resulting in acute renal failure. This recovered after several days peritoneal dialysis.

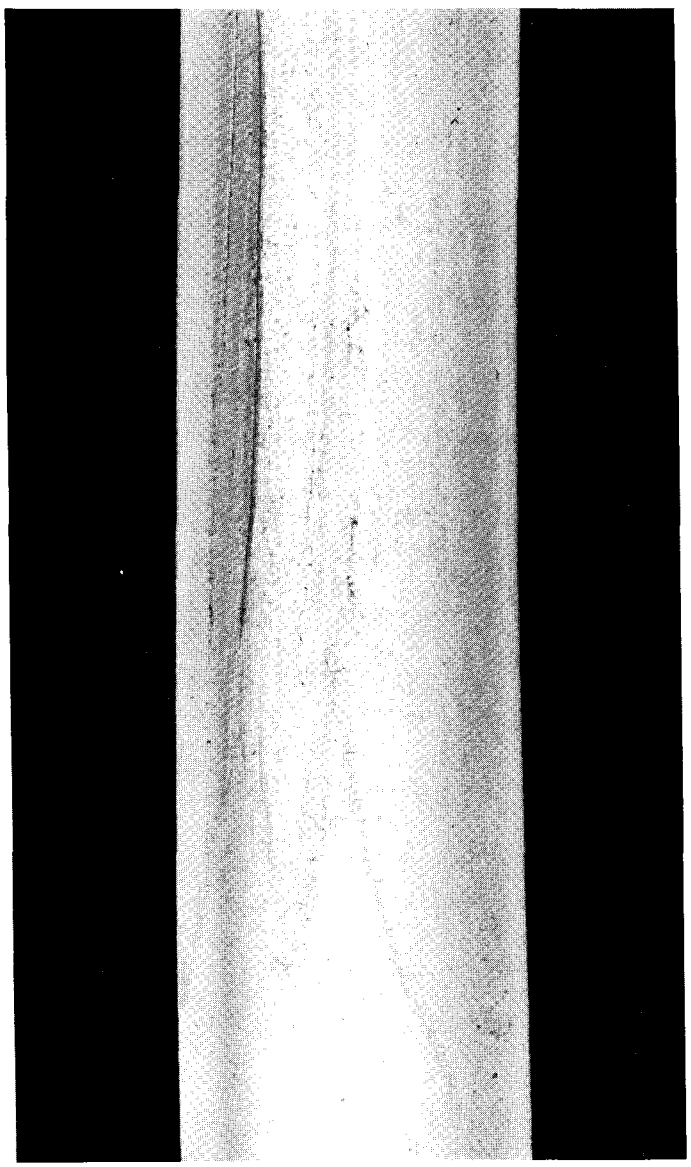
The patient was finally discharged to a convalescent hospital 45 days after admission.

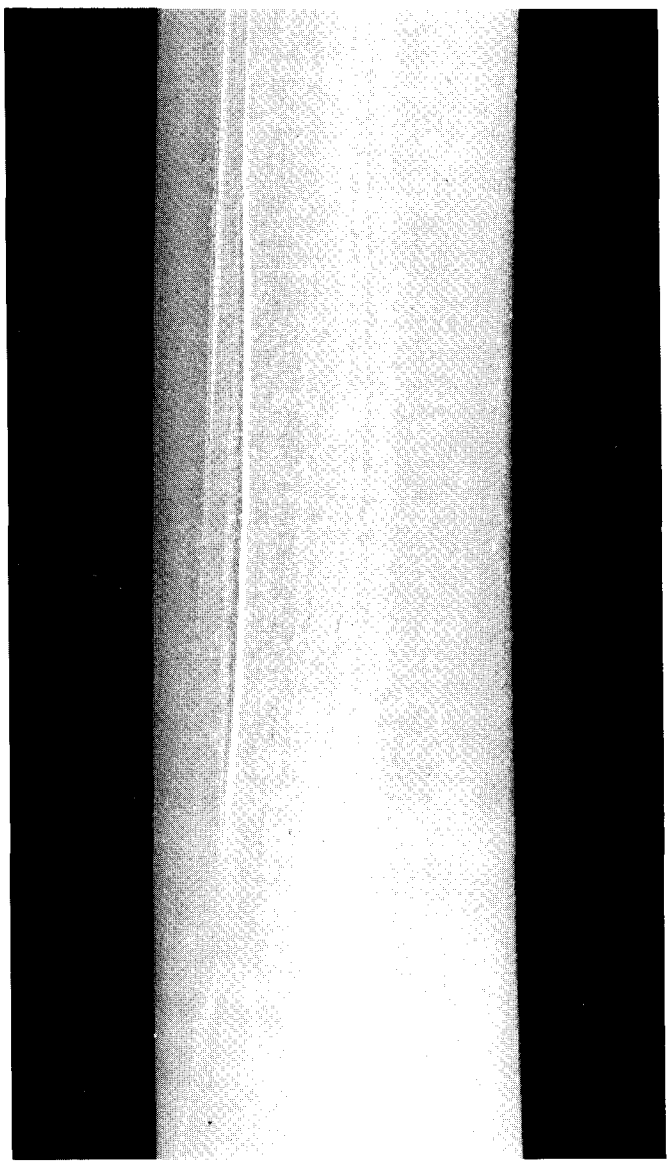
COMPLICATIONS

The only aspect of the bypass circuit to cause worry and concern was the silicone pump tube. It was increasingly evident towards the end of the perfusion that the pump tube was being damaged by the constant action of the roller pump.

A decision to stop the perfusion in order to change the pump tube was being considered but the termination of bypass made this unnecessary.

Examination post-bypass of the pump tube showed that deep grooves had been produced and it was evident that the life of the tubing was dangerously short.





Respiratory Support

With the advent of long term perfusion stresses on perfusion components can result in technical problems. The pump tube will in future be changed to latex rubber. It is not known whether latex rubber under these conditions will perform better than silicone rubber and the following procedure is to be adopted.

The pump tube will be made three times longer than necessary. The redundant two thirds will be placed on the distal side of the pump that is between the pump and heat exchanger, an area of high pressure. Each 48 hours the pump would be stopped and one third of the tube will be drawn through the pump from the distal to the proximal side.

This should not cause cessation of perfusion for more than 15 seconds and by moving tubing in this direction, if that which has been in the pump is now weakened it will be on the low pressure side. This technique will also prevent the possibility of air embolus which could by tubing replacement with other techniques be a hazard.

As this patient required large transfusion volumes and with the increased accumulated evidence of micro-emboli from whole blood transfusions a filter will be placed in the transfusion line and introduced into the circuit via the venous line prior to oxygenation. It would be appropriate to use a filter that would not remove functional platelets and the filter of choice at the time would be the Barrier 40 filter. The membrane oxygenator used in this case exhibits good filtering properties and therefore by introducing the blood and priming solutions prior to the membranes will make use of this property.

A mechanism of reservoir level sensing with feed back to the pump speed control would be an advantage. It would allow the perfusionist more mobility to perform associated tasks more safely. The mechanism could be sensed either by levels in the reservoir bag or perhaps the weight of the reservoir contents.

The merit of any procedure of this nature is the patient's survival. With the described circuit no major problems were encountered and prolonged support of the patient was achieved without difficulty. Two 3M[2] membrane oxygenators provided satisfactory oxygen and carbon dioxide levels in the patient with minimal blood trauma. The suggested modifications to the circuit seem to us to warrant further application and study.

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Home Dialysis Training Unit

A very complete programmed study manual. Included in each subsection is a study-aid segment composed of questions the answers to which lie in the margin. By covering the margin with a strip of paper, the trainee can respond to the question then, by exposing the answer, confirm his response.

The first edition of this manual was published in 1967 by the Northwest Kidney Center. This edition is an attempt to correlate the advances in the technology with the experience gained in both dialyzing and patient training during the past five years.

The approach intended as well as the information presented make this volume a necessary reference book as well as a fine patient textbook. In addition to the usual material, there are additional sections on special medical problems peculiar to the dialysis patient as well as problems that may occur during dialysis. There are, too, sections on transplantation, how to vacation, and about missing a dialysis.