

# Arteriovenous Bypass for Respiratory Assistance: A Case Report

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This work is supported by the Canadian Medical Research Council Grant in aid MA 4167 and MA 4502.

## INTRODUCTION

Respiratory insufficiency is encountered more frequently in the population today and this medical problem remains partly unresolved in spite of the technical advancements of modern medicine. The increase in respiratory diseases may be related to various aspects of modern life such as pollution, industrial diseases, chronic infections of the respiratory system, trauma, smoking, etc. . . .

Certain types of treatments for respiratory distress have become classical over the years. These, however, are not always sufficient to overcome the problem and at best they remain somewhat unpredictable. This type of therapy is also very costly because of the number of highly qualified people involved. Moreover, in recent years a plateau of efficiency seems to have been achieved and we cannot foresee in the near future any major improvement in the methods of treatment for these patients. The problem of treatment is sometimes related to the disease of the patient. For example, a patient suffering from silicosis cannot be improved permanently without removing the causal factor; since the intoxicating agent is not soluble in liquids, it cannot be removed from the lungs of the patient. A much more radical approach will need to be used in this type of patient if we are to improve his condition. Homologous lung transplantation or the implantation of an artificial lung may be the methods of treatment of the future.

Homologous lung transplantation has been attempted with some degree of success.<sup>1-8</sup> The results depend largely on the immunocompatibility of the individuals used for the transplant. When the immunological problems will have been solved this avenue of treatment may become quite successful. A second group of research scientists wishes to explore the possibility of replacing the deficient organ with an artificial one. Each group of researchers believes his method to carry the best chances of success. It is our view, that a rational decision on the methods of treatment to be used in these patients cannot be taken until both have been thoroughly investigated. We know the successes and the failures up to date. In transplantation, success is dependant on the control of the rejection mechanism while in the artificial lung, problems of blood coagulation, of respiratory mechanics and of hemodynamics are far from solved.

The bubble and screen oxygenators presently available today are quite useful for open heart surgery. The changes in blood produced by these oxygenators, however, preclude any long term use of this type of artificial lung in man.<sup>9</sup> Trauma to the blood cells,<sup>10</sup> denaturation of proteins,<sup>9</sup> and changes in the lungs,<sup>11-12</sup> kidneys,<sup>13</sup> liver,<sup>14</sup> and brain<sup>15</sup> occur during cardiopulmonary bypass and are apparently due to the direct-

Article available at <https://ject.edpsciences.org> or <https://doi.org/10.1051/ject/197464215>

contact gas-blood oxygenators.<sup>9</sup> Direct-contact oxygenators which are more efficient and cheaper than membrane oxygenators are still widely used in cardiac surgery where the period of bypass is short and these lesions are not severe. Hypothermia and hemodilution<sup>16</sup> may also be used quite successfully to minimize the trauma to the blood elements which results from the blood gas interface.

The work of Lee<sup>9</sup> and of Dobell<sup>17</sup> suggest strongly that artificial blood oxygenation carried out using the principles of gas diffusion through a thin semipermeable membrane should be the direction of future research to overcome the problems of prolonged or long term bypass. The work of Kolff,<sup>18</sup> of Clowes<sup>19</sup> of Peirce<sup>20</sup> and many others<sup>21, 22, 23</sup> has given us relatively reliable membrane oxygenators.

During the past three years, we have carried out extensive studies on the biochemical, hematological and pathological changes which occur during prolonged (24 hr.) pumpless arteriovenous bypass with the "Modulung 750".\* The results of these studies, which will be published shortly, have convinced us of the safety of the device and its suitability for use in patients. This report deals with the use of this membrane lung for prolonged respiratory assistance in a small child.

## CASE REPORT

A first patient was referred to our group by the selection committee of Laval University Hospital. This committee is made up of five Hospital staff members but does not include any members of the respiratory assistance team.

The history of the patient may be summarized as follows: The patient was a 5 year old child suffering from mucoviscidosis. When first admitted to hospital and examined it was noted that the child appeared dyspneic and cyanosed. His temperature was 39.5°C, the pulse was at 168/min. and respiration at 68/min. On auscultation bilateral rales were noted and the liver appeared to be enlarged. X-ray examination revealed bilateral pneumonia. The leucocyte count was 35,000. The usual therapy with antibiotics (orbenine and garamycin) and inhalation therapy (propylene glycol 10%, neosynephrine 1/8 % and carbenicilline) was started. At that time blood chemistry was Na = 123 mEq, K = 5.2 mEq, chlorides = 85 mEq, BUN = 20 Total CO<sub>2</sub> 46.1, base excess + 11.2. The pH was at 7.38 and the pCO<sub>2</sub> at 74 mm Hg.

In spite of the medical treatment, the condition of the child deteriorated over the following days and on the fifth day he became comatose. Respiratory assistance using membrane oxygenators was deemed necessary and he was transferred to our care. A blood gas analysis was carried out with the following results: Total CO<sub>2</sub> 58, base excess + 19, pH 7.30 pCO<sub>2</sub> 110 mm Hg and pO<sub>2</sub> 47 mm Hg. Since the main problem facing the patient appeared to be a deficiency in CO<sub>2</sub> elimination, an arteriovenous bypass was instituted.

## THE EXTRACORPOREAL CIRCUIT

The circuit originated at the femoral artery of the patient, passed through an electromagnetic flow meter, through the artificial lung and returned to the femoral vein. Y cannulae were used for the femoral cannulations. This is done to reestablish circulation in the extremities of the patient. With the above shunt, the flow rate was 50 ml/min; this flow rate was estimated to be insufficient and a roller pump was therefore added to the circuitry between the flowmeter and the artificial lung. With the pump, flow could be increased to 200 ml/min. (see Fig. 1) This was estimated as sufficient. Two

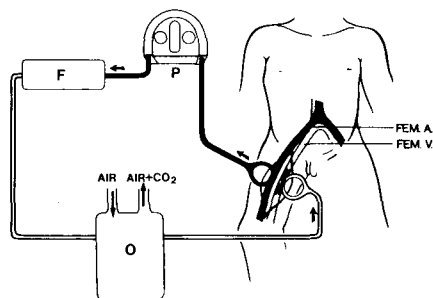


Figure 1: The veno arterial bypass was constituted of P: The roller pump; F: The electromagnetic Flowmeter; O: The membrane lung; Fem A and Fem V. The venous and arterial cannulae.

\*Artificial Organs Div. Travenol Laboratories, Morton Grove, Illinois.

liters/min. of air were circulated in the lung. The patient was placed on a heating blanket to compensate for the heat lost in the circuit. The blanket proved to be efficient enough to maintain the patient's temperature. Gradually the oxygen concentration in the gas mixture of the Angstrom respirator was decreased to 50%.

Approximately half-way through the perfusion (30 hours) the measurements carried out gave: Blood pressure: 100/70, temperature 35°C, pulse 120/min., pump flow 180 ml/min., hemoglobin 10g, hematocrit 31, red cells 3.65 million, white cells 12,100, pH at the entrance into the circuit 7.49, at the outlet 7.73, pCO<sub>2</sub> in 66 mm Hg, pCO<sub>2</sub> out 36 mm Hg, pO<sub>2</sub> in 106 mm Hg out 172 mm Hg. (Note the results obtained at the entrance into the circuit, i.e. *in*, are the same as the arterial blood gas samples). Na was 140 mEq., K was 3.0 mEq, the chlorides were at 87 mEq. (Fig. II)

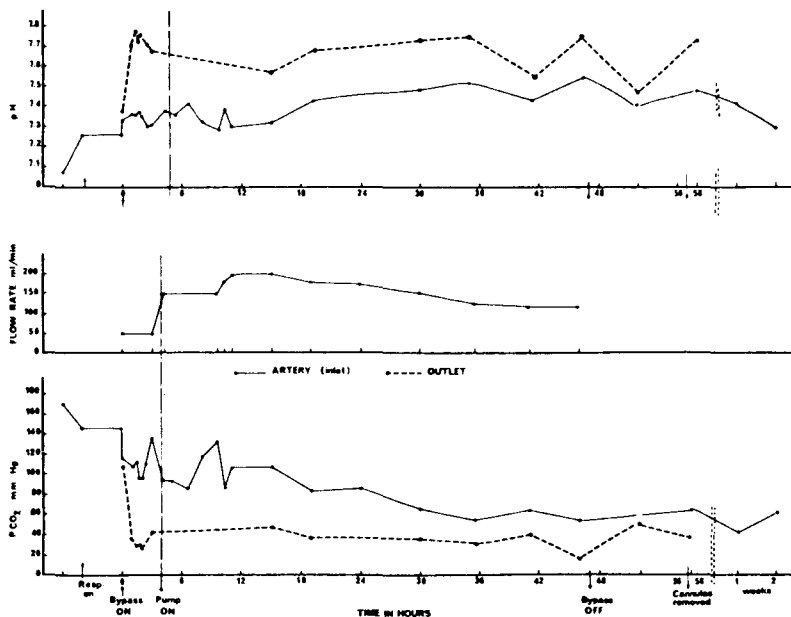


Figure II: Blood gas and pH differences at the by-pass inlet and outlet. The patient's arterial blood values are the same as the inlet values since an arterio-venous by-pass was used.

## ANTICOAGULATION

Anticoagulation is one of the most critical points to be controlled during this type of bypass. It is well known that plastics tend to promote blood coagulation at their surface; silastic is not an exception although it is much better than any other surface presently available. The degree of anticoagulation must, therefore, be extremely well controlled. Too high a dose of anticoagulants will result in blood which cannot coagulate and peripheral hemorrhages are likely to occur. Too low a dose will favor coagulation in the circuit. In this case, 3 mg/kg was administered at the time of cannulation 1 mg/kg was given an hour later. From then on heparin was given every two hours in the dosage needed. A half hour prior to the administration of heparin an activated prothrombin time was done and the heparin dosage calculated from the results; if the coagulation time was high, i.e., 4 to 5 times the control value, 0.5 to 1.0 mg/kg was given. If the coagulation time was below 2 to 2.5 times the control value, 1.0 to 1.5 mg/kg heparin was given. Anticoagulation was controlled quite satisfactorily by this method and could be maintained between 2.0 to 3.0 times the control level.

Fig. 2 gives an idea of the most important parameters measured during perfusion. It was interesting to note that during bypass, the platelet count decreased rapidly when the coagulation time dropped below 2.0 times the control. This point seems to have been critical in this patient.

## MEDICAL TREATMENT

During bypass, the patient's respiration was assisted with an Angstrom respirator. Ventilation was at 7 liters/min. Twice a day, or more, bronchial lavage was carried out. Since the patient was anemic a unit of ACD blood was administered over a 4 to 5 hour period. The unit was heparinized prior to administration (25 mg. heparin). During perfusion the patient was fed intravenously taking care to replace the lipids by another energetic substance.

After 48 hours of bypass the patient was disconnected from the circuit and the cannulae removed. The patient continued to improve over the next few days. A month later, however, during a Lavage with enzymes given in an attempt to prevent continuing weight loss, the patient vomited, had diarrhea, and his abdomen became distended. His condition rapidly became critical and he expired. Autopsy was refused.

## DISCUSSION

Originally, the first successful case of assisted respiration carried out on a human in Canada appeared to be quite an undertaking. However, as the perfusion progressed it became evident that this was not so. The circuit described was easy to use and quite safe; anticoagulation was also relatively easy to control. It is important to establish a routine with the nursing personnel in order to avoid disasters. In this case the pump was stopped and the lines into and out of the patient were clamped each time a sample was to be taken from the circuit. All the conditions had to appear normal before unclamping the lines and restarting the pump. A second point noted concerns the connectors used to join the various parts of the circuit together.

These seem to promote coagulation at their inner lumen and should be kept at a minimum. Nylon and polycarbonate are also worse than polypropylene or silastic. The artificial lung itself did not present major problems during use.

As a result of this first try it would seem as if this type of assistance can be carried out quite successfully by many centers throughout the country. It is important, however, to carry out a few experiments in the laboratory prior to clinical use . . . just to try out the circuit. A qualified perfusionist must also be present during the bypass; extracorporeal circulation is a profession which takes time to acquire and the absence of such a specialist definitely jeopardizes the life of the patient.

## ACKNOWLEDGMENT

The authors wish to express their gratitude to Miss Raymonde Jean for the transcription of this text and to the Laval Hospital Photography Department for the graphics.

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