

The Future of Membrane Oxygenators

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Perhaps the first question in a discussion of new technology should be: What is the advantage that the new presents over the old? The most important advance of membrane oxygenators over the traditional blood/gas interface devices is the margin of safety which they provide. Cardiopulmonary bypass and manipulation of the heart is one of the most drastic procedures a human being could be subjected to. The more safety factors that can be accumulated on the side of the patient the better.

One of the uncommon, but most worrisome complications that does occur in the operating room is the inability to wean the patient from the heart-lung machine. In this situation the membrane oxygenator presents its greatest advantage over the bubbler type of device. With membrane oxygenators the surgical team is not limited to a few hours of perfusion. The patient can be supported for several hours, even days if the situation warrants. Modern membrane oxygenators are just as effective as the gas interface devices in terms of gas transfer performance, and that performance is not subject to deterioration for at least twenty-four hours in commercially available devices.¹

It is also of great benefit to the patient that membrane oxygenators tend to be more gentle to the blood elements than do the blood/gas interface devices. Studies show that there is only a negligible increase in plasma hemoglobin regardless of the duration of perfusion. Platelets also seem to be less affected as demonstrated by a smaller decrease in the platelet count.² There is also evidence that there are far fewer gas emboli generated in membrane systems than in bubbler devices.³ All of these factors add safety to the procedure and enhance the patient's prospects for a favorable outcome and an uneventful recovery.

There are of course disadvantages. These center around the attendant costs involved in converting to the newer membrane systems. Although the cost of the oxygenators themselves are now competitive, the ancillary equipment required to use some types of membrane devices remains quite expensive. This, of course, assumes that one wishes to purchase the entire equipment specifically designed for a particular membrane device. There are available kits that adapt available equipment for use with membrane oxygenators for a smaller investment of funds. There are, however, two factors that cannot be circumvented: 1) pump teams must be re-trained to use the membrane devices; and 2) the membrane oxygenators tend to be somewhat more complex in their use.

The safe and efficient use of a membrane oxygenator requires that the pump team be well versed in the science and technology of perfusion. This is the price of advances in patient care and, unfortunately, there seems to be a degree of hesitancy on the part of some to invest the time and effort necessary to understand and master the new devices. This is understandable since apprehension usually ensues when one moves from something one is comfortable with to unfamiliar equipment. There is no substitute, however, for an in-depth understanding of the mechanisms. Presently the trend is toward automation. Fewer variables are left to the discretion of the operator thereby

rendering the newer devices simpler to operate. The other side of that coin, however, is that fewer manipulations are available and the operator is essentially “locked in” to a particular mode of operation. This situation is also beneficial to the manufacturers of devices because they can recommend a specific mode of use and release themselves from liability for other applications of the devices.

There are other valid questions that arise in the consideration of membrane oxygenation. An obvious one is that of cost/benefit ratio. Under the conditions of the specific institution, will there be enough patient benefit and enough use of the equipment to justify the cost involved in tooling up for a new technology? This must include all of the attendant expenses such as hardware, disposable software, re-training of personnel, etc. Given the tendency and track record of our society to elect advances in health care at whatever expense, it would seem that the cost of membrane oxygenation would amount to little more than an initial administrative inconvenience. Re-training the pump team is probably the greatest problem in terms of time and effort. For all practical purposes, the membrane lung equipment will be used only for the acute application of the cardiac surgery theater. Of late, the few institutions that were using membrane devices for long-term (days or weeks) pulmonary support has been curtailing such activities. The benefit of long-term pulmonary support has been questioned because seriously damaged lungs tend to progress towards fibrosis rather than repairing themselves under the cover of membrane oxygenation. This raises serious questions as to whether or not the patient can ever recover pulmonary function irrespective of how lung pulmonary support is continued.⁴ Furthermore, sustaining a patient on long-term pulmonary support is quite functional; but, the biological aspects of the question have for the moment relegated long-term support to a “back burner” for further consideration.

Progress in the membrane oxygenator field is now mainly at the commercial development stage. As a matter of fact some of the membrane devices are into their second or third generations of refinement. The major thrust is now toward automation. The early suspicions about porous membrane oxygenators, for instance, have proven largely unfounded. Many people initially expected porous membranes to act essentially as microbubble generators, but in actual practice they do not. As research into biomaterials progresses the resultant new membrane materials will provide for even better performance and more “physiologic” handling of blood.

Presently, some of membrane oxygenator technology is moving towards the concept of the implantable artificial lung. With better membranes and designs we are moving closer to the time when adequate oxygenation will be realized with atmospheric oxygen (approx. 21% O₂) instead of pure oxygen. There is work in progress dealing with the questions of how and where to put the implantable devices as well as on the devices themselves. This presents some very interesting problems in experimental surgery as well as in bioengineering. The current view is that these devices will serve as “booster lungs” rather than as replacement lungs⁴ and we have met with some success in the experimental surgical aspects of the question.

This, more or less, implies that the use of membrane devices in the operating room situation is an accepted thing. Generally, membrane devices are well accepted, there is only the usual lag time involved that occurs between the time any new advance is developed and accepted, and the time it is found in most places that deal with that technology. Membrane devices are the way of the future.

REFERENCES

1. Laboratory and Clinical Experience with a Microporous Membrane Oxygenator; W. Murphy, L.A. Trudell, L.I. Friedman, M. Kakvan, P.D. Richardson, K. Karlson and P.M. Galletti, *Trans. Amer. Soc. Artif. Int. Organs* 20, 1974.
2. Evaluation of the Travenol Teflo Microporous Oxygenator (STX-433 and 434); L. A. Trudell, W.R.C. Murphy, L. R. Boudreau, P. D. Richardson and P. M. Galletti, *J. AmSECT* VII, 3, 1975.
3. Computerized Discrimination of Microemboli in Extracorporeal Circuits; L. Abts, R. Beyer, P. Galletti, P. Richardson, D. Caron, R. Massimino and K. Karlson, *Amer. J. Surgery*, in press.
4. Artificial Hearts, Lungs and Kidneys; P. M. Galletti *Proc. of the 2nd Ann. Maine Biomedical Symposium*, p. 317-328, S. Zell Edit., Univ. Maine, Orono College of Atlantic, Bar Harbor, 1977.