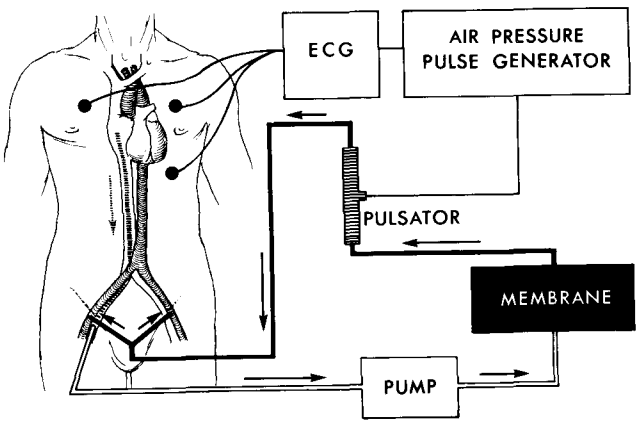


Figure 1: This is a diagramatic representation of the extracorporeal unit for assisted circulation. Blood is removed from the right atrium and returned to both femoral arteries. The arterial line contains a pnueumatic pulsatile chamber that returns the blood to the body during the diastolic phase of the cardiac cycle. The timing, duration and force of the pulsation is controlled by the air pressure pulse generator.*,**

Figure II: This is a cross section of the pulsator. It shows the inlet and outlet valve with the inner silastic tubular blood ventricle. When the machine is not functioning in a pulsatile nature, the chamber simply functions as a large straight connector.*

# Assisted Circulation

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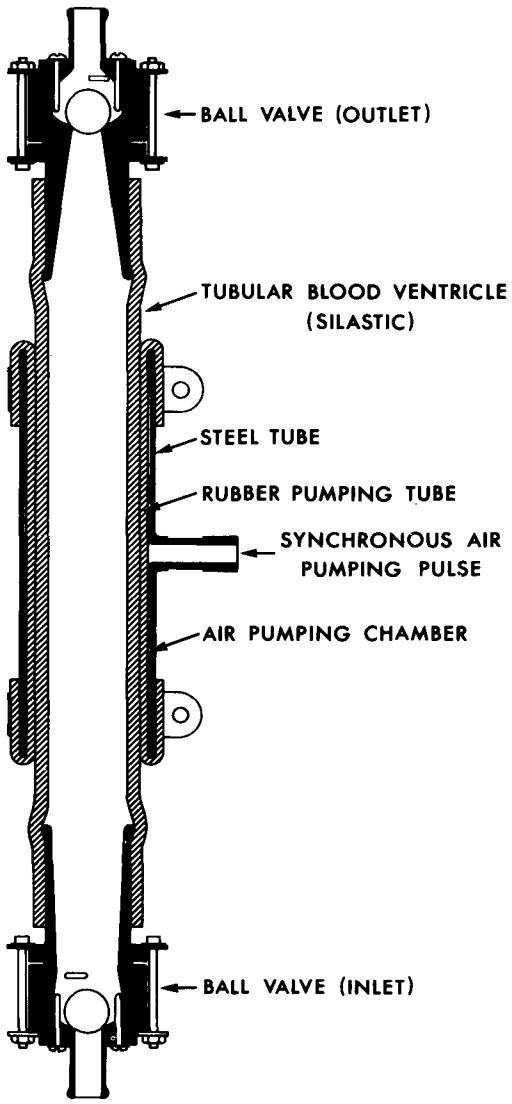
Following the development of open heart surgical techniques 15 years ago, surgeons and bioengineers have worked towards systems of artificial support of the circulation. Most systems that involved the use of an oxygenator were doomed to an early failure because conventional oxygenators were too traumatizing to the blood to be used for long periods of time. In the absence of a safe oxygenator, methods of supporting the circulation without oxygenating were developed. These methods were: a) closed left heart bypass,[1] b) counterpulsation,[2] c) intra-aortic balloon counterpulsation,[3] d) open left heart bypass.[4] All of these methods are still being developed and used clinically. Several hold promise for practical future use.

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In 1964, we developed a practical membrane oxygenator.[5, 6] Extensive laboratory testing has indicated that it can be used for periods of 24-36 hours without producing significant damage to the blood or organs of the body.[7]

The average hemolysis at the termination of 24-36 hours of perfusion was 33 mg%. Histological studies on the lungs following long perfusion indicated no significant lung pathology.[8]

Utilizing this oxygenator in combination with the Bramson Heart-Lung Machine for which it was constructed, we have developed a method of assisted circulation using partial heart-lung bypass and diastolic augmentation.

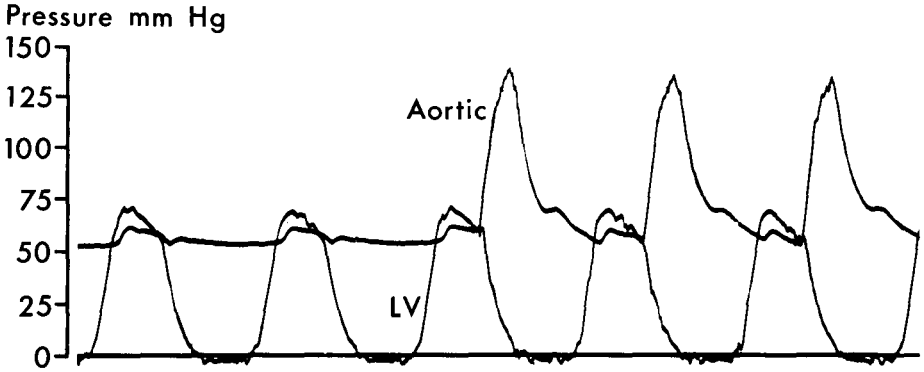


**Figure III: This tracing demonstrates the effect of going to pulsatile flow while on bypass. The pulsation is inserted in the diastolic phase of the cardiac cycle. This raises both the mean and aortic pressure.*,**

**Description**

Blood is removed from the right atrium via a size 32 French vinyl cannula inserted in the right femoral vein. The blood is then pumped by a Mayo roller occlusive pump through the membrane oxygenator. The pressure drop across the oxygenator is 25 mm Hg. The blood is returned to both femoral arteries in the groin. Inserted in the arterial line is a ventricle type pump that can produce pulsatile flow. The pulsatile pump is part of the arterial line. It contains valves at each end, so as to maintain blood flow in one direction.

The pulsatile flow is produced by the pneumatic pulsation of the inner wall. Helium, because of its low density, is used. The flow of helium to and from the chamber is controlled by an electropneumatic pulse generator. The generator enables us to control the timing, duration and force of pulsation. The generator is activated by the R wave of the electrocardiogram.

We can vary the time after the R wave that the pulse is transmitted. This arrangement makes it very easy to insert the pulse into the diastolic phase of the cardiac cycle. (See Figures I and II.) We can do this with pulse rates up to 130/min. Figure III shows the effect of going to pulsatile flow while on bypass. The mean and peak aortic pressure is increased. The left ventricle pressure is not changed.[9]

Partial heart lung bypass with diastolic augmentation has certain advantages. The bypass flow of 3-3.5 liters/min. enable us to prevent the deterioration of the other organs of the body and prevent metabolic acidosis. The bypass also reduces the pressure work of the left ventricle. The pulsatile flow raises the mean aortic pressure. This is extremely important since it aids in opening up valuable collateral myocardial flow and prevents the extension of the infarct.

**Summary**

A system for assisted circulation is described using the Bramson Heart-Lung Machine. This system provides a bypass flow of 3-3.5 liters/min. and also pulsatile flow with diastolic augmentation. This system is nontraumatic for periods up to 24-36 hours. Currently the mortality for cardiogenic shock is 85-90%. The use and improvement of systems like this and others should be pursued aggressively to help these patients who otherwise have a hopeless prognosis.

**References**

1. Dennis, C.; Hall, D. P.; Moreno, J. R. and Senning, A. Left atrial cannulation without thoracotomy for total left heart by-pass Acta Chir. Scand., 123:267, 1962.
2. Clauss, R. H.; Birtwell, W. C.; Albertal, G.; Lunzer, S.; Taylor, W. J.; Fosberg, A. and Harken, D. E. assisted circulation. J. Thor. Cardiov. Surg., 41:447, 1961.
3. Kantrowitz, A.; Tjonneland, S.; Freed, P. S.; Phillips, S. J.; Butner, A. N. and Sherman, J. L., Jr. Initial clinical experience with intra-aortic balloon pumping in cardiogenic shock. JAMA, 203:113, 1968.
4. Hall, C. W.; Liotta, D.; Henly, W. S.; Crawford, E. S. and DeBakey, M. Development of artificial intrathoracic circulatory pumps. Amer. J. Surg. 108:685, 1964.
5. Bramson, M. L.; Osborn, J. J.; Main, F. B.; O'Brien, M. F.; Wright, J. S. and Gerbode, F. A new disposable membrane oxygenator with integral heat exchange. J. Thor. Cardiov. Surg., 50:391, 1965.
6. Gerbode, F.; Osborn, J. J.; and Bramson, M. L. Experiences in the development of a membrane heart-lung machine. Amer. J. Surg., 114:16, 1967.
7. Hill, J. D.; Bramson, M. L.; Hackel, A.; Deal, C. W.; Sanchez, P. A.; Osborn, J. J. and Gerbode, F. Laboratory and clinical studies during prolonged partial extracorporeal circulation using the Bramson membrane lung. Circulation, 37-38 (suppl. II): 139, 1968.
8. Hill, J. D.; Bramson, M. L.; Kleinhenz, R.; Raison, J. C. A.; Hackel, A.; Osborn, J. J. and Gerbode, F. Lung Morphology Following Veno-Venous Perfusion with the Bramson Membrane Lung. Chapter 16 in **Organ Perfusion and Preservation.** John C. Norman, Ed., Appleton-Century-Crofts, New York, 1968, pp. 177-188.
9. Bramson, M. L.; Hill, J. D.; Osborn, J. J. and Gerbode, F. Partial veno-arterial perfusion with membrane oxygenation and diastolic augmentation. To be published in Transactions of Amer. Soc. for Artificial Internal Organs.

* From Bramson, M. L.; Hill, J. D.; Osborn, J. J. and Gerbode, F. Partial veno-arterial perfusion with membrane oxygenation and diastolic augmentation. To be published in Trans. Amer. Soc. for Artificial Int. Organs.

** From Hill, J. D.; Bramson, M. L.; Rapaport, E.; Scheinman, M.; Osborn, J.; and Gerbode, F. Experimental and clinical experiences with prolonged oxygenation and assisted circulation. To be published in the Annals of Surgery.