AXIAL FLOW PUMP FOR CARDIAC ASSISTANCE: PRELIMINARY RESULTS

E.I.NAKAYAMA[1], M.S.OSHIRO[1], I.A.CESTARI[1], A.A.LEIRNER[1], A.D. JATENE[2]

Abstract-- This paper presents an axial flow blood pump for ventricular assistance. To allow assessment of pump's hydrodynamic performance and efficiency a testing set up was assembled. According to the results, this pump can supply a minimum flow rate of 2.2 L/minute.

Introduction

Mechanical assist devices can be classified according to their therapeutic application as: total artificial heart, biventricular, univentricular, intra-aortic baloon pump (IAP), and rotary pump. This paper presents an axial flow pump which has been developed and tested "in vitro".

The axial pump can be compared to an IABP as regard its physical dimensions and the maneuvers it requires for its clinical application .

Its basic operating system is composed of a) a driving electric motor (Bosch 500 W / 110 V/ 25000 rpm maximum ratings), b) a rotation transmission cable c) a screw like element. (see Figure 1).

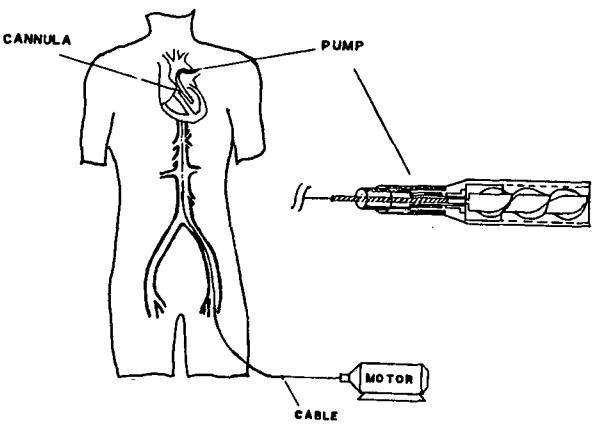

Figure 1. Axial flow blood pump assembly.

[1] Bioengineering Division, Heart Institute
Av. Dr. Enêas de Carvalho Aguiar, 44/ SS São Paulo 05403
[2] Scientific Director, Heart Institute

The most important factors to be considered for evaluating the performance of an assist device are: the effective degree of circulatory aid, the degree of hemolisys and the complexity involved with its application.

There are several possible sources of hemolisys whenever blood is artificially pumped e.g. shear stress, velocity gradient, solid surface interaction, centrifugal forces, cell-cell interactions and turbulence. Although it is very difficult to isolate the exact influence of each one of these factors it is known that the main cause of mechanical cell damage is the hydrodynamic shear rate.

Williams (1973) has studied shear-induced fragmentation of red cell and found that in very low concentration the shear stress required to disrupt a red cell is 50 N/m^2 (during 5 min.) and that this value was influenced by the time of exposure. Richardson (1973) found a correlation of the time of exposure (residence time) of a human erytrocytes to various shear stress rates and the hemolisys rate. Reul (1983) investigated the correlation of residence time and shear stress rate based upon Richardson's work and defined a normal range of shear rate in the circulation.

The exact influence of shear stress and transit time is a controversial issue and therefore the determination of the safe region of operation of a pump must be determined as a function of its specific geometric caractheristics and its operating condition.

In vitro testing

To study the hydrodynamic performance of the pump a testing set up was built (fig.2) The set up allowed the measurement of flow rate for varying pressure gradient (output - input), which is proportional to the water height column (08). A valve (04) controls fluid inlet in chamber 1 as to maintain it at a constant level. A second reservoir is used to provide flow rate measurement (03).

To access pump performance, two parametres were measured: the necessary electric power for actuating the pump itself, (considered as the cable and screw assembly) and the effective hydraulic power delivered by it.

A load testing condition was defined for a flow rate of 2.2 L/min against 100 mmHg pressure gradient. Thus, the following procedure was carried out:

a) the effective power delivered was indirectly estimated by varying the power consumption of the motor itself, which is the power difference measured with the motor isolated (zero load) and when the above defined load is imposed to it. A power variation of 7.5 W was obtained.

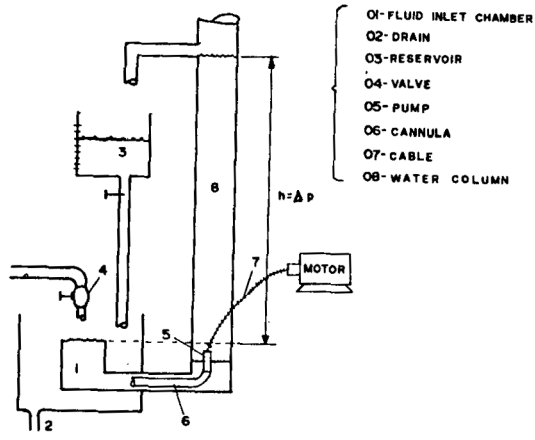

Figure 2. Schematic of "in vitro" testing set up

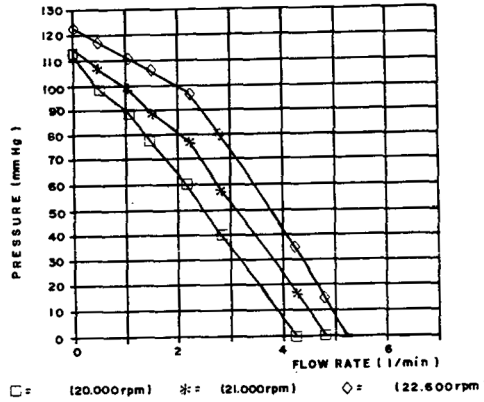

Figure 3.Pump flow rates vs.pressure gradient

b) Assuming that the motor utilized has 80% efficiency, the necessary power for actuating the device is 6 W. The hydraulic power for 100 mmHg pressure gradient and 2.2 L/min is 0.48 W. The efficiency of the pump was obtained by the ratio of the

electric power consumed and the hydraulic power delivered by the pump , thus yielding a 8.2% index.

c) To obtain the performance curve for this pump its flow rate were measured for varying pressure gradient and motor speed. Figure 3 shows the flow rate obtained as a function of pressure gradient for various motor rate settings.

Results

The results obtained "in vitro" suggest that this pump can supply a flow rate of 2.2 L/min against a pressure gradient of 100 mmHg. Considering that it would represent 44% of a physiological cardiac output, approximately, the pump can be used as a heart supporting device.

Discussion of The Results

The physical caractheristics of the pump itself is a limiting factor as regard its capacity as a full ventricular assistance device mainly due to :the reduction of the cannula cross-sectional area as compared to aortic valve cross-sectional area, and the length of the cannula. Both factors when associated cause a pressure gradient enough to cause hemolisys. Therefore the result obtained (44%) can be considered good.

Conclusion

The preliminary results suggest the applicability of this pump, even though the device has not yet being tested for pumping blood. Nevertheless its performance is expected to be even better when blood is being utilized (Hager, 1988). Future investigation will consider the relation between pump geometric caractheristics, hydrodynamic performance and hemolisys.

References

Hager J,Brandstaetter F, Koller I, Unger F (1988) : The Spindle Pump - Development of a nonpulsatile blood pump for assisted circulation International Workshop on Rotary Blood Pumps , Obertauern.

Reul H (1983): Blood Pumps-General Design Considerations. Adv. cardiovasc. Phys. vol.5(part IV): 55-71 (Karger, Basel)

Richardson E: (1973) Deformation and Haemolisys of red cells in shear flow. Euromech Colloquium. London, Imperial College.

Williams A. R (1973): Shear-Induced Fragmentation of Human Erytrocytes. Biorheology, 10: 303-311.

Whorlow R. W. (1980) :Rheological Techniques ch. 1:17-58, ch.3:114-190.