COMPARISON OF MYOCARDIAL DAMAGE CAUSED BY A CENTRIFUGAL PUMP AND A ROLLER PUMP, BY MEASURING CREATINE KINASE MB DURING CARDIOPULMONARY BYPASS, IN HUMANS

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SUMMARY : Centrifugal pumps offer an attractive alternative for short term to intermediate applications as in heart-lung-machines or as left ventricular assist devices. Artificial bloodpumps cause both mechanical trauma and complex immunological and cellular reactions. The centrifugal Bio-pump involves an entirely new concept for non-traumatic and fail-safe circulation support. Advantages of this pump over the conventional roller pump have been described. This study compares the myocardial damage between the roller pump and the Bio-pump under identical conditions by measuring the plasma creatine kinase MB levels during cardiopulmonary bypass. A traditional roller pumping system was used in the patients (Group 1), and a centrifugal heart pump (Bio-pump) was used in the other ten patients (Group 2). There was no significant difference between the two groups with respect to CK-MB levels determined from the coronary sinus blood samples obtained just before aortic cross-clamping and just after unclamping.

***Key Words :** Cardiopulmonary Bypass, Creatine Kinase MB, Centrifugal Pump, Roller Pump.*

INTRODUCTION

A number of different vaneless and impeller pumps have been developed for blood pumping and some of them have already been brought up to clinical appliccations (Pennington et al. 1986).

Both vaneless and impeller types have their benefits and disadvantages and the question "which is the better concept" is still unanswered. The reason for inconsistent results may be the interaction of multiple effects, the methodology necessary to get reproducable results of the test setups and the large variation of some of the measurement methods.

Artificial bloodpumps cause both mechanical trauma and complex immunological and cellular reactions. Most of these reactions involve thrombocytes, causing thromboembolism during experimental and clinical use of the pumps (Jarvik et al. 1981; Peninington et al. 1986).

The centrifugal blood pumping for open heart surgery was born of research for an artificial heart, a human heart substitute, and is more than an evolution of previous successive hydrolic pumps used for the purpose of propelling blood from an oxygenator to a patient. Previous pumps have included the Dale Schuster pump, the multicam sigmamotor pump, and the various models of roller pumps (Lynch et al. 1978; Nose, 1988). The centrifugal Bio-pump involves an entirely new concept for non-traumatic and fail-safe circulation support (Mandi, 1977; Papantonis and Croba, 1988).

We have attempted to study the traumatic qualities of the Bio-pump in a consecutive series of pati-

ents by measuring the plasma creatine kinase MB levels during cardiopulmonary bypass in order to determine the myocardial damage. Measuring the elevation of plasma levels of the myocardial specific isoenzyme of creatine kinase (CK-MB) is one of the most specific and sensitive methods in the determination of the myocardial damage (Schlant, 1978; Seguin et al. 1988).

Considering any parameters, such as surgical procedure, type of oxygenator, priming mixture, temperature, and the amount of use of cardiotomy suction, etc, to be closely parallel. We have compared the plasma creatine kinase MB levels during cardiopulmonary bypass in a consecutive series of patients undergoing open heart surgery, using the Bio-pump with a prior series of patients using a roller pump at the recommended fittings.

MATERIALS AND METHODS

Two different heart pumps were randomly evaluated in twenty patients undergoing mitral valve replacement operation. A traditional roller pumping system was used in ten patients (Group 1), and a centrifugal heart pump (Bio-pump) was used in the other patients (Group 2).

The two groups were well matched and there were no significant differences in terms of age, sex, aortic cross-clamping time or cardiopulmonary bypass time (P>0.005) (Table 1).

	Male	Female	Age (Years)	Cross-clamp time (min)	CPB (min)
Group 1 :	4	6	36.3	36.7	61.3
Group 2 :	5	5	34.0	30.3	50.4
P Value :	>0.05	>0.05	>0.05	>0.05	>0.05

Table - 1 : The difference between the two groups in terms of sex, age, aortic cross-clamping time and cardiopulmonary bypass (CPB) time.

The centrifugal heart pump used in our clinical experience was the Bio-pump (Bio-Medicus, Inc. Eden Prairie, Minnesota 55344), developed by Kletschka and Rafferty, which operates on the constrained vortex principle. During cardiopulmonary bypass, blood is driven through the arterial line and returned to the patient by centrifugal forces generated within the pump.

Cardiopulmonary bypass was performed by selective cannulation of the superior vena cava and inferior vena cava via the right atrium and cannulation of the distal ascending aorta. The core body temperature was cooled to 28-30°C (rectal temperature). When spontaneous fibrillation occurred, an aortic cross-clamp was applied, and 10-15 ml/kg of cold (4°C) crystalloid hyperkalemic cardioplegic solution was immediately administered through a 16-gauge catheter in the right side of the ascending aorta. Topical cooling was accomplished by pouring iced isotonic solution (4°C) into the pericardial sac.

Blood samples for assesment of creatine kinase isoenzyme-MB (CK-MB) levels were obtained from the coronary sinus just before aortic cross-clamping and just after unclamping. CK-MB was analyzed by an enzymatic radioimmunoassay method with the use of creatin kinase MB Assay Kit (Oliver, 1955).

Data were entered into a computer for analysis, for statistical analysis of the difference between the two groups, the t-test for paired groups and Mann Whitney U test were applied.

RESULTS

Table 1, displays clinical profiles and perioperative data for each group and demonstrate that the two groups were well matched, with respect to age, sex, type of the operation, aortic cross-clamping time and cardiopulmonary bypass time (P>0.05).

There was no significant difference between the two groups with respect to CK-MB levels determined from the coronary sinus blood samples obtained just before aortic cross-clamping and just after unclamping (p>0.05) (Table 2).

DISCUSSION

Centrifugal pumps offer an attractive alternative for short term to intermediate applications as in heart-lung-machines or as left ventricular assist devices.

	CK-MB just before cross-clamp (IU/L)	CK-MB just after unclamping (IU/L)	Increase in CK-MB (IU/L)
Group 1 :	10.2	36.5	26.3
Group 2 :	12.0	37.6	25.6
P Value :	>0.05	>0.05	>0.05

Group 1 : The roller pump
Group 2 : The Bio-Pump
Table - 2 : Mean values of the plasma CK-MB levels of the two groups.

According to Olsen a special type of centrifugal pump could even serve as an implantable total artificial heart (Olsen and Bramm, 1985). Artificial blood pumps cause both mechanical trauma and complex immunological and cellular reactions.

It is felt that the development of a centrifugal pump, such as the Bio-pump adds a new advance in automatic fail-safe blood pumping for open heart surgery.

The Bio-pump is an innovative non-occlusive blood pump. It operates on the constrained forced vortex principle : Blood passes through a vortex created by the spinning action of smooth nested cones. Energy is then transferred from the cones to the blood in the form of pressure and velocity, gently moving the blood into the arterial line.

Centrifugal pumps are nonocclusive pumps that offer several advantages over roller pumps:

Studies have shown the Bio-pump to be considerably less hemolytic than the roller pump because of its non-occlusive design, translating into less blood usage (Kletschka et al, 1975; Kress et al. 1987; Matsukura et al. 1974). Dr.Lynch has found that in a consecutive series of patients using a centrifugal heart pump (Bio-pump), post operative chest drainage was foud to be significantly decreased when compared to a similar consecutive series of patients using a traditional roller pumping system (Lynch et al. 1978). We can easily say that the Bio-pump handles blood more atraumatically.

Narrow pulse pressure differences is felt to decrease hemolysis when blood is forced through a cannula, and the Bio-pump has no pulse pressure.

The more often column of blood is suddenly interrupted per unit time there becomes greater trauma to red blood cells. The Bio-pump exhibits no sudden interruptions (Kletschka et al. 1975).

Takeda recognized preservation of platelet number during cardiopulmonary bypass by Bio-pump. Serum free hemoglobin was less in amount than that of roller pump. He also showed that the Bio-pump altered prostacyclin and thromboxane profiles during cardiopulmonary bypass and favored platelet disaggregant prostacyclin (Takeda et al. 1984).

Because of the constrained forced vortex design, the Bio-pump will only pump what it receives. If a large bolus of air was to enter the Bio-pump, the pump would deprime. If smaller amounts of air enter the pump they are displaced by their low density to the center of the vortex. These properties make it virtually impossible to produce air embolization during cardiopulmonary bypass as a result of a faulty blood pumping system (Mandi, 1977).

Since the pump is not a positive displacement device, the load sensitive characteristics of the Bio-pump make it resistance dependent. Forward propulsion of blood stops immediately if the arterial line become kinked, obstructed, or ocluded inadvertently, This prevents the generation of excess line pressures leading to disruption of connections, adapters, and fittings (Kletschka et al. 1975).

Focal microscopic infarcts of the brain and other organs have been reported in patients with early and late deaths following cardiopulmonary bypass. Emboli have been implicated as the cause of these findings. An important potential source of such microembolization relates to the spallation of plastic tubing particles into the lumen of the conduits of the roller pumping systems through erosion and fatiguing action of the roller on the tubing in the pump head (Hubbard et al. 1975 ; Kletscha et al. 1975; Kurusz et al. 1980). The Bio-pump avoids such spallation problems of roller pumping systems, whether the plastic tubing be silastic, polyvinyl chloride or polyethylene.

The Bio-pump also avoids the problems of splitting and cracking of the tubing that have occurred as a result of fatiguing action of the roller pump. Splitting and cracking can result in air embolization.

This study compares the myocardial damage by measuring the plasma CK-MB levels under identical conditions between the roller pump and the Bio-pump. We found that there is no significant diffe-

rence in the plasma creatine kinase MB levels between the Bio-pump and the roller pump during cardiopulmonary bypass in humans.

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