# MYOCARDIAL PROTECTION DURING OPEN HEART SURGERY BY CARDIOPLEGIC SOLUTIONS.

Essay submitted in partial fulfilment
of the master degree in
Anaesthesia.

By

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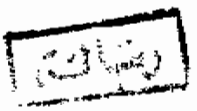

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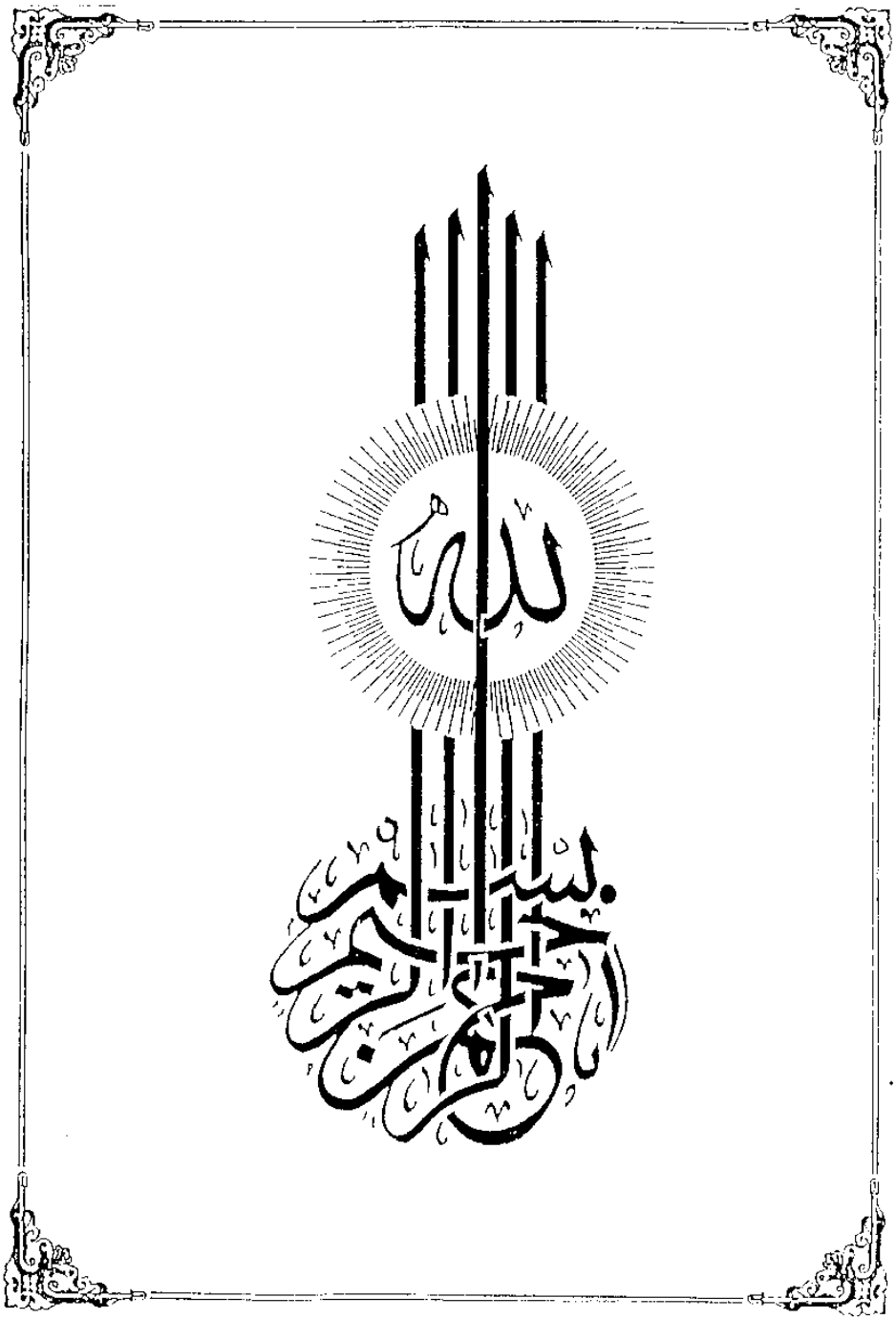

# ACKNOWLEDGEMENT

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# INTRODUCTION

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Myocardial protection during open heart surgery will continue to be a challenge,aiming to perfection and fruitful outcome.

Doctor John Gibbon of Philadelphia in 1953 introduced cardiopulmonary bypass which is considered the first corner stone in modern cardiac surgery. During cardiopulmonary bypass,ischemic arrest is often used as a convenient way to provide the surgeon with a non beating,bloodless,and relaxed heart. During the period of cross clamping,the heart is dependent mainly on anaerobic metabolism with limited energy production (Bretschnieder et al.,1975).

Surgeons and anaesthesiologists have always been perplexed by the observation that a technically successful cardiac operation could result in a low cardiac output state or failure to resume cardiac contraction. Early failures were attributed in vague terms to unavoidable stress of anaesthesia,cardiopulmonary bypass, and direct manipulation of diseased heart (Williams et al.,1965).

More recently it has been recognized that low cardiac output syndrome results from measurable perioperative necrosis and that better results in cardiac surgery can only be achieved when definitive operation is combined with optimal preservation of viable myocardium. Myocardial damage

starts mainly on applying the aortic cross clamp. This event stops coronary blood flow and deprives the myocardium from its oxygen and substrate supply, inducing acute myocardial ischemia, with its metabolic, pathophysiological, ultrastructural and hemodynamic consequences.(Kirklin and Stiles,1981).

A number of methods of myocardial protection during cardiac surgery have been used through the years. Myocardial hypothermia,systemic hypothermia,and pharmacological cardiac arrest greatly extend the safe time of global cardiac ischemia. Much of the safety of contemporary cardiac surgery can be attributed to the use of cardioplegic solution for intraoperative myocardial protection. Since the introduction of cardioplegic techniques in 1973,solutions containing elevated levels of potassium delivered at low temperatures, have constituted the mainstay of this protection (Ferguson et al.,1986).

The purpose of pharmacological cardioplegia is to produce immediate and sustained cessation of all electromechanical activity of the heart with reduced high energy phosphate utilization to such low levels that on going energy production is sufficient to sustain the energy dependent processes essential for cell survival. Setting aside the cardiac mechanical performance brings the highest absolute reduction of myocardial requirements. Therefore often the terms cardioplegia and myocardial protection are employed as synonyms (Ionescu,1981).

The combination of cardioplegia,to eliminate electro-mechanical activity,and hypothermia to reduce basal metabolism results in even greater energy conservation than can be achieved with either intervention alone (Rosenfeldt et al.,1980). Different techniques and additives of cardioplegic solution are commonly employed now during open heart surgery.

# PHYSIOLOGY OF THE MYOCARDIUM

## Physiology of the myocardium

The function of the heart is to propel unoxygenated blood to the lungs and oxygenated blood to the peripheral tissues in accordance with their metabolic requirements.

Microscopic structure of the heart:

It was believed that the myocrdial muscle is composed of a multinucleated syncytial network made up of branched fibres that had no ends.By the electron microscope,it became apparent that myocardial fibres are composed of individual muscle cells that are joined together end to end by cell junctions. The slit like space between fibres contains endomysium that brings capillaries and lymphatic vessels close to the muscle fibres. Numerous cross-banded strands or bundles,termed myofibrils,traverse the length of the fibres.

Myofibrils are composed of longitudinally repeating sarcomeres separated by two adjacent dark lines,the Z lines. The centre of the sarcomere is occupied by a dark band,the A band. The A band (the anisotropic or birefringent band that rotates polarized light),is flanked by two lighter bands, termed I (isotropic) bands. The bands of the sarcomere reflect the disposition of interdigitating myofilaments made up of contractile proteins. The filaments composed of actin

are attached to each Z-line and project longitudinally into the middle of the sarcomere,where they interdigitate with an array of thicker filaments composed of myosin molecules. Interactions between the thick and thin myofilaments in the A band generate force and shortening of the myocardium, with the myofilaments sliding past one another while maintaining a fixed length. (Guyton ,1987).

The nucleus is centrally placed within the myocardial cell. Mitochondria are situated between and in close opposition to the myofibrils as well as just beneath the sarcolemma. The close proximity of the mitochondria,the organelles in which adenosine triphosphate (ATP) is produced to the contractile filaments may facilitate the transfer of ATP from its site of production to its site of utilization during contractile process. The sarcolemma ,a surface membrane surrounds the myocardial cells and invaginates at the Z-lines of the sarcomere. It is composed of thin bimolecular phospholipid layer,the plasmalemma,which is the site of electrical polarization. Just exterior to the plasmalemma is the glycocalyx,the basement membrane,which in turn is composed of an inner and outer coats.

The sarcolemma possesses enzyme systems that utilize ATP for energy in order to maintain the difference in ion concentration (Na+,k+,and Ca++ ).

Near the Z-lines the sarcolemma contains wide invaginations,the T-system,which branch both longitudinally

and transversely,through the cell. Closely coupled to but not continuous with the T-system,is the sarcoplasmic reticulum,a complex network of anastomosing membrane limited tubular intracellular channels,which surround each myofibril and play a critical role in excitation of the muscle.

Unlike,the T-system the sarcoplasmic reticulum is not continuous with the extracellular space. Where the sarcoplasmic reticulum approaches the T-tubules or the sarcolemma,it widens into flattened sac like enlargements (cisternae). At their junction,the sarcoplasmic reticulum and T tubules are separated by gaps of 10 to 20 nm. Depolarization of the sarcolemma may be channelled through the T-system to release calcium from the sarcoplasmic reticulum,which mediates myofibrillar activation. Like the sarcolemma, the sarcoplasmic reticulum has a bilayer matrix consisting principally of phospholipids.

Adjacent myocardial cells are connected end to end by thickened portion of the sarcolemma,termed the intercalated disc,a segment of which -the gap junction- represents a low resistance pathway to the propagation of electrical activity between cells (Braunwald,1988).

The coronary vessels:

The left main coronary artery (LCA) arises from the upper portion of the left posterior aortic sinus. It passes behind the right ventricular outflow tract and then usually bifurcates into left anterior descending (LAD) and circumflex

branches. The LAD passes down the anterior interventricular groove toward the cardiac apex. Its major branches are the septal and diagonal branches. The septal branches pass downward into the interventricular septum. The diagonal branches pass over the anterolateral aspect of the heart and it is usually one of these branches which supplies the apex itself. The circumflex artery originates at the bifurcation of the main LCA and passes down the left atrioventricular groove. The left circumflex artery gives off one to three large obtuse marginal branches as it passes down the atrioventricular groove. They supply the free wall of the left ventricle along its lateral aspect. The circumflex artery may also give rise to one or two left atrial circumflex branches. These branches supply the lateral and posterior aspects of the left atrium.

The right coronary artery (RCA) originates from the anterior aortic sinus. It passes down the right atrioventricular groove toward the crux ( a point on the diaphragmatic surface of the heart where the right atrioventricular groove,the left atrioventricular groove and the posterior interventricular groove come together). The first branch of the RCA is generally considered to be the conus artery. In 50 percent of persons, it arises at the RCA ostium. It passes upward and anteriorly over the right ventricular outflow toward the LAD. It serves as a source of collateral circulation in patients with LAD obstruction. The sinoatrial node artery,the second branch of RCA,passes