

MYOCARDIAL INFARCTION AND CELL THERAPY

Abstract

Acute myocardial infarction is the major cause of morbidity and mortality worldwide. As the regenerative potential of mammalian heart is limited to a short period in the neonatal state the treatment for myocardial infarction is limited. The only realistic approach to recover heart function is to replace failing heart by transplantation, but this is not a common practice due to limited availability of healthy heart donors. Although recent advances have been made in the treatment for acute myocardial infarction no therapies are available to induce formation of cardiomyocytes in damaged heart till date. Hence cellular therapy using embryonic stem cells or somatic cells remains to be an effective strategy for futuristic MI therapy.

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I. INTRODUCTION

Myocardial infarction or heart attack is responsible for 13.7% of cardiovascular death in 2015 (1). An occlusion in the coronary artery decreases the blood flow to the nearby cardiomyocytes causing oxygen deprivation or ischemia. Prolonged deprivation of oxygen in the myocardium can lead to myocardial infarction. The proliferative capacity of cardiomyocytes differs in species and phase of life. The cardiomyocytes of adult mammals are terminally differentiated cells which can hardly regenerate after injury. Whereas the cardiomyocytes of axolotls, newts, frogs, and zebrafish, can divide lifelong. However, the neonatal mouse heart can regenerate within 7 days of neonatal period. Due to the lack of regenerative potential for cardiomyocytes, the cells in the infarct region undergo necrosis resulting in the formation of a fibrotic scar. Although there have been significant advancements in the management of cardiovascular diseases and its complications, the prognosis still remains poor due to the lack of regenerative potential for the injured myocardium.

II. PATHOPHYSIOLOGY OF MYOCARDIAL INFARCTION

Coronary atherosclerosis constitutes about 80% of acute myocardial infarction and other causes include thrombosis, coronary spasm and coronary embolism. 60-90 % of Adenosine triphosphate (ATP) for cardiomyocytes is derived from fatty acid metabolism and 10-40% from glycolysis and oxidation of lactate. Coronary occlusion causes a shift in aerobic metabolism to anaerobic glycolysis stimulating glucose uptake as well as glycogen metabolism. A decrease in ATP inhibits Na-K ATP ase and increases Na^+ and Cl^- in cells. This alters the transport system in sarcolemma and sarcoplasmic reticulum increasing cytosolic Ca^{2+} and a fall in intracellular pH. The severity of alterations depends on the size of the infarct. And these alterations are reversible upon restoration of the coronary flow if the duration of ischemia is <15-20 minutes. Whereas 20-30 minutes of severe coronary occlusion cause irreversible changes in cardiomyocytes of sub endothelial region. In experimental models of myocardial infarction post myocardial infarction remodelling also involves inflammatory alterations, cardiomyocyte hypertrophy and fibrotic alterations in the non-infarcted segments (2). Overload of the non-infarcted myocardium following myocardial infarction leads to hypertrophy and fibrosis.

III. DIAGNOSIS OF MYOCARDIAL INFARCTION

Fourth Universal Definition of Myocardial infarction (UDMI) categorized myocardial injury into acute and chronic myocardial injury based on cardiotroponin concentration as in Figure 1. Acute myocardial is manifested by dynamic changes in cardiotroponin concentrations during serial measurements. Whereas chronic myocardial injury is characterised by a stable or minimal change in cardiotroponin concentration. MI is further sub-classified by suspected pathophysiology. Type 1 myocardial infarction is attributed to atherothrombotic plaque lysis or erosion. Type 2 Myocardial infarction occurs is marked by an imbalance between oxygen supply and demand for example microvascular dysfunction, coronary artery spasm, coronary embolism, anaemia, arrhythmias, hypertension etc. The first stage in the diagnosis of coronary heart disease is from the clinical history and interpretation of symptoms of ischemia. Cardiac ischemia can be assessed by the electrocardiogram (ECG) as shown in figure 2. Cardiac troponin T (cTnT) or cardiac troponin I (cTnI) measurement

(99th percentile) is also made along with the assessment of renal function. Troponin measurement is important in the differential diagnosis of non-ST segment elevation myocardial infarction (NSTEMI) which needs immediate intervention. Elevated troponin along with other clinical symptoms raises the possibility of NSTEMI. However high troponin level with a normal ECG is suspicious of an alternate diagnosis. Narrowing of coronary arteries can be checked by angiography of the heart and blood vessels. Classical myocardial infarction can also be detected by creatine kinase –myocardial band (CK-MB) along with the existing cardiac biomarkers.

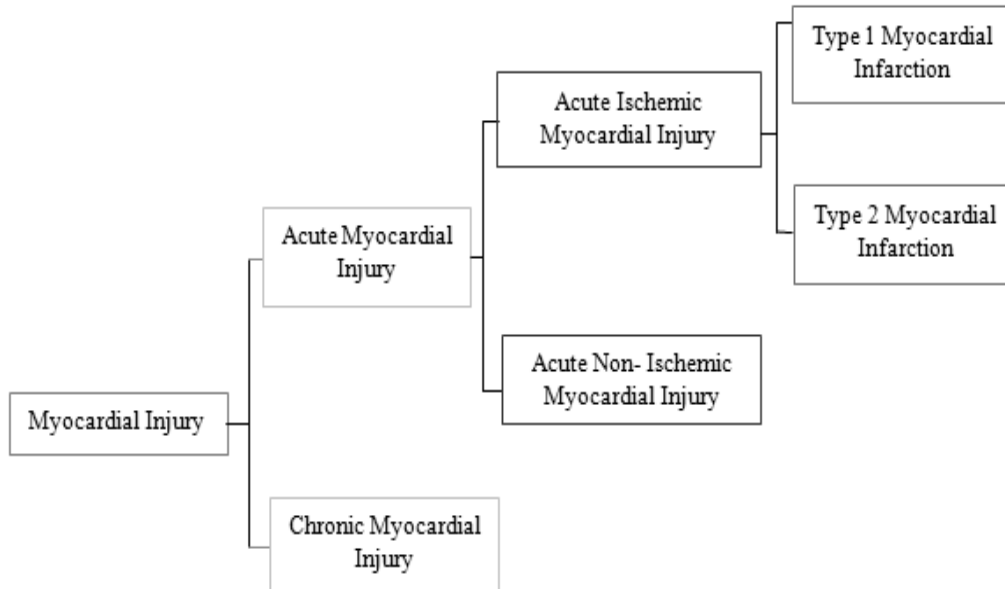


Figure 1: Classification of myocardial injury

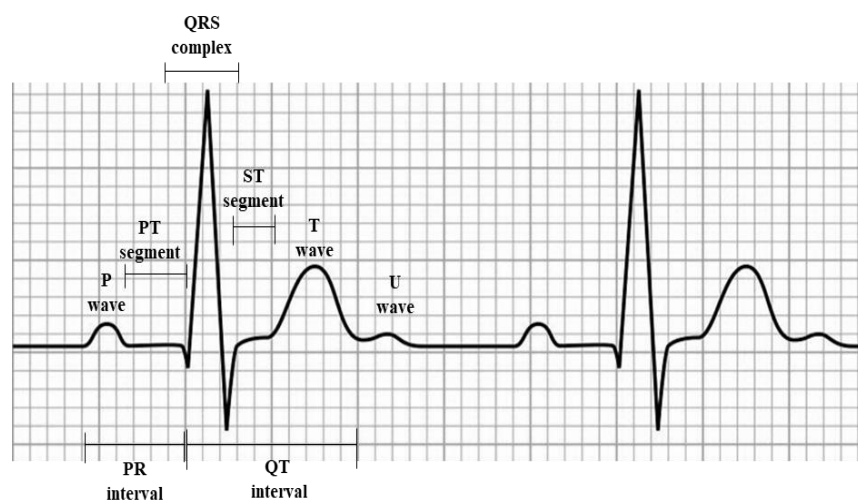


Figure 2: Normal ECG

Table 1: ECG interpretation

Segments	Indication	Disease condition
P wave	Atrial depolarization/contraction	Increased pulmonary artery pressure, Hypertrophy in the right atrium, Pulmonary valve stenosis.
PR segment Normal range (0.12 sec – 0.22 secs)	Impulse conduction through the atrioventricular node	PR interval greater than 0.22 secs – AV block (First degree; age related degenerative fibrosis) A short PR interval (<0.12 secs) indicates pre excitation
QRS complex Normal (<0.12 secs)	Depolarization of the ventricle/Ventricular contraction	Wide QRS complex – Bundle branch block, Hyperkalaemia, Drugs (Class I antiarrhythmic drugs, tricyclic antidepressants etc), Ventricular rhythm, ventricular tachycardia, external pacemaker, Wolf- Parkinson- White syndrome, Aberrant ventricular conduction
ST segment depression	Ventricular relaxation	Occurs during Physical exercise, Hyperventilation, Digoxin, Sympathetic tone, Hypokalaemia, Heart failure, Supra ventricular tachycardia, Pacemaker stimulation, Ischemia, hypertrophy
ST segment elevation	ST segment is displaced such that the level is above the PR segment	Ischemia
T- wave	Ventricular repolarisation	Inversion in myocardial ischemia
U wave	Occurs after T wave, one fourth of T wave	Inversion in ischemic heart disease and hypertension
QT duration	Sum of ventricular depolarization and repolarization duration	Inversely related to the rate of heartbeat, ventricular arrhythmia
Correction QT interval (QTc) (0.38 – 0.42 secs)	Heartbeat adjusted QT interval	Increases risk of ventricular arrhythmias, Psychiatric medications, hypocalcaemia, bradycardia, hypothyroidism, ischemia, cardiomyopathy

IV. MANAGEMENT STRATEGIES

In 2005, The European Resuscitation Council published guidelines for the emergency care of acute ST-elevation in myocardial infarction. Coronary artery occlusion by thrombus is responsible for 80% of hospitalization in cardiovascular diseases. The blood flow to the heart should be re-established as quickly as possible to protect heart muscles from further damage.

Aspirin should be administered for the symptoms to dissolve the arterial blockage or thrombolytic clot. Treatment with thrombolytic drugs such as Urokinase or streptokinase within 3 hours of myocardial infarction has been reported to improve the condition in 30 % of patients of acute myocardial infarction and tissue plasminogen activator in 54% of patients. (3–7).

V. CELL THERAPY AND ITS BENEFITS

Numbers of stem cells have been investigated over the past decades for cardiac repair in preclinical and clinical studies. This can be broadly categorised into pluripotent stem cells and adult stem cells.

- 1. Pluripotent stem cells:** Pluripotent stem cells are cells that can proliferate and differentiate into other cells. There are namely two types of pluripotent stem cells – Embryonic stem cells and induced pluripotent stem cells. Embryonic stem cells (ESC) are derived from the embryo, specifically from the inner mass of the blastocyst. Whereas Induced Pluripotent Stem Cells (iPS) are derived from skin or blood cells which are reprogrammed to a pluripotent state by expressing pluripotent factors Oct3/4, Sox2, KLF4, cMyc. iPS are therapeutically equivalent to ESCs, ESC transplantation significantly improved cardiac function and structure in animal models. However, there is immune rejection after transplantation in patients and ethical issues in using ESC (8-10).
- 2. Somatic stem cells:** Somatic stem cells (SSCs) are the self-renewable undifferentiated population of cells seen in virtually all organs of the body. Endogenous stem cells expressing c-kit are Cardiac stem cells (CSC) which can differentiate into three cardiovascular cell types' namely cardiac myocytes, endothelial cells and smooth muscle. These are responsible for the formation of ≥ 1 % of new heart cells after birth in mammals through proliferation and dedifferentiation (11). New natal mice can completely regenerate lost myocardium until 7 days of the postnatal period. Whereas some vertebrates such as Zebrafish (12-15) newts (16-18), and neonatal mice (19), can regenerate lost myocardium through proliferation. Though cardiomyocytes are ideal cells for cardiomyoplasty, finding a good source that can provide an efficient and enough population of cells for transplantation is challenging. Hence several different embryonic cell lines have been reprogrammed to produce cardiomyocyte cells to date as shown in table 1.

Table 2: Potential cell types for cardiac therapy

Cell Type	Advantages	Disadvantages
Cardiomyocytes (Adult/Foetal)	Electro-physiologically compatible, cardiomyocyte phenotype	Immunosuppression required, Ethically debatable, Low survival rate and limited supply
Haemopoietic stem Cells (Bone Marrow/ Blood)	Autologous transplantation, multipotent, No Immunogenicity	Not Enough Population
Epithelial Progenitor Cells (Peripheral Blood And Bone Marrow)	Autologous trans plantation, No immunogenicity	Need for expansion
Mesenchymal stem cells (Bone marrow, skin, adipose Tissue & muscles)	Allogeneic or autologous transplantation, No immunogenicity, pluripotent	Need for expansion
Skeletal myoblast	Autologous transplantation, high yield No immunogenicity	Electro-physiologically incompatible, arrhythmogenic no gap junction formation

VI. CONCLUSION

Personalized stem cell reprogramming seems to be a less explored area in stem cell research. A recent report also suggested the effect of age on the quantity and quality of cardiosphere-derived cells (20). The effect of ageing, food habits and epigenetics on stem cells needs to be addressed.

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