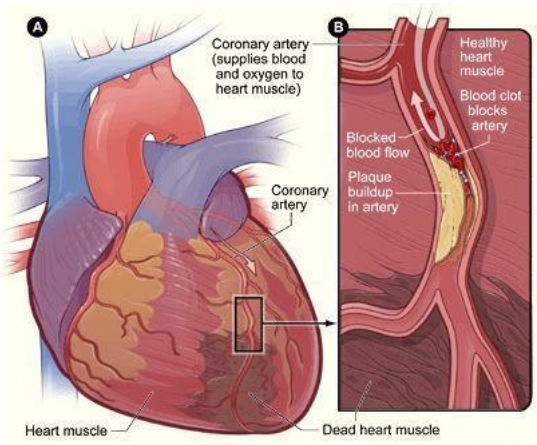
Myocardial infarction (heart attack)

Introduction

Definition and overview:

Myocardial infarction is the scientific name for the condition that is known as heart attack. A myocardial infarction is a medical case where the heart muscle begins to die due to the lake of blood flow reaching to it. This lack of blood flow can occur because of many different factors but mostly from the blockage that may happen in the arteries that supports the heart. Also, a myocardial infarction can cause permanent heart damage and death.

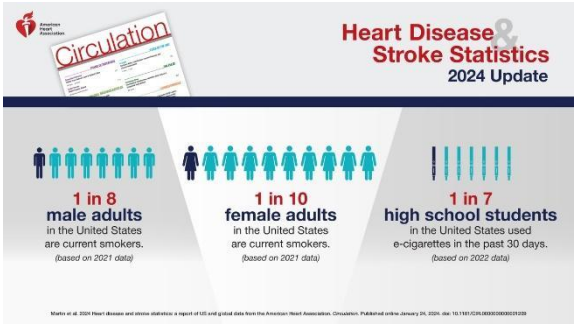


Historical context:

The process of diagnosing myocardial infarction (MI) has improved in a noticeable way over time. 4000 years ago, ancient Egyptians noticed signs of atherosclerosis. In the 19th century, the fundamental concepts of thrombogenesis related to heart attacks were introduced. In 1879, coronary thrombosis was connected to MI. By 1912, bed rest and active monitoring were pointed out for heart attack patients. By the late 1990s, the introduction of troponins was seen as highly specific and sensitive markers for cardiac injury. In 1971, the WHO standardized the first definition of acute myocardial infarction. By 2000, the ESC/ACC committee designated cardiac troponins as the gold standard for diagnosis. The third universal definition of myocardial infarction was updated in 2012 to reflect new developments. In the meantime, troponins are the preferred biomarkers for diagnosing and managing myocardial infarction.

Epidemiology:

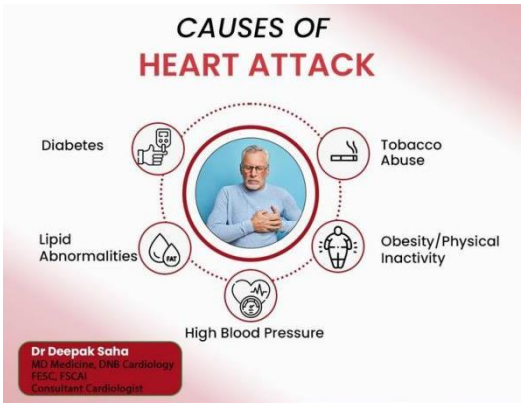
Today, MI is the main cause of over 15% of deaths worldwide and the rates of deaths are typically higher in high-income countries. Adults are more likely to get a MI with men experiencing it at a younger age compared to women.



Etiology

Causes and risk factors:

The most common cause of heart attacks is coronary artery disease, which is caused by cholesterol plaques blocking heart arteries. Severe squeezing of an artery, mainly caused by cholesterol plaques or early vessel hardening can lead to MI. Virus-related infections, including COVID-19, may damage the heart muscle. A tear inside a heart artery that can also lead to MI. Men older than 45 and women older than 55 are at high risk of getting MI. Tobacco usage, high blood pressure, excess body weight, stress, illegal drug usage…etc. are putting the person in the risk of getting MI.



Genetic and environmental influences:

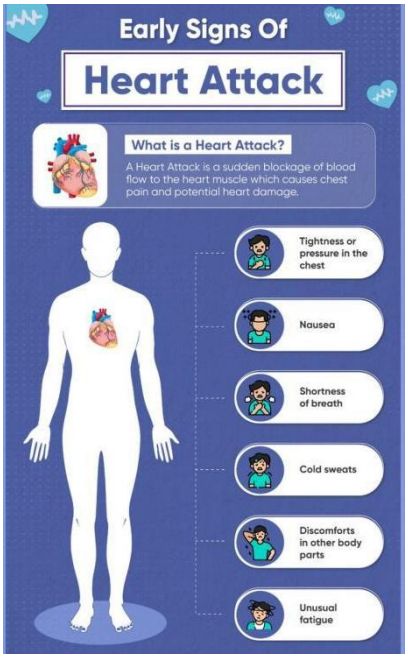
A family history, genetic disorders, cholesterol metabolism, and individuals with a genetic inclination towards higher stress sensitivity are from genetic factors that may lead to MI. Environmental influences that may cause MI are the following: exposure to pollutants like nitrogen dioxide, living in areas with limited access to healthcare, and extreme temperatures (cold and hot).

Clinical Features

Signs and symptoms:

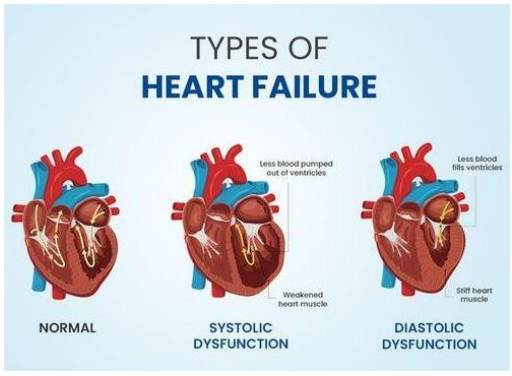
Often, there are no symptoms of the underlying disease of the blood vessels. A myocardial infarction or stroke may be the first sign of underlying disease. Symptoms of a heart attack may include pain or discomfort in the center of the chest and/or pain or discomfort in the arms, the left shoulder, elbows, jaw, or back. In addition, the person may have trouble in breathing or shortness of breath; nausea or vomiting; light-headedness or

faintness; a cold sweat; and turning pale. Women are more likely than men to have shortness of breath, nausea, vomiting, and back or jaw pain. The most common symptom of a myocardial infarction is sudden weakness of the face, arm, or leg, most often on one side of the body. Other symptoms include sudden beginning of:
- numbness of the face, arm, or leg, especially on one side of the body.
- confusion, difficulty speaking or understanding speech.
- difficulty seeing with one or both eyes.



difficulty walking, dizziness and/or loss of balance or coordination. severe headache with no known cause; and/or fainting or unconsciousness.
Women may have atypical symptoms such as brief or sharp pain felt in the neck, arm or back. Sometimes, the first symptom sign of a myocardial infarction is sudden cardiac arrest. Some heart attacks strike suddenly. But many people have warning signs and symptoms hours, days or weeks in advance. Chest pain or pressure (angina) that keeps happening and doesn't go away with rest may be an early warning sign. Angina is caused by a temporary decrease in blood flow to the heart.

Disease stages and progression:



Stage 1: Stopped myocardial infarction (no/minimal myocardial necrosis). No or minimal damage to the heart muscle. In the best case the entire area of myocardium at risk may be rescued.
Stage 2: Myocardial infarction with significant cardiomyocyte necrosis, but without microvascular injury. Damage to the heart muscle and no injury to small blood vessels in the heart.
Stage 3: Myocardial infarction with cardiomyocyte necrosis and microvascular dysfunction leading to microvascular obstruction. Damage to the heart muscle and blockage of small blood vessels in the heart.
Stage 4: Myocardial infarction with cardiomyocyte and microvascular necrosis leading to reperfusion hemorrhage. Damage to the heart muscle, blockage and rupture of small blood vessels resulting in bleeding into the heart muscle.

Complications:

Most complications present < 24 hours after an acute myocardial infarction, but mechanical complications may occur anytime in the first week after an acute myocardial infarction. Complications during hospitalization for acute myocardial infarction may include: cardiogenic shock, acute heart failure, right ventricular infarction, mechanical complications, electrical complications (such as ventricular arrhythmias, atrial fibrillation, and atrioventricular block.), ischemic complications (such as reinfarction, infarct extension, and postinfarction angina.), embolic, thrombotic, and bleeding complications (such as left ventricular thrombus, venous thromboembolism, and vascular access site bleeding after percutaneous coronary intervention.), and pericardial complications such as pericarditis.

Diagnosis

Diagnostic criteria:

Patients with MI typically experience chest pain or discomfort, which is often described as pressure, squeezing, fullness, or pain in the center of the chest. This pain in the arms, neck, jaw, or back, and is repeatedly accompanied by other symptoms such as shortness of breath, nausea, vomiting, sweating, and lightheadedness.

Diagnostic tests and procedures:

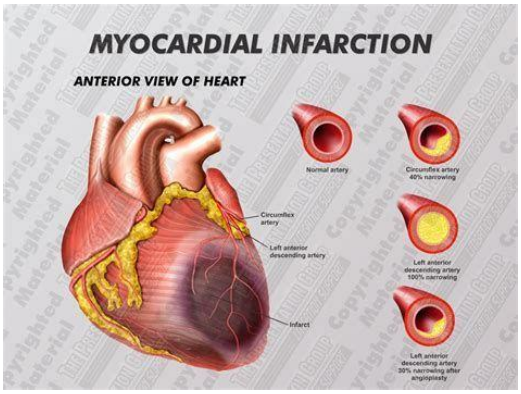
Taking a detailed history background and physical examination from the patient are very important in diagnosing MI. Physicians should carefully explore the nature, onset, and duration of chest pain, along with associated symptoms like shortness of breath, nausea, and sweating.
Additional laboratory tests that should be taken to complement the diagnostic process are the following:
- Blood Tests include complete blood count (CBC), lipid profile (cholesterol and triglycerides), and blood glucose (HbA1c).
- Stress Testing: Both exercise and pharmacologic stress tests evaluate the heart's response to physical exertion or medications.
There are also additional procedures like intracoronary imaging techniques which includes intravascular ultrasound (IVUS) and optical coherence tomography (OCT) provide detailed images of coronary artery walls.

Differential diagnosis:

The differential diagnosis of MI divides into two parts, which are the following:
- Cardiac causes which includes unstable angina, pericarditis, aortic dissection, pulmonary embolism, takotsubo cardiomyopathy, and myocarditis.
- Non-cardiac causes which include gastrointestinal conditions, musculoskeletal conditions, panic attack, pleurisy, and pneumonia.

Pathophysiology

Mechanisms of disease development:



Atherosclerosis formation aims to damage the endothelial lining of coronary arteries due to high blood pressure, smoking, or high cholesterol. Plaque rupture which is thinning of the fibrous cap exposes the lipid core, activating platelets and leading to thrombus formation. Platelet aggregation where platelets adhere to the exposed plaque and form a thrombus, leading to artery occlusion. Coronary artery occlusion where thrombus can completely block the artery, causing myocardial ischemia and infarction. Restoration of blood flow which means revascularization therapies can cause oxidative stress and inflammation, potentially worsening tissue damage.Energy depletion and ion imbalance it happens when ischemia leads to ATP depletion, intracellular calcium overload, and activation of cell death pathways.

Cellular and molecular changes:

Energy depletion & ion imbalance: reduced ATP production and calcium/sodium buildup disrupt cell function.
Cellular injury: prolonged lack of oxygen leads to cell death. Inflammatory response: neutrophils and macrophages exacerbate tissue damage and aid in cleanup.
Oxidative stress: reperfusion creates reactive oxygen species that damage cells.
Mitochondrial dysfunction: calcium overload and oxidative stress lead to cell death.
Scar formation: fibroblasts create scar tissue and cause cardiac remodeling.
Clinical signs: changes in ECG and elevated troponin levels indicate heart damage.
Long-term effects: increased risk of heart failure and arrhythmias; secondary prevention involves medications and lifestyle changes.

Impact on body systems:

Cardiovascular system: Myocardial damage may happen due to infarction that leads to irreversible cardiac muscle cell damage, impairing contractility and reducing cardiac output. Also, heart failure can be a result of the decreased pumping efficiency and structural heart changes after MI. Respiratory system: left-sided heart failure post-MI can cause pulmonary congestion and edema, leading to dyspnea and respiratory distress. Renal system: reduced cardiac output can lead to renal ischemia and AKI. Nervous system: thromboembolic events post-MI can lead to ischemic strokes. Immune System: MI triggers an inflammatory response, influencing systemic immune function.

Management and Treatment

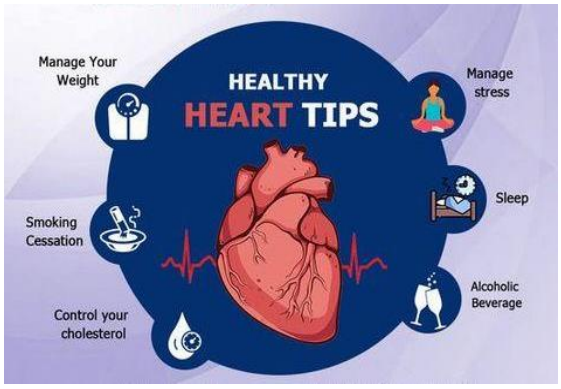
Medical and surgical treatments:

Medical treatments for MI include reperfusion therapy, antiplatelet and anticoagulant therapy, beta-blockers, ACE inhibitors, and statins. However, surgical interventions in the meantime revolves around the coronary artery bypass grafting which is used when medical therapy is insufficient or for complex coronary artery disease, involves bypassing blocked arteries with healthy blood vessels.

Pharmacological therapies:

Antiplatelet agents like aspirin and P2Y12 inhibitors. Anticoagulants like unfractionated heparin and low molecular weight heparins. Thrombolytic therapy like fibrinolytic agents. Beta-blockers like metoprolol, carvedilol, and bisoprolol.

Lifestyle and dietary modifications:



To help preventing getting MI, you should educate yourself about the healthy lifestyles and dietaries hobbies such as the following: increasing physical activities, quit smoking, focus on eating healthy food, weight and stress management, alcohol moderation, and regular medical check-ups.

Rehabilitation and supportive care:

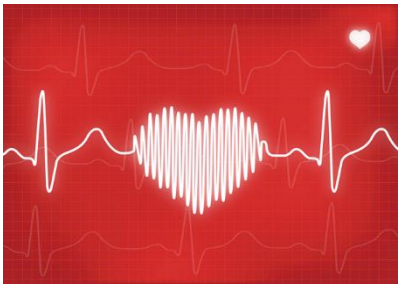
Cardiac rehabilitation programs focus on education, counseling, and psychosocial challenges.

Prevention and Control

Primary, secondary, and tertiary prevention strategies:

- Primary prevention helps to prevent the initial occurrence of MI. it evolves around adopting a heart-healthy diet (fruits, vegetables, whole grains, lean proteins), regular exercise, smoking cessation, and moderate alcohol consumption.
- Secondary prevention helps to prevent recurrence and progression of MI in individuals who have had an initial event, and it focuses mainly on using medicals and continuously monitoring.
- Tertiary prevention minimize disability, improve quality of life, and reduce mortality in individuals who have experienced MI. It focuses on maintaining cardiovascular fitness, addressing chronic conditions, and promoting heart-healthy behaviors.

Public health interventions:



The public health interventions involve but not limited to the following: awareness campaigns and education, risk factor awareness, symptom recognition, promotion of healthy lifestyle, nutrition education, physical activity problems, and tobacco control.

Vaccination and screening programs:

Influenza vaccination targets individuals with cardiovascular diseases, the elderly, and healthcare workers. It aims to reduce flu-related complications that can trigger cardiovascular events. Pneumococcal vaccination focuses on adults over 65 and younger individuals with certain medical conditions. Protects against pneumonia and invasive pneumococcal diseases. Helps mitigate cardiovascular risks associated with systemic inflammation and infection-induced stress.

- Screening programs:
Cardiovascular risk factor screening includes blood pressure monitoring, lipid profiles, and blood glucose tests. Aims to identify high-risk individuals early and enable timely interventions. Electrocardiography (ECG) screening detects abnormalities in heart rhythm and electrical activity, indicating potential underlying heart conditions. Integral to routine health check-ups and targeted programs in community settings, workplaces, and health fairs. Facilitates early detection and referral to specialized cardiovascular care.

Prognosis

Disease outcomes and survival rates:

About 805,000 people have a heart attack every year in the United States. Of these, 605,000 are a first heart attack, and 200,000 are people who have already suffered one before. Not all myocardial infarctions are noticeable. In fact, one in five is silent. A silent heart attack is where the heart is damaged by irregular blood flow without obvious symptoms.
Chances of survival depend on the severity of the myocardial infarction. According to recent studies, massive heart attack survival rates are low, but the survival rate after heart attacks in hospital care is between 90% to 97%.

Factors influencing prognosis:

There is so many factors that influences the prognosis of MI, but the most important are the following: extent of myocardial damage, timeliness of reperfusion therapy, presence of

complications, underlying cardiovascular health, age and sex, secondary prevention strategies, psychological factors, and genetic and biological factors.

Quality of life: influencing prognosis:

Common symptoms include chest pain, shortness of breath, fatigue, and reduced exercise tolerance, which are symptoms of post-MI, may limit daily activities and quality of life. Moreover, anxiety, depression, and PTSD are common post-MI symptoms.

Current Research and Future Directions

Recent advances and discoveries:

- Adoption of distal embolic protection devices and bioresorbable scaffolds, and techniques tailored to individual patient needs, reducing complications and enhancing recovery. Utilization of remote monitoring, wearables, and mobile apps for patient engagement in recovery. Real-time data exchange supports early intervention and self-management, improving accessibility and quality of life.

Ongoing clinical trials:

CeleCor Therapeutics - Zalunfiban (Phase III Trial): this trial values safety and efficacy in treating ST-elevation myocardial infarction. BioCardia - CardiAMP Cell Therapy (Phase III Trial, NCT02438306): this trial evaluates safety and efficacy in heart attack patients, focusing on high-risk ischemic cardiomyopathy. Thrombolytic Science International - HisproUK (TS-01, Phase II Trial): this trial tests safety and efficacy in clearing blocked blood vessels post-cardiac arrest.

Future research needs:

The world needs additional research in the field of MI because it is a very dangerous disease. Thus, the following are some points that should be covered scientifically to help maintaining MI cases. Develop personalized treatments based on genetic profiling and

biomarkers to optimize therapy. Enhance technologies and predictive models for identifying high-risk individuals before symptoms appear. Explore new drugs and therapies. Refine percutaneous coronary intervention (PCI) techniques and develop novel devices for revascularization. Advance stem cell-based therapies to repair damaged cardiac tissue and improve long-term outcomes.

Conduct longitudinal studies to assess long-term outcomes, recurrence rates, and complications post-MI.

Develop effective primary prevention programs focusing on lifestyle modifications.

Case Studies

Example cases:

The case report of a 66-year-old man with systemic hypertension and a chronic smoker that presented with acute severe chest pain. After medical assessment, he was diagnosed with acute myocardial infarction and the patient underwent coronary angiography, which disclosed proximal occlusion of the left anterior descending artery with images suggesting the presence of thrombi. He was submitted to balloon-angioplasty in the affected segment without restoration of distal coronary flow (unsuccessful procedure) and the patient developed irreversible cardiac arrest and died.

The autopsy confirmed acute myocardial infarction, which was very extensive, affecting the left ventricular anteroseptal wall and the right ventricular anterior wall. Histological dating was 24-48 hours of onset, consistent with the clinical history. It is noteworthy the fact that the detailed examination of the ventricular septum showed the presence of two previous microinfarctions, an old (healed) one and an ongoing one.

The presence of atherosclerosis of the coronary arteries was identified, with massive plaques in the proximal segment of the left anterior descending artery, which resulted in chronic obstruction of 80% of the lumen. The fatty plaques had extensive lipid cores and there were areas of marked thinning of the fibrous cap that covered the cores, as well as areas of rupture associated with acute thrombosis of the remaining lumen in the first two centimeters of the left anterior descending artery. It is known that acute coronary occlusions with luminal thrombosis are usually associated with large lipid-core plaques, which undergo rupture due to the instability of their thin fibrous cap, as observed in this case.

Aside from the great extent of the infarcted area, the patient developed an important mechanical complication of acute myocardial infarction, the occurrence of ventricular septal rupture with the establishment of VSD - which certainly aggravated his hemodynamic condition, progressing to cardiogenic shock -, acute pulmonary edema and death. It should be emphasized that the patient had two classic risk factors for atherosclerosis and myocardial infarction: systemic hypertension and chronic smoking.