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THE MECHANISM OF ATHEROSCLEROSIS IMPACT ON CARDIAC FUNCTION.

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Abstract: Atherosclerosis is the buildup of fats, cholesterol, and other substances in and on the artery walls (plaques), which can restrict blood flow or rupture and trigger blood clots. While it is commonly associated with coronary artery disease, it can affect arteries throughout the body. This article explores the pathophysiology of atherosclerosis, especially how it impacts the heart. The review includes developmental stages of atherosclerosis, its systemic effects, diagnostic techniques, clinical manifestations, and both pharmacological and interventional treatment options.
Keywords: atherosclerosis, plaque, cholesterol, ECG, blood test, endothelial dysfunction, thrombosis, atherosclerotic lesion, heart attack, stroke, carotid angiography, beta blocker, stent, infarction, echocardiography, arrhythmia, LDL, chronic inflammation, physical activity, diet, nitroglycerin, statins, stress, blood flow, valve, ischemia, myocardium, thrombus, fibrinosis, shortness of breath, tachycardia, cardiomyopathy, necrosis, subclinical atherosclerosis, genetic predisposition.

INTRODUCTION

Atherosclerosis is the main enemy of the cardiovascular system, which develops slowly, but if not monitored or controlled, can lead to heart attack and heart failure. Serious complications of this disease can be prevented through timely diagnosis, a healthy lifestyle, and the use of modern treatment measures.

Atherosclerosis is a chronic, progressive inflammatory disease characterized by the accumulation of lipids, cellular elements, and fibrous tissues within the arterial wall, forming plaques. This process can narrow arteries and restrict blood flow, leading to ischemic conditions like heart attacks and strokes. It is initiated by endothelial dysfunction and perpetuated by oxidative stress, lipid infiltration, and immune response. Importantly, the disease often begins silently in adolescence or even childhood and progresses over decades.

Epidemiology: Globally, cardiovascular diseases remain the leading cause of mortality, with atherosclerosis being a primary contributor. According to the World Health Organization, approximately 17.9 million people die each year from cardiovascular diseases. In low- and middle-income countries, limited access to quality health care and poor water and food safety exacerbate the prevalence of atherosclerosis. Urbanization, sedentary lifestyles, smoking, and unhealthy diets significantly contribute to the global burden.

Types of Atherosclerosis:

- **Subclinical atherosclerosis:**

It begins without symptoms and can only be detected through specialized diagnostic examinations.

- **Clinical atherosclerosis:**

It presents with conditions such as coronary heart disease, myocardial infarction, stroke, or impaired blood circulation in the lower extremities.

Aspect	Description
Type	Chronic inflammatory arterial disease
Onset	Begins with endothelial dysfunction
Main factors	LDL, inflammation, genetic predisposition
Development	Progresses gradually over years
Complications	Heart attack, stroke, sudden death

Stages of Atherosclerosis

1. Endothelial Dysfunction: The inner lining of healthy blood vessels, the endothelium, regulates blood flow and protects against inflammation. However, factors such as high blood pressure, smoking, diabetes, and poor diet can damage endothelial cells, leading to the onset of atherosclerosis.

2. LDL Accumulation and Oxidation: Low-density lipoproteins (LDL) enter the endothelial layer and become oxidized. Oxidized LDL is recognized by the immune system as a foreign substance, initiating the inflammatory process.

3. Macrophages and Foam Cells: Macrophages that ingest oxidized LDL become foam cells. These cells play a key role in the formation of plaque (atheroma).

4. Smooth Muscle Cell Proliferation: Inflammatory mediators stimulate smooth muscle cells to migrate into the intima and proliferate. These cells produce collagen, stabilizing the plaque.

5. Plaque development and calcification: Over time, plaques enlarge, calcium builds up, and the plaque hardens. This reduces the elasticity of blood vessels and restricts blood flow.

6. Plaque rupture and thrombosis: Unstable plaques rupture, releasing plaque material into the bloodstream. This can cause blood to clot, forming a blood clot, which can lead to a heart attack or stroke.

MATERIALS AND METHODS

Atherosclerosis is not just a lipid accumulation, but an inflammatory process. Oxidized LDL activates the immune system and releases inflammatory mediators. This affects the growth and stability of plaque.
• Modifiable factors: Smoking, high blood pressure, high cholesterol, diabetes, poor diet, lack of physical activity.
• Non-modifiable factors: Age, gender, genetic predisposition. Atherosclerosis is not only a disease of adults, but is now also widespread in adolescents. As evidence for our statement, the Pathobiological Determinants of Atherosclerosis in Youth Study was a multi-institutional autopsy study conducted at US medical centers that included 2,876 black and white men and women aged 15 to 34 years who died of external causes and underwent autopsy between June 1, 1987, and August 31, 1994. The main outcome measures were the extent, distribution, and topography of atherosclerotic lesions.

Treatment method:
1. Drug treatment:

Drug	Effect
Aspirin	Blocks platelet aggregation and reduces the risk of heart attack
Clopidogrel	Given when aspirin is contraindicated or in combination with aspirin

Statins (lower cholesterol levels)	
Drug	**Effect**
Atorvastatin, rosuvastatin	Reduces LDL levels, increases plaque stability
According to Braunwald: lowering LDL to <1.4 mmol/l significantly reduces atherosclerotic risk	

Beta-blockers (reduce the workload of the heart)	
Drug	**Effect**
Bisoprolol, metoprolol	Slows the heart rate, reduces ischemia

ACE inhibitors or ARBs (vasodilators, protect the heart)	
Drug	**Effect**
Enalapril, Ramipril/losartan	Lowers blood pressure, reduces cardiac remodeling

Nitrates (to reduce pain)	
Drug	**Effect**
Nitriglitserin (til ostiga)	Dilates coronary vessels, reduces chest pain

II. Lifestyle changes
Key recommendations:
• Quitting smoking is one of the strongest risk factors.
• Lowering cholesterol is limiting animal fats.
• Reducing salt intake is to control blood pressure.
• Physical activity is at least 150 minutes of walking/jogging per week.
• Diet is a healthy diet similar to the DASH or Mediterranean diet.
III. Interventional (surgical) treatment
1. Percutaneous coronary intervention (PCI - stent placement)
• The blocked area is expanded with a balloon and a stent is placed.
• Usually used in acute infarction or symptomatic stenosis.
2. Coronary artery bypass grafting (CABG)

• In severe stenoses or multivessel disease, a blood circulation path is created around the heart vessels.
IV. Additional treatment and monitoring
• Regular monitoring with ultrasound of the heart (echocardiography).
• Rhythm monitoring with ECG.
• Blood lipid profile check every 3 months.
• Rehabilitation: Special physical rehabilitation program for those with heart disease.

RESULTS

Let's look at the impact of atherosclerosis, which is part of clinical atherosclerosis, on the heart.
1. Early stages of atherosclerosis related to the heart
1.1 Endothelial dysfunction - the beginning of heart problems
• The inner layer (endothelium) of the heart arteries (coronary arteries) is damaged (due to smoking, hypertension, diabetes).
• This condition reduces the production of nitric oxide (NO) and impairs vasodilation (blood vessel dilation).
Evidence: Endothelial dysfunction is considered an early sign of ischemic heart disease.
2. Lipid infiltration and plaque formation
2.1 Oxidized LDL - triggers inflammation
Source: Vascular Medicine: A Companion to Braunwald's HD, Ch. 10
• Oxidized LDL accumulates under the endothelium.
• These substances attract **immune cells (macrophages)**.
• Macrophages engulf LDL and become **foam cells**.
Evidence: The 2001 PDAY Study confirmed that plaques are present in young people and that this process is associated with lipid accumulation.
3. Plaque Growth – Restriction of Blood Flow to the Heart Muscle
3.1 Coronary Arteries Narrow
Source: Harrison's Internal Medicine, Vol. II, Section: Cardiovascular Disease
• When the arteries narrow, the myocardium (heart muscle) is starved of oxygen.
• This condition leads to angina pectoris (heart pain) or myocardial ischemia.
Evidence: Symptoms occur when coronary plaques are 70% or more narrowed.
4. Plaque Rupture and Heart Attack (Infarction)
4.1 Thrombosis and Heart Muscle Damage
Source: Braunwald's HD, Ch. 53 – Acute Coronary Syndromes
• When a plaque ruptures, the underlying lipids are exposed.
• When it comes into contact with blood, platelets aggregate to form a thrombus.
• Blood flow is blocked and part of the heart muscle dies.
Evidence: 75% of myocardial infarctions are associated with plaque rupture and thrombosis.
5. Heart failure and heart failure
5.1 Ischemic cardiomyopathy
Source: Braunwald's HD, Ch. 57 – Heart Failure
• After repeated ischemia, the heart muscle remodels – it stretches and loses its contractility.
• This leads to a decrease in ejection fraction, i.e., the pumping power of the heart.
Evidence: Atherosclerotic disease is reported to be the cause of 60–70% of cases of heart failure.
Intimal lesions were found in all aortas and more than half of the right coronary arteries in the youngest age group (15-19 years), and their prevalence and severity increased with age in the oldest group (30-34 years). Fatty streaks were wider in Black individuals than in White

individuals, but raised lesions did not differ between these groups. Raised lesions in the aortas of women and men were similar, but raised lesions in the right coronary arteries were less frequent in women compared to men. The overall prevalence of lesions was lower in the right coronary artery than in the aorta, but the proportion of raised lesions among all lesions was higher in the right coronary artery compared to the aorta.
From the study, it can be concluded that atherosclerosis begins in youth. Between the ages of 15 and 34, the prevalence and severity of fatty streaks and clinically significant raised lesions increase rapidly. Primary prevention of atherosclerosis, unlike primary prevention of clinically manifest atherosclerotic disease, may begin in childhood or adolescence.

DISCUSSION

The main clinical signs of atherosclerosis affecting the heart
1. Stable angina pectoris (stable heart pain)
Source: Braunwald's HD, Ch. 56
• Occurs when the heart arteries are narrowed by more than 70%.
• The pain is pressing, squeezing in the chest area, aggravated by physical exertion, and relieved by rest.
• Often radiates to the left arm, neck, or jaw.
Evidence: Braunwald's stable angina is associated with a gradual narrowing of the heart arteries.
2. Irregular heart rhythms (arrhythmias)
Source: Harrison's IM, Vol. 2, Cardiovascular Section
• Myocardial ischemia disrupts the electrical conduction in the heart muscle.
• Sinus tachycardia, bradycardia, ventricular extrasystoles, or fibrillations are observed.
• Cardiac arrhythmias are especially common in myocardial infarction.
Evidence: Some type of arrhythmia is detected in 80% of patients with ischemic heart disease.
3. Shortness of breath (dyspnea)
Source: ESC Guidelines 2021
• The heart muscle begins to work poorly due to lack of oxygen → left ventricular pressure increases → pulmonary circulation is impaired.
• Shortness of breath occurs during physical activity and even at rest.
Evidence: Shortness of breath is the earliest and most common symptom of heart failure, which is ischemic heart disease.
4. Pain that progresses to symptoms of a heart attack (myocardial infarction)
Source: Braunwald's HD, Ch. 53 – Acute Coronary Syndromes
• Pain lasts more than 20 minutes as a result of plaque rupture and sudden blockage of the vessel.
• Nitrates do not help.
• Sweating, nausea, increased heart rate, fainting are observed.
Evidence: Myocardial infarction is associated with plaque rupture and thrombosis and is manifested by acute pain in 80–90% of cases.
5. Symptoms of heart failure
Source: Braunwald's HD, Ch. 57 – Heart Failure
• The heart muscle weakens → blood circulation slows down.
• Symptoms: swelling in the legs, shortness of breath at night, fatigue during physical activity.
• Blood output from the heart is reduced (low ejection fraction).
Evidence: Ischemic heart disease is one of the most common causes of heart failure.

Clinical sign	Description	Reason
Chest pain	Compressive, pressing, spreads to the left hand	Narrowing of the artery
Shortness of breath	In activity or at rest	Decreased cardiac output
Heartbeat disorder	Fast, irregular, or slow heartbeat	Electrical conductivity disorder
Swelling in the legs	Swelling in the feet, heels, and calves	Heart failure
Fainting, weakness	Anemia, decreased cardiac output	Coronary blockage or arrhythmia

Diagnostics: There is an arsenal of diagnostic tests and tools to confirm the presence of atherosclerosis - these include angiogram (arteriogram), cholesterol tests, chest x-ray, CT (computed tomography), duplex scanning, echocardiogram, electrocardiogram (EKG or stress test (EKG)), ultrasound, MRI (magnetic resonance imaging), PET (positron emission tomography), and pharmacological stress testing.

Blood tests – Blood tests check the levels of certain fats, cholesterol, sugars, and proteins in the blood, and abnormal levels can indicate risk factors for atherosclerosis.

ECG (electrocardiogram) - An ECG is a simple test that detects and records the electrical activity of the heart, showing how fast the heart is beating and whether it has a regular rhythm. It also shows the strength and timing of electrical signals as they travel through each part of the heart. Certain electrical patterns detected by an ECG may indicate the possibility of CAD. An ECG can also show signs of a previous or current heart attack.

Chest X-ray - A chest X-ray takes pictures of the organs and structures inside the chest, including the heart, lungs, and blood vessels - a chest X-ray can also detect signs of heart failure.

Ankle/Brachial Index - This test compares the blood pressure in your ankle with the blood pressure in your arm to see how well your blood is flowing. This test helps diagnose PAD.

Echocardiography - This test uses sound waves to create a moving picture of your heart and provides information about the size and shape of your heart, and how well its chambers and valves are working. The test can also identify areas of poor blood flow to the heart, areas of the heart muscle that are not contracting normally, and previous damage to the heart muscle due to poor blood flow.

Stress test - During a stress test, exercise is used to make the heart work harder and faster, and heart tests are performed - if the person is unable to exercise, drugs are given to make the heart beat faster. When the heart is working harder and faster, it needs more blood and oxygen, and arteries narrowed by plaque cannot supply enough oxygen-rich blood to meet the heart's needs - a stress test can show possible signs of CAD, such as:

Abnormal changes in heart rate or blood pressure;

Symptoms such as shortness of breath or chest pain;

Abnormal changes in heart rhythm or electrical activity of the heart.

During a stress test, if a person is unable to exercise for a period of time that is considered normal for their age, this may be a sign that not enough blood is flowing to the heart. - but other factors besides CAD may also prevent a person from exercising for long enough (such as lung disease, anemia, or poor general fitness).

Some stress tests use radioactive dye, sound waves, positron emission tomography (PET), or cardiac magnetic resonance imaging (MRI) to take pictures of your heart working hard and at rest. - These imaging stress tests can show how well blood is flowing through different parts of the heart and how well the heart is pumping blood when it beats.

Angiography - Angiography is a test that uses dye and special X-rays to show the inside of the arteries and can tell if plaque is blocking the arteries and how severe the plaque is. A thin, flexible tube called a catheter is inserted into a blood vessel in the arm, thigh (upper thigh), or neck. The dye, which is visible on X-ray, is then injected into the arteries, and the doctor can see the blood flow through the arteries by looking at the X-ray images.

Echocardiography - An ultrasound examination of the heart. This test examines the contractility of the heart muscle, wall motion abnormalities (hypokinesia or aknesia), blood flow, and valve function.

Myocardial perfusion scan (MPT) - SPECT or PET - this test measures the level of oxygen and blood flow to parts of the myocardium. It helps detect hidden ischemia.

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