Research Progress on Atherosclerosis

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Abstract. Atherosclerosis is one of the major risk factors for cardiovascular disease, and its incidence has significantly increased under the background of changes in lifestyle and diet structure in modern society. The pathogenesis of atherosclerosis mainly involves multiple pathological processes such as inflammation, lipid deposition and oxidative stress. At present, clinical treatment strategies mainly include anti-inflammatory therapy, lipid-regulating therapy and antiplatelet therapy. In terms of prevention, comprehensive interventions such rational diet, regular exercise, smoking cessation and limiting alcohol intake have been shown to be effective in reducing the risk of atherosclerosis.

Keywords: Atherosclerosis, Pathogenesis, Treatment, Prevention

1 Introduction

Atherosclerosis is a common disease of the arteries. The lesion begins in the intima of the artery with major pathological features including lipid aggregation, fibrous tissue hyperplasia and calcinosis, which then locally forms atherosclerotic plaque [1]. According to statistics, about 20 million people worldwide die each year from cardiovascular-related diseases [2]. As the main pathological basis of cardiovascular and cerebrovascular diseases, atherosclerosis can cause serious complications such as myocardial infarction and stroke, posing a major threat to global public health [3]. The purpose of this article is to review the pathogenesis, treatment strategy and prevention measures of atherosclerosis in order to provide references for clinical practice and disease management.

2 Clinical Manifestation

Atherosclerosis is a systemic disease that affects blood vessels in all parts of the body, especially coronary arteries, carotid arteries, renal arteries and peripheral arteries [4]. The early stages of atherosclerosis often have no obvious clinical manifestations, but once the artery is embolized, the artery wall can harden and form plaque, leading to organ ischemia and associated symptoms. Depending on the vessels involved, the clinical manifestations may vary. Coronary atherosclerosis can lead to many complications

K. Bellitürk et al. (eds.), *Proceedings of the 2025 2nd International Symposium on Agricultural Engineering and Biology (ISAEB 2025)*, Advances in Biological Sciences Research 50,
https://doi.org/10.2991/978-94-6463-910-0_7

such as angina pectoris, myocardial infarction and myocardial fibrosis [5]. Due to insufficient blood supply to the heart muscle, patients usually have chest pain, shortness of breath and palpitations, which can even lead to acute myocardial infarction, which is life-threatening. Carotid atherosclerosis can lead to transient ischemic attacks and ischemic stroke, which are characterized by abnormal sensory and motor function in one limb, vision loss, memory loss, headache and dizziness [6]. Renal atherosclerosis may cause renal artery thrombosis and refractory hypertension [7]. Chronic ischemia can lead to pain in the kidney area and atrophy of the kidney, which may eventually progress to renal failure. Patients often have proteinuria due to renal insufficiency, and then hypoproteinemia occurs. Patients with peripheral atherosclerosis often have no obvious symptoms, and a small number of patients may experience lower limb ischemia, resulting in lower limb pain, weakness, and numbness, with intermittent claudication [8]. In severe cases, patients may develop complications such as ulcers and gangrene.

3 Pathogenesis

3.1 Inflammation

The inflammatory theory holds that monocyte aggregation is the key initiating factor of atherosclerosis. Studies have shown that monocytes preferentially attach to atherosclerotic plaques, adhere to the surface of endothelial cells, and eventually enter the intima of blood vessels and differentiate into macrophages [9]. In the early stages of atherosclerosis, macrophages are able to engulf denatured LDL, convert into foam cells, and form early fat streaks. In addition, macrophages induce the production of a variety of inflammatory factors, causing more immune cells to migrate into the arterial plaque, thus accelerating the progression of the disease. In the advanced stages of atherosclerosis, macrophages degrade the extracellular matrix by secreting proteases, leading to plaque rupture, which may eventually form blood clots, seriously endangering life [10].

3.2 Lipid Deposition

Elevated blood lipids are one of the main factors leading to atherosclerosis [11]. In a state of hyperlipidemia, the concentration of low-density lipoprotein cholesterol (LDL) in the plasma is significantly increased, prompting large amounts of LDL to be deposited in the inner lining of the arteries. As the cells in the inner lining of the artery become damaged and dysfunctional, their permeability also increases, resulting in circulating lipoproteins in the blood entering the inner lining more easily. As shown in Figure1, the LDL that enters the inner membrane is transformed by oxidation into oxidized low-density lipoprotein, and these oxidized LDL are swallowed and absorbed by macrophages, eventually forming foam cells rich in cholesterol esters. This process breaks the balance between the inflow and outflow of cholesterol, which easily leads to the accumulation of lipids, which promotes the formation of arterial plaque [12].

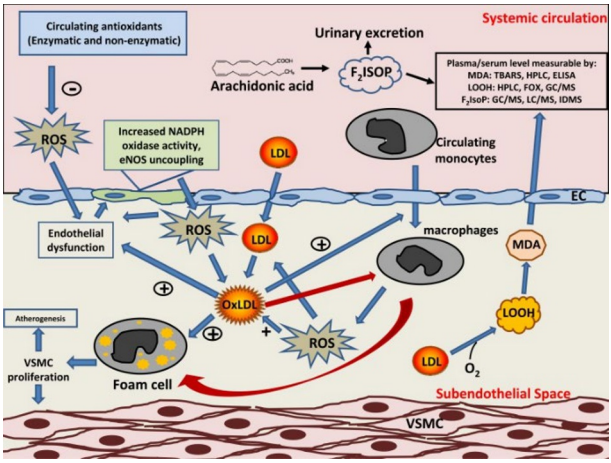

Fig. 1. The role of LDL in atherosclerosis [13].

3.3 Oxidative Stress

Reactive Oxygen Species (ROS) are a class of highly chemically active oxygen-containing molecules whose excessive or persistent production can trigger significant oxidative stress responses [14]. When low-density lipoprotein cholesterol (LDL) is deposited on the lining of arteries, ROS is produced in large quantities, which accumulates in the body, causing cytotoxic effects and activating oxidative stress responses [15]. As shown in Figure 2, excessive ROS can cause vascular dysfunction, cell damage, and point mutations and even aberrations in DNA, which further promote the formation of atherosclerosis.

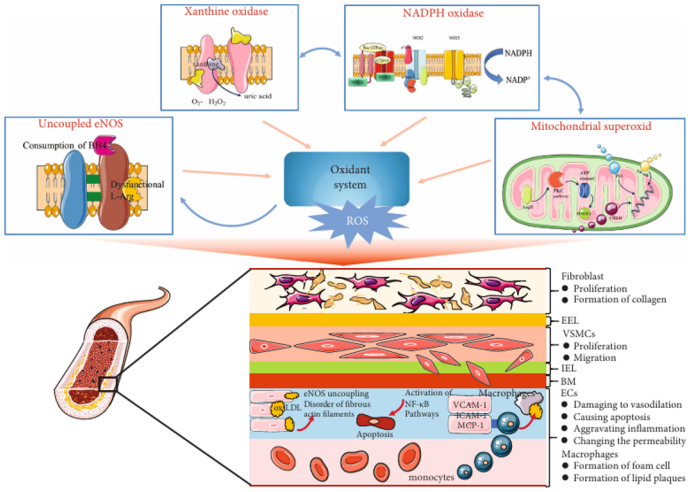

Fig. 2. The role of ROS in atherosclerosis [16].

3.4 The Interactions Between Inflammation, Lipid Deposition, and Oxidative Stress

The pathogenesis of atherosclerosis involves lipid deposition, oxidative stress, and inflammation in a self-amplifying cycle. Oxidized LDL (ox-LDL) forms via NADPH oxidase/myeloperoxidase activity, promoting foam cell formation via scavenger receptors [17]. Ox-LDL also induces endothelial adhesion molecules (VCAM-1/ICAM-1), recruiting monocytes that differentiate into pro-inflammatory M1 macrophages. ROS from oxidative stress activates TLR4/2 and NLRP3 inflammasome, triggering NF-κB-mediated cytokine release (IL-1β/TNF-α), which recruits T cells and inhibits collagen synthesis [18]. Pro-inflammatory cytokines (e.g., IFN-γ) further enhance ROS, causing mitochondrial dysfunction. This oxidation-inflammation cycle ultimately destabilizes plaques, increasing rupture and thrombosis risk.

4 Treatment of Atherosclerosis

4.1 Anti-inflammatory Therapy

Inflammatory response is a key factor in promoting the formation and development of atherosclerotic plaques, so anti-inflammatory therapy is regarded as one of the important means to reverse plaque accumulation. Common anti-inflammatory drugs include colchicine, among others. These drugs reduce the inflammatory response by inhibiting the chemotaxis and phagocytosis of white blood cells to the inflammatory site and reducing the release of inflammatory mediators [19].

4.2 Lipid-regulating Therapy

In the treatment of atherosclerosis, lowering cholesterol levels is one of the core strategies. Clinically, lipid-lowering drugs are usually used for treatment, among which statins, as first-line drugs, effectively reduce lipid levels by inhibiting cholesterol synthesis, stabilizing plaque and delaying the progression of atherosclerosis [20]. In addition, lipid-lowering drugs can also reduce blood viscosity and further improve blood vessel function.

4.3 Antiplatelet Therapy

Platelet adhesion and aggregation in the blood play an important role in the formation of atherosclerotic plaques. Antiplatelet therapy prevents the formation of thrombus by inhibiting platelet adhesion and aggregation. This treatment not only helps to prevent the development of vascular obstructive diseases, but also effectively prevents serious complications such as coronary heart disease and cerebral artery thromboembolism [21]. At present, the commonly used antiplatelet drugs in clinic include aspirin.

4.4 Nanotherapy

In the treatment of atherosclerosis, nanocarriers such as liposomes, dendrimers, and polymeric micelles can be employed to achieve targeted drug delivery. These nanocarriers significantly enhance the bioavailability of therapeutic agents, including anti-atherosclerotic peptides, anti-inflammatory cytokines and nucleic acids, while reducing their toxic side effects [22]. Although novel materials still face challenges in clinical translation, nanomedicine has demonstrated considerable potential for improving therapeutic outcomes in atherosclerosis [23].

4.5 Other Therapies

In the treatment of atherosclerosis, there are many other therapies available, such as thrombolytic therapy, antioxidant therapy, and vasodilator therapy [24]. When blood clots in an artery narrow or block the vessel cavity, thrombolytic drugs can be used to unclog the blocked vessel and prevent serious consequences such as myocardial infarction. In terms of antioxidant treatment, antioxidants help to enhance the ability of patients to resist oxidative stress, thereby reducing the inflammatory response. Vasodilator therapy helps to relax blood vessels and slow the progression of atherosclerosis. In addition, this treatment can also relieve vasospasm, promote collateral circulation, and further improve blood flow.

5 Prevention of Atherosclerosis

5.1 Balanced Diet

Rational dietary intervention has a significant effect on the regulation of cardiovascular disease risk factors, so rational diet plays an important role in the prevention of atherosclerosis [25]. In terms of fat and oil intake, it is recommended to focus on foods rich in unsaturated fatty acids, such as olive oil, nuts and deep-sea fish. These foods not only have anti-inflammatory effects, but also improve blood lipid levels, which is of great benefit to cardiovascular health. Sugar is one of the important causes of atherosclerosis, and limiting the intake of added sugars can effectively reduce the risk of obesity and cardiovascular disease. It is also vital to increase your intake of dietary fiber, such as oats, beans and fruits, which can help improve blood sugar control by lowering cholesterol levels and delaying the absorption of carbohydrates. At the same time, increasing the intake of antioxidants is also an important strategy to prevent atherosclerosis. Foods rich in vitamin C and vitamin E, as well as dark vegetables, berries, and green tea, are good choices. These antioxidants help reduce oxidative stress and protect blood vessel health.

5.2 Active Exercise

Active exercise plays an important role in the prevention of atherosclerosis [26]. Exercise improves cardiovascular health, which significantly reduces the risk of atherosclerosis. First of all, regular aerobic exercise, such as brisk walking, running and swimming, can effectively reduce blood lipids, blood sugar and blood pressure. By lowering LDL cholesterol, aerobic exercise reduces the deposition of lipids in artery walls. In addition, these forms of exercise also reduce resting blood pressure and improve insulin sensitivity, thereby reducing major risk factors for atherosclerosis such as hypertension and diabetes. In addition, exercise also helps to reduce weight and body fat, especially reducing the accumulation of visceral fat. This can not only reduce the level of systemic inflammation, but also further inhibit the occurrence of atherosclerosis.

5.3 Quit Smoking and Limit Alcohol Consumption

Smoking cessation and limiting alcohol intake are important measures to directly interfere with the main risk factors for atherosclerosis and improve vascular health, which can significantly reduce the risk of cardiovascular disease [27][28]. Smoking cessation is one of the key measures to prevent atherosclerosis. Harmful substances in tobacco smoke, such as carbon monoxide, nicotine and tar, damage the endothelial cells of blood vessels, promote oxidative stress and inflammatory responses, and accelerate the formation of arterial plaque. In addition, smoking also increases the aggregation of platelets, which further increases the risk of blood clots. For example, the study conducted by Ding et al. demonstrated that smoking is significantly associated with three major atherosclerotic diseases: peripheral arterial disease, coronary heart disease, and stroke [29]. Furthermore, the study indicated that the disease risk associated with smoking is long-term, with the risk persistence for peripheral arterial disease and coronary heart disease found to last up to 30 and 20 years, respectively. Therefore, smoking cessation can effectively prevent the occurrence of atherosclerosis. Similarly, limiting alcohol intake is important for the prevention of atherosclerosis. Excessive alcohol consumption can lead to high blood pressure and heart muscle damage, increasing the risk of atherosclerosis. Therefore, controlling alcohol intake can protect cardiovascular health and avoid potential harm.

6 Conclusion

The prevention of atherosclerosis is the key to reduce the incidence of cardiovascular disease. By taking a variety of preventive measures, risk factors can be effectively controlled, thereby reducing the probability of disease occurrence. Looking forward to the future, with the continuous emergence of new medical treatments, the prevention and treatment of atherosclerosis will be more accurate and efficient, providing a more solid guarantee for cardiovascular health.

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