Cardiac Shock Wave Therapy in Cardiovascular Diseases

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Abstract

Cardiovascular disease is one of the leading causes of death worldwide, placing a huge burden on patients and healthcare systems. Cardiac shock wave (CSW) technology is a non-invasive treatment method. In recent years, some scholars have discovered that extracorporeal shock wave can improve cardiovascular ischemic lesions. This article reviews the latest progress in basic research and clinical application of cardiac shock wave technology in cardiovascular medicine and reviews its efficacy and potential mechanisms in different diseases. First, the principle of shock waves and their application potential in cardiovascular medicine are introduced. Then, from the aspects of basic research and clinical application, the mechanism and clinical efficacy of shock waves in cardiovascular diseases such as coronary heart disease, myocardial ischemia-reperfusion injury, atrial fibrillation, atherosclerosis, and coronary artery calcification are discussed, as well as its advantages and limitations. Animal experiments and clinical studies have found that extracorporeal shock waves can upregulate the expression of vascular endothelial growth factors, promote angiogenesis, promote nitric oxide production, increase local blood perfusion, significantly reduce angina symptoms, and improve left ventricular function and remodeling. Finally, the future development trend of shock wave technology is prospected. This review provides an introduction to the properties, biomechanical effects, treatment mechanisms of cardiovascular diseases, research status and development prospects of extracorporeal shock waves.

Keywords: Cardiac shock Wave Therapy, Cardiovascular diseases, ESWT

Introduction

Cardiovascular disease is one of the most common diseases in the world and one of the leading causes of death [1]. Cardiovascular diseases such as coronary heart disease, myocardial ischemia-reperfusion injury, atrial fibrillation, and atherosclerosis are major health problems worldwide, placing a significant burden on patients and healthcare systems [1]. Traditional treatments for cardiovascular disease include drug therapy, interventional surgery, and open surgery. However, these treatments have certain limitations. Therefore, finding new treatments and strategies is of great significance to improve the prognosis of cardiovascular diseases. In recent years, cardiac shock wave technology has been widely used in cardiovascular diseases as a new treatment method and has made significant progress [2-4]. It has received widespread attention and research in the field of cardiovascular medicine in recent years. Cardiac shock wave technology has become a new method of treating cardiovascular diseases due to its non-invasive and high-efficiency characteristics [3-5]. Shockwave technology is a method of treating disease by generating high-energy sonic shock waves. It uses the mechanical effect of high-energy shock waves to treat diseases by acting on specific parts of the patient's body to improve blood flow, promote blood vessel regeneration and repair, and other mechanisms [3,6]. In the cardiovascular field, the main applied shock wave technologies include medical shock wave (extracorporeal shock wave therapy, ESWT) and surgical shock wave (intracorporeal shock wave therapy, ISWT) [3-7]. ESWT generates shock waves outside the body and conducts them to target tissues through the skin, and is used to treat coronary heart disease, angina pectoris and other diseases. ISWT is used to treat atherosclerosis, thrombosis, coronary artery calcification and other diseases by directly delivering shock waves in the body. This article will review the latest progress in basic research and clinical application of shock wave technology in cardiovascular medicine, with a view to providing a reference for further promoting the application of this technology in the treatment of cardiovascular diseases. This review will discuss the progress in the application of shock waves in cardiovascular diseases and explore its future development directions in the cardiovascular field.

The principle of shock wave in cardiovascular medicine

Shock waves act on human tissues through short high-voltage pulses to generate

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mechanical energy, thereby producing biological effects on the tissues [8]. Its mechanism of action mainly includes mechanical effects, biochemical effects and biological effects. In cardiovascular medicine, cardiac shock waves are widely used to treat diseases such as coronary heart disease, myocardial ischemia-reperfusion injury, atrial fibrillation, and atherosclerosis [2-5,7]. They have the advantages of non-invasiveness, repeatable operation, and accurate curative effect. A shock wave is a mechanical wave that transfers energy by producing high-energy pressure waves. The principle of shock waves is to generate high-pressure pulse waves in a short period of time, subjecting local tissues to mechanical stress and strain, thereby producing a series of biological effects [9].

Shock wave therapy has made a series of progress in basic research in cardiovascular medicine. Studies have found that cardiac shock wave therapy can enhance plaque stability and reduce plaque rupture and cardiovascular events [4,10]. This may be because shock wave therapy can improve the inflammatory response within the plaque, promote the proliferation of smooth muscle cells on the plaque surface, and reduce compensatory hyperplasia. Shock wave therapy can improve arterial hemodynamics, increase blood flow velocity and blood vessel flexibility. Studies have found that shock wave therapy can increase nitric oxide synthesis in vascular endothelial cells, thereby promoting vasodilation and dilation [5,8,11]. Shock wave therapy can stimulate the proliferation and angiogenesis of vascular endothelial cells, thereby improving blood supply and oxygen supply. This has important implications for the treatment of cardiovascular diseases such as ischemic heart disease. Shock wave therapy can reduce the inflammatory response on the arterial wall, inhibit the release of inflammatory mediators and the infiltration of inflammatory cells. This may help reduce the extent of atherosclerotic lesions and inflammatory damage [5,12]. Shock wave therapy can increase the activity of the thrombolytic system within the plaque and promote the dissolution and absorption of thrombus within the plaque. Although these findings indicate that shock wave therapy has potential and application prospects in basic research in cardiovascular medicine, further research is still needed to deeply understand the mechanism of action of shock waves and optimize treatment options. In addition, clinical studies also need to further verify the safety and effectiveness of shock wave therapy in the treatment of cardiovascular diseases. Basic research on shock wave therapy for coronary heart disease mainly focuses on the formation mechanism of coronary neovascularization and the improvement of coronary microcirculation [2,13]. Studies have found that shock waves can promote the formation of coronary new blood vessels by promoting the proliferation of vascular endothelial cells and releasing growth factors, and can also improve coronary microcirculation [2,5,11,14].

Basic research on shock wave therapy for myocardial ischemia-reperfusion injury mainly studies the mechanism of its protective effect on myocardium [15,16]. Studies have found that shock waves can have a certain protective effect on myocardial ischemia-reperfusion injury by regulating oxidative stress, reducing inflammatory responses, inhibiting cell apoptosis, etc. The specific mechanism of shock wave technology in the treatment of myocardial ischemia-reperfusion injury is not fully understood, but there are some hypotheses that may explain its efficacy. Here are some possible mechanisms [6,7,14,17]:

(1) Promote neovascularization: Shock waves can stimulate the proliferation and migration of vascular endothelial cells and interstitial cells, promoting the formation of new blood vessels. This helps to increase the blood supply to the myocardium, improve the oxygen supply to the ischemic area of the myocardium, and reduce ischemia-reperfusion injury. (2) Reduce inflammatory response: Shock waves can reduce inflammatory responses, inhibit the activation of inflammatory cells and the release of inflammatory mediators. This helps reduce the inflammatory response and cell damage caused by myocardial ischemia-reperfusion injury. (3) Regulation of apoptosis: Shock waves can regulate cardiomyocyte apoptosis and survival signaling pathways. It can inhibit the expression of apoptosis-related proteins, increase cell survival rate, and reduce cardiomyocyte death. (4) Release of growth factors: Shock waves can promote the release of growth factors, such as vascular endothelial growth factor (VEGF), basic fibroblast growth factor (bFGF), etc. These growth factors promote blood vessel proliferation, vascular regeneration, and myocardial repair. It should be noted that the exact role and interrelationship of these mechanisms require further research and verification. In addition, different types of shock wave technology (such as ESWT and ISWT) may have different mechanisms and effects. Therefore, we need further exploration and in-depth research on the mechanism of shock wave technology in the treatment of myocardial ischemia-reperfusion injury.

The mechanism of cardiac shock wave treatment of coronary artery calcification lesions is multifaceted, including mechanical effects, cavitation effects, biological effects, and anti-inflammatory effects [18-21]. These effects work together to make shock waves effective in treating calcified coronary artery lesions. The mechanism of shock wave treatment of coronary artery calcification lesions mainly includes the following aspects [10,19,20,22,23]: (1) Mechanical effect: The shock wave will produce a strong mechanical effect during the propagation process, which can strip the calcium ions in the calcified plaque from its surface, thus to achieve the purpose of reducing blood vessel stenosis and improving blood flow. (2) Cavitation effect: During the propagation process of the shock wave, it will excite the bubbles in the medium to form cavitation bubbles. These cavitation bubbles will explode instantly at the calcification lesions, generating strong shock waves and further stripping the calcium ions in the calcification plaques. (3) Biological effects: Shock waves can cause biological effects, such as promoting cell apoptosis, inhibiting cell proliferation, etc., thus helping to treat coronary artery calcification lesions. (4) Anti-inflammatory effect: Shock waves can reduce the inflammatory response, thereby helping to relieve symptoms caused by calcified coronary artery lesions.

Clinical application of shock waves in cardiovascular medicine

In cardiovascular medicine, the potential application of shock waves has several aspects. Coronary heart disease is a heart disease caused by insufficient blood supply in the coronary arteries. Cardiac shock wave technology has shown certain efficacy in the treatment of coronary heart disease [2,4,24]. Coronary heart disease is a disease that causes myocardial ischemia due to narrowing or blockage of the coronary arteries. Studies have shown that cardiac shock wave therapy can improve coronary blood flow by stimulating the proliferation of vascular endothelial cells, promoting angiogenesis, and improving blood supply, thereby alleviating the symptoms of myocardial ischemia [13,25,26]. Multiple studies have shown that ESWT can improve myocardial perfusion, reduce angina symptoms, and improve quality of life in patients with coronary heart disease [27,28]. In addition, ISWT has also shown certain potential in interventional treatment of coronary heart disease, which can improve the efficacy and prognosis after vascular reconstruction. The clinical application of cardiac shock wave therapy for coronary heart disease mainly includes coronary artery neovascularization treatment and ischemic myocardial protection treatment. Studies have shown that cardiac shock wave therapy can improve patients' myocardial ischemia symptoms, improve exercise tolerance, reduce the incidence of cardiac events, and can, to a certain extent, replace interventional treatment of coronary artery stenosis[13,25,29].After myocardial infarction, pathological remodeling of myocardial tissue occurs, including myocardial fibrosis and cardiac hypertrophy [26,30]. Coronary heart disease is a common cardiovascular disease, the main cause of which is coronary artery stenosis or obstruction. Cardiac shock wave lithotripsy is a method that uses shock wave energy to break up plaque in diseased blood vessels to restore blood flow. Studies have shown that shock wave lithotripsy can significantly improve the symptoms of myocardial ischemia and improve the quality of life in patients with coronary artery stenosis or obstruction [19,31].

Cardiac shock wave treatment of coronary artery calcification lesions is a new treatment method that uses shock wave energy to shatter calcified plaques in blood vessels to achieve the purpose of treatment [10,18-20]. Specifically, the principle of shock wave treatment of coronary artery calcification lesions is to focus high-energy shock waves on the blood vessel parts of the calcified lesions to produce strong mechanical vibration and biological effects, which can strip the calcium ions in the calcified plaque from its surface, thereby achieving the purpose of reducing blood vessel stenosis and improving blood flow. Cardiac shock waves can effectively break up calcified plaques and make them more evenly distributed and closer to the blood vessel wall, thereby reducing the pressure and time required for balloon expansion and reducing the risks of vascular damage, perforation, and no-reflow [29,30,32]. CSW improves the tissue structure of calcified plaque, promote contact and fit between it and the stent, increase the accuracy and stability of stent implantation, and reduce problems such as stent deformation, displacement, and incarceration. It stimulates the blood vessel wall to produce a certain degree of endothelial damage, and releases growth factors and anticoagulant factors that are beneficial to vessel repair and recanalization, thereby reducing complications such as restenosis and stent thrombosis. This treatment method has the advantages of less trauma, fast recovery, and high safety, and has been used in some medical institutions. The indications for cardiac shock wave treatment of coronary artery calcification lesions mainly include: patients with symptoms such as angina pectoris and chest tightness caused by coronary artery calcification lesions, and for whom drug treatment is not effective; patients with limited blood flow caused by coronary artery calcification lesions and unable to undergo traditional coronary surgery [10,18-22,32]. Patients undergoing arterial interventional therapy; patients with mild coronary artery calcification lesions who still need further treatment. However, for some patients, cardiac shock wave therapy may cause complications [4,7,13,24,26,29], such as vascular damage, arrhythmia, myocardial infarction, etc. Cardiac shock waves may cause a certain degree of damage to the blood vessel wall, leading to inflammation of the blood vessel wall, plaque rupture and other problems, thereby causing complications such as acute coronary syndrome. During shock wave therapy, it may have a certain impact on the heart, leading to cardiovascular events such as arrhythmia. Because shock wave therapy may cause plaque rupture, resulting in the formation of blood clots, it may lead to serious complications such as myocardial infarction. Other complications: such as coronary artery spasm, stent thrombosis, etc., but these complications are relatively rare. In short, shock wave treatment of coronary artery calcification lesions is a new treatment method with good application prospects.

CSW technology also shows certain application prospects in the treatment of heart failure [25,30]. Research shows that shock waves can improve myocardial contractile function and myocardial remodeling, promote myocardial repair and recovery of cardiac function [30,33,34]. Heart failure is a complex clinical syndrome of cardiovascular disease characterized by the inability of the heart to pump blood effectively, resulting in impaired function of multiple organs throughout the body. Shockwave therapy can improve heart function, relieve symptoms, and reduce the risk of cardiovascular disease in patients with heart failure by stimulating the regeneration and repair of heart muscle cells. Studies have shown that shock wave therapy can significantly improve the quality of life and extend the survival of patients with heart failure [25,35]. Studies have found that shock wave therapy can promote the repair and regeneration of myocardial tissue, reduce myocardial fibrosis and myocardial hypertrophy, thereby improving myocardial function and preventing the occurrence of heart failure. Myocardial regeneration is an important direction in the treatment of cardiovascular diseases. Researchers found that shock waves can stimulate the proliferation and differentiation of cardiomyocytes, thereby promoting myocardial regeneration [6,36]. Shock wave therapy can significantly improve cardiac function after myocardial infarction, reduce the size of the myocardial injury area, and promote myocardial regeneration [34]. In addition, shock wave therapy can reduce the incidence of heart failure and arrhythmias after myocardial infarction [37,38].

Atherosclerosis is one of the main pathological bases of cardiovascular diseases. Atherosclerosis is a chronic progressive disease. Shock wave technology, as a method to improve arterial blood flow and promote vascular regeneration, has shown potential application value in the treatment of atherosclerosis [39,40]. ISWT can improve exercise tolerance, hemodynamics and vascular function in patients with atherosclerosis, and reduce thrombosis and inflammatory responses. Shock wave therapy can reduce the inflammatory response on the arterial wall, promote the dissolution and absorption of thrombus in the plaque, thereby reducing the extent of atherosclerotic lesions and inflammatory damage [10,32,41,42]. The clinical application of shock wave treatment for atherosclerosis mainly works by improving arterial blood flow, reducing plaque formation and stabilizing plaque. Studies have found that shock wave therapy can improve arterial hemodynamic parameters, reduce plaque formation and stabilization, and reduce the formation of arterial thrombosis, thereby reducing the incidence of cardiovascular events. Shock wave technology has shown some potential in the treatment of thrombosis. Shock waves can help treat thrombosis-related cardiovascular diseases by destroying thrombus structures, promoting thrombolysis, and improving hemodynamics.

Advantages and limitations

As a non-invasive treatment method, cardiac shock wave technology has many advantages in cardiovascular medicine [2-7,23-25]. First of all, shock wave therapy is non-invasive and requires no surgical incision for the patient, reducing the patient's pain and recovery time. Secondly, shock wave therapy is effective and can significantly improve patients' symptoms and quality of life. In addition, shock wave therapy is repeatable and can be individualized according to the patient's condition. However, shock wave therapy also has some limitations, such as pain, skin bruising and other adverse reactions that may occur during the treatment process, and the therapeutic effect may vary due to individual differences.

Shock wave technology is still in the development stage and is not yet available in all hospitals, so there may be certain treatment limitations [26,27,29,35]. Shock wave therapy is mainly suitable for moderate to severe calcified lesions. The therapeutic effect on mildly calcified or non-calcified lesions is unclear. A certain amount of pain and discomfort may occur during shock wave treatment, which requires the patient to have a certain tolerance. Shockwave therapy is relatively expensive and may not be suitable for all patients.

Conclusion

Cardiac shock wave technology has made a series of progress in basic research and clinical application of cardiovascular medicine, showing broad application prospects. As the understanding of cardiac shock waves and technology continue to advance, the application of cardiac shock wave therapy in the treatment of cardiovascular disease will be further expanded. In addition, cardiac shock wave technology can also be applied to the treatment of other cardiovascular diseases, such as heart failure, valve disease and other fields, and is expected to provide more clinical treatment options. Cardiac shock wave therapy, as a novel non-invasive treatment method, has achieved certain results in the treatment of cardiovascular diseases. However, there are still some challenges and problems that need to be solved, such as the clarification of treatment mechanisms, optimization of treatment parameters, and long-term stability of treatment effects. Future research can focus on the treatment mechanism, treatment dose and treatment timing of shock waves to optimize the treatment effect. At the same time, the combined application of shock waves with other treatment methods can also be explored to further improve the efficacy. We should further strengthen the exploration of the mechanism and efficacy of cardiac shock wave treatment for cardiovascular diseases, as well as conduct large-scale clinical trials to ensure its safety and effectiveness and provide more adequate support for its promotion and application in clinical practice. Future development directions include optimizing treatment options, in-depth exploration of treatment mechanisms, and combined application with other treatment methods. It is believed that with the continuous deepening of research and the continuous improvement of technology, cardiac shock wave technology will play an increasingly important role in the clinical practice of cardiovascular medicine.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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