Treatment of aortic coarctation: modern achievements in surgery and cardiology

Tratamiento de la coartación aórtica: avances modernos en cirugía y cardiología

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Abstract

Aortic coarctation is one of the most common congenital heart defects characterized by narrowing of the lumen of the arch or thoracic aorta. This pathology can lead to serious complications such as hypertension, impaired blood supply to internal organs and the progression of cardiovascular insufficiency. Modern medicine offers a wide range of treatments for this disease, including both traditional surgical approaches and innovative endovascular technologies.

The authors consider the latest achievements in the field of surgical and interventional treatment of aortic coarctation. Special attention is paid to the comparative analysis of various techniques, such as subclavian flap repair resection, stent implantation, as well as combined approaches. The authors discuss the advantages and limitations of each method based on clinical studies and long-term patient follow-up results.

The article also highlights the role of modern diagnostics, including the use of computed tomography, magnetic resonance angiography and echocardiography, to accurately determine the location and degree of narrowing of the aorta, which allows you to choose the most effective treatment strategy, taking into account the specifics of each specific case.

The key areas of development in the treatment of aortic coarctation are minimizing the traumatic effects of interventions, reducing the risk of recurrence, and improving the quality of life of patients. The importance of a multidisciplinary approach combining the efforts of cardiologists, surgeons and functional diagnostics specialists to achieve optimal treatment results is emphasized.

Keywords: aortic coarctation, surgical treatment, endovascular correction, stenting, diagnosis, multidisciplinary approach.

Introduction

Aortic coarctation (AC) is a congenital malformation of the cardiovascular system characterized by segmental narrowing of the lumen of the arch or thoracic aorta[1]. This pathology occupies one of the leading places among congenital heart diseases, occurring in 5-10% of patients with congenital heart defects and accounting for about 2-4 cases per 10,000 newborns[2]. Despite the fact that AC can be diagnosed both in the neonatal period and later in life, it requires timely treatment, as it leads to the development of serious complications such as systemic arterial hypertension, left ventricular hypertrophy, stroke, aneurysms of the neck vessels and other life-threatening conditions.

Modern advances in cardiology and surgery have significantly expanded the possibilities for correcting aortic coarctation. Traditional open surgical techniques are still effective, especially in difficult cases[3]. However, the development of endovascular technologies has opened up new horizons in the treatment of this pathology, allowing minimally invasive procedures using stents, which are becoming preferred for adult patients and older children.

Despite significant advances in the diagnosis and treatment of aortic coarctation, challenges remain related to the choice of optimal therapy tactics, the risk of recurrence of narrowing, and the need for long-term follow-up of patients after correction. In this regard, the relevance of further research and the introduction of new treatment methods remains high.

The purpose of this article is to review modern approaches to the diagnosis and treatment of aortic coarctation, analyze the clinical effectiveness of various techniques, and consider the prospects for the development of this field in cardiology and vascular surgery.

Materials and methods

A set of methods was used to conduct the study, which made it possible to systematize knowledge, analyze existing approaches and identify current trends in the diagnosis and treatment of this pathology. An analysis of the literature allowed us to study scientific publications, clinical recommendations, guidelines and monographs related to the diagnosis, treatment and rehabilitation of patients with aortic coarctation. For example, a review of international clinical guidelines (for example, the European Society of Cardiology, the American Heart Association) was conducted to determine treatment standards; analysis of articles from PubMed, Cochrane Library, Scopus, and Web of Science databases on comparing the effectiveness of surgical and endovascular AC correction methods; study of medical histories of patients with aortic coarctation presented in scientific journals or dissertation studies.

Using comparative analysis, the incidence of complications and relapses after various correction methods was assessed (for example, a comparison of restenosis statistics after stenting and surgical resection), and differences in the use of techniques in newborns, older children, and adult patients were determined. Logical analysis was used to identify cause-and-effect relationships between factors influencing the choice of treatment method, its effectiveness and possible complications. Thus, the relationship between the patient's age and the choice of aortic coarctation correction method was determined, and risk factors for complications after surgical or endovascular intervention were identified (for example, the presence of concomitant heart defects, the degree of narrowing of the aorta, and the size of the patient).

Results

Aortic coarctation (AC) is one of the most common forms of congenital malformations of the cardiovascular system, characterized by local segmental narrowing of the lumen of the arch or thoracic aorta[4]. This pathological condition leads to disruption of normal blood flow, creating an obstacle to the movement of blood from the left ventricle to the peripheral vessels. Depending on the level and degree of narrowing, AC can cause significant changes in the hemodynamics of the body, such as increased blood pressure in the upper body and decreased blood supply to the lower extremities.

The AC detected in an adult patient is a systemic condition, not just an anatomical anomaly[5]. Coarctation is usually a discrete narrowing in the aortic isthmus, but variations such as long segment stenosis, arch involvement, including arch hypoplasia, and other narrowing sites have been described. Bicuspid aortic valve, intercostal artery aneurysms, ventricular septal defects, and intracranial artery aneurysms have also been associated with COA. COA accounts for 5-10% of congenital heart abnormalities, and most of them are diagnosed and treated at an early age[6].

Some patients with postductal AC have no symptoms until the moment when systemic hypertension combined with a weakened femoral pulse or inappropriate blood pressure measurements of the upper and lower extremities lead to further diagnostic assessments[7]. Recoarctation at the site of the previous recovery is manifested in a similar way. Rarely, an adult with an accidentally detected AC will be normotensive at rest. However, many of them will have an exaggerated blood pressure response to exercise: exercise-induced hypertension has been shown to correlate with cardiovascular risk, with an increase in the incidence of cardiovascular events by up to 50%[8].

The consequences of persistent systemic hypertension include increased afterload, leading to an increase in the mass of the left ventricular wall (VW), decreased ductility of the arterial walls, blunted baroreceptor reflex and endothelial dysfunction. AC is associated with fragmentation of elastic fibers, fibrosis, cystic medial necrosis of the aorta, and an increase in intimal-medial thickness, even in infants and children, which demonstrates the systemic nature of this condition. Congestive heart failure, intracranial aneurysm, post-infarction aneurysm, dissection, and post-recovery complications such as aneurysm, pseudoaneurysm, and re-coarctation contribute to shortening life expectancy. Without treatment, the average age of death in patients with AC is 35 years, while 75% of patients die by the age of 46[9].

Despite successful treatment, defined by a reduction in the pressure gradient after recovery to less than 10-20 mmHg, most patients will still require antihypertensive medications after recovery. The goal of AC management is early detection, early treatment, reliable follow-up of complications after surgery, as well as ongoing hypertension management to reduce the risks of prolonged, persistent hypertension[10]. Moreover, reducing VW mass will reduce the prevalence of congestive heart failure and improve long-term survival.

The pathology in question requires timely diagnosis and correction, since its consequences can be serious and even life-threatening for the patient[11]. Untimely treatment can lead to the development of complications such as systemic arterial hypertension, left ventricular hypertrophy, abdominal aortic aneurysms, strokes and other vascular diseases. Modern medicine offers a wide range of treatment methods, including surgery and endovascular techniques, which can significantly improve the effectiveness of therapy and the quality of life of patients.

This pathology can lead to serious complications such as hypertension, impaired blood supply to internal organs and the progression of cardiovascular insufficiency[12].

Aortic coarctation, as a pathological narrowing of the aortic lumen, significantly disrupts normal blood circulation in the body, which can cause many serious complications, presented in Table 1.

The main consequences of aortic coarctation

A complication	Mechanism of development	Clinical manifestations
Arterial hypertension	Increased resistance to blood flow before narrowing of the aorta leads to increased pressure in the upper body.	Headaches, tinnitus, nosebleeds, risk of stroke, left ventricular hypertrophy.
Violation of blood supply to internal organs	Decreased blood flow to the lower extremities and abdominal cavity due to narrowing of the aorta.	Pain in the legs when walking (klaudikacija), coldness of the extremities, decreased kidney function, abdominal pain.
Cardiovascular insufficiency	Chronic increased stress on the left ventricle due to overcoming an obstacle in the form of a narrowed aorta.	Shortness of breath, fatigue, swelling, increased heart size, decreased physical activity.
Vascular aneurysms	Compensatory vasodilation to bypass the constriction can lead to the formation of aneurysms.	The risk of aneurysm rupture, for example, in the brain or aorta, which is a life-threatening condition.
The coarctation collateral	Formation of additional vessels to compensate for impaired blood flow.	Noises in the back or chest area, increased pulsating blood circulation in the collateral area.
Stroke	Chronic hypertension and impaired vascular structure of the brain increase the risk of thrombosis.	Speech disorders, weakness in limbs, paresis, loss of consciousness.

The table clearly demonstrates how aortic coarctation affects various body systems, emphasizing the importance of timely diagnosis and treatment of this disease.

Modern medicine has a variety of methods for the treatment of aortic coarctation, which can effectively eliminate the narrowing of the vessel lumen and normalize blood circulation. Such methods can be divided into traditional surgical approaches and innovative endovascular technologies. The choice of a specific method depends on the patient's age, location and degree of narrowing, the presence of concomitant heart defects, as well as long-term prognoses[13].

Traditional surgery remains the main method of treating aortic coarctation, especially in difficult cases or in newborn patients. Endovascular methods are less traumatic and preferable for the treatment of adult patients and older children. Key approaches include:

– stenting. As part of this procedure, a special stent is inserted through a catheter into the narrowed area of the aorta — a metal mesh structure that mechanically expands the lumen of the vessel. This method is widely used to correct recurrent narrowing after previous surgeries.;

– balloon angioplasty. The procedure consists of inserting a balloon through a catheter to the site of constriction, after which the balloon is inflated to mechanically expand the aortic walls. Although this method is less effective than stenting, it can be useful in some clinical situations.

In difficult cases, it may be necessary to use combined techniques that combine surgery and endovascular technologies. For example, after resection of a narrowed section of the aorta, stenting can be performed to prevent repeated narrowing[14].

Modern research focuses on improving existing methods and developing new technologies. Among them:

– using biocompatible materials to create safer and more durable stents;

– robotic surgery, which allows performing high-precision operations with minimal injury;

– genetic diagnostic methods for early detection of aortic coarctation and other congenital heart defects.

Thus, modern medicine provides a wide range of possibilities for the treatment of aortic coarctation, which significantly improves the effectiveness of therapy and the quality of life of patients. The choice of treatment method should be carried out individually, taking into account all clinical factors and recommendations of a multidisciplinary team of specialists.

Discussion. Accurate determination of the location, degree, and nature of aortic narrowing is a key factor in choosing the most effective treatment strategy for AC[15]. Modern diagnostic methods such as computed tomography (CT), magnetic resonance angiography (MRI/MRA) and echocardiography provide detailed information about pathology, which significantly improves the accuracy of therapy planning (Table 2).

Table 2. Modern methods of diagnosis of localization, degree and nature of aortic narrowing

Method	Accuracy	Safety	Application Features	Role in treatment planning
Echocardiography	Average	High	Primary diagnosis, accessibility	Assessment of heart function, identification of concomitant defects
Computed tomography	High	Average	Accurate measurements, stenting planning	Stent size selection, collaterals assessment
MRI/MRA	Very high	High	Safety for children, hemodynamic assessment	Comprehensive assessment of the condition of the aorta and surrounding structures

Echocardiography is a non-invasive method of ultrasound examination of the heart and blood vessels, which makes it possible to assess the structure and function of the heart, including the detection of narrowing of the aorta[16]. This method is safe, as it does not require the use of radiation or contrast agents, is widespread and can be performed in almost any clinic. ECHOCG is informative for determining the location of narrowing, its degree, the speed of blood flow through the narrowed area and the presence of reverse blood flow. However, there are limitations: the limited ability to evaluate the distal aorta due to the anatomical features of the patient and the dependence on the qualifications of the doctor performing the study. In treatment planning, ECHOCG is used for the primary diagnosis of aortic coarctation (AC), assessment of left ventricular function, and detection of concomitant heart defects, helping to determine the need for further examination by more specialized methods.

Computed tomography with contrast is a highly informative imaging method that allows obtaining three–dimensional images of the aorta and surrounding structures[17]. Its advantages include high accuracy in determining the location, shape and size of the narrowed aortic area, as well as the ability to evaluate collateral vessels, which are additional vessels formed in response to impaired blood circulation. CT with 3D reconstruction helps to choose the optimal size and type of stent for stenting. The limitations of the method are related to the use of radiation, which can be a problem for children and pregnant women, as well as the need to use contrast, which is contraindicated in patients with renal insufficiency or allergy to iodine-containing substances. CT is especially useful for assessing complex forms of aortic coarctation, such as combined narrowing or the presence of aneurysms, which makes it possible to plan surgical intervention or endovascular stenting with high accuracy[18].

Magnetic resonance angiography is based on the use of a magnetic field and radio waves and allows obtaining detailed images of blood vessels without the use of ionizing radiation[19]. The method is safe for children and pregnant women due to the absence of radiation, provides high-detail images, including assessment of not only the aorta, but also surrounding tissues such as nerves, muscles and other vessels. The MRA also allows you to evaluate hemodynamics by showing the direction and speed of blood flow, which is important for understanding functional disorders. However, the study requires a long time, which can be a problem for young children or patients with anxiety, and has contraindications for patients with metal implants. MRI/MRA is often used for a comprehensive assessment of the condition of the aorta, especially in children and young patients, helping to identify hidden developmental abnormalities and assess the risk of complications.

Treatment of aortic coarctation requires special attention to minimizing the traumatic effects of interventions, reducing the risk of recurrence, and improving the quality of life of patients. Modern treatment methods, such as endovascular technologies and combined approaches, make it possible to achieve these goals, especially in comparison with traditional surgical methods.

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Minimization of injury is a key factor that affects the patient's recovery rate after treatment of aortic coarctation[20]. Modern approaches are aimed at using minimally invasive techniques, which significantly reduces the risk of complications and accelerates rehabilitation. Endovascular techniques such as stenting and balloon angioplasty are performed through a catheter inserted through peripheral vessels, such as the femoral artery, eliminating the need for thoracotomy or sternotomy, which are typical for traditional surgical procedures. Thanks to this technique, patients undergo surgery more easily, and the recovery period is significantly reduced. Combined approaches are also used in modern practice[21]. In some cases, the combination of endovascular technologies with minimally invasive surgery allows for optimal results with less trauma compared to classical resection.

Reducing the risk of recurrence of narrowing (restenosis) is one of the main problems after correction of aortic coarctation, especially in children whose vascular system continues to grow[22]. Modern treatment methods are aimed at minimizing this phenomenon. The use of modern materials, such as biocompatible stents with antiproliferative coatings or hydrogels, helps prevent the formation of scar tissue and restenosis. Personalized solutions, including the creation of individual stents using 3D printing, take into account the size and shape of the aorta of a particular patient, which increases the effectiveness of treatment. In addition, regular monitoring of the postoperative period using high-precision diagnostic methods such as MRI or CT allows you to identify early signs of restenosis and take timely measures to correct it.

Improving the quality of life of patients is the ultimate goal of any treatment. Modern approaches ensure not only physical recovery, but also psychological well-being. Physical well-being is achieved through rapid recovery after minimally invasive procedures. For example, endovascular methods allow patients to return to daily activities faster, which is especially important for adults, working people, or children attending school. Reducing the risk of complications such as infections, thrombosis, or bleeding also helps patients feel better. As for psychological well-being, minimally invasive methods are less traumatic for the patient's psyche, especially for children and their parents. In addition, the high efficiency of modern treatment methods ensures stable results for many

years, which reduces patients' anxiety about the need for repeated interventions.

In clinical practice, different categories of patients may receive different types of treatment depending on their age and condition. Modern techniques such as robotic surgery can minimize the trauma of surgery even in this age group. In adult patients, stenting becomes the preferred choice due to minimal injury and rapid rehabilitation. New types of stents, such as self-expanding or biodegradable, reduce the risk of restenosis. In complex forms of aortic coarctation, combined approaches, such as resection followed by stenting, can solve the problem with minimal injury and high efficiency. Thus, modern aortic coarctation treatment methods provide an integrated approach that takes into account both the physical and psychological aspects of patient recovery.

Conclusions. Based on the analysis of modern approaches to the diagnosis and treatment of aortic coarctation, the following key conclusions can be drawn. Modern medicine offers a wide range of AC correction methods, including traditional surgical operations and innovative endovascular technologies. The choice of method depends on the patient's age, location and degree of narrowing, the presence of concomitant diseases and long-term prognosis.

Endovascular technologies such as stenting can significantly minimize the traumatic nature of interventions, accelerate rehabilitation, and reduce the risk of postoperative complications. They are especially effective for adult patients and in the treatment of recurrent cases of AC.

The combination of surgical and endovascular methods makes it possible to successfully treat complex forms of AC, where one method may not be effective enough. This approach requires multidisciplinary collaboration between cardiologists, vascular surgeons, and interventional specialists.

The use of high-precision diagnostic methods such as computed tomography (CT), magnetic resonance angiography (MRA) and echocardiography makes it possible to accurately determine the location and degree of narrowing of the aorta, which is crucial for choosing the most effective treatment strategy. These methods also help to control the results of treatment and prevent possible complications.

Reducing the risk of relapses is achieved through technological innovation. This includes the development of new types of stents coated with antiproliferative substances or biocompatible materials, reduces the risk of restenosis, especially in children, personalized solutions such as the use of 3D printing to create individual stents, increase the accuracy and effectiveness of treatment.

Modern treatment methods are aimed at minimizing injury, rapid recovery and reducing psychological stress. Successful AC treatment allows patients to lead a full life without the limitations associated with hypertension, impaired blood supply to organs, or other complications.

Despite successful AC correction, patients need regular monitoring to monitor blood pressure, heart function, and vascular health. Timely detection of possible complications or restenosis helps to prevent the progression of the disease.

The treatment of aortic coarctation continues to evolve due to the introduction of new technologies, materials and techniques. The modern approach to AC therapy combines minimal injury, high efficiency and improved quality of life for patients. However, the choice of treatment method should be based on a thorough diagnosis and consideration of the individual characteristics of each case. Due to the development of multidisciplinary cooperation and scientific and technological progress, the prospects for treating SC are becoming more favorable.

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