ARTIFICIAL HEART VALVES: INDICATIONS FOR IMPLANTATION, THEIR FUNCTION, AND MODERN TECHNOLOGIES

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Abstract:

This scientific article provides an analytical overview of the functional structure of heart valves, their significance, and defects caused by diseases. The primary function of heart valves is to ensure unidirectional blood flow between the heart chambers and blood vessels. When valves are damaged, serious problems occur in the cardiovascular system, which can be life-threatening. The article analyzes mechanical and biological artificial valves that replace native valves, discussing their structure, advantages, and disadvantages. It especially covers clinical recommendations on choosing the valve type based on the patient's age, overall heart condition, and other individual factors. Mechanical valves offer long durability but require lifelong anticoagulation therapy; biological valves have shorter lifespan but are closer to natural valves. The article also discusses modern technologies such as TAVI (Transcatheter Aortic Valve Implantation), 3D-printed valves, and hybrid technologies. These methods offer less risk compared to traditional invasive (open-heart) surgeries and reduce recovery time. This work is useful theoretically and practically for students studying cardiac surgery and cardiology, practicing physicians, and specialists working with medical technologies.

Keywords: Artificial heart valves, heart valve defects, mechanical valve, biological valve, TAVI technology, valve prosthesis, cardiac surgery, circulatory disorders, cardiology, anticoagulants, 3D-printed valves, mitral and aortic valves, modern medical technologies, valve replacement surgery, minimally invasive surgery.

Introduction:

The heart, located in the chest cavity, is the central organ of the circulatory system. In a middle-aged person, the heart beats on average 70-75 times per minute, or about 100,000 times per day. This generates a force sufficient to lift 20 tons one meter high. The heart consists of four chambers: two atria (right atrium and left atrium) and two ventricles (right ventricle and left ventricle). The left atrium and ventricle make up the left or arterial part of the heart, and the right atrium and ventricle form the right or venous part. In September 1960, Dr. Albert Starr successfully implanted the first artificial mitral valve in a human heart. This valve was a mechanical device based on a ball-and-cage design, replacing the mitral valve. This operation marked a revolutionary milestone in cardiac surgery history. During the 1960s and 1970s, many other types of mechanical valves were developed. Since the 1970s, biological (tissue-based) valves have also been used. From the 2000s onward, minimally invasive technologies such as TAVI (Transcatheter Aortic Valve Implantation) have been developed.

Heart Valves: Heart valves play a vital role in the normal functioning of the heart and ensuring unidirectional blood flow. They are located between heart chambers and at the junctions between the heart and large arteries, regulating blood flow. Valves prevent backflow (regurgitation), ensuring the heart works efficiently. During systole (heart contraction) and diastole (relaxation), valves open and close accordingly, maintaining normal pressure gradients. **Systolic Pressure** is the highest pressure in the arteries during ventricular contraction when the left ventricle pumps blood into the aorta. The normal systolic pressure in healthy adults is 110–130 mmHg. A value above 140 mmHg is considered hypertension. Systolic pressure reflects heart pumping efficiency, arterial elasticity, and is an important diagnostic measure for diseases such as hypertension, heart failure, and aortic stenosis.

Diastolic Pressure is the lowest arterial pressure during ventricular relaxation when the heart chambers fill with blood. Normal diastolic pressure is 60–80 mmHg in healthy adults; above 90 mmHg indicates hypertension, below 60 mmHg suggests hypotension.

TAVI (Transcatheter Aortic Valve Implantation):

TAVI is an advanced, minimally invasive cardiology procedure for replacing aortic valve prostheses without open-heart surgery. It is especially important for elderly patients or those unsuitable for surgery. A catheter is inserted, usually through the femoral artery, and guided to the heart. The new valve is deployed inside the diseased valve, restoring normal blood flow without stopping the heart. TAVI reduces surgical risk, hospital stay, and recovery time. Although safer, potential complications include bleeding, arrhythmias, valve leakage, or the need for pacemaker implantation. Individual evaluation is essential before the procedure. Overall, TAVI is a safe and effective treatment for high-risk patients with aortic stenosis.

Valve Prostheses:

Valve prostheses replace malfunctioning heart valves to normalize blood flow. They are classified into mechanical and biological types. Mechanical valves, made from metal or carbon materials, last a lifetime but require lifelong anticoagulation therapy to prevent thrombosis.

Biological valves, made from animal tissues (usually pig or cow pericardium) or human donors, last 10–20 years and generally do not require anticoagulants. Valve prostheses can be implanted via open-heart surgery or minimally invasive methods like TAVI. Open surgery involves stopping the heart, removing the diseased valve, and sewing in the new valve. TAVI implants the valve via catheter without open surgery, suitable mainly for aortic stenosis in elderly patients. Prosthetic valves are indicated in severe valve disease, heart failure, or infective endocarditis. Post-implantation, patients require medication, regular monitoring, and lifestyle adjustments.

3D-Printed Valves:

3D-printed heart valves represent a new generation of prostheses manufactured using 3D printing technology. They are anatomically customized to the patient's heart, providing high precision and better biocompatibility. This technology is revolutionary for heart valve replacement and repair, especially in children, congenital defects, and complex cases. 3D valves use biomaterials like biocompatible polymers, tissue-compatible materials or patient-derived cells. They fit perfectly within the heart anatomy, reducing rejection risk and improving function. 3D valves are modeled using CT or MRI scans and printed with specialized printers. Though experimental, some clinical trials are promising. In the future, 3D valves may enable tissue regeneration and growth with the patient. Thus, 3D valves represent individualized, highly accurate, biocompatible solutions and the future of cardiac surgery.

Artificial Heart Valve Surgery:

Artificial heart valve surgery involves replacing damaged or malfunctioning valves with prosthetic valves to treat life-threatening valve diseases (aortic, mitral, tricuspid, or pulmonary). Usually performed as open-heart surgery under general anesthesia, the patient is connected to a heart-lung machine that temporarily takes over heart and lung function. The surgeon opens the heart, removes the diseased valve, and implants the artificial valve using special sutures. Mechanical valve recipients require lifelong anticoagulant therapy; biological valve recipients usually do not, but valves may wear out over time and need replacement. Postoperative care includes ICU monitoring of heart rhythm, blood pressure, respiration, and coagulation status. Recovery typically lasts 4–6 weeks, with early improvement in heart function. Rehabilitation, diet, and ongoing cardiologist follow-up are mandatory. Overall, artificial valve surgery restores heart function, improves quality of life, and longevity, but requires careful preparation and follow-up.

Conclusion:

Artificial heart valves are essential for treating congenital or acquired valve diseases such as stenosis and regurgitation, improving patient quality of life and survival. Mechanical and biological valve types each have unique benefits and drawbacks. Modern surgical methods, including open-heart surgery and minimally invasive TAVI technology, enable safe and effective valve implantation. 3D printing technology for patient-specific valves is an emerging field that promises to revolutionize cardiac surgery. Artificial valve implantation significantly restores heart function and reduces symptoms but requires lifelong medical monitoring, anticoagulation therapy if needed, and rehabilitation. Thus, artificial heart valves represent one of the greatest achievements in modern cardiology and cardiac surgery, playing a vital role in managing heart diseases.

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