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Analysis of the current status and development prospects of artificial hearts

Yuan Yuan

NanTong University medical school, NanTong, China, 226000

15951199726@163.com

Abstract. Confronted with the rapid need for transplantable hearts, patients who need a heart transplant cannot receive the suitable configuration. Thus contributes to the development of artificial hearts, which can be created to substitute the old, the ill heart without waiting for transplantable hearts. Nowadays, this paper shows the public the artificial hearts. Through the extensive literature, it is clear that the development of artificial hearts. Dating back to the fifties of the last century, scientists began studying artificial hearts. Till now, China has created four generations of artificial hearts. They became more and more strong. The importance of the heart goes without saying, however, every year there are more and more heart failure patients. Paying more attention to the artificial hearts helps reduce the death rate of heart failures. Actually, although the patients can get the heart donors, they may not tolerate rejection. So research into artificial hearts more suitable for patients is imminent. This paper mainly introduces the fourth-generation artificial hearts (in fact, it is an improved version of the third generation), the magnetic levitation artificial heart attracts much more attention, and its composition and function have been greatly improved, reducing the difficulty of surgery. It is hoped that people can know much more about artificial hearts, and prospects for better methods to make better artificial hearts, and promote heart transplantations.

Keywords: artificial hearts, in vitro self-made, magnetic levitation artificial heart, foam artificial heart, individualized exercise rehabilitation

1. Introduction

In 2018, cardiovascular deaths accounted for the first total causes of death among urban and rural residents in China, with 46.66% in rural areas and 43.81% in urban areas. It is estimated that the number of cardiovascular diseases is 330 million, including 13 million strokes, 11.39 million coronary heart disease, 5 million pulmonary heart disease, 8.9 million heart failure, 4.87 million atrial fibrillation, 2.5 million rheumatic heart disease, 2 million congenital heart disease, 45.3 million lower limb artery disease, and 245 million hypertension [1]. According to the data above, we can understand that the demand for heart transplantation far outweighs its supply. Thus the development of artificial hearts can help solve this dilemma. On December 18, 2013, the French company Carmat claimed that they had accompanied the first artificial heart transplantation successfully [2]. From then on, many laboratories began their studies. Besides, the materials used to make artificial hearts are varied. Now this paper shows people artificial hearts with different materials whether they have different benefits, whether some materials can decrease the damage to the human body. Although the fourth generation

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artificial hearts, magnetic levitation artificial heart, are widely applied in clinical practice. It is still not guaranteed to function optimally with other organs of the body. So, the better artificial hearts or heart transplants need to be innovated. This paper studies the topic through many articles by seniors. Through this study, it is hoped that people can know much more about artificial hearts, and discuss if people can have better methods to make better artificial hearts, and promote heart transplantations.

2. The operating mode of the hearts

Actually, artificial hearts mean ventricular assist devices. It is known that the function of heart is to provide the human body with blood and oxygen. The heart is like a pump, it can convey blood and oxygen to different organs or tissues of the human body. The mode is that right atrium receives upper and lower vena cava bleeding. After passing through the atrioventricular mouth, the blood is fed into the right ventricle. The right ventricle pumps out the blood through the pulmonary artery to the lungs, and then converts the venous blood into oxygenated arterial blood through ventilation in the alveolar membrane of the lungs. The oxygenated arterial blood flows the blood back to the left atrium through the pulmonary vein, from the left atrium to the left ventricle, and then from the left ventricle through the heart pumping blood into the aorta, and then the blood is transported to the organs of the human body. However, if there is something wrong with the pump, that situation is called heart failure. To solve the problem, the artificial hearts came into being. Thus, the artificial hearts work as the pump, it is put in a certain ventricle, which helps the relaxation and contraction of the heart.

3. The installation of magnetic levitation artificial heart

Long ago, doctors used to split the sternum open to expose the heart, insert a tube into the aorta of the heart to connect to a perfusion tube, and then connect a tube into the vena cava to connect to a drainage tube on the machine. The tube was drawn out through the skin on the surface of the sternum and operated in this situation, which caused significant trauma to the heart. For this reason, there have also been improvements in the surgical method, cleverly utilizing the structure of the heart. A small incision is made on the side of the rib near the left atrium, revealing the location of the left atrium pulmonary vein. A perfusion tube is passed through this place, and the night artery is connected to an artificial blood vessel for perfusion. This method greatly reduces the trauma to the human body caused by the installation of artificial hearts. Before the whole heart transplant, the whole heart of the patient with heart failure needs to be transplanted, which is a challenge for the patient's immune system, but for the full magnetic levitation artificial heart, only need to open an opening in the patient's problematic ventricle to place the instrument to help the broken ventricle operate, which also greatly reduces the damage to the patient's body.

4. Different materials used to the artificial hearts and its advantages or disadvantages

The University of Maryland Hospital completed the second transplant of a gene-edited pig heart into a human body, which caused quite a stir, and recent clinical tests have been good. The patient is off the ventilator and can sit up in the bed and perform some normal activities. This is another major advance in heart transplantation, but we have to take into account the adenovirus vector carried by the pig heart itself and the rejection reaction of the human body, so such a transplant operation still needs to be observed for a longer time. Due to the special function of the heart, the biomaterials used to make the artificial hearts should be taken into serious consideration. On July 3th, 2001, Louisville Jewish Hospital in the United States completed the implantation of the world's first independently functioning artificial heart. The main body of this artificial heart is a pump made of titanium and plastic, weighing about 1kg, with an electronic control system that can adjust the speed of the pump according to the needs of the body. The disadvantage is that it is so large that it can hardly fit into the heart of a female patient [2]. The weight of the female heart is about 250g.

China's National Medical Products Administration approved the registration application for an "Implantable Left Ventricular Assist System". The product consists of a blood pump, rechargeable lithium battery, adapter, battery charger, communication isolation module, monitor, surgical tool, and

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shower bubble [3]. Magnetic levitation artificial heart is widely used in heart transplantation operations. The third generation of magnetic levitation artificial heart, with a thickness of only 26mm, a diameter of 50mm and a weight of less than 180g, is the latest artificial heart research result in China [4]. The 1-year survival rate of patients with left ventricular assist device artificial heart implantation is nearly 90%, and the 2-year survival rate is 70% [5].

Compared with artificial hearts made of other materials, the magnetic levitation artificial heart can decrease the damage to the human body, its pump helps separate the operation of external organs and pumps. As is known to all that, the operation of the pump can release the heat, which is harmful to other organs. But with the maglev device, it can protect the other organs. The first generation was a mechanical pump, using a mechanical method to continuously compress a cavity to pump it. The second generation is an axial pump type that uses a propeller to facilitate blood flow. The third generation is a centrifugal pump, and the so-called magnetic levitation is also an improved version of the third generation.

5. The importance of the study of the artificial hearts

The five-year mortality rate for heart failure is 50%, and the mortality rate in the terminal stage is as high as 50% in one year [6]. The best treatment for people with heart failure is an allogeneous heart transplant. However, leaving aside the fact that it's hard to wait for the donor, if it is lucky for the patients to get the donors, they may face other difficulties. First of all, the patients have to get long-term oral immunosuppressants to avoid the patients rejecting the transplanted organs. This process will damage the patients' immune systems. Secondly, the patients should adjust the drug periodically according to changes in physical function. Compared with that, the artificial hearts can be improved according to the patient's physical condition. Thus the patients can adapt to the new foreign organs easily.

6. Post-artificial heart transplant care

Heart transplantation is one of the more difficult in cardiac surgery, the whole surgical process includes thoracotomy, cardiopulmonary bypass, and the process of placing the transplanted heart, so it is also important to recover after surgery, and patients need to take medication and exercise, postoperative recovery also takes a long time, taking three weeks or more to improve cardiopulmonary function, the graft works better in the patient's body. Because of the individualized treatment plan, the treatment process requires individualized care. Individualized exercise rehabilitation is a better choice. Many patients with heart failure cannot do strenuous exercises like running, climbing, or swimming. After transplanting the artificial hearts, the patients worry much more about whether they can live a normal life. With individualized exercise rehabilitation, patients can little by little contact movement [7]. After the care, the patients' athletic ability and maximum heart rates improved. The Self-Rating Anxiety Scale (SAS) and Self-rating depression scale (SDS) scores in the study group were lower than those in the control group ($P < 0.05$). The activity time, exercise time, exercise level, and maximum heart rate of getting out of bed were better than those of the control group ($P < 0.05$). The quality of life scores in the study group were better than those in the control group ($P < 0.05$) [8].

7. Conclusion

As for the operation of the heart, the artificial heart is used to solve problems with insufficient pumping function. With the development of artificial hearts, the latest generation of magnetic levitation artificial heart (the third generation of the improved version) is convenient for heart failure patients to the great greatest extent. Considering the specialty of the human body, the materials used to create the artificial hearts are important. Due to the high cost of artificial hearts, the precision of artificial hearts and the difficulty of heart transplantation, the entire surgical process needs to be cautious. In addition, postoperative treatment also requires the active cooperation of medical care. At present, the application of artificial hearts in clinical trials is relatively short, and there are many aspects of artificial heart research that are debatable. The convenience of the latest generation of

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magnetic levitation artificial heart is that it is tight and it doesn't need to replace the entire heart. Actually, in contrast to whole-heart transplantation, which requires the removal of the entire heart. The third generation of the improved version maglev artificial hearts only require a pump-like device to be installed in the failed ventricular to assist the ventricles in ejecting blood. That is already a major breakthrough. However, the third generation of the improved version maglev artificial hearts still need an external power supply, it is not big, and people can image whether it is possible to reduce the volume, but with a long period of power use. As for the artificial hearts themselves, today's stainless steel materials can isolate the heat energy of mechanical movement, but it is ultimately metal, whether in the future can be developed. The nearest bionic material similar to the heart while maximizing the operation of the organ artificial heart, it is worth looking forward to by the public.

Compared with the third magnetic levitation heart, the latest all-maglev artificial heart is that the rotor can operate in a levitation way. At present, the full magnetic levitation artificial heart is recognized as the latest generation of ventricular assist devices on the tool. But science doesn't stop, exploration doesn't stop, and scientists are still not exploring better ventricular assist devices. Whether 3D printing model technology can be used in the future to replicate the heart of heart failure patients, simulate the operation of the heart in the ex vivo replica model, and whether it is possible to consider starting in the lungs to promote the circulation of blood circulation in the lungs, so that the blood from the pulmonary vein into the left atrium and the right ventricle of the blood flow to the pulmonary vein is full of power, thereby assisting the circulation of blood in the heart. This idea is based on the idea that heart failure is due to the weakened movement of the heart and the blood flow is not available, and we can consider driving blood flow on the other hand, but with the help of other organs such as the lungs and possibly other organs. It is hoped that relevant aspects can be innovated and practiced in the future.

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