ARTIFICIAL ORGANS

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Summary. *The article discusses the development and history of artificial organs, which have become a significant area of focus for the scientific industry. The article traces the origin of artificial organs back to ancient times, with scientists attempting to create substitutes for natural organs, commonly referred to as "spare parts." The first implantable artificial heart was developed in the early 20th century, and since then, significant advancements have been made in the field of artificial organs, including the creation of hemodialysis machines, stationary heart-lung machines, and implantable artificial hearts. Recent developments in stem cell research, tissue engineering, and 3D printing have led to promising developments in the field of artificial organs, such as the successful 3D printing of a silicone heart in Switzerland. Despite ongoing efforts, there is still a shortage of organs, and artificial organs offer a solution for patients who are in desperate need of a transplant but are far down the list for a donor organ.*

Keywords: *artificial organs, life support, medical devices, tissue engineering, 3D printing*

Introduction

In the 20th – 21th century, the scientific industry shifted its focus to new priorities as the modern world demanded solutions to numerous problems, such as finding cures for fatal diseases, regenerating human body cells, and decoding the genetic code. Another significant problem that emerged was the deterioration of human organs, which led to the development of artificial organs as an alternative solution. This has resulted in a fundamental question in biological science - whether to treat or replace the organ [1].

One of the most advanced fields in modern medicine is the development of devices that can replicate the functions of various organs in the human body. While the body has numerous functions, such as motor, sensory, and intellectual, the function of life support is especially critical. Without this function, the implementation of the others becomes meaningless. The lungs, heart, kidneys, vascular and digestive systems, liver, and other components are all critical organs necessary for sustaining life. Fortunately, there are already existing devices that are capable of replacing the functions of most of these life support organs for extended periods of time.

History

The development of artificial organs dates back more than a dozen years, as people have been attempting to create substitutes for natural organs, commonly referred to as "spare parts". Evidence of this quest for artificial organs dates back to ancient times, such as the story of a Greek warrior, as described by the historian Herodotus, who escaped captivity by chopping off his chained foot and later walked with a wooden leg. Archaeologists excavating near the Italian city of Capua even found the bronze leg of a Roman legionnaire from over 1,500 years ago, which replaced the one he lost in battle. In the Middle Ages, prosthetic limbs began to be designed with movable features.

The origin of artificial organs dates back to 1925, when Soviet scientists S. Bryukhonenko and S. Chechulin conducted an experiment with a stationary device capable of replacing the heart. They found that a dog's head, separated from the body but connected to donor lungs and a new apparatus, could remain viable for several hours and even eat *(Fig1).* This experiment marked the beginning of the development of artificial organs.

Figure 1. Dog's head connected to life support equipment

In 1936, S. Bryukhonenko developed an oxygenator, which replaced lung function, making it theoretically possible to sustain the life of separated animal heads for several days. However, in practice, there were many limitations, such as the destruction of red blood cells, blood clots, and a high risk of infection, which prevented the use of similar devices on humans for another 17 years.

In early 1937, V. Demikhov created the first implantable heart *(Fig2)* and tested it on a dog. However, the new device's low technical characteristics allowed it to be used for only an hour and a half, resulting in the dog's death.

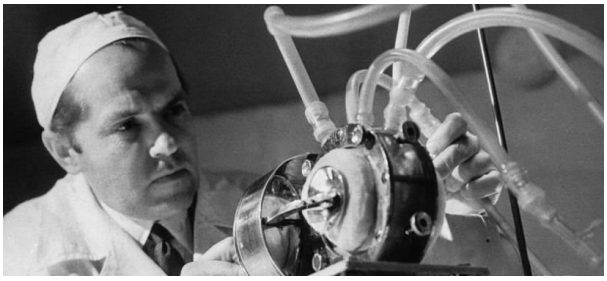

Figure 2. First implantable heart

In 1943, W. Kolff, a Dutch scientist, created the inaugural hemodialysis machine or artificial kidney. He implemented the device in medical practice one year later, using it to sustain the life of a patient with severe renal failure for 11 hours. In 1953, J. Gibbon, a scientist from the United States, achieved the first successful utilization of artificial stationary hearts and lungs during a human heart operation. Following this breakthrough, stationary heart-lung machines have become an indispensable component of cardiac surgery.

In 1963, an experiment conducted by R. White demonstrated that a monkey brain could remain viable for approximately three days. Then, in 1969, D. Liotta and D. Cooley conducted the first test of an implantable artificial heart in a human patient *(Fig3*). The device kept the patient alive for 64 hours while awaiting a human heart transplant, but unfortunately, the patient passed away soon after the transplant [2].

Figure 3. Liotta-Cooley Artificial Heart

Following these early pioneering experiments, the development of new devices was slowed, as researchers focused on addressing the flaws and errors of previous inventions. This process continued over the following decades, with the goal of improving the safety and efficacy of implantable medical devices.

Back in 2007, an individual with completely artificial but stationary lungs lived for 117 days, setting a new record for life expectancy. In 2008, medical professionals successfully sustained the

life of a patient for 16 days through simultaneous artificial support of heart and lung function, while awaiting a donor heart. During the same year, a team of scientists at the University of California unveiled the world's first portable artificial kidney, alongside significant advancements in the creation of various other artificial organs and body parts. Touch Bionics also introduced a groundbreaking prosthetic hand, which boasted a remarkably lifelike appearance. Moving ahead to 2010, the University of California developed the first implantable bionic kidney *(Fig4)*, although it has yet to be mass-produced.

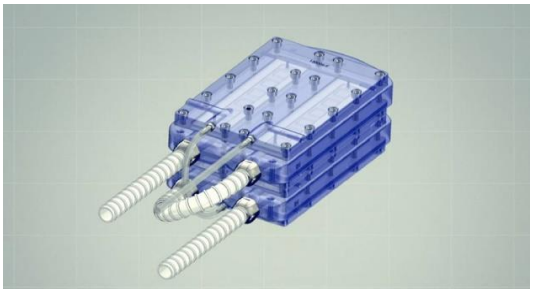

Figure 4. Implantable bionic kidney

Modern Artificial Organs

The process of developing artificial organs can be lengthy and complex, as it involves clinical trials, manufacturing, approvals, and other factors that can delay the availability of the technology to patients. However, advances in stem cell research, tissue engineering, and 3D printing have led to promising developments in the field of artificial organs. For example, a laboratory in Switzerland has successfully 3D printed a silicone heart that closely resembles a human heart, which may offer a solution to the shortage of organ donors. This technology has the potential to become an easy, affordable, and reliable way to address donor shortages in the future.

Despite ongoing efforts, there is still a shortage of organs, as evidenced by the more than 600,000 people on dialysis in the United States and over 6,500 people relying on mechanical circulatory support devices. The demand for kidneys, in particular, continues to rise. Artificial organs, such as those used for ventricular assistance, life support, dialysis, and insulin control, can offer a solution for patients who are in desperate need of a transplant but are far down the transplant list. The goal of artificial organ technology is to improve an individual's quality of life.

The maintenance of artificial organs is a major concern, given the variety of technologies involved and the need to ensure the safety and effectiveness of replacements for obsolete devices. Ethical considerations include addressing the frequency of replacement, ensuring that knowledgeable clinical providers and technicians are available for routine examinations and emergencies, establishing commercial marketing policies and standards, and safeguarding the privacy of tracking data for artificial organs. The experience gained from the pacemaker, which was first developed in 1960, has been instrumental in shaping current policies and standards for this type of medical device. Manufacturers have consistently produced improved models for the market, and policies are in place to ensure that new pacemakers work with old pacemaker leads, which can be risky to replace. It is clear that examining the ethical challenges associated with pacemaker technology will provide insight into the challenges that will arise with the development of other types of artificial organs.

The average cost of an artificial organ is $20,000, and around 2% of Americans have an artificial organ or joint. Artificial organs are necessary for various medical conditions such as cardiac assist devices, orthopedic devices, neuroprostheses and neurological support, urological support, visual support, blood cell and tissue replacement, and autoimmune and metabolic therapy treatments. The global market for this technology was estimated to be worth approximately $415 billion in 2016. Healthcare costs are increasing, with the US spending $8,500 per person annually. However, the number of patients who require artificial organs exceeds the number of people who receive treatment, with the situation projected to become worse. The cost-effectiveness of this technology is controversial, as it also affects mobility and quality of life. Healthcare professionals must focus on preventive measures such as the use of artificial organs to restore normal organ function rather than treating end-stage organ failure [3].

Although the development of fully functional, dimension-matched artificial organs is still in progress, the pharmaceutical industry is eagerly awaiting the creation of tissues that resemble human tissues. San Diego-based company, Organovo, has been a leader in commercializing 3-D bioprinting of tissues for medical research. The company has successfully printed patches of tissues of the liver, lung, heart, and kidneys for use in preclinical drug testing and toxicology studies. This application of artificial organs has great potential to speed up the drug development process, lower costs, and reduce the need for animal and clinical testing. L'Oreal, the global cosmetics company, has partnered with Organovo to source 3-D-printed human skin tissues, aiming to reduce animal testing. L'Oreal already owns a patent on Episkin, a tissue-engineered skin product developed by incubating skin cells donated by surgery patients. The partnership with Organovo will make it easier for L'Oreal to print the skin tissues to their exact requirements [4].

Public Attitude

People's attitudes towards artificial organs are diverse and can vary depending on cultural, ethical, and personal beliefs. Some people are enthusiastic about the development of artificial organs, as they hold the potential to save lives and improve the quality of life for those who are suffering from chronic organ failure. Others may be more hesitant, concerned about the safety and efficacy of such technologies, or concerned about the ethical implications of using artificial organs in humans.

There are also concerns about the availability and accessibility of artificial organs, as these technologies are often expensive and may not be accessible to everyone in need. Additionally, some people may have concerns about the use of animal or synthetic materials in artificial organs, or may be uncomfortable with the idea of using technology to replace natural human organs.

Overall, attitudes towards artificial organs are complex and nuanced, reflecting a range of personal, cultural, and societal values and beliefs. As with any emerging technology, it is likely that public attitudes towards artificial organs will continue to evolve as these technologies become more advanced and accessible.

Conclusion

In conclusion, the development of artificial organs has a long and fascinating history, dating back to ancient times. From the first stationary device capable of replacing the heart, to the development of the first implantable heart and kidney machines, to the more recent breakthroughs in stem cell research and 3D printing, the field of artificial organs has made significant progress. While there are still challenges to overcome, including clinical trials, manufacturing, and regulatory approval, advances in technology offer the potential to address the shortage of organ donors and provide new hope for patients suffering from organ failure. As the demand for life-saving interventions increases, the need for continued innovation and development of artificial organs will remain critical.

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