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Artificial Organs: SynCardia Heart

Kaity Keesling

Abstract: With an increased prevalence of cardiovascular disease, heart transplants are on the rise. As a result, the need for donor hearts exceeds current availability. To care for heart failure patients, healthcare professionals have developed the SynCardia total artificial heart. This article explains the artificial heart and its implementation into clinical practice.

A pressing public health issue currently affecting the United States is the rising prevalence of heart disease. This illness accounted for over 600,000 deaths in 2016, placing heart disease as the leading cause of death in the nation.[1] While the demand for heart transplants grows in response to increasing disease prevalence, the availability of donor organs remains unchanged. This disparity between supply and demand has led medical professionals to seek solutions elsewhere. An alternative for patients in need of a new organ is the utilization of artificial organs. An artificial organ is any human made machine, device, tissue or other material that is used to replace the functions of an organ in the human body.[2] In order to combat the high mortality rates related to heart disease, the total artificial heart (TAH) was developed. This device is a pump that is surgically inserted to replace diseased or damaged heart ventricles and provide circulation.[3] Although the artificial heart is not a permanent solution, it buys patients time until they receive a heart transplant. The growing prevalence of heart disease has created an imbalance between availability and need of donor organs. However, the artificial heart serves as a lifesaving solution for patients awaiting a transplant.

As heart disease continues to rise and cause health complications, the number of people waiting for a new heart has increased as well. To date, there are over 3,700 people on the heart transplant waiting list, which drastically exceeds organ availability.[4] For those in need of a transplant, the waiting time is often long because the donor heart must be similar in size and blood type. This long waiting period can be extremely difficult to endure, especially for those in end stage heart failure. The low donor availability combined with unfavorable heart health conditions continues to split the gap between organ supply and demand, encouraging medical professionals to seek alternative care options.

Artificial organs were developed to meet the high demand for organ transplants. Artificial organs vary greatly, depending on the structure and function they are intended to replace. While many artificial organs are completely synthetic, others are grown in a lab. Lab grown organs use stem cells to regenerate, repair, or replace damaged tissue or whole organs.[5] Potential advantages of lab grown organs include reduced likelihood of transplant rejection and permanent replacement of the faulty organ or tissue. Still, complex organs such as the heart are difficult to produce in this manner.[5] Due to its size and complexity, stem cells are unable to generate a fully functioning, adult-sized heart. Instead, artificial hearts are made from biocompatible plastic. This type of plastic minimizes the likelihood of rejection so that the body is more likely to accept the artificial organ.

The first recorded artificial heart transplant performed on a human occurred in 1982 using the Jarvik-7 model heart.[6] Today, the Total Artificial Heart (TAH) by SyCardia is the only FDA approved fully synthetic heart that is designed for use as a temporary bridge to live organ transplant.[7] It is a pump that is surgically installed to provide circulation and replace heart ventricles that are diseased or damaged. The structure of the synthetic heart closely mimics that of a natural, live heart.[8] The TAH contains two artificial ventricles made from biocompatible plastic. The two ventricles are connected in the middle by velcro, which allows unique positioning and placement of the heart depending on the anatomy of each individual patient. An external machine performs the pumping action rather than live muscle tissue.[8]

Within each ventricle in the artificial heart are two valves, one for inflow and one for outflow, which control the movement of blood in and out of the heart.[8] There is also a flexible diaphragm membrane which splits each ventricle into two chambers, one for air and one for blood. The formation of these two areas helps the external pumping system control blood flow by inflating and deflating portions of the heart in a regular pattern. The tubes that connect the internal artificial heart to the external system that regulates blood flow are called cannulae. These tubes are partially covered in velour fabric, similar to a plush velvet, promoting proper healing at the tube exit site through the abdominal wall. The cannulae connect further to two additional external tubes called drivelines which connect to the external pumping system.[8]

Along with the artificial heart on the interior of the body, external drivers, which act as the battery pumping the heart, are equally necessary. There are various types of external drivers that serve different purposes, depending on the situation and needs of the patient. Some external pumping systems are portable while others are not, but each work in a similar way. The machine produces pulses of air and vacuum in order to inflate and deflate the diaphragms which push blood in and out of the ventricles.[8] In 2004, the CCS driver was approved for medical use, followed by the C2 driver in 2012. Although effective and serve their intended purpose, these batteries limit patient freedom since they are used in a stationary position, typically in a hospital.[7] A new model called the Freedom Driver was FDA approved in 2014, granting freedom of movement to patients who received a total artificial heart.[7] Patients can be switched to this lighter, portable battery and sent home once they are clinically stable. The minimal maintenance and ease of use allow patients to lead a nearly normal lifestyle while waiting for a donor heart.

Since its approval, the SynCardia heart has been implanted over 1300 times in the United States, Canada, and Europe.[9] As a result, total artificial heart transplants have dramatically improved the 'bridge to transplant' survival period from 46% to >79%.[10] The limitations to its efficacy include durability and length of time the artificial heart can remain in a person's body without causing secondary complications. The longest known usage of the SynCardia total artificial heart is currently 4.6 years or approximately 1700 days.[11] Since it's not a permanent solution to poor heart health, an artificial heart is only indicated to sustain life. Criteria to meet eligibility requirements for a TAH are very specific.[12] First, a patient must be suffering from very advanced or end stage heart failure. Both sides of the heart (biventricular) must also be affected. Lastly, patients must be eligible or likely to become eligible for a heart transplant. Since heart failure is irreversible, the TAH is the greatest chance for survival until a donor heart becomes available.[12] However, it comes at a high cost. The estimated cost of a TAH is about $150,000 without insurance, though this cost may differ depending on who performs the transplant.[10] Despite this high price tag, most insurance companies will cover the majority of expenses. There is little to no cost for upkeep of the synthetic heart, although there is some maintenance work to ensure its continued efficacy.

In response to the growing prevalence and mortality related to heart disease, the United States has a growing disparity between the need and supply of donor organs available for transplant. The excess demand for life-saving intervention has led to the development of a wide variety of artificial organs. While many of these devices are not intended for permanent use, like the SynCardia total artificial heart, they are effective at bridging patients to transplant of a live organ. The future of artificial organs is promising, as more effective treatment options are being developed, allowing for increased quality of patient care as synthetic organs help to sustain life.

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