ARTIFICIAL HEART

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ABSTRACT

An artificial heart is a prosthetic device that is implanted into the body to replace the original biological heart. Artificial hearts are typically used to bridge the time to heart transplantation, or permanently replace the heart in case heart transplantation is impossible. Heart disease currently affects more than 100 million people around the world some of these diagnosed cases are so severe that patients may not survive the wait for a donor heart. In 1995, 2400 heart transplants were performed while 4000 patients awaited donor hearts; 731 of these patients died waiting. With the number of patients suffering from severe heart disease increasing and the number of donor hearts remaining constant, an immediate need exists for the advancement of artificial hearts. Artificial hearts provide a viable option for patient awaiting heart transplantation. Future developments on artificial hearts have the hope of eliminating the need for the transplantation completely.This paper evaluates the importance of artificial heart it aims prove to become the most effective choice for severely ill patients.Biomedical scientists and engineers have developed devices such as defibrillators, pacemakers, and artificial hearts to keep patients alive until a donor heart becomes available.

Keywords: Artificial Heart, Heart Failure, How Many People Suffer From Heart Failure

I. INTRODUCTION

Artificial hearts have been around since the early 1980s. The Jarvik-7 became the first permanent artificial heart in 1982. The patient implanted with the device lived for 112 days on the artificial organ. Patient was unable to leave his bed and was in severe pain until his death. Human life could be prolonged by artificial means, but patients still had to suffer after implantation. At this time, the risks, such as sub-standard quality of life, outweighedfuture benefits of artificial heart technology and all research was put off until positive results could be expected. After many technological developments in materials science as well as pharmaceuticals, artificial hearttechnology is once more in the spotlight. The complete artificial implantable heart and the ventricular assist device provide a mobile option for severely ill cardiac patients.At the end of 1998 American heart specialist Michael DeBakey performed a world - first in heart surgery with a totally new device. If this electric heart proves successful, it could be a permanent alternative to heart transplant.

II. HEART ANATOMY AND DISEASE

To completely understand the design development of the device, it is imperative to know the functions and diseases of the human heart. The heart is the most important organ in the human body. Even if a patient is considered brain dead, the patient is still considered alive until the heart stops beating. Though it serves such an essential role the mechanisms behind the human heart are relatively simple. The heart is pump that works based on positive displacement. Positive displacement refers to a change in volume with in a chamber due to the movement of fluid across its boundaries. From this volume change, pressure differences arise that drive the

blood pumping

process. The heart has four chambers. These chambers or cavities are the right atrium, right ventricle, left atrium, and left ventricle. Each chamber connects to a one-way valve. When a cavity contracts, a valve opens and blood flows into the chamber. In summary, there are four valves, each associated with individual chamber. The following list identifies each valve with respective chamber.

•Mitral valve & left atrium

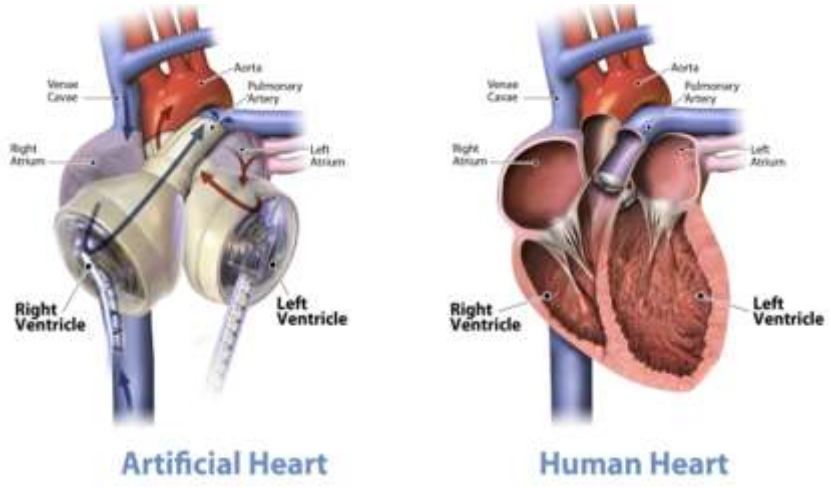
•Aortic valve & left ventricle

•Tricuspid valve & right atrium

•Pulmonary valve& right ventricle

The heart pumps blood to the body in two steps.First,the right and left atria contract, moving blood to the right and left ventricles. Second, the ventricles contract simultaneously to push the blood out of the heart and through the body. The heart then relaxes, allowing new blood to fill the atria. This contraction of the atria and the ventricles makes up aheartbeat.

Figure1 illustrates the anatomy of the human heart.



Artificial Heart Human Heart

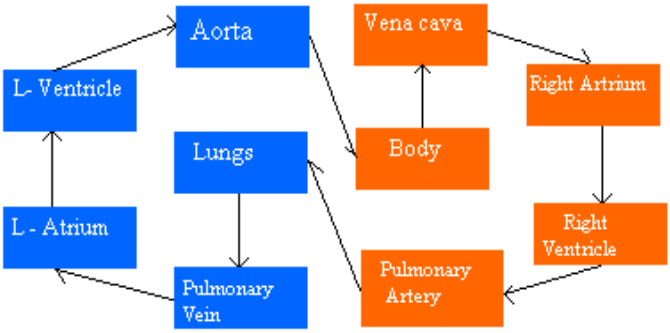
The human body needs oxygen in order to live. The circulatory system is responsible for filtering oxygenated blood and deoxygenated blood from the body. Blood enters into heart through two veins, the superior vena cava and the inferior vena cava. Both of these veins feed de-oxygenated blood into the right atrium. The right atrium contracts sending blood to the right ventricle. Blood flows from the right ventricle through the lungs by means of the pulmonary valve. Within the lungs the deoxygenated blood becomes oxygenated. The newly oxygenated blood flows through left atrium and ventricle, and the blood disperses through the body. Figure 2 recaps flow of blood through the heart. Like all machines, the Heart can malfunction numerous ways. Cardiovascular disease occurs when the heart becomes “clogged, broken down, or in need of repair”. Severe cardiovascular disease is the leading cause for heart transplantation, but other malfunctions such as valve damage and chamber problems also require the need for a new heart. Currently, 12 million Indians have at least one kind of cardiovascular disease. Heart disease is

thenumber one cause of death in India. Since many conditions fall under the in category of cardiovascular disease, we will focus on the two main causes for heart transplantation and artificial hearts:

1. Coronary Heart Disease(CHD):-afflicts approximately 20 percent of all patients diagnosed with cardiovascular disease. Patient’s symptoms can range from being mild to intolerable. CHD is the hardening of artery walls inside the heart. Arteries are essentially piping that connects heart valves together. In CHD,

the transportation of blood becomes impaired when a mixture of fat and cholesterol, or plaque, lines the arteries the buildup of plaque restricts the free flow of blood, which induces pressure drop between the valves. The heart compensates for this pressure drop by pumping harder in order to provide enough blood for the entire body. Patients suffering from CHD often exhibit symptoms such as severe chest pain and fatigue due to the lack of oxygenated blood. For severe cases of CHD, the only cure is a heart transplant.

2. Congestive heart failure (CHF):- arises when the heart does not efficiently pump blood. Since the heart is unable to pump enough oxygen-rich blood, blood starts to fill in the lungs, which leads to congestion. Therefore, the heart must work harder in order to meet the body's oxygen demands. This behavior cause's excessive wear to the diseased organ initial symptoms of CHF, such as fatigue and swelling of the ankles, is usually so option. Until the condition becomes much more severe. As the disease progresses patients start to suffer from shortness of breath and palpitations even while remaining stationary. For extremely, severe cases, transplantation is the only option.



III. EFFECTIVENESS OF TRANSPLANTATION

Surgeons started developing heart transplantation techniques early as the 1900s. Preliminary transplantations conducted on animals proved to have fatal consequences caused by the donor organ rejection.Therefore doctorswere skeptical to try transplantation procedures on humans. In 1905, the first cardiac heart transplant was performed by two surgeons on a dog. They removed the heart of a dog and placed into the chest cavity of larger dog(Transplantation). Then the heartbeat resumed but the dog transplantation. Though the experiment had fatal results, this event stunned the medical community and spearheaded further research in field of cardiac expiredtwo hours after the operation.By definition, heart transplantation is "The replacement of a patient's diseased or injured heart with a healthy donor heart". Reaching the exact definition of transplantation proved to be an extremely difficult task. In order to deter organ rejection after transplantation, research was launched in field of immunosuppressant drugs. An immunosuppressant drug restrains a transplanted patient's immune system to prevent rejection of the implantedorgan. Dr. Gertrude Elion developed the first with end stage cardiovascular disease in 1957. Azathioprine proved to be useful tool that helped facilitate future advancements in organ transplantation.In 1967, Dr. Barnard performed the first human heart transplant in Cape Town, South Africa. Dr. Barnard implanted the donor heart from a 25-year old female into a 55-year old female with end stage cardiovascular disease. She lived for 18 days with the transplanted organ. Ironically, the medication prescribed to suppress rejection of the new organ weakened his immune system.Current heart transplantation techniques prove to be a viable option. According to the United Network of Organ Sharing (UNOS), 2,202 heart transplants were performed in 2001 compared to 170 transplants performed in 1970. Currently, approximately 70% of transplant patients live for five or more years after transplantation [UNOS, 1999]. These current

statistics are staggering in comparison to the 14% survival rate from the early 1970s. As of now more than 11,163 patients were awaiting heart transplant [UNOS, 2004]. Only about quarter of these patients will receive a new heart [UNOS, 2004].Since there is such a shortage of donor hearts. Therefore, further development provides a solution for all patients. Current development of artificial hearts strives to is necessary to provide a universal solution for these patients.

IV. TOTAL ARTIFICIAL HEART DEVELOPMENT

The development of artificial hearts reflects a transition from a support device to a completely self-contained machine. In the 1960s, the purpose of an artificial heart was to temporarily support patients until a donor heartbecame available. Surgeons attempted successful; however, many surgeons became wary of this device because it early 1980s by implanting an artificial heart intended for long-term therapy. The device they used was the Jarvik-7, a blood pump that replaces the heart's ventricles. The procedure was initially successful; however, many surgeons became wary of this device because it did not offer an acceptable quality of life. As a result, the public began to question the need for permanently removing vital components of the heart. The world of artificial heart technology then separated into two classes: assist devices and artificial hearts. In the 1980s, several organizations, including Penn State Medical Center, and the Texas Heart Institute, began developing ideas for new designs. Their intent was to engineer artificial hearts that could permanently sustain heart failure patients while providing a decent quality of life. These companies immediately encountered one huge barrier infection due to precutaneous or skin piercing, tubes. During the 1980s, every artificial heart had power cords, blood tubes, or air tubes protruding from skin. It was not until the early 1990s with the advent of transcutaneous technology.

V. MILESTONES IN THE ARTIFICIAL HEART TECHNOLOGY

•1960s – Surgeons implant the first temporary artificial heart.
•1970s – Engineers develop the ventricle assist device as an alternative to artificial heart
•1980s – First long term artificial heart results in poor quality of life.
VAD's show potential for long term support.
•1990s – Transcutaneous technology eliminates the need for skin –Protruding.
Electrical wiring, patients with long-term VDA's recovers from heart failure.
•2000s – Improved quality of life for patients after implantation.

VI. A COMPLETE ARTIFICIAL IMPLANTABLE HEART

This device is a permanent artificial heart that is completely self- contained within the body. Some cases like they may have failure on both left and right side of the heart. Before the introduction of the device, doctors had no option than to let these patients die. However, artificial heart developers, such as Penn State, focused their design parameters for patients who's hearts have irreversibly failing left and right ventricles. This category of patients comprises about 20% of those in need of a heart transplant. Designs for this device initially began in the early 1980s, around the time of the Jarvik-7. Only recently has the device artificial heart received. The device which was prepared by Abiomed with the same principle was approved by FDA for clinical testing. The large time span for approval results from the controversy caused by the Jarvik-7. The device design addresses key

pitfalls encountered with the Jarvik-7. Improvements include better surface materials to reduce blood clotting and a newly engineered power system that does not require skin piercingelectrical cords. These design considerations were applied to the new model and clinical testing of the device made by Abiomed has begun in the recent times. The first patient implanted with the device, was lived for nearly five months. This event caught the attention of the public because it was the first time a patient with an artificial heart was able to stand up and walk around. As of patients are alive today.

VII. DESIGN OF THE COMPLETE ARTIFICIAL IMPLANTABLE HEART

Three subsystems implanted under the skin make up the design of the device. These subsystems include the heart pump, a computerized pump controller, and a power source. All of the subsystems cumulatively,Weigh around 4 pounds and operate so quietly that stethoscope is needed to listen to the heart sounds. Surgeons implant the heart pump in the area from where the ventricles are removed. Channels that connect naturally to the ventricles are then sewn into artificial cuffs that snap on to the heart. Two independent hydraulic motors lie inside the heart. One motor maintains the pumping function to each ventricle while the other motor operates the motion of the four heart valves. The pumping motion operates through hydraulics by an oscillating pusher plate that squeezes sacs which alternatively expel blood to the lungs and the body. When the blood sacs become full, the exit valves are shut and the entrance valves are open. The pump then squeezes the sacs, which allows the exit valves to open and the entrance valves to close. The device is capable of producing more than two gallons of blood every minute, which signifies a higher output than the Ventricular assist devices(VAD). Similar in design to the VAD, a small computer secured in the abdomen of a patient automatically adjusts the output of the pump.The continual monitoring of blood flow guarantees that incoming flow matches outgoing flow. This rhythm ensures steady state pumping of the heart.

Picture of Complete Artificial Implantable Heart

The transfer of energy is also the same as in the VAD. Surgeons implant an electric coil in the abdomen area to allow for energy transfer across the skin. Patients wear a battery pack around the waist and must change the batteries several times daily. The system also includes an internal battery so that patient may uncouple the external power source in order to take a shower. One significant advantage to the device is the smooth surface of the blood sacs. Smooth plastics are important in order to ensure constant motion of blood cells. Any time blood stops moving along the of the device clotting develops. The smoothness of the plastic, called Angioflex, allows for minimal damage to the blood. Angioflex is also durable enough towithstand 1,00,000 beats a day for several years. This plastic is a major contibution to the life and to the safety of the device.

VIII.CONCLUSION

Heart failure is the leading cause of death in India and also all over the World. Most people die from heart failure chambers, fail to push enough blood through the body. A solution to donor heart rejection surfaced in the early 1980s with the advent of cyclosporine an immunosuppressant and this discovery, the average survival rate of heart transplant patients increased to more than 5 years. One of the drawbacks to heart transplantation is its availability is only half of the patients needing a heart transplant will receive a donor heart. The development of artificial hearts resurfaced again in 1993 with the advent of transcutaneous technology. Transcutaneous technology is based on the transfer of power across the skin by electric coils.This technology eliminates infection due to skin- protruding electrical tubes. Artificial hearts and heart transplantation are the only methods for saving the lives of patients with heart failure. As of today, heart transplantation is the official method for replacing the human heart. But, donor hearts are not available to all patients. Heart transplantation and artificial hearts are not a competing source of technology. These technologies exist parallel to each other in order to encompass the whole population of patients in need of a new heart. Hope this technology will soon reach to the common man in INDIA.

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