BIOMEDICINE AND BIOMATERIAL: A STUDY OF ARTIFICIAL ORGANS AND XENOTRANSPLANTATION

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ABSTRACT

Organ demand is outpacing the supply of donated organs. In order to solve this problem, biomedicine is a rising trend in the science world. Biomedicine is a branch of medical science that applies biologic and other natural-science principles to clinical practice such as developing artificial organs. As biomedicine progressed artificial organs and xenotransplantation, which is transplantation of organs from one species to another, advanced. Biomedicine is hope to lots of people who are suffering from organ failure. However, rejection of the organs by the body and ethical problems are the barriers of this area of biomedicine development.

KEYWORDS

Artificial organs, Xenotransplantation, Biomaterial

Organ demand is outpacing the supply of donated organs. In order to solve this problem, biomedicine is a rising trend in the science world. Biomedicine is a branch of medical science that applies biologic and other natural-science principles to clinical practice such as developing artificial organs. As biomedicine progressed artificial organs and xenotransplantation, which is transplantation of organs from one species to another, advanced. Biomedicine is hope to lots of people who are suffering from organ failure. However, rejection of the organs by the body and ethical problems are the barriers of this area of biomedicine development.

There are a lot of patients who are waiting for organ transplantation but not everyone can get organ transplanted because the supply of organs is not on-demand. Three million Americans suffer from congestive heart failure. Also deaths related to this condition are estimated at 250,000 each year also 27,000 patients die yearly from liver disease. In 2002 in the UK, 667 people have donated organs, 2055 people have received transplants. However, 5615 people are still awaiting transplants. Even though, it is impossible to estimate how many people die for want of donor organs, there are uncountable people who fail to make it onto the waiting lists and disappear from the statistics. It is obvious that loss of life is a major crisis, and a major problem that needs to be solved immediately.

1. ARTIFICIAL ORGANS

An artificial organ is a man-made device that replaces a natural organ to be implanted or integrated into a human to keep functions so that the patient can return to as normal a life. Artificial organs originated for transplantation which is the moving of an organ from one body to

another to replace the recipient's damaged or absent organ. Due to the increase of organ demand, the supply of the donated organs could not support because not only supply was the problem, but also finding a right organ for the body was the problem. In order to solve this problem, scientists are developing artificial organs to supply right organs to patients at the right time.

Artificial organs are the organs that are made of special materials that our body does not reject. One of the most developed artificial organs is the heart. The artificial heart has a long history since the nineteenth century when it was first discussed in Germany. In 1928, English physiologists, Dale and Schuster, made a pump that functioned like a heart at the National Institute for Medical research in Hempstead. The pump was intended to carry out whole-body perfusion. In 1930s, Lindbergh invented an "artificial heart" that had a rotary valve which created a pulse. He developed it for Alexis Carrel, who is a French surgeon and biologist, whose research included experiments about keeping organs alive outside the body. Lindbergh's device could pump the substances necessary for life throughout the tissues of an organ. The first implantation of an artificial heart in a human being was carried out in 1969 by Denton Cooley and his surgical team at the Texas Heart Institute. The artificial heart was implanted as a temporary measure. Its goal is to keep a cardiac patient alive until a heart is transplanted. In June 1996, a 46-year-old Chinese American Mr. Yao ST received total artificial heart implantation. After 15 days of bridging, Mr. Yao received heart and kidney transplantation. He was still alive of September 2011. On October 27, 2008, French professor and Alain F. Carpentier who is a leading heart transplant specialist announced that a fully implantable artificial heart will be ready for clinical trial by 2011 and for alternative transplant in 2013. In August 2010, 50-year-old Angelo Tigano got his disfunctioning heart removed and replaced with a total artificial heart. On March 12, 2011, an experimental artificial heart was implanted in 55-year-old Craig Lewis and resulting in the patient being alive without a pulse.

Figure 1. Photo of Artificial Heart

Figure 2. Image of Artificial Heart

The fundamental limitation on artificial organs has always been the battery life needed to keep them running because batteries need to be continuously replaced over a patient's lifetime. Currently Serge Cosnier and other researchers at Joseph Fourier University in Grenoble, France, are studying a bio-fuel cell that uses glucose and oxygen at concentrations found in the human body to generate electricity. They estimate that within a decade or two, biofuel cells may be used to power a range of medical implants, from sensors and drug delivery devices to entire artificial organs. A bio-fuel cell is made of two special electrodes: one removes electrons from glucose, and the other donates electrons to oxygen and hydrogen molecules, producing water. This can solve the battery problem that could cause serious problems when the organ runs out of battery and stops operating.

Another fundamental problem of artificial organs is that there is not possible for the patients to get certain medical examinations. Because of magnetic reaction of the metals of artificial organs, MRI was impossible for the patients who have artificial organs in their bodies. However, there was a study in Spain that developed antimagnetic protective film which enables MRI. Also the superconductivity is used to allow patients to get certain medical examinations. Artificial organs will relieve patients who suffer from damaged or absent organs.

2. XENOTRANSPLANTATION

Xenotransplantation is transplantation of cells, tissues or organs from one species to another. Human xenotransplantation offers a potential treatment for organ transplantation saving thousands of patients waiting for donated organs. Xenotransplantation uses the animal organs from pigs or baboons that are genetically altered with human genes using genetic engineering techniques. These techniques are generally known as recombinant DNA technology which is using DNA molecules from different sources, which are combined into one molecule to create new genes. These genes trick patient's immune system so the body does not reject the organ. In 1985 two British scientists, Drs. David White and John Wallwork founded a xenotransplantation research company called Imutran. In 1992, Astrid, the first transgenic pig, was born. He was injected with human DNA. Only one millionth of Astrid's DNA was composed of human DNA. Imutran broke down the wall of immune system rejection to non-human organs in human recipients.

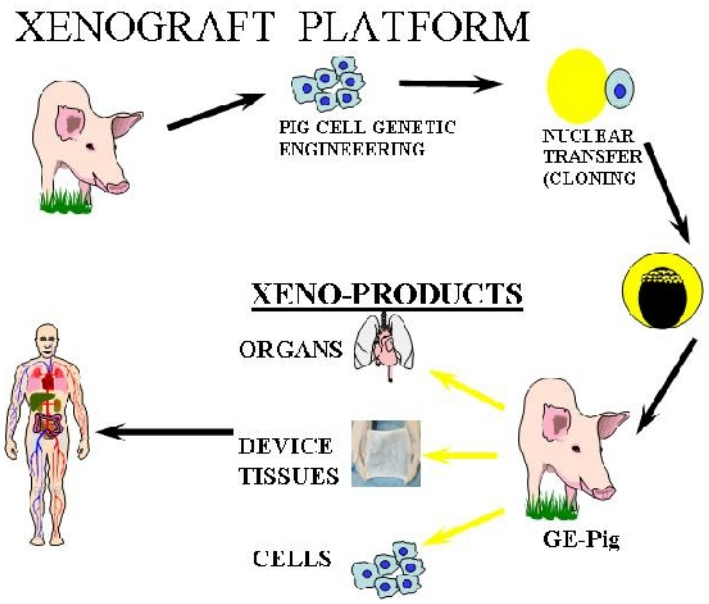

Figure 3. Xenograft Platform

Xenotransplantation has a long history. The first recorded xenotransplantation occurred in 1682. Part of a dog's skull was used to repair the broken skull of a Russian nobleman. The first xenotransplantation that was successful occurred in 1963. Chimpanzee's kidneys were transplanted to 13 patients and one patient survived more than nine months. In 1964, Stephanie Fae Beauclair, who was born with hypoplastic left heart syndrome, which is a rare congenital heart defect in which the left ventricle of the heart is severely underdeveloped, received a baboon heart and liver and he lived for about 20 days.

Pigs are the best organs donor. As the distance from humans increase, the risk of cross species disease transmission also decreases. Also pigs are easy to access and the anatomical size of organs is similar to human organs. Currently experiments of xenotransplantation are done to baboons using pigs as donors.

Xenotransplantation reduces the rejection of our body and allows on-demand supply. Genetically modified animals, decrease the massive rejection that human body has to foreign organs by tricking the immune system. Also the "humanized" animal organs can offer on-demand supply of organs. Xenotransplantation can be another solution to lack of donated organs for the patients.

3. DANGER

Artificial organs and xenotransplantation raise a lot of medical and ethical problems. Small breakdown of artificial organs can cause a serious problem and can be threatening to the patient. Due to the immune system of our body, artificial organs can often be rejected. There are four types of rejections: hyper acute rejection, acute vascular rejection, cellular rejection and chronic rejection. Hyper acute rejection and acute vascular rejection is based on humeral immune system. Hyper acute rejection is a rejection that is rapid and violent that occurs within a few minutes to hours from the time of the transplant. It occurs when XNAs(xenoreactive natural antibodies) binds to the donor endothelium which activates human complement system. Hyper acute rejection results in endothelium (a thin layer of cells of the interior surface of blood vessels) damage, inflammation, thrombosis (the formation of a blood clot inside a blood vessel that obstructs the flow of blood through the circulatory system), and necrosis (the premature death of cells in living tissue).

Acute vascular rejection occurs within two to three days in discordant xenografts (surgical grafts of tissue from one species to another species) when hyper acute rejection is prevented. Acute vascular rejection usually occurs by interacting between the graft endothelial cells and host antibodies, macrophages that are produced by the differentiation of monocytes (a type of white blood cells in tissues), and platelets.

Cellular rejection is based on cellular immunity, and is mediated by natural killer cells and T-lymphocytes. Natural killer cells accumulate in and damage the xenografts and through both direct and indirect xenorecognition, T-lymphocytes are activated by MHC (Major histocompatibility complex) molecules which are surface molecules encoded by a large gene family in all vertebrates. The Final type of rejection is chronic rejection which is slow and progressive. It is still unclear how chronic rejection works but it leads to pathologic changes of the organs, and it is the reason why transplanted organs have to be replaced after a few years. Artificial organs and xenotransplantation raise serious medical issues.

Xenotransplantation could be a life-saving answer for many awaiting organ transplants. However, the use of animal organs for human transplantation has ethical issues. A lot of animal rights groups strongly oppose killing animals in order to get organs for human use and animal experimentation. "The abuse of animals, including their use in investigations in the life sciences, has been a sensitive and emotional topic for centuries." Animal rights advocates insist that it is immoral to sacrifice animals for the benefits of human lives, both for the use of organs and experiments. Also pigs have shorter life spans than human which can cause problems because their tissues will age quicker than human's tissues. Medical and ethical problems are the barriers of artificial organs and xenotransplantation development that needs to be cleared up.

4. IMPORTANCE

Despite the danger of the artificial organs and xenotransplantation, developing alternative material for the organs is inevitable. Limited supply of organs is causing serious crimes. There are a lot of patients waiting for donated organs and because there are so few, illegal trafficking of human organs is occurring. A kidney can be not only the donor source of an organ but also monetary source.

> "Organ trafficking entails the recruitment, transport, transfer, harboring or receipt of persons, by means of the threat or use of force or other forms of coercion, of abduction, of fraud, of deception, of the abuse of power, of a position of vulnerability, of the giving or receiving of payments or benefits to achieve the consent of a person having control over another person, for the purpose of exploitation by the removal of organs, tissues or cells for transplantation. The reason to oppose organ trafficking is the global injustice of using a vulnerable segment of a country or population as a source of organs (vulnerable defined by social status, ethnicity, gender or age)." (Definition of organ trafficking is derived from the United Nations Trafficking in Persons)

A lot of criminals are abusing the desperation of guardians and patients and overcharge for human organs that are illegally trafficked.

5. BIOMATERIAL

The most important part of artificial organ is material. Materials used to create artificial organs are called biomaterial. Biomaterial can be defined as any matter or construct that interacts can contacts with biological systems of our body. Nature proteins such as collagen and gelatin processed in porosity sponge forms are used as biomaterials. Also natural polymers such as alginic acid and chitosan are used since they are biocompatible and biodegradable. Specially, materials that directly contacts with blood are flexible macromolecule. For example, nylon and acrylonitrile were used in artificial blood vessels during initial stage. Currently, blood vessels that are made of polyethylene terephthalate, polytetrafluoroethylene, and Gore-Tex are developed. Also in artificial skin, sponge form of poly L-leucine, chitin form crab shell, and chitosan are used. Hydroxy-apatite, alumia, bioglass, apatite-wollastonite glass ceramic are being studied to develop artificial bones. Above all, the most important qualities of biomaterial are miniaturization and weight lightening, so that our bodies do not get affected by artificial organ and do not reject. Energy storage system also should be considered to prevent biomaterials from breaking down.

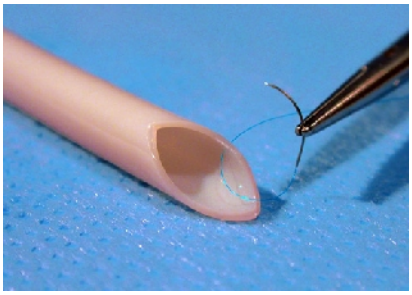

Figure 4. Artificial Blood Vesssel

Figure 5. Artificial Bone

6. FUTURE

Scientists are looking for various ways to deal the organ shortage problem. For example, stem cells are a rising trend in finding methods to cure liver disease. Liver tissues are created from stem cells, which are the biological cells that divide and differentiate into diverse specialized cell types and also they can self-renew to produce other stem cells). Stem cells can now be artificially grown and transformed into specialized cell types with characteristics consistent with cells of various tissues such as muscles or nerves. Stem cell transplantation gives a potential new approach for safer treatment of a large variety of clinical disease. Because the stem cell transplantation treatment is using the stem cells from the patient's own body, there is no rejection and ethical issues with animal experiments. Therefore stem cell transplantation treatment is much safer future of transplantation.

Sang-Hoon Lee who is a scientist in Korea University developed a method creating artificial organs using superfine fiber inspired by the spider web. Using superfine fiber with chemicals, it can be possible to combine cells which will form a tissue and eventually an organ. Using this method, even neuranagenesis, the regeneration of nerve tissue, can be possible by putting neurons together using superfine fiber. The transplantation of organs has advanced significantly in the 50 years since the first kidney graft.

Artificial organs and xenotransplantation are the answers to the phenomenon of the supply of donated organs outpacing demand of organs. However, before we solve the medical and ethical problems, this major crisis cannot be settled. "Courage, endurance, and will to survive that the patients show" will be an impetus of relieving the negative aspects of the artificial organs and xenotransplantation.

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