

Nano Technology for the Development of Artificial Internal Organs

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Abstract— Everybody knows that smaller is better when we consider the development of an internal artificial organ system. For the development of smaller and light weight internal artificial organs, micromachining technology and nano technology will have the possibility of the usefulness. For example, artificial sphincter, artificial esophagus, super stent system, convulsion stop machine, artificial heart, ventricular assist device, artificial myocardium system are now under development by the use of various kinds of nano technologies. Furthermore, implantable artificial organ system enables the patients to come back to their homes. So, not only for the life of the patients, but also for the QOL of the patients, nanotechnology will be useful in the development in near future.

Keywords— nano technology, artificial sphincter, artificial esophagus, super STENT system, convulsion stop machine .

I. INTRODUCTION

The Aim of the research in the Medical Engineering field is the development of the new diagnosis tool and therapeutic tools for the medical fields. One example of the research theme is an artificial internal organs based on Nanotechnology. As for an implantable type artificial organ, a space for implantation is restricted. Therefore, micro device development is indispensable. Nanotechnology and micromachining technology development are very important. In Tohoku University, various artificial organ development is furthered according to the tradition of Nano machine micro machine development. Various artificial organ project in Tohoku University are introduced.

II. ARTIFICIAL INTERNAL ORGANS FOR DIGESTIVE TRACTS

A. Totally Implantable Artificial Sphincter

After the surgery of Colon Cancer, several patients must have Stoma.. And they cannot control the defecation by themselves. So, it is not so good for their quality of Life(QOL). The artificial sphincter that we invented makes it possible for a patient to control defecation. Therefore, we used the shape memory alloy. Two boards of a shape memory alloy were combined. Energy was transmitted by the transcutaneous energy transmission system (TETS) by the

use of nano technology for the magnetic shielding to improve the efficiency. Fig.1 is a schematic illustration of the totally implantable artificial sphincter system. When a patient goes to a toilet, a patient brings TETS. An artificial sphincter opens and enables a patient to defecate. A patient can control defecation if this system is used. Thus, a patient's QOL will be improved greatly.

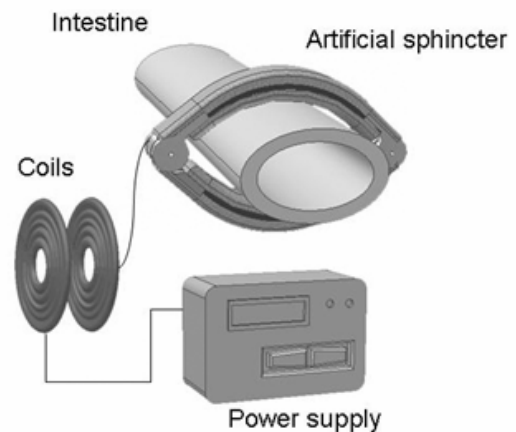


Fig.1 Schematic diagram of an artificial sphincter

B. Totally Implantable Artificial esophagus

An about 10,000 Japanese per year died with an esophagus cancer. Everybody know that an operation of an esophagus cancer is difficult, because the reconstruction of an esophagus is needed. An operation will become easy if there is an artificial esophagus. An esophagus moves food by peristalsis. An simple pipe is not enough as an esophagus.

We invented the esophagus in which a peristalsis is possible. The developed artificial esophagus consists of a macromolecule material and artificial peristalsis muscles. The Gore Tex sheat was used as a bio compatible material.

Human esophagus can swallow a thing by peristalsis. In order to realize a peristalsis, the shape memory alloy ring was used. The coil was made from the fiber of the shape memory alloy which improved durability by nanotechnology molecular crystal arrangement. The ring of a coil contracted in order and the peristalsis took shape.

The animal experiment using the goat of the same weight as Japanese people was tried after the allowance of the animal experimental ethical committee allowance in Institute of Development, Aging and Cancer, Tohoku University.

As we shown in fig.2, the developed artificial esophagus was replaced with the excised esophagus. It was confirmed that the peristalsis had been realized in the body of a goat.

By the use of an artificial esophagus, an operation of an esophagus cancer becomes easy.

In the future, we can undergo an operation using an endoscope with artificial esophagus. Since there is little invasion, an operation of an old man will become possible. It is expected that invention of the artificial esophagus with peristalsis movement brings big progress to esophagus cancer surgical therapy.

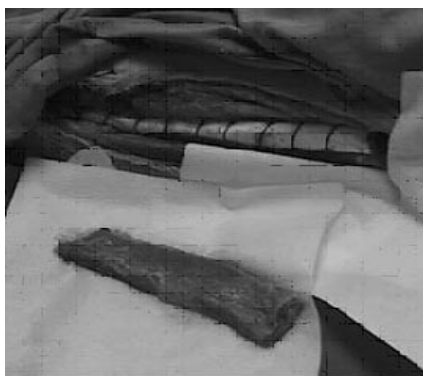


Fig.2 Photograph of an artificial esophagus system

C. Super STENT with hyperthermia

An operation of an esophagus cancer is one of the most difficult operations even now, when medical science has progressed. One of the most important points is the difficulties of esophagus reconstruction. In an operation, since the stomach and intestines are used as a substitute, an invasion becomes large and an operation of elderly people becomes difficult. Although the improvement in a life prognosis is expectable if cancer is resectable, there are a lot of cases, who were too late for surgery of the esophageal cancer at the time of diagnosis.

Then, a Peristalsis Stent with Hyperthermia function for the terminal esophageal cancer patients, for whom an operation cannot be conducted, was invented.

This super Stent system with Hyperthermia function has three characteristics. 1. Completely noninvasive, 2. Hyperthermia on the carcinoma tissue. 3. Peristalsis function.

Possibilities are expected as one of the alternative candidates for a terminal esophagus cancer therapy.

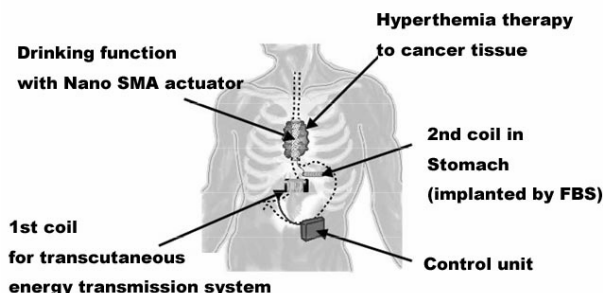


Fig.3 Super stent system

III. REGENERATIVE ARTIFICIAL ORGANS

New regenerative methodology was invented in Tohoku University by the use of the Bio absorbable material with nano structure and shown below. Regenerative digestive tracts and trachea were embodied in animal experiments.

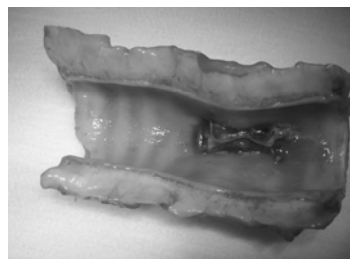


Fig.4 Regenerative trachea

Furthermore, new bio compatible shape memory alloy scaffold by the use of nano technology are now under development.

IV. ARTIFICIAL MYOCARDIUM

The purpose of this research is developing nano artificial myocardium. Therefore, nano sensor development is performed. And nano control chip development is performed. An artificial myocardium actuator is also developed by nanotechnology. A control-objectives value setup which imitated baroreflex system is tried using a nano sensor and a micro control chip. As a nano sensor, by this research, the nano thin film sensor adapting diamond-like carbon (DLC) was developed, and it applied for the patent (application for patent 2003-317956). The outstanding organism affinity can be expected and the application to the artificial organ of all

fields can be expected. Furthermore, the nano sensor adapting an optical fiber was also developed and it succeeded in the animal experiment. Since information, such as each ventricle, can be evaluated simultaneously, the optimal drive of artificial myocardium is possible.

An artificial myocardium is a system with which the pulsation of the heart is assisted. The external surface of the heart is equipped with an artificial myocardium. Therefore, like the conventional artificial heart, there is no risk of a thrombus and it does not have the problem of the durability of an artificial valve. When there is no necessity, an artificial myocardium does not operate, and since circulation is performed only with the heart, improvement in the durability of an artificial-myocardium system is expected.

Currently, artificial-myocardium research is under promotion using an electrohydraulic system. Furthermore, the molecular crystal arrangement of a shape memory alloy is prepared by application of nanotechnology. Development of the artificial muscles which have improved durability and the speed of response is progressing by reducing a hysteresis. Now, cultivation of a heart muscle cell attracts attention with reproduction medical treatment. Although it is easy to create a cell sheet, 3-dimensional construction is very difficult. Of course, reconstruction of the coronary arteries is needed, and it is apprehensive also about thrombus formation. On the other hand, the nano level actuator by nanotechnology is important. If it succeeds in this development, it is expected that it becomes applicable to various artificial organs.



Fig.4 Artificial Myocardium

V. CONVULSION STOP MACHINE

0.5-1% of the general population have the epilepsy (NIH Consensus Panel, 1990). Seizures cannot be controlled by medications in 20% of epilepsy patients. A third of these patients need the surgical resection of epileptic focus for the control of the attacks. However, surgical resection of a part of brain have a risk of complications. There is a patient who feels a sign before the convulsions of epilepsy. When feeling a sign, there is a treatment, which performs a vagal

nerve stimulus. However, a stimulus of a vagal nerve is not a trustworthy treatment. We had invented the method of cerebral partial cooling and applied for the patent (2004-304964). By this method, if a patient feels the sign of the attack of epilepsy, a switch will be pushed. Control switch was implanted under the skin. By switch on, the focus of epilepsy is cooled and a convulsion attack is prevented beforehand. A battery is used in a patient with few attacks. Transcutaneous energy transmission system (TETS) is used in a patient with a frequent attack. In this system, if a patient feels a sign, TETS will be used. Outer coil will be attached to the inner coil under the skin. Energy is supplied and a focus is cooled. Now, we are studying the prediction algorithm of epilepsy. If prediction is possible, the automatic control of epilepsy will become possible.

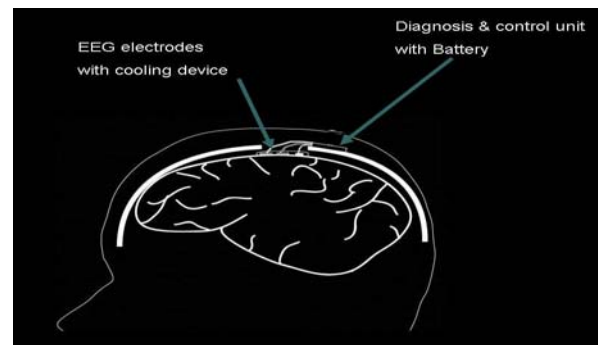


Fig.5 Epilepsy attack control machine

Now, application of automatic diagnostic equipment is also planned to this system. A system consists of a nano temperature sensor and EEG measurement. Since it is the sensor of a super-thin shape, it can embed into a skull easily.

By EEG and blood-flow change, an epilepsy attack is diagnosed automatically, and a convulsion attack is prevented by cooling.

If this invention will be embodied and industrialized, 60 million patients will be saved and QOL will be improved in all over the world.

So, the animal experimental series was tried using three goats. Based on animal experiment ethics regulation, we conducted the animal experiment strictly. The skull was opened using the traditional method after the anesthesia slow induction. The brain surface was exposed and EEG measurement and temperature measurement were tried. The thermometer was used and the temperature of the depths was also recorded.

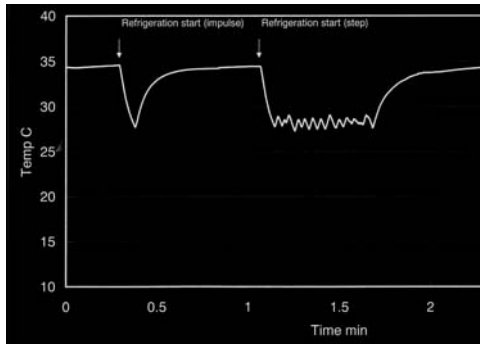


Fig.6 Cooling effect of newly developed device

After checking the stable measurement, the antibiotic was used and epilepsy-attack induction was tried. Induction of an epilepsy attack was checked by spraying to the brain surface of an antibiotic.

Brain surface cooling was tried after induction of an epilepsy attack. The stop of an epilepsy attack and the activity fall of EEG were observed by the effect of a cooling device.

Therefore, it is thought that the implementability of this invention was confirmed.

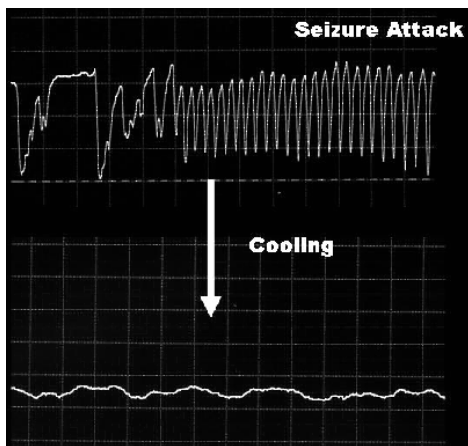


Fig.7 Therapeutic effect of focal cooling for the epilepsy attack

It is expected that it becomes good news for the patient of epilepsy.

VI. CONCLUSION

Nano technology may be useful for the development of the various kinds of artificial internal organs.

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