

Expansion Capsules for Diet control with artificial organ technology

Tomoyuki Yambe, Yasuyuki Shiraishi, Hidekazu Miura, Norihiro Sugita, and Makoto Yoshizawa,
Member, IEEE

Abstract—When we consider the medical economy, the Obesity is one of the leading preventable causes of death worldwide. However, a lot of previous scientific papers reported that 95% of obesity patients would not be able to control their weight by the diet. The surgical operation has been considered to the subjects with severe obesity. But, there is a possibility of complication or comorbidity in surgical operation. Tohoku University started to develop the expanding capsule with transcutaneous energy transmission system (TETS) having the same effect as the surgical operation. The capsule in the stomach will expand mechanically by energy transmission from outside of the body, when the obesity patients will feel hungry. Small linear drive with folding umbrella type actuator would enable us the expansion of the diet capsules. Satisfactory characteristic of the energy transmission was obtained by the trial model of TETS during animal experiments. Animal experiments with healthy adult goats enabled us the evaluation of the inner stomach pressure time series changes, and feasibility study. Double blind test of the expanding capsule is now under planning. If the expanding capsule diet control system will be embodied, it becomes the gospel of the obese subject.

I. INTRODUCTION

EVERYBODY knows the Obesity is one of the leading preventable causes of death for elder people. Almost patients with severe obesity failed to control their weight by only the diet. Surgical operation must be considered for the severe cases of obesity (1-5).

Nanotechnology and micro-machining technology are the important technology for the development of the artificial Internal organs, because the space for implantation is so limited. Various kinds of artificial internal organs development are undergoing in Tohoku University. For example, artificial esophagus, artificial sphincter, artificial heart, ventricular assist device, artificial myocardium system and epilepsy control machine are under development. By the use of the technology of micromachining and nano technology, mechanical expand capsule for diet control has

Manuscript received March 28, 2012. This work was partly supported by support of Tohoku University Global COE Program "Global Nano-Biomedical Engineering Education and Research Network Centre". 21st century COE program: Future Medical Engineering based on Bio Nanotechnology

T.Yambe, Y.Shiraishi, H.Miura, N.Sugita, and M.Yoshizawa are with the Tohoku University, Sendai 980-8575, Japan (81-22-717-8513; fax: 81-22-717-8518 e-mail: yambe@idac.tohoku.ac.jp)

been started to develop.

The technology for the transcutaneous energy transmission system (TETS) with nano technology for the energy supply for the various kinds of artificial internal organs has been used in the development for the energy to the expanding capsule in the stomach (6-10).

II. EXPANDING CAPSULE WITH TRANSCUTANEOUS ENERGY TRANSMISSION SYSTEM (TETS)

In our developing concept, obesity patients should drink capsule, when feel hungry. After the capsule go into the stomach, energy will transmitted to the capsule by the transcutaneous energy transmission system (TETS). By the energy transmission, the capsule will expand and the patients will be able to feel full stomach by their stretch receptor on internal surface of stomach.

After the session, TETS will be switched off. And the capsule will shrink. So, easily go out from stomach and intestine, and will go out from the anus.

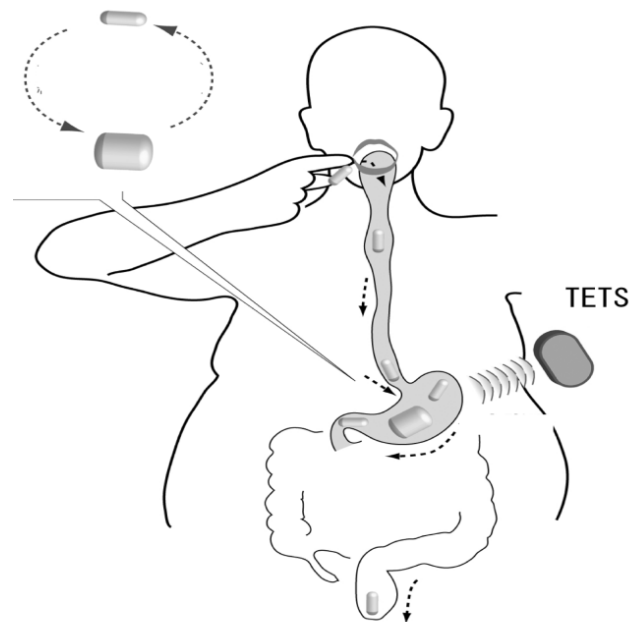


Fig.1 A Schematic diagram of an Expanding capsule for the diet control with Transcutaneous energy transmission system (TETS)

Various kinds of TESTS had been designed and evaluated in this study. An example of the candidates of the TEST design with belt type was shown in fig.2.

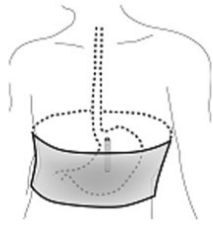


Fig.2 Anatomical position concept of the belt type 1st coil and capsule type 2nd coil of TETS

After drinking, the capsule with 2nd coil will enter into the stomach. Belt type 1st coil will generate the magnetic force. The magnetic field will cause the electrical current of the 2nd coil with the capsule in the stomach.

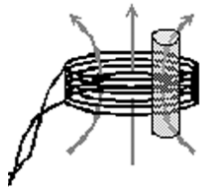


Fig.3 Magnetic field line induced by belt type electrical current

When electrical current would be applied into the belt type 1st coil, magnetic field would induce the electrical current in 2nd coil in the capsule, as we shown in fig.3. By the use of this concept, energy transmission experiment was performed as we shown in fig.4.

In this system, almost 5.0 w energy transmission had been achieved. This data would show the satisfactory expanding power against intra-stomach pressure, because the induced power is satisfactory to work.

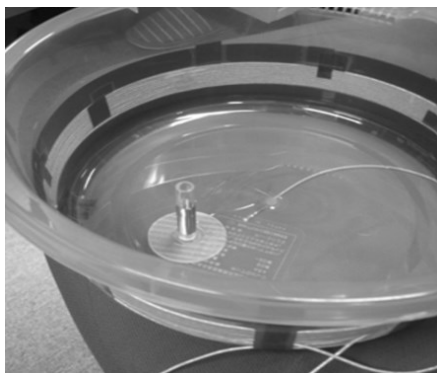


Fig.4 A photograph of an energy transmission experiment by belt type 1st coil and capsule type 2nd coil

Effective energy transmission was embodied by the use of larger surface of coils for belt type 1st coil TETS. However, belt type coils may have the possibility to disturb the human

body action. And furthermore, connection of the belt will be a little bit difficult. So, smaller type TETS might be desirable, when we consider the quality of life (QOL) of the patients.

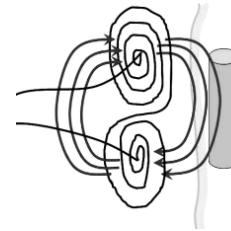


Fig.5 Concept of the energy transmission of eight shape 1st coil

Simple method may be desirable when we will consider the clinical application. So, we had developed 8-shape 1st coil TETS as we shown in fig.5. Moc up model of human stomach was developed for the optimization of the design and fitting study as we shown in fig.6. And the satisfactory level of the energy transmission had been embodied in the test piece.

2nd coil had been designed as the circle with the radius of 5.0mm and 5.0cm length. So, this system may be able to transfer the power to the mechanism in the capsule, and entering into the stomach.

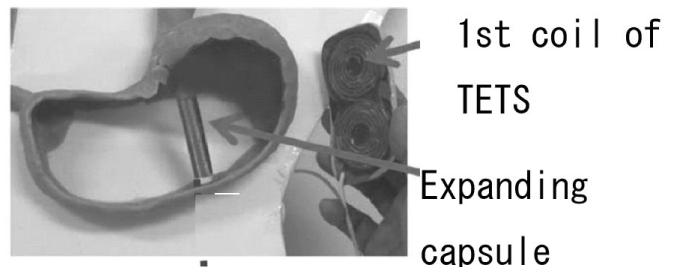


Fig.6 Trial Mock up model of TETS with eight shape 1st coil

If the patients feel hungry, the diet control capsule with expanding mechanism can be drunk, easily.

1st coil of TETS will be attached to the abdominal wall from outside, and energy will transfer into capsule in the stomach, non-invasively. Linear actuator can be actuated and the capsule can be expanded.

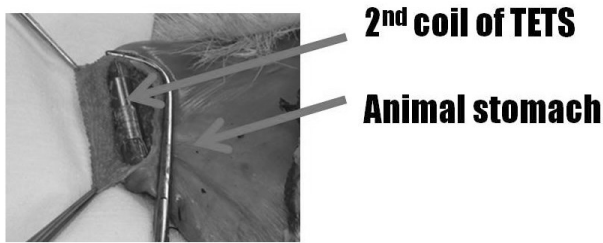


Fig.7 A photograph of an animal experiment using healthy adult goat

After the Tohoku University animal experimental ethical committee allowance, animal experiments of energy transmission using healthy adult goats had been carried out. Satisfactory energy transmission was observed to be embodied. Electrical current was induced with 2nd coil in animal's stomach. The second electric power of about 5.0w was obtained in the animal experiments. So, satisfactory actuator power would be able to be obtained.

III. EXPANDING MECHANISM FOR CAPSULE

By the use of the linear actuator concept, mechanical design of an expanding capsule with TETS system is now under development as we shown in fig.8. If the energy will be transmit to the capsule in the stomach, magnetic power will be induced and internal membrane will be pushed up and the capsule will be expanded by this mechanism us we shown in fig 8,9.

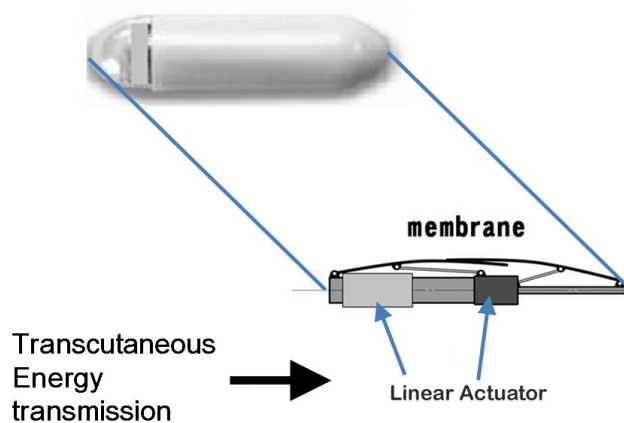


Fig.8 Expand capsule by the use of linear actuator

After the expansion, if the patients feel still hungry, one more capsule can be drunk. Patients will be able to drink untill feeling full stomach. The capsule will be able to keep expansion during the contact of the 1st coil on abdominal wall. 1st coil can induce the magnetic power. And magnetic power will be able to induce linear actuator drive. Linear actuator drive can expand the capsule in the stomach.

When the patients want to shrink the expand capsule, they can easily detach the 1st coil. And the linear actuator will be switched off. So that the capsule will shrink. So, the capsule will easily to go from stomach, to intestine, and will go out from anus.

From mechanical engineering field, various kinds of expanding mechanism may be able to be considered. Another example of the expanding mechanism may be able to be embodied by the use of the shape memory alloy (SMA) actuator, if SMA can achieve the satisfactory power. And another example may be able to be embodied by the use of miniature motor.

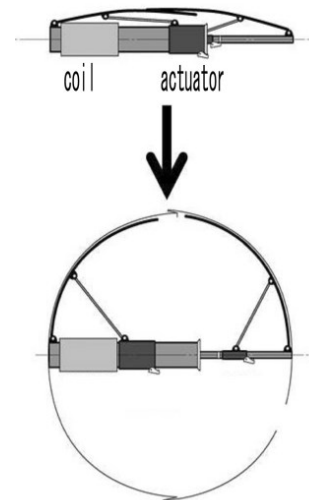


Fig.9 Expand capsule by the linear actuator

IV. ANIMAL EXPERIMENTS

For the measurements of intra stomach pressure changes in creature, animal experiments were performed by the use of healthy adult goats after the ethical committee allowance. Pressure sensors were implanted into the stomach, and the results showed us that over 10 mmHg pressure changes in the stomach was observed. Expanding capsule power must overcome the intra stomach pressure changes. Continuous study will be needed in various physiological conditions. And experimental measurements is now undergoing .

V. MOCK MODEL FOR THE DEVELOPMENT OF EXPANDING CAPSULE

Before the clinical application, basic characteristics of the expanding capsule must be evaluated in the model stomach. So, mock of intra-stomach pressure change was developed as we shown in fig.10

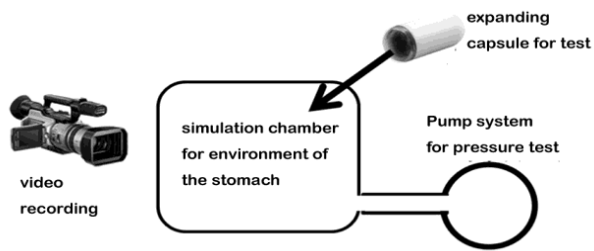


Fig.10 Moc model of intra stomach pressure changes

VI. TRIAL MODEL AND ANIMAL EXPERIMENTS

In this system, capsule will expand by the energy transmission from outside of the body. 1st coil attached from outside of the body will be portable small device, so, smaller device will be desirable. Trial manufacture model of the TETS for expanding capsule was shown in the figure 11. For the portability of the device, name card size 1st coil was developed and shown in the figure 11. Photograph of the 2nd coil in the stomach during an animal experiment was shown.

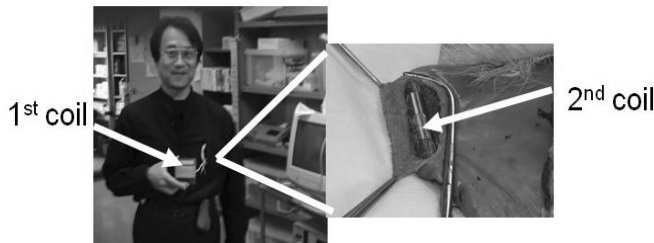


Fig.11 Trial manufacture model of the TETS for the expanding capsule.

VII. DISCUSSION

After the expansion of the drinking capsule, sensor in the internal surface of the stomach will be able to be stimulated. So, the patients will feel full stomach. If the sensation will not satisfactory, the patients can drink more capsule, until feel full stomach.

After the finishing the session, if the patients take off the first coil of TETS. The capsule will shrink and this reduction will enable the capsule to go into the intestine, and go out by defecation form anus.

Linear actuator or SMA actuator will be enabled us the expanding mechanism.

Double blind animal experiments using healthy adult goats weighting almost same with Japanese male with true expanding capsule and pseudo non-expanding capsule are now under planning.

There is limitation of this development. Place in the stomach will be influenced to the risk of closing the internal side of intestine. Discussion will be needed in future.

If the diet effect is satisfactory, we want go into the clinical application in near future.

In summary, expanding capsule for diet control was invented in this paper. When the patients feel hungry, can drink the expand capsule. And attach the TETS from outside of the body. Energy will be transmitted to the capsule, and the capsule will be expanded by the linear actuator. After using the capsule, TETS will be removed the contact. The capsule will be shrunk till out from anus ring.

Expand capsule will be good news for the patients with severe obesity resistant to the diet therapy.

Acknowledgements

This work was partly supported by support of Tohoku University Global COE Program "Global Nano-Biomedical Engineering Education and Research Network Centre". 21st century COE program: Future Medical Engineering based on Bio Nanotechnology,

References

- [1] Picot J, Jones J, Colquitt JL, Gospodarevskaya E, Loveman E, Baxter L, Clegg AJ. The clinical effectiveness and cost-effectiveness of bariatric (weight loss) surgery for obesity: a systematic review and economic evaluation. *Health Technol Assess.* 2009 Sep;13(41):1-190, 215-357.
- [2] Flancbaum L, Choban PS. Surgical implications of obesity. *Annu Rev Med.* 1998;49:215-34. Review.
- [3] Coon D, Gusenoff JA, Kannan N, El Khoudary SR, Naghshineh N, Rubin JP. Body mass and surgical complications in the postbariatric reconstructive patient: analysis of 511 cases. *Ann Surg.* 2009 Mar;249(3):397-401.
- [4] Okoro T, Sintler M, Khan A. Outcome of gastroplasty and gastric bypass in a single centre in the UK. *BMC Res Notes.* 2009 Sep 13;2:181.
- [5] Jpn Pt Appl 2009-277242 Expanding capsule in the stomach
- [6] Wang Q, Yambe T, Shiraishi Y, Esashi M, Haga Y, Yoshizawa M, Sato F, Matsuki H, Imachi K, Abe Y, Sasada H, Nitta S, Component engineering for an implantable system. *Artif Organs.* 2004 Oct;28(10):869-876
- [7] Yambe T, Shiraishi Y, Yoshizawa M, Tanaka A, Abe K, Sato F, Matsuki H, Esashi M, Haga Y, Maruyama S, Takagi T, Luo Y, Okamoto E, Kubo Y, Osaka M, Nanka S, Saijo Y, Mibiki Y, Yamaguchi T, Shibata M, Nitta S. Artificial myocardium with an artificial baroreflex system using nano technology. *Biomed Pharmacother.* 2003 Oct;57 Suppl 1:122s-125s.
- [8] Yambe T, Yoshizawa M, Tanaka A, Abe K, Kawano S, Matsuki H, Maruyama S, Amae S, Wada N, Kamiyama T, Takagi T, Luo R, Hayashi J, Kovalev YA, X D Sha D, Nanka S, Saijo Y, Mibiki Y, Shibata M, Nitta S. Recent progress in artificial organ research at Tohoku University. *Artif Organs.* 2003 Jan;27(1):2-7. Review.
- [9] Yambe T, Kawano S, Nanka S, Kobayashi S, Tanaka A, Owada N, Yoshizawa M, Abe K, Tabayashi K, Takeda H, Hashimoto H, Nitta S. Peripheral vascular resistances during total left heart bypass with an oscillated blood flow. *Artif Organs.* 1999 Aug; 23 (8): 747-50.
- [10] Yambe T, Owada N, Kobayashi S, Sonobe T, Naganuma S, Nanka S, Hashimoto H, Yoshizawa M, Tabayashi K, Takayasu H, Takeda H, Nitta S. Left heart bypass using the oscillated blood flow with totally implantable vibrating flow pump. *Artif Organs.* 1998 May;22(5):426-9.