35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

# Development of a tool system to support endoscope

Y. Omori, Y. Takahashi, S. Yamamoto, and T. Komeda

*Abstract*— **Natural Orifice Translumenal Endoscopic Surgery (NOTES) is a type of minimally invasive surgery. This surgery needs working space for operating the endoscope, but there is no space for it in body cavity. Therefore, we have been developing a surgical tool system which can be inserted from the mouth and ensure space in body cavity. We use magnets and a tool to ensure space, like in abdominal wall lifting method, without use of wire. In this paper, we designed and realized a system which used a tool consisting of link mechanism and magnets. The link mechanism consists of four-bar linkage and a compression spring. It can be driven only by pulling wires, changing the diameter of the tool. We designed this surgical tool prototype, analyzed the stress and did basic experiments.**

## I. Introduction

Currently, the gastric cancer has higher mortality than other organs, and mortality shows an increasing trend [1]. However, this trend has been decreasing recently due to the increase of early detection and screening, and the possibility of complete care by advances in diagnostic and therapeutic technology.

Fig.1 shows the basic concept of Natural Orifice Translumenal Endoscopic Surgery (NOTES) [2] and Fig.2 shows the abdominal wall lifting method [3]. There are some methods for the treatment of gastric cancer. The doctor decides between open surgery and endoscopic surgery, and the removal of lymph node of the stomach is decided depending on degree of metastasis and progression of cancer. When a doctor cuts the stomach by open surgery, sentinel lymph nodes biopsy are performed as a way to check for the presence of metastasis to the surrounding lymph nodes. From this biopsy, the doctor determines the extent of resection of the stomach. A sentinel lymph node biopsy is a diagnosis method that determines how far the cancer has spread. However this biopsy has a potential to be invasive for patients. Researchers pay attention to a new way to use NOTES in this diagnosis. According Kalloo, was reported that NOTES can be used by inserting an endoscope from the mouth or vagina, and come to a body cavity through the wall of lumen [4]. NOTES can expand possibilities for less invasive and preoperative diagnoses. However, it is difficult to operate the endoscope in narrow working space like the body cavity. This causes the difficulties of removing the sentinel lymph node. The endoscopic surgery must ensure working space to operate the endoscope. Thus there are three ways to ensure space during surgery. The first method uses the air with constant flow rate from the air supply of an endoscope. The second method also uses air. This one provides air using constant pressure from a pneumoperitoneum apparatus [5]. The third method uses wire from outside the body to lift the abdominal wall. Because the long air supply time, gas pressure and steel wire are invasive for patient, those are not the best ways either. Hence, it is important for the current methods to become minimally invasive.

In this study, we focused on the problem of steel wire in abdominal wall lifting method. Therefore, we aimed to ensure space in a minimally invasive method, using supporting tool.

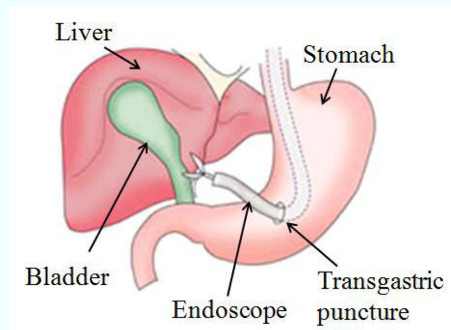


Fig. 1 Basic concept of NOTES

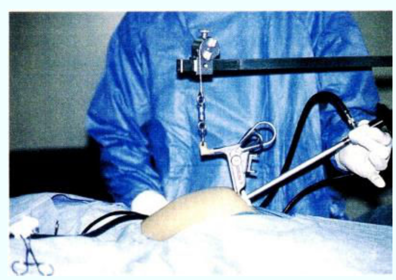

Fig. 2 The abdominal wall lifting method

## II. REQUESTED SPECIFICATION

We decided to use the stomach-like approach way which is applied regardless of gender. Next, we decided the required specifications about supplementary tool based on anatomy and conventional abdominal wall lifting method.

- The size of outer diameter and the length is less than 0.02 m at the time when it passes the pharynx and the esophagus.
- The structure is required to have a simple mechanism to assure a safety in body.
- The length of parts that supports the abdominal wall has the same length of the steel wire that is about 0.07 m [6].

Y. Omori is with Shibaura Institute of Technology, 307Fukasaku, Minumaku, Saitama, 3378570 JAPAN (phone: 048-688-9477; fax: 048-688-9477; e-mail: mf12017@ shibaura-it.ac.jp).

Y. Takahashi is with Toyo University, 48-1Oka, Saitama, 3518510, JAPAN. (e-mail:y-takahashi@toyo.jp)

S. Yamamoto is with Shibaura Institute of Technology, 307Fukasaku, Minumaku, Saitama, 3378570 JAPAN. (e-mail: yamashin@se.shibaura-it.ac.jp).

T. Komeda is with Shibaura Institute of Technology, 307Fukasaku, Minumaku, Saitama, 3378570 JAPAN. (e-mail: komeda@sic.shibaura-it.ac.jp).

## III. THE FIRST PROTOTYPE TOOL OF ABDOMINAL WALL LIFTING METHOD

### *A. The Support tool Design Overview*

We worked out the method which uses a support tool and magnets to lift the abdominal wall without inserting the steel wire. As reported by Sara, a magnet was used in two places: inside the body cavity and outside the body. The magnet was fitted to a device and inserted into body cavity. The two magnets adhered through abdominal wall to anchor the device which helped the endoscopic surgery [7]. Therefore, we decided to use magnets instead of steel wire. In our research, we add the operation that lifts extracorporeal magnet. When surgeon lifts it, we can ensure the space in body cavity.

However, if the tool has a length of 0.07 m as well as conventional steel wire, it can-not be inserted into a body cavity. Therefore, we designed the device tool with reference to the structure of the umbrella. It means that the tool can change its diameter and divide its length, and can be insert into the body cavity by maintaining a minor state. When surgeon lifts the abdominal wall, the tool can be opened in a wide range like an umbrella to hold the abdominal wall.

Fig.3 shows the support tool view from the top, Fig.4 shows view from side. It consists of tube for inserting, four frames for holding the abdominal wall, frame cap, tension spring, steel wire, flange. Frames are opened or closed by the elastic force which is generated from pulling steel wire. We achieved the lengths of 0.1 m in two directions when the frame opens. The cross-sectional view of the frame is U-shaped to increase the strength.

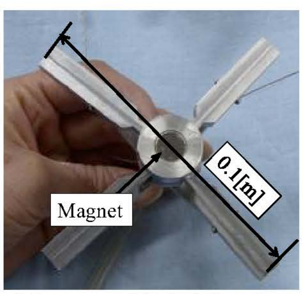


Fig. 3 Support tool looked from the top

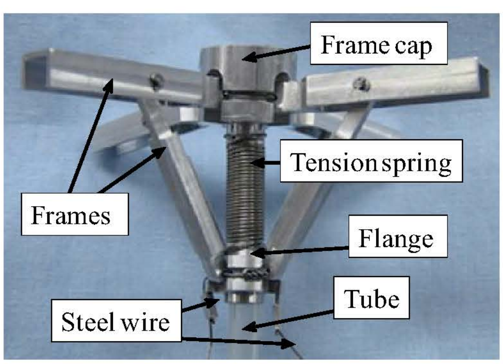


Fig. 4 First support tool

### *B. Deployment of the support tool*

Fig.5 shows the schematic of the motion of the support tool. When it reaches body cavity, the endoscope is inserted in the tube and controls it. Moreover, it gets magnetic force through the extracorporeal magnet. The frames keep the closed shape by pulling the steel wire that is connected to the flange. This mechanism is useful to open and close the frames, to change diameter. This is a small and compact tool, which can satisfy the basic function as a support tool. However, it is necessary to meet specifications against the length when the tool is inserted into human body. It is too long to pass the pharynx yet. Therefore, we improved the mechanism of the frame to shorten the length of the tool.

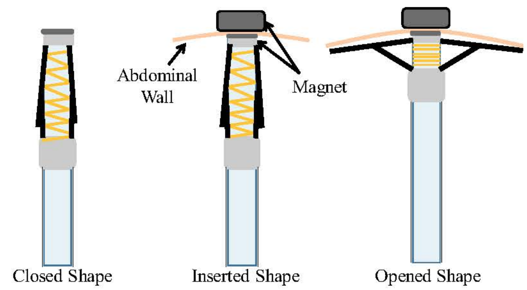


Fig. 5 How to use the first tool

## IV. THE IMPROVED SUPPORT TOOL

### *A. The second support tool using compression spring*

Fig.6 and Fig.7 show the improved support tool. We improved it by shortening the length in closed state to pass the pharynx. As a result, the tool consists of a washer with an insertion tube, frame cap letting a magnet adhere, four frames, compression spring, steel wire to pull a spring, a flange to pull a spring and the flange, and a washer with saliva. We assumed that the tool should be used as disposable type. Therefore, all the materials were made of Aluminum (A5052) which is easily-worked and has low cost.

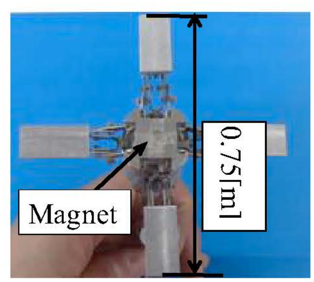


Fig. 6 Improved support tool

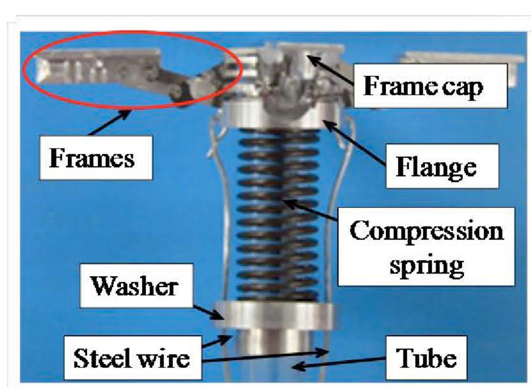


Fig. 7 Improved support tool

### *B. Four-link mechanism*

Fig.8 shows a four-link mechanism. We designed a four-link mechanism to make length shorter. The frames were divided into four links and made each one length less than 0.02 m. They also could fold up when the tool is closed, to prevent to injury other organs. We assumed that the frame is of cantilever type, consisting of movable support and hinged support mechanically [8] [9].

When we pull a flange by using two stainless steel wires, the mechanism drives the linear motion of movable support. We can accumulate the driving force by compressing the compression spring. The driving force of the frame occurs from elastic force of the spring, same way as the previous system. The compression spring is inserted in compressed state, it will be able to shorten the overall length of the tool. We use an elastic force from compression spring to open the mechanism.

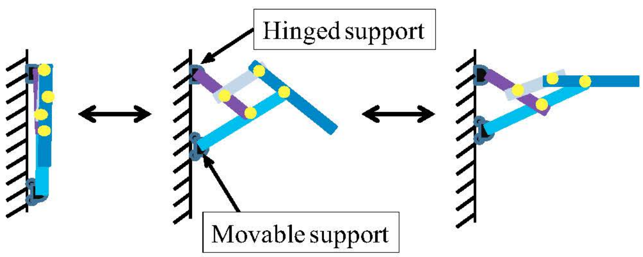

Fig. 8 The four-link mechanism

Fig.9 shows the shape of improved support tool, Fig.10 shows the support tool when it is inserted to the stomach model, Fig.11 and Fig.12 show the view after opening the frames outside the model. By controlling the elastic force, we achieved the mechanism to change the diameter anytime. The risk of damage to other organs during insertion becomes smaller because the links are completely folded in the closed state.

First, the endoscope is inserted into tube, and leads the tool into the body cavity. After the tool is fixed at abdominal wall, so we can pull the endoscope from the tube to treat an organ. It keeps opened state during a surgery to prevent from reducing space. Finally, we insert the endoscope into the tube again, and unfix the extracorporeal magnet. The frames are closed by pulling steel wire until outside of the body. In this way, we realized the structure which can change the size at any location just using the compression spring and the link mechanism.

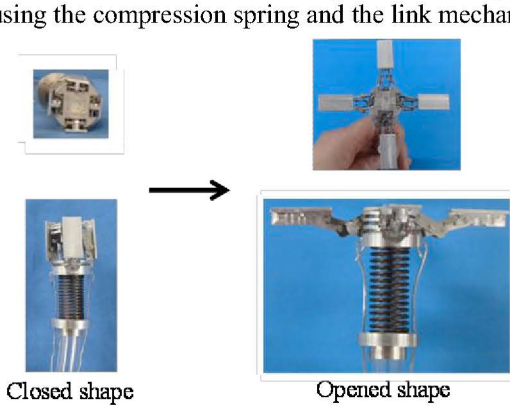

Fig. 9 How to use the support tool


Fig. 10 The support tool when inserting

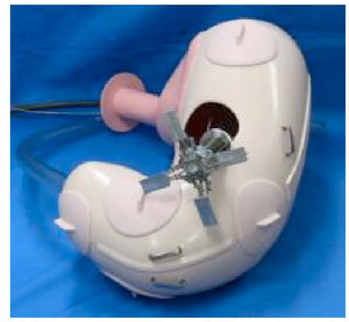
Fig. 11 The support tool outside the abdominal wall


Fig. 12 The support tool looked from right side

## V. OVERALL STRUCTURE OF SUPPORT TOOL

Fig.13 shows a component of formulated system. In this system, we use the support tool and magnets to ensure space into the body. After reaching into a body cavity by endoscope, this tool is fixed to the abdominal wall by the magnetic force between the inside magnet and outside magnet at first. Whenever we lift abdominal wall, magnetic force is needed. However, the force is inversely proportional to the square of the thickness of abdominal wall, according to Coulomb's law [10]. Therefore, we need strong magnetic force because magnets aren't supposed to disengage from adsorbed state during procedure. The level of magnetic force is required to correspond to the thickness of the abdominal wall of patient. Moreover, the tool should bear loads from abdominal wall in this way.

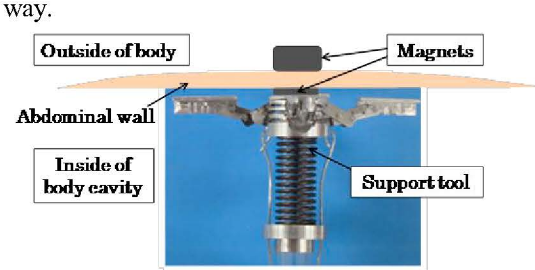

Fig. 13 Component of formulated system

## A. *Stress analysis of flame*

Fig.14 shows a result of the stress analysis of the frame part. We analyzed the stress of the tool which supports the abdominal wall from the center until the edge of frame. We assumed the frame to be a model constituted by a cantilever and the rotary fulcrum and analyzed it. The analysis took a uniformly distributed load of 10 kgf against the places contacting with the abdominal wall. We analyzed the most outside frame. The load comes from the conventional abdominal wall lifting device [11]. In regard to the condition, two holes are connected with other frames. They have a degree of rotational freedom on vertical direction. The materials of the part used is stainless steel (SUS304). The result of the analysis was that the biggest stress occurred was of 84.6 MPa in the axis joint of the distal side, and the safety factor became 2.4. The maximum stress was of 136 MPa, and the safety factor became 1.5. Therefore, the device was designed to withstand a load of double.


Fig. 14 A result of the stress analysis

## B. *Experiment*

Fig.15 shows the scheme of experiment and Fig.16 shows an experimental image. Based on the results of stress analysis, we performed to experiment to check whether the tool could withstand the load. In this experiment, the tool in open state is covered with a rubber sheet with weight, which is used in place of abdominal wall. To distribute the load, weights are attached to the four corners of the sheet. We set the target load to 10 kgf, based on the stress analysis. From this experiment, we confirmed that the tool could keep the open state until the target value. We have so confirmed the usefulness of the device, according to the load from the abdominal wall. We than confirmed its operation when the device is fixed by magnets, making contact with pork flesh on the frames. We used electromagnet, that has stronger magnetic power than simple magnet, and neodymium magnet, that is the most strong between magnets.

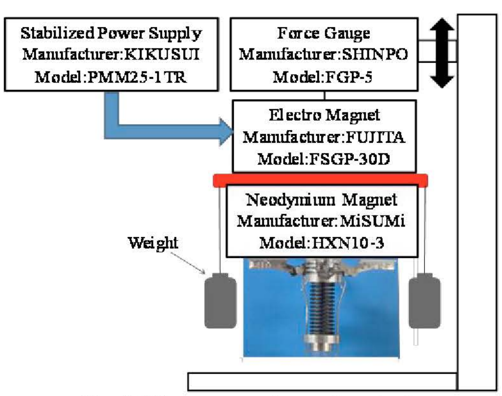


Fig. 15 The scenery of operation check

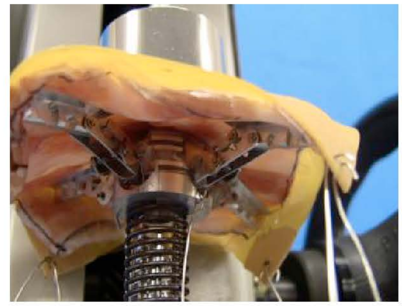

Fig. 16 An experimental image

# VI. Conclusion

A new method with the magnetic force of magnets and the support tool was designed to secure the space in body cavity without damaging to the abdominal wall. We confirmed the basic functions, in spite of fewer operations, by using the link mechanism and the spring. In the future, we will improve the tool towards practical application and discuss about the safety of magnetic force.


# ACKNOWLEDGMENT

We would like to thank to Dr. Wada, who is working on Keio University Hospital, for giving clinical advice.


# References


[1] Cancer Resesrch Center for Cancer Control and Information Center of the National Institute, Latest cancer statistics, available at <http://ganjoho.ncc.go.jp/public/statistics/pub/statistics01.html>

[2] Japan NOTES, Outline of research and research indicator, available at <http://www.notes-med.jp/about/index.html>

[3] Sakamoto A., Naishikyousyuzyutu no zyutucyu kanri to taraburusyu-tingu(Intraoperative care of endoscopic surgery and troubleshooting), Shinkokoui Isyosyuppanbu, Tokyo(2000)

[4] Kalloo AN, et al., "Flexible transgastric peritoneoscopy : a novel approach to diagnostic and therapeutic interventions in the peritoneal cavity. Gastrointest," GIE, Vol.60, No.1,(2004) pp.114-117

[5] Nakajima K., et al., "Optimal Insufflation for Natural Orifice Translumenal Endoscopic Surgery(NOTES)"(in Japanese),JJSCAS, Vol.9, No.2, (2007)pp.73-77

[6] Suzuki N., Syoukakinaishikyou no kotu to otoshiana(Trick and Catch of Gastrointestinal Endoscopy), Nakayamasyoten, Tokyo(1997)

[7] Sara L. Best, et al.,"Magnetic Anchoring and Guidance System Instrumentation for Laparo-endoscopic Single-site Surgery/Natural Orifice Transluminal Endoscopic Surgery: Lack of Histologic Damage After Prolonged Magnetic Coupling Across the Abdominal Wall", UROLOGY, Vol.77, No.1,(2011)pp.243-247

[8] Ito S., Mekanizumu no Ziten(Dictionary of the mechanism), Rikougakusya, Tokyo(1983).

[9] Ogawa K., Saishin Kikaikougaku Shiri-zu1 Kikougaku(Latest mechanical engineering series 1 Mechanics), Morikita Syuppan Kabushikikaisya, Tokyo(1995).

[10] Sangtae Park, et al., "Trocar-less Instrumentation for Laparoscopy Magnetic Positioning of Intra-abdominal Camera and Retractor," Annals of Surgery, Vol.245, No.3, (2007) pp.379-384

[11] Suzuki H., Syoukaki Naishikyou no Kotu to Otoshiana Hukukoukyoukasyuzyutu(Tips and Pitfalls of Gastriuntestinal Endoscopy Laparoscopy), Nakayama Syoten, Tokyo(1997)