Magnetic Anchor for More Effective Endoscopic Mucosal Resection

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Background: Technical difficulties are involved in endoscopic mucosal resection (EMR) of gastric cancer since it is a ‘one handed surgery’. These difficulties prevent this technique from being indicated for larger lesions, even when it can possibly be performed for patients with such lesions. If microforceps could assist EMR, this procedure would become easier and safer. Since magnetic force can control objects without direct contact, it can be applied to control microforceps internally in assistance with EMR.

Methods: We developed a magnetic anchor consisting of three parts: a magnetic weight with dimensions of 1.0 × 1.0 × 1.5 cm, microforceps and a connecting thread. Endoscopic clips used in hemostasis were used as the microforceps of the magnetic anchor in this study. The magnetic control system consisted of a 0.68 kOe/10 cm/100 A electromagnet, 350 mm in diameter and a circumventing positional frame. The microforceps were inserted into a sheath within the endoscope, and the magnetic weight was secured to the tip of the sheath protruding from the endoscope. The magnetic anchor, along with the endoscope, was inserted through an over-tube into the gastric cavity of a swine under general anesthesia. The magnetic anchor was used in a manner similar to that in standard surgery, and EMR was thereby performed.

Results: The mucosa to be resected was satisfactorily dragged and stabilized. The magnetic anchor facilitated EMR, regardless of the technical skills of the endoscopist and region of the stomach at which the technique was performed.

Conclusion: The magnetic anchor is considered to have alleviated some technical problems involved in EMR. It has the potential for making EMR a safer and quicker procedure for the treatment of early gastric cancer, when appropriately indicated.

Key words: endoscopic mucosal resection (EMR) – microforceps – magnetic anchor – gastric cancer – endoscopic surgery

INTRODUCTION

Endoscopic mucosal resection (EMR) of gastric cancer is a representative procedure of minimally invasive surgery (1). While this approach seems theoretically appropriate, it has serious problems especially when its indications are extended to lesions larger than those recommended by the Japanese Gastric Cancer Association (2). These problems arise from the fact that all resection procedures are carried out using only one endoscope. Thus, resection is performed without appropriate tissue tension provided by an assistant holding the tip of the mucosa. This ‘one handed surgery’ is the root cause of several problems, particularly when performing EMR on large lesions. In EMR, the resection line cannot be fully observed because the ablated mucosa cannot be stabilized and pulled up. Consequently, it is difficult to make an accurate incision into the mucosa. Cutting of unconfirmed blood vessels causes bleeding, and hemostatic procedures are hindered because the bleeding point cannot be confirmed directly by operator’s eyes. It is also of consequence that the depth of the mucosa at the site of ablation cannot be confirmed, which may lead to perforation of the gastric wall (1,3). These dilemmas have not caused serious problems so far, because EMR is indicated only for relatively small lesions.

Several new techniques and types of equipment have been developed to overcome these technical difficulties and complications that are problematic even for experienced endoscopists. The insulation-tipped electro-surgical knife (IT knife) is one such device that was designed by covering the tip of the electric knife with a ceramic ball to prevent accidental penetration of the gastric wall (1,4).

The rationale behind this development is that the tip of the electric knife, which is the most penetrative part for surgical incision, cannot be used. Thus, theoretically, resection is limited to a certain extent and the penetration is prevented.
However, perforation is still encountered, leading to prolonged resection time. Therefore, EMR for gastric cancer requires an endoscopist with technical skills higher than those required for other endoscopic procedures.

A basic technical principle of surgical resection is the resection of appropriate tissues, which are made to stand out by pulling them up. If this basic technique is integrated into EMR, then the procedure would become easier, less risky and more effective. This, in turn, could make it possible to establish EMR as the standard procedure whenever the nature of the lesions is an indication for resection with EMR, irrespective of their size.

Magnets and magnetic fields have been applied to catheter examinations to control the tips of catheters for years (5). They may also be providing a way to alter tissue contour configurations without any direct contact, such as through electric cables. A direct current magnetic field, as is used in MRI, is regarded as the least invasive, or even the most appropriate, non-invasive procedure that can be applied medically.

If a magnetic field is properly controlled and made to generate enough power to give sufficient force by using microforceps for stabilization of the mucosa during EMR (Fig. 1), then the procedure would be made much easier. If such a device design is developed, then indications for EMR could be expanded to change the current concept of endoscopic surgery for cancer treatment, including gastric cancer.

Thus, this study was initiated to evaluate the potential of magnetically controlled forceps and a magnetic anchor in an animal subject.

Figure 1. The concept of the magnetic anchor. The concept of the magnetic anchor is shown by microforceps that stabilize and pull up objects by employing a magnetic field. The magnetic anchor consists of three parts: microforceps, a magnetic weight and the connecting thread between them. One application of this concept is the use of the forceps to assist endoscopic resection of gastric cancer. The concept can even be applied to other procedures outside medical practice when stabilization and traction of objects are required and where direct contact is not possible.

SUBJECTS AND METHODS

MAGNETIC CONTROL SYSTEM

A magnetic control system was designed for clinical application in a standard endoscopic room, thus limiting the size of the system. The magnetic control system primarily consisted of a 0.68 kOe / 100 A electromagnet, 350 mm in diameter, at 10 cm from the center of the magnetic yoke.

The electromagnet was fixed on belts contained in a semi-circular positioning frame that revolved around the trails of the frame. In this manner, a pulley system was formed allowing a 180° control of the magnet’s position in relation to the patient (Fig. 2).
**MAGNETIC ANCHOR**

The magnetic anchor consists of three parts: a hand-made magnetic weight comprising magnetic stainless steel (SUS420F), microforceps and a connecting thread (Fig. 3). The weight, with dimensions of $1.0 \times 1.0 \times 1.5$ cm, was designed to generate sufficient traction for tissues and to allow insertion into the gastric cavity through the esophagus. The weight of the anchor can be varied by using differently shaped weight components of different weights. The anchor weight used for this procedure is approximately 6 g.

Hemostasis clips (endo-clips) were used as microforceps in order to confirm the feasibility of the magnetic anchor’s proposed function of tissue traction. However, it is likely that forceps designed specially for this procedure will be developed in the future.

![Figure 3. Magnetic anchor. The magnetic anchor consists of three parts: (a) a magnetic weight, (c) microforceps and (b) a thread connecting them.](image)

![Figure 4. Preparation of the magnetic anchor. (a) The magnetic anchor (x) is prepared by the following procedure: First, the endoscopic hemostasis sheath (y) is inserted into the working channel of an endoscope (z) and pushed out from the tip of the endoscope. (b) The microforceps are connected to the sheath and pulled backwards into the sheath. (c) The thread is pulled further into the sheath together with the magnetic weight, and the magnetic weight is secured at the tip of the sheath. (d) The sheath is pulled into the endoscope. (e) The weight is fixed at the tip of the endoscope. (f) The magnetic anchor is pushed out from the tip of the endoscope at the time of its use. The target is grasped after opening the microforceps. x: magnetic anchor, y: endoscopic hemostasis sheath, z: endoscope.](image)
PREPARATION OF THE MAGNETIC ANCHOR

First, the endoscopic hemostasis sheath is inserted into the working channel of an endoscope as shown in Fig. 4. The microforceps are then connected to the sheath and are pulled backwards into the tip of the sheath protruding from the tip of the endoscope; subsequently, the thread follows and the anchor is secured at the tip of the sheath. The sheath is then withdrawn into the working channel, and the anchor is fixed at the tip of the endoscope.

TEST SUBJECT

A 45 kg female swine laid in the left lateral position, was placed on an examination table under intravenous anesthesia.

PROCEDURE

Prior to insertion of the magnetic anchor, an incision was made by the standard EMR technique in the mucosa surrounding the region of the stomach intended for resection (4). An overtube was first inserted into the esophagus to facilitate smooth insertion of the endoscope along with the magnetic anchor to reach the gastric cavity. Inside the gastric lumen, the magnetic weight was pushed out from the sheath, followed by the microforceps. The tip of the mucosa, in which the incision was made in advance, was grasped by the microforceps. In order to lift the tip of the mucosa, a magnetic field was then generated by increasing the electric current through the electromagnet of the magnetic control system.

The EMR procedure was performed by several physicians of the National Cancer Center Hospital at four representative regions of the stomach: the anterior wall of the gastric angle, the lesser curvature of the gastric corpus, the posterior wall of the gastric angle and the greater curvature of the gastric corpus. These areas were selected in order to represent the varying techniques and problems that are incurred with the anatomy of each specific area.

RESULTS

Insertion of the fixed magnetic anchor through the overtube incurred no difficulties. In fact, the magnetic anchor was easily

Figure 5. Resection using the magnetic anchor. (a) The mucosa is pulled to create sufficient space to show the line of resection. (b) The resection is performed using an electric knife through an endoscope. (c) The resection line can be clearly shown as a result of traction by the magnetic anchor. (d) The traction of the magnetic anchor is sufficient to allow the mucosal flap to be turned over.
Magnetic anchor for EMR

introduced even without the overtube. Once introduced inside the gastric lumen, the magnetic weight smoothly dislodged from the sheath and the forceps were easily pushed out. The mucosal target site for traction was easily grasped by the microforceps in the same manner as in endoscopic hemostasis, despite the heaviness of the weight component of the anchor.

As a result of magnetic attraction, the magnetic anchor rose rapidly when the electric current of the electromagnet was sufficient for the operation, pulling up the mucosa in a stable tent-like form (Fig. 5). The direction of the traction for the magnetic anchor could be controlled simply by changing the position of the electromagnet over the animal. Application of magnetic attraction only from above was sufficient to pull the magnetic anchor in the desired direction. The control of the magnetic anchor could also be facilitated by adjusting the position of the swine and/or placing a spacer between the swine and the bed. Thus, the magnetic anchor pulled up the mucosa sufficiently to show the resection line. Moreover, hemorrhage was rare because blood vessels could be clearly visualized endoscopically, and electrocoagulation hemostatic procedures were conducted before cutting the blood vessels. Even on occasions of unexpected hemorrhage, hemostasis proved easier because the site of bleeding was clearly visible by stretching the mucosal folds using the magnetic anchor.

The basic features and functions of the magnetic anchor were similar at all the four tested representative areas of the stomach, and the magnetic anchor could be controlled in the same manner at all sites. Sizes of resected specimens and the procedure time required for each are shown in Table 1.

### DISCUSSION

Conventional surgery for cancer is highly stressful and sometimes burdensome for patients. Standard treatment for gastric cancer at present is gastrectomy, which is performed even for early gastric cancer. One alternative to gastrectomy that has recently emerged is EMR, although it has several technical problems related to its one handed surgery approach. This procedure, in turn, demands additional skills that are beyond those required for a standard endoscopic technique.

However, the magnetic anchor is not a technique in itself but just an additional tool which is optionally used by the endoscopist during EMR. In the present experiment, endoscopists used the magnetic anchor throughout the procedure and found that EMR was much easier by using it. This opinion was unanimous even on their first exposure to the new device. The magnetic anchor facilitated resection even with the techniques used for standard EMR, which are different from those used for standard surgery. It is worth noting that it was not necessary for the endoscopists to modify their technique in using the magnetic anchor. In fact, they found that the use of the anchor offered more benefits.

The first EMR procedure using the magnetic anchor was performed by a senior physician, the following two by resident physicians, and the last one by a senior physician with a resident physician. All the procedures were performed with few or no incidents regardless of the skills of the physicians. The senior physician, who has developed skills for using the IT knife, had to modify technique he used for standard surgery in order to maximize the efficacy of the magnetic anchor. However, he did not find it difficult. Even for resident physicians inexperienced with an IT knife, EMR with the magnetic anchor proved easy to perform. According to the endoscopists, one touch to the mucosa made it sufficient for cutting. This was a great contrast to the frustration that they had when performing standard EMR without the magnetic anchor, which demanded much effort and patience.

However, several noteworthy incidents had occurred during the procedure. Prominent among them were separation of the magnetic weight from the thread connecting the forceps and slipping of the microforceps from the mucosa. In these cases, new magnetic anchors could be inserted without any problems, and the procedure was continued. The malfunctioned anchors could be easily removed causing no problem, even when left in the gastric lumen during the resumed resection procedure with a new anchor. Slipping of the forceps occurred twice for the same physician at the same mucosal site. Thus, this may be attributed to his inexperience in surgical techniques, which would be similar to the problems encountered with some assistants in standard surgery. Of greater importance was the unproblematic retrieval of the dislodged magnetic anchor. In fact, one of the reasons for involving various physicians in this experiment was to evaluate the nature of incidents with the device and to consider possible countermeasures for future improvement. Thus, the magnetic anchor will certainly be improved, and refined, and will present with few benign problems that we expect to overcome easily. We emphasize that the magnetic anchors used in this study were merely handmade ones devised to experimentally assess the conceptual feasibility of the technique.

Problems with standard EMR such as perforation and incomplete resection are serious and potentially hinder the EMR procedure from being indicated to lesions proposed for resection by the National Cancer Center Hospital of Japan. Even though indications for EMR procedures may be discussed in later papers, we believe that several current problems with EMR are solved to a great extent by the use of the magnetic anchor.

The results of this study showed that all procedures were satisfactorily performed using an electric current of less than 50 A for the electromagnet, which is comparable to 0.6 kOe/10 cm. Consequently, the intensity of the magnetic field required for

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**Table 1. Sizes of resected specimens and the procedure times required**

<table>
<thead>
<tr>
<th>Site in the stomach</th>
<th>Size (cm)</th>
<th>Time (min)</th>
</tr>
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<tbody>
<tr>
<td>Anterior wall of the gastric angle</td>
<td>5.1 × 2.7</td>
<td>51</td>
</tr>
<tr>
<td>Lesser curvature of the gastric corpus</td>
<td>2.4 × 1.7</td>
<td>47</td>
</tr>
<tr>
<td>Posterior wall of the gastric angle</td>
<td>2.9 × 1.7</td>
<td>25</td>
</tr>
<tr>
<td>Greater curvature of the gastric corpus</td>
<td>9.4 × 5.1</td>
<td>73</td>
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the magnetic anchor for EMR was less than what had been expected prior to this procedure. Our next model of the magnetic control system will be smaller and simpler. New concepts of magnetic anchor will expand the indications of endoscopic surgery beyond the treatment of gastric cancer.

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