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ORIGINAL ARTICLE

Magnetic compression gastrostomy in the rat

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Abstract

Purpose Magnetic compression anastomosis is used for gastrointestinal, biliary, and urinary anastomoses. We have developed a simple magnetic compression gastrostomy technique in rats.

Methods Animals were randomized into two groups ($n = 12$ each): magnetic gastrostomy (MG) and surgical gastrostomy (SG) (control). In the MG group, a magnetic insertion catheter was coupled with the first magnetic ball and introduced transorally into the stomach. A second magnetic ball was placed subcutaneously into the left upper quadrant. The two magnetic balls (4 mm) were strongly coupled together. On postoperative day (PD) 20 (MG group) and PD10 (SG group), rats were killed, gastrostomies were evaluated macroscopically and histopathologically, and mechanical burst testing was performed.

Results Two animals died due to suspected leaks. Macroscopic evaluation indicated no gastrostomy canal in one rat in each group. Mild adhesion was observed in two rats in the MG group. Moderate adhesion was observed in all rats in the SG group. No significant differences were observed in burst pressure between the two groups (means: MG group, 143 mmHg, $n = 9$; SG group, 159 mmHg, $n = 8$).

Conclusions Magnetic compression gastrostomy can be performed easily in rats, and may be developed in future as a simple alternative to some gastrostomy procedures in humans.

Keywords Magnetic compression anastomosis · Magnetic compression gastrostomy

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Introduction

Gastrostomy is performed frequently in children. Various gastrostomy insertion techniques have been developed, including surgery, laparoscopy, endoscopy, and fluoroscopy [1, 2]. Despite their strong safety record, gastrostomy procedures have been associated with overall major and minor complication rates of 4.9 and 50%, respectively (e.g., procedural complications associated with surgery, endoscopy, and anesthesia; bleeding; leakage; peritonitis; sepsis; and organ injury), mortality rates of 0.5–1.2%, and morbidity rates of 3–12% [1, 2].

Magnetic compression anastomosis (MCA) has been reported previously for gastrointestinal, biliary, urinary, and vascular anastomosis [3–14].

Here, we report the development of a simple technique for magnetic compression gastrostomy (MCG) in rats.

Methods

Two spherical strong neodymium–iron–boron magnets coated with chrome (N35 strength, outer diameter 4 mm), which is the largest size that can be swallowed by a rat, for patency of the fistulae and rapid fistula creation were used for magnetic gastrostomy in rats (Fig. 1).

The magnetic insertion catheter was specially designed for insertion of the intragastric magnet through the esophagus into the stomach of the rat. The tip was cut from an 8-F feeding tube, and two small cylindrical magnets (N35 strength, outer diameter 2 mm, thickness 1 mm) were inserted into the tip. The tube was then pushed 2 mm proximally to couple with the magnetic ball, while allowing easy withdrawal after coupling of the two magnetic balls (Fig. 1).

Twenty-four adult male Wistar albino rats weighing 285–380 g were used in this study. All of the experimental protocols were reviewed and approved by the Institutional Animal Care and Use Committee of Dicle University (approval no. 2011/09).

The rats were fasted overnight before the experiments, but were given free access to water. Animals were anesthetized by intraperitoneal injection of ketamine (Ketalar Flakon; Pfizer Ilaclari, Ltd. Sti., Istanbul, Turkey) at a dose of 75 mg/kg of body weight.

The animals were randomized into two groups ($n = 12$ each): the magnetic gastrostomy (MG) group, in which rats were subjected to the magnet insertion procedure described below, and the surgical gastrostomy (SG) group, in which rats were subjected to the surgical gastrostomy procedure described below. The procedure times are noted for the rats in each group.

In the MG group, the magnetic insertion catheter described above coupled with the first magnetic ball was introduced transorally into the stomach of rats in the MG group. Once the first magnet was in the stomach, a small skin incision was made on the midline. The subcutaneous tissue was dissected through the left upper quadrant by a clamp. The second magnetic ball was placed subcutaneously into the left upper quadrant to prevent it becoming dislodged by the animals, and the two magnetic balls were strongly coupled together. The magnetic insertion catheter was then easily removed.

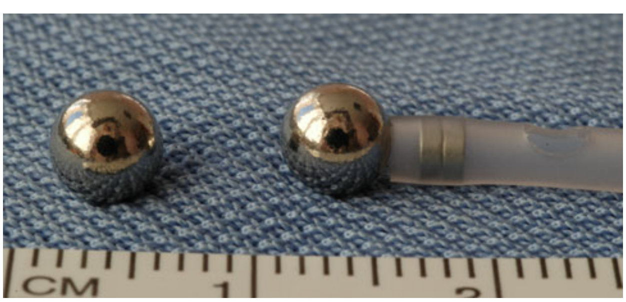

Fig. 1 Spherical magnets (outer diameter 4 mm) coated with chrome and magnetic insertion catheter made from an 8-F feeding tube

In the SG group, a laparotomy was performed through a 3-cm upper midline incision. The subcutaneous tissue was dissected through the left upper quadrant by a clamp. A 5-F polyurethane catheter, used as a gastrostomy catheter, was inserted subcutaneously into the stomach through the abdominal wall. The catheter was secured with a purse-string suture using 6-0 Vicryl (Ethicon Inc., Somerville, NJ, USA), and the stomach was fixed to the abdominal wall with two primary sutures with the same suture material. The proximal end of the catheter was cut and occluded by tying with 3-0 Vicryl (Ethicon, Inc.). The catheter was fixed to the abdominal fascia with the same suture material. The fascial layer of the abdominal wall was continuously closed with the same suture material.

In all animals, the abdominal skin was closed with an interrupted suture using 3-0 Vicryl (Ethicon, Inc.). The animals were allowed food and water immediately after the operation and recovery from anesthesia.

On postoperative day (PD) 20 after full tubularization in the MG group and PD10 after completion of wound healing in the SG group, the rats were deeply anesthetized by intraperitoneal injection of ketamine at a dose of 100 mg/kg of body weight. The external magnetic balls with internal magnets and the gastrostomy catheters were carefully disengaged through the abdominal wall. Gastrostomies were examined to determine patency of the ostomy and externally calibrated with feeding tubes. All animals subsequently underwent laparotomy and exploration of the abdomen for the evidence of leaks, adhesions, intestinal obstruction, peritonitis, incorrect gastrostomy side, or other complications. All gastrostomy segments including the abdominal wall, stomach, esophagus, and duodenum were then dissected and totally excised with scissors.

For mechanical burst testing, two catheters were inserted through the esophagus and duodenum into the stomach. Each gastrostomy was evaluated by suturing the ends of the esophagus and duodenum around the catheters. The esophageal catheter was connected to a syringe for instillation of 0.9% normal saline solution. The duodenal catheter was connected to a calibrated pressure-measuring circuit. The gastrostomy opening was occluded from the abdominal wall by compressing with a clamp. Saline was injected into the stomach with monitoring for pressure changes. Continuous infusion of saline solution was administered intragastrically until gastrostomy failure on the peritoneal surface or surrounding stomach was observed as evidenced by leakage or bursting. The pressure at the point of leakage or bursting was recorded as the burst pressure of the gastrostomy.

Tissue was subsequently fixed in 10% formalin. Gastrostomies were evaluated with hematoxylin and eosin and Masson's trichrome stain.

The Mann–Whitney U test was used to determine the differences in procedure times and bursting pressures between groups. Data were analyzed using SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA). In all analyses, $P < 0.05$ was taken to indicate statistical significance.

Results

Twenty-four rats underwent successful operations. There were no episodes of intestinal obstruction or food intolerance. Two animals in the SG group, one of which experienced intraoperative posterior gastric perforation because of catheter placement that required repair with sutures, died on PD5 and PD7, respectively, because of suspected leaking and peritonitis. Thus, 22 total gastrostomies remained for analysis. In the macroscopic evaluation, gastrostomy canal did not occur because the gastrostomy catheter was removed in one rat in the SG group, and all magnetic balls were removed in one rat in the MG group. There was no evidence of leakage, intestinal obstruction, peritonitis, or incorrect gastrostomy side in the other rats. However, mild adhesion was observed in two rats in the MG group, and moderate adhesion was observed in all rats in the SG group (Fig. 2). Two magnetic and one surgical gastrostomy were damaged during harvesting. Burst pressure data could be obtained for the remaining 17 (9 magnetic and 8 surgical) gastrostomies. Average burst pressure for the MG group was 143 mmHg (SD 35 mmHg, SEM 12 mmHg), and that for the SG group was 159 mmHg (SD 31 mmHg, SEM 11 mmHg). All burst failures occurred at the corpus of the stomach (Fig. 3). No significant differences were observed in burst pressure between the SG and MG groups ($P = 0.321$). However, procedure times differed significantly between the MG and SG groups (mean $\pm$ SD, SEM in the MG group $=$ 4.17 ± 1.03, 0.30 min vs. the SG group $= 15.00 \pm 2.90$, 0.84 min; $P < 0.001$).

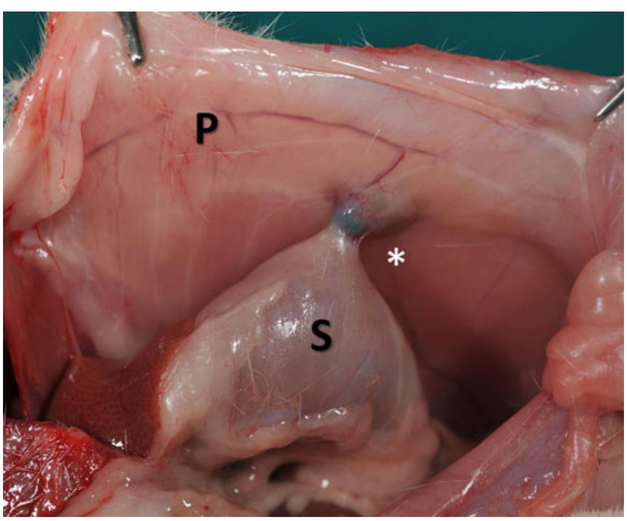

Fig. 2 Macroscopic evaluation of the magnetic gastrostomy. The gastrostomy canal was strong and patent (*S* stomach, *asterisk* gastrostomy canal, *P* peritoneum of the abdominal wall)

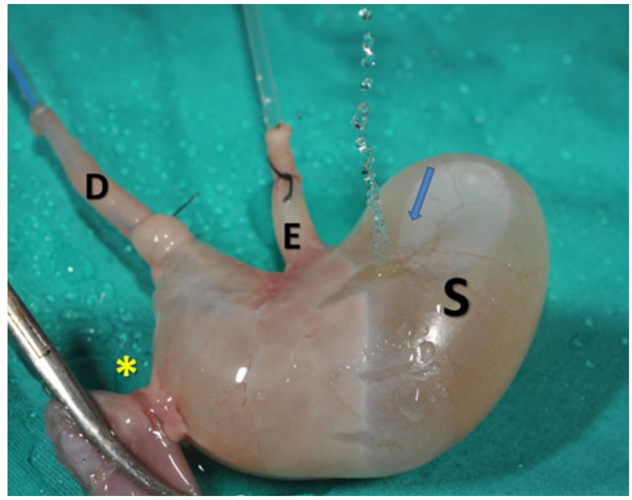

Fig. 3 Mechanical burst pressure testing of gastrostomy (*asterisk*). All burst failure (*arrow*) occurred at the corpus of the stomach (*S*) (*E* esophagus, *D* duodenum)

Histological analysis showed the evidence of epithelization across the gastrostomy within the submucosa between the gastric and abdominal walls, which exhibited less inflammation compared with surgical gastrostomies.

Discussion

The use of enteric magnets was first described by Cope et al., who generated anastomoses by compression necrosis first in animals and eventually in humans [3, 4]. Magnets have been increasingly used in medical fields to treat several diseases, such as biliary duct and urethral strictures, malignant gastric outlet obstruction, esophageal atresia, pectus excavatum, and other gastrointestinal diseases that require gastrointestinal bypass anastomosis [4, 5, 9–12, 14, 15]. The results of the present study suggest that MCG can be performed in animals.

Previously, all experimental studies of MCA have used large animals (pigs and dogs) [3, 6–8, 13]. In the present study, we used rats to study MCA, which we believe will accelerate the development of magnetic device studies in the medical field.

We used spherical magnetic balls for MCA. These magnetic balls have a smooth, round shape and can roll and move. All surfaces in contact with tissues are identical. Therefore, insertion, coupling, and removal of magnetic balls can be performed easily and noninvasively compared with other shapes. The results of this study may lead to further studies, and as in our MCG, in the future it may be possible to use magnets to perform all ostomies, such as cystostomy, colostomy, nephrostomy, and ureterostomy.

The gastrostomy procedure techniques require general or local anesthesia, special expensive medical equipment and devices, and X-ray exposure in the fluoroscopic technique. They also have major and minor complications and mortality rates [1, 2]. In the present small study, the MCG technique did not require expensive equipment, and no complications were observed in any of the rats. The method described here requires anesthesia for animals. However, in the future it may be possible to fix the external magnet on the skin with transparent film or other types of dressing material for use in humans. Therefore, anesthesia may not be required in humans.

Adhesion was less numerous and less severe in the MG group compared with the SG group. Mild adhesion in two rats was associated with peritoneal inflammation due to the compression of magnets. Although no evidence of leakage or peritonitis was observed, further studies are required to confirm the safety of this technique before it can be applied clinically.

Pichakron et al. [6] reported that MCA were immediately patent and developed strength equal to or greater than that of hand-sewn or stapled anastomoses over 3–10 days in a pig model. However, in the present study, the anastomosis between the stomach and abdominal wall was wholly created at 20 days because of the thick abdominal wall. Thus, this technique cannot be used in patients that require immediate feeding. Further investigations are required to examine pressure differentials of magnetic forces in comparison to tissue thickness and duration required to create the ostomy in animals and humans. Jamshidi et al. [8] and Pichakron et al. [6] reported that MCA was effective in a pig model and may be a safe and effective alternative to current anastomotic strategies in humans. In the future, MCG may also be an easy alternative to some gastrostomy procedures in humans.

Our observations of MCG are limited by the small number of rats used in this study. Nonetheless, the present results suggest that MCG is technically easy to perform. The findings suggest that MCG may be created via an orogastric tube approach using gastric magnets that are inserted with a magnetic insertion device developed in our laboratory.

The MCG is easy in the rat model, and may be a simple alternative to some gastrostomy procedures in humans. However, further investigations are required to develop magnetic compression ostomy in animals and humans.

Conflict of interest The authors declare that they have no conflicts of interest.

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