Original article

Greater curvature as a gastric pouch for sleeve gastrectomy: a novel bariatric procedure. Feasibility study in a canine model

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Received 29 November 2017; received in revised form 17 August 2018; accepted 22 August 2018

Abstract Background: Laparoscopic sleeve gastrectomy (LSG) has serious complications, such as leaks, reflux, stenosis, and kinks, which are also consequences of shortcomings in the LSG technique. Objectives: We evaluated the feasibility and weight loss of a novel bariatric procedure, using the greater curvature as the gastric pouch for sleeve gastrectomy (SG) in dogs. Setting: Animal house in Faculty of Medicine, Cairo University. Methods: Five 20- to 25-kg stray mongrel male dogs were subjected to open SG using the greater curve as the gastric pouch (GCSG group). The weight was monitored at day of surgery and at postoperative weeks 2, 4, 6, and 8; weight progression was compared with a sham and a standard SG group. By the end of the follow-up period autopsy was done. Results: The mean operative time in GCSG group was 39.6 ± 3.97 minutes. At the end of the study, dogs in the sham group had gained 8% of their preoperative weight, while the GCSG and standard SG groups lost 24.7% and 25% of their preoperative weight, respectively. At autopsy, the gastric sleeve in the GCSG group showed excellent healing with no stenotic areas, kinks, or mucosal ulcerations. Conclusion: Greater curvature SG is technically feasible in a canine model. Larger studies with longer follow-up period will be needed to assess weight progression and resolution of the metabolic co-morbidities. (Surg Obes Relat Dis 2018;14:1814–1821.) © 2018 American Society for Bariatric Surgery. Published by Elsevier Inc. All rights reserved.

Keywords: Bariatric surgery; Sleeve gastrectomy; Canine; Greater curvature; Leakage

When a novel bariatric procedure emerges as safe and effective in the short term, its long-term results on a large scale usually reveal some shortcomings inherited in a previously seamless procedure. Since the introduction of laparoscopic sleeve gastrectomy (LSG) in the late 1990s [1,2] until the global overview of worldwide bariatric surgery report [3], LSG gained popularity for obvious advantages [4]. Nevertheless, it was equally conspicuous that leakage from the proximal staple line at the gastroesophageal junction (GEJ) was the Achilles’ heel for LSG [5–9], due to the high pressure zone inside the gastric sleeve, which helps to keep the fistula open [10, 11], firing the last staple close to the GEJ [12], and most importantly the poor blood supply of proximal part of the staple line at the GEJ [11]. The LSG technique...
also entails destruction of the phrenoesophageal liga-
ment, blunting the angle of His[13], partial removal of
the sling fibers impairing the function of the crural high-
pressure zone of the lower esophageal sphincter[14], de-
taching the gastric peritoneal attachments to the abdomi-
cavity facilitating intrathoracic proximal stable line migra-
tion[15], lack of greater curvature natural fixation allowing
for kinking[16] or volvulus[17,18] of the gastric tube,
and creation of a high-pressure zone inside the sleeve as
it prevents the stomach from emptying effectively[19,20].
Recently, sleeve stenosis, which is an insidious complica-
tion of LSG, was reported typically at the junction between
the vertical and horizontal limbs[21] of the sleeve at
the level of the incisions angularis[16,18,20]. It is either func-
tional stenosis due to kinks and twists[19] or organic due
to fibrous scarring[16,18]. It has been reported that loss
of abdominal ligament fixations along the greater curva-
ture of the gastric sleeve may result in improper gastric
pouch positioning causing food intolerance and persistent
reflux[20]. Herein, we proposed a possible solution for
the aforementioned shortcomings in LSG technique while
emulating its merits[4]. Our technique was analogous to
the standard LSG technique[5], except that the gastric
sleeve was constructed using the greater curvature instead
of the lesser curve. After detaching the lesser curve of
its omental attachments juxtapastric avoiding the Latarjet
nerves, followed by clearing all adhesions in the lesser sac,
including freeing the part of the fundus adherent to the
left crus, a 36-Fr bougie was introduced along the greater
curve, followed by applying staplers along the bougie to
excise the lesser curvature, gastric body, and almost all of
the fundus by starting stapling just above the incisures an-
gularis and ending just distal to the first left gastric branch
on the lesser curve. The primary endpoint of this study was
to evaluate the feasibility of constructing a gastric sleeve
using the greater curve in a large animal model (dogs).
Weight loss, food intake, and complications were assessed
at a short follow-up period.

Methods

Study design

The study was submitted on April 2017 and approved on
May 2017 by the Institutional Animal Care and Use Com-
mittee of Cairo University (CU-IACUC), approval number
(CU-III-S-1-16). All applicable institutional and national
guidelines for the care and use of animals were followed. A
qualified staff veterinarian supervised all the manipulations
and perioperative care. This is a preliminary exploratory
study focusing mainly on the technical feasibility of using
the greater curve as the gastric pouch for sleeve gas-
trectomy (SG). Dogs were chosen because their stomach is
anatomically similar to the human stomach[22]. Five 20-
to 25-kg stray mongrel male dogs (2- to 3-yr old) were
subjected to open SG using the greater curve as the gastric
pouch (greater curve sleeve gastrectomy [GCSG] group).
The dogs were kept in the animal house of the Faculty
of Medicine, Cairo University for 7 days before surgery
and received an equal amount of calories per day (1200
calories). The dogs were fed a soft meal that consisted of
220 g bread (570 calories) + 200 g minced meat (570 calo-
ries) + 100 g carrot (60 calories) once a day. For 12 hours
before surgery, the animals were maintained nil per os.
The dogs were premedicated with subcutaneous injections
of atropine sulphate .1 mg/kg and intramuscular xylazine
HCl 1 mg/kg. An intravenous line with sodium chloride
.9% solution was started at 100 mL/h. Induction of general
anesthesia was performed using ketamine HCl 10 mg/kg
intravenously. The endotracheal intubation was carried out
and general anesthesia was maintained with isoflurane (2%
end tidal concentration). Cefotaxime sodium 10 mg/kg was
administered intramuscularly before surgery. The surgical
site was then shaved and aseptically prepared. The animal
was placed supine on the table.

Our technique is analogous to that of a standard sleeve
gastrectomy (SSG)[5], except that the gastric sleeve will
be constructed on the greater curvature (Fig. 1). Through
an upper abdominal midline incision, we detached the
lesser curve of its omental attachment juxtapastric avoid-
ing injuring the nerve of Latarjet, starting just above the
crow’s foot and ending just distal to the first left gastric
branch on the lesser curve, followed by clearing all ad-
hesions in the lesser sac and dissecting the part of the

Fig. 1. A diagram demonstrating the use of the greater curve as the
gastric pouch for sleeve gastrectomy (dotted area). (a) The first branch
of the left gastric vessels on the lesser curve. (b) Staple line. (c) The
gastric pouch constructed on the greater curve. (d) Right gastric vessels.
(e) Coeliac trunk. (f) The resected part of the stomach.
posterior fundus adherent to the left crus. A 36-Fr bougie was introduced transorally along the greater curve, followed by resection of the lesser curvature, gastric fundus, and body by stapling medial to the bougie using repeated 75-mm firings with linear stapler starting just above the incisure angularis (avoiding the crow’s foot of the vagus nerve, sparing the antpyloric innervations) and ending just distal to the first left gastric branch on the lesser curve (Figs. 2 and 3). Afterward, a methylene blue test was used to check for leaks from the gastric staple line. Because of the GCSG technique, the GEJ was left untouched, with excellent blood supply from the preserved short gastric vessels. A form of highly selective vagotomy was done to minimize the need for antacid medications postoperatively. There was no blunting of the His angle and no interference with the sling fibers or the phrenoesophageal ligament to help maintain the GEJ intra-abdominally and keep all natural gastric attachments along the greater curvature, from the phrenogastric ligament to the short gastric vessels and the greater omentum, with its weight accompanied by the loaded transverse colon, which exerts traction on the greater curvature. This technique maintains a gentle C-curve of the gastric sleeve, avoiding kinks and twists for better gastric pouch positioning and luminal patency.

Outcomes assessment

Variables recorded included operative time, perioperative morbidity (leakage, bleeding, vomiting, infections), weight progression, and food intake. The animals were weighed before surgery, and weight was monitored at the end of postoperative weeks 2, 4, 6, and 8. Weights were compared with dogs from 2 groups with identical strain, age, sex, and preoperative weight: a sham group, in which 5 dogs underwent an upper abdominal midline laparotomy, without any gastric surgery or manipulations, and closure of the laparotomy, and an SSG group, in which 3 dogs underwent an SSG [5] through an upper abdominal midline laparotomy by stapling 6 cm from the pylorus on the greater curve after detaching it from its attachments along a 36-Fr bougie positioned on the lesser curve till reaching the GEJ using repeated 75-mm firings with linear stapler. In both groups, the same anesthesia and aseptic precautions done in the GCSG group were followed. The same surgeon performed all procedures in the 3 groups. All dogs in the 3 groups were kept nil per os for the first 3 postoperative (PO) days and received 250 mL of dextrose 5% solution given intravenously twice daily during this period. All dogs received half of the normal meal once daily from the fourth to sixth day PO. From the 7th day PO until the end of the study period, the dogs received their
normal meal (1200 calories), which consisted of 220 g bread (570 calories) + 200 g minced meat (570 calories) + 100 g carrot (60 calories); all dogs had free access to the meal from the seventh PO day till the end of the study. A daily intramuscular dose of cefotaxime sodium 10 mg/kg and diclofenac sodium 1.1 mg/kg was given to all dogs for the first 5 PO days [23]. At the end of the follow-up period, autopsy was done, and the gastric sleeve was evaluated for healing, presence of mucosal ulceration, stenosis, or twists.

Data were shown as mean ± standard deviation. Using IBM SPSS Statistics Release 22.0.0.0 (Armonk, NY, USA), the significance of the differences between groups was evaluated by one-way analysis of variance with Dunn’s post hoc test. The results were considered statistically significant when $P < .05$.

Results

The mean surgical time was 39.6 ± 3.97 minutes in the GCSG group and 40 ± 5 minutes in the SSG group. There were no intraoperative major complications. In the sham group, the mean weight was 21.2 ± 1.3 kg on the day of surgery and 21.9 ± 1.02, 22.6 ± .82, 22.92 ± .642, and 22.9 ± .652 kg at the end of postoperative weeks 2, 4, 6, and 8, respectively, gaining 8% of the baseline weight at the day of surgery. The mean weight for the GCSG group was 21.7 ± 1.45 kg on the day of surgery and 18 ± 1.9, 17 ± 1.87, 16.26 ± 1.078, and 16.32 ± 1.021 kg at the end of postoperative weeks 2, 4, 6, and 8, respectively, losing 24.7% of their preoperative weight at the end of the study. In the SSG group, the mean weight at the day of surgery was 21.33 ±1.53 kg and 19.16 ± .73, 18.08 ± .18, 16.93 ± .75, and 15.96 ± .2 kg at the end of postoperative weeks 2, 4, 6, and 8, respectively, losing 25% of their preoperative weight. There was no significant difference in preoperative weight among the 3 groups ($P = .925$). At the end of the study, dogs in the GCSG group had a significant weight loss in comparison to the sham group ($P < .001$), while there was no significant difference between weight loss in GCSG group and SSG group ($P = .586$; Fig. 4). We had no postoperative complications in all groups. All dogs received half of the normal meal (600 calories/d) once daily from the fourth to sixth day PO. From the seventh day PO until the end of the study period, the dogs received their normal meal (1200 calories/d), and all dogs in the 3 groups had free access to the meal throughout the day from the seventh PO day until the end of the study; however, none of the dogs in the gastrectomy groups managed to consume all of their meals. After starting oral feeding, all dogs in the GCSG group and the SSG group vomited some of their meal immediately after finishing the meal in the first 3 to 5 days, and then the vomiting stopped. Starting from the second week PO, in the GCSG group, 4 dogs (80%) had their food intake reduced by 50% and the remaining dog (20%) had its food intake reduced by 25%, resulting in 55% overall reduction in this group, which plateaued until the end of follow-up period. In the SSG group, 2 dogs (66.7%) had 50% reduction in food intake, and the remaining dog (33.3%) had 25% reduction in food intake, resulting in 58.3% overall reduction in this group, which also plateaued until the end of follow-up period. The difference between the 2 gastrectomy groups in food intake was not significant. In the sham group, dogs did not vomit postoperatively and consumed all of their daily meals throughout the study period, with a significant difference in food intake from the GCSG group ($P < .001$). All animals tolerated the surgery with no cases of leakage, infection, or bleeding during the follow-up period. At autopsy, the gastric sleeves of the GCSG group showed excellent healing with no stenotic areas, kinks, or mucosal ulcerations (Fig. 5).

Discussion

To date, we have not reached the ideal bariatric procedure. The use of animal models to explore feasibility, safety, and postsurgical physiology of a new technique in bariatric surgery has significantly contributed to most of the well-established bariatric procedures today [22]. In LSG, the leakage from the proximal end of the staple line due to its poor blood supply [11] is the most feared complication, as the management of the resulting fistula is usually elusive [9,24]. The GEJ poor blood supply is a direct consequence of the LSG technique, due to depriving the GEJ at the angle of His of the blood supply from the gastric submucosal layer by stapling. The left and right gastric arteries do not share in the submucosal layer anastomosis and, according to Griffith [25], are end arteries because they supply only the lesser curve (His angle is not part of the lesser curve). The LSG technique also interrupts blood supply to His angle from the left phrenic vessels by careful dissection of the phrenoesophageal ligament and the esophageal pad of fat, leaving only the blood supply from the left gastric artery that gives origin to a cardiosophageal branch, which supplies the esophagus and cardia in only 78% of specimens [26]. Consequently, the proximal staple line at the GEJ is left relatively ischemic in a considerable sector of LSG patients. The aforementioned anatomic findings are supported by data from clinical trials, as the incidence of leakage from the proximal staple line in LSG is 9 to 1 elsewhere [27] and the wide agreement that the reinforcement of the staple line does not necessarily lower the incidence of leakage, eliminating the mechanical failure probability as the cause of leakage [12,28–34]. On the contrary, a study that refutes this agreement found that after reinforcing the staple line, although the overall incidence of leakage decreased, 85% of the leaks also occurred at the GEJ [35]. In GCSG technique, there is no interruption of the blood supply to any part of the staple
Fig. 4. Average percentage of total weight progression in the GCSG, SSG, and sham groups.

Fig. 5. The resected gastric pouch of GCSG at autopsy, showing good healing with no stenosis, kinks, or twists.

line; additionally, it keeps all the gastric attachments along the greater curve to maintain the position and orientation of the gastric pouch after surgery to avoid twists, kinks, and the resulting stenosis of the gastric pouch for better luminal patency. Furthermore, it shares most of LSG’s advantages such as pylorus preservation, continuity for endoscopy, no gastrointestinal segment exclusion, the fact that it can be a revision for failed gastric band, and that it is convertible to Roux-en-Y, mini gastric bypass, or duodenal switch [4].

Our results indicate that after a short follow-up period, the mean weight of the dogs in the GCSG group was significantly reduced (24.7% reduction of the preoperative weight) compared with a group of dogs that underwent a sham procedure (which gained 8% of their preoperative weight) and was not significantly different from the weight reduction of dogs in the SSG group. Our results regarding weight loss were comparable with similar restrictive procedures in obese and nonobese canine model [36–38]. The dogs in both gastrectomy groups suffered from immediate vomiting after meals in the first 3 to 5 days after starting oral feeding, which was probably due to rapid overfeeding because vomiting stopped spontaneously after dogs adapted to their new gastric capacity, consuming only 50% to 75% of their meals until the end of the study. This is similar to food intake reduction in other studies on gastric restriction in dogs [36,37].

Our results demonstrated a significant weight loss, which was associated with reduction in the amounts consumed by dogs in the GCSG group with comparable results in the SSG group. Yet, weight loss in both gastrectomy groups cannot be solely attributed to the reduction in food intake, as accelerated gastric emptying and decreased
serum ghrelin are other known mechanisms for weight loss after SG. For that reason, further studies are needed to elucidate these variables’ effect on weight loss after GCSG technique. We believe that our technique can be performed laparoscopically following similar steps in the LSG standard technique with similar port sites [5]. The difference is the stapler introduction, which will be through the right subcostal port and the epigastric port. We are willing to conduct a study on the feasibility of our technique laparoscopically.

Our study had some limitations, such as the small sample size, short follow-up period, and the completely exploratory nature, which focuses mainly on assessment of the feasibility of our technique in dogs. For these reasons, we cannot reach a conclusion regarding the safety or the long-term effects of the GCSG technique.

Conclusion

Greater curvature SG is technically feasible in a canine model. Larger studies with a longer follow-up period will be needed to assess weight progression and resolution of the metabolic co-morbidities.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

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Editorial comment

Comment on: greater curvature as a gastric pouch for sleeve gastrectomy: a novel bariatric procedure. Feasibility study in a canine model

Bariatric surgery is the most effective treatment for obesity and is increasingly being accepted as a therapy and cure for type 2 diabetes [1,2]. Even though clinical evidence continues to mount, the mechanisms underlying these powerful operations continue to be incompletely understood. As surgeons and scientists, we routinely use laboratory insight to work toward better understanding and designing clinical studies not only to improve outcomes and quality of care, but also to identify novel and innovative treatments for our patients. For example, the fields of gastrointestinal physiology and endocrinology would not have been made possible without fundamental basic scientific studies. Numerous life-saving operations (e.g., the ‘blue baby operation’) and other medical advancements (e.g., total parenteral nutrition) have been made possible by surgeon-scientists. Similarly, our understanding of the molecular underpinnings of metabolic and bariatric surgery has grown by leaps and bounds in the past approximately 20 years since these operations have been examined in animal models [3–6].

Vertical sleeve gastrectomy is the most popular bariatric operation worldwide and, because of its technical ease in preclinical models, is widely used to study the physiology of bariatric surgery. In the preceding manuscript, the authors undertook a novel approach to constructing a gastric sleeve in a canine model. Instead of creating the gastric sleeve from the lesser curvature of the stomach, the authors devised a way to construct the sleeve from the greater curvature—that is, the portion of stomach typically resected during a standard sleeve gastrectomy. Overall, this study demonstrates the feasibility of such an operation in the canine and opens the door for its potential use in future mechanistic and effectiveness studies. Even though the short- and long-term weight and other metabolic outcomes cannot be inferred from the present study, which is limited by sample size and follow-up, this important work provides another potential tool for surgeons and scientists alike to better understand these operations that may spur further innovation.

Scientifically, this study raises a number of questions, including whether a sleeve composed of the greater curvature of the stomach will function similarly to a standard sleeve. Moreover, as we better appreciate that the weight loss and other benefits of bariatric surgery are less dependent on “gastric restriction” than previously thought, then how would a sleeve constructed out of the stomach tissue that is typically removed from the body perform? What metabolic and endocrine differences might exist? Numerous future questions can be asked by this novel procedure.

One of the important caveats of extrapolating from animal models is that the same biologic mechanisms