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The Use of Fluorescence Angiography During Laparoscopic Sleeve Gastrectomy

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ABSTRACT

Background and Objectives: A new technology involving indocyanine green (ICG) fluorescence angiography has been introduced to assess tissue perfusion and perform vascular mapping during laparoscopic surgery. The purpose of this study was to describe the use of this technology to identify the variable blood supply patterns to the stomach and gastroesophageal (GE) junction during laparoscopic sleeve gastrectomy (LSG), which may help in preserving the blood supply and preventing ischemia-related leaks.

Methods: Eighty-six patients underwent LSG and were examined intraoperatively with fluorescence angiography at an academic bariatric center from January 2016 to September 2017. Before the construction of the SG, 1 mL ICG was injected intravenously, and near infrared fluorescence imaging technology was used to identify the blood supply of the stomach. Afterward, the LSG was created with attention to preserving the identified blood supply to the GE junction and gastric tube. Finally, 3 mL ICG was injected to ensure that all the pertinent blood vessels were preserved.

Results: Eighty-six patients successfully underwent the laparoscopic procedure with no complications. The following patterns of blood supply to the GE junction were found: (1) a right-side–dominant pattern (20%), arising from the left gastric artery; (2) a right-side–accessory pattern (36%), running in the gastrohepatic ligament and comprising either an accessory hepatic artery or an accessory gastric artery; and (3) a left-side accessory pattern arising from tributaries from the left inferior phrenic artery significantly contributing to the right-side blood supply. In addition, in 10% of the cases both right and left accessory patterns were present simultaneously.

Conclusion: ICG fluorescence angiography allows determination of the major blood supply to the proximal stomach before any dissection during sleeve gastrectomy, so that an effort can be made to avoid unnecessary injury to these vessels during the procedure.

Key Words: Bariatric surgery, Fluorescence angiography, Laparoscopic sleeve gastrectomy, Leaks, Obesity.

INTRODUCTION

Bariatric surgery has become the most effective tool for achieving significant weight loss and mitigating the numerous morbid conditions associated with obesity. The obesity epidemic predominately affects industrialized countries, including the United States, and it is continuing to increase.[1] Laparoscopic sleeve gastrectomy (LSG) has become the most common bariatric surgery performed in the United States[2] because of its technical simplicity and a lower complication rate than Roux-en-Y gastric bypass, with comparable weight loss and improvement of comorbidities.[3] However, LSG is not exempt of complications. Leaks occur in a relatively low percentage of cases (<0.5–6%), but represent the most concerning complication after this procedure.[4–6] Leaks commonly occur near the angle of His.[7] Ischemic and mechanical factors may explain why this is an at-risk location.[8–10] However, despite advancements in staple formation and improvement in surgical technique, leaks still occur, and ischemic factors contributing to leaks have not been formally addressed. Most bariatric surgeons perform LSG preserving the blood supply on the lesser curvature arcade—the right and left gastric arteries—without much attention to other sources of blood supply to the sleeve stomach. Anatomic studies of the stomach suggest that the vascular supply of the proximal part of the gastric tube is unequal and can be

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injured during LSG, resulting in potential gastric wall ischemia, and in turn, the risk for development of a leak.[11]

Recently, a new technology involving indocyanine green (ICG) fluorescence angiography has been introduced to assess tissue perfusion and to perform vascular mapping during laparoscopic surgery. This method complements the surgeon's clinical judgment by (1) revealing the arterial inflow and venous return from a target tissue area and (2) the rate at which tissue perfusion is occurs between the arterial and venous phases. ICG is a water-soluble anionic probe with excitation and emission wavelengths in serum at 778 and 830 nm. The dye is excreted through the liver immediately, via the first-pass effect. It binds to plasma lipoproteins and essentially travels to wherever blood goes. The utility of this technique has been described in other surgical disciplines.[12,13] Clinical studies suggest that real-time assessment of vascular perfusion with this technique may decrease the potential development of leaks associated with ischemia.[14,15]

Along these lines we described the use of intraoperative ICG fluorescence angiography to identify the variable blood supply patterns of the gastroesophageal (GE) junction, which may aid in improving the LSG surgical technique to prevent ischemia-related leaks.

MATERIALS AND METHODS

Eighty-six patients underwent LSG and were examined with fluorescence angiography at a single academic center from January 2016 to September 2017. The procedures were performed by the same surgeon using the technique described herein. Abdominal access was gained with a 4-port technique. Dissection of the gastroepiploic and short gastric vessels along the greater curvature was performed with an energy device. Before the construction of the sleeve gastrectomy, 1 mL ICG was injected intravenously (intraoperatively) and Pinpoint Endoscopic Fluorescence Imaging System (Novadaq Technology, Mississauga, ON L4W 4X6, Canada) was used to identify the blood supply of the stomach. The perfusion pattern was noted and recorded. Next, a sleeve gastrectomy was fashioned with a 36-French lighted bougie in place using Tri-Staple technology (Medtronic, Minneapolis, Minnesota, USA) with tissue reinforcement material and with attention to preserving the identified blood supply to the GE junction and gastric tube. Finally, 3 mL ICG was injected at the completion of the procedure, and Pinpoint technology was used again to ensure that all the pertinent blood vessels were preserved.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all participants included in the report.

RESULTS

Eighty-six patients successfully underwent the entire laparoscopic procedure with no complications. Three patterns of blood supply to the GE junction were found. These patterns are described in **Table 1** and depicted in **Figure 1**.

The incidence of overall accessory blood supply (70%) to the expected right-side dominant pattern (20%) was more common than expected. The right-side accessory blood supply was present within the gastrohepatic ligament in 36% of our patients, and in nearly half of them, the blood flow was toward the stomach, suggesting that it was functioning as an accessory gastric artery. In 10% of the cases,

Table 1.
Blood Supply Patterns to the GE Junction

Pattern	% Incidence	Significant Blood Supply to GE Junction
Right-side dominant	20	Left gastric artery
Right-side accessory	36	Accessory artery in the gastrohepatic ligament: Accessory hepatic artery (55%) Accessory gastric artery (45%)
Left-side accessory	34	Tributaries from the left inferior phrenic artery significantly contributing to the right-sided supply
Right + left–side accessory	10	Accessory gastric artery and tributaries from the left inferior phrenic artery, simultaneously

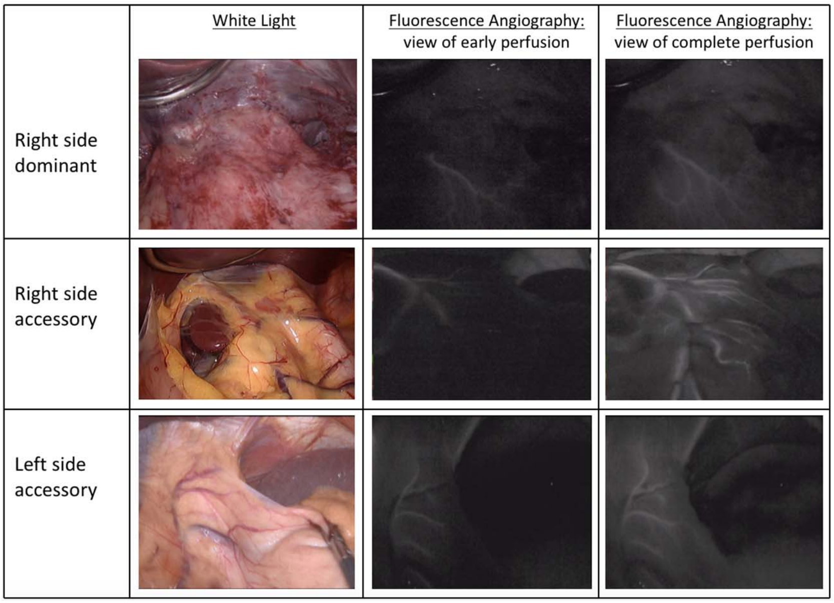

Figure 1. Blood supply patterns before surgical dissection.

both right- and left-side accessory blood supplies (left inferior phrenic artery and accessory gastric artery) were present in the same patient.

DISCUSSION

The proximal stomach vascular supply derives mainly from the left gastric artery, short gastric arteries, and inferior phrenic artery.[16,17] In addition, an accessory left gastric artery found in the gastrohepatic ligament arises from the left hepatic artery and supplies the cardia and fundus.[18] To perform LSG, almost all of the greater curvature blood supply is coagulated and divided, starting just a few centimeters from the pylorus and working cephalad until all the short gastric arteries and the small blood vessels near the left crus are coagulated and divided. The dissection is carried very close to the angle of His to avoid leaving behind a significant part of the fundus. Unfortunately, anatomic studies have demonstrated that the vascular supply of the upper part of the gastric tube can be damaged during this procedure. When 1 or 2 branches of the left gastric artery are severed, the vascular submucosa plexus allows replacement of blood flow, but when 3 branches are stapled, the blood supply is not sufficient.[19] Likewise, if the branch of the left inferior phrenic artery is present, it can be easily coagulated and divided during the left crural dissection. Furthermore, if a concurrent hiatal hernia repair is to be performed along with LSG, a common practice among bariatric surgeons[20] to mitigate the risk of postoperative esophageal reflux, the accessory gastric artery in the gastrohepatic ligament may be inadvertently coagulated and divided. Intraoperative ICG fluorescence angiography allows identification of the variable patterns of blood supplying the proximal portion of the stomach, therefore assisting with the preservation of perfusion to the sleeve stomach where mechanical forces (functional pylorus and decreased gastric volume) and reduced local perfusion makes this specific location vulnerable to tissue damage.[10]

As mentioned before, there are other potential causes of leaks besides ischemia, such as mechanical increase in intragastric pressure secondary to relative stenosis at the incisura, functional pylorus in the setting of decreased gastric volume, or both. In certain cases, it may be a combination of both mechanical and ischemic events that leads to a leak. For example, a relatively ischemic area near the GE junction that perforates secondary to exacerbation caused by increased gastric pressure from distal obstruction. Several corrective techniques have been reported to address the mechanical etiologic principle leading to leaks.[21,22] However, only a few studies have been conducted to investigate the gastric vascular modifications and potential ischemia induction resulting from LSG.[15,19]

Saber et al,[19] using an abdominal CT scan, evaluated the pattern of gastric vascular perfusion. The group measured 5 gastric points and demonstrated a statistically significant decrease in the mean perfusion index at the angle of His. The group concluded that the increased incidence of LSG leaks at the upper third of the stomach may point to an underlying impaired vascular perfusion as a cause of the leakage.

Delko et al[23] performed real-time intraoperative microperfusion measurements at 9 different locations across the stomach: (1) at the beginning of the surgery, (2) after the greater curvature mobilization, (3) and immedictely after the sleeve resection. They found a statistically significant reduction in perfusion at the most cephalad region, from before mobilization of the stomach to resection. The group concluded that the reduced postprocedure perfusion at this region potentially explains this location as the predominant site of leak formation.

In our series, we noted 3 different patterns of vascular supply to the proximal stomach: (1) right-side dominant, mainly arising from the left gastric artery; (2) left-side accessory pattern arising from tributaries of the left inferior phrenic artery perfusing the proximal stomach at the same time as the inflowing perfusion for the right side of the stomach is taking place; and (3) a right-side accessory pattern running in the gastrohepatic ligament composed either of an accessory hepatic artery or an accessory gastric artery providing supplemental blood supply to the main left gastric artery. The right-side dominant pattern is the one that we would have predicted to be the most common pattern based on our common understanding of the blood supply of the proximal stomach. In our series, the pure right-side dominant pattern was seen in only 20% of the cases, whereas a variation was seen in most the cases (70%).

If the patient has a pure right-side dominant pattern, routine LSG dissection can be performed without jeopardizing the blood supply to the proximal stomach. However, if the patient has a significant contribution from the left inferior phrenic artery or accessory gastric artery or both, care must be taken to avoid injuries to these tributary blood vessel(s) to mitigate potential ischemic complications as a result of injury. Ten percent of the patients in our series had both left-side significant patterns and an accessory gastric artery. In these patients, if we had performed a hiatal hernia repair (and had to sacrifice the accessory gastric artery for exposure) and also injured the left inferior phrenic artery during the left crural dissection, it is plausible to conclude that the proximal stomach area would be rendered relatively ischemic.

Because we do not have the demographics of these 86 patients, such as age, race, sex, and body mass index, it is likely that the incidence of these 3 vascular supply patterns may differ depending on the specific population of patients being studied. The purpose of this paper is to describe the variability of the blood supply patterns to the stomach that we have observed. Some of these patterns may have clinical relevance in certain situations, and we are proposing a practical and feasible way of checking for these variabilities during an actual procedure. The most common pattern we encountered was not the one we had expected to find; but instead, we found that the most common pattern was a variation of the "textbook" blood supply to the stomach. This finding is analogous to the incidence of the "textbook" anatomy of the cystic duct with respect to the common bile duct, in which the variation of the "common anatomy" is also the most common finding.

ICG fluorescence angiography allows us to determine the entire major blood supply to the proximal stomach before any dissection, so that an effort can be made to avoid unnecessary injury to these vessels during the procedure. Furthermore, if an accessory vessel is present in the gastrohepatic ligament, this technology allows us to determine the direction of the blood flow to see whether the vessel is an accessory gastric or an accessory hepatic artery. Because ICG injection can be repeated multiple times throughout the procedure, we also performed a second injection at the completion of our sleeve gastrectomy to ensure that the blood vessels we were trying to preserve are indeed preserved, including the transverse blood supply on the lesser curvature of the stomach to the body of the sleeve.

CONCLUSION

Fluorescence imaging is currently being used for multiple applications across multiple subspecialties of surgery. Regarding gastrointestinal surgery, this technology can be used to assess proper tissue perfusion and vascular mapping of the patient's arterial/venous anatomy, as described in this article. Our group is currently exploring this technology in LSG cases to perform "perfusion-preserving" dissection and checking for adequate perfusion of the sleeve product afterward.

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