Left Gastric Artery Reconstruction after Distal Pancreatectomy with Celiac Axis En-Bloc Resection: How We Do It

Ken-ichi Okada a, Seiko Hirono a, Manabu Kawai a, Shinya Hayami a, Shinichi Asamura b, Yoshitaka Wada b, Masaki Ueno a, Motoki Miyazawa a, Atsushi Shimizu a, Yuji Kitahata a, Hiroki Yamaue a

a Second Department of Surgery and b Department of Plastic Surgery, Wakayama Medical University, Wakayama, Japan

Keywords
Bypass · Left gastric artery · Middle colic artery · Reconstruction

Abstract

Background/Aims: Ischemic gastropathy remains as a persistent problem after left gastric artery (LGA) resection in distal pancreatectomy with celiac axis en-bloc resection (DP-CAR). The middle colic artery (MCA) was found to be a useful vessel for compromised collateral flow. However, intraoperative gross evaluation of gastric ischemia is technically difficult even after artery reconstruction. Methods: We performed LGA reconstruction by MCA-LGA bypass after LGA-resecting DP-CAR assisted by intraoperative indocyanine green fluorescence imaging (ICG) blood flow evaluation in a clinical trial (UMIN000020414). The LGA was reconstructed with the MCA microscopically by plastic surgeons with an everting interrupted suture in end-to-end anastomosis. Results: We could evaluate ICG blood flow not only in the reconstructed artery, but also simultaneously in the gastric wall through a monitor connected to a detector. We could also assess the congestive status of the gastric wall by ICG disappearance from the gastric wall. Conclusion: We present LGA reconstruction by MCA-LGA bypass after LGA-resecting DP-CAR. We conducted a perioperative assessment of ischemic gastropathy to confirm the feasibility and safety of this procedure.

Introduction

In 2014, we introduced preservation of the left gastric artery (LGA) on the basis of anatomical features in patients undergoing distal pancreatectomy with celiac axis en-bloc resection (DP-CAR) [1–3]. Although favorable results of DP-CAR in terms of avoiding ischemic
gastropathy have been reported [4], delayed gastric emptying and ischemic gastropathy after LGA-resecting DP-CAR remain a persistent problem [4, 5]. A previous study reported that the middle colic artery (MCA) is a useful vessel for compromised collateral flow [6, 7]. However, intraoperative gross evaluation for gastric ischemia is technically difficult even after artery reconstruction. Therefore, we started LGA reconstruction by MCA-LGA bypass after LGA-resecting DP-CAR assisted by intraoperative indocyanine green fluorescence imaging (ICG) blood flow evaluation in a clinical trial. Here, we describe and detail the feasibility of the surgical procedures and the perioperative management.

Surgical Technique of DP-CAR with the Intention of LGA Reconstruction

Indication

Patients whose LGA does not branch antecedently or who have a distance of <10 mm between the LGA and a tumor undergo LGA-resecting DP-CAR in our institution in order to avoid R1 curability [2]. The distance between the tumor and the LGA was measured by multi-detector row computed tomography prior to surgery.

Division of the Common Hepatic Artery

First, the right gastroepiploic artery/vein and the right gastric artery/vein were encircled by vessel tapes and preserved. Then, we confirmed that the periarterial nerve plexuses around the gastroduodenal artery or the common hepatic artery (CHA) were free from cancer cell infiltration to determine resectability based on the result of frozen sections (Fig. 1). We checked the pulsation of the gastroduodenal artery and the proper hepatic artery before clamping the CHA, which was divided at the distal end after declamping (Fig. 2).

Division of the Celiac Axis and the LGA

Second, we encircled the LGA by vessel tape in the early stage as an anatomical landmark (Fig. 2). The root of the celiac axis (CA) was exposed and encircled by mobilization of the distal pancreas and the CHA with lymph nodes around the CHA (Fig. 3). The left hemisphere of the superior mesenteric artery was dissected from the surrounding lymph nodes and nerve
plexuses toward its root. Extreme care was taken not to damage the inferior pancreaticoduodenal artery arising from the superior mesenteric artery or the first jejunal artery. The dissecting layer around the superior mesenteric artery was converged with the CA from the caudal side to the dorsal side. After assessment of the distance between each end of the MCA and the LGA, the LGA was divided to prepare for reconstruction. The root and the direction of the inferior phrenic arteries should be carefully dissected around the CA in front of the aorta since it is one of the feeding arteries of the fundic area of the stomach. The depth of the dissecting layer of retroperitoneal tissue was controlled with a wide margin according to the position and size of the tumor.

**Surgical Technique of LGA Reconstruction**

After DP-CAR, the MCA was exposed from the root to the distal side in order to reach the distal cut end of LGA (Fig. 4). The LGA was reconstructed with the MCA microscopically by plastic surgeons with an everting interrupted suture by 8-0 diadem® (Kono Seisakusho, Japan) in end-to-end anastomosis (Fig. 5). In case of short LGA length, the sacrifice of the puzzle.
ascending branch of the LGA enables to prolong the lengthening of the LGA. It takes approximately 30 min for plastic surgeons to perform artery reconstruction.

Intraoperative ICG Blood Flow Assessment of the LGA and the Stomach

According to the protocol of our clinical trial, the ICG blood flow was assessed 3 times intraoperatively: first, just after laparotomy as a control condition; second, after division of the LGA upon completion of DP-CAR (Fig. 6); and third, after the completion of artery reconstruction by MCA-LGA bypass (Fig. 7). In the first patient, we could confirm ICG blood flow not only in the reconstructed artery, but also in the gastric wall simultaneously through a monitor connected to a detector. We could also assess the absence of congestive status by ICG disappearance from the gastric wall. We collected the ICG data regarding duration from intravenous administration to maximum luminance or extent of recovery of luminance after artery reconstruction at the region of interest where the LGA supplies the blood flow by analysis with HiPic Image acquisition software U8913-01 (Hamamatsu, Japan).
Perioperative Endoscopic Assessment of Ischemic Gastropathy

Endoscopy was performed in the patients to precisely evaluate the mucosal condition and mucosal change through this operation within 30 days before surgery and within 7 days following surgery (Fig. 8). Further endoscopies were conducted 3, 6, and 12 months postoperatively to identify signs of ischemic gastropathy as an interior assessment. In the first case, we could confirm the endoscopic findings without ischemic gastropathy, such as ulcer dis-
ease, pallor of the gastric mucosa, and decreased peristaltic motion, and compare with the findings obtained preoperatively without anticonvulsant agent use.

**Postoperative Management after DP-CAR with MCA-LGA Bypass**

The nasogastric tube was left in place until confirmation of the absence of the findings of ischemic gastropathy by endoscopy. The patients ate their first solid meal after postoperative day 7 to prevent excess tension loading on the artery reconstruction site; otherwise, the bed rest level was free from postoperative day 1. Low-molecular-weighted heparin for 2 days, followed by normal heparin for 2 weeks, were administered intravenously after surgery at the usual dose for arterial reconstruction.

**Complications**

All morbidities, the global morbidity rate, and the type of complications will be evaluated by means of the Dindo classification [8]. We also intend to prospectively record the incidence of complications related to artery reconstruction with MCA-LGA bypass.

**Discussion**

In the era of safer modification of DP-CAR and the appearance of the concept of borderline resectable pancreatic carcinoma, our procedure has appealed to many pancreatic surgeons. They have adopted it as a radical pancreatectomy for borderline resectable pancreatic body carcinoma [9]. Ischemic gastropathy with a considerable incidence [1, 3, 10] can lead to lethal complications such as stomach necrosis, poor nutritional status, and failure to complete postoperative adjuvant chemotherapy. In a previous study, the majority of patients underwent combined total gastrectomy to prevent gastric ischemic complications during LGA-resecting DP-CAR [5]. Depending on anatomical features or tumor position, the LGA was divided with CA and tumor. Since the LGA is a major feeding artery for the lesser curvature of the stomach and the fundic area, division of this artery directly affects gastric ischemia. Conversely, the MCA is a desirable vessel because of its anatomical position and flexibility through a meso-

**Fig. 8.** Endoscopy performed on postoperative day 4 revealed no findings of ulcer disease, pallor of the gastric mucosa, and decreased peristaltic motion in the fundic (a) and body (b) part of the stomach.
colon route. Even after reconstruction of the LGA, the blood supply at the fundic area could be influenced by the division of the left inferior phrenic artery. In addition, apparent gastric ischemia does not always become obvious intraoperatively, and intraoperative ICG blood flow evaluation can compensate for the potential weakness of gross evaluation of gastric ischemia by detecting a very small amount of change in blood flow [11]. However, there has been no objective parameter reported for DP-CAR. Therefore, we collected various parameters to predict irreversible ischemic changes at the early phase of surgery in a clinical trial (UMIN000020414).

**Conclusion**

We presented LGA reconstruction by MCA-LGA bypass after LGA-resecting DP-CAR. We conducted a perioperative assessment of ischemic gastropathy to confirm the feasibility and safety of this procedure.

**Acknowledgments**

We would like to thank the Department of Clinical Research Center, Wakayama Medical University, for proofreading and editing the manuscript.

**Statement of Ethics**

The study was carried out in accordance with the Declaration of Helsinki. The protocol was approved by the ethics committees of all participating institutions, and informed consent was obtained.

**Disclosure Statement**

The authors have no conflicts of interest to declare. There was no funding or material support for this study.

**References**

1 Okada K, Kawai M, Tani M, Hirono S, Miyazawa M, Shimizu A, Kitahata Y, Yamaue H: Preservation of the left gastric artery on the basis of anatomical features in patients undergoing distal pancreatectomy with celiac axis en-bloc resection (DP-CAR). World J Surg 2014; 38: 2980–2985.
2 Okada K, Kawai M, Tani M, Hirono S, Miyazawa M, Shimizu A, Kitahata Y, Yamaue H: Surgical strategy for patients with pancreatic body/tail carcinoma: who should undergo distal pancreatectomy with en-bloc celiac axis resection? Surgery 2013; 153: 365–372.
3 Okada K, Kawai M, Tani M, Hirono S, Miyazawa M, Shimizu A, Kitahata Y, Yamaue H: Isolated Roux-en-Y anastomosis of the pancreatic stump in a duct-to-mucosa fashion in patients with distal pancreatectomy with en-bloc celiac axis resection. J Hepatobiliary Pancreat Sci 2014; 21: 193–198.
4 Hirano S, Kondo S, Harata T, Ambo Y, Tanaka E, Shichinohe T, Suzuki O, Hazama K: Distal pancreatectomy with en bloc celiac axis resection for locally advanced pancreatic body cancer: long-term results. Ann Surg 2007; 246: 46–51.
5 Yamamoto Y, Sakamoto Y, Ban D, Shimada K, Esaki M, Nara S, Kosuge T: Is celiac axis resection justified for T4 pancreatic body cancer? Surgery 2012; 151: 61–69.
6 Kondo S, Ambo Y, Katoh H, Hirano S, Tanaka E, Okushiba S, Morikawa T, Igawa H, Yamamoto Y, Sugihara T: Middle colic artery-gastroepiploic artery bypass for compromised collateral flow in distal pancreatectomy with celiac artery resection. Hepatogastroenterology 2003; 50: 305–307.
7 Sato T, Saiura A, Inoue Y, Takahashi Y, Arita J, Takemura N: Distal pancreatectomy with en bloc resection of the celiac axis with preservation or reconstruction of the left gastric artery in patients with pancreatic body cancer. World J Surg 2016;40:2245–2253.

8 Dindo D, Demartines N, Clavien PA: Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205–213.

9 Okada K, Yamaue H: The role of the Appleby operation and arterial resection in the multimodality management of borderline resectable pancreatic cancer; in Katz MHG, Ahmad SA (eds): Multimodality Management of Borderline Resectable Pancreatic Cancer. Cham, Springer International Publishing, 2016, pp 247–264.

10 Kondo S, Katoh H, Hirano S, Ambo Y, Tanaka E, Maeyama Y, Morikawa T, Okushiba S: Ischemic gastropathy after distal pancreatectomy with celiac axis resection. Surg Today 2004;34:337–340.

11 Saito T, Yano M, Motoori M, Kishi K, Fujiwara Y, Shingai T, Noura S, Ohue M, Ohigashi H, Ishikawa O: Subtotal gastrectomy for gastric tube cancer after esophagectomy: a safe procedure preserving the proximal part of gastric tube based on intraoperative ICG blood flow evaluation. J Surg Oncol 2012;106:107–110.