Pancreaticoduodenectomy preserving aberrant gastroduodenal artery utilized in a previous coronary artery bypass grafting

A case report and review of literature

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Abstract

**Rationale:** Pancreaticoduodenectomy (PD) is a technically demanding procedure with high rates of morbidity and mortality. Therefore, preoperative evaluation of anatomy is indispensable. Multi-detector row computed tomography (CT) enables us to precisely understand arterial anatomy. It is a well-known fact that anatomical variants are often present in the hepatic artery (HA) but rarely in the gastroduodenal artery (GDA). We present the case of a patient with ampullary cancer with a rare anatomical anomaly, “replaced GDA (rGDA)” arising from the superior mesenteric artery, along with a history of coronary artery bypass grafting (CABG) using right gastroepiploic artery (RGEA).

**Patient concerns:** A 69-year-old male patient was referred to our department for further investigation of elevated hepatobiliary enzymes. He presented with no symptoms besides intermittent fever of 38°C. He had an operative history of CABG using the RGEA.

**Diagnosis:** Abdominal CT and esophagogastroduodenoscopy showed an ampullary tumor and biopsy specimen from the lesion revealed adenocarcinoma. CT angiography revealed the rGDA instead of a normal common HA.

**Intervention:** We performed a safe PD, preserving the rGDA and the RGEA to maintain hepatic and cardiac perfusion.

**Outcomes:** Owing to the presence of a refractory pancreatic fistula, the length-of-hospital stay was extended, and he was discharged on postoperative day 72 without vascular complications. At present, the patient is in good physical condition and does not present with tumor recurrence at 6 months after surgery.

**Lessons:** This is possibly the first case of a patient who underwent PD and has a proper HA following a GDA arising from a superior mesenteric artery (rGDA) and has a previous operative history of CABG using the gastroepiploic artery. The coexistence of the history of cardiovascular surgery made PD for this patient considerably more challenging.

In the case of a rare anatomical anomaly, a coronary artery bypass via the RGEA should not be considered as an obstacle when R0 resection is achievable.

**Abbreviations:**
- CHA = common hepatic artery
- (r)GDA = (replaced) gastroduodenal artery
- CABG = coronary artery bypass grafting
- CeA = celiac axis
- CTA = CT angiography
- HA = hepatic artery
- MDCT = multi detector-row computed tomography
- PD = pancreaticoduodenectomy
- PHA = proper hepatic artery
- RGEA = right gastroepiploic artery
- SMA = superior mesenteric artery

**Keywords:** computed tomography angiography, coronary artery bypass grafting, pancreaticoduodenectomy, replaced gastroduodenal artery, superior mesenteric artery
1. Introduction
Pancreaticoduodenectomy (PD) is a technically demanding procedure with high rates of morbidity and mortality. Hence, anatomical knowledge is essential before surgery. Identifying arterial abnormalities is the key to reduce ischemic or hemorrhagic morbidity and mortality. Multi detector-row computed tomography (MDCT) and CT angiography (CTA) enable us to understand the anatomical structure of blood vessels. It is well known that the hepatic artery (HA) has several anatomical variants. Contrarily, a gastroduodenal artery (GDA) variation is scarce and causes concern. GDA usually arises from the common HA (CHA) as a branch of the celiac axis (CeA), and the vessel is usually dissected during conventional PD. We experienced the case of ampullary cancer with a rare arterial anomaly, replaced GDA (rGDA), which originates from the superior mesenteric artery (SMA). The patient also had an operative history of coronary artery bypass grafting (CABG) using the right gastroepiploic artery (RGEA). Finally, both were safely preserved, and the patient was discharged without any cardiovascular event.

2. Case presentation
A 69-year-old male patient with elevated hepatobiliary enzymes was referred to our department for additional investigation. He presented with no symptoms but an intermittent fever of 38°C. The laboratory analysis provided the following results: serum aspartate aminotransferase, 100 U/L (normal range, 13–30 U/L); alanine aminotransferase, 224 U/L (normal range, 10–42 U/L); alkaline-phosphatase, 1400 U/L (normal range, 0–359 U/L); γ-glutamyl transpeptidase, 1061 U/L (normal range, 0–55 U/L); amylase, 12 U/L (normal range, 40–126 U/L); and total bilirubin, 1.2 mg/dL (normal range, 0.4–1.5 mg/dL); the serum level of CeA and CA19-9 were within the normal range.

Contrast-enhanced CT showed a tumor with a diameter of 10 mm around the ampulla of the duodenum (Fig. 1). The upstream common bile duct and intrahepatic bile duct expanded significantly but the pancreatic duct did not. Moreover, the wall thickening of the second part of the duodenum was visible. No distant metastases or lymph node metastases were noted. Esophagogastroduodenoscopy showed a tumor of exposed protruding type, and biopsy from the lesion revealed adenocarcinoma. Additionally, the thickening of the mucosa suggested adenoma as well. When evaluating vascular anatomy, 3D CTA revealed a rare vascular anomaly (Fig. 2A). CHA from the celiac artery was absent, and there was a proper hepatic artery (PHA) following GDA arising from the SMA instead. The artery ascended anterior to the surface of the pancreas and had branches corresponding to RGEA or superior pancreaticoduodenal artery, after which the GDA continued predominantly and ended with the PHA passing through the hepatoduodenal ligament. Furthermore, the patient had undergone CABG utilizing RGEA for angina pectoris when he was 50-year-old. By this procedure, RGEA was passing through the surface of the stomach and liver, eventually reached the mediastinum. Due to this operative

![Figure 1](attachment:figure1.png)

**Figure 1.** Contrast-enhanced abdominal CT revealed a 1 cm-sized tumor (yellow arrowhead) in the distal bile duct. The common bile duct and intrahepatic bile duct were dilated (blue arrowhead) due to this tumor. Wall thickening was seen in the second portion of the duodenum (yellow arrow). The endoscopic finding suggested the wall thickening as the mucosal lesion.
history, he has a median sternotomy and laparotomy scar. No other findings were observed on physical examination.

Since the tumor demonstrated no invasion in the vascular system, we planned to perform conventional PD with total preservation of the rGDA to maintain cardiac and hepatic perfusion. The procedure began with an abdominal exploration through an upper to middle abdominal midline laparotomy, confirming the RGEA graft pulsating. The artery was found running anterior to the left lateral lobe of the liver into the pericardial space (Fig. 3A). Intraoperative findings showed no liver metastasis or disseminated nodules; it was decided that the operation would be continued. Dissection around the superior mesenteric vein revealed aberrant GDA on the anterior surface of the pancreatic neck. The artery emerged from a crevice between the lower border of the pancreatic neck and gastrectic trunk. After the division of the stomach, we carefully dissected the pancreatic branches from the rGDA and preserved the RGEA to mobilize the rGDA totally from the pancreatic parenchyma (Fig. 3B). Next, lymph node dissection of the hepatoduodenal ligament and division of the distal duodenum was performed. Finally, the pancreas was transected above the superior mesenteric vein, and transection between SMA and pancreatic nerve plexus was performed in the usual method (Fig. 3C) to accomplish resection. Reconstruction was performed by the modified Child method, and during operation, we continuously monitored electrocardiography with no significant changes detected in the ST segment. Postoperatively, the hospital stay was extended because of the refractory pancreatic fistula. The pancreatic fistula was managed by persistent drainage and periodical tube exchange. We did not require additional drainage tubes after the operation. Postoperative CT revealed patent PHA and RGEA. He was discharged on the 72nd postoperative day without cardiovascular complications. Histopathological revealed well differentiated adenocarcinoma classified as clinically T1 (localized to lamina propria mucosae) and N0, M0 (without lymphnode and distant metastasis) according to TNM Classification of Malignant Tumors, 8th Edition. Drainage tube for pancreatic fistula was removed on the 105th postoperative day at outpatient unit. At present, the patient is in good physical condition without cardiovascular complications and tumor recurrence at 6 months after surgery.

3. Discussion

In hepatobiliary-pancreatic neoplasm surgery, preoperative examination of anatomical abnormalities and tumor resectability is essential. MDCT and CTA play an important role in it. [4] It is well known that HA typically has anatomical variants, and many studies have been accomplished to classify these variations.[7,12–15] Meta-analysis on surgical, radiological, and cadaveric anatomical studies indicated a range of 11% to 45% in HA variation.[7,8,16–20] The replaced right HA or the replaced CHA was in around 10% to 12% or 1% to 3%, respectively. These HA derived from SMA usually runs posteriorly and through the pancreatic nerve plexus, which requires special attention to preserve during PD.[2,21] Contrarily, variation of GDA is scarce. According to Lipshutz[12] report, GDA originates from CHA in 92% of the cases. The name “replaced GDA” refers to the artery which derived from SMA that passes through the front of the neck of the pancreas during its course. The artery branched superior pancreaticoduodenal artery and RGEA, and finally terminates in the PHA. Only a few available studies have mentioned rGDA,[9] and there are only 3 reported cases of PD similar to the kind of anomaly in our case.
study\cite{10,11,22} (Table 1). The exception is that in one of these cases, the rGDA was terminated to the left HA, and the right HA was derived from the CeA. There was no mortality due to operation, but 1 patient had a postoperative myocardial infarction in the reported cases.

Preoperatively identifying rGDA prevents its misrecognition as a normal GDA, which descends on the surface of the pancreas during operation. Furthermore, it prevents ligation of the rGDA at the upper border of the pancreas when lymph node dissection of the hepatoduodenal ligament which is usually performed before transection between the pancreatic nerve plexus and SMA. The misidentification of rare vascular abnormalities such as ours can lead to serious complications, such as total hepatic ischemia, so the performance of PD requires precise anatomical understanding using MDCT or CTA.

In addition to rare anatomical variants, this patient also had a history of CABG using RGEA. As the population ages, we face patients with comorbidities more frequently. RGEA has been used for severe stenosis of the right coronary or left circumflex artery, a suitable conduit for CABG in terms of low surgical risk, high patency rate, and excellent patient outcome\cite{23} Some case reports have documented surgical interventions in patients with gastric, hepatobiliary, and pancreatic malignancies who have previously received CABG via in situ RGEA graft\cite{24,25} Surgery remains the only curative option in biliary and pancreatic malignancy. Patients with a CABG history must overcome the problem of cardiac perfusion. In other words, considering the resectability of the tumor during PD, GDA and RGEA must be preserved or reconstructed. There are 13 articles (including 5 Japanese articles\cite{26–38}) that discuss PD after CABG using RGEA (Table 2). There were 16 patients in total including our case, and one of them was female, with a mean age of 70 years. Ten patients (63%) underwent conventional PD, and three patients each underwent subtotal stomach preserving pancreaticoduodenec-

Table 1

| Year | Author | Age | Gender | Malignancy       | Operation | Termination of rGDA | Morbidity           | Mortality |
|------|--------|-----|--------|------------------|-----------|---------------------|---------------------|-----------|
| 2017 | Patil et al\cite{10} | 47  | M      | Pancreatic cancer | PD        | PHA                 | unspecified         | None      |
| 2017 | CreTu et al\cite{22} | 60  | M      | Pancreatic cancer | PD        | PHA                 | Myocardial infarction | None      |
| 2016 | Younan et al\cite{11} | 55  | F      | Ampullary cancer | PD        | LHA                 | None               | None      |
| 2021 | Our case | 69  | M      | Ampullary cancer | PD        | PHA                 | Pancreatic fistula  | None      |

F = female, LHA = left hepatic artery, M = male, PD = pancreaticoduodenectomy, PHA = proper hepatic artery, rGDA = replaced gastroduodenal artery.
Preoperative identification of vascular anomalies is the key to successful surgical intervention. MDCT and CTA revealed the anatomical variant precisely, and it contributed to intraoperative safety. The coexistence of CABG history made PD even more difficult for this patient. However, a CABG using RGEA in a patient with rare anatomical aberrant GDA should not be considered as an obstacle when R0 resection is achievable.

Acknowledgments

We would like to thank Enago (http://www.enago.jp/) for the English language editing.

Author contributions

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Table 2

Table of published cases undertook pancreaticoduodenectomy with coronary artery bypass grafting.

| Year   | Author         | Age | Gender | Malignancy | Operation                | Sacrificed | Revascularization | Cardiovascular event | Mortality |
|--------|----------------|-----|--------|------------|--------------------------|------------|-------------------|----------------------|-----------|
| 2019   | Homysy et al 26| 73  | M      | Pancreatic cancer | PD          | Yes                      | Intraoperative rerouting to GDA | None               | None      |
| 2018   | CreTu et al 22 | 70  | M      | Pancreatic cancer | PD          | Yes                      | Intraoperative rerouting to GDA interposition of SVG | None               | None      |
| 2015   | Uemura et al 23| 73  | M      | Ampullary cancer | PPPD        | No                       | None                  | Pseudoaneurysm of RGEA | None      |
| 2015   | Ito et al 24    | 63  | M      | Bile duct cancer | PD          | Yes                      | Intraoperative rerouting to CHA interposition of SVG | None               | None      |
| 2014   | Kitamura et al 25| 67 | M      | Pancreatic cancer | SSPPD       | Yes                      | Preoperative PCI to RCA | None               | None      |
| 2014   | Mikawa et al 26 | 72  | F      | Pancreatic cancer | PPPD        | No                       | None                  | None               | None      |
| 2014   | Fukuhara et al 27| 66 | F      | Pancreatic cancer | PD          | Yes                      | Preoperative PCI to RCA | None               | None      |
| 2013   | Turcanu et al 28| 71  | M      | Pancreatic cancer | PD          | No                       | None                  | None               | None      |
| 2011   | Takami et al 29 | 80  | M      | Bile duct cancer | PD          | Yes                      | Intraoperative rerouting to GDA interposition of SVG | None               | None      |
| 2011   | Nakamura et al 30| 69 | M      | Ampullary cancer | PD          | No                       | None                  | None               | None      |
| 2009   | Kaji et al 31   | 72  | M      | Pancreatic cancer | PPPD        | Yes                      | Intraoperative rerouting to CHA interposition of SVG | None               | None      |
| 2007   | Mikawa et al 32 | 72  | M      | Pancreatic cancer | PD          | Yes                      | Preoperative PCI to RCA | None               | None      |
| 2001   | Ohtsuka et al 33| 62  | M      | Bile duct cancer | PD          | Yes                      | Preoperative additional bypass using SVG graft to AxA | None               | None      |
| 2021   | Our case        | 69  | M      | Ampullary cancer | PD          | No                       | None                  | None               | None      |

AxA = axillary artery, CHA = common hepatic artery, F = female, GDA = gastroduodenal artery, LGA = left gastric artery, M = male, PCI = percutaneous coronary intervention, PD = pancreaticoduodenectomy, PPPD = pylorus preserving pancreaticoduodenectomy, RCA = right coronary artery, RGEA = right gastroepiploic artery, SpA = splenic artery, SSPPD = subtotal stomach preserving pancreaticoduodenectomy, SVG = saphenous vein graft.
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