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Upper Abdominal Surgery in Patients with Coeliac Artery Stenosis

Kyoji Ito, Nobuyuki Takemura*, Ryo Oikawa, Fuyuki Inagaki, Fuminori Mihara and Norihiro Kokudo

Department of Surgery, National Centre for Global Health and Medicine, Shinjuku-ku, Tokyo, Japan

***Corresponding author:** Nobuyuki Takemura, Hepato-Biliary-Pancreatic Surgery Division, Department of Surgery, National Centre for Global Health and Medicine, 1-21-1 Toyama, Shinjuku-ku, Tokyo 162-8655, Japan, Tel +81-3-3202-7800; Fax +81-3-5273-0113; E-mail: nkokudo@hosp.ncgm.go.jp

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Abstract

Background and aim: Coeliac artery stenosis (CAS) is known as stenosis or obstruction of the coeliac artery (CA) due to various factors including median arcuate ligament (MAL) syndrome and atherosclerosis. Although CAS is often asymptomatic because of the formation of collateral blood flow, it occasionally causes ischemic complications after upper abdominal surgery. The aim of the present study was to overview reports on upper abdominal surgery in patients with CAS.

Methods: The articles on the clinical relevance of CAS and upper abdominal surgery were searched for in the PubMed database.

Results: Surgical procedures with relevance to CAS-related complications are pancreaticoduodenectomy, liver transplantation, oesophagectomy, and gastrectomy. Vascular clamping tests and Doppler ultrasonography are useful to evaluate the haemodynamics of CAS during surgery, although there were some reports with postoperative organ ischemia despite no signs of ischemic findings during surgery. The main strategies to resolve CAS are divided into four approaches: MAL division, preservation of the collateral artery, vascular reconstruction, and angioplasty by interventional radiology; although there were few reports comparing these approaches in upper abdominal surgery with CAS.

Conclusion: There was no established consensus on when an intervention is required for CAS in upper abdominal surgery. Therefore, careful assessment of arterial flow during and after surgery should be required to avoid CAS-related complications in upper abdominal surgery.

Keywords: Coeliac Artery Stenosis; Upper Abdominal Surgery; Ischemic Complication; Pancreaticoduodenectomy; Liver Transplantation; Oesophagectomy; Gastrectomy

Abbreviations: CA: Coeliac Artery; CAS: Coeliac Artery Stenosis; CHA: Common Hepatic Artery; GDA: Gastroduodenal Artery; IPDA: Inferior Pancreaticoduodenal Artery; IVR: Interventional Radiology; MAL: Median Arcuate Ligament; MALS: Median Arcuate Ligament Syndrome; PD: Pancreaticoduodenectomy; SMA: Superior Mesenteric Artery; SPA: Splenic Artery; MDCT: Multidetector Computed Tomography.

Introduction

The coeliac artery (CA) is the first major branch of the abdominal aorta supplying blood to the liver, stomach, spleen, duodenum, and pancreas. Stenosis or obstruction of the CA, known as coeliac artery stenosis (CAS), can result from various factors, including median arcuate ligament syndrome (MALS), atherosclerosis, invasion of malignancies, pancreatitis, acute and chronic aortic dissection, congenital causes, and iatrogenicity [1]. The incidence of CAS varies from 2%-24% among subjects and across studies. CAS is often asymptomatic because of the formation of collateral blood flow from the superior mesenteric artery (SMA) system to the CA system [2]. However, CAS is reportedly associated with ischemic complications after upper abdominal surgery because of the division of the collateral arteries or lower arterial supply from CA to the upper abdominal organs. However, there have been few articles reviewing upper abdominal surgeries in terms of CAS. In the present report, we review these upper abdominal surgeries with special reference to ischemic complications and treatment approaches in patients with CAS.

Upper Abdominal Surgeries and CAS

A search for reports on CAS in upper abdominal surgery was conducted using the PubMed database on May 2, 2020. The search words were "(celiac artery OR celiac axis) AND (stenosis OR occlusion OR compression OR obstruction) AND (ischemia OR complication)". Thus far, surgical procedures reportedly associated with ischemic complications due to CAS are pancreaticoduodenectomy (PD), liver transplantation, oesophagectomy, and gastrectomy.

In patients with CAS, the reduction of arterial supply to organs in the CA region is compensated by the SMA through the collateral arteries around the pancreas. In many cases, the main collateral pathway is the gastroduodenal artery (GDA) [2-5] and therefore, surgical procedures including the division of the GDA must pay attention to CAS to avoid organ ischemia in the perioperative period. In this context, the most cautious surgical procedure in patients with CAS is PD in which the GDA is divided [6]. On the other hand, CAS-associated postoperative ischemic complications in the upper abdominal organs were also reported in other surgical procedures without GDA division including liver transplantation, oesophagectomy, and gastrectomy, which is most likely due to the potential decreased arterial flow to the organs from the CA and consequent susceptibility to perioperative hypotension after surgery. The summary and cautionary points stratified by the surgical procedures were described as follows.

Pancreaticoduodenectomy

CAS-related complications after PD include ischemia of the upper gastrointestinal organs including the liver [7-10], pancreas [8-11], spleen [11], and stomach [11,12]. In addition, a recent report showed that substantial atherosclerotic CA stenosis may be a risk factor for biliary fistula [12]. Preoperative evaluation and diagnosis of CAS are crucial in PD to avoid these CAS-related complications, and Giovanardi et al. presented an intraoperative flowchart using a GDA clamping test for the assessment and management of CAS [13]. Briefly, under the GDA clamping test, arterial flow in the coeliac region is evaluated by digital pulsation or Doppler ultrasonography. If the GDA clamping test is negative, namely no reduction in the arterial flow in the CA system, typical PD with GDA division is usually possible [13]. However, if the GDA clamping test is positive, namely a significant decrease or loss of arterial flow in the CA system, additional procedures to avoid ischemia in the upper abdominal organs would be required. In cases of CAS due to median arcuate ligament (MAL) compression, MAL division is a safe and feasible procedure and should be attempted first [13,14]. If MAL division is not effective or CAS is caused by other reasons, the effective strategies reported previously include preservation of the collateral arteries, vascular reconstruction, and angioplasty by interventional radiology (IVR). The preservation of the collateral arteries may be an option when there exists a subsequent collateral artery bypass between the SMA and CA systems, and preservation of the artery should be technically permissible and oncologically acceptable. The candidate arteries for preservation are the GDA [7,15-17], dorsal pancreatic artery [18,19], replaced or accessory right hepatic artery [10-20], and the arc of Buhler [21,22]. As for vascular reconstruction, the reported procedures include direct artery-to-artery anastomosis and bypass using the great saphenous vein. Direct artery-to-artery anastomosis has been conducted in an end-to-end fashion between the inferior pancreatoduodenal artery (IPDA)-GDA [11,12], middle colic artery (MCA)-GDA [23,24], and MCA-right gastroepiploic artery [10], and in an end-to-side fashion between the splenic artery (SPA)-SMA [25], common hepatic artery (CHA)-aorta [7], CA-aorta [7,26], and left gastric artery-aorta [27]. The bypass routes reconstructed using the great saphenous vein are the IPDA-SPA [16], left iliac artery-SPA [28], and aorta-CHA [29-31]. Angioplasty by IVR is also reportedly effective to resolve CAS. Although balloon dilatation was initially reported [32], recent reports showed the efficacy of endovascular stenting to CA [33-35]. Endovascular stenting by IVR can be conducted anytime in the pre-, intra-, and postoperative period, and the arterial flow in the CA system can be secured less invasively compared with other surgical approaches, although an endovascular approach is sometimes difficult in cases of severe stenosis or complete CA obstruction.

Currently, there have been no reports comparing the treatment approaches mentioned above, and thus, further studies are required to establish a strategy for CAS in PD. In addition, there were some reported cases with postoperative organ ischemia despite no signs of ischemic findings after GDA division [8,36,37]; therefore, careful assessment of the arterial flow in the upper abdominal organs in the postoperative period should be required to avoid CAS-related ischemic complications in PD.

Liver transplantation

CAS is reported to predispose transplantation recipients to hepatic artery thrombosis (HAT) due to a decrease in the CHA flow [38,39]. Vilatobá et al. reported a case of postoperative early HAT due to MALS, in which immediate MAL division and re-anastomosis was effective to restore adequate flow to the hepatic artery [39]. Mochizuki et al. reported the efficacy of test occlusion of GDA or CHA to determine the indications of additional procedures to resolve CAS [40].To minimize the risk for HAT in recipients with MALS, various vascular reconstructive techniques were proposed: release of the MAL, aorto-hepatic graft interposition, or standard reconstruction of the hepatic artery without division of the GDA (standard anastomosis) [41]. Of these, Czigany et al. recommend the MAL division in all recipients with MALS and revealed no difference in early- and long-term outcomes [42]. Aorto-hepatic graft interposition was reportedly performed using an iliac artery graft, and the incidence of thrombosis was 5.3%-21.8% [43,44]. Lubrano et al. reported no significant difference in HAT incidence between aorto-hepatic bypass and standard anastomosis in orthotopic liver transplantation [41], suggesting the GDA could be functioned as a sufficient collateral artery from the SMA system.

As for donor hepatectomy, there have been a few reports showing the relevance of CAS. Akamatsu et al. reported the safety of donor hepatectomy in patients with CAS by careful dissection of the hepatic artery so as not to damage the contralateral arteries from the SMA system, confirming favourable hepatic arterial flow after hepatectomy under test clamping of the CHA [45]. Douard et al. reported a case of donor hepatectomy with MALS in which the thin middle hepatic artery due to MALS was enlarged by a two-step strategy including MAL and GDA divisions in the first operation and subsequent left liver procurement five weeks later [46].

In almost all reports on CAS in liver transplantation, the aetiology of CAS was MAL compression, and there were few reports on atherosclerotic CAS in liver transplantation. Further studies are required to demonstrate the influence of atherosclerotic CAS on the outcomes of liver transplantation.

Oesophagectomy

There were a few reports showing the association between CAS-related ischemic complications and oesophagectomy. A recent large cohort of 481 oesophagectomies reported by Lainas et al. revealed that CAS was associated with gastric conduit necrosis [47].They classified CAS into extrinsic (caused by MAL compression) and intrinsic (mainly due to atherosclerosis) stenosis. In the gastric conduit necrosis group, the incidences of extrinsic and intrinsic stenosis of CA were 50% and 80%, respectively, which was significantly higher in the no oesophageal conduit necrosis group. On the other hand, Jefferies et al. reported no significant association between the incidence of gastric conduit necrosis and atherosclerotic CAS [48].They scored the calcification of the proximal aorta, distal aorta, coeliac trunk, and branches of the coeliac trunk, and there was no significant correlation between the calcification of any of the vessels and gastric conduit necrosis. Further studies are required to reveal the relationship between CAS and gastric conduit necrosis in oesophagectomies.

Gastrectomy

Thus far, there have been a few case reports on the relationship between gastrectomy and CAS. Rego et al. reported a case of CAS-related liver ischemia associated with anastomotic failure and sepsis after distal gastrectomy, in which the stenotic CA was ballooned and stented by IVR and almost all of the liver was re-perfused [49]. Nakano et al. showed the diagnostic difficulty of CA occlusion in patients with former distal gastrectomy with Kocher's manoeuvre due to the displacement of the coeliac arterial branches [50]. Whereas the clinical significance between CAS and gastrectomy has been hardly reported, Yoshida et al. reported the efficacy of simultaneous MAL division in laparoscopic gastrectomy [51].Considering the easiness to approach MAL during gastrectomy, simultaneous MAL resection with gastrectomy may be an option in patients with MALS.

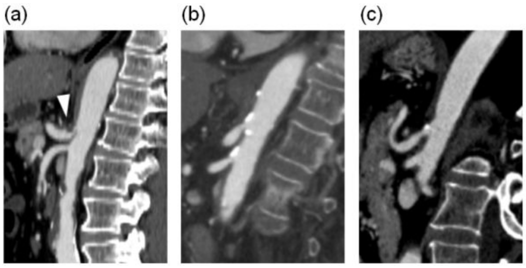

Figure 1: Representative images of CAS in the sagittal plane on MDCT are presented. (a) CAS due to MAL compression. The characteristic hooked appearance is observed (arrowhead). (b) Atherosclerotic CAS. (c) Concomitant CAS by MAL compression and atherosclerosis.

Diagnosis and treatment indication of CAS in upper abdominal surgery

CAS is traditionally diagnosed using catheter angiography [52], and recent reports revealed the usefulness of MDCT (Figure 1) and MRI for the diagnosis of CAS [4,53], and is deemed significant if there is ≥50% luminal narrowing of the CA orifice [52]. Although the treatment indication of CAS itself is reported to be the presence of symptoms [54], there is no established consensus on when an intervention is required for CAS according to the stenotic rate in upper abdominal surgery. Therefore, intraoperative evaluation is essential to determine the requirement of additional procedures for CAS. The GDA clamp test is the most feasible and effective procedure to assess haemodynamics in PD [13] and the CHA clamp test is also helpful in liver transplantation [40-45]. Doppler ultrasonography is used to confirm the arterial flow in the liver after GDA clamping [14] and dynamic nature of MALS with respiration [55].Indocyanine green fluorescence is useful to evaluate the arterial flow in the remnant organs during a vascular clamp test or after resection [56]. However, these intraoperative methods are not definitive considering some reports in which postoperative organ ischemia developed despite no signs of ischemic findings during surgery [8,36,37], and therefore, careful assessment of the arterial flow in the upper abdominal organs during and after operation should be required to avoid CAS-related complications in PD.

Summary of Treatment Strategies in CAS

The treatment strategies for CAS in upper abdominal surgery are summarized in Table 1 below. The strategies are practically divided into four approaches: MAL division, preservation of the collateral artery, vascular reconstruction, and angioplasty by IVR. MAL division is an easy, feasible, and a less invasive procedure, although it can be applied only for CAS due to MAL compression. In addition, special care should be taken when dividing the MAL not to injure the enlarged collateral veins due to portal hypertension in liver transplantation [40] or CA itself [38]. Preservation of the collateral artery is physiological and less invasive but requires substantial collateral artery, and preservation of the artery should be technically and oncologically permissible. Vascular reconstruction is an eventual method to solve CAS during surgery, which is applicable to almost all patients. However, the procedure is technically complicated and demanding and careful attention must be paid to postoperative anastomotic failure. Finally, angioplasty by IVR is the least invasive and can be conducted anytime in the perioperative period; however, the approach would be difficult in cases with severe stenosis or complete obstruction of CA. Considering the characteristics of these treatment strategies, an adequate approach should be selected according to the extent of CAS, vascular anatomy of patients, patient’s condition, surgeon’s experience, and institutional resources.

Procedure	Comment	Advantages	Disadvantages
MAL division	-	Easy, feasible, less invasive	Only in CAS due to MAL compression
Preservation of collateral artery	Candidate of collateral artery GDA Dorsal pancreatic artery Replaced or accessory RHA Arc of Buhler	Physiological, less invasive	Only in case with substantial collateral artery Preservation of the arcade should be technically and oncologically permissible
Vascular reconstruction	Direct artery-to-artery anastomosis End-to-end anastomosis IPDA-GDA MCA-GDA MCA-RGEA End-to side anastomosis SPA-SMA CHA-aorta	Applicable to any patients	Complicated procedure Possibility of anastomotic failure

	CA-aorta LGA-aorta Reconstruction using vascular graft CHA-aorta CA-aorta IPDA-SPA bypass Left iliac artery-SPA bypass		
Angioplasty by IVR	Balloon dilation or stent insertion	Less invasive, anytime available in perioperative periods	Difficulty in severe stenosis or complete obstruction of CA
Abbreviations: CA: Coeliac Artery; CAS: Coeliac Artery Stenosis; CHA: Common Hepatic Artery; GDA: Gastroduodenal Artery; IPDA: Inferior Pancreaticoduodenal Artery; LGA: Left Gastric Artery; MAL: Median Arcuate Ligament; MCA: Middle Colic Artery; RGEA: Right Gastroepiploic Artery; RHA: Right Hepatic Artery; SMA: Superior Mesenteric Artery; SPA: Splenic Artery.			

Table 1: Treatment options of CAS in upper abdominal surgery.

Conclusion

We overviewed the reports on upper abdominal surgery in patients with CAS. As there is no established consensus on when an intervention is required for CAS in upper abdominal surgery, careful assessment of the arterial flow during and after surgery should be required to avoid CAS-related complications in upper abdominal surgery.

Conflict of Interest

All the authors have no conflict of interest to declare.

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Author Contributions

NT and KI contributed to the conception and design of the study. All authors contributed to the acquisition and analysis of data. KI, and NT were a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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