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Case Report

Usefulness of Middle Colic Artery Transposition Technique for Hepatic Arterial Reconstruction in Conversion Surgery for an Initially Unresectable, Locally Advanced Pancreatic Cancer

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The outcomes of pancreatectomy with resection and reconstruction of the involved arteries for locally advanced pancreatic cancer following chemotherapy have improved in recent years. In pancreatic head cancers in which there is contact with the common and proper hepatic arteries, margin-negative resection requires pancreaticoduodenectomy, with the resection of these arteries and the restoration of hepatic arterial flow. Here, we describe a middle colic artery transposition technique in hepatic arterial reconstruction during pancreatoduodenectomy for an initially unresectable locally advanced pancreatic cancer. This technique was effective and may provide a new option for hepatic artery reconstruction in such cases.

Key words: hepatic artery, locally advanced pancreatic cancer, middle colic artery, pancreatoduodenectomy, reconstruction technique

Pancreatic ductal adenocarcinoma (PDAC) is currently the 4th leading cause of cancer-related deaths worldwide and is estimated to be the 2nd leading cause of cancer-related deaths by 2030 [1,2]. Although surgical resection is mandatory for prolonged survival of patients with PDAC, the tumor is commonly unresectable at initial diagnosis. Recently, with the advancement of systemic chemotherapy, many conversion surgeries for initially unresectable, locally advanced pancreatic cancer (URLA-PC) have been reported [3,4]. Resection and reconstruction of infiltrated arteries in conversion surgery have been reported to be associated with no significant increase in mortality and may contribute to improved prognosis in carefully selected patients [5,6]. Therefore, it is important to develop an effective surgical method for safe arterial reconstruction.

Herein, we present a successful case of conversion surgery for URLA-PC involving the nerve plexus around the common hepatic artery (CHA) and proper hepatic artery (PHA), using a middle colic artery (MCA) transposition technique.

Case Presentation

A 63-year-old man with obstructive jaundice was admitted to our institute from a local hospital. Initial laboratory examination showed an extremely high level of cancer antigen 19-9 (CA19-9) at 4,016 U/ml. A 36-mm tumor without significant contrast effect in the pancreatic head was noted on multidetector-row com-

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puted tomography (CT). The tumor was in contact with the entire length of the CHA, up to the distal portion of the PHA, with invasion of the nerve plexus around them (Fig. 1A). Fine needle aspiration biopsy using endoscopic ultrasound confirmed that the tumor was an adenocarcinoma. Distant metastasis was not observed in the patient. Based on these findings, the patient was diagnosed with URLA-PC. Written informed consent was obtained from the patient for the disclosure of the treatment progress and images.

We administered systemic chemotherapy with gemcitabine plus nab-paclitaxel (gemcitabine 1,000 mg/m^2 and nab-paclitaxel 125 mg/m^2 on days 1, 8, and 15 every 4 weeks). After four treatment cycles, side effects of visual impairment, possibly due to the systemic chemotherapy, occurred. Thus, we changed the combination chemotherapy regimen to modified FORFIRINOX (oxaliplatin 85 mg/m^2, irinotecan 150 mg/m^2, and leucovorin 200 mg/m^2 administered as a bolus, and fluorouracil 2,400 mg/m^2 as a 46-hour continuous infusion, every 2 weeks). After 12 treatment cycles and 15 months of chemotherapy, the CA19-9 levels normalized. The tumor shrank significantly, and the effectiveness of the chemotherapy was judged as "partial response", based on the Response Evaluation Criteria In Solid Tumors (RECIST). However, the spread of soft tissue density, suspected to be nerve plexus invasion around the CHA and PHA, persisted (Fig. 1B). Therefore, after a comprehensive review of the patient's treatment progress in a multidisciplinary conference, we decided to perform conversion surgery.

After laparotomy, the peripheral side of the right and left hepatic arteries were exposed and dissected toward the PHA in the hepatoduodenal ligament. Intraoperative pathological examination showed no malignancy in the nerve plexus around the distal side of the PHA. Expectedly, the proximal side of the PHA and CHA could not be detached from the stiff tissue around it. The root of the CHA could be exposed and taped, without findings of nerve plexus invasion. Based on these findings, we decided to perform a radical resection with curative intent; therefore, subtotal stomach-preserving pancreaticoduodenectomy, combined with CHA-PHA, portal vein (PV) resection, and D2 lymph node dissection was conducted. For the reconstruction of the hepatic artery, the peripheral portion of the

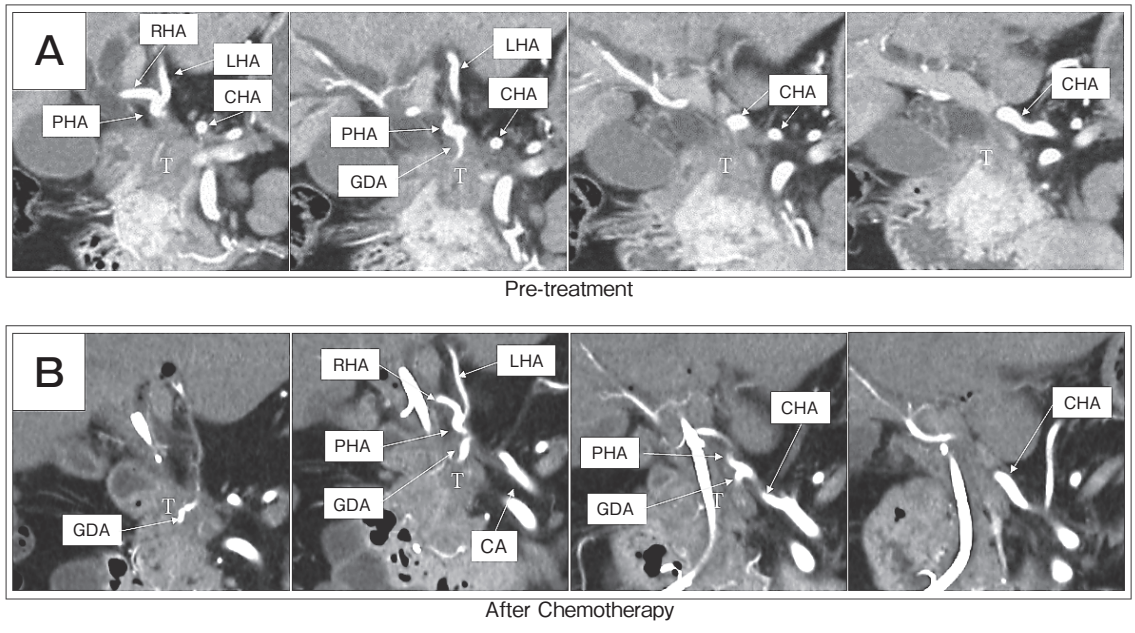

Fig. 1 Contrast-enhanced CT coronal imaging (**A**) pre-treatment and (**B**) post-chemotherapy. The tumor is in contact with the entire length of CHA, up to the distal portion of PHA, with the invasion of the nerve plexus around the CHA and PHA. Despite tumor shrinkage with systemic chemotherapy, the contact with the CHA and PHA and the nerve plexus invasion, persists.
CT, computed tomography; T, tumor; CHA, common hepatic artery; PHA, proper hepatic artery; GDA, gastroduodenal artery; RHA, right hepatic artery; LHA, left hepatic artery; CA, celiac artery.

MCA was exposed, mobilized in the transverse mesocolon, and dissected towards its root. The MCA was resected at the first bifurcation and transposed upward to the hepatoduodenal ligament. After transecting the distal portion of the PHA, the stump of the PHA and the branch patch of the MCA stump were anastomosed using an interrupted end-to-end technique, with 7-0 prolene (17 stiches) and surgical loupes at 3.5× magnification (Fig. 2, 3). For PV reconstruction, an internal jugular vein graft was interposed between the PV and the superior mesenteric vein. The surgery was completed after confirming intact perfusion of the transverse colon. The duration of the operation was 539 min, and the amount of blood loss was 740 mL. Histopathological examination confirmed that viable cancer cells extended into the resected nerve plexus surrounding the PHA and CHA (Fig. 4). The final diagnosis was as follows: invasive ductal carcinoma, TS1 (20×19 mm), ypT3, ly1, v0, ne3, ypCH1, ypDU1, ypS1, ypRP1, ypPV1, ypA0, ypPL1, ypOO0, ypPCM0, ypDPM0, ypN0 (0/16), ypStage IIA, according to the Japan Pancreatic Society classification, 7th edition. No cancer cells were detected in the surgical margin (R0). The efficacy of chemotherapy was categorized as Evans grade IIb.

Using Doppler ultrasonography, we observed that the hepatic arterial flow was favorable from postoperative day 1 to 7. Patency in the PHA-MCA anastomosis was confirmed using 3D-CT angiography on postoperative day 15 (Fig. 5). No major postoperative complications occurred, except for surgical site infection of the surgical wound, and the patient was discharged on the 40th postoperative day. The patient received S-1 (80 mg/kg body weight, administered orally for 4

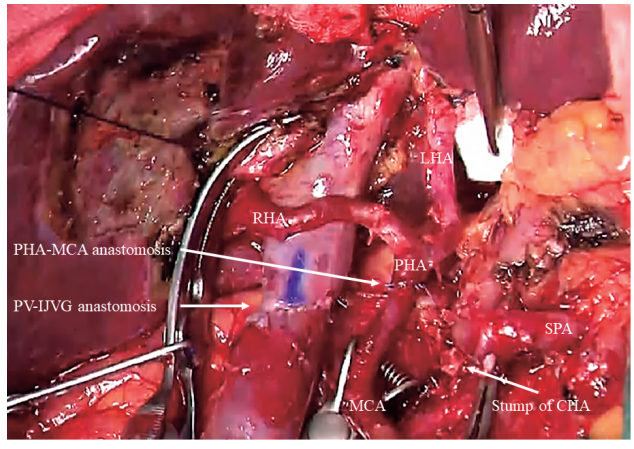

Fig. 3 Intraoperative image after the reconstruction of the hepatic artery and portal vein.
CHA, common hepatic artery; PHA, proper hepatic artery; RHA, right hepatic artery; LHA, left hepatic artery; SPA, splenic artery; MCA, middle colic artery; PV, portal vein; IJVG, internal jugular vein graft.

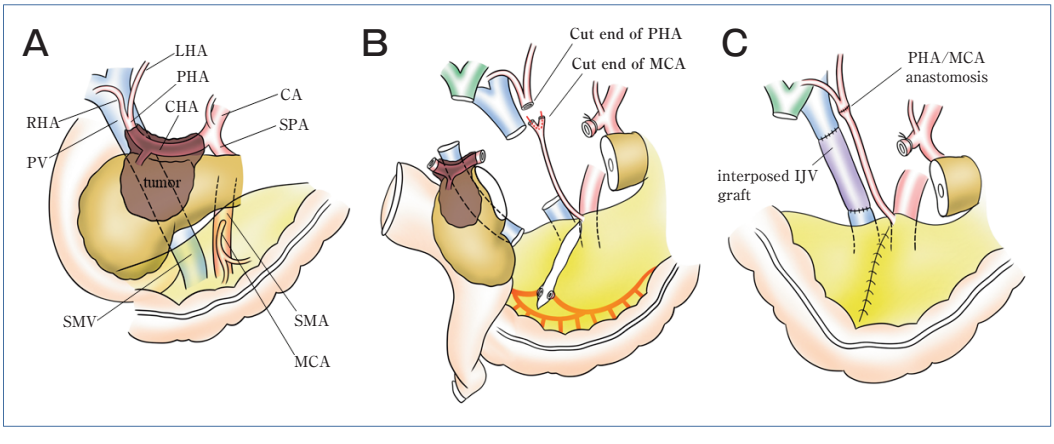

Fig. 2 Graphic illustration of the operation record. (**A**) The tumor is in contact with the entire length of the CHA, up to the distal portion of the PHA, with nerve plexus invasion around them. (**B**) The MCA is exposed, mobilized in the transverse mesocolon, and dissected toward its root. The MCA is resected at the first bifurcation and transposed upward to the hepatoduodenal ligament. (**C**) Anastomosis of the PHA and transposed MCA using an end-to-end technique.
CHA, common hepatic artery; PHA, proper hepatic artery; RHA, right hepatic artery; LHA, left hepatic artery; CA, celiac artery; SMA, superior mesenteric artery; SPA, splenic artery; MCA, middle colic artery; PV, portal vein; SMV, superior mesenteric vein; IJV, internal jugular vein.

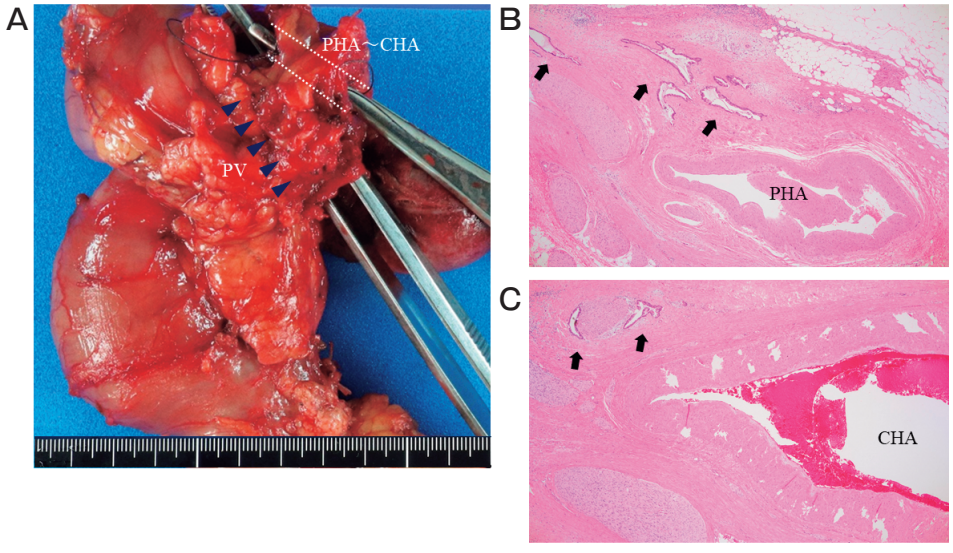

Fig. 4 (A) Macroscopic examination of the resected specimen showing a hard mass in the pancreatic head. (B, C) Histopathological examination of hematoxylin and eosin-stained sections reveals generated cancer cells, extending to the resected nerve tissue around the PHA and CHA (arrow).

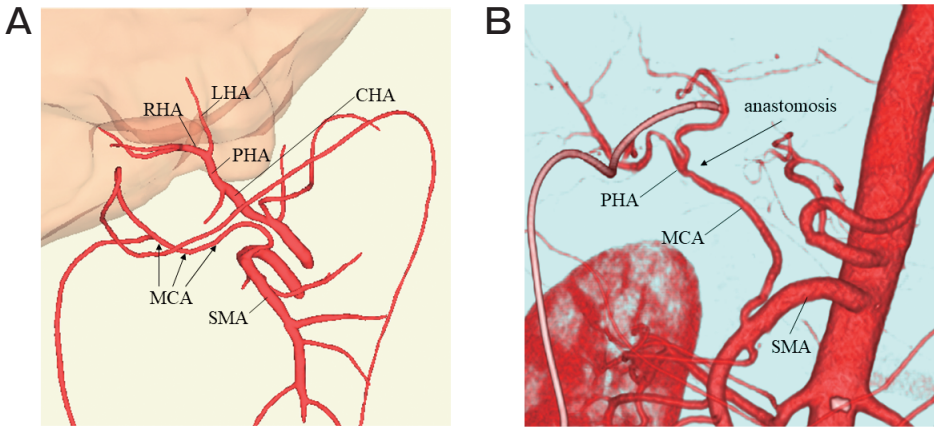

Fig. 5 (A) Preoperative evaluation of the running pattern of the MCA using 3D-CT angiography. The arrow indicates the MCA. (B) Postoperative evaluation of the hepatic artery by 3D-CT angiography on postoperative day 15. The arrow indicates the anastomosis of the PHA and MCA.
CHA, common hepatic artery; PHA, proper hepatic artery; RHA, right hepatic artery; LHA, left hepatic artery; SMA, superior mesenteric artery; MCA, middle colic artery.

weeks followed by a 2-week rest) as adjuvant chemotherapy for 6 months. He is currently alive, 47 months after the initial treatment (31 months after surgery), although with local tumor recurrence around the celiac artery.

Discussion

Recent advances in chemotherapy have enabled "conversion surgery", even for unresectable pancreatic cancer in patients, because of a positive response to preoperative treatment [7]. Since the 2010s, there have been increasing reports of conversion surgery for URLA-PC from high-volume centers [8-9]. According

to the recent National Comprehensive Cancer Network guidelines (2021) [10], surgical resection for URLA-PC is a second-line treatment option for patients with good disease response and performance status after initial treatment. Several recent reports indicate that a significant decrease in CA19-9 levels after neoadjuvant therapy correlates with good prognosis after pancreatectomy [4, 11, 12]. In this case, conversion surgery after chemotherapy with normalized preoperative CA19-9 levels may have had a positive impact on long-term survival.

Regarding the surgical procedure, we performed subtotal stomach-preserving pancreaticoduodenectomy, combined with CHA-PHA resection. It is very difficult to accurately detect viable tumors in the soft tissue density area around the great vessels from CT findings. Therefore, we have adopted this procedure with arterial resection to obtain radical resection, even when cancer cells remain in the nerve plexus around the CHA/PHA. Total pancreatectomy could be an alternative in this case. However, we usually attempt to avoid total pancreatectomy because it results in poor glycemic control and malnutrition, which might lead to a low completion rate of adjuvant therapy. In a case of positive surgical margins, based on intraoperative pathological findings during pancreatoduodenectomy, total pancreatectomy with celiac artery resection can be selected to achieve curative resection.

Conversion surgery occasionally requires simultaneous vascular resection and reconstruction; however, for locally advanced pancreatic cancer, combined arterial resection remains debatable because of the associated high rates of severe complications [13]. Arterial reconstruction is commonly required for patients undergoing pancreaticoduodenectomy with hepatic artery resection, except when the patient presents with aberrant hepatic arteries [14]. The crucial point is to ensure hepatic perfusion while achieving curative resection [15, 16]. Therefore, sufficient knowledge of arterial reconstruction during pancreaticoduodenectomy with hepatic artery resection is essential. Several methods of hepatic artery reconstruction, such as CHA-PHA direct anastomosis, CHA-PHA anastomosis with a vein graft interposition, splenic artery-PHA anastomosis, and left gastric artery-PHA anastomosis, have been described previously [17-21].

In the present case, we decided to use MCA for hepatic artery reconstruction. From a technical viewpoint, the most important aspect in this reconstruction is the careful dissection of the nerve plexus around the root of the MCA to avoid tension when the MCA is transposed upward for anastomosis. This is the first report, to the best of our knowledge, of anastomosis between the PHA and MCA during pancreatoduodenectomy. MCA was used for the following reasons. First, since this pancreatic head carcinoma was presumed to have originated from the dorsal primordium of the pancreas, there was a greater possibility of local recurrence in the retroperitoneal tissue around the celiac artery than around the superior mesenteric artery. Moreover, we considered that if the left gastric artery or the splenic artery was used as the reconstructive vessel, hepatic artery blood flow might be obstructed by the recurrent lesion. Actually, local recurrence was occurred around the celiac artery 18 months after conversion surgery. Next, the MCA would be exposed easily in the transverse mesocolon under the same field of view during pancreatoduodenectomy, and the stump of the MCA would be close to that of the PHA when it is transported upwards to the hepatoduodenal ligament. Finally, when the difference between PHA and MCA was identified, the diameter of the stump of the MCA could be adjusted using a branch patch with the bifurcation of the MCA (Fig. 2). The reconstructed MCA-PHA anastomosis was patent, 31 months after conversion surgery, despite local recurrence around the celiac artery.

Conclusion

In conclusion, the described MCA transposition technique for reconstruct the hepatic artery during pancreatoduodenectomy in patients with URLA-PC could be a useful surgical option for hepatic artery reconstruction. Further studies are required to determine the efficacy of this technique.

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