Hypothesis: Blood supply to the peripancreatic region is derived from the celiac and superior mesenteric arteries, complementary to each other.

Design: Cohort analytic study.

Setting: Tertiary care public hospital.

Patients and Methods: Computed tomography (CT) during superior mesenteric artery arteriography (SMAA-CT) and during celiac artery arteriography (CEAA-CT), in which a catheter tip was inserted into the common hepatic or gastroduodenal artery, was performed in 25 patients.

Main Outcome Measure: Distribution and correlation of these areas of marked enhancement on SMAA-CT and CEAA-CT were analyzed.

Results: The right cephalic part of the pancreatic head that is derived from the dorsal bud was enhanced on CEAA-CT, and the left caudal part of the pancreatic head that is derived from the ventral bud was enhanced on SMAA-CT. Blood supply to the intrapancreatic bile duct, including the ampulla of Vater, is derived from the CEA. The boundary between the areas of the duodenum supplied from the CEA and SMA was in the second or third portion.

Conclusion: The pancreatic head can be separated into 2 segments by the arterial supply, and each segment may be removed separately.

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The pancreatoduodenectomy (PD) described by Whipple et al in 1935 is still performed in various situations requiring resection of the head of the pancreas. However, this procedure is extremely radical and compromises pancreatic endocrine functions and digestion. In 1978, Traverso and Longmire developed a pylorus-preserving PD aimed at the preservation of postoperative digestive function. Since then, numerous authors have reported favorable results with this procedure, especially for preserving endocrine function. However, pylorus-preserving PD also requires transection of the common bile duct (CBD) and subtotal duodenal resection, despite the absence of disease in these organs. Berger et al described a duodenum-preserving resection of the head of the pancreas. The resulting postoperative conditions in these patients have been much better than those in patients who underwent conventional PD. In Japan, this type of surgery has been performed mainly for mucin-producing tumor of the pancreas. In 1993, Takada reported ventral pancreatectomy in which the dorsal segment was preserved along with the whole duodenum and the CBD. Other researchers have also performed such limited resection of the pancreas. Despite these recent surgical trends, little has been reported regarding the detailed surgical or radiological vascular anatomy of this region. Several authors have analyzed the vessels of the head of the pancreas using autopsy or arteriography. However, these techniques frequently make clarification of the distribution area of each vessel difficult. Helical computed tomography (CT) during arteriography can demonstrate the 3-dimensional blood distribution of a particular artery injected with contrast medium. We evaluated the supplying vessels to the pancreatic head, bile duct, and duodenum using this technique.

RESULTS

DISTRIBUTION OF THE HYPERATTENUATING AREAS IN THE PANCREATIC HEAD PARENCHYMA

On CEAA-CT, pancreatic parenchymal enhancement was present on the right cephalic side of the pancreatic head (Figure 1 and Figure 2). In contrast, the
left caudal side of the pancreatic head that was equal to the uncinate process was enhanced on SMAA-CT (Figures 1 and 2). These areas were complementary to each other in the whole pancreatic head parenchyma. The main pancreatic duct in the pancreatic head was running through the boundary between both areas of marked enhancement on CEAA-CT and SMAA-CT (Figures 1 and 2). The results are summarized in Figure 3.

BLOOD SUPPLY TO THE INTRAPANCREATIC BILE DUCT

In all 25 patients, the whole CBD, including the ampulla of Vater, was enhanced on CEAA-CT (Figures 1, 2, and 3). The posterior inferior pancreaticoduodenal artery (PIPD) derived from the SMA, which formed an arcade with the posterior superior pancreaticoduodenal artery (PSPD) derived from the CEA, ran along the bile duct (Figure 2). Although the distal end of the intrapancreatic bile duct was slightly enhanced in 7 (28%) of 25 patients on SMAA-CT, in the other 18 patients, the CBD was not enhanced on SMAA-CT, even when the PIPD was demonstrated along with the intrapancreatic bile duct (Figure 2).

BLOOD SUPPLY TO THE DUODENUM

The oral side of the duodenum was enhanced on CEAA-CT, and the anal side was enhanced on SMAA-CT. The boundary between both areas of marked enhancement was the second portion in 14 patients (56%), the third portion in 10 patients (40%), and the fourth portion in 1 patient (4%) (Figures 1 and 2). These areas were complementary to each other in the duodenum similarly to those of the pancreatic parenchyma.

COMMENT

The pancreas arises from 2 primordia during embryogenesis. Both primordia fuse at about the sixth to seventh fetal week.12 The smaller ventral bud forms the cephalic part of the pancreatic head, which is equal to the uncinate process, whereas the cephalic part of the pancreatic head and the body and tail are derived from the larger dorsal bud. The dorsal pancreatic duct becomes the major pancreatic duct by fusing with the proximal portion of the ventral duct, draining the body and tail and a portion of the head of the organ and emptying into the duodenum through a common opening with the CBD at the ampulla of Vater.

In our series using CT during arteriography, the right cephalic part of the pancreatic head was enhanced on CEAA-CT, and the left caudal part of the pancreatic head was enhanced on SMAA-CT. This means the superior pancreaticoduodenal artery departing from the CEA provides blood to the part of the pancreas derived from the dorsal bud, and the inferior pancreaticoduodenal artery departing from the SMA supplies that derived from the ventral bud. These findings were consistent with the development of the human pancreas. Thus, the pancreas can be separated clinically into dorsal and ventral segments by the arterial blood supply. If some sophisticated surgical technique is used to preserve the outlet for pancreatic juice, each segment can be removed separately.46-68

The CBD, including the ampulla of Vater, was enhanced on CEAA-CT in all cases. Even if the PIPD derived from the SMA was demonstrated along with the in-
trapancreatic bile duct on SMAA-CT, the bile duct was not enhanced. Using autopsy materials, Kimura and Nagai\(^\text{11}\) also reported that arterial branches to the bile duct and the ampulla of Vater were derived from the PSPD, which was located along the intrapancreatic bile duct and was communicating with the PIPD. Preservation of the PSPD during surgery may be important to preserve better blood supply to the bile duct.

**Figure 1.** Comparison of computed tomographic (CT) images obtained during celiac artery arteriography (CEAA-CT), in which a catheter tip was inserted into the common hepatic artery, and during superior mesenteric artery arteriography (SMAA-CT). A, The CEAA-CT at the level of the superior mesenteric artery (SMA) shows an area of marked enhancement in the right side of the pancreas and the second portion of the duodenum (D) in which the common bile duct (CBD) is depicted as a hypoattenuating area. B, The SMAA-CT at the same level shows an area of marked enhancement in the left side of the pancreatic head. The CBD and surrounding area are not enhanced. The main pancreatic duct (MPD) is demonstrated at the boundary of both areas of marked enhancement on A and B. C, The CEAA-CT at the level of the gastrocolic trunk (GCT) shows an area of marked enhancement in the right ventral side of the pancreas and the duodenum. D, The SMAA-CT at the same level shows an area of marked enhancement in the left dorsal side of the pancreas. The main pancreatic duct (MPD) is depicted at the boundary of both areas of marked enhancement on C and D.
Maintaining duodenal blood flow is an important aspect of duodenum-preserving pancreatic head resection. In most of our cases, preserving the duodenal branches from the SMA is necessary to maintain the blood supply to the anal side of the duodenum. Similarly, the duodenal branches from the CEA are important to maintain blood supply to the oral side of the duodenum, including the ampulla of Vater. Thus, duodenal branches

Figure 2. Comparison of computed tomographic (CT) images obtained during celiac artery arteriography (CEAA-CT) and during superior mesenteric artery arteriography (SMAA-CT). A, The CEAA-CT at the level of the celiac axis shows an area of marked enhancement in most of the pancreatic head and the right side of the pancreatic body. The common bile duct (CBD) is depicted in this area of marked enhancement. B, The SMAA-CT at the same level shows areas of marked enhancement in the left dorsal side of the pancreatic head and the left side of the pancreatic body. The CBD is not enhanced, although the posterior inferior pancreaticoduodenal artery (PIPD) is depicted along it. C, The CEAA-CT at the level of the left renal vein shows an area of marked enhancement in the right ventral side of the pancreatic head and the duodenum. D, The SMAA-CT at the same level shows an area of marked enhancement in the left dorsal side of the pancreatic head. The main pancreatic duct (MPD) is depicted at the boundary between both areas of marked enhancement on C and D. The CBD is not enhanced as shown in B, although the PIPD is also depicted. AIPD indicates anterior inferior pancreaticoduodenal artery.
derived from the CEA and SMA should be preserved to avoid ischemic change of the duodenum in duodenum-preserving surgery.

To our knowledge, this is the first study of the blood supply to the peripancreatic region using CT during arteriography. Although unusual opacification induced by high-pressure injection might be a potential pitfall, each artery was catheterized and injected without reflux, then helical CT was performed so that 3-dimensional evaluation of the anatomy of the enhanced area could be performed under quasiphysiologic conditions.

In conclusion, the pancreas can be separated into 2 segments by the arterial supply. Blood supply to the intrapancreatic bile duct, including the ampulla of Vater, is derived from the CEA. The boundary between the areas of the duodenum that are supplied blood from the CEA and SMA is in the second or third portion. These data will be useful for limited resection of the pancreatic head and their adnexa.

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