Hypothsis: 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 arterial arteriography (SMAA-CT) and during celiac arterial 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 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
PATIENTS, MATERIALS, AND METHODS

From May 1, 1997, through April 30, 1998, 25 patients with suspected hepatopancreaticobiliary abnormalities were selected. Patients with deformity of the pancreas due to severe pancreatitis or advanced pancreatic carcinoma, obstructive jaundice, and portal hypertension were excluded. Patients underwent helical CT during visceral artery injection at the time of conventional preoperative angiography.

In the angiography suite, celiac artery (CEAA) and superior mesenteric artery arteriography (SMAA) was performed to visualize the peripancreatic arterial anatomy. After confirming the branching pattern of the CEA and SMA, helical CT during the injection of the contrast medium into the visceral artery was performed to evaluate the perfusion areas of the pancreaticoduodenal region.

All studies were performed using a commercially available system (IVR-CT system; Toshiba Medical Systems, Tokyo, Japan), which consisted of a digital subtraction angiography system and a helical CT scanner. This equipment is capable of performing digital subtraction angiography and CT scanning with the patient in the same position. The helical CT was obtained with a 1:1 pitch, 5-mm collimation, 2- to 5-mm reconstruction, 120-kV peak, and 250 mA. Scanning was started 5 to 10 seconds after the commencement of injection of ioversol (350 mg/mL iodine) diluted with isotonic sodium chloride solution (1:2 ratio) at a rate of 1 to 3 mL/s for a total volume of 20 to 60 mL (40 mL in most cases) using a power injector. We confirmed the absence of reflux into the celiac axis or superior mesenteric axis of this condition on previous arteriograms and CT images. A vasodilator was not injected through the catheter.

All CT and angiographic images were analyzed by 2 experienced radiologists (H.F. and R.I.); discrepancies were resolved by consensus. The evaluation was focused on the following 3 points: (1) distribution and correlation of the hyperattenuating areas in the pancreatic head parenchyma injected with contrast medium from the CEA in which a catheter tip was inserted into the common hepatic artery or the gastroduodenal artery and from the SMA; (2) the degree of enhancement of the intrapancreatic bile duct by injection of contrast medium from the CEA and SMA; and (3) distribution and correlation of the enhanced areas in the duodenum injected with the contrast medium from the CEA and SMA. The caudal part of the duodenum was divided into the following 3 areas: the second portion, located on the right side of the inferior vena cava, including the ampulla of Vater; the third portion, located in front of the inferior vena cava; and the fourth portion, located on the left side of the inferior vena cava and in front of the aorta.

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. The smaller ventral bud forms the caudal 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.

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-

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.
trapancreatic bile duct on SMAA-CT, the bile duct was not enhanced. Using autopsy materials, Kimura and Nagai 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.
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
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