

Carcinoid tumors of the pancreas: dynamic CT and MRI features with pathological correlation

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Abstract

Background: Carcinoid tumor of the pancreas is rare, and there are few reports that described its CT or magnetic resonance imaging (MRI) findings. We describe the characteristic CT and MRI findings in four cases of carcinoid tumor of the pancreas.

Methods: Radiologic and pathologic features were analyzed in four patients. All patients underwent triple-phase dynamic CT and MRI.

Results: The tumor size in the four cases ranged 15–20 mm and intratumoral calcification was detected in one case. On triple-phase dynamic CT, the peak enhancement of the tumors was seen at the arterial dominant phase in three cases; the remaining one was at the portal venous phase with prolonged contrast-enhancement effect. The tumors showed low to high signal intensity on T2-weighted images. Dilatation of the main pancreatic ducts (MPDs) distal to the tumors was seen in three cases, in which tumor invasion into the MPDs was pathologically confirmed. Furthermore, the tumors having mild to severe fibrosis pathologically invaded into the peripancreatic lymphatics or nerves.

Conclusion: It would be characteristic of carcinoid tumor of the pancreas to be well enhanced at the arterial dominant phase on dynamic CT, and to highly invade into the MPDs and the peripancreatic lymphatics or nerves.

Key words: Pancreas—Carcinoid tumor—Dynamic CT—Main pancreatic duct

Carcinoid tumor of the pancreas is a rare endocrine tumor originating in the pancreatic argentaffin cells with serotonin secretion. According to a recent pathological report [1], carcinoid tumor of the pancreas was found in only 1.4% (156/11,343 cases) of the entire carcinoid group. There are few case reports [2–6] describing the CT or magnetic resonance imaging (MRI) findings. However, its contrast-enhancement behavior on dynamic CT study has not been documented.

We report the dynamic CT and MRI features of carcinoid tumor of the pancreas in four patients, with pathological correlation.

Materials and methods

Patients

Our review of pathological records at two institutions from 1999 to 2006 resulted in the identification of 4 patients (3 female and one male) with histopathologically proved carcinoid tumor of the pancreas. All patients underwent preoperative dynamic CT and MRI. Patient age at the time of the diagnosis ranged from 30 to 66 years (mean age, 54 years). In all patients the pancreatic mass was indicated by US or CT screening. Only one patient (Case 1) had a symptom of diarrhea for 9 months. The serum amylase level was slightly elevated in 2 patients (Cases 1 and 2), but the tumor markers (CA19-9, CEA) were normal in all cases. All patients underwent complete tumor resection and the clinical courses after surgical operation were uneventful with follow-up periods of 5–85 months (mean, 32.5 months).

Scanning technique

Dynamic CT was performed in all 4 patients. Two patients were scanned on single-detector helical CT scanners (HiSpeed Advantage, GE Medical Systems,

Milwaukee, WI), and other two patients were scanned on multidetector scanners (Aquilion 32 detectors, Toshiba Medical Systems, Tokyo, Japan). All triple-phase dynamic CT images were obtained at 40 (arterial dominant phase), 70 (portal venous phase), and 150 s (delayed phase) after starting the infusion of contrast medium. A total of 100 mL contrast medium (Iopamiron 370; Nihon Schering, Osaka, Japan, or Omnipaque, Daiichi, Tokyo, Japan) was infused at a rate of 3 mL/s with a power injector.

Scanning parameters were used as follows: single detector CT: 120 kVp, 200–250 mAs, 5 mm collimation, a pitch ratio of 1:1, and 5 or 2.5 mm reconstruction; multidetector CT: 120 kVp, 400 mAs, 27 × 1 mm collimation, a rotation time of 0.5 s, a pitch of 0.6 (table speed = 42 mm/s), and a 1 mm reconstruction thickness.

MRI was performed using a 1.5-T superconducting unit (Signa; GE Medical Systems, Milwaukee, WI, USA) with a phased-array body coil. T1-weighted (spin echo [SE] 400–600 ms/15–35 ms = repetition time [TR]/echo time [TE]) and T2-weighted images (WI) (SE 2000–3500 ms/70–110 ms) images were obtained with 6 mm section thickness and 1.5 mm intersection gap.

Imaging analysis

Imaging and pathologic findings were retrospectively evaluated with the consensus of two experienced radiologists (RT, YY) by focusing on the following features: location of the tumor in the pancreas, maximal transverse diameter of the tumor, intratumor condition (homogeneity, the presence of calcifications), fibrous capsule, contrast-enhancement behavior on the dynamic images, invasion into the main-pancreatic duct (MPD), direct invasion into the peripancreatic tissues (peripancreatic veins, etc.), or metastases (liver, lymph nodes, etc.).

Results

The tumor could not be detected on precontrast-enhanced CT in all 4 cases, because of iso-attenuation of the tumor compared to the surrounding pancreatic parenchyma. On dynamic CT (Table 1), the tumor showed homogeneous enhancement in all but one case (Cases 1–3, Fig. 1). The remaining one case showed

rim-like enhancement that was most clearly seen at the delayed phase (Case 4, Fig. 2). The tumor was located at the pancreatic head in two cases, the body in one case, and the tail in one case. The tumor size in the maximal transverse diameter ranged from 15 to 20 mm (average size, 17 mm) on CT. There was only one case showing punctate calcifications in the tumor. The tumor was most conspicuous at the arterial dominant phase (40 s) and the portal venous phase (70 s) in 2 cases each. Regarding the time-attenuation curves (Fig. 3), all but one case showed a peak of enhancement at the arterial dominant phase. The remaining one showed a peak of enhancement at the portal venous phase with prolonged contrast-enhancement effect.

Dilatation of the MPD, which was suggestive of tumor invasion into the MPD, was (Cases seen in three cases 1–3, Fig. 1). There were no findings suggesting direct invasion into the peripancreatic tissues or distant metastases on CT.

On MRI, all of the tumors showed homogeneous, low signal intensity (SI) compared to the surrounding pancreatic parenchyma on T1-WI (Fig. 1). On T2-WI, the tumor showed high SI relative to the surrounding pancreatic parenchyma in two cases (Fig. 1, 2), iso-SI in one case, and low SI in one case. On T2-WI, the low SI rim was identified in one case (Case 4, Fig. 2). MPD dilatation was also observed in 3 cases. These 3 cases showed narrowing of MPD. There were no findings suggesting direct invasion into the peripancreatic tissues or distant metastases.

On pathologic examinations (Table 2), it was found that the tumor size ranged from 11 to 18 mm (mean, 14.5 mm). Pathologically, the tumor had mild to severe fibrous stroma. Case 1, having the most conspicuous fibrous stroma, showed a peak of enhancement at the portal venous phase in contrast to the other cases showing that at the arterial dominant phase. Fibrous capsule was seen in Case 4 (Fig. 2), which was well correlated with the rim-like enhancement on dynamic CT and the low SI rim on T2-weighted MRI. In three cases showing the dilated MPD on CT and MRI, direct tumor invasion was pathologically confirmed. In contrast to CT and MRI findings, pathologic examinations revealed tumor invasion into the parapancreatic tissues, including the lymphatics or extrapancreatic nerves.

Table 1. CT findings of carcinoid tumors of the pancreas

Case	CT findings				
	CE effect	Most conspicuous phase	Peak phase of CE	MPD dilatation	Ring enhancement
1	Homogeneous	PV	PV	+(10 mm)	–
2	Homogeneous	A	A	+(5 mm)	–
3	Homogeneous	PV	A	+(22 mm)	–
4	Inhomogeneous	A	A	–	+

Note: CE: contrast enhancement, PV: portal venous phase, A: arterial phase
MPD: main pancreatic duct

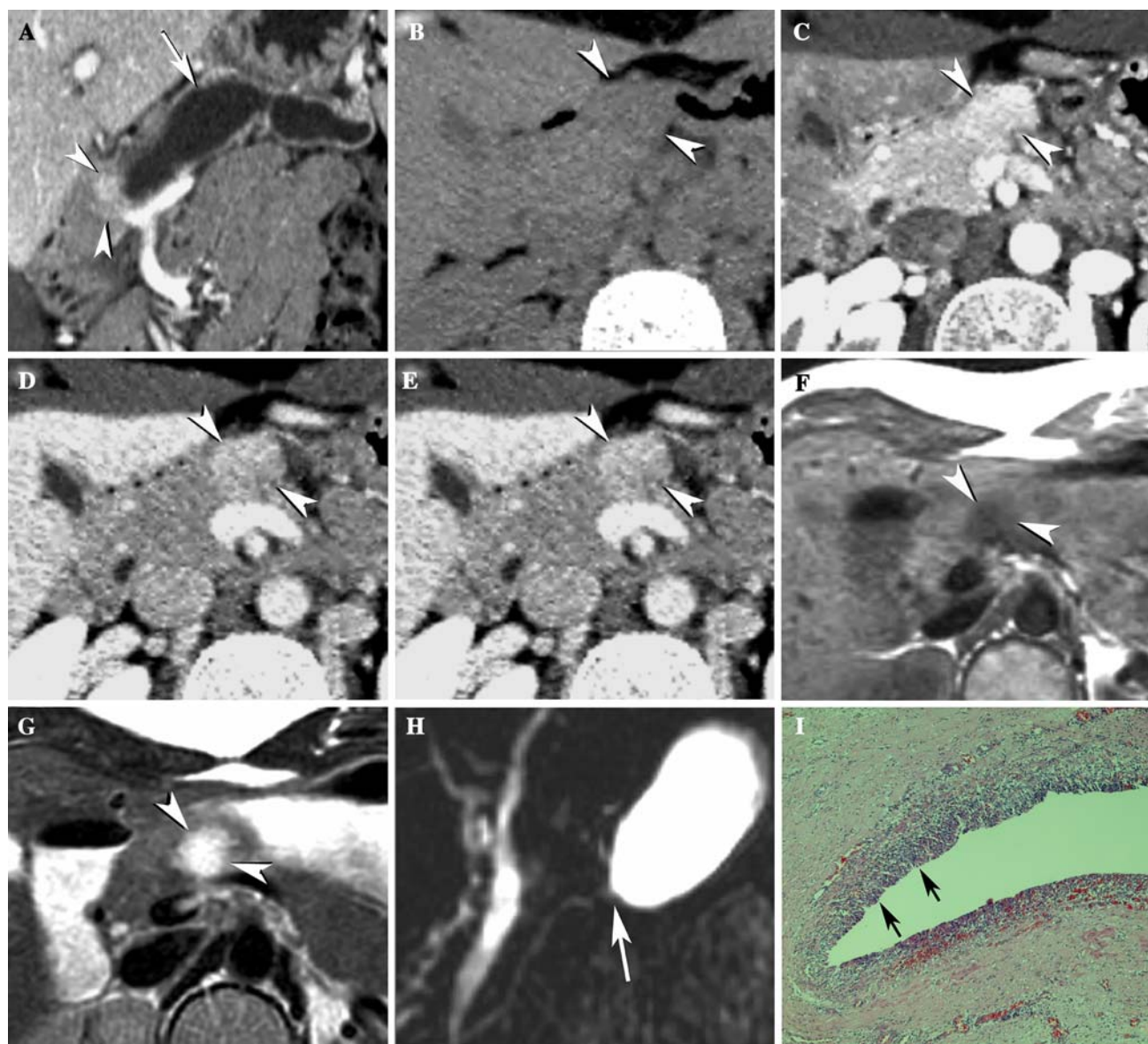


Fig. 1. Case 3: A 30-year-old female. **A** On postcontrast MDCT with coronal curved planar reformations obtained through the main pancreatic duct (MPD), the dilated MPD (*arrow*) and hyperattenuating tumor (15 mm in size) (*arrowheads*) in the pancreatic body is demonstrated. **C--E** On three-phase dynamic CT, the peak of enhancement of the tumor (*arrowheads*) is seen at the arterial dominant phase (**C**). The CT attenuation values are relatively maintained until the delayed

phase. CT attenuation values of the tumor are 55 HU in pre-contrast-enhanced images (**B**), 204 HU in arterial dominant phase (**C**), 128 HU in portal venous phase (**D**), and 112 HU in delayed phase (**E**). **F--H** On MRI, the tumor (*arrowheads*) shows low signal intensity on T1-WI (**F**) and high signal intensity on T2-WI (**G**). MRCP shows severe stenosis of the MPD (*arrow* in **H**) and upstream MPD dilatation. **I** Microscopic examination shows the MPD invasion (*arrow*).

Discussion

Carcinoid tumors most commonly arise in the midgut (appendix or small intestine) and rarely in organs derived from the embryonic foregut, i.e., stomach or pancreas. Carcinoid tumor of the pancreas resembles other endocrine tumors and is differentiated only on the basis of the secretory substance in the tumor cells. The clinical diagnosis of carcinoid tumor is based on certain clinical

symptoms, including cutaneous flushing, diarrhea, and vascular heart disease.

Recently, Soga [1] analyzed 11,343 cases of carcinoid tumors in the entire organs, and 156 cases (1.4%) of carcinoid tumor of the pancreas were finally diagnosed. According to this report, the male-female ratio was 0.9 (72:84) and the average age of patients was 48.9 years. The tumors were 68.6 mm in average size and were

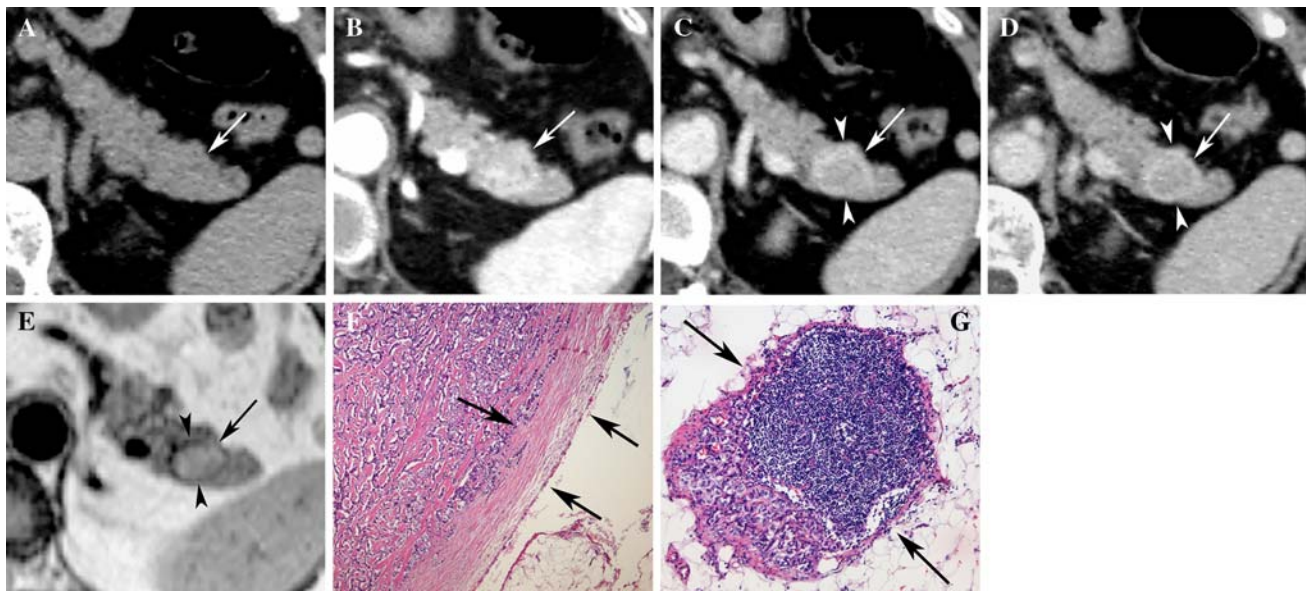


Fig. 2. Case 4: A 56-year-old female. **A–D** On three-phase dynamic CT, the peak of enhancement of the tumor (18 mm in size) is seen at the arterial dominant phase (**B**). The CT attenuation values are relatively maintained until the delayed phase. CT attenuation values of the tumor are 41 HU in precontrast-enhanced images (**A**), 165 HU in arterial dominant phase (**B**), 120 HU in portal venous phase (**C**), and 102 HU in delayed phase (**D**). Portal venous and delayed

phase CT images (**C** and **D**) demonstrates peripheral rim enhancement suggesting a fibrous capsule around the tumor (*arrowheads*). **E** On T2-weighted MRI, the tumor shows iso-signal intensity with low signal intensity peripheral rim (*arrowheads*). **F** and **G** Microscopic examination shows well-demarcated tumor with fibrous capsule (*arrows* in **F**). The tumor shows lymphatic invasion (*arrow* in **G**).

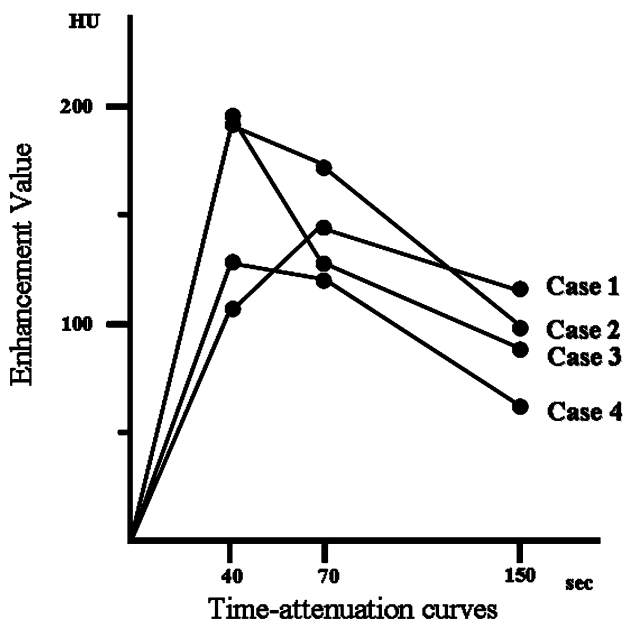


Fig. 3. Time-attenuation curves of carcinoid tumors of the pancreas in 4 cases. The tumor in Case 1 showed a peak of enhancement at the portal venous phase with prolonged contrast-enhancement effect and the tumors in Case 2–4 showed a peak of enhancement at the arterial dominant phase.

predominantly located in the pancreatic head (44.9%). Carcinoid syndrome was observed in 23.3% of the cases. In our cases, tumor size was small (average size, 14.5 mm); 2 of 4 cases were located in the head, and carcinoid syndrome was observed as a diarrhea in 1 case. According to earlier studies, carcinoid tumors of the pancreas showed a high metastatic rate (66.7%), and the five-year survival rate was extremely low ($28.9\% \pm 16.7\%$). In our cases, there were no distant metastases at a time of surgery and the clinical courses were uneventful after surgical operation. This is probably due to tumor detection at the relatively early stage (average size, 14.5 mm), although the tumor invasion to the peripancreatic tissues was highly seen on pathologic examinations.

According to our English literature review, there are few case reports of carcinoid tumor of the pancreas describing the CT and MRI findings [2–6]. In these cases, intratumoral calcifications, cystic changes, or marked contrast-enhancement were documented. However, there are no previous reports regarding its dynamic CT findings. In our cases, the tumors could not be clearly detected on precontrast-enhanced CT. On triple-phase dynamic CT, the tumors were most conspicuous at the arterial dominant phase (40 s) or portal venous phase (70 s). The time-attenuation curves of the tumors showed a peak of enhancement at the arterial dominant phase in

Table 2. Pathologic findings of carcinoid tumors of the pancreas

Case	Tumor size (mm)	Fibrous stroma	Fibrous capsule	MPD dilatation	Peripancreatic tissues invasion
1	15	Moderate to severe	–	+	–
2	14	Mild	–	+	Lymphatics
3	11	Moderate	–	+	Nerves
4	18	Mild	+	–	Lymphatics

Note: MPD: main pancreatic duct

three cases and at the portal venous phase in one; the latter showed the prolonged contrast-enhancement effect till the delayed phase. Pathologically, the tumors had mild to severe fibrous stroma and a case having a peak of enhancement at the portal venous phase had more fibrous stroma than the other three cases. It has been documented that pancreatic carcinomas show delayed enhancement due to the retention of contrast medium, reflecting a great amount of fibrous tissues histologically [7, 8]. Therefore, the peak of enhancement or the most conspicuous phase would be affected by the degree of fibrous stroma in the tumors. Regarding the contrast-enhancement pattern of other endocrine tumors on dynamic CT, King et al. [9] described that the enhancement values at the arterial phase images (30 s) were superior to that at the portal venous phase (70 s) in the small insulinomas. In turn, Ichikawa et al. [10] described that portal venous CT images were significantly superior to arterial phase CT images for pancreatic endocrine tumor detection. Therefore, the contrast-enhancement behavior of carcinoid tumor of the pancreas is thought to be similar to other endocrine tumors on dynamic CT. Villanueva et al. [3] reported that all four cases of carcinoid tumors of the pancreas had intratumoral calcifications. However, in our four cases, calcifications were seen in only one case.

Regarding MRI findings, Semelka et al. [6] described a case, which showed low SI on T1-WI, and iso-SI on T2-WI, with intense heterogeneous enhancement. In our cases, the tumors showed low SI on T1-WI, and low to high SI on T2-WI. The variable SI on T2-WI might be affected by the degree of fibrous stroma. In one case, thick low-SI rim was identified on T2-WI, which pathologically corresponded to the dense fibrous capsule. To our knowledge, carcinoid tumor of the pancreas having a fibrous capsule has never been reported, although solid pseudopapillary tumor of the pancreas is well known as having a fibrous capsule [11, 12]. Thus, this type of carcinoid tumor of the pancreas would be required to be differentiated from solid pseudopapillary tumor of the pancreas.

Several previous reports [2, 13–15] documented carcinoid tumors of the pancreas with obstructive pancreatitis, although the frequency has not clearly been mentioned. In our four cases, three (75%) showed dilatation of MPD distal to the tumor, in which the tumor invasion was pathologically confirmed. In other

endocrine tumors, obstructive pancreatitis caused by stenosis of MPD has seldom been reported [16]. Therefore, carcinoid tumor of the pancreas is thought to have high frequency of MPD involvement when compared to other endocrine tumors. The pancreas is formed from two endodermal buds from the dorsal and ventral surfaces of the portion of the foregut. Argentaffin cells are present along the entire foregut, including the pancreatic ducts and acini. Carcinoid tumors of the pancreas are considered to arise from these argentaffin cells [13]. Therefore, the high frequency of MPD invasion by carcinoid tumors is probably related to the origin of tumor cells being located in the MPD. Pathologically, the tumors invaded into the peripancreatic lymphatics or nerves in three cases, but CT and MRI could not sufficiently identify such pathological findings, and therefore, radiologists should recognize high malignant potential of carcinoid tumors of the pancreas, even though it is small in size.

In conclusion, carcinoid tumors of the pancreas are well enhanced with a peak of enhancement on the arterial dominant phase (40 s) or portal venous phase (70 s) on dynamic CT. Carcinoid tumor of the pancreas is highly associated with the dilatation of MPD on CT and MRI, suggesting tumor invasion. When a pancreatic mass shows a peak of enhancement mainly on the arterial dominant phase (40 s) and is accompanied by dilatation of upstream MPD, carcinoid tumor of the pancreas should be strongly considered.

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