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CT findings of pancreatic ductal adenocarcinoma at King Chulalongkorn Memorial Hospital: A study of 40 cases with histological verification

Ekkasit Swangjitmetta* Laddawan Vajragupta*
Nareumon Wisedopas** Nattaporn Tanpowpong*

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Background : *The incidence of pancreatic cancer has been increasing. CT scan is effective and standard modality for imaging of pancreatic cancer.*

Objective : *To describe CT findings in pancreatic ductal adenocarcinoma at King Chulalongkorn Memorial Hospital and to subgroup analyze the enhancement patterns and presence of metastasis of each histological grading.*

Setting : *Department of Radiology and Department of Pathology, Faculty of Medicine, Chulalongkorn University*

Design *Retrospective descriptive study*

Materials and Methods : *Preoperative dual phase abdominal CT scans and pathological reports of 40 patients with pancreatic adenocarcinoma in King Chulalongkorn Memorial Hospital from 2003 to 2008 were retrospectively reviewed.*

* Department of Radiology, Faculty of Medicine, Chulalongkorn University
** Department of Pathology, Faculty of Medicine, Chulalongkorn University

Results : *In 40 patients, 13 were male and 27 were female with their mean age of 61.9 ± 2.36 years old. Most common location was pancreatic head in 29 patients. The tumor size ranged from 1.4-10.9 cm with the mean of 3.9 cm. On the precontrast study, 28 tumors were isodense and 12 tumors were hypodense. On arterial phase, all were hypodense. On portovenous phase, 36 tumors were hypodense and 4 tumors were isodense. Pancreatic duct dilatation was seen in12 patients (30%) and bile duct dilatation was seen in13patients (32.5%). Arterial involvement was seen in 22 patients (55%); the splenic artery was the most commonly involved. Venous involvement was seen in 27 patients (67.5%); the splenic vein and SMV were the most commonly involved. Adjacent organ invasion was seen in 17 patients (42.5%); the duodenum was the most commonly involved. Regional node involvement was seen in 12 patients (30%); the aortocaval node was the most commonly involved. Metastasis was seen in 15 patients (37.5%); liver metastasis was the most common. There was no statistically significant correlation of enhancement pattern and the presence of metastasis with tumor grading.*

Conclusion : *The most common CT findings of pancreatic ductal adenocarcinoma was ill-defined mass with hypodensity on arterial phase. The most common location was pancreatic head. There was no statistically significant correlation of enhancement pattern and the presence of metastasis with tumor grading.*

Keywords : *CT, enhancement pattern, metastases, pancreas, pancreatic ductal adenocarcinoma, tumor grading.*

Reprint request: Wisedopas N. Department of Pathology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

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เอกสิทธิ์ สว่างจิตเมตตา, ลัดดาวัลย์ วัชระคุปต์, นฤมล วิเศษโอภาส, ณัฐพร ตั้นเผ่าพงษ์. ลักษณะภาพเอกซเรย์คอมพิวเตอร์ของมะเร็งตับอ่อนชนิดดักตัลอะดีโนคาร์ซิโนมาในโรงพยาบาลจุฬาลงกรณ์ : การศึกษาในผู้ป่วย 40 รายที่มีผลยืนยันทางพยาธิวิทยา. จุฬาลงกรณ์เวชสาร 2553 พ.ย. – ธ.ค.; 54(6): 563 – 80

เหตุผลของการทำวิจัย : *อุบัติการณ์ของมะเร็งตับอ่อนในปัจจุบันเพิ่มขึ้นเรื่อย ๆ เอกซเรย์คอมพิวเตอร์เป็นการตรวจที่เป็นมาตรฐานและมีประสิทธิภาพ*

วัตถุประสงค์ : *เพื่อบรรยายลักษณะภาพเอกซเรย์คอมพิวเตอร์ของมะเร็งตับอ่อนชนิดดักตัลอะดีโนคาร์ซิโนมาในโรงพยาบาลจุฬาลงกรณ์ และหาความสัมพันธ์ระหว่าง Histological Grading กับรูปแบบ Enhancement และการกระจายไปอวัยวะอื่น*

สถานที่ทำการศึกษา : *ภาควิชารังสีวิทยาและพยาธิวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์-มหาวิทยาลัย*

รูปแบบการวิจัย : *การศึกษาย้อนหลังเชิงพรรณนา*

ตัวอย่างและวิธีการศึกษา : *โดยการวิเคราะห์ภาพเอกซเรย์คอมพิวเตอร์ก่อนการผ่าตัดและรายงานผลทางพยาธิวิทยาของผู้ป่วยมะเร็งตับอ่อน 40 ราย ในโรงพยาบาลจุฬาลงกรณ์ ตั้งแต่พ.ศ. 2546 - 2551*

ผลการศึกษา : *จากผู้ป่วย 40 ราย เป็นชาย 13 ราย และหญิง 27 ราย อายุเฉลี่ย 61.9 ± 2.36 ปี ตำแหน่ง ที่พบรอยโรคมากสุดคือ pancreatic head (29 ราย, 72.5%) ขนาดก้อนอยู่ระหว่าง1.4 -10.9 ซม. (เฉลี่ย 3.9 ซม.) ก้อนใน 28 รายให้ลักษณะ isodense และ 12 รายให้ลักษณะ hypodense ใน precontrast study ก้อนในทุกรายให้ลักษณะ hypodense ใน arterial phase ก้อนใน 36 รายให้ลักษณะ hypodense ใน portovenous phase ท่อตับอ่อนขยายตัวพบใน 12 ราย (30%) ท่อน้ำดีขยายตัวพบใน 13 ราย (32.5%) Arterial involvement พบใน 22 ราย (55%) พบมากสุดที่ splenic artery และ venous involvement พบใน 27 ราย (67.5%) พบมากสุดที่ splenic vein และ SMV การลุกลามอวัยวะข้างเคียงพบใน17 ราย (42.5%) พบมากสุดที่ดูโอดีนัม การกระจายไปต่อมน้ำเหลืองพบใน12ราย (30%) พบมากสุดที่ aortocaval node การกระจายไปอวัยวะอื่น พบใน15 ราย (37.5%) พบมากสุดที่ตับ ไม่มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติ ระหว่าง histological grading กับรูปแบบ enhancement และการกระจายไปอวัยวะอื่น*

สรุป : *ลักษณะภาพเอกซเรย์คอมพิวเตอร์ของมะเร็งตับอ่อนชนิดดักตัลอะดีโนคาร์ซิโนมาที่พบมากสุดคือก้อนขอบไม่ชัดเจน, hypodense ใน arterial phase ตำแหน่งที่พบมากที่สุด คือ pancreatic head การลุกลามเส้นเลือดมีผลต่อการวางแผนการผ่าตัด ไม่มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติ ระหว่าง histological grading กับรูปแบบ enhancement และการกระจายไปอวัยวะอื่น*

คำสำคัญ : *เอกซเรย์คอมพิวเตอร์, รูปแบบ enhancement, การกระจายไปอวัยวะอื่น, ตับอ่อน, มะเร็งตับอ่อน, tumor grading.*

The incidence of pancreatic cancer has been increasing over the past 40 years.[1] In the United States, pancreatic cancer is the fourth leading cause of cancer deaths.[2] More than 90% of patients present in the late stage of the disease. This observation emphasizes the role of radiology in early detection and determination of the resectability of the tumor.

CT scan is the standard imaging modality for the diagnosis and determination of the resectability of pancreatic cancer.[3] The objectives of this study are to describe CT findings in pancreatic ductal adenocarcinoma at King Chulalongkorn Memorial Hospital and to subgroup analyze the enhancement patterns and presence of metastasis of each histological grading.

Materials and Methods

There were 66 patients with definite pathological diagnosis of pancreatic ductal adeno carcinoma at King Chulalongkorn Memorial Hospital from January 1, 2003 to December 31, 2008. Forty of them were recruited in this study. We excluded 22 patients: eight of them were due to no available CT scans in PACS (Picture Archiving and Communication System); four had no dual phase contrast CT study; and, 14 only had available CT scan of post surgery or post intervention. Preoperative dual phase abdominal CT scan and pathological reports of all the 40 cases were retrospectively reviewed. We analyzed CT findings, enhancement pattern and presence of metastasis of each histological grading.

Pathological criteria[4]

Well-differentiated adenocarcinomas are defined as the tumors form well-defined glands. The glands are complete, and the neoplastic cells are cuboidal to columnar with basally oriented uniform round to oval nuclei with evenly dispersed chromatin. Intensive mucin production is present. Only minimal nuclear pleomorphism is seen. Mitoses are not more than five per high power field. The gland formation in moderately differentiated adenocarcinoma is less well-defined with incomplete glandular lumina and nuclear pleomorphism. The nucleoli are larger and more irregular. Mitoses are 6-10 per high power field and may be atypical. Poorly differentiated adenocarcinomas are composed of poorly formed glands, with individual infiltrating cells and solid areas. Mucin production is abortive. Nuclear pleomorphism is prominent with large bizarre nuclei and the nucleoli are large, multiple and more irregular. Mitoses, including atypical mitoses, are seen more than 10 per high power field.

CT Protocol

Siemens Somatom Sensation Plus 4 is used with 4 mm slice width, 2.5 mm collimator, 12.5 mm feed per rotation and 0.5 sec rotation time. The Somatom Sensation Plus 16 is used with 16x1.5 mm collimator, 24.0 mm feed per rotation and 0.5 sec rotation time (140 mAs, 120 kVp and pitch = 1).

A bolus injection 3-4 ml/sec of 100 ml non-ionic contrast medium was done with the bolus tracking placed at the abdominal aorta and the threshold is 100 HU. Then arterial and portovenous phases were obtained by the location of monitoring in mid hepatic level for upper abdomen studies or just above the level of the pancreas for pancreatic protocol. The images of arterial phase were obtained at about 30-35 seconds and portovenous phase were

obtained at 65-70 seconds after contrast injection.

CT Findings Review

Two gastrointestinal radiologists retrospectively reviewed the CT findings from PACS independently in aspect of the followings: (In case of different opinion, the images were interpreted by consensus.)

1. Location: head, uncinate, body, tail, more than one compartment
2. Tumor size: 2 cm or less, more than 2 cm but not more than 4 cm, more than 4 cm
3. Margin: well-defined, ill-defined
4. Density and enhancement (relative to normal pancreatic tissue in precontrast, arterial and portovenous phases): hyperdense, isodense, hypodense
5. Homogeneity: homogeneous, heterogeneous
6. Main pancreatic duct dilatation: absent, present
7. Bile duct dilatation: absent, present
8. Vascular involvement: absent, arterial involvement, venous involvement
9. Adjacent organ invasion: absent, present
10. Regional lymph nodes enlargement: absent, present
11. Metastasis: absent, present

Image Analysis and Operational Definitions

Tumor size was measured at its longest diameter by the caliper tool on PACS.

Tumor density was measured in Hounsfield unit (HU) by drawing a region of interest (ROI) of each lesion and computed by CT software and was compared with a normal pancreas in the same phase. The ROI of 0.5 cm^2 was used in normal pancreas and the lesions smaller than 4 cm and ROI of 1 cm^2 was used in the lesions of 4 cm or more. Hypodense lesion was defined as density of the lesion lower than 10 HU as compared to a normal pancreas. Density of the lesion less than or equal to 10 HU different from of a normal pancreas was defined as isodense. Hyperdense lesion was defined as density of the lesion greater than 10 HU of normal pancreas.[5 - 8]

Main pancreatic duct dilatation was defined as the diameter of dilated portion was greater than 5 mm in the head and 3 mm in the tail. Bile duct dilatation was defined when the largest diameter of the common bile duct that exceeded 8 mm and/or of common hepatic duct that exceeded 6 mm.[9,10]

CT findings of major arterial involvement included obliteration of the normal fat between the pancreatic margin and the adjacent vessel, greater than 180-degree contact between the tumor and the vessel, and morphologic changes of the artery including narrowing or encasement of the affected artery.[9,10]

Criteria for venous invasion included greater than 180-degree contact with a soft tissue mass and the vein. Collateral venous channels and another characteristics such as “tear drop” configuration of the superior mesenteric vein were also be assessed.[10]

Adjacent organ invasion was defined as interrupted, obliterated or loss of fat plane between the pancreas and the adjacent structures.[10]

Regional lymph nodes involvement[11] was evaluated by short axis diameter. The criteria were as followings: retrocrural and porta hepatis nodes exceeded 6 mm; gastrohepatic ligament nodes

exceeded 8 mm; and, pancreaticoduodenal, perisplenic, retropenitoneal, celiac axis, mesenteric nodes exceeded 10 mm or multiple slightly smaller (8-10 mm) in these regions containing necrotic area.

Correlations of enhancement pattern and presence of metastases with tumor grading were evaluated by Fisher's exact test using SPSS program. Interobserver agreement was evaluated by Kappa analysis.

Results

In 40 patients, 13 were male and 27 were female. The age of the patients ranged from 29 to 83 years old with the mean of 61.9 +/- 2.36 years and median of 63 years. Pathological diagnoses were obtained from surgical specimens (Whipple operation and *en bloc* resection) in 22 patients and from FNA, biopsy under ERCP or core needle biopsy in 18 patients.

The histological grading was well-differentiated in 14 patients (35%), moderately-differentiated in 12 patients (30%), poorly-differentiated in six patients (15%) and not available in eight patients (20%).

All patients revealed a single pancreatic mass with tumor location shown in Figure 1. The most common location was the pancreatic head in 29 cases (72.5%), followed by pancreatic body in 15 cases (37.5%).

Tumor size ranged from 1.4 to 10.9 cm with the mean of 3.9 cm. Six tumors (15%) were less than 2 cm, 18 (45%) were 2-4 cm and 16 (40%) were more than 4 cm in size.

On precontrast study, 28 tumors (70%) were isodense and 12 tumors (30%) were hypodense. All tumors were hypodense on arterial phase. On portovenous phase, 36 tumors (90%) were hypodense and 4 tumors (10%) were isodense. (Fig 2 and 3)

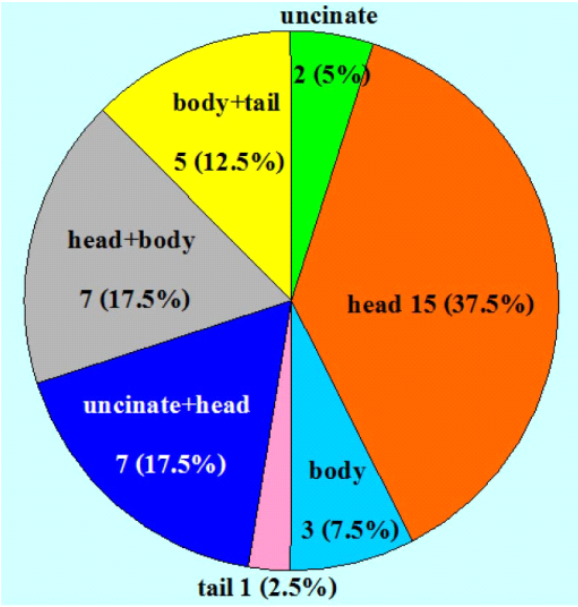


Figure 1. Pie chart reveals percentage of tumor location.

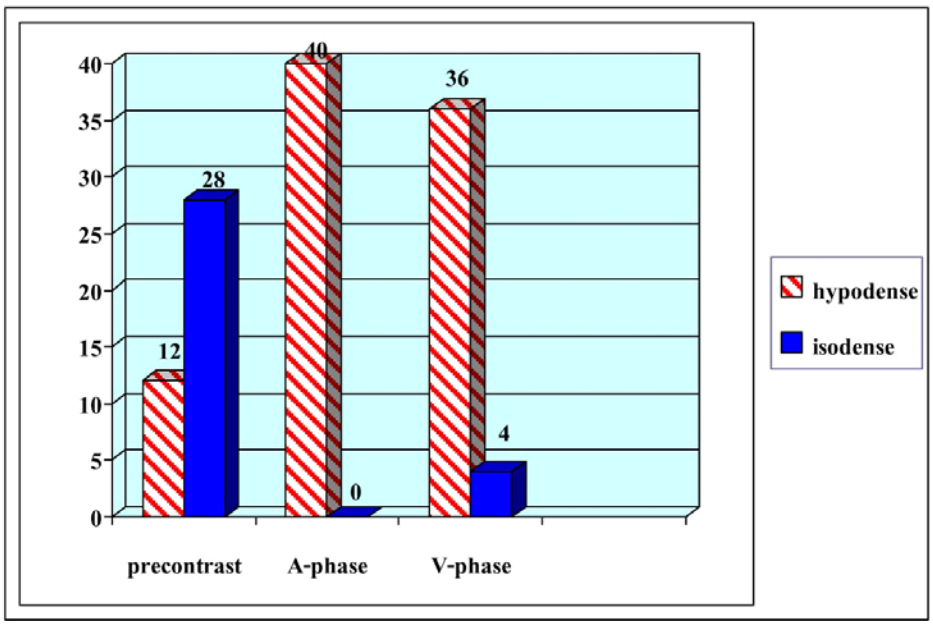
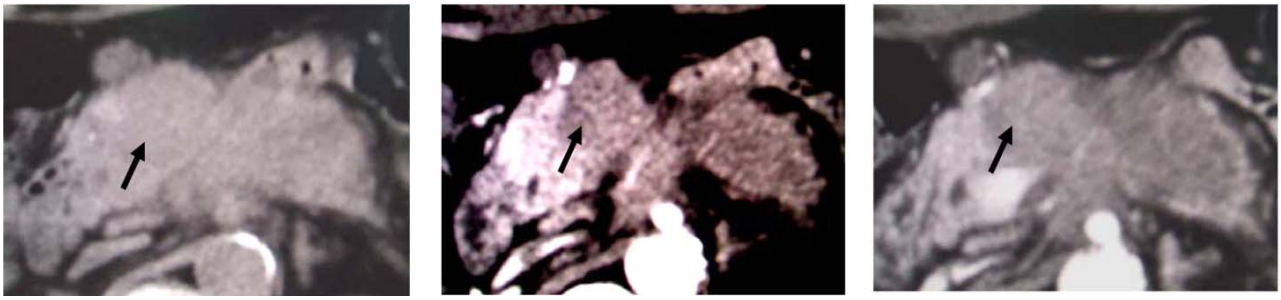


Figure 2. Histogram demonstrates number of tumor in each density on precontrast study, arterial phase (A-phase) and portovenous phase (V-phase).



a) b) c)

Figure 3. A 68-year-old patient with an ill-defined heterogeneous pancreatic ductal adenocarcinoma in the pancreatic body (poorly-differentiated adenocarcinoma). The tumor (indicated by arrows) revealed isodensity on the precontrast study (a), hypodensity on the arterial (b) and the portovenous phases (c).

There was no statistically significant correlation between histological grading and enhancement pattern (P-value = 1 in precontrast study and P-value = 0.498 in portovenous phase) as shown in Table 1.

Tumors with ill-defined margin (see Fig 3) were seen in 38 patients (95%). Tumor with well-defined margin was found in two patients (5%). Cystic degeneration within the tumor was seen in the two cases with well-defined margin. (Fig 4)

Tumors with heterogeneous were detected in 33 patients (82.5%). (see Fig 3) Tumor with homogeneous density on pre and post contrast enhanced studies were seen in seven patients (17.5%).

Table 1. Tumor density of each histological grading.

Histological grading	Precontrast		Arterial phase		Portovenous phase	
	Hypodense	Isodense	Hypodense	Isodense	Hypodense	Isodense
Well-differentiated	4	10	14	0	11	3
Moderately-differentiated	3	9	12	0	11	1
Poorly-differentiated	2	4	6	0	6	0
P-value	1.000		-		0.498	

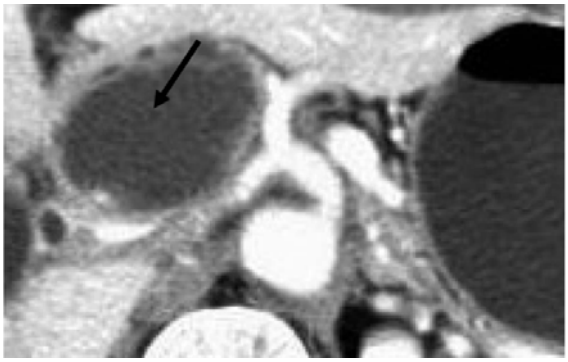


Figure 4. CT scan of a 63-year-old patient with poorly-differentiated pancreatic adenocarcinoma at pancreatic head shows a well-defined cystic tumor (arrowed).

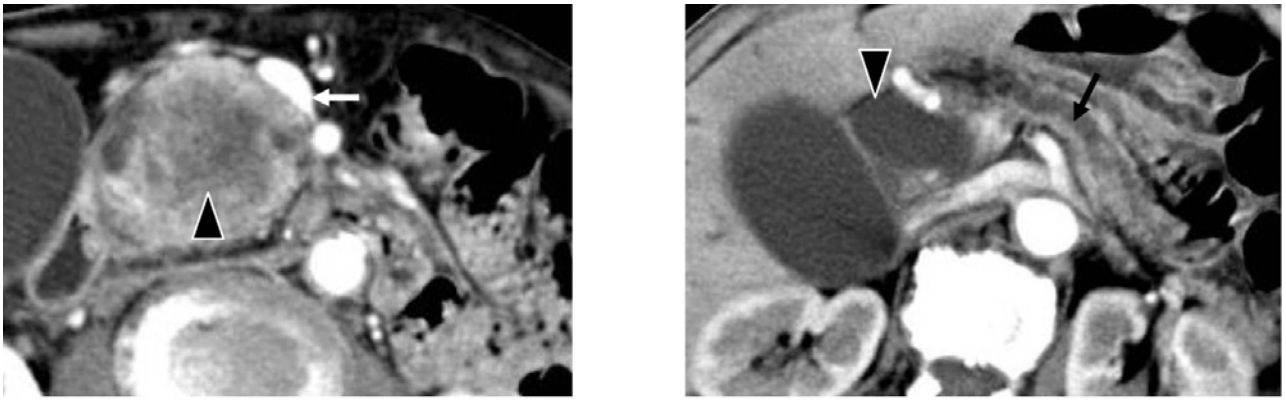
There were 28 patients (70%) with pancreatic duct dilatation (Fig 5b) and 12 patients (30%) without pancreatic duct dilatation. Tumors at the pancreatic head and/or uncinate process with pancreatic duct dilatation were depicted in 24 of 28 patients. Another four tumors were located in the pancreatic body or tail and the tumors were greater than 4 cm in size.

Bile duct dilatation was found in 27 patients (67.5%) (see Fig 5b and Fig 6a). All tumors with bile duct dilatation located in the pancreatic head and/or uncinate.

Arterial involvement was depicted in 22 patients (55%). The most common arterial involvement was the splenic artery in 11 patients (Figure 7a); following by SMA in eight patients, the celiac trunk in six patients, the common hepatic artery in six patients, the gastroduodenal artery in six patients (Fig 6b) and the aorta in one patient.

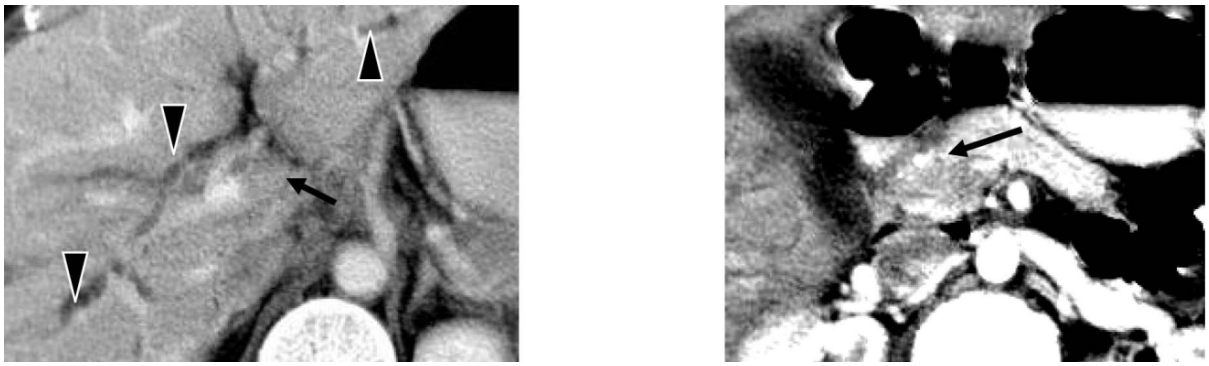
Twenty-seven patients (67.5%) had venous involvement by the tumors. The most common venous involvement were splenic vein (Fig 7b) and SMV (Fig 5a) each in 16 patients, following by portal vein (Fig 6a) in 9 patients, IVC in 2 patients and left renal vein in 1 patient.

Seventeen tumors (42.5%) revealed adjacent organ invasion. Invasion of the duodenum (Fig 8a) was found in 10 patients; followed by the stomach (Fig 8b) in 7 patients, hepatoduodenal ligament in one patient (see Fig 6a); the colon (splenic flexure) in one patient and the spleen in one patient.



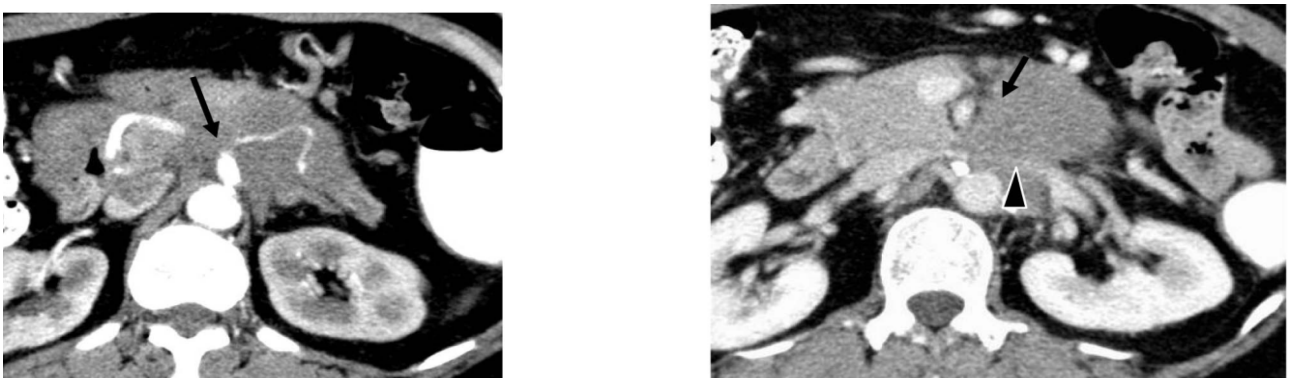
a) b)

Figure 5. CT scan on arterial phase of a 68-year-old patient with a hypodense mass at the pancreatic head and uncinate process (poorly-differentiated adenocarcinoma) seen as in : (a) (arrowhead) with tear-drop configuration of SMV (white arrow) representing SMV involvement; (b) the mass causes dilatation of CBD (arrowhead) and pancreatic duct (arrowed) or double duct sign.



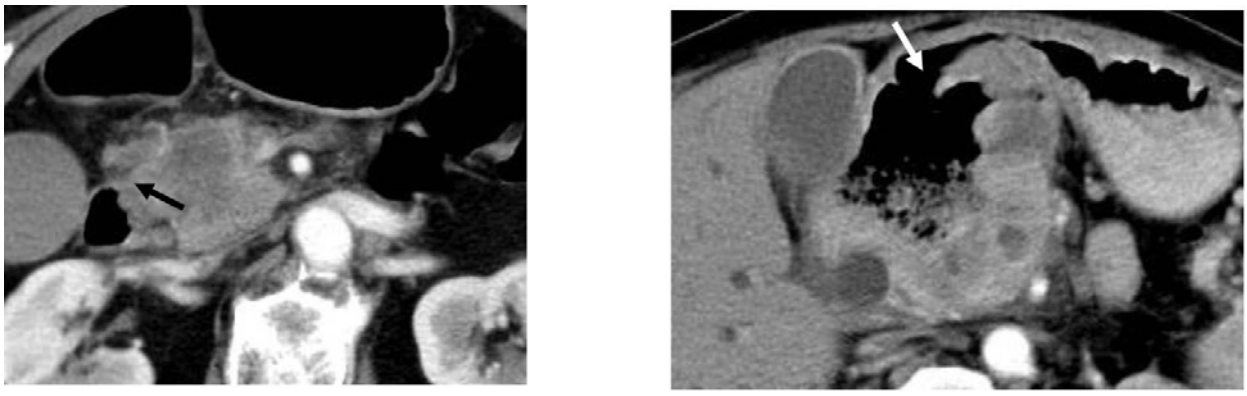
a) b)

Figure 6. (a) CT scan of a 54-year-old patient with diagnosis of moderately-differentiated pancreatic adenocarcinoma demonstrates intrahepatic duct dilatation in both hepatic lobes (arrowheads). There is an ill-defined soft tissue density invading and causing pressure effect to posterior aspect of deformed right main portal vein (arrowed), representing hepatoduodenal ligament and portal vein involvement. (b) CT scan of the same patient reveals an ill-defined pancreatic mass encasing gastroduodenal artery (arrowed), representing GDA involvement.



a) b)

Figure 7. CT scan of a 59-year-old patient with diagnosis of well-differentiated pancreatic adenocarcinoma shows a hypodense mass on the arterial phase at the pancreatic body and tail encasing the celiac trunk and the splenic artery (arrowed in a). The mass on the portovenous phase also causes splenic vein occlusion (arrowed in b) and encased the left renal vein (arrowhead in b).

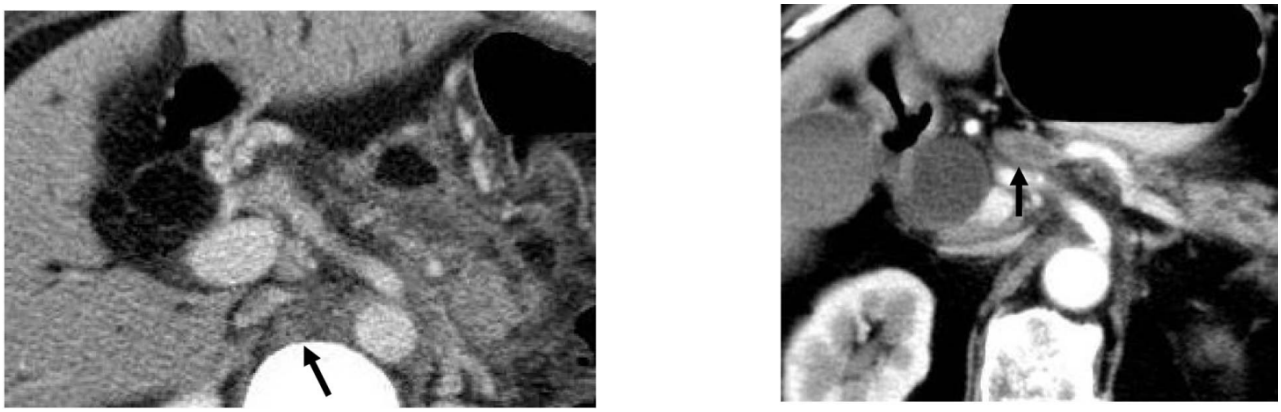


a) b)

Figure 8. Adjacent organ invasion. a) CT scan of a 67-year-old patient with diagnosis of moderately-differentiated pancreatic adenocarcinoma shows an ill defined hypodense mass at pancreatic head invading medial wall of the second part of duodenum (arrow). b) CT scan of a 61-year-old patient reveals a pancreatic mass invading the stomach causing a fistula between the stomach and the tumor (white arrow).

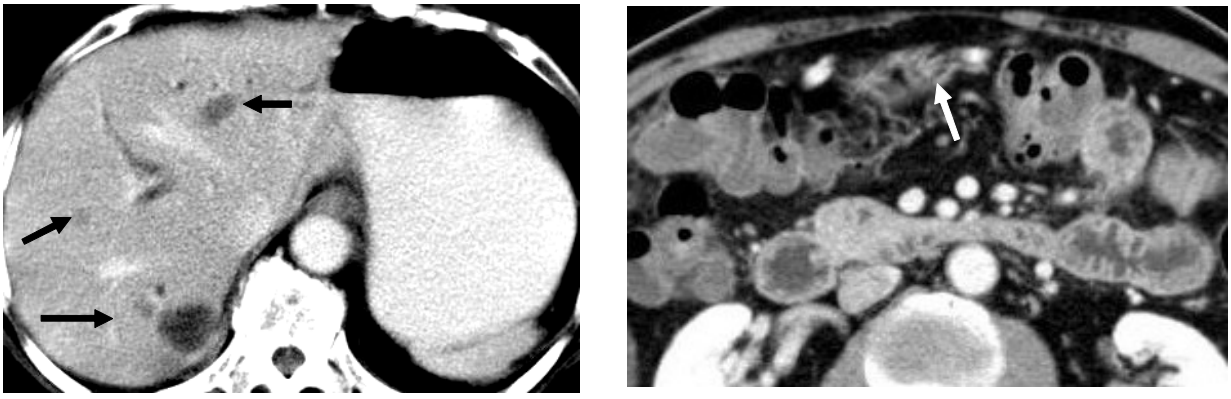
Regional node involvement was seen in 12 patients (30%). The most common nodal involvement was the aortocaval node (Fig 9a) in five patients; followed by the celiac node (Fig 9b) in three patients; the peripancreatic node in three patients, hepatoduodenal ligament node in three patients and the peripancreatic node in two patients.

Fifteen patients (37.5%) had metastases. Liver metastases were noted in 14 of 15 patients (Fig 10a); peritoneal and omental metastases in two patients (Fig 10b). Metastasis was detected in five of fourteen of well-diffentiated tumors, five of twelve of moderately-differentiated tumors and one of six of poorly-differentiated tumors. There was no statistically significant relationship between the histological grading and the presence of metastasis (P-value = 0.639).



a) b)

Figure 9. Regional node involvement. a) CT scan of a 62-year-old patient with diagnosis of well-differentiated pancreatic adenocarcinoma shows an enlarged aortocaval node (arrowed). b) CT scan of a 67-year-old reveals celiac node involvement with intranodal necrotic area (arrow).



a) b)

Figure 10. Metastasis. a). CT scan of a 67-year-old with diagnosis of moderately-differentiated pancreatic adenocarcinoma reveals multiple hepatic metastases (arrowed). b) CT scan of a 50-year-old shows enhancing soft tissue mass anterior to the transverse colon representing omental cake (arrowed).

Interobserver agreement was evaluated by Kappa analysis with kappa values of each item shown in Table 2.

Discussion

CT findings of pancreatic adenocarcinoma in our study is comparable to previously reported studies. Most common location is pancreatic head, similar to studies of Ward *et al*[12], Freeney *et al*[13] and Vajragupta *et al*.[14] Tumor size in our study ranged from 1.4 to 10.9 cm, not significantly different from those studies.

The attenuation pattern of the tumor in our study was corresponds to the study of Ward *et al*[12] which stated that opacity of solid pancreatic cancers was either the same or slightly less than that of

Table 2. Kappa values of each item.

Variables	Kappa value (K)
Location	0.802
Size	1.000
Margin	0.113
Density	1.000
Homogeniety	0.432
Pancreatic duct dilatation	0.875
Bile duct dilatation	1.000
Vascular involvement	0.651
Adjacent organ invasion	0.536
Regional node involvement	0.536
Metastases	0.838

($K \geq 0.75$ - excellent agreement, $0.40 \leq K < 0.75$ - good agreement , $K < 0.40$ - poor agreement)

adjacent normal pancreatic tissue on precontrast study and became accentuatedly hypodense after injection of the contrast agent.

We found that arterial phase provided superior tumor conspicuity to the precontrast and portovenous phases since all tumors were hypodense to normal pancreatic parenchyma, corresponding to many previous studies. The delayed time of the arterial phase in our institute was about 30 - 35 seconds after contrast injection which was comparable to the delayed time of pancreatic parenchymal phase in study of McNulty *et al*.[15] Their study showed that tumor conspicuity during the pancreatic parenchymal phase (delayed time = 35 seconds) and portovenous phase (delayed time = 60 seconds) was equivalent but superior to that during the arterial phase (delayed time = 20 seconds). Prokesch *et al*[7], Boland *et al*[16] and Lu *et al*[17] also showed that mean tumor to pancreas contrast in pancreatic phase (delayed time = 40 seconds) was higher than in portovenous phase (delayed time = 70 seconds). The study of Graf *et al*[18] showed that tumor conspicuity was significantly greater in the portovenous phase (delayed time = 60 seconds) than in the arterial phase (delayed time = 18 seconds).

However, exact delayed time of pancreatic and portovenous phases in each study may be slightly different due to different injection rate of contrast agent, type of scanners, scan time and protocol. Fukukura *et al*[19] showed that pancreatic parenchymal enhancement and tumor-to-pancreas contrast were significantly greater in autonomic bolus tracking than in empirical scan delay during pancreatic parenchymal phase. With no visible tumor-pancreas contrast for isoattenuating tumors, indirect signs such as mass effect, atrophy of pancreatic part distal to the tumor, and an interrupted duct sign are important indicators for the presence of tumor. A combination of pancreatic parenchymal phase and portovenous phase imaging is sufficient for the

detection of pancreatic adenocarcinoma and vascular involvement.

Our study (32 patients with available histological grading) revealed no significant correlation between enhancement pattern of the tumor and histological grading. The result contradicts to the study of Wang *et al*[20] (n = 34), which showed significant correlation between CT enhancement and histological grading. The extent of CT enhancement is inversely proportional to the degree of histological grading. Assessment of the correlation in both studies was different. Our study assessed attenuation on precontrast, arterial and portovenous phases with 2 degrees of density (isodense and hypodense) while their study assessed only pancreatic phase (arterial phase) with 4 degrees of enhancement. Statistical methods, therefore, were also different. Additionally, apart from tumor grading, enhancement of the tumor was influenced by many pathological factors. Hiroshi *et al*[21] showed that enhancement pattern was influenced by cellularity of tumor cells, coexisting acinar tissues, fibrosis, mucin and extent of necrosis. Hattori *et al*[22] proved that histological features affecting the enhancement pattern were angiogenesis (determined by vascular endothelial growth factor (VEGF) and microvessel density) and the extent of fibrosis.

The percentage of pancreatic duct and bile duct dilatation in our study is higher than those of Ward *et al*[12], Freeney *et al*[13] and Vajragupta *et al*.[14] Most tumors with pancreatic duct dilatation in our study were located at pancreatic head and/or uncinate. All tumors in the pancreatic body or tail with pancreatic duct dilatation were greater than 4 cm in size. All cases with bile duct dilatation in our study also revealed tumor located in pancreatic head and/or uncinate. This reflects that main pancreatic duct dilatation is mainly determined by the tumor location and tumor size. Tumor location also determines the presence of bile duct dilatation.

In light of vascular involvement, most common arterial involvement in the study of Ward *et al*[12] were *the* celiac axis and SMA while in our study was *the* splenic artery. The most common arterial and venous involvements in our study were similar to the study of Li *et al* [23], Lee *et al*[24] and Vajragupta *et al*.[14]

Most common adjacent organ invasion in our study was duodenum, also similar to studies of Freeney *et al*[13] and Vajragupta *et al*.[14]

In aspect of regional lymph nodes enlargement, the percentage in our study was higher than those of Ward *et al*, Freeney *et al*[13] and Diehl *et al*[25] but lower than that of Vajragupta *et al*.[14] The most common node involvement in our study was the aortocaval node while that in the study of Ward *et al*[12] was left paraaortic node.

The percentage of metastasis in our study was not significantly different from that of Ward *et al*[12], Freeney *et al*[13] and Vajragupta *et al*.[14] The liver is the most common organ of metastasis in all studies. We found that there was no significant correlation between histological grading and the presence of metastasis. There has been no study that proves the significant correlation between histological grading and metastasis.

Interobserver agreement in our study was excellent in most radiological features. Tumor margin was the only one showing poor agreement. This was probably due to varied subjective

perception of individuals to evaluate whether each tumor was ill-defined or poorly-defined. However, this feature does not significantly influence making diagnosis, determining tumor resectability or tumor staging. Cystic degeneration was the feature that shows obviously well-defined margin.

There were two cases with cystic degeneration which is uncommon condition of pancreatic adenocarcinoma and can be misdiagnosed as other cystic neoplasms of the pancreas. Cystic degeneration may be seen when the tumor increases in size and the majority tend to be large and poorly-differentiated tumors, with a single large cavity lined by tumor cells and containing hemorrhagic debris.[26] In our cases, one was well-differentiated and the other was poorly-differentiated. Cystic change in pancreatic adenocarcinoma should be considered in the differential diagnosis of a cystic pancreatic lesion, apart from the more common pseudocysts and true cystic pancreatic neoplasms.

We also found a 29-year-old male patient with pancreatic adenocarcinoma which is rare under the age of 40 years.[27] He had no underlying disease nor family history of pancreatic cancer. The presenting symptoms were abdominal pain and jaundice. CT scan showed a 1.6-cm ill-defined tumor at pancreatic head and uncinate. Whipple's operation was performed and the pathological findings revealed moderately-differentiated pancreatic ductal adenocarcinoma.

Luttges *et al*[28] reviewed of the literature from 1818 to 2001 and found 71 cases diagnosed as ductal adenocarcinoma in patients under 40 years of age. According to the WHO classification system of 1996 and data available in the reports, only 20 of these were thought by the authors to represent true ductal adenocarcinomas. Most were male patients. They and some other studies[29,30] noted that young patients with ductal adenocarcinoma of the pancreas tend to have special circumstances or familial predisposition. Genetic conditions associated with increased risk of pancreatic carcinoma include hereditary pancreatitis, hereditary pancreatic cancer syndrome, hereditary non-polyposis colon carcinoma, Peutz-Jeghers syndrome, familial atypical multiple mole melanoma, and the *BRCA2* gene. Imaging findings of pancreatic adenocarcinoma in younger patients is similar to those of the older age group.

Some limitations in our study should be considered. First, the number of cases was small. Assessment of statistically significant correlation of histological grading, enhancement pattern and presence of metastasis could be limited. Second, this study was performed retrospectively. Some cases did not have thin slices images for pancreatic region (pancreatic protocol) or sagittal or coronal reconstructions. These could make some difficulties in the evaluation of small structures especially vascular or adjacent organ involvements. However, the available images of those cases were satisfying and interobserver agreement was excellent and good in almost all the features to review.

Conclusion

The most common CT findings of pancreatic ductal adenocarcinoma are ill-defined heterogeneous mass with isodensity on precontrast phase and hypodensity on the arterial and portovenous phases. Most of the tumors are best depicted on the

arterial phase in which normal pancreas reveals homogeneous enhancement while the tumor reveals less enhancement. The most common location is pancreatic head. Pancreatic duct and bile duct dilatation mainly depend on the tumor location. The most common arterial and venous involvements are the splenic artery, splenic vein and SMV. Most common adjacent organ involvement, regional node involvement and metastatic site are duodenum, the aortocaval node and the liver, respectively. There is no statistically significant correlation between tumor grading and enhancement pattern or the presence of metastasis.

References

1. Office for National Statistics. Cancer Statistics Registrations: Registrations of cancer diagnosed in 2004, England. Series MB1 no.35. 2007
2. American Cancer Society. Cancer Facts & Figures 2005. Cancer, New York: American Cancer Society 2005:1–60.
3. Paspulati RM. Multidetector CT of the pancreas. Radiol Clin N Am. 2005 Nov;43(6):999-1020
4. Hruban RH, Fugushima N. Pancreatic adenocarcinoma: update on the surgical pathology of carcinomas of ductal origin and PanINs. Modern Pathology 2007; 20: S61–S70
5. Hollett MD, Jorgensen MJ, Jeffrey RB. Quantitative evaluation of pancreatic enhancement during dual-phase helical CT. Radiology 1995 May;195(2):359-61
6. Fletcher JG, Wiersema MJ, Farrell MA, Fidler JL, Burgart LJ, Koyama T, Johnson CD, Stephens DH, Ward EM, Harmsen WS.Pancreatic malignancy: Value of arterial, pancreatic and hepatic phase imaging with multi–detector row CT. Radiology 2003 Oct;229(1):81-90
7. Prokesch RW, Chow LC, Beaulieu CF, Bammer R, Jeffrey RB. Isoattenuating pancreatic adenocarcinoma at multi–detector row CT: Secondary signs.Radiology 2002 Sep;224(3): 764-8
8. Baron RL. Understanding and optimizing use of contrast material for CT of the liver. AJR 1994 Aug;163(2):323-31
9. Berland LL, Lawson TL, Foley WD, Geenen JE, Stewart ET. Computed tomography of the pancreatic duct: Correlation with pancreatic ductography. Radiology 1981 Dec;141(3): 715-24
10. Megibow AJ. Pancreatic neoplasms. In: Gore RM, Levine MS. Textbook of Gastrointestinal Radiology. 3th ed. Philadelphia: Saunder, 2008: 1915-31
11. Einstein DM, Singer AA, Cilcote WA, Desai RK. Abdominal lymphadenopathy: spectrum of CT findings. RadioGraphics 1991 May;11(3): 457-72
12. Ward EM, Stephens DH, Sheedy PF. Computed tomographic characteristics of pancreatic carcinoma: An analysis of 100 cases. Radiographics 1983 Nov;3(4): 547-65
13. Freeny PC, Marks WM, Ryan JA, Traverso LW. Pancreatic ductal adenocarcinoma: Diagnosis and staging with dynamic CT. Radiology 1988 Jan;166(1 Pt 1):125-33
14. Vajragupta L, Jirappapa B. CT Findings of pancreatic adenocarcinoma. Asean J Radiol 2002;3(1):21-8

15. McNulty NJ, Francis IR, Platt JF, Cohan RH, Korobkin M, Gebremariam A.Multi–detector row helical CT of the pancreas: Effect of contrast-enhanced multiphasic imaging on enhancement of the pancreas, peripancreatic vasculature, and pancreatic adenocarcinoma. Radiology 2001 Jul;220(1):97-102
16. Boland GW, O' Malley ME, Saez M, Fernandez-del-Castillo C, Warshaw AL, Mueller PR. Pancreatic-phase versus portal vein-phase helical CT of the pancreas: Optimal temporal window for evaluation of pancreatic adenocarcinoma. AJR 1999 Mar;172(3):605-8
17. Lu DS, Vedantham S, Krasny RM, Kadell B, Berger WL, Reber HA. Two-phase helical CT for pancreatic tumors: Pancreatic versus hepatic phase enhancement of tumor, pancreas, and vascular structures. Radiology 1996 Jun;199(3):697-701
18. Graf O, Boland GW, Warshaw AL, Fernandez-del-Castillo C, Hahn PF, Mueller PR. Arterial versus portal venous helical CT for revealing pancreatic adenocarcinoma: Conspicuity of tumor and critical vascular anatomy. AJR 1997 Jul;169(1):119-23
19. Fukukura Y, Takumi K, Kamiyama T, Shindo T, Higashi R, Nakajo M. Pancreatic adenocarcinoma: a comparison of automatic bolus tracking and empirical scan delay. Abdom Imaging [online] 2009 Jul 9. [Epub ahead of print] [cited 2009 Jul 9]:[8 screens]. Available from: http//www.springerlink.com/content/a572255v6j865768/fulltext.html
20. Wang ZQ, Li JS, Lu GM, Zhang XH,Chen ZQ, Meng K. Correlation of CT enhancement, tumor angiogenesis and pathologic grading of pancreatic carcinoma. World J Gastroenterol 2003 Sep;9(9):2100-4
21. Demachi H, Matsui O, Kobayashi S, Akakura Y, Konishi K, Tsuji M, Miwa A, Miyata S. Histological influence on contrast-enhanced CT of pancreatic ductal adenocarcinoma. J Comput Assist Tomogr 1997 Nov-Dec;21(6): 980-5
22. Hattori Y, Gabata T, Matsui O, Mochizuki K, Kitagawa H, Kayahara M, Ohta T, Nakanuma Y. Enhancement patterns of pancreatic adenocarcinoma on conventional dynamic multi-detector row CT: Correlation with angiogenesis and fibrosis. World J Gastroenterol 2009 Jul 7;15(25):3114-21
23. Li H, Zeng MS, Zhou KR, Jin DY, Lou WH. Pancreatic adenocarcinoma: the different CT criteria for peripancreatic major arterial and venous invasion. J Comput Assist Tomogr 2005 Mar-Apr;29(2):170-5
24. Lee JK, Kim AY, Kim PN, Lee MG, Ha HK. Prediction of vascular involvement and resectability by multidetector-row CT versus MR imaging with MR angiography in patients who underwent surgery for resection of pancreatic ductal adenocarcinoma. Eur J Radiol [online] 2008 Dec 12. [Epub ahead of print] [cited 2008 Dec 13]: 1-7. Available from: http://www.sciencedirect.com/
25. Diehl SJ, Lehmann KJ, Sadick M, Lachmann M, Georgi M. Pancreatic cancer: Value of dual-phase helical CT in assessing resectability. Radiology 1998 Feb;206(2): 373-8

26. Kosmahl M, Pauser U, Anlauf M, Klöppel G. Pancreatic ductal adenocarcinomas with cystic features: neither rare nor uniform. Mod Pathol 2005 Sep;18(9):1157-64

27. Chung EM, Travis MD, Conran RM. Pancreatic Tumors in Children: Radiologic-Pathologic Correlation. RadioGraphics 2006 Jul-Aug; 26(4):1211-38

28. Lüttges J, Stigge C, Pacena M, Kloppel G. Rare ductal adenocarcinoma of the pancreas in patients younger than age 40 years: an analysis of its features and a literature review. Cancer 2004 Jan 1;100(1):173-82

29. IvyEJ, Sarr MG, Reiman HM. Nonendocrine cancer of the pancreas in patients under age forty years. Surgery 1990 Sep;108(3): 481-7

30. Tersmette AC, Petersen GM, Offerhaus GJ, Falatko FC, Brune KA, Goggins M, Rozenblum E, Wilentz RE, Yeo CJ, Cameron JL, et al. Increased risk of incident pancreatic cancer among first-degree relatives of patients with familial pancreatic cancer. Clin Cancer Res 2001 Mar;7(3): 738-44