

## Pancreatic Neoplasms

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### Introduction

This discussion focuses on diagnosing and staging the various pancreatic neoplasms with computed tomography (CT) and magnetic resonance imaging (MRI) and addresses endosonography (EUS), positron emission tomography combined with CT (PET/CT), and somatostatin receptor scintigraphy (SRS or Octreoscan) where appropriate. To assess patients with suspected pancreatic disease, ultrasound (US), CT, and MRI have been used.<sup>1</sup> With the introduction of multi-detector row CT (MDCT), imaging of the pancreas has been further improved and even small lesions now can be diagnosed with a high degree of accuracy.<sup>2</sup> While MRI also has benefitted from technological advances and magnetic resonance cholangiopancreatography (MRCP) has helped improve assessment of the pancreatic and biliary ducts, MDCT remains the primary tool in evaluating patients with suspected pancreatic disease. EUS and MRI are used as problem-solving modalities to confirm suspected lesions not identified with CT, to find additional lesions, and to obtain a definitive tissue diagnosis with EUS-guided tissue sampling.<sup>3-8</sup> PET/CT in recent year has been increasingly employed for assessing patients with suspected pancreatic tumors, but its ultimate role awaits further definition.<sup>9-16</sup> Also, SRS has gained popularity in recent years for neuroendocrine tumors.<sup>17-20</sup>

### Ductal Adenocarcinoma

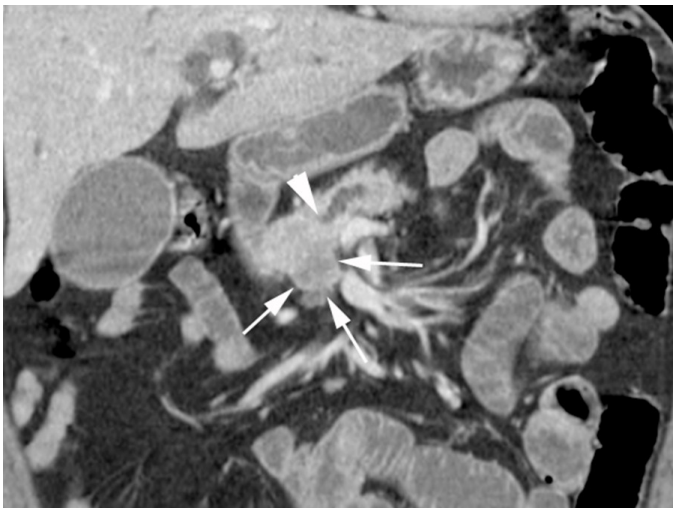
Pancreatic adenocarcinoma is the fourth leading cause of cancer death in the United States.<sup>21</sup> For 2012, it is estimated that 43,920 men and women will be diagnosed with and 37,390 will die from cancer of the pancreas.<sup>21</sup> About 90% of all neoplasms of the pancreas are ductal adenocarcinomas. The overall relative 5-year survival rate of only 4.8% is dismal, with the median survival time ranging from 6 to 12 months.<sup>22</sup> Late clinical presentation with advanced disease and aggressiveness of the tumor leads to a low

rate of surgical intervention and overall poor outcome. The tumor serum marker CA 19-9 is sensitive for the diagnosis of adenocarcinoma of the pancreas, although it is not specific. The approach to treatment is based upon whether or not the tumor can be resected at presentation. Imaging can stage pancreatic adenocarcinoma and plays a crucial role in the management of this neoplasm.

If the patient presents with jaundice and the tumor is located in the head, the initial diagnosis of pancreatic tumor may be made by US. Ultrasonographic signs of pancreatic carcinoma include a focal or diffuse pancreatic mass, which is hypoechoic relative to normal gland parenchyma, and dilation of the pancreatic duct without or with biliary duct distention (double duct sign). The accuracy of US for detecting the level of bile duct obstruction varies greatly, and US staging of pancreatic carcinoma is inferior to CT. US often fails to provide an adequate examination of the entire gland, resulting in an overall decrease in its sensitivity. Some of these limitations can be overcome by EUS, but tumors in the tail of the pancreas are also difficult to visualize by EUS. Contrast-enhanced transabdominal US shows promise, but the contrast agent is not widely available in the USA.<sup>23</sup>

MDCT is the modality of choice for optimal evaluation of pancreatic neoplasms. A triple-phase protocol is recommended that includes thin sections (0.625 or 1.25 mm) through the abdomen, initially without intravenous contrast followed by a rapidly delivered bolus of contrast material (at UCSF we use bolus tracking and 150 ml at 5 ml/sec chased by 30 ml of saline). It is best to administer a neutral oral contrast agent (water or VoLumen® [Bracco Diagnostics, Inc.]). This approach allows optimal determination of tumor extension to the stomach and/or duodenum and does not interfere with evaluation of vascular invasion. We use a scan delay of 40-45 sec (10 sec delay from peak aortic enhancement) for the late arterial or pancreatic phase and a scan delay of 80 sec for the hepatic or portal-venous phase. Rarely, an arterial phase at 20-25 sec is performed if requested

by surgery or for hypervascular pancreatic neoplasms.<sup>24,25</sup> In general, arterial involvement and tumor mass are best detected in the pancreatic phase, whereas the hepatic phase serves for optimally visualizing the liver, veins, and the entire abdomen in the search for liver metastases and peritoneal seeding. One paper demonstrated that a single-phase thin-slice MDCT technique could be sufficient for accurately assessing resectability of pancreatic adenocarcinoma.<sup>26</sup>

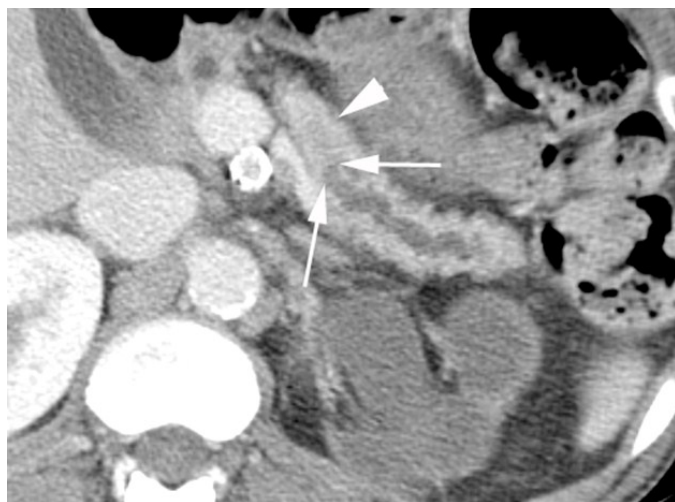


**Figure 1.** Pancreatic carcinoma in a 65-year-old man. The mass is well outlined in the head of the pancreas as an area of lower attenuation (arrows) and was diagnosed as resectable, which was confirmed at surgery. The duct proximal to the mass is dilated (arrow head).

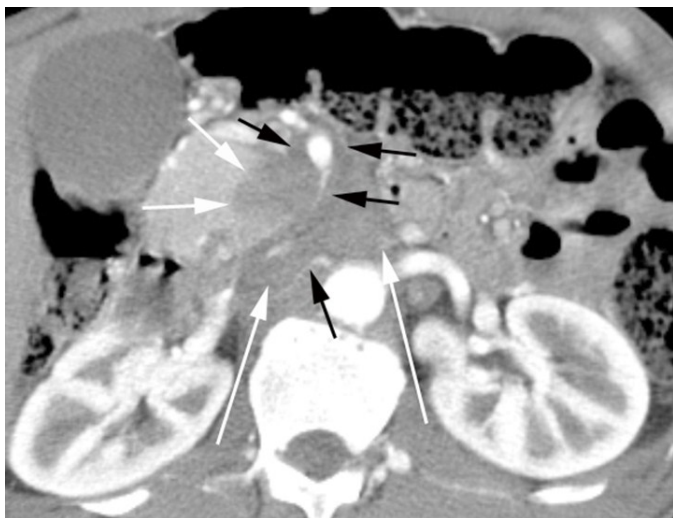
On MDCT, pancreatic adenocarcinoma appears as a low-density mass often associated with poorly defined margins (Fig. 1). The pancreatic duct proximal to it usually is dilated because the neoplasm originates from the pancreatic duct (Fig. 1). The bile duct also may be dilated when the pancreatic adenocarcinoma encases it. The low-density central zone represents hypovascular, scirrhous tumor surrounded by normal parenchyma or inflammatory tissue caused by obstructive pancreatitis. Cystic degeneration rarely appears within the tumor.<sup>27</sup> Atrophy of the pancreatic parenchyma proximal to the neoplasm frequently is associated with dilation of the pancreatic duct. Tumor obstruction of the main pancreatic duct can lead to rupture of side branches, resulting in formation of cysts. Occasionally, a low-density mass cannot be identified because the tumor is isodense to the surrounding normal parenchyma. In these cases, often a dilated duct with abrupt cut off can be seen proximal

to a small imperceptible tumor mass (Fig. 2). Ancillary findings are local tumor extension, including direct invasion of neighboring organs such as the liver and stomach, arteries (loss of fat planes surrounding celiac axis, superior mesenteric artery [SMA], etc., so-called vascular “cuffing”), and veins (tear drop sign, flattening, irregularity of margins, etc. of the portal vein, superior mesenteric vein [SMV] and its branches), and metastatic disease to local lymph nodes, liver, peritoneum (often associated with ascites), and more distant sites (Fig. 3). The so-called “double-duct sign” (dilatation of the biliary and pancreatic ducts) occurs in less than 5% of patients with pancreatic carcinoma. Biductal obstruction is a nonspecific sign and may also be seen in bile duct or ampullary carcinoma, metastases, chronic pancreatitis, and ampullary stenosis.<sup>28</sup>

For MRI, dynamic T1-weighted fat-suppressed sequences with gadolinium (spoiled gradient recalled [SPGR] pulse sequences) appear to be superior to T2-weighted sequences.<sup>29</sup> This is related to the fact that most pancreatic carcinomas have a significant desmoplastic reaction that renders the tumor less conspicuous on T2-weighted images. A gadolinium-enhanced 3D vascular time of flight SPGR sequence using an early (arterial) phase provides the best delineation of the tumor, particularly if it is a small mass which does not change the contour of the pancreas. Diffusion-weighted MRI appears promising, especially for metastases to the liver. Often MRCP sequences consisting of thin and thick axial and



**Figure 2.** Pancreatic carcinoma in a 55-year-old man. The pancreatic mass is only faintly seen (arrow head) but the abruptly terminating pancreatic duct (arrows) clearly points to the location of the tumor distal to the cut off.



**Figure 3.** Inoperable pancreas carcinoma in a 74-year-old man. The low density pancreatic mass (short white arrows) with encasement of the superior mesenteric artery and right renal artery (black arrows) is clearly seen. Extension into the retroperitoneum (long white arrows) with lymphadenopathy is also noted.

coronal sequences with heavy T2-weighting and breath holding are added to better assess the pancreatic and biliary ducts.

### Imaging Results for Pancreatic Adenocarcinoma

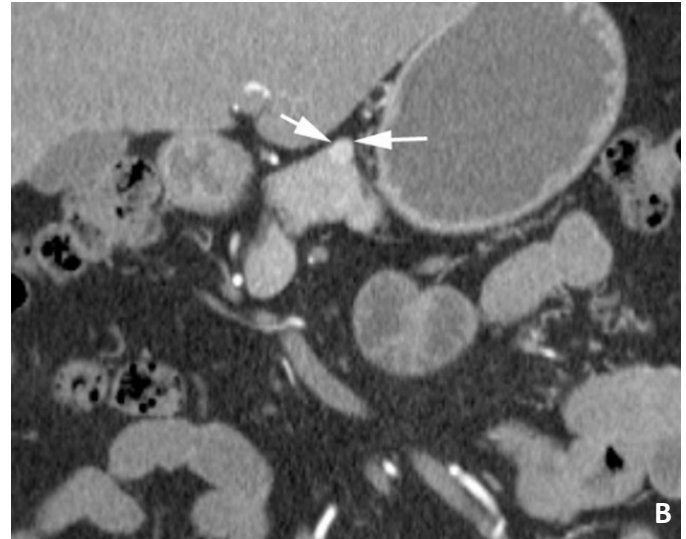
CT imaging results for pancreatic carcinoma vary widely, but a sensitivity of >90% for detecting pancreatic carcinoma can be achieved with current generation scanners and state-of-the-art scanning techniques.<sup>1,26</sup> Nevertheless, even with advanced technology, small metastatic implants on the liver and peritoneum can be missed by MDCT. MDCT with a pancreatic protocol generally provides accurate information on vascular involvement and sensitivities of >80% have been obtained for resectability.<sup>30</sup> The positive predictive values for unresectability are much better than those for resectability. Presently, most studies show a slight advantage of MDCT over MRI for detecting and staging pancreatic adenocarcinoma. A meta-analysis that compared CT, MRI, and US for detection of pancreatic cancer demonstrated sensitivity and specificity of 91% and 85% for helical CT and sensitivity and specificity of 84% and 82%, for MRI, respectively; but the results of CT and MRI for resectability were similar.<sup>1</sup> For US, the sensitivity for diagnosing pancreas carcinoma and the specificity for determining resectability were much lower. MRI is

thought to be advantageous for detecting small tumors that do not alter the contour of the gland and for hepatic metastases.<sup>29</sup> At present, MRI appears to be a problem solving modality. MRI should be considered in patients with suspected pancreatic neoplasms in the presence of (1) an allergy to iodine contrast or other contraindications for iodine contrast administration; (2) a MDCT scan with focal enlargement of the pancreas but no definable mass; (3) a clinical history suggesting malignancy and MDCT images that are equivocal or difficult to interpret; and (4) a need to distinguish between chronic pancreatitis with focal enlargement and pancreatic cancer. Also, diffusion-weighted MRI holds great promise for differentiating healthy pancreatic tissue from pancreatic carcinoma.<sup>31</sup> When choosing an imaging modality, one must consider that MDCT of the pancreas takes a small fraction of the time needed for a complete MRI of the pancreas.

Because false positive MDCT diagnoses of pancreatic cancer can occur, percutaneous aspiration biopsies are needed if non-operative treatment is planned, especially in patients with chronic pancreatitis. Fine-needle aspiration (FNA) biopsy of pancreatic cancer using CT-guidance frequently is performed; this procedure causes severe pancreatitis in < 3%.<sup>32</sup> The sensitivity of percutaneous CT biopsies reaches 79% with a positive predictive value of 100%, a negative predictive value of 47% and an overall accuracy of 81%.<sup>32,33</sup> Because of possible tumor seeding in the needle tract, patients with potentially resectable tumors (only 10% of all cases) who are acceptable candidates for surgery should undergo exploratory surgery rather than FNA.<sup>33</sup>

EUS excels in detecting even small pancreatic adenocarcinomas, reaching sensitivities as high as 97%. However, it demonstrates poor sensitivity and specificity for diagnosing vascular involvement by tumor due to its limited depth penetration.<sup>34,35</sup> Today, endoscopic ultrasound-guided biopsies often replace percutaneous CT biopsies of the pancreas. They have a sensitivity of 95% and a specificity of 98% with a positive predictive value of 99% and a negative predictive value of 91%.<sup>36</sup> They are particularly indicated when CT is equivocal or negative with a strong clinical suspicion for tumor and when the lesion is <3cm in size.<sup>33</sup>

PET/CT has emerged as an important modality for



**Figure 4.** Insulinoma in a 43-year-old woman with Whipple triad (hypoglycemia, low blood glucose level [40 to 50 mg/dL], and relief of symptoms after intravenous administration of glucose). **(A)** On this axial scan, a very small (1 cm) hypervascular lesion (arrows) is seen near the neck of the pancreas, which was confirmed at surgery. **(B)** Same patient as Figure 4A. The hypervascular lesion (arrows) is noted to lightly project off the surface of the pancreas.

effectively managing patients with suspected pancreatic cancer.<sup>37</sup> Nevertheless, more studies are needed to demonstrate its true value and cost-effectiveness, since some studies found no benefit over CT alone.<sup>9</sup> In one study, the diagnostic accuracy of 18F-fluorodeoxyglucose (FDG) PET/CT for pancreatic malignancy was 89%, compared to 76% for MDCT and 79% for MRI.<sup>38</sup> In 17 patients with advanced pancreatic adenocarcinoma analyzed in the same study, FDG-PET/CT had a sensitivity of 30% for N- and 88% for M-staging, whereas both MDCT and MRI had sensitivities of 30% for N- and 38% for M-staging. The clinical management was altered in 26% (10 patients) after FDG-PET/CT.<sup>38</sup> In another PET/CT study, management was changed in 16% of patients with pancreatic cancer that initially had been staged as being resectable.<sup>10</sup> In suspected tumor recurrence, PET/CT reliably detected local recurrence and was advantageous in diagnosing distant disease.<sup>11</sup>

## Neuroendocrine Neoplasms of the Pancreas

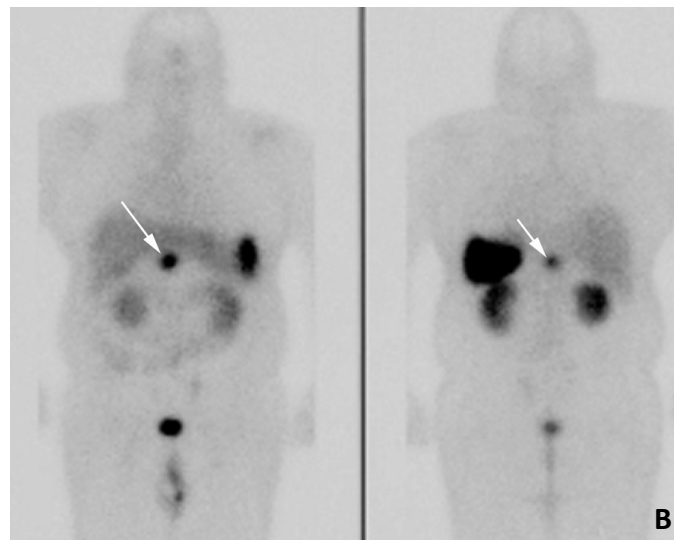
### Hyperfunctioning Neuroendocrine Neoplasms.

The term “functioning islet cell tumor of the pancreas” has been replaced by “hyperfunctioning or syndromic neuroendocrine neoplasm” (NEN). Among these NENs, insulinoma is the most common tumor, followed by gastrinoma, glucagonoma, VIPoma, and other rarely encountered secretory neoplasms. In

hyperfunctioning pancreatic adenomas, cross-sectional imaging is used only for localizing the pancreatic neoplasm, since the clinical diagnosis is based on clinical data and laboratory tests that usually permit an accurate diagnosis.<sup>39</sup>

Insulinomas and especially extrapancreatic NENs that are small and located in the duodenal or gastric wall (Fig. 4A and B) may be difficult to detect preoperatively by any of the radiographic techniques; even intraoperative ultrasonography fails to detect some of these lesions. Nevertheless, MDCT with 0.625 mm sections has improved these results. These ectopic lesions are more likely to occur in patients with multiple endocrine adenomatosis (MEA) or multiple endocrine neoplasia (MEN). A combination of intraoperative palpation and intraoperative ultrasonography was found to achieve the best results for complete resection. Intraoperative ultrasound is particularly important in patients with multiple lesions and MEN.

On MDCT and MRI, functioning NENs generally show intense enhancement in the arterial phase with rapid washout in the portal venous phase. The most common NEN, the insulinoma, usually is small ( $\leq 2$  cm in diameter). Metastases occur in only 5-10% of insulinomas. All other NENs tend to be large and have metastases in 60-65% of cases. The appearance of liver metastases in patients with functioning NENs is similar to that of the primary tumor (intense arterial



**Figure 5.** Ectopic gastrinoma in a 36-year-old woman with Zollinger-Ellison syndrome (elevated gastrin levels, intractable peptic ulcerations with gastric hypersecretion and hyperacidity). **(A)** A hypervascular mass (arrows) is identified between the pancreas and the caudate lobe which represents the gastrinoma. **(B)** The SRS (octreotide study) of the same patient as Fig. 5A in supine and prone position confirmed the presence of the hyperfunctioning neuroendocrine neoplasm (arrows).

enhancement with rapid washout).

The reported sensitivity of conventional CT for detecting insulinomas is low and only slightly higher for gastrinomas - primarily due to their larger size (Fig. 5A). EUS usually allows detection of even small NENs and their precise location. The dual-phase MDCT protocol with thin sections improved the detection rate to 94% and reached 100% when combined with EUS.<sup>40</sup> While EUS provides excellent results in the head of the pancreas, detection rates for lesions in the tail of the pancreas are much lower because of the distance of the EUS probe from the stomach. Ectopic gastrinomas may be missed by EUS, but combining it with SRS increases the overall sensitivity for gastrinomas to 86% (Fig. 5A and B).<sup>41</sup> The sensitivity of transabdominal ultrasound for detecting insulinomas is low (mean of 46%), and therefore should not be used for this purpose.

On MRI, functioning NENs of the pancreas are of low signal intensity on T1-weighted images and high signal intensity on T2-weighted images.<sup>4</sup> Occasionally, an insulinoma can be of dark signal intensity on T2-weighted sequences due to a fibrous stroma. In our study, we reached an MRI sensitivity of 85% for detecting functioning NENs of 2 cm or less in diameter, which is similar to the sensitivity achieved by invasive procedures.<sup>4</sup> For gastrinomas, an MRI sensitivity of up to 62% has been reported.<sup>42</sup> With present techniques, MRI should detect lesions >2 cm with a sensitivity

greater than 85%. Therefore, MRI with state-of-the-art equipment and optimal MRI techniques appears to be a useful technique for diagnosing small pancreatic NENs; however, contrast-enhanced MDCT surpasses MRI in diagnosing these small neoplasms with its superior spatial resolution and very thin sections.

SRS - based on various derivatives of long-acting somatostatin analogues - can be employed for patients with MEN, small gastrinomas, somatostatinoma, glucagonoma, carcinoid, and VIPoma; however, insulinomas may be missed due to reduced receptor expression.<sup>17,43</sup> While EUS is the most sensitive imaging procedure for the detection of small (< or = 10 mm) NENs, SRS is the procedure of choice for the identification of metastases (staging), particularly in patients with MEN.<sup>43</sup>

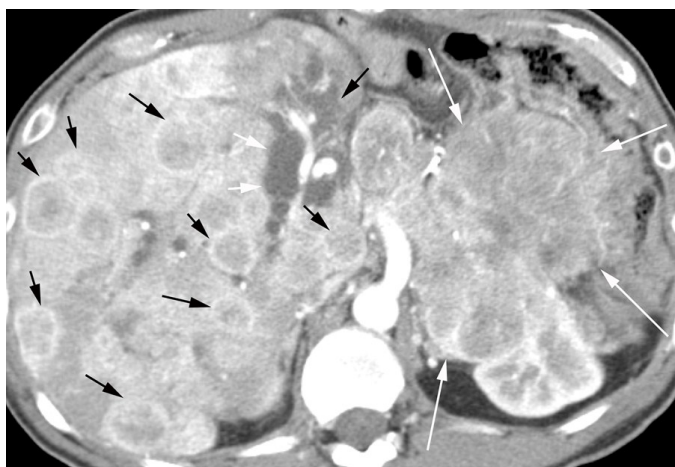
#### Non-Hyperfunctioning Neuroendocrine Neoplasms.

Non-hyperfunctioning or nonsyndromic NENs are less frequently encountered than insulinomas or gastrinomas and represent 15-25% of all NENs.<sup>39</sup> They arise from alpha or beta cells. These neoplasms are hormonally quiescent (probably very minimal secretion) and often present as masses with or without jaundice or gastric outlet obstruction. The tumors are mostly located in the head of the pancreas and may reach up to 20 cm in diameter (Fig. 6). They may consist of solid and necrotic components, and

Table 1: Imaging distinction between serous and mucinous cystic neoplasms of the pancreas

Feature	Serous	Mucinous
Size of cysts	≤ 2 cm	> 2 cm
Number of cysts	uni/multilocular (>6)	uni/multilocular (<6)
Calcifications	central (10%)	peripheral (25%)
Papillary excres.	(+)	+
Debris	—	+
Contour	lobulated	smooth
Wall thickness	thin	thick
Enhancement	Swiss-cheese, no wall enh.	septa, wall and papillary excrescences

coarse calcifications are present in up to 25% of cases. The masses are hypervascular with a late capillary stain. The tumors do not encase vessels, but in 80-100% of cases, they show malignant transformation with liver metastases and lymphadenopathy. The estimated cumulative 5-year survival with malignant tumors is 52 +/- 10%.<sup>44,45</sup> The key features of non-functioning NENs are large size, hypervascularity, and absence of vascular encasement. Results with CT and MRI are similar.



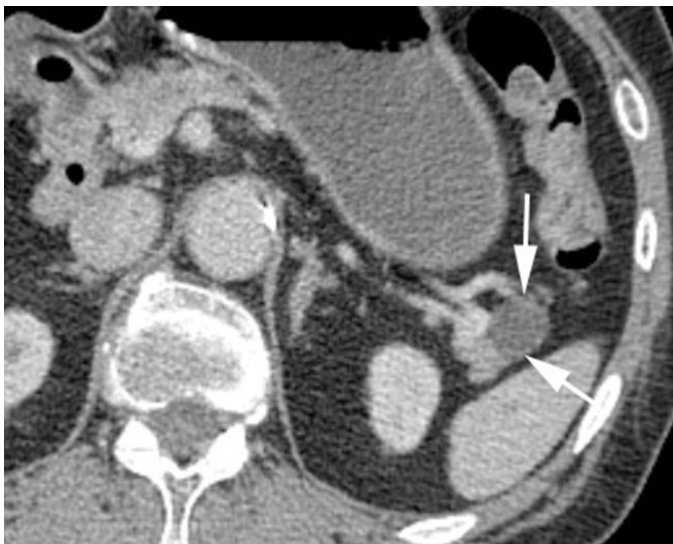
**Figure 6.** Large non-hyperfunctioning neuroendocrine tumor in a 56-year-old man with jaundice. The axial MDCT demonstrates a very large mass in the head and neck of the pancreas (long white arrows) with multiple partially hypervascular metastases in the liver (black arrows) that produce intrahepatic biliary ductal dilation (short white arrows).

## Cystic Neoplasms of the Pancreas

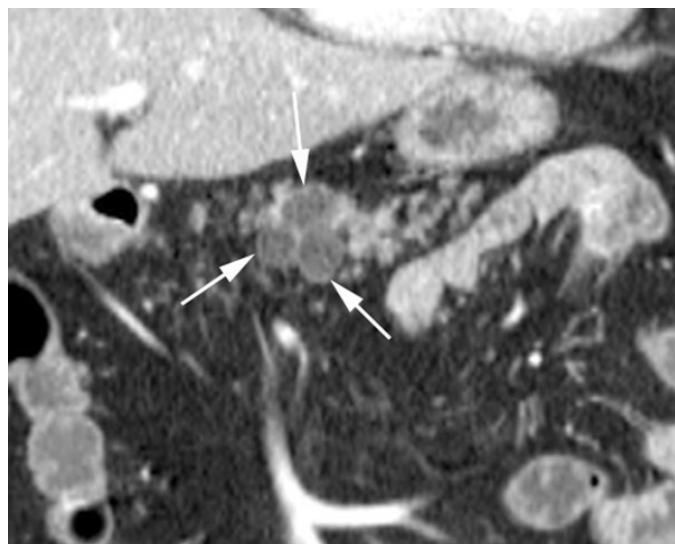
### Serous and Mucinous Cystic Neoplasms.

Cystic neoplasms of the pancreas account for less than 5% of pancreatic neoplasms. Pancreatic cystic neoplasms are classified into two categories: serous cystic (usually microcystic, occasionally macrocystic: unilocular [Fig. 7] or oligocystic [Fig. 8]) neoplasms that usually are benign, and mucinous cystic (macrocystic) neoplasms that are potentially malignant or already malignant at the time of diagnosis. A rare macrocystic variant is benign but exhibits radiological features similar to those of mucinous cystadenoma. Serous and mucinous cystic neoplasms do not communicate with the pancreatic duct, whereas intraductal papillary mucinous neoplasms (IPMN) (discussion to follow) demonstrate communication with the pancreatic duct.

Serous cystic neoplasms of the pancreas are observed in middle-aged and elderly women. This type of tumor may not require surgical treatment, whereas mucinous cystic tumors should be resected because of their malignant potential. Nevertheless, some surgeons prefer to resect the serous type as well. In general, the patient's age, symptoms, overall condition, location of the lesion, and growth over time are factors that help in deciding if surgery is needed.<sup>46,47</sup> Often, patients with a cyst that increases significantly in size over time, is symptomatic, or occurs in older fit patients are selected for surgery. CT can accomplish preoperative differentiation of the two types in many cases.<sup>27</sup> Traditionally, the diagnosis of



**Figure 7.** Unilocular serous cystic neoplasm in a 61-year-old woman. One simple appearing cyst (arrows) is present in the tail of the pancreas. The wall of the cyst is thin and no septations are present, as confirmed by ultrasound.



**Figure 8.** Oligocystic serous cystic neoplasm in a 68-year-old woman. Three cystic structures (arrows) form one mass in the body of the pancreas.

serous cystic tumor is made if the number of cysts within the tumor is more than six and the diameters of the cysts are less than 2 cm. A newer nomenclature prefers to call cysts  $\leq 1$  cm definitely serous,  $>1$ - 2 cm equivocal and  $> 2$  cm definitely mucinous. Grossly, these serous tumors appear either as solid tumors with innumerable tiny cysts or as honeycombed cystic tumors, depending on the amount of connective tissue (Table 1). At times, it is difficult to visualize the cystic areas. The lesions have lobulated margins (Fig. 9). Calcifications in serous tumors are central in location. A central enhancing scar may be present and is characteristic of a serous tumor.<sup>27</sup>

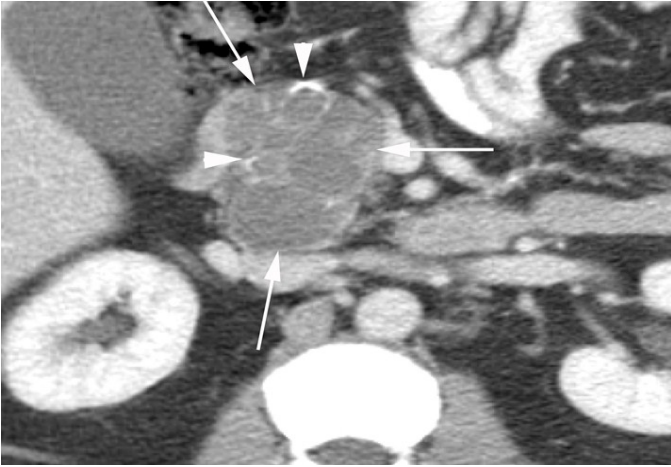


**Figure 9.** Serous cystic neoplasm in a 72-year-old woman (microcystic). The lobulated mass (arrows) consists of multiple tiny cysts with septations barely noticeable.

Mucinous cystic neoplasms of the pancreas (also called “cystadenomas” and “cystadenocarcinomas” according to the old nomenclature) have six or fewer cysts; the diameters of the cysts measure more than 2 cm; a central enhancing scar is rarely seen; and calcifications are peripheral (Table 1).<sup>27</sup> The margins usually are smooth, and metastatic disease may be present at the time of diagnosis (Fig. 10).

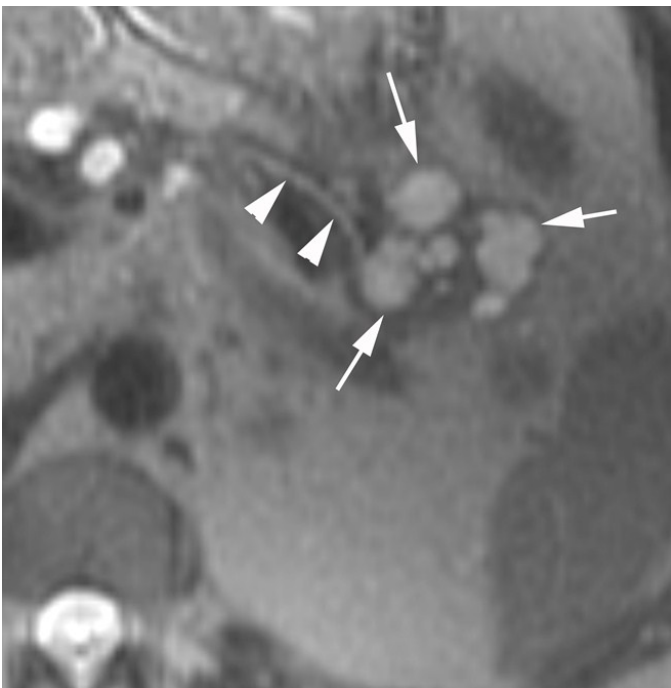
Based upon the above-mentioned criteria, a correct diagnosis of a serous cystic pancreatic tumor can be made in 62% of cases by CT, 74% by US, and 84% using both modalities.<sup>48</sup> In general, results for mucinous cystic tumors are inferior. Pancreatic walled-off necroses and cystic forms of islet cell tumors, ductal carcinomas, solid and papillary tumors, and lymphangioma of the pancreas can be indistinguishable from cystic neoplasms on CT. Thus, EUS needle biopsies of the lesions often are necessary.<sup>49</sup>

MRI often provides better definition of the internal architecture of cystic neoplasms (Fig. 11) than CT and demonstrates the presence of mucin based on increased signal intensity within the cysts on T1-weighted sequences. Also, diffusion-weighted MRI may become part of the array of tools to differentiate mucinous from nonmucinous lesions and may help in the management of pancreatic cystic lesions. Septa and wall thickness of the lesions are well demonstrated by MRI, but calcifications are not always



**Figure 10.** Mucinous cystic neoplasm in a 45-year-old woman. The mass consists of large cysts (white arrows) with peripheral calcifications (arrow heads) and thick septations. The mass is not lobulated.

seen. MRI helps distinguish cystic neoplasms from walled-off necroses of the pancreas, particularly if they are multiple. Both MRCP and MDCT with curved planar reconstruction can demonstrate the absence of a connection to the main pancreatic duct.



**Figure 11.** Mucinous cystic neoplasm in a 47-year-old woman. Large cysts (arrows) form a mass in the tail of the pancreas with thick septations. The main pancreatic duct (arrow heads) is normal, because there is no communication between the neoplasm and the pancreatic duct.

### Intraductal Papillary Mucinous Neoplasms.

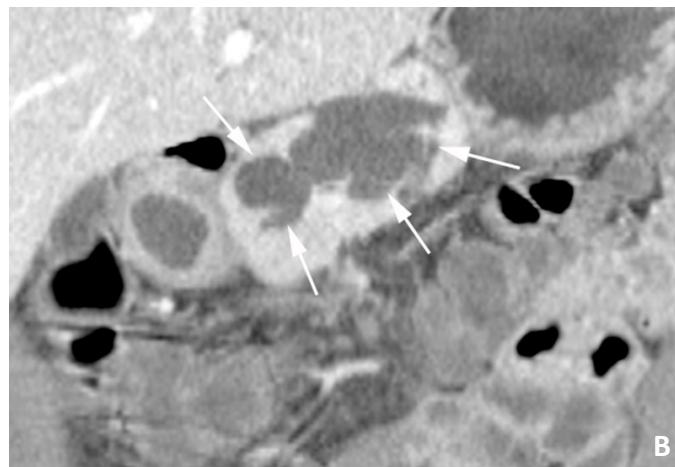
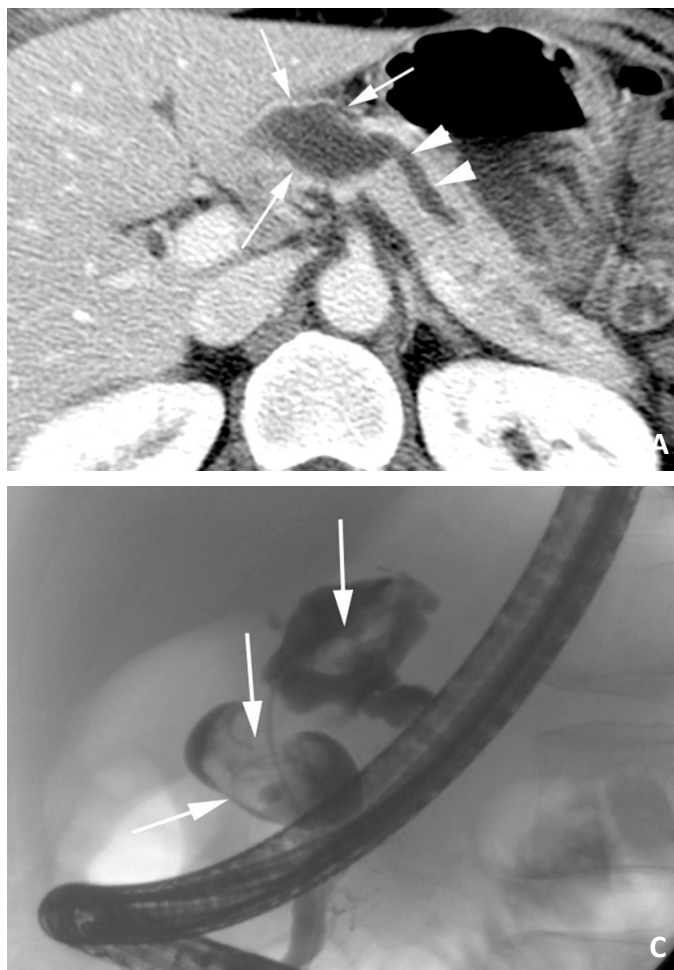
IPMN (formerly also called “ductectatic cystadenoma” or “ductectatic cystadenocarcinoma”) is a rare tumor that is considered a subtype of the mucinous cystic neoplasms of the pancreas. IPMNs can be classified as branch duct (side-branch), main duct, or mixed type depending on the site and extent of involvement.<sup>27,50</sup> The cystic changes always demonstrate a connection to the pancreatic duct (Fig. 12), which is a diagnostic feature that can be seen on MDCT and even better on MRCP (Fig. 13). The branch duct type consists of cystic dilation of the side branches of the pancreatic duct, usually in the uncinate process. These ducts are lined with atypical, hyperplastic, or clearly malignant epithelium. In the late stages, the tumor nodules of the ducts produce copious mucinous secretions that fill the entire duct. The overall prognosis is good in branch duct type IPMN, because extension into the parenchyma and beyond occurs relatively late in this type of tumor; overall malignant degeneration is rare. In contrast, malignancy is present in 25-44% of resected specimens of the other two types, and resection is the treatment of choice in these patients.

CT shows markedly dilated ducts and cystic-appearing structures filled with mucinous material that has slightly higher attenuation than that of water. Based on MDCT scans, a main pancreatic duct diameter of 6 mm or larger, a mural nodule of 3 mm or larger, and an abnormal attenuating area are independently predictive of malignancy.<sup>50</sup> A mural nodule of 6.3 mm or larger in the main pancreatic duct and an abnormal attenuating area are independently predictive of parenchymal invasion. According to these criteria, the sensitivity, specificity, and accuracy for identifying malignancy in patients with IPMN were 83%, 81%, and 82% and for identifying parenchymal invasion were 90%, 88%, and 89%, respectively.<sup>50</sup> MRI appears to have a slight advantage over CT. MRI can visualize mucin within the cysts and the internal architecture of the lesion, including a solid mass and mural nodules, slightly better than CT. EUS also is well suited to detecting mural nodules.

### Solid Pseudopapillary Epithelial Neoplasm.

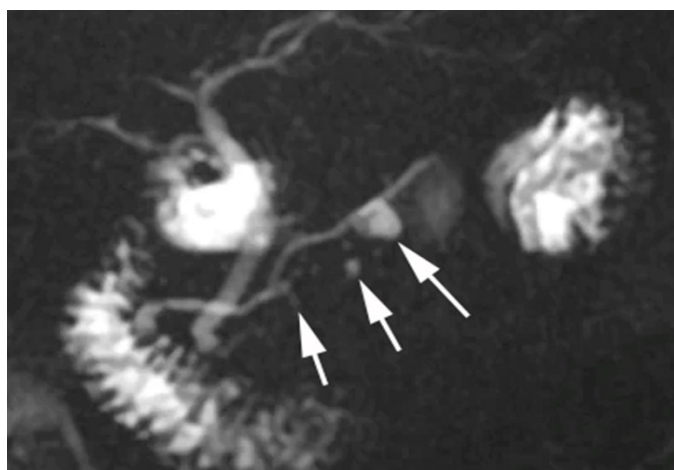
Solid pseudopapillary epithelial neoplasms (SPEN), previously called “solid and cystic tumors of the





**Figure 12.** Mixed-type IPMN in a 74-year-old man. **(A)** On this axial image, the cystic mass (arrows) clearly communicates with the main pancreatic duct (arrow heads). **(B)** Same patients as 12A. On this coronal image, the dilated main duct and the dilated side branches (arrows) are clearly evident. **(C)** The ERCP in the same patient as **(A)** demonstrates a massively dilated main pancreatic duct containing large filling defects that represent mucus (arrows).

pancreas”, are rare tumors seen almost exclusively in young women and are located mostly in the tail of the pancreas (Fig. 14). SPEN is a mixed cystic and solid mass characterized by a solid peripheral area of tumor and a central zone of degeneration, consisting of



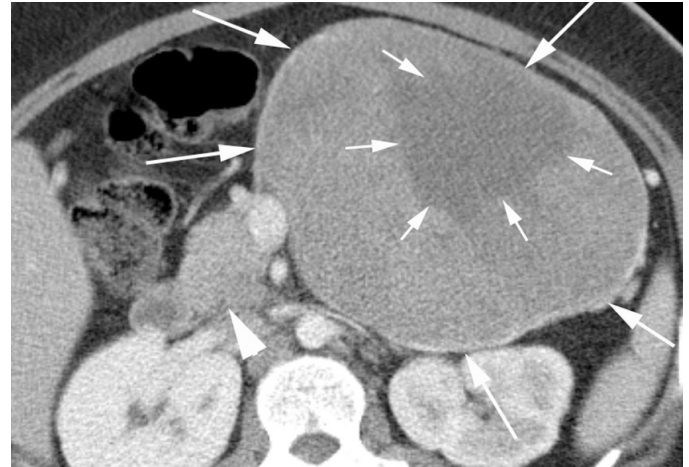
**Figure 13.** Side-branch type IPMN. The MRCP demonstrates several cystic structures (arrows) arising from side branches of the main pancreatic duct.

hemorrhage and cystic spaces filled with necrotic debris; these characteristics can be visualized by CT and MRI. On imaging, SPEN appears as sharply defined, heterogeneous, large cystic pancreatic masses with solid components and may have increased vascularity. This type of cystic tumor usually is benign, but it may be malignant in older women.<sup>51</sup> Calcifications are rare and, if present, are located in the capsule or in the inner portion of the mass. EUS also may be helpful in visualizing the nodules and internal architecture of these masses.

Follow-up Imaging for Cystic Neoplasms of the Pancreas.

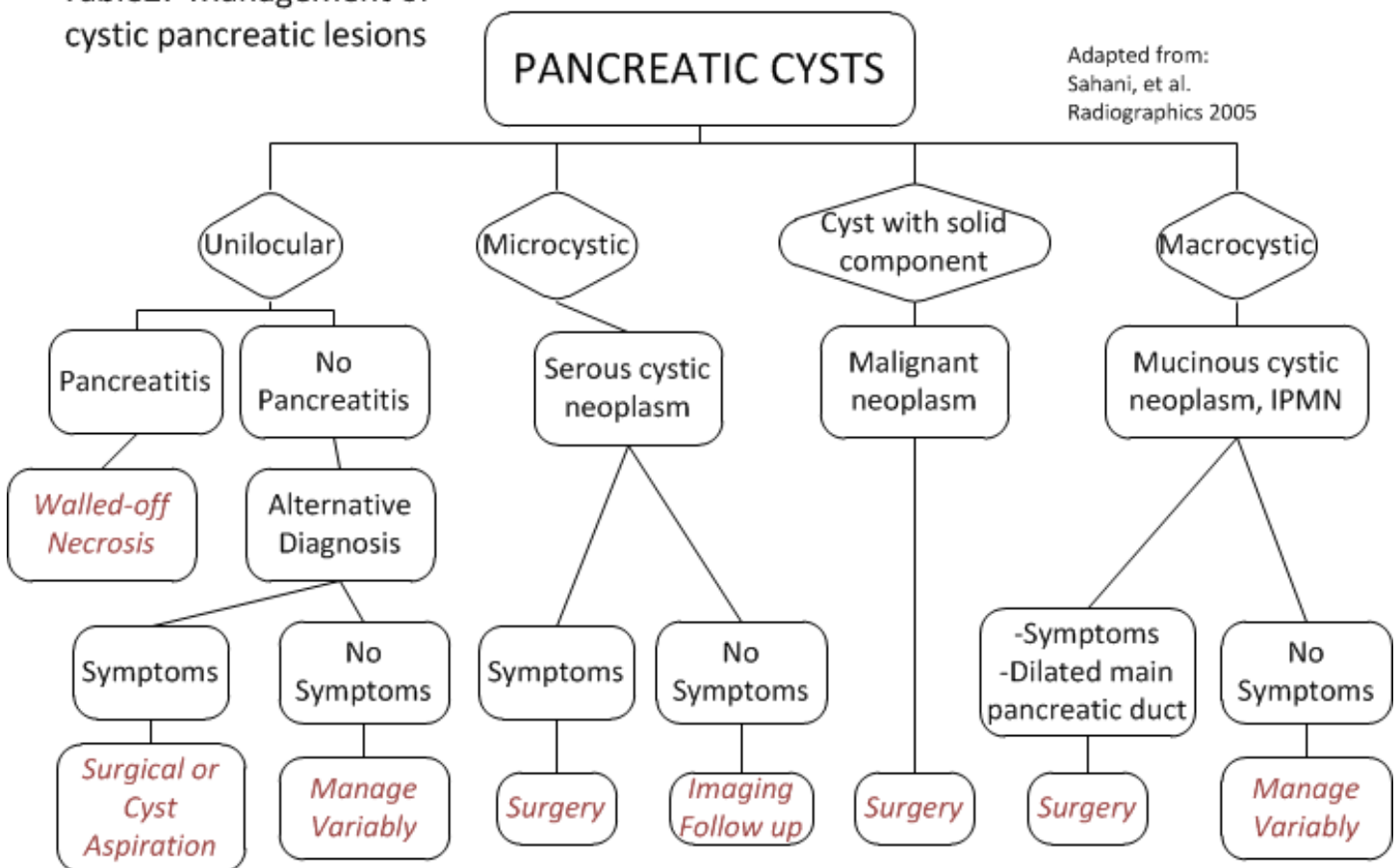
Small cystic lesions ( $\leq 3$  cm) that are asymptomatic, show no sign of malignancy, and have a negative FNA can be followed every 6 months for one year and then annually for a total of 4 years.<sup>27</sup> The lesions should be surgically removed if they become symptomatic; increase in size during observation; show malignant

features, including a thick wall, multiple irregular septations, and mural nodules; and/or have increased CEA or CA 19.9, positive cytology or mucin in the aspirate.<sup>27,50</sup> Often, pancreatic cysts detected in elderly and fit patients are removed regardless of the features, because of the increased incidence of malignancy in these lesions. For detailed flow chart for cystic lesions, see Table 2.



**Figure 14.** Solid pseudopapillary epithelial neoplasm in the tail of the pancreas of a 17-year-old woman. The solid peripheral area of tumor (long white arrows) and more central zone of degeneration (short white arrow), consisting of hemorrhage and cystic spaces filled with necrotic debris is well visualized by MDCT. Arrow head indicates the normal head of the pancreas.

**Table 2: Management of cystic pancreatic lesions**



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