REVIEWS

Imaging of cystic pancreatic lesions

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Received: March 30, 2012 **Accepted:** May 17, 2012 **Published:** December 1, 2012
DOI: 10.5430/jbgc.v2n2p128 **URL:** http://dx.doi.org/10.5430/jbgc.v2n2p128

Abstract

Cystic lesions of the pancreas are encountered on abdominal imaging studies on a routine basis. Cystic pancreatic lesions represent a variety of both benign and malignant disease entities that present with a wide spectrum of clinical symptoms. Cystic pancreatic lesions are being detected at an ever increasing rate due to increasingly sophisticated imaging techniques. Various imaging modalities can be employed in the evaluation of cystic pancreatic lesions. While CT serves as the mainstay of routine pancreatic imaging, MR is becoming increasingly utilized in the detection and characterization of suspected cystic pancreatic lesions. Accurate characterization of such lesions is imperative in order to select the most appropriate clinical management.

Key words

Cystic pancreatic lesions, Imaging, Magnetic resonance, Computed tomography

1 Introduction

Cystic lesions of the pancreas represent a variety of disease processes that are encountered with ever increasing frequency in modern clinical imaging. The detection of cystic pancreatic lesions continues to increase due to progressively sophisticated imaging techniques that offer detection of small or subtle lesions. Pancreatic cystic lesions entail a variety of both benign and malignant processes. Accurate characterization of these lesions is essential in order to provide the most appropriate clinical management.

Various imaging methods are commonly employed to assess the pancreas. Transabdominal ultrasonography (US) may frequently detect the presence of pancreatic lesions. US is the most cost effective method of evaluating the pancreas. Additional benefits of US include widespread availability and lack of ionizing radiation. However, the lack of spatial and soft-tissue contrast resolution is a significant drawback in the evaluation of focal pancreatic masses. Additionally, evaluation of the pancreas may be significantly limited by the presence of shadowing bowel gas or large body habitus. Endoscopic US may provide improved conspicuity of pancreatic lesions. However, disadvantages include the invasive nature of the study, which requires additional expense, lower patient tolerance and limited availability when compared to conventional transabdominal US. In general, US plays little role in the characterization of cystic pancreatic lesions, and will not be discussed within this article.

Computed tomography (CT) is an excellent means of assessing the pancreas. Cystic pancreatic lesions are often incidentally detected on CT that has been performed for an unrelated indication. Advantages of CT include widespread availability, high reproducibility and rapid imaging time. CT provides the most superior means of assessing calcifications associated with cystic pancreatic lesions. However, disadvantages include the use of ionizing radiation, particularly when serial examinations are required to provide long term surveillance of concerning pancreatic lesions. Additionally, the internal architecture of cystic lesions such as fluid content and internal septa are suboptimally evaluated with CT due to its inherently limited soft tissue contrast resolution.

Magnetic resonance (MR) imaging has emerged in recent years as the gold standard for noninvasive imaging of the pancreas due to its inherent superior soft-tissue contrast resolution [1]. MR provides the most accurate means of evaluating the internal features of cystic pancreatic lesions. Accurate depiction of the internal architecture of pancreatic cysts can of aid in a more specific diagnosis in many instances [2]. Additionally, MR provides the most accurate depiction of the pancreatic ductal system, which is often crucial in the evaluation of cystic pancreatic lesions [3]. Diffusion-weighted imaging (DWI) is being increasingly utilized in both the detection and characterization of cystic pancreatic neoplasms. DWI techniques show great potential in the characterization of internal contents of a potentially cystic lesion.

2 CT imaging techniques

High-resolution dual-phase (arterial and portal) contrast enhanced CT is essential in the evaluation of suspected pancreatic masses. Negative oral contrast is routinely administered prior to image acquisition. Arterial phase imaging is generally performed 30-40 seconds following contrast injection which allows superior visualization of pancreatic masses and peripancreatic arteries. Maximal contrast between hypovascular or cystic masses and the background pancreas provides optimal tumor visualization in this phase [4]. Arterial phase images are routinely displayed at 3 mm intervals. Portal phase imaging is generally performed 60-70 seconds after injection which provides optimal visualization of the peripancreatic venous system. The portal venous phase likewise provides optimal depiction of liver metastases. Portal venous images are routinely displayed at 5 mm intervals.

3 MR imaging techniques

An optimal MR imaging protocol for the evaluation of the pancreas consists of rapid image acquisition of both T1-weighted and T2-weighted sequences. The acquisition of both unenhanced and enhanced T1-weighted images is essential for optimal assessment of cystic pancreatic lesions. Axial 3D T1-weighted GRE in and opposed phase images of the entire abdomen can be obtained with a single breath hold. Unenhanced T1-weighted images are essential in the detection of hemorrhage or protein deposits within cystic lesions. Enhanced T1-weighted images provide optimal visualization of enhancing soft tissue components within cystic lesions. Enhanced axial T1-weighted are obtained through the pancreas at serial intervals up to 5 minutes following IV gadolinium administration.

T2-weighted imaging is essential in the evaluation of cyst contents, as well as optimal visualization of the pancreatic ductal dystem. Multiplanar T2-weighted single-shot fast spin-echo sequences are routinely obtained. Axial T2-weighted images with fat saturation are likewise routinely performed in order to depict pancreatic or peripancreatic inflammatory changes. MR cholangiopancreatography (MRCP) uses heavily T2-weighted sequences obtained in the coronal plane which provides optimal depiction of the pancreatic ductal and biliary system.

Diffusion-weighted imaging is a technique that was initially applied to neuroimaging for the detection of acute ischemia. Over the past decade, DWI is being increasingly used in abdominal imaging applications. Diffusion-weighted imaging can evaluate the movement of water molecules with a cellular matrix as representative apparent diffusion coefficient (ADC) values [5]. Several variables account for the movement or diffusion of water molecules within the extravascular space, such as tissue cellularity and organization, extracellular space tortuosity and the integrity of cellular membranes [6]. The physics

of diffusion-weighted imaging are beyond the scope of this article. However, simple cysts demonstrate increased signal intensity at DWI with a relatively low b value (b=50 s/mm²), decreased signal intensity on high-b-value images (b=800 s/mm²), and high signal intensity on ADC maps because of T2 shine-through. The high ADC values associated with purely cystic lesions are due to the greater freedom of motion of water molecules in a fluid environment [7].

4 Overview of lesions

Frequently encountered primary cystic lesions of the pancreas include pseudocysts, serous cystadenomas and various mucinous cystic lesions, including mucinous cystadenomas and intraductal papillary mucinous tumors (IPMT). Lympho-epithelial cysts occur less commonly.

Solid pancreatic tumors with cystic degeneration also account for a minority of cystic pancreatic lesions. Cystlike degeneration uncommonly occurs in the setting of pancreatic ductal adenocarcinomas, solid pseudopapillary tumors and pancreatic endocrine (islet cell) tumors. Cystic pancreatic metastases are extremely rare.

5 Pseudocysts

Pseudocysts are the most commonly encountered cystic lesions of the pancreas. They occur as a result of fat necrosis in the setting of pancreatitis. The lesions are referred to as pseudocysts given the fact that they lack a true epithelial lining. Pseudocysts result from encapsulation of fluid, tissue, debris, pancreatic enzymes and blood by granulation tissue and a fibrous capsule [8]. Pseudocysts tend to evolve over time from poor marginated, heterogeneous fluid collections with irregular margins to progressively well circumscribed, discrete cystic lesions over a period of weeks to months.

Pseudocysts on unenhanced CT generally present as homogeneous, hypodense lesions with attenuation values similar to water. However, hemorrhage or infected pseudocysts may demonstrate regions of variable increased attenuation. Contrast enhanced CT may demonstrate capsular enhancement, but not of the internal contents. The presence of gas within a pseudocyst is suggestive of either infection due to the presence of a gas-forming organism, or communication with adjacent gut. CT is a useful modality for evaluating complications of pseudocyst formation, such as secondary pseudoaneurysm formation.

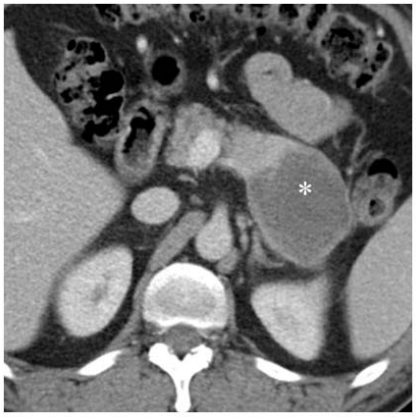

Figure 1. Pseudocyst

Axial contrast enhanced CT shows a sharply marginated cystic lesion within the body of the pancreas (*) consistent with a pseudocyst.

 ISSN 1925-4008 E-ISSN 1925-4016

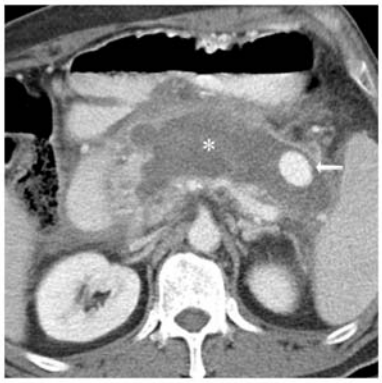

Figure 2. Pseudocyst with splenic artery pseudoaneurysm

Axial contrast enhanced CT shows a large, heterogeneous fluid within the pancreatic bed (*). Areas of increased attenuation within the pseudocyst are most consistent with internal hemorrhage. A focal area of enhancement (arrow) is noted in the region of the pancreatic tail, consistent with splenic artery pseudoaneurysm as a result of necrotizing pancreatitis with subsequent pseudocyst formation.

MR is generally considered the gold standard for evaluating the internal complexity of pseudocysts [2]. Fat saturated T2-weighted images may be helpful in depicting inflammatory changes of the adjacent pancreas in the setting of underlying pancreatitis. Pseudocysts do not possess internally enhancing soft tissue elements. The presence of enhancing internal element on enhanced T1-weighted images virtually excludes the presence of a pseudocyst, and should suggest an alternative diagnosis such as a mucinous cystic neoplasm [9]. A characteristic imaging feature of pseudocysts is the evolution of these lesions during a relatively short period of time, often over the course of weeks to months. Short term changes in the size or morphology of a cystic lesion is highly suggestive of a pseudocyst.

Diffusion-weighed imaging shows great promise in the evaluation of cystic pancreatic lesions. Recent studies have demonstrated that simple cystic lesions such as congenital cysts or pseudocysts are hyperintense on diffusion-weighted images with low or intermediate b values (b=50 s/mm² and b=400 s/mm² respectively) and are nearly isointense to background pancreatic parenchyma at higher b values (b=800 s/mm²). Additionally, ADC values for simple cysts are shown to be higher than values obtained from more complex cystic lesions [10].

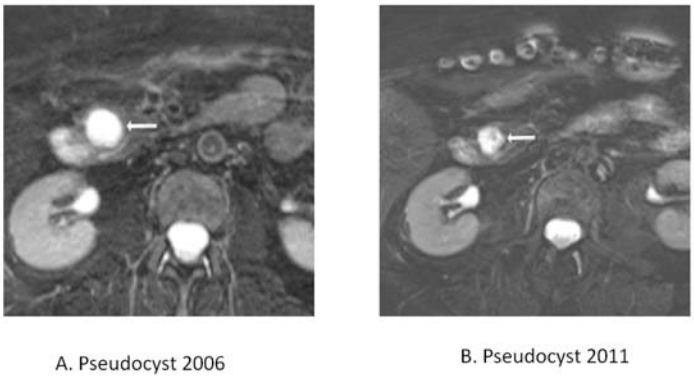

Figure 3. Evolution of pancreatic head pseudocyst

Axial T2-weighted MR with fat saturation obtained in 2006 shows a uniformly T2 hyperintense lesion within the pancreatic head (arrow), consistent with pseudocyst.

Axial T2-weighted MR with Fat saturation obtained in 2011 shows interval size decrease of the previously noted pseudocyst within the pancreatic head (arrow). Ill-defined hypointensity within the lesion is suggestive of evolving internal necrotic debris.

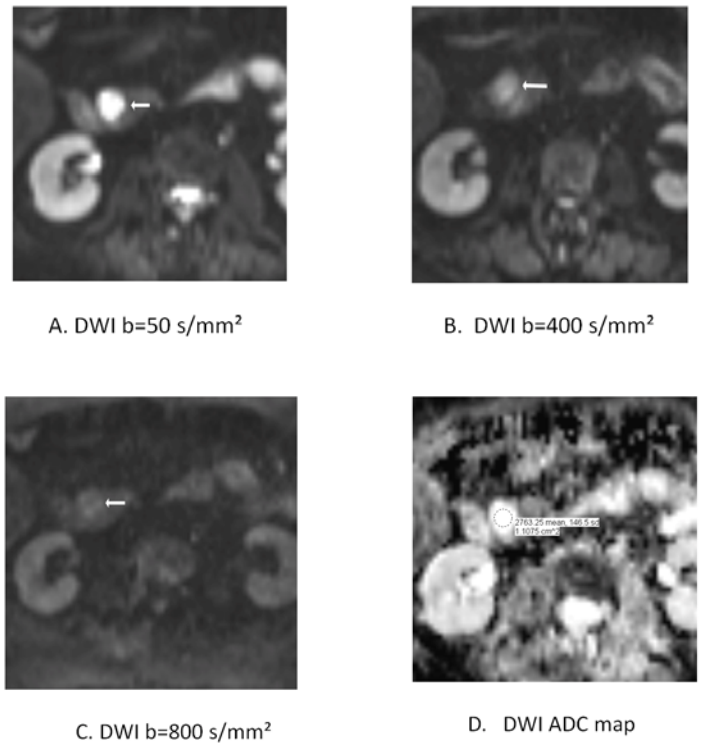

Figure 4. Diffusion-weighted imaging of a pseudocyst

Diffusion-weighted image with a b value of 50s/mm² shows the same lesion in figure 3 (arrow) that is markedly hyperintense.

DWI with a b value of 400 s/mm² shows the same pseudocyst in A that is moderately hyperintense to the background pancreas.

DWI with a b value of 800 s/mm² shows the same pseudocyst in A that is slightly hyperintense to background pancreas.

Apparent diffusion coefficient (ADC) map shows an ADC value of 2.7×10^{-3} mm²/s.

6 Serous cystadenomas

Serous cystadenomas are benign cystic neoplasms of the pancreas. These lesions typically occur in older individuals with a median age of 65 years. Serous cystadenomas are roughly four times more common in females than in males. These lesions account for between 10-15% of all pancreatic cysts, and are much less common than mucinous cystic tumors of the pancreas. Serous cystadenomas are composed of a honeycomblike network of multiple small cysts. The individual cystic elements range from 0.1 to 2.0 cm in size, but are typically less than 1cm. The term microcystic adenoma has frequently been applied to these lesions due to the presence of predominantly subcentimeter cysts [1]. The cysts in a serous cystadenoma are often separated by fibrous septa that radiate from a central scar that may be calcified.

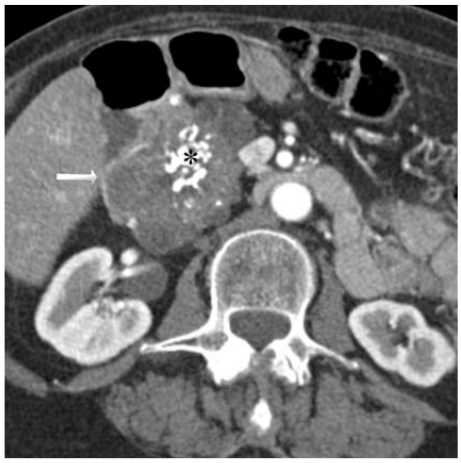

Figure 5. Serous cystadenoma

Axial contrast enhanced CT shows a hypodense, multilobular lesion arising from the pancreatic head (arrow), consistent with serous cystadenoma. Stellate calcifications are noted centrally within the lesion (*), consistent with a classic central scar.

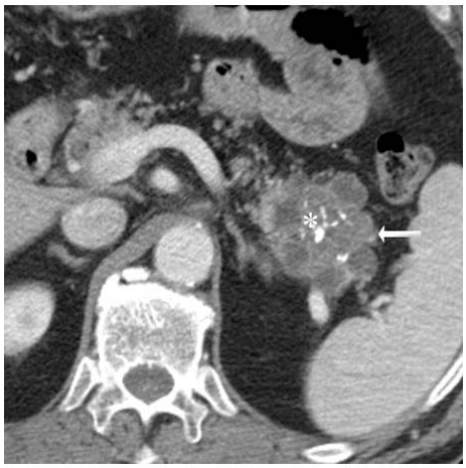

Figure 6. Serous cystadenoma

Axial contrast enhanced CT shows a hypodense, multilobular lesion arising from the pancreatic tail (arrow), consistent with a serous cystadenoma. Central stellate calcifications (*) are likewise noted within the lesion, similar to figure 4.

Serous cystadenomas are slow growing lesions that typically range in size from 5-10cm. They most commonly arise from the pancreatic head. Serous cystadenomas have no malignant potential, and are usually discovered as an incidental finding on imaging studies.

A subtype or variant of a serous cystadenoma is a macrocystic serous cystadenoma or oligocystic serous cystadenoma. These lesions are pathologically similar to a conventional serous cystadenoma, but are typically unilocular or contain few cystic elements. Similar to conventional serous cystadenomas, these lesions most commonly arise in the pancreatic head, and have no malignant potential.

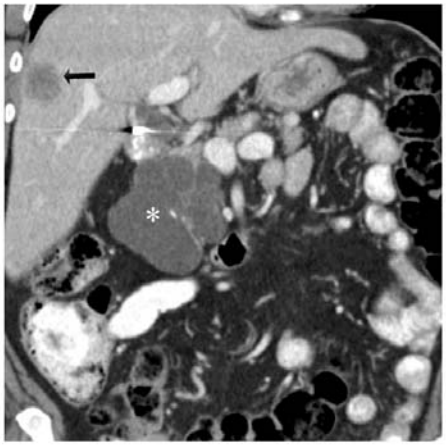

Figure 7. Oligocystic serous cystadenoma

Coronal contrast enhanced CT shows a cystic lesion arising from the pancreatic head (*). The cystic elements are larger and fewer in number than typically seen in a classic serous cystadenoma. The lesion was incidentally discovered on a CT scan that was performed for staging of a colon carcinoma. A liver metastases is noted within the right lobe of the liver (arrow).

Serous cystadenomas on CT typically present as a sharply marginated mass comprised of innumerable subcentimeter cysts in a honeycomb pattern separated by thin, frequently enhancing septa. The cystic elements may be so small that the enhancing septa predominate, mimicking a solid neoplasm. Calcifications within the central scar or septa may be seen. Capsular enhancement is commonly seen. Common bile duct and/or pancreatic ductal dilatation may be seen with larger lesions.

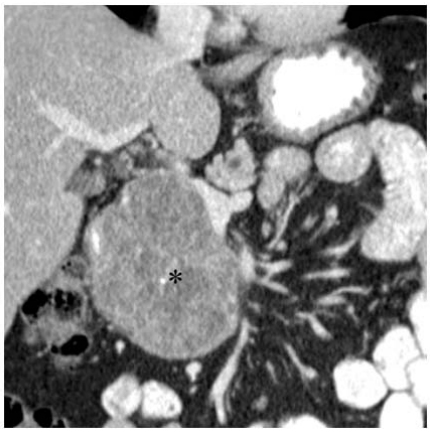

Figure 8. Serous cystadenoma

Coronal contrast enhanced CT shows a heterogeneous, predominantly solid appearing lesion arising from the pancreatic head (*). Serous cystadenomas that are comprised of very small cystic elements are often misinterpreted as solid masses on CT. MR is particularly helpful in this scenario due to its inherently superior soft tissue resolution.

MR features of a serous cystadenoma include a well defined mass comprised of innumerable T2 hyperintense cystic elements that do not communicate with the pancreatic duct [1]. MR is superior to CT when attempting to characterize complex internal architecture of these lesions. Cystic elements within a serous cystadenoma are typically T1 hypointense,

but may demonstrate intermediate signal intensity in the setting of internal hemorrhage. Septal calcifications are optimally visualized on CT, but may be seen as areas of stellate or clustered regions of central T1 hypointensity. Capsular enhancement may be seen on enhanced T1-weighted images. The central scar may likewise enhance on delayed images. MRCP provides optimal visualization of the relationship of a serous cystadenoma and the pancreatic duct.

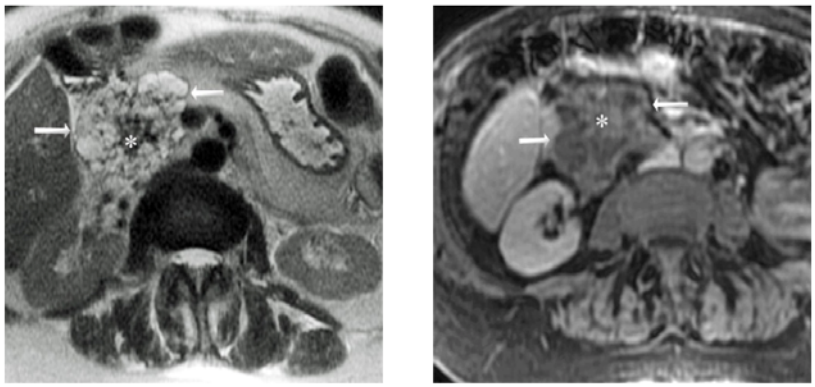

Figure 9. Serous cystadenoma

Axial T2-weighted MR shows a mass arising from the pancreatic head (arrows) that is comprised of innumerable, predominantly subcentimeter hyperintense cysts, consistent with serous cystadenoma. A hypointense central scar is noted (*), consistent with a calcified stellate scar.

Axial enhanced T1-weighted MR shows mild capsular and internal septal enhancement of the lesion (arrows). Mild enhancement of the central scar (*) is likewise noted.

The use of diffusion-weighted imaging in the evaluation of a suspected serous cystadenoma is somewhat limited due to the variable amount of fibrous septa within the lesions. In general, cystic lesions that are more complex than simple cysts are generally more hyperintense on high b values (b=800 s/mm²) due to restricted diffusion. However, serous cystadenomas with extensive fibrous septa may show relatively higher signal intensity on DWI with subsequently high b values and lower ADC values compared to simple, nonneoplastic cysts.

Diffusion-weighted image (b=50 s/mm²) shows a serous cystadenoma within the body of the pancreas (arrow) that is uniformly hyperintense.

Diffusion-weighted image (b=400 s/mm²) shows the same lesion in A (arrow) that is moderately hyperintense relative to the background pancreas.

Diffusion-weighted image (b=800 s/mm²) shows the same lesion in A (arrow) that shows variable signal with some foci that are mildy hyperintense to the background pancreas, while other elements are nearly isointense. The heterogeneity of such lesions at high b values is reflective of the variable fluid composition of the cystic elements within a serous cystadenoma.

ADC map of the same lesion in A shows an ADC value of 2.4×10^{-3} mm²/s, slightly lower than that of the pseudocyst in figure 4.

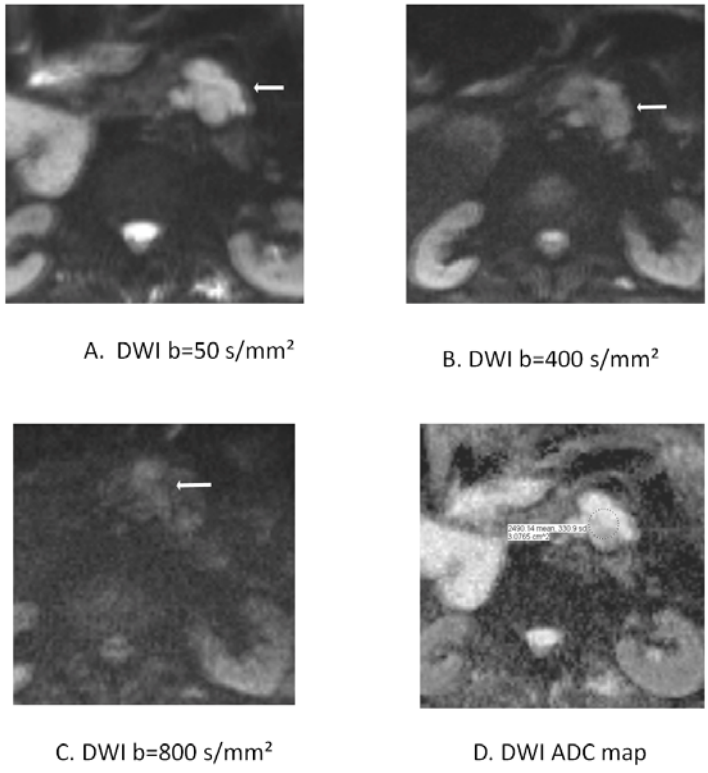

Figure 10. Serous cystadenoma

7 Mucinous cystic lesions

Mucinous cystic lesions are comprised of mucinous cystadenomas and intraductal papillary mucinous neoplasms (IPMN). Mucinous cystadenomas account for approximately 10% of pancreatic cystic neoplasms, and represent the most common cystic pancreatic neoplasm. These lesions are thick walled, low grade malignant tumors that are comprised of large, mucin-containing cysts. Mucinous cystadenomas are typically unilocular or contain a few cystic elements that are generally larger than 2 cm. These lesions typically arise from the body or tail of the pancreas [12]. Unlike IPMN's, these lesions do not communicate with the pancreatic duct [9]. The vast majority of mucinous cystadenomas occur in females with a mean age of 50 years.

Mucinous cystadenocarcinomas are thought to occur as a result of malignant transformation of a mucinous cystadenoma. Patients with cystadencarcinomas are significantly older on average than those with newly diagnosed benign mucinous cystadenomas, which is suggestive of a progression from benign mucinous cystadenoma to mucinous cystadeno-carcinoma [13].

Mucinous cystadenomas on CT typically present as a hypodense unilocular or multilocular cyst. A thick, enhancing wall is often seen. Multilocular lesions may also demonstrate enhancement of thin internal septa. Focal mural or septal calcifications are occasionally seen.

Axial contrast enhanced CT shows a sharply marginated cystic lesions arising from the proximal body of the pancreas (*), consistent with a mucinous cystadenoma. The lesion shares similar features as a pseudocyst. However, the capsule is somewhat thicker than typically seen in a pseudocyst. Additionally, the patient denied a history of prior pancreatitis, which aided in establishing the correct diagnosis.

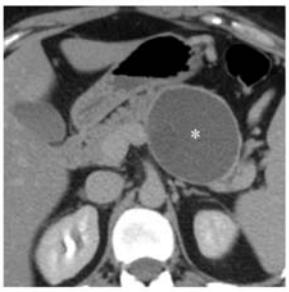

Figure 11. Mucinous cystadenoma

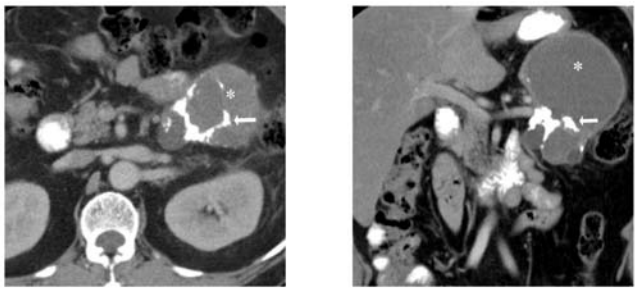

Figure 12. Mucinous cystadenoma

Axial (A) and coronal (B) contrast enhanced CT shows a multicystic lesion arising from the pancreatic tail (*), consistent with a mucinous cystadenoma. Coarse, partially calcified internal septations are noted within the mass (arrows).

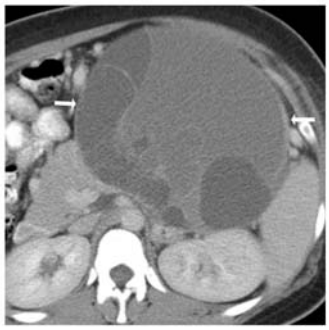

Figure 13. Mucinous cystadenoma

Axial contrast enhanced CT shows a large cystic lesion arising from the pancreatic tail (arrows). Complex internal septations are noted throughout the lesion. The internal cystic elements show regions are variable attenuation, consistent with loculated proteinaceous internal debris.

T1-weighted MR images may demonstrate variable signal intensity depending on the fluid content. Lesions containing simple fluid are uniformly T1 hypointense, whereas lesions containing more complex hemorrhagic or proteinaceous fluid are often intermediate or even hyperintense on T1 weighted images [14]. These lesions may demonstrate mild mural or septal enhancement following contrast administration. Mucinous cystadenomas tend to be uniformly hyperintense on T2 weighted images. MRCP images demonstrate no communication between these lesions and the pancreatic duct.

Unilocular mucinous neoplasms are particularly difficult to differentiate from simple nonneoplastic cysts. Mucinous neoplasms on diffusion-weighted images with high b values may demonstrate relatively higher signal when compared to simple, nonneoplastic cysts depending on the fluid composition.

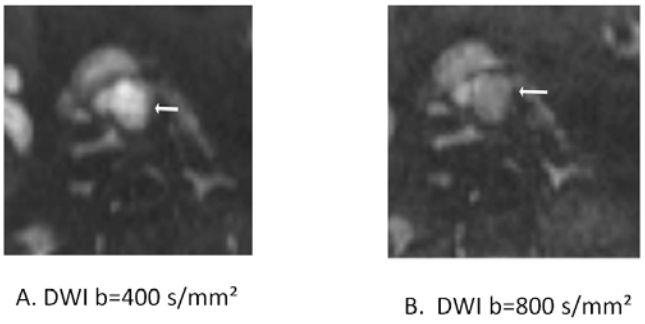

Figure 14. Mucinous cystadenoma

DWI with a b value of 400s/mm² shows a unilocular cyst in the neck of the pancreas (arrow) that shows moderately increased signal intensity relative to the background pancreas.

DWI of the same lesion in A with a b value of 800 s/mm² shows some loss of signal when compared to the b400 image, but is nevertheless considerably higher in signal than the background pancreatic parenchyma, indicative of relatively complex fluid composition.

The presence of enhancing mural elements is suggestive of malignancy. Any enhancing soft tissue within a cystic neoplasm on MR warrants surgical resection. Mucinous cystadenocarcinomas generally occur in mucinous lesions larger than 4 cm [13].

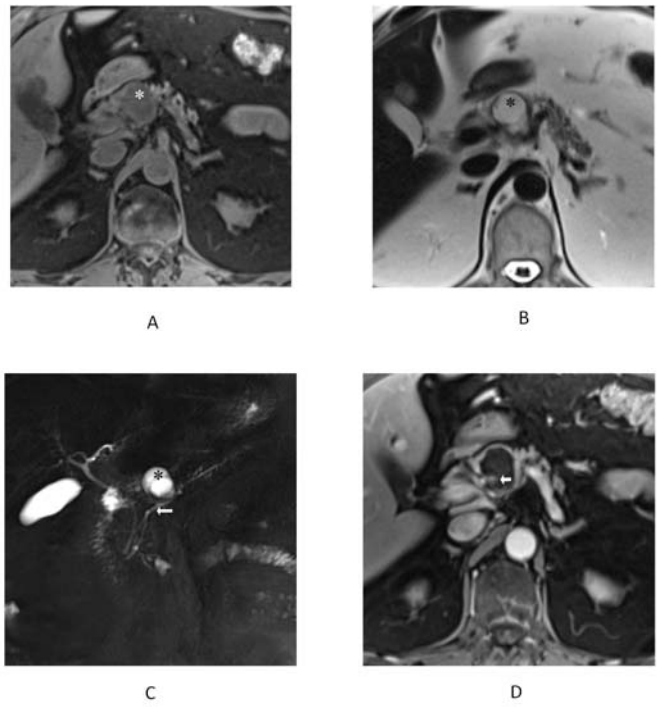

Figure 15. Mucinous cystadenocarcinoma

Axial T1-weighted (A) and T2-weighted (B) MR shows a sharply marginated lesion within the head of the pancreas (*). Subtle areas of increased signal are noted on T1-weighted images, consistent with internal proteinaceous debris. Thick slab MRCP (C) shows that the lesion (*) does not communicate with the normal caliber pancreatic duct (arrow), an important feature in distinguishing this lesion from an IPMT. Axial enhanced T1-weighted MR shows an enhancing mural nodule (arrow) that prompted resection.

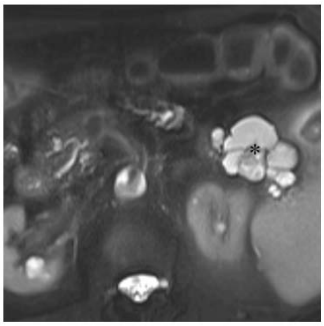

Figure 16. Mucinous cystadenocarcinoma

Axial T2-weighted MR with fat saturation shows a multilocular cystic lesion arising from the pancreatic tail (*), consistent with a mucinous lesion of the pancreas. Internal nodularity (*) was concerning for malignancy, which was histologically confirmed following excision.

Intraductal papillary mucinous tumors (also commonly referred to as intraductal papillary mucinous neoplasms) are mucinous cystic tumors of the pancreas that are histologically distinct from mucinous cystadenomas, and were first described relatively recently by Sessa et al in 1994 [15]. These low-grade malignancy lesions occur most frequently in men with a mean age of 65 years. Intraductal papillary mucinous tumors (IPMT's) occur as a result of mucinous transformation of the pancreatic ductal epithelium. These lesions are characterized by excessive mucin production which results in cystic dilatation of the pancreatic duct. A characteristic clinical feature is excess mucin spillage from the ampulla of Vater on endoscopic retrograde cholangiopancreatography. IPMT's are typically classified according to their relationship to the pancreatic duct as either main pancreatic duct (MPD) or branch pancreatic duct (SPD) type. This classification has significant clinical relevance, since main pancreatic duct IPMT's demonstrate invasive carcinoma in 60-70% of cases, whereas only 22% of branch pancreatic duct lesions demonstrate invasive carcinoma [16-18]. Combined main duct and branch duct lesions account for the most common subtype of IPMT.

CT findings of branch pancreatic duct IPMT's include lobular "grape-like" multicystic lesions, typically within the head or uncinate process of the pancreas that are contiguous with a frequently dilated main pancreatic duct.

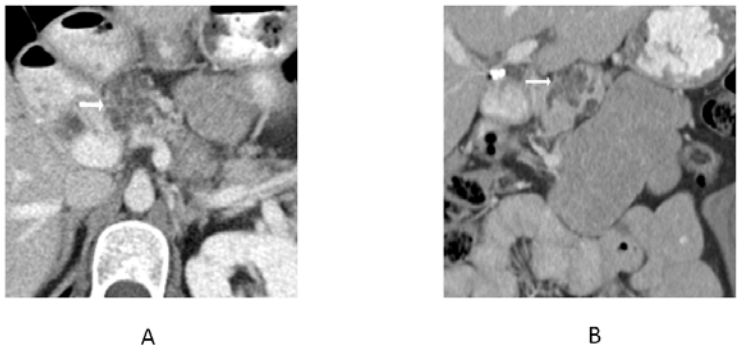

Figure 17. Intraductal papillary mucinous tumor

Axial (A) and coronal (B) contrast enhanced images show a poorly marginated, nonencapsulated lesion comprised of multiple subcentimeter cystic elements within the head of the pancreas (arrow), consistent with an IPMT.

Main pancreatic duct IPMT's generally present with diffuse dilatation and tortuosity of the entire pancreatic duct. Combined type lesions are frequently seen as a multicystic lesion that communicates with a dilated main pancreatic duct.

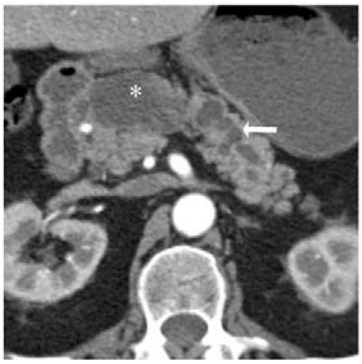

Figure 18. Intraductal papillary mucinous tumor

Axial contrast enhanced CT shows a cystic lesion arising from the head and neck of the pancreas (*). There is diffuse dilatation of the main pancreatic duct (arrow). These findings are most consistent with a combined type IPMT with involvement of both main and side branches of the pancreatic duct.

Dilatation of the main pancreatic duct > 6 mm is worrisome for a malignant IPMT. Other features suggesting malignancy is the presence of intraductal nodules > 6 mm and solid nodules > 2 cm arising from or adjacent to the primary cystic lesion of an IPMT.

Coronal contrast enhanced CT shows a lobular lesion arising from the pancreatic head containing enhancing mural nodules (white arrow). There is marked diffuse dilatation of the pancreatic duct (*). Poorly marginated hypodense lesions were seen throughout the liver (black arrows), consistent with metastatic disease.

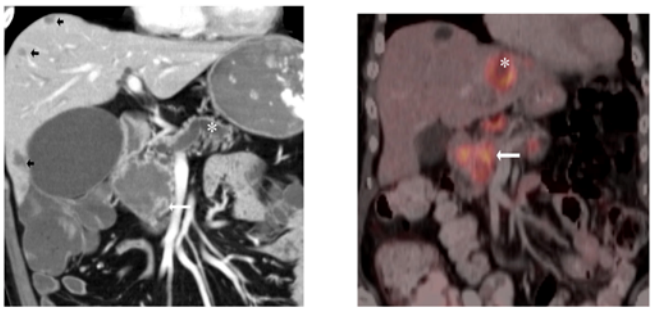

Figure 19. Malignant intraductal papillary mucinous tumor

Coronal CT-PET obtained several weeks later in the same patient shows intense metabolic activity arising from the solid elements of the previously visualized cystic lesion within the pancreatic head (arrow). Peripheral metabolic activity was likewise seen within a hypodense lesion within the left lobe of the liver, consistent with metastatic disease.

 ISSN 1925-4008 E-ISSN 1925-4016

MR imaging is generally considered to be the modality of choice for characterizing IPMT's. MR provides superior depiction of the internal architecture of these lesions. Classic features of an IPMT on MR include T1 hypointense cystic clusters usually adjacent to a dilated pancreatic duct. T2 weighted images generally demonstrate T2 hyperintense cystic clusters that likewise communicate with the dilated main pancreatic duct.

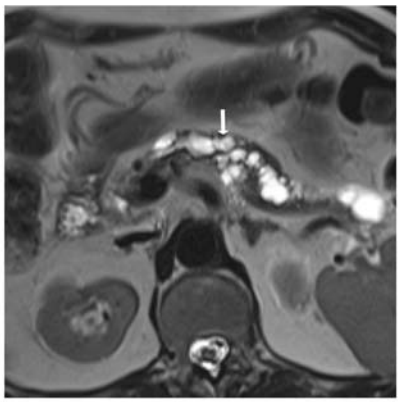

Figure 20. Intraductal papillary mucinous tumor

Axial T2-weighted MR shows multiple cystic lesions (arrow) arising from a dilated main pancreatic duct, consistent with IPMT

Thick slab coronal MRCP shows marked diffuse dilatation of the main pancreatic duct, consistent with IPMT.

Coronal T2-weighted MR with fat saturation shows multiple cystic lesions arising from the main pancreatic duct (*), consistent with multiple side branch dilatations in the setting of an IPMT.

IPMT's typically demonstrate elevated ADC values throughout the dilated duct due to the presence of fluid. ADC values tend to vary depending on the composition and viscosity of the mucin. In general, DWI does not play a significant role in the characterization of IPMT's.

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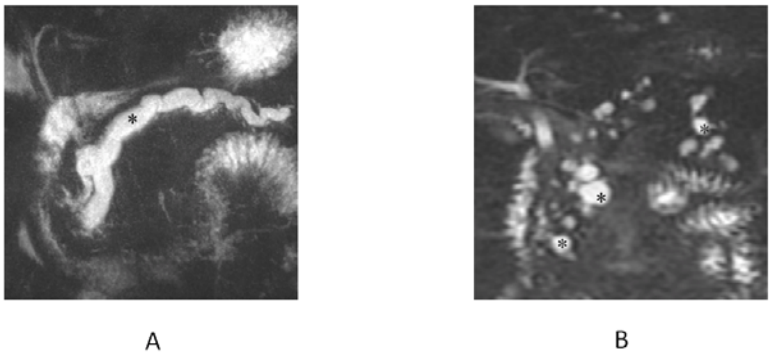

Figure 21. Intraductal papillary mucinous tumor

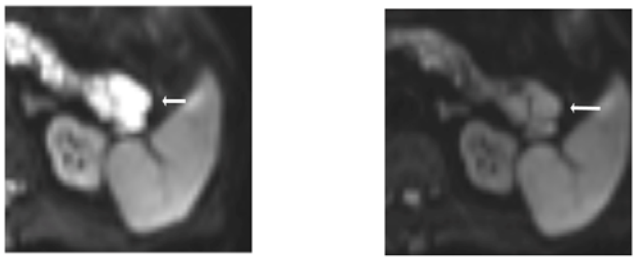

Figure 22. Intraductal papillary mucinous tumor

Diffusion weighted image (b=50 s/mm²) shows a markedly hyperintense, multilocular mass (arrow) arising from the pancreatic tail.

Diffusion weighted image (b=400 s/mm²) of the same lesion in A (arrow) shows a decrease in signal intensity when compared to the b50 image.

Diffusion weighted image (b=800 s/mm²) of the same lesion in A (arrow) shows that the cystic lesion is relatively isointense to the background pancreas, suggesting an IPMT that is comprised of relatively simple fluid.

ADC map of the lesion in A shows a relatively elevated value of 3.1×10^{-3} mm²/s, further indicative of relatively simple fluid composition.

T2-weighted images frequently show ductal nodules or papillary excrescences in the setting of a malignant IPMT. T1-weighted enhanced images may demonstrate enhancing nodular elements that are particularly worrisome for the presence of underlying malignancy. MRCP offers optimal visualization of the relationship of the lesion to the pancreatic ductal system that is often not feasible by CT [3].

Axial T2-weighted MR shows a mixed solid and cystic lesion arising from the pancreatic head (*). There is marked dilatation of the main pancreatic duct (arrow). Such lesions can be difficult to distinguish from pancreatic ductal adenocarcinoma.

Coronal enhanced T1-weighted MR in the same patient shows a heterogeneously enhancing mass within the head of the pancreas with mixed solid (arrow) and cystic (*) elements.

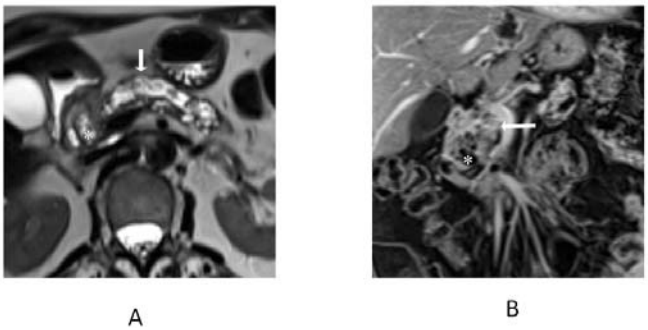

Figure 23. Malignant intraductal papillary mucinous tumor

8 Lymphoepithelial cysts

Lymphoepithelial, or true congenital cysts of the pancreas are rare, representing < 1% of all cysts encountered in the pancreas [19]. These lesions occur most commonly in men with a mean age of 55 years. The lesions are usually < 2 cm, are round or oval in shape, and should contain no internal solid elements. The lesions have no malignant potential, and are often indistinguishable from pseudocysts. A clinical history of prior pancreatitis will often aid in differentiating between these two entities. Multiple simple cysts within the pancreas are rarely encountered, but can be seen in association with von Hippel-Lindau disease or autosomal dominant polycystic kidney disease.

On CT, a lymphoepithelial cyst is a simple appearing, unilocular cyst with attenuation values of simple fluid. Cyst walls should be thin or imperceptible. On MR, these lesions are uniformly T2 hyperintense, T1 hypointense and do not communicate with the pancreatic duct. These lesions demonstrate no mural or internal enhancement.

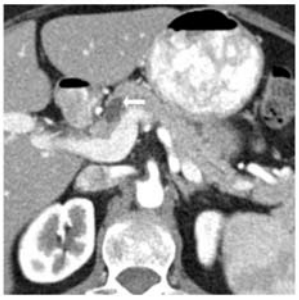

Figure 24. Lymphoepithelial cyst

Axial contrast enhanced CT shows a sharply marginated cystic lesion within the head of the pancreas that does not communicate with a normal caliber pancreatic duct. Such lesions are difficult to differentiate from a small pseudocyst. There was no history of prior pancreatitis in this particular patient, which led to the diagnosis of lymphoepithelial cyst.

Axial (A) and coronal (B) T2-weighted MR images show innumerable simple cysts arising from the pancreas (*). An important feature in differentiating this disease entity from an IPMT is the presence of a normal caliber pancreatic duct that does not communicate with the parenchymal cysts. (C) DWI with a b value of 50 s/mm² shows uniformly hyperintense cysts throughout the pancreatic tail. (D) DWI with a b value of 800 s/mm² shows that the cysts are isointense to the background pancreas and are no longer detectable. (E) ADC map shows a relatively elevated ADC value of 3.1×10^{-3} mm²/s, indicative of simple fluid composition.

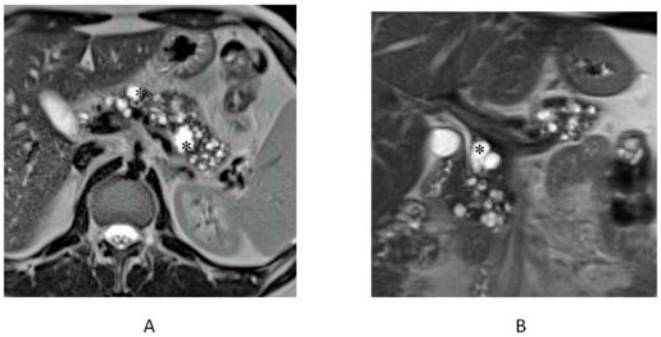

Figure 25. von Hippel-Lindau disease

9 Solid pancreatic tumors with cystic degeneration

9.1 Ductal adenocarcinoma

Ductal adenocarcinoma is the most common and most lethal of all pancreatic tumors, accounting for 90% of pancreatic neoplasms [1]. The prognosis of ductal adenocarcinoma is dismal, with a 5 year survival of less than 3%. Although these tumors are predominantly solid, cystlike features from either cystic degeneration, retention cysts or pseudocysts may be seen at histologic analysis in up to 8% of ductal adenocarcinomas [20]. Early distant metastatic disease to the liver, peritoneum and regional lymphadenopathy is commonly seen.

Ductal adenocarcinoma on CT typically presents as a heterogeneous, poorly marginated, ill-defined hypodense mass with early pancreatic ductal and/or common bile duct obstruction. These lesions are most commonly seen in the pancreatic head, followed by body and tail in descending order of frequency. Direct local invasion of adjacent structures and vascular invasion is likewise frequently seen at an early stage. Cystic degeneration may infrequently occur, mimicking a more benign primary cystic pancreatic mass.

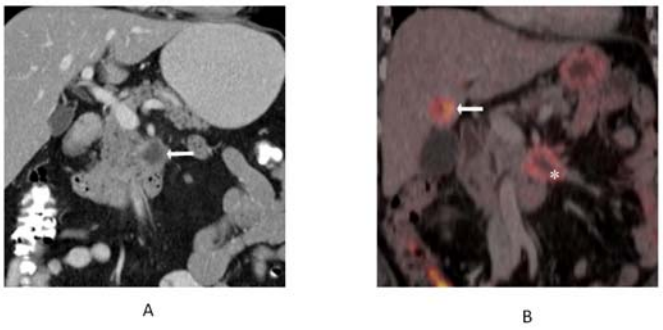

Figure 26. Cystic ductal adencarcinoma

Coronal contrast enhanced CT shows a cystic lesion within the uncinate process of the pancreas (arrow) with ill defined margins that was of indeterminate etiology on CT.

Coronal image from a CT-PET that was performed 2 weeks later showed avid peripheral metabolic activity of the uncinate process mass (*), consistent with a pancreatic malignancy. A metabolically active lesion was likewise noted within the liver (arrow), consistent with metastatic disease.

MR features will similarly demonstrate a poorly defined mass with early ductal and vascular invasion. Cystic elements on MR may represent tumoral necrosis, adjacent pseudocyst development or side branch obstruction of the pancreatic duct that appears hypointense on T1-weighted images and hyperintense on T2-weighted images. Pancreatic ductal obstruction is commonly seen at a relatively early stage on MRCP [9].

9.2 Solid pseudopapillary tumors

Solid pseudopapillary tumors, previously known as solid and papillary epithelial neoplasms (SPEN) are uncommon lesions that occur predominantly in women with a mean age of 28 years. These lesions have a low grade malignant potential, and tend to be well-defined, heterogeneous and large at presentation. The appearance of a solid pseudopapillary tumor varies from completely solid to mostly cystic, depending on the degree of internal degeneration.

On CT, these lesions typically present as a large, encapsulated solid mass with a variable degree of cystic or hemorrhagic foci.

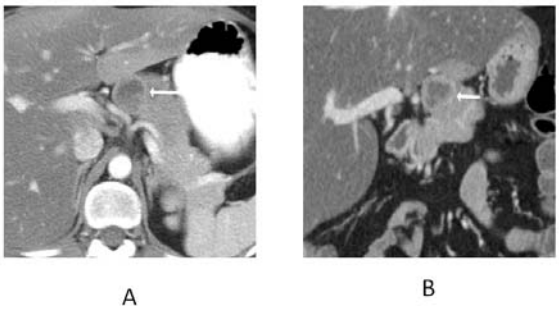

Figure 27. Solid pseudopapillary tumor

Axial (A) and coronal (B) contrast enhanced CT shows a predominantly cystic lesion within the neck of the pancreas (arrow) that was indeterminate in etiology. Following Whipple procedure, the lesion was histologically confirmed as a solid pseudopapillary tumor.

Axial contrast enhanced CT shows a large, predominantly solid mass arising from the pancreatic head (arrows). Scattered cystic elements are noted throughout the lesion (*).

On MR, T1-weighted images typically demonstrate a large, well-delineated mass with central areas of heterogeneous signal consistent with simple or complex cystic degeneration. T2-weighted images demonstrate variable signal that is usually more heterogeneous than that of primary cystic lesions of the pancreas. Following contrast administration, enhancing soft-tissue components are frequently seen that may overlap with a mucinous cystadenocarcinoma. Other differential considerations include a cystic pancreatic endocrine (islet cell) tumor, which show both imaging and cytologic similarities [9].

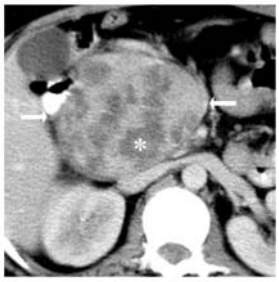

Figure 28. Solid pseudopapillary tumor

9.3 Pancreatic endocrine tumors

Pancreatic endocrine tumors (PET), also known as islet cell or neuroendocrine tumors, arise from pancreatic endocrine cells or islets of Langerhans. These relatively rare tumors show no gender predilection and occur in middle aged adults with a mean age of 53 years. The most common subtype is insulinoma, followed by gastrinoma and other nonfunctional subtypes in order of descending frequency. These lesions tend to be small, but may be as large as 10 cm. Pancreatic endocrine tumors are generally solid and well vascularized. Cystic pancreatic endocrine tumors are relatively rare, occurring in approximately 17% of 170 surgically resected specimens in a recent study [21]. The cystic elements found in pancreatic endocrine tumors are thought to be due to tumor degeneration [22]. The presence of a cystic PET may be highly relevant, since these individuals are significantly more likely to have an underlying multiple endocrine neoplasia (MEN) syndrome than a patient with a uniformly solid PET [21].

On CT, pancreatic endocrine tumors are typically small and sharply marginated. Conventional pancreatic endocrine tumors are generally hypervascular and frequently demonstrate avid, homogeneous enhancement in the arterial phase.

Imaging findings of a cystic PET are highly nonspecific, and a definitive diagnosis is generally difficult to establish. When cystic degeneration occurs, the presence of residual peripheral enhancement when seen can be helpful in establishing the diagnosis of a cystic PET.

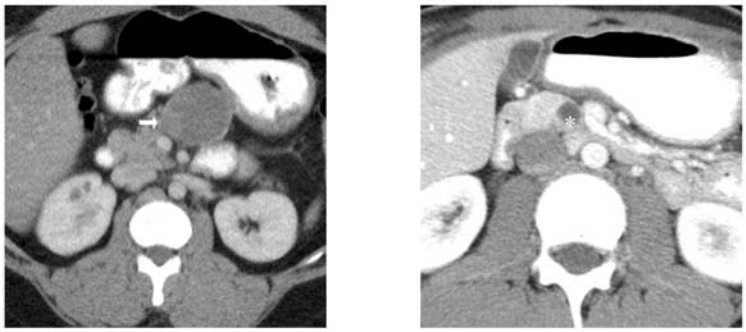

Figure 29. Cystic pancreatic endocrine tumor

Axial contrast enhanced CT shows a sharply marginated cystic lesion arising from the pancreatic neck containing an enhancing mural nodule (arrow). The findings were nonspecific, and a diagnosis of a mucinous cystic lesion was favored. Following resection, the diagnosis of a pancreatic endocrine tumor was established at pathology.

Axial contrast enhanced CT showed a small, sharply marginated, nonenhancing cyst within the pancreatic neck that was assumed to represent a lymphoepithelial cyst. Following resection, a pancreatic endocrine tumor was histologically confirmed.

On MR, these lesions are typically T1 isointense to the background pancreas, although larger lesions may be heterogeneous, particularly in the setting of necrosis and cystic degeneration. T2-weighted images demonstrate areas of increased signal in the setting of cystic degeneration. Cystic pancreatic endocrine tumors on T1 enhanced images are predominantly hypointense, corresponding to areas of degeneration, but may show areas of peripheral nodular or ring enhancement in regions of viable tumor [9].

Diffusion weighted imaging may aid in the characterization of such lesions. Cystic pancreatic endocrine typically remain hyperintense on DWI images with high b values and show low ADC values due to the complex nature of the fluid.

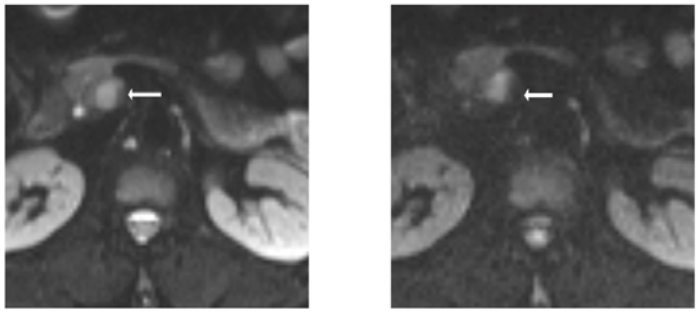

Figure 30. Cystic pancreatic endocrine tumor

Diffusion-weighted image with a b value of 50 s/mm² shows an intermediate signal lesion in the pancreatic head (arrow). Diffusion-weighted image of the same lesion in A (arrow) with a b value of 400 s/mm² demonstrates little change in the

signal intensity when compared to the b50 image. Diffusion-weighted image with a b value of 800s/mm² again shows a hyperintense lesion (arrow) similar to the b50 image. ADC map shows a relatively decreased ADC value of 1.3×10^{-3} mm²/s, consistent with complex cystic fluid.

9.4 Cystic pancreatic metastases

Cystic metastases to the pancreas are very uncommon. Hypovascular metastases to the pancreas have been described in the setting of primary malignancies of the lung, breast, colon, melanoma and sarcoma. Such lesions may be sufficiently hypodense as to appear cystic on both CT and MR studies depending on the size and chronicity of these lesions.

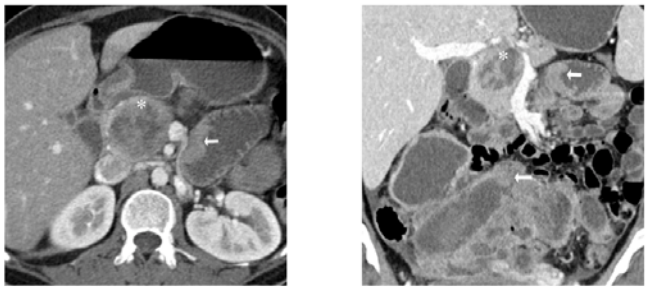

Figure 31. Cystic melanoma metastases

Axial (A) and coronal (B) contrast enhanced CT shows a heterogeneous, predominantly cyst mass arising from the pancreatic head (*) in this patient with widespread metastatic melanoma. Mural nodules are likewise noted within the small bowel (arrows), consistent with metastatic disease. Post mortem evaluation confirmed the presence of pancreatic metastases.

10 Conclusion

Cystic lesions of the pancreas are seen in a variety of different disease processes. While some lesions are purely cystic de novo, other lesions of the pancreas may undergo cystic degeneration. An understanding of the various disease manifestations on imaging is essential to establish the most appropriate diagnosis. Optimal depiction of the internal architecture of cystic pancreatic lesions is essential in order to establish a definitive diagnosis. While CT can be useful in the detection and characterization of these lesions, MR remains the gold standard for the noninvasive evaluation of cystic pancreatic lesions due to its inherently superb soft-tissue resolution. Newer MR techniques such as diffusion-weighted imaging may prove to be an essential tool in the detection and characterization of cystic pancreatic lesions. Accurate classification of these lesions is a crucial step in selecting the most appropriate clinical management.

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