PANCREAPEDIA
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Imaging in Chronic Pancreatitis

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1. Introduction

Pancreatitis is the most common benign condition affecting the pancreas and it occurs in two forms - acute and chronic characterized by different clinical, morphological and histological features (10). Chronic pancreatitis (CP) is characterized by progressive inflammation and fibrosis of pancreas leading to irreversible structural changes causing both endocrine and exocrine dysfunction. The hallmarks of CP include abdominal pain, malabsorption, malnutrition, diabetes and pancreatic calcification. Currently there is no effective medical treatment for treating this disease especially when it is recognized at a late stage. Early detection of this condition may prevent further progression of the disease process. Diagnosis and evaluation of CP can be quite challenging and usually needs a battery of tests. Endoscopic Retrograde Cholangio-Pancreatography (ERCP) was earlier considered as the gold standard for the diagnosis for CP but today other modalities such as Ultrasonography (US), Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Endoscopic ultrasound (EUS) are used to evaluate the structural changes in the parenchyma and pancreatic duct. Furthermore to evaluate the exocrine function many indirect and direct methods are available. Fecal elastase 1 (FE 1) is one of the commonly used indirect method which is easy to perform but has low sensitivity and its utility in diagnosing CP is controversial (7, 16, 50). Tubed secretin test is a direct method which involves prolonged intubation and serial collection of pancreatic juice after hormonal stimulation is considered as a reference standard for the evaluation of exocrine function of pancreas in spite of many issues with this technique (5, 43). Secretin enhanced Magnetic Resonance Cholangio-Pancreatography (S-MRCP) in which secretin is used to stimulate the pancreatic juice is emerging as a one stop shop modality for the evaluation of both structural and functional aspects in CP (43). Advancements have been made in MRI technique in which diffusion weighted imaging (DWI) along with apparent diffusion co-efficient (ADC) can be used to study the microscopic diffusion of water molecules. This can give a unique insight in to the tissue characteristics of pancreas which will be discussed later in this chapter (2, 18, 38).

2. Etiopathogenesis of CP

Alcohol abuse is one of the common causes of chronic pancreatitis constituting up to 90% of cases in western countries (38). Other factors such as cigarette smoking, genetic predisposition and high protein diet are also thought to play an important role apart from alcohol intake (27). Pancreatic or periampullary neoplasms, sphincter of oddi dysfunction, ampullary stricture and congenital lesions like abnormal pancreaticobiliary junction and pancreatic divisum are also important causes of CP. Hereditary pancreatitis is a rare form of CP caused by trypsinogen gene mutation. Other causes of CP include hypercalcemia, hyperparathyroidism and chronic renal failure.

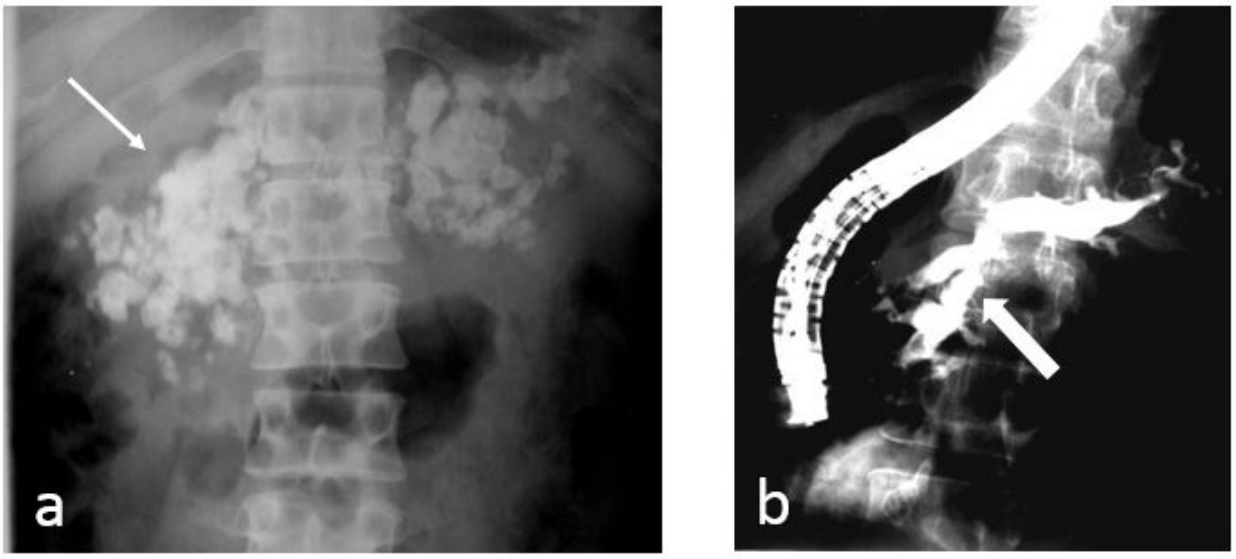

Figure 1. Abdominal radiograph in AP projection (a) shows multiple well defined calcific opacities (thin arrow) seen along the expected course of pancreas on either sides of spine suggestive of pancreatic calcification. ERCP image of a different patient (b) shows dilated and tortuous MPD and its side branches (thick arrow). These findings are suggestive of chronic pancreatitis.

Autoimmune pancreatitis (AIP) is an unusual and distinct form of CP which will be discussed later in the chapter.

3. Imaging Modalities

There are various imaging modalities for the diagnosis of CP which have their own advantages and limitations and no single modality provides all the information.

Abdominal Radiographs

Decades ago, before the advent of cross sectional modalities, the imaging diagnosis of CP was based on plain radiography. CP is manifested on abdominal radiographs as multifocal calcifications in the epigastric region **(Figure 1a)**. These calcifications are typically seen across the spine along the course of pancreas. Since calcifications are usually seen in the advanced cases and only seen in certain types of CP, radiographs are not sensitive (30-70%) (38). Although the calcifications are specific they have to be differentiated from calcifications from other causes and overlying organs. Because of the above limitations abdominal radiographs are not routinely done for the evaluation of CP. Often pancreatic calcification is detected on radiographs done to rule-out other causes for abdominal pain.

ERCP

ERCP is considered as the gold standard for the diagnosis of CP because of its superior spatial resolution and its ability to depict side branch abnormalities in early CP. It has an added advantage of therapeutic interventions whenever needed. Its limitations are the invasive nature of the procedure and procedure related complications. After the advent of MRCP the popularity of ERCP for the diagnostic evaluation has reduced considerably as MRCP is a non-invasive technique (32). However, ERCP has the advantage of showing the ductal system in distended state which is very helpful in detecting subtle lesions like pancreatic divisum. The diameter of normal Main Pancreatic Duct (MPD) varies with the region of pancreas (3-4 mm in head, 2-3 mm in body and 1-2 mm in tail region) (38). Multiple side branches are seen to join the MPD at right angles in alternating fashion. The earliest features of CP may be seen only on ERCP in the form of irregularity and dilatation of side branches. These changes can become more severe along with dilatation, loss of normal tapering and irregularity of MPD as the disease

progresses **(Figure 1b)**. Alternate dilatation and stenosis of MPD can give the appearance of chain of lakes. Intraductal calculi can be seen as filling defects. ERCP is also helpful in diagnosing other obstructive causes of CP such as ampullary lesions, intraductal neoplasms and congenital anomalies such as pancreatic divisum. The Cambridge classification of CP based on ERCP is used to group patients in to equivocal, mild, moderate or marked type. The status of MPD, side branches, presence of calculi and ductal strictures are taken in to account in Cambridge classification (44).

AIP unlike other forms of CP shows focal, segmental or diffuse narrowing of MPD and non-visualization of side branches on ERCP (45). The narrowing can also be seen in the lower end of Common Bile Duct (CBD) causing biliary dilatation. AIP can have association with primary sclerosing cholangitis which is seen as multifocal narrowing in more proximal biliary ducts.

Ultrasonography (US)

Sonography of pancreas is challenging because of its retroperitoneal location and overlapping bowel loops. It is also dependent on the body habitus of the patient and the skill of the operator. Various manoeuvres such as changing the position of patient, distending the stomach with water and using the spleen as a window to visualise the tail of pancreas may be necessary to image the pancreas in its entirety. In spite of the above limitations US is still the first line modality for the evaluation of abdominal pain, because of its easy availability, lower cost and lack of ionising radiation. Pancreatic evaluation is done in fasting state to avoid bowel gas obscuring the visualisation.

Normal pancreas is iso or hyperechogenic compared to normal liver and progressive fatty replacement can occur with age (13). In early stage of CP, pancreas loses its hyperechogenicity and becomes heterogeneous because of focal inflammatory changes. With disease progression from moderate to severe stage the changes become more prominent and they are appreciable in up to 70% of patients (6, 23). In late stage disease, the changes of CP are striking in the form of irregular dilated MPD with pancreatic and intraductal calculi and associated atrophy of pancreas (6, 19) **(Figure 2a,b)**. It can also show collections or pseudocysts around the pancreas. Occasionally, US can detect pancreatic focal lesions which are responsible for the development of obstructive type of CP.

Elastography is a novel method to evaluate the tissue hardness which can be used to evaluate the extent of involvement in CP and also to evaluate the extent of fibrosis which can be a prognostic indicator in patient undergoing surgical procedures. Elastography can be used along with transabdominal and endoscopic ultrasound. There are two types of elastography commercially available (13). The first is strain imaging which qualitatively evaluates the tissue strain in response to an exogenous acoustic pulse. The second type is shearwave elastography which quantitatively evaluates the tissue hardness based on the velocity of shear waves in the tissues. In both the methods, the elastogram is represented as a color map superimposed over the B-mode images.

Computed Tomography (CT)

Wider availability and technical advances over the last two decades have made CT the imaging modality of choice for the evaluation of CP. The pancreatic calcifications which are crucial for clinching the diagnosis of CP are best seen on CT **(Figure 2c)**. It is sensitive to even small punctate calcifications which can be missed on other imaging modalities.

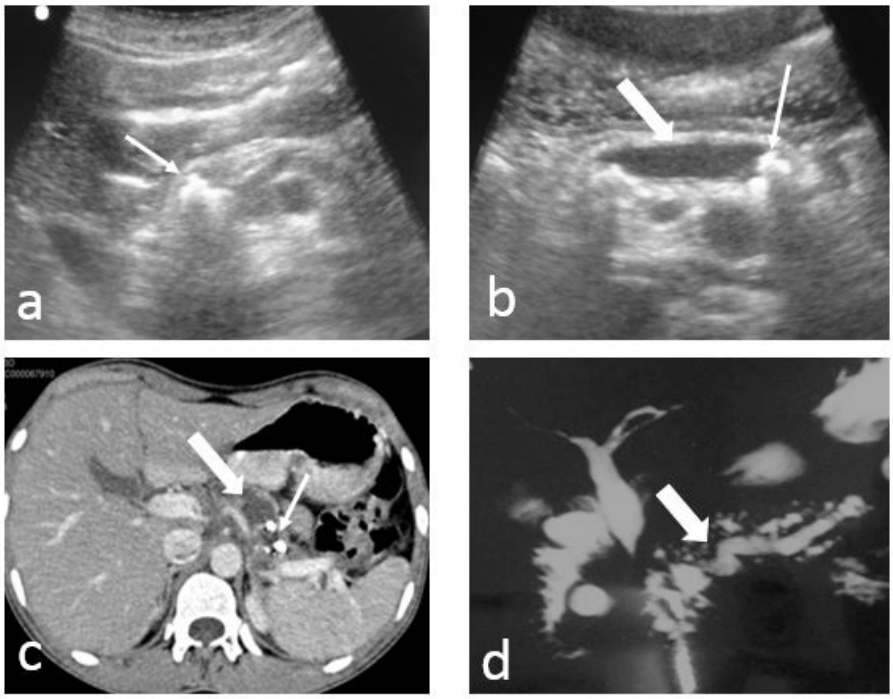

Figure 2. Transabdominal sonography images (a,b) show calcification (thin arrow) in the head and tail of pancreas with dilated MPD (thick arrow). Axial contrast enhanced CT image (c) also shows multiple intraductal calcifications (thin arrow) and dilated MPD (thick arrow). Heavily T2W thick slab MRCP image (d) shows irregularly dilated MPD and its side branches (thick arrow). Also a small fluid collection is seen in the region of head of pancreas and the common bile duct is dilated till the lower end with smooth tapering suggestive of benign stricture. The above findings are typical for chronic calcific pancreatitis (CCP).

However lack of information on the exocrine function of pancreas, limited contrast resolution and exposure to radiation are the most important limitations of CT. The complete evaluation of CP on CT is optimally done using a multiphase protocol which includes unenhanced scan, pancreatic phase and a venous phase scan.

Pancreatic parenchymal and intraductal calcifications are detected on unenhanced scan and detection of arterial complications and arterial mapping as a part of surgical planning are done using the pancreatic phase scan. Pancreatic parenchymal and ductal evaluation, pseudocysts and focal lesions are evaluated using the venous phase scans.

Normal pancreas on CT is seen as a homogeneous structure with smooth lobulated borders. Any inflammation in pancreas leads to focal or diffuse hypodensity and surrounding fat stranding. The characteristic features of CP are atrophy of pancreas (54%), ductal dilatation (up to 68%) and multiple parenchymal and intraductal calcifications (50%) (29). The pancreatic head is the commonest location of parenchymal calcifications. The calcification can vary in size and morphology and the degree of calcification is directly proportional to the duration of the disease (12, 38). Calcifications are seen early in alcoholic CP and certain hereditary pancreatitis as compared to obstructive CP. Alcohol related CP shows calcification in 20-40% of patients and it is usually seen after 5-10 years (17). The MPD shows segments of stenosis alternating with dilatation containing multiple calculi of varying sizes and irregular morphology.

In patients with cystic fibrosis having CFTR mutations the calcifications appear late and they are smaller when compared to other genetic mutation related CP (15). The stones in genetic

mutation related CP other than cystic fibrosis are usually round or oval in shape measuring more than 2-3 cm (20). On CT they have a typical appearance with hypodense centre and hyperdense periphery which is due to the lack of calcium in the centre. It is often referred to as bull's eye stone (20, 22, 23). These stones are usually arranged linearly within the dilated MPD (24). The above features of multiple large round to oval bull's eye stones should point towards the diagnosis of CP secondary to genetic mutations. Tropical pancreatitis which is predominantly a disease of developing countries also presents with parenchymal atrophy (50%), ductal dilatation and large calculi (80%) which can reach up to 5 cm in size and can extend in to side branches (13, 25, 26). This finding is in contrast to alcoholic CP in which calcifications are small and speckled. CT in this scenario has an edge over MRI in giving a specific diagnosis.

In patients with obstructive CP the MPD is dilated however parenchymal or intra ductal calcifications are usually not seen differentiating it from other non-obstructive causes (27). Ductal dilatation is best seen on venous phase after contrast administration where the hypodense MPD stands out against the enhancing parenchyma. In the early stage of CP the MPD and side branches changes are not noticeable on CT and the contrast enhancement is also relatively homogeneous. With disease progression multifocal fibrotic changes lead to heterogeneity of enhancement as the normal parenchyma enhances earlier in the venous phase whereas the fibrotic areas show delayed enhancement. Progressive fibrosis causes atrophy of parenchyma and ductal dilatation **(Figure 3)**. Another important role of CT is to evaluate the cause for obstructive CP. Focal lesions such as pancreatic adenocarcinoma, periampullary carcinoma, and rarely non-functioning neuroendocrine tumors can lead to MPD obstruction and causes repeated attacks of pancreatitis eventually presenting as CP. Cystic tumors of pancreas such as serous, mucinous and intraductal tumors can also cause obstructive form of CP. CT is very helpful in characterising these solid tumors and to some extent cystic tumors.

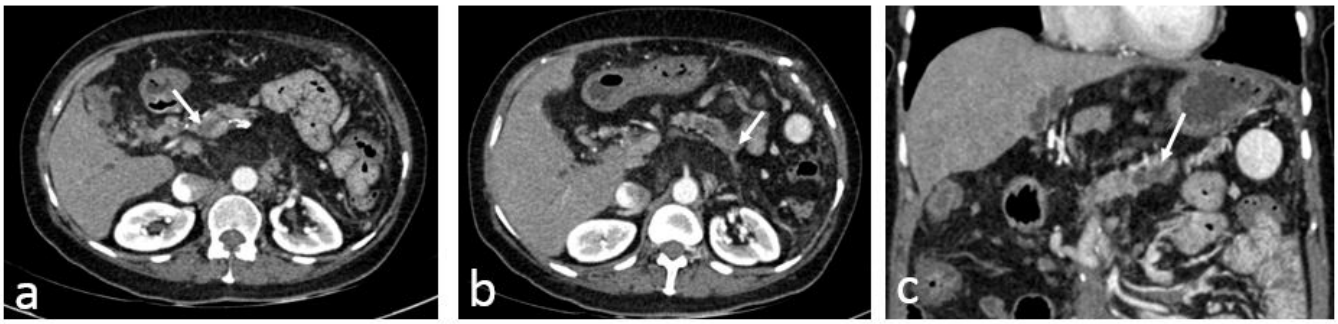

Figure 3. Contrast enhanced CT in axial (a,b) and coronal plane (c) in a patient with chronic pancreatitis show that the pancreatic parenchyma is atrophied and MPD is dilated (arrow). In this patient the calcifications are conspicuously absent.

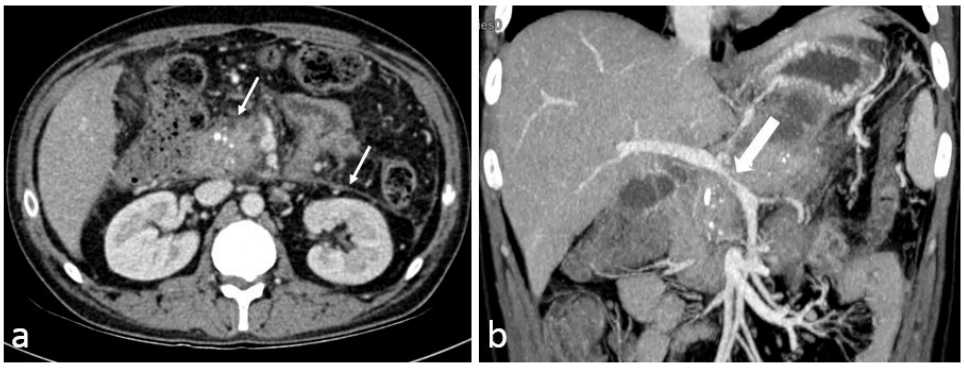

Figure 4. CECT images in axial plane (a) and thin maximum intensity projection in coronal plane (b) of a patient of CCP who presented with acute abdominal pain show features of CCP as evidenced by the presence of multiple calcific densities distributed throughout the pancreas. In addition there is marked fat stranding and fascial thickening (thin arrow) seen around the pancreas. There is pressure effect seen over the main portal vein (thick arrow) caused by the inflamed pancreas. These findings are suggestive of acute exacerbation of CCP.

Pancreatic divisum is one of the common congenital causes for CP for which the modality of choice is MRI. However, in advanced stages CT can recognise the changes due to pancreatic divisum. The inflammatory, fibrotic changes and the ductal changes are limited to the dorsal part of pancreas whereas the ventral pancreas appears normal (39). Rarely, duodenal dystrophy which is considered to be due to the presence of ectopic pancreatic tissue in the duodenal wall can be the cause of CP. Recurrent inflammation leads to fibrosis and cyst formation in the duodenal wall leading to MPD compression and obstructive type of CP which can be recognised on CT. On contrast enhanced CT (CECT) the fibrotic area enhances late in the delayed phase compared to the rest of normal pancreas. If the lesion is predominantly solid it can mimic pancreatic adenocarcinoma. Since it is primarily a duodenal pathology the mass effect causes shift of gastroduodenal artery to left, whereas primary head of pancreas mass such as adenocarcinoma causes shift of artery to right. In equivocal cases sampling will clinch the diagnosis (40).

CT has the ability to evaluate the complications related to CP. One of the most important complications is the formation of pseudocysts. Pseudocysts are cystic lesions with a wall and usually they are well defined. They can be seen in up to 25% of cases of CP (38). They can be seen in peripancreatic region, intraperitoneal, retroperitoneal or even in remote locations like chest. In CP pseudocysts are generally formed during the evolution of peripancreatic fluid collections after an episode of pancreatitis. Pseudocysts are closely mimicked by retention cysts which occur in pancreas as a result of obstruction to MPD or side branch by calculi or as a result of fibrosis (17). The resulting cystic lesions are seen on CT as nonenhancing well defined lesions and they are not usually associated with an acute episode of pancreatitis. Pseudocysts along with peripancreatic inflammation can involve the venous structures in the vicinity leading to phlebitis and thrombosis. These complications can be seen in splenic, superior mesenteric and portal vein and are seen as filling defects or occlusion on contrast enhanced CT **(Figure 4)**. The resulting portal hypertension which is usually limited to left side can lead to the development of multiple collaterals. When the inflammation involves the arteries in the vicinity it can cause pseudoaneurysm. In CP, gastroduodenal, pancreaticoduodenal and splenic arteries are the commonest to be involved. They can rupture and bleed in to peritoneal cavity, bowel or biliary system and present an acute emergency. Sometimes they are detected on routine imaging in which case they have to be treated at the earliest to prevent catastrophic complications.

Pseudoaneurysms are best seen on arterial phase CT scan when the concentration of contrast in arteries is at its peak. They can be missed on routine portal venous scan which makes the arterial phase acquisition important in this scenario. Sometimes in CP pancreatic fistula can develop with the peritoneal cavity or even pleural cavity (4). It can occur secondary to rupture of pseudocyst. On CT they are seen as ascites or pleural effusion, however the actual fistula site may not be demonstrated on CT scans. Biliary complications due to CP can manifest as fistula or inflammatory strictures which are better evaluated by MRCP. CP increases the risk of developing pancreatic adenocarcinoma especially in hereditary and tropical CP which is a dreaded complication. Pancreatic carcinoma in patients with CP can mimic inflammatory mass forming chronic pancreatitis, focal AIP and groove pancreatitis. Reliable distinction between these lesions on imaging is quite challenging and is not always possible. Advances in CT techniques in the form of perfusion CT have added another dimension to the diagnostic capability of CT scanners. Perfusion CT is novel technique in which scans of a particular area are acquired in quick succession. The data collected is post processed and the contrast dynamics of the given area is depicted as color coded maps. Perfusion parameters such as blood flow and blood volume can be quantified. There are promising reports in which researchers have used perfusion CT to differentiate pancreatic carcinoma from mass forming chronic pancreatitis (28).

Magnetic Resonance Imaging (MRI)

MRI is a non-invasive imaging modality for biliary and pancreatic pathology and can accurately characterise various pancreatic lesions. MRCP has replaced ERCP for the diagnostic imaging of biliary and pancreatic ducts. It is a specialised MR technique in which heavily T2 weighted sequences are used to image fluid filled structures without a need for contrast agent **(Figure 2d)**. MR has the additional advantage of having excellent contrast resolution without using ionising radiation. Normal pancreas appears hyperintense on T1 weighted sequences with or without fat saturation. It is the most T1 hyperintense structure in abdomen with the exception of fatty liver (52). The hyperintensity of pancreas is due to the presence of proteinaceous secretion with in the gland. T1 fat saturated sequence is a very sensitive sequence for the identification of any focal lesion within the pancreas as many of the focal lesions appear hypointense and they are easily recognised. Similarly any inflammation in pancreas leads to drop in signal on T1 weighted sequences. In early stages of CP, because of the inflammation and onset of fibrosis there is drop in T1 signal (31). The gland may be heterogeneous because of focal areas of inflammation and fibrosis. There is heterogeneous and delayed enhancement in the post contrast images because of fibrosis and this delayed enhancement compared to the normal pancreas is considered as an early marker of CP (54).

The ductal changes are better visualised on MRCP as compared to CT scan; however, subtle side branch changes can be missed (49). The ductal findings of early disease can range from normal looking MPD to mild irregularity of MPD and side branches. With progression of disease there is progressive glandular atrophy and poor enhancement in portal venous phase and increased enhancement in delayed phase. Severe ductal changes in the form of irregular dilatation of both MPD and side branches along with interposed strictures gives the appearance of chain of lakes on MRCP. MR is also good in depicting the associated complications such as pseudocysts and fistula. Intraductal calcifications are seen as filling defects in the hyperintense background of fluid. The sensitivity of MR for small calcification is limited when compared to CT scan. MR can also detect ductal abnormalities such as pancreatic divisum, and any solid or cystic focal lesion causing obstructive type of CP **(Figure 5)**.

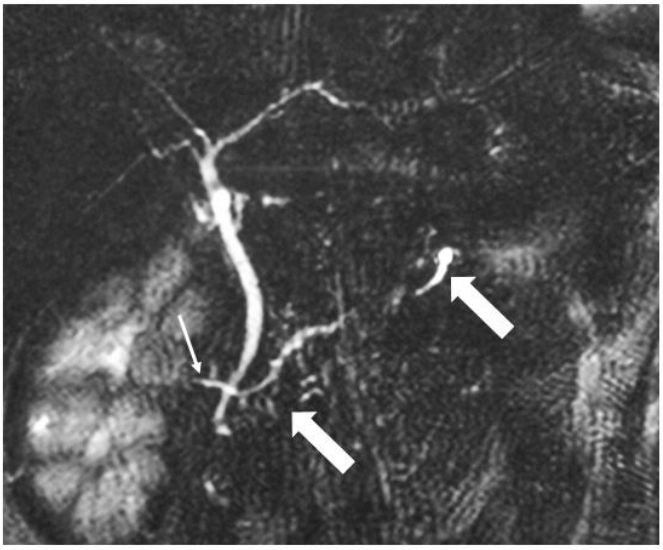

Figure 5. T2W thick slab MRCP image of a young male patient who presented with multiple episodes of abdominal pain shows the dorsal pancreatic duct draining separately in to the minor papilla (thin arrow) and there is no communication with the ventral duct seen suggestive of pancreatic divisum. In addition there is mild dilatation of dorsal duct in the tail region and side branches in the head region (thick arrow). These findings favour the diagnosis of pancreatic divisum with chronic pancreatitis.

It can also differentiate CP from other mimics like intraductal papillary mucinous neoplasms (IPMN) and other variants such as groove pancreatitis and AIP.

It is challenging to differentiate mass forming chronic pancreatitis from pancreatic adenocarcinoma even on MRI. Duct penetrating sign on MRCP which means that a normal or smoothly stenotic MPD is seen to penetrate the mass, has been reported to be associated with inflammatory mass rather than carcinoma. It has a reported sensitivity of 85% and specificity of 96% (36). Recently, diffusion weighted imaging (DWI) has been used to accurately differentiate mass forming pancreatitis from carcinoma (37). The role of Flurodeoxyglucose-Positron Emission Tomography (FDG-PET) in this scenario still remains controversial (38, 39).

One of the major limitations of MRCP in the evaluation of CP is the lack of functional information and inability to image the ductal system in distended state. This drawback can be overcome by using secretin and acquiring serial MR images which is known as secretin enhanced MRCP or secretin stimulated MRCP (S-MRCP). Secretin is an amino acid polypeptide normally secreted by the duodenal mucosa. Secretin acts primarily on pancreas and to some extent on biliary tree (2). It causes transient increase in the tone of sphincter of Oddi and increased secretion of bicarbonate rich fluid. Secretin is a safe drug and it can be administered easily without any serious side effect. Patient should be fasting for 4-6 hours and a negative oral contrast is administered 30 minutes before the study to suppress the signals from pre-existing fluid in the duodenum. Baseline images are taken and secretin is injected as a slow intravenous injection to prevent side-effects. After injection, T2 weighted images are acquired every 30 seconds for a period of 15 minutes. This leads to the dilatation of MPD and the maximum dilatation occurs at 2-5 minutes after which the sphincteric tone decreases and MPD diameter comes to baseline after 10 minutes. The pancreatic secretions can be seen in the duodenum and can be graded in quantitative or semi-quatitative manner and reflect the exocrine function of the pancreas (5).The MPD should show an increase of at least 1 mm compared to baseline in patients

with normal sphincter, absence of which would imply impaired ductal compliance (7). In normal pancreas the side branches are not visualised after secretin whereas in patient with early CP because of subtle fibrosis the side branches can show dilatation which are not otherwise seen on conventional MRCP (7). This is an important advantage of S-MRCP as it distends the MPD so that even the subtle abnormalities are better shown akin to ERCP. For the same reason it is superior to conventional MRCP in delineating ductal anomalies such as pancreas divisum. The exocrine function can be graded as follows: fluid confined to duodenal bulb is grade 1, confined to first and second part of duodenum is grade 2 and fluid reaching in to the third part is grade 3. Grade 3 is considered normal and grade 1 and 2 are considered as impaired exocrine function. This quantification is found to consistently correlate with fecal elastase 1 values (5). Thus s-MRCP has the capability to provide both the structural and functional information which is crucial for the management of these patients. Diffusion weighted imaging (DWI) is also used for the evaluation of CP using the apparent diffusion coefficient (ADC) values. ADC of pancreas in patients with CP was found to be less than in normal patients. It is because of the decreased exocrine reserve of pancreas leading to decreased water diffusion and fibrosis which can by itself restrict diffusion. ADC values can potentially be used as an indicator of fibrosis and its extent in patients with CP which can be used to predict the outcome in patients who undergo surgery. Furthermore, DWI was combined with S-MRCP to study the increase in ADC with the administration of secretin which increases secretion and hence promotes water diffusion. In normal patients the ADC is expected to increase in the early part of the S-MRCP study. A study found that in high risk and in patients with CP the expected ADC peak was either delayed or did not occur at all (40). This can be a potential method of quantification of exocrine function of pancreas in future.

4. Miscellaneous Types of Chronic Pancreatitis

Autoimmune Pancreatitis (AIP)

AIP is an unusual type of chronic pancreatitis which is also known as lymphoplasmacytic sclerosing pancreatitis or chronic sclerosing pancreatitis and is considered as pancreatic involvement in IgG4 systemic disease. It is a systemic chronic fibroinflammatory disease which can affect other regions like biliary duct (primary sclerosing cholangitis), salivary glands, retroperitoneum (retroperitoneal fibrosis), mesentery (sclerosing mesenteritis) and bowel (inflammatory bowel disease). AIP constitutes around 1.8-11% of all cases of chronic pancreatitis (45). On histology, lymphoplasmacytic infiltration is seen around the veins and ducts sparing the arterioles (36, 51). It can be differentiated from other types of pancreatitis and focal lesions by immunostaining with IgG4. Because of the variations in the diagnostic criteria used the diagnosis of AIP was not uniform among different countries. Based on the current understanding, AIP has two distinct sub-types (9, 30). Type 1 is known as lymphoplasmacytic sclerosing pancreatitis (LPSP) which is characterised by elevated serum IgG4 levels, abundant infiltration with IgG4 positive cells and extrapancreatic involvement. Type 2 is known as idiopathic duct centric pancreatitis (IDCP). Typical feature of IDCP is the presence of granulocyte epithelial lesions (GEL). Unlike Type 1, IDCP usually does not have elevated serum levels of IgG4 and infiltration by IgG4 positive cells. In addition, extrapancreatic involvement is not seen in IDCP except that it can be associated with inflammatory bowel disease.

Imaging plays a crucial role in the evaluation of AIP and detecting other associated extrapancreatic manifestations of IgG4 disease.

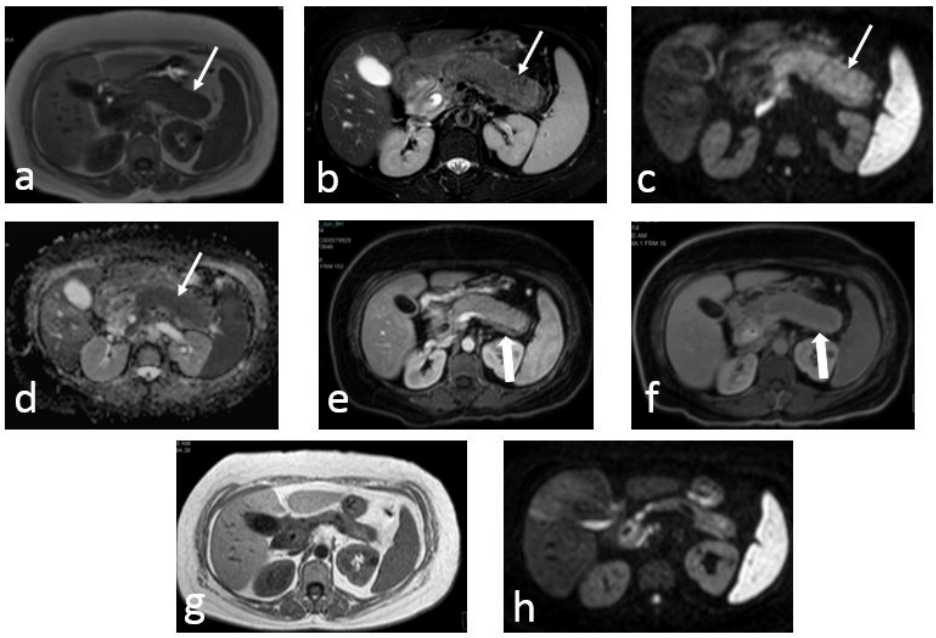

Figure 6. T1W axial MR image (a) shows hypointense and swollen pancreas with loss of normal peripheral lobulations (thin arrow). The tail of the pancreas shows a rounded contour. T2W image with fat suppression (b) shows a swollen pancreas with a hypointense peripheral rim. Intrapancreatic CBD is dilated with stent in situ. Diffusion weighted image with b value of 800 (c) shows diffuse hyperintensity of pancreas. ADC map (d) at the same level shows hypointensity suggestive of diffusion restriction. Post contrast image in pancreatic phase (e) shows diffusely hypoenhancing pancreas with a hypointense rim (thick arrow). In the delayed phase image (f) the peripheral rim is retaining contrast suggesting its fibrous nature. Based on these findings and elevated serum IgG4 levels diagnosis of autoimmune pancreatitis was made and the patient was treated with corticosteroids. The patient's symptoms resolved and follow-up images after three months (g and h) show significant reduction in the size of pancreas and normalization of diffusion.

The Japan Pancreatic Society criteria is one of the most commonly used criteria for the diagnosis of AIP and is based on imaging features supported by either a positive serology or histopathology (37). Mayo Clinic HISORt criteria which is based on typical imaging features, histology, serology, other organ involvement and response to steroid therapy is also widely accepted (8). In 2011, an International consensus diagnostic criteria (ICDC) was developed based on the various existing and commonly used criteria (46). ICDC is considered to be the most sensitive and specific criteria for diagnosing AIP (34). ICDC is based on the imaging features of pancreatic parenchyma, ducts, serology, involvement of other organs, histology and response to steroid therapy. CT scan is the diagnostic modality of choice and on imaging three distinct patterns (diffuse, focal and multifocal) have been described and the imaging features vary with the pattern. Diffuse pattern which is the commonest type is seen as featureless or sausage like pancreas because of the loss of lobular architecture. The involved pancreas is homogeneous and the MPD is either non-dilated or diffusely narrowed which is a characteristic finding in AIP. Calcification is rare unlike other types of chronic pancreatitis. There can be a hypoattenuating rim with associated fat stranding and involution of pancreatic tail. The rim shows a characteristic delayed enhancement. On ERCP, characteristic finding is focal, segmental or diffuse narrowing and irregularity of MPD (45). MRI can show a mildly enlarged pancreas with loss of signal intensity on T1 weighted images and mild hyperintensity on T2 weighted images. After contrast administration the involved part of the pancreas shows delayed enhancement

(Figure 6). The rim around the pancreas is hypointense on both T1 and T2 weighted images and shows delayed enhancement (38). MRCP can show features similar to ERCP and it can also show associated strictures in biliary tree which occurs in primary sclerosing cholangitis.

The diffuse form of AIP can mimic lymphoma and other diffuse infiltrative disorders. The focal type of AIP can present as a focal mass lesion on all imaging modalities mimicking carcinoma pancreas. Because of this morphological similarity, 2-6% of all resections for suspected carcinoma pancreas turn out to be AIP (53). Focal type can also present with upstream dilatation of MPD in which case the dilatation is less severe when compared to carcinoma pancreas (24). Delayed enhancement in AIP is another feature which differentiates it from carcinoma pancreas. Corticosteriods are used for treating AIP and the response is usually dramatic.

Groove Pancreatitis

Groove pancreatitis is a rare type of chronic pancreatitis which is localised to the pancreaticoduodenal groove which is a potential space between the head of pancreas, duodenum and CBD (47). The pathogenesis of this entity is still not fully understood. Several factors such as penetrating duodenal ulcer, post gastric resection, duodenal wall cysts, pancreatic heterotopia, obstruction to the flow of pancreatic secretions have been implicated (22). It is also unclear whether groove pancreatitis, cystic dystrophy of duodenum and paraduodenal wall cysts are different or related entities. These entities have many features in common and hence they are collectively categorised as paraduodenal pancreatitis (1). There are two types of groove pancreatitis: pure and segmental form. In the pure form the scar tissue is localised to the groove without involving pancreas and in the segmental form the head of pancreas is also involved. On CT, groove pancreatitis is characterised by a sheet of relatively hypoenhancing tissue which usually shows delayed enhancement relative to normal pancreas **(Figure 7)**. In segmental form, the scar tissue involves the pancreatic head and mimics pancreatic carcinoma. Displacement of gastroduodenal artery towards pancreatic head, with associated cystic changes of duodenal wall which occurs in groove pancreatitis and abrupt cut-off of MPD which occurs in carcinoma pancreas can be helpful in differentiation.

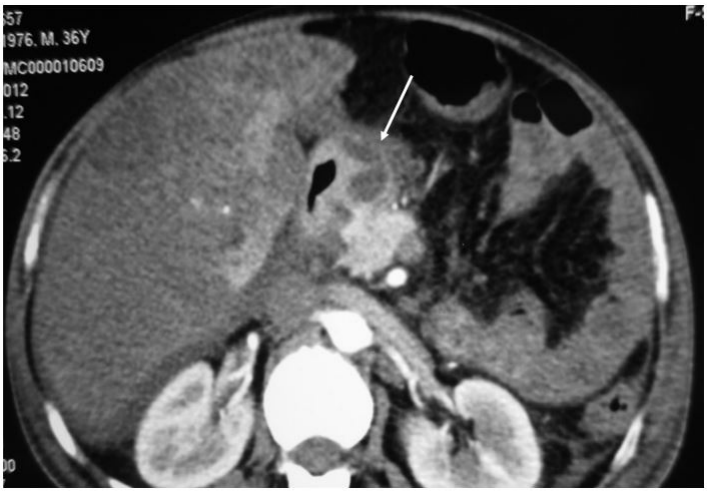

Figure 7. Axial CECT image of a chronic alcoholic patient who presented with abdominal pain shows a hypodense plaque like soft tissue seen in the pancreatico-duodenal groove (thin arrow) with relative sparing of uncinate process of pancreas. The rest of the pancreas (not shown here) is also normal. There is mild free fluid in abdomen and there is abnormal enhancement of liver which became homogeneous on portal venous phase (not shown here) suggestive of transient hepatic attenuation differences. Based on these findings diagnosis of groove pancreatitis was made.

On MRI, the scar tissue is hypointense on T1, hyperintense on T2 weighted images and shows delayed enhancement on contrast administration. The cystic lesions in the wall of duodenum with associated wall thickening of duodenum are better visualised on MR. These changes can cause tapering of MPD and lower CBD.

Chronic Pancreatitis in Cystic Fibrosis

Cystic fibrosis is an autosomal recessive inherited disease which is associated with the chloride channel gene mutation. It is one of the common causes of pancreatic exocrine failure in young patients. The mutation causes inspissation of secretion which obstructs the flow of secretion and triggers the disease process. Patients presenting with frank acute pancreatitis are rare and the ongoing low grade inflammation causes progressive fibrosis and calcification (11). Eventually, the parenchyma is replaced by fat which is a characteristic feature. This fatty replacement correlates with the exocrine dysfunction and it is seen as hyperechogenicity on US and hypodensity on CT in the background of CP.

Parenchymal and intraductal calcification is unusual unlike other hereditary pancreatitis. Rarely, the entire pancreas can be replaced by multiple cysts of varying sizes which is known as pancreatic cystosis. MRI is more sensitive than CT in detecting the abnormality. Pancreatic signal intensity on T1 weighted images can be variable depending on the extent of fatty replacement. Irregularity and dilatation of the ducts are better visualised on MRI. It has an additional advantage of not using ionising radiation which is all the more relevant in young patients.

Chronic Pancreatitis and Pancreatic Adenocarcinoma

Focal pancreatitis in the form of mass forming chronic pancreatitis can closely mimic carcinoma pancreas on all imaging modalities and CP itself predisposes to development of pancreatic carcinoma.

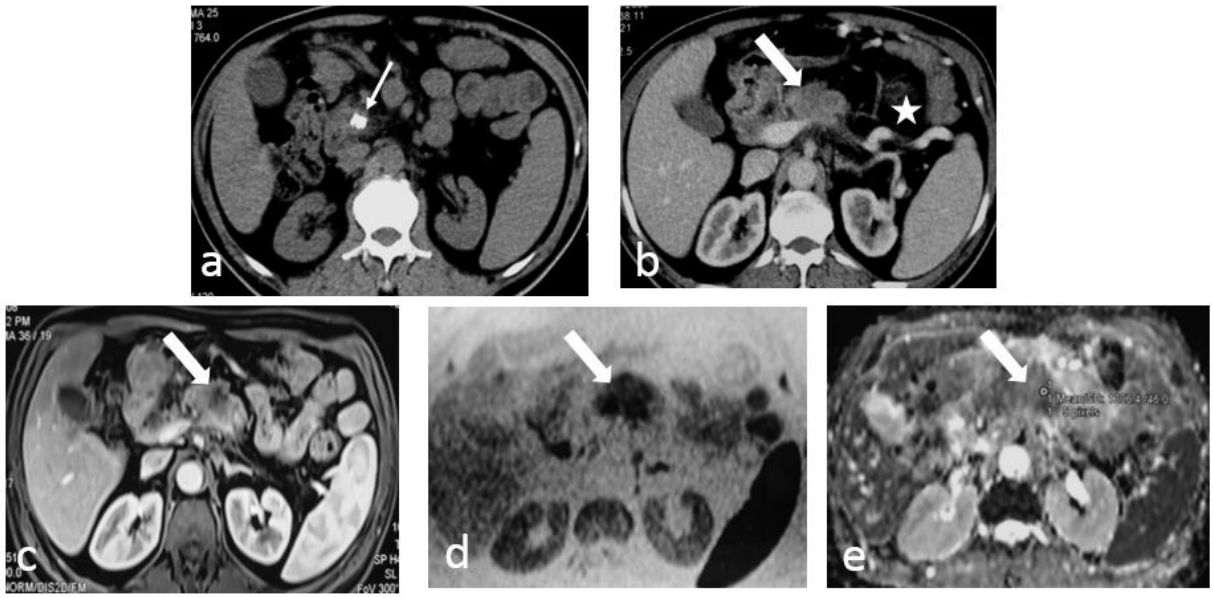

Figure 8. Axial non-contrast CT (a) of a patient with CCP who presented with worsening of pain shows calcification in the head of pancreas (thin arrow) with parenchymal atrophy. Axial CECT (b) shows a hypoenhancing mass lesion in the body of pancreas (thick arrow) causing contour bulge. Multiple peripancreatic collaterals are also seen (asterix) which are due to narrowing of the splenic vein. Post contrast MRI (c) confirmed this hypoenhancing lesion (thick arrow). Diffusion weighted MRI (d) using b value of 1000 with inverted grey scale shows profound hypointensity and the focal lesion is hypointense on ADC map (e) also (thick arrow). These imaging features are suggestive of pancreatic carcinoma in the background of CCP and this was confirmed on cytology.

It is of paramount importance to detect the development of carcinoma pancreas in the setting of CP and to differentiate mass forming chronic pancreatitis from carcinoma pancreas. Any abnormal contour bulge or change in the morphology in the form of mass effect and alteration or disappearance of pre-existing calcification should raise the suspicion of carcinoma of the pancreas **(Figure 8)**. Advances in CT and MR imaging have enhanced the ability to differentiate inflammatory mass from carcinoma. Smoothly stenotic or non-stenotic MPD on MRI (duct penetrating sign) should favour the diagnosis of inflammatory mass **(Figure 9)** whereas abrupt cut-off of grossly dilated MPD, and peripancreatic vascular invasion should favour the diagnosis of carcinoma pancreas. Pancreatic perfusion CT can generate perfusion parameters which help in this distinction. Although blood flow and blood volume are reduced in both inflammatory mass and carcinoma, the values are much lower in carcinoma than in inflammatory mass **(Figure 10)** (28). Diffusion weighted imaging is emerging as a helpful tool to differentiate inflammatory mass from carcinoma, in which carcinoma is shown to restrict diffusion (35). FDG-PET CT has also been used for the same purpose with varying degree of success (25,42).

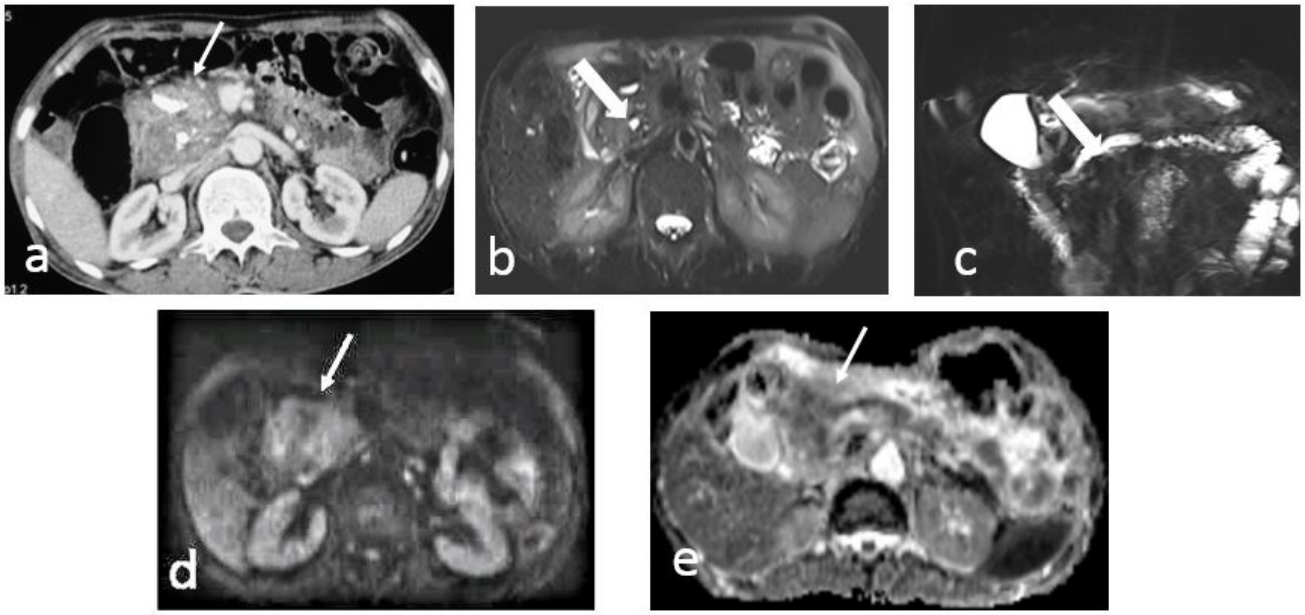

Figure 9. Axial contrast enhanced CT (a) in a patient with CCP shows a heterogeneous mass lesion in the head of pancreas (thin arrow) with multiple calcific foci. Heavily T2W MR images (b,c) show the dilated tortuous MPD coursing through the mass lesion (thick arrow) which is called as duct penetrating sign. Diffusion weighted image (d) and ADC map (e) shows that there is no significant diffusion restriction in the mass. Based on the above findings diagnosis of mass forming chronic pancreatitis was made. Patient was later subjected to EUS guided sampling which confirmed the diagnosis.

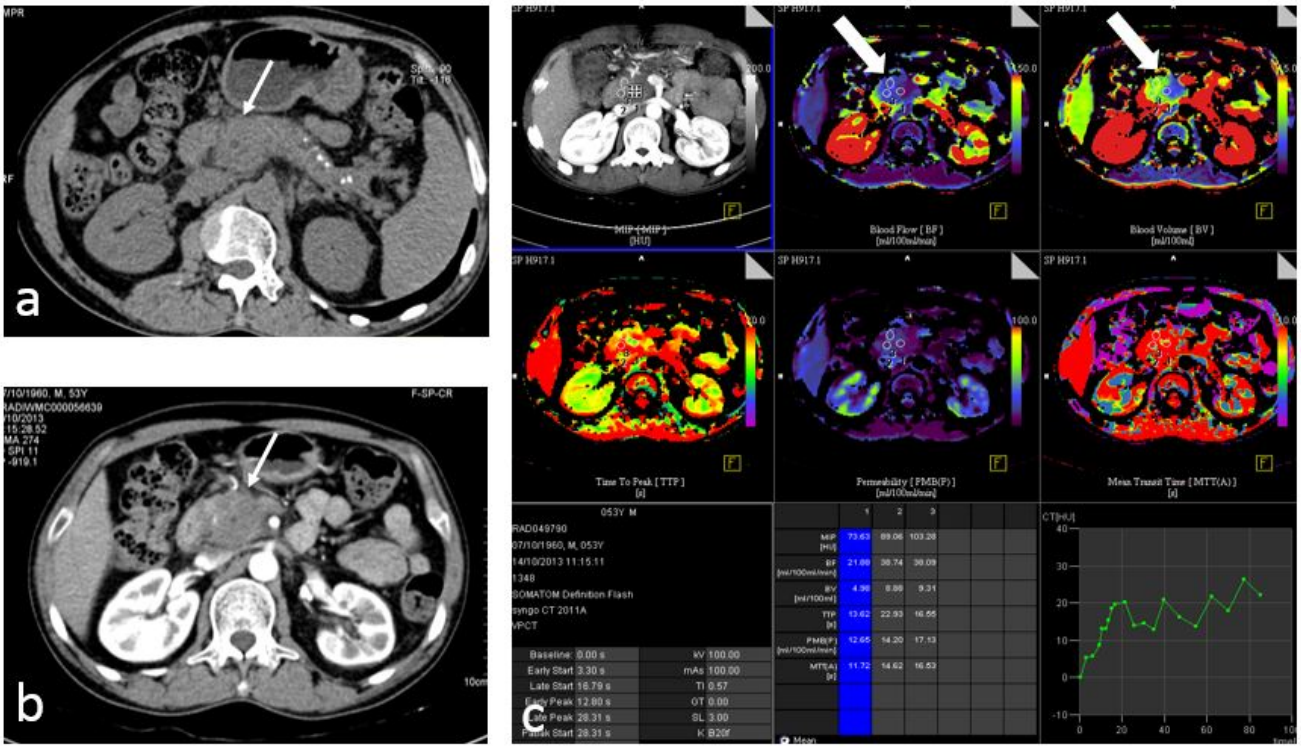

Figure 10. Axial non-contrast CT and contrast enhanced CT (a,b) of a patient with CCP shows an ill-defined hypoenhancing mass lesion in the head of pancreas (thin arrow). Perfusion CT of pancreas with color-coded maps depicting various perfusion parameters (c) shows that blood volume and blood flow are decreased (blue color) in the head region as comparison to the rest of pancreas (thick arrow) which is shown in green color. Although decreased perfusion parameters are also seen in pancreatic carcinoma, but the extent of decrease is significantly more in carcinoma. EUS guided sampling revealed only inflammatory cells suggestive of mass forming chronic pancreatitis.

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