

Review

# Magnetic resonance imaging of less common pancreatic malignancies and pancreatic tumors with malignant potential

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## Abstract

Pancreatic tumors are an increasingly common finding in abdominal imaging. Various kinds of pathologies of the pancreas are well known, but it often remains difficult to classify the lesions radiologically in respect of type and grade of malignancy. Magnetic resonance imaging (MRI) is the method of choice for the evaluation of pancreatic pathologies due to its superior soft tissue contrast. In this article we present a selection of less common malignant and potentially malignant pancreatic neoplasms with their characteristic appearance on established MRI sequences with and without contrast enhancement.

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## 1. Introduction

The pancreas is a non-encapsulated organ located retroperitoneally. It is known to be affected by a broad spectrum of

malignant as well as benign conditions. Pancreatic lesions are often discovered incidentally in asymptomatic patients, and if the lesions cannot be classified further, clinical management can be difficult. Routine imaging modalities for assessing the pancreas include transabdominal ultrasound, endosonography, endoscopic retrograde cholangiopancreatography (ERCP) and computed tomography. However these examination tools are limited in their ability to depict the soft tissue differences in

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detail. Thus, today, pre- and post gadolinium magnetic resonance imaging (MRI) is the method of choice for the evaluation of pancreatic pathologies. Morphology and histologic pattern of malignant pancreatic tumors such as adenocarcinoma are well described. In this article we present a selection of rare malignant and potentially malignant pancreatic neoplasms with their typical appearance on MRI, since they have a better prognosis than ductal adenocarcinoma. Hence knowledge of these rare entities is important with respect to diagnosis and treatment. [Table 1](#) gives an overview of the different entities with their characteristic MR imaging features.

## 2. MRI/MRCP protocol

Our routine pancreas MRI protocol includes a coronal and transverse T2 half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequence of the complete abdomen, transverse diffusion weighted echoplanar (DWI-EPI) sequences, T1 FLASH sequences of the pancreas as well as MR-cholangiopancreatography (MRCP). Moreover, dynamic pre- and post-gadolinium images of the pancreas using transverse T1 3D-VIBE sequences, and a transverse post-contrast T1 FLASH 2D fat saturated sequence are acquired.

### 2.1. Intraductal papillary mucinous neoplasm

Intraductal papillary mucinous neoplasm (IPMN) mostly occurs in the elderly with a male predominance [1]. Based on the highest degree of cytoarchitectural atypia and invasiveness, IPMN can be classified according to the WHO as IPMN with low- to intermediate-grade dysplasia- previously called intraductal papillary-mucinous adenoma, IPMN with high grade dysplasia – previously called non-invasive intraductal papillary-mucinous carcinoma, and IPMN with an associated invasive carcinoma [1]. IPMN arise from the epithelium of the pancreatic ducts. The production of mucin results in dilatation of the main pancreatic duct or cystic dilatation of the branch ducts [2,3]. Most IPMN are discovered incidentally in asymptomatic patients. If symptoms are present, they may include nausea, abdominal pain or pancreatitis.

MRI shows pleomorphic or unilocular cystoid lesions, while the tumor itself is usually not seen. Depending on the involvement of main- or branch-ducts, IPMN can be categorized as main-duct, branch-duct or mixed type. All three types can be associated with atrophy of the adjacent pancreatic parenchyma. Main-duct involvement shows as dilatation of the main pancreatic duct (MPD) over 5 mm without other causes of obstruction ([Fig. 1](#)). Branch-duct IPMN appears as clustered, often grape-like cystoid lesions in the pancreas. The mucin-filled thus dilated branch ducts communicate with the healthy pancreatic duct system. Consequently, BD-IPMN can be suspected if cystoid lesions with communication to the pancreatic ductal system are present [4]. The cystoid lesions, which appear hyperintense on T2-weighted images (WI) and hypointense on T1-WI, can be found throughout the whole pancreas and vary in size. Images in the axial and coronal plane may reveal thin septae between the

lesions. In rare cases, T2-WI may display solid portions within the lesion.

Contrast enhanced images can also help identify solid components such as small nodular lesions in the periphery of the lesions (mural nodules) ([Fig. 1F](#)). Diffusion weighted MR images are likely to predict the malignant potential of IPMN, with lower apparent diffusion coefficient (ADC) values of the lesions in IPMN with high-grade dysplasia and invasive IPMN [5]. MRCP shows lobulated cystoid lesions in BD-IPMN and a dilated MPD in MD-IPMN, or both in mixed type-IPMN. Furthermore, it can help depict the relation of the cystoid lesions and the ductal system [6]. Intraductal mucin and solid components may be seen as filling defects on MRCP.

Predictors for malignant potential have been identified, known as the Sendai criteria. With respect to imaging they include cyst size more than 3 cm, involvement of the main pancreatic duct with dilatation over 5 mm, mural nodules or contrast enhancing components and lymphadenopathy. IPMN with one or more of those characteristics are highly likely to be malignant and surgical resection is recommended [4]. Otherwise, lesions should be monitored.

### 2.2. Mucinous cystic tumor

Mucinous cystic tumors (or neoplasms, MCN) usually occur in women during the 4th and 5th decade of life [7]. They are relatively rare, accounting for about 8% of surgically resected cystic lesions of the pancreas [8]. MCN have malignant potential. According to the WHO and analogous to IPMN, they can be categorized as MCN with low- or intermediate-grade dysplasia- previously called mucinous cystadenoma, MCN with high-grade dysplasia- previously called non-invasive mucinous cystadenocarcinoma, and MCN with an associated invasive carcinoma [1]. Invasive carcinoma is usually diagnosed in significantly older patients than non-invasive MCN, suggesting a progression from non-invasive to invasive MCN [9]. MCN are often discovered incidentally, and if symptoms occur, they are mostly related to mass effects [10]. They are usually located the body or tail of the pancreas [11]. In contrast to IPMN, MCN do not communicate with the pancreatic ductal system on MRCP [3]. Larger lesions may cause partial obstruction of the pancreatic duct due to mass effects.

On MRI, MCN present as unilocular or multilocular large cysts. Thickness of cyst wall and septae is variable. MR signal of the cysts is usually low on T1-WI and high on T2-WI, but can vary, based on the content of the cysts (e.g., mucinous/hemorrhagic) [12]. After administration of gadolinium-chelate, on T1-weighted, fat-suppressed images the wall may show contrast enhancement while the cysts themselves usually do not enhance [13] ([Fig. 2](#)). A large study found a correlation between tumor size and malignancy: 92% of tumors equal to or greater than 60 mm in size showed malignancy. Furthermore, the presence of mural nodules or contrast-enhancing soft tissue elements within the lesion is associated with malignancy [9,14]. Focal calcifications, usually seen on MR images as hypointense spots on all sequences and better detectable on computed tomography, can be another indication of malignancy

Table 1

Overview of less common pancreatic malignancies and tumors with malignant potential in terms of WHO-classification, demographics and imaging features.

Type of lesion	WHO-classification [1]	Demographics	MRI features
Intraductal papillary mucinous neoplasm	Premalignant/malignant epithelial tumors	Male predominance Occurs mostly in the elderly [1]	Pleomorphic or unilocular cystoid lesions with connection to the pancreatic ductal system Dilatation of the MPD > 5 mm in main-duct-involvement Lesions T1 hypointense, T2 hyperintense Solid, contrast enhancing components suggest malignancy [4,6] Predictors for malignancy: Sendai criteria ADC in benign/non-invasive lesions 2.95/2.67; lower in malignant/invasive lesions (2.05/1.51) [5]
Mucinous cystic tumor	Premalignant/malignant epithelial tumors	Almost exclusively in women (4th-5th decade) [7]	No communication with pancreatic ductal system [3] Unilocular cysts in 80% of the cases, multilocular cysts in 20%. Cysts T1 hypointense, T2 hyperintense Variable thickness of cyst wall and septae [12] Wall may show contrast enhancement [13] Indicators of malignancy: cyst size $\geq$ 6 cm, focal calcifications, presence of mural nodules or contrast-enhancing soft tissue elements within the lesion [14]
Acinar cell carcinoma	Malignant epithelial tumors	Accounts for 1–2% of all pancreatic neoplasms Typically occurs during 5th to 7th decade of life Male predominance [1]	Large, well defined exophytic lesion Mostly solid; T1: low to intermediate signal intensity, T2: intermediate to high signal intensity compared to surrounding pancreas [20] [4] Can contain cystic components/hemorrhage/necrotic components/calcifications [20] Heterogeneous contrast enhancement, less than the surrounding parenchyma [20]
Solid pseudopapillary neoplasm	Malignant epithelial tumors	Mostly in young women (2nd-3rd decades of life) Metastases can be found in up to 15% of cases [23]	Rounded, often large mass T1: low signal intensity, T2: intermediate to high signal intensity Small lesions homogeneous, large: often hemorrhagic, cystic or necrotic, with calcifications or a T2 hypointense or contrast enhancing capsule Heterogeneous contrast enhancement with progressive central filling and late enhancement of the capsule [24,25]
Neuroendocrine tumor	Neuroendocrine neoplasms	Usually in patients over 50 years Slight male predominance [1]	T1: hypointense; T2: hyperintense compared to healthy pancreas [13] Hyperintense on contrast-enhanced T1-WI, especially during arterial phase in dynamic studies [26] Larger tumors sometimes with cystic or necrotic components due to degeneration Glucagonomas often with ring-like contrast-enhancement ADC-values in small solid tumors lower ( $\sim$ 1.4) than in normal pancreas [27]
PEComa	Mesenchymal tumors	Very rare mesenchymal neoplasm of the pancreas Female predominance [29]	T1: iso- to hypointense, T2: hyperintense compared to skeletal muscle [31] May exhibit hemorrhage [32] Show contrast-enhancement [31]
Primary lymphoma	Lymphomas	Only 0.5% of all pancreatic malignancies [34] Mostly extranodal manifestations of B cell non-Hodgkin's lymphoma [33,34]	Focal form: well-circumscribed homogeneous lesion; T1: hypointense, T2: intermediate, heterogeneous signal intensity. Heterogeneous contrast enhancement, less than in surrounding healthy pancreatic parenchyma [36] Diffuse form: T1: decreased signal intensity, T2: variable signal intensity [36,37] Contrast enhancement homogeneous with or without small spared spots [37]
Metastases	Secondary tumors of the pancreas	Incidence: pancreatic metastases in 3–12% of patients with widely metastatic disease in autopsy studies and 2–5% in clinical studies [40–43]	Small and well-defined masses [45] Due to the variety of entities, appearance on MRI is diverse

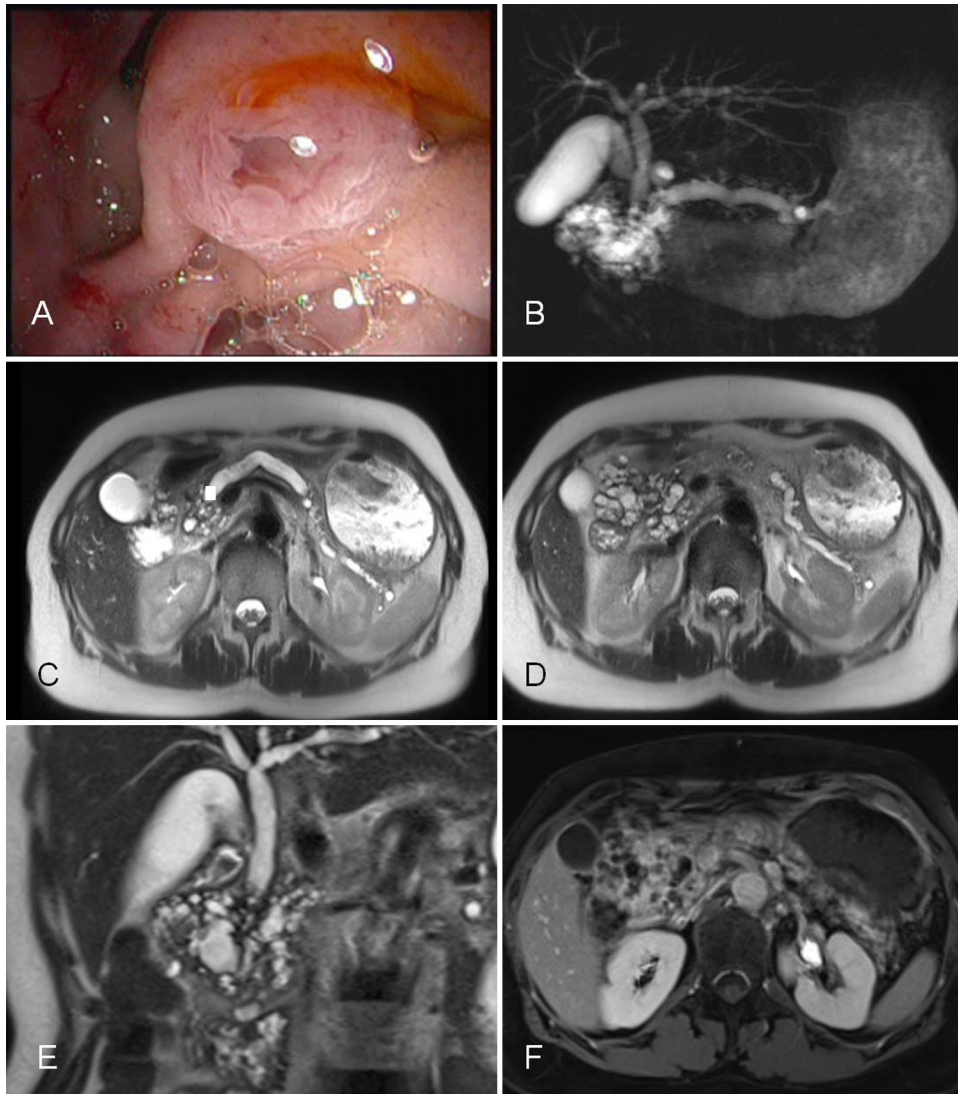


Fig. 1. Mixed-type intraductal papillary mucinous neoplasm with invasive carcinoma in a 60-year-old woman. (A) Photograph shows characteristic fish-mouth appearance of the ampulla of Vateri on endoscopy. (B) Coronal MRCP shows an irregular dilatation of the main pancreatic duct and a multicystic-appearing lesion in the pancreatic head/uncinate process. (C) Axial T2-W HASTE sequence shows an irregular dilatation of the main pancreatic duct, representing the main-duct component, and cystoid lesions in the pancreatic head, representing branch-duct components. (D) T2-W HASTE sequence in the axial plane shows a well-circumscribed, clustered hyperintense lesion of the pancreatic head. (E) Coronal T2-W HASTE sequence shows a well-defined, multiloculated, hyperintense lesion of the pancreatic head/uncinate process. (F) Fat-suppressed T1-WI in the axial plane obtained after intravenous administration of gadolinium-chelate shows a hypointense, multiloculated cystoid mass of the pancreatic head, partially enhancing and with nodular, solid appearing parts, pointing to malignancy

[15]. Due to their malignant potential, surgical resection is the method of choice in treatment of MCN.

### 2.3. Acinar cell carcinoma

Acinar cell carcinoma (ACC) is a rare malignant epithelial neoplasm with an exocrine differentiation. ACC accounts for 1–2% of all pancreatic neoplasms. It typically occurs during late adulthood (5th–7th decade) with a male predilection [16]. A second peak in age distribution can be found in childhood [17]. Up to 50% of patients with ACC present with metastatic disease [18]. Clinical symptoms are rather variable and nonspecific. However, symptoms such as adiponecrosis or arthritis, which are related to pancreatic enzyme production, and symptoms due to mass effects and metastases may occur.

Only few studies deal with radiological findings in ACC. Most ACC arise in the pancreatic head. Average size at the time of diagnosis is large, in one study up to 10 cm [19]. Morphologically, ACC present as well-defined large oval or round masses with an exophytic growth pattern. The solid parts of the tumors present with low to intermediate signal intensity on T1-WI and intermediate to high signal intensity on T2-WI compared to the surrounding normal pancreas, of which it is sharply demarcated [20]. Signal intensity can be heterogeneous due to hemorrhage, necrotic components or, rarely, calcifications. Cystic components can be seen in larger lesions. On contrast-enhanced MRI, enhancement is heterogeneous. Since the lesions are usually hypovascular, the contrast-enhancing solid components may enhance less than the surrounding healthy pancreatic parenchyma [20,21], which is not in line with our example,

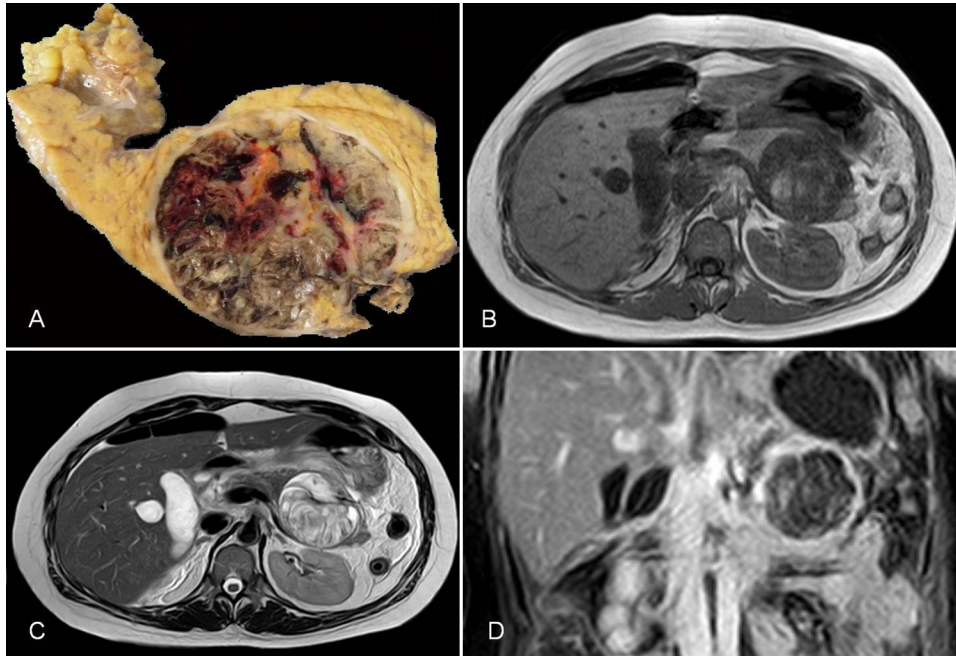


Fig. 2. Mucinous cystic neoplasm in a 42-year-old woman. (A) Photograph shows gross appearance of the 7 cm × 6 cm × 4 cm measuring unilocular cyst with fibrous capsule filled with light brown material containing mucin, granulation tissue and inflammatory infiltrates as well as hemorrhagic portions. (B) Axial T1-WI shows a well-circumscribed round heterogeneous mass in the pancreatic tail. Hyperintense parts represent hemorrhage. (C) Axial T2-WI shows a hyperintense heterogeneous lesion with complex internal architecture; hypointense parts representing granulation tissue and inflammatory infiltrates. (D) Coronal fat suppressed T1-WI after intravenous administration of gadolinium-chelate shows a hypointense, heterogeneous mass with a thick surrounding capsule with marked enhancement.

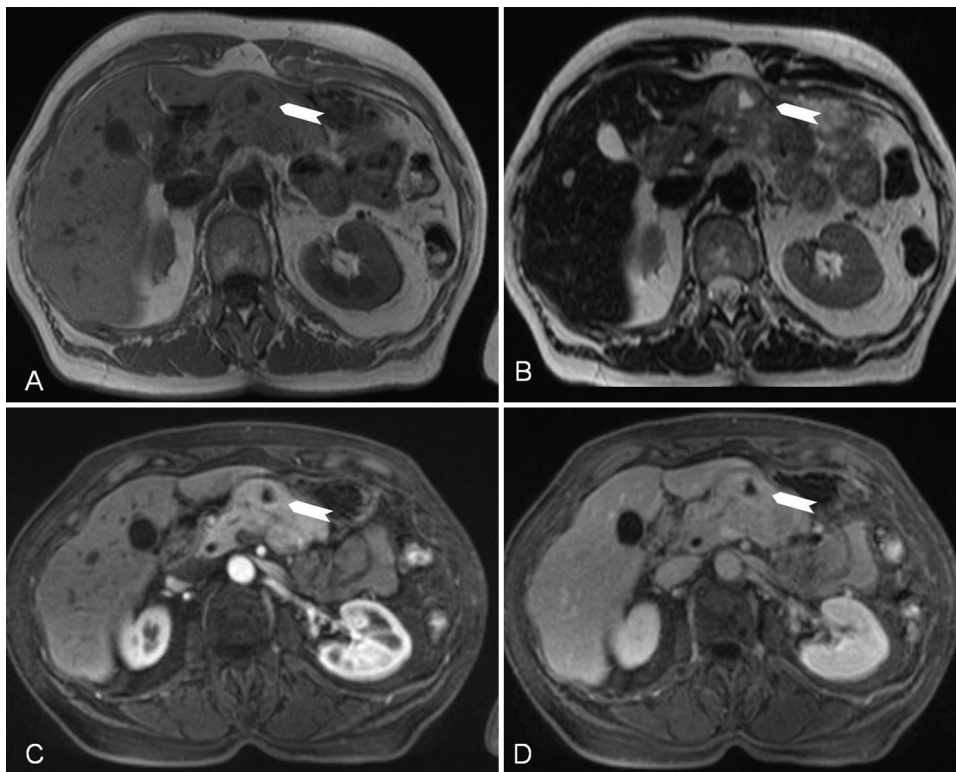


Fig. 3. Acinar cell carcinoma in a 63-year-old woman. (A) Axial T1-WI reveals a well-defined isointense lesion in the pancreatic body with a small hypointense center, representing a cystic portion. (B) T2-WI in the axial plane shows an exophytic growing lesion in the pancreatic body with an intermediate signal intensity compared to the surrounding normal pancreas and a hyperintense, cystic component. (C) Fat-suppressed T1-WI in the axial plane obtained early after intravenous administration of gadolinium-chelate exhibiting atypical contrast behavior of the lesion, showing moderate homogeneous contrast enhancement of the lesion except for the cystic portion. (D) Fat-suppressed T1-WI in the axial plane obtained later after intravenous administration of gadolinium-chelate reveals a decline in contrast enhancement of the lesion.

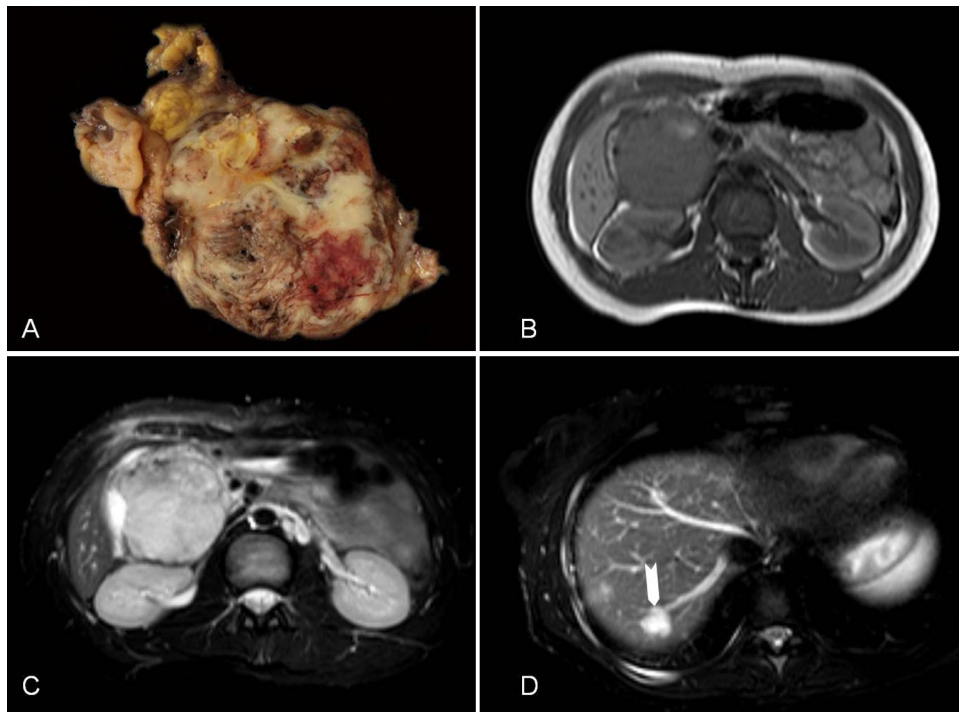


Fig. 4. Solid pseudopapillary neoplasm (SPN) in a 17-year-old female with liver metastases (Fig. 4B–D: Courtesy of the Department of Diagnostic and Interventional Radiology and Pediatric Radiology, Klinikum Schwabing, Munich, Germany). (A) Photograph shows macroscopic appearance of SPN of the pancreatic head. The 7 cm × 6 cm × 6 cm measuring tumor with a thin capsule shows an infiltration of the duodenal wall. The tumor itself is mainly solid with hemorrhages and few necrotic areas. (B) T2-W HASTE sequence shows a large, mostly homogeneous, well-defined rounded pancreatic mass with low signal intensity. (C) On fat-suppressed T2-WI in the axial plane the lesion appears more heterogeneous, mostly hyperintense. (D) Axial fat-suppressed T2-WI shows hyperintense liver metastasis (arrow).

showing a ring-like enhancement after contrast administration (Fig. 3). However, there are reports in the literature about hypervascularity of ACC [22].

#### 2.4. Solid pseudopapillary neoplasm

Solid pseudopapillary neoplasm (SPN) is a rare tumor with low-grade malignant potential, whose pathogenesis is not fully understood. Synonyms are solid pseudopapillary tumor (SPT), papillary and solid epithelial neoplasm, papillary cystic neoplasm, and (Gruber-)Frantz tumor. SPN mostly occur in young women (2nd–3rd decades of life). In general, SPN are of low-grade malignancy but can develop metastases in up to 15% of cases [23]. The lesions are usually solitary and often located in the pancreatic body or tail. SPN can reach a remarkable size and often contain necrotic or hemorrhagic areas.

In terms of MR imaging findings, some characteristics differ between smaller (<3 cm) and larger lesions [24]. In general, MR imaging shows a well circumscribed, rounded solid mass with low signal intensity on T1-WI and high to intermediate signal intensity on T2-WI. Cystic components can be present and are secondary to tumor degeneration. If lesions are predominantly cystic, signal intensity is closer to fluid on T2-WI. Smaller SPN usually present homogeneously [25]. Large SPN often appear heterogeneous as they contain hemorrhagic, cystic or necrotic parts, calcifications or a T2 hypointense or contrast-enhancing capsule (Fig. 4). If hemorrhage, also secondary to degeneration, is present, T1 signal within the lesion can be

increased. On gadolinium-enhanced images, SPN show heterogeneous enhancement with a gradual central filling, which is helpful for differentiating SPN from lesions with early arterial enhancement. If a capsule is present, it tends to show late enhancement [23]. Regarding clinical management, complete surgical excision is recommended as SPN are potentially curable by resection of the primary tumor [23].

#### 2.5. Neuroendocrine tumors

Neuroendocrine tumors (or neuroendocrine neoplasms, NET) of the pancreas arise from the pancreatic endocrine cells. They usually occur in patients over 50 years, with a slight male predominance. The tumor grading proposed by The World Health Organization (WHO) is based on mitotic count and Ki67 index. Neoplasms can be graded as neuroendocrine tumor (NET) G1 (carcinoid) or G2 and neuroendocrine carcinoma (NEC), G3 [1]. NET can present with typical clinical findings due to hormone hypersecretion (“functioning” or “syndromic” NET) or they can be non-functioning (or “nonsyndromic”). Depending on the type of hormone they secrete the most and the clinical presentation, syndromic tumors can be further classified as gastrinoma, insulinoma, somatostatinoma, VIPoma and glucagonoma as well as rare types such as ACTHoma.

On MRI, neuroendocrine tumors appear hypointense on fat suppressed T1-WI compared to the surrounding healthy pancreas while they usually seem hyperintense compared to the normal pancreas on T2-WI [13]. Especially larger tumors may

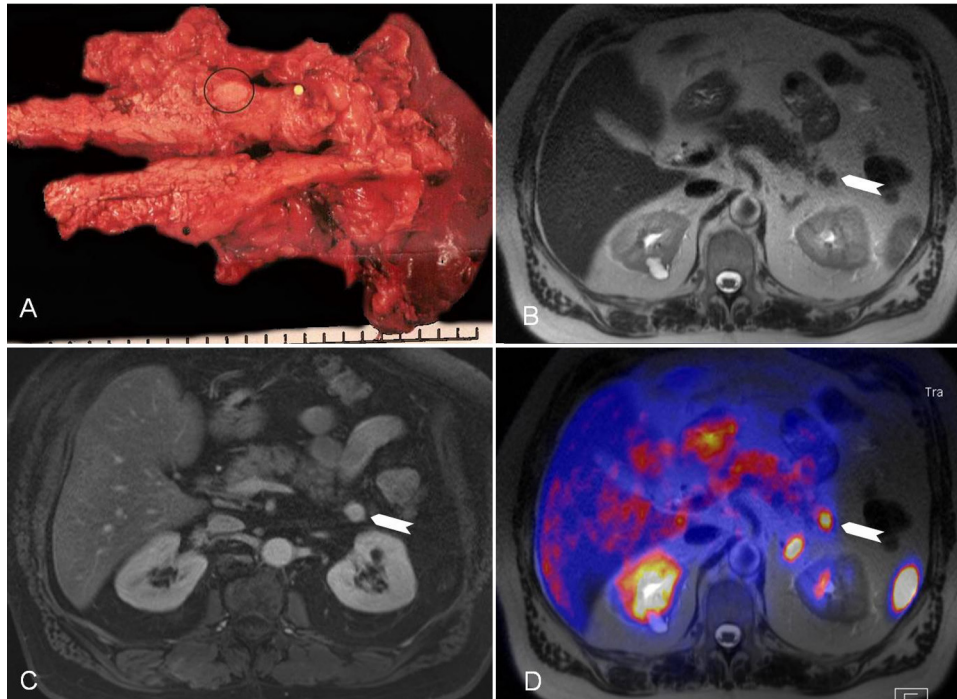


Fig. 5. Glucagonoma in a 69-year-old man. (A) Photograph shows gross appearance of a small white solid tumor of the pancreatic tail (circle). (B) Axial T2-W HASTE sequence shows a solitary hypointense mass of the pancreatic tail (arrow), pointing to fibrous tissue within the lesion. (C) Fat-suppressed T1-WI after intravenous administration of gadolinium-chelate exhibits contrast enhancement of the lesion (arrow). (D) On PET-MR fusion image the lesion is highly metabolically active (arrow).

contain cystic or necrotic parts due to degeneration, which results in a heterogeneous appearance. On post-contrast images, both functioning and non-functioning tumors show significant contrast enhancement. Enhancement may appear homogeneous, diffuse heterogeneous, ring- or target-like, depending on the composition of the lesion. Cystic or necrotic components do not enhance and appear hypointense compared to the rest of the lesion on post-contrast T1-WI. Even in markedly cystic degenerated lesions, well-vascularized tissue can be found, pointing to the diagnosis of NET [14]. On dynamic contrast enhanced studies, NET enhance earlier and more intensely than the healthy pancreatic parenchyma, thus appear hyperintense during the arterial phase [26].

Metastases, for example in the liver, are hypervascular as well and therefore their contrast behavior is comparable to that of the primary lesions. Rarely, tumors contain a lot of fibrous tissue hence show low signal intensity on T2-WI (Fig. 5) and less contrast enhancement [13]. DWI might be helpful in detecting small neuroendocrine tumors due to its higher image contrast; ADC-values tend to be lower than in the surrounding healthy pancreas [27].

Insulinomas, as most of the neuroendocrine tumors, appear hypointense on T1-WI and hyperintense on T2-WI. On post-gadolinium-images, small insulinomas usually enhance homogeneously or, more rarely, target-like.

Gastrinomas demonstrate very low signal intensity on T1-WI and high signal intensity on T2-weighted fat suppressed images. On contrast-enhanced images, they often show peripheral ring-like enhancement, as well as their liver metastases do. As gastrinomas may occur outside the pancreatic parenchyma,

fat-suppressed T2-WI can be helpful for their detection due to their hyperintensity compared to the surrounding suppressed fat [28].

## 2.6. Perivascular epithelioid cell neoplasms

Perivascular epithelioid cell neoplasms (PEComas) of the pancreas, also called clear cell “sugar” tumors, are “well-vascularized neoplasms (are) composed of large, clear, epithelioid smooth-muscle cells”, as defined by The World Health Organization [1]. PEComas are very rare mesenchymal neoplasms of the pancreas. There is a female predominance [29]. Due to its rarity, little is known about clinical and imaging appearances, treatment and outcome of this disease. The PEComa family contains angiomyolipoma, clear cell “sugar” tumors and lymphangiomyomatosis, as well as a variety of unusual visceral, intra-abdominal, and soft tissue/bone tumors [30].

Few is known about MRI-features of PEComas. In general, PEComas mostly appear as well-defined soft tissue mass. A recent study described MRI-features of malignant PEComas. They appeared iso- to hypointense compared to skeletal muscle on T1-WI and heterogeneously hyperintense on T2-WI compared to skeletal muscle [31] (Fig. 6C). PEComas sometimes show hemorrhagic parts [32]. Thus, if hemorrhage is present, lesions seem heterogeneous in all sequences. The above-mentioned study also found that after administration of gadolinium-chelates, PEComas enhance avidly [31], which is not in line with our example (Fig. 6B).

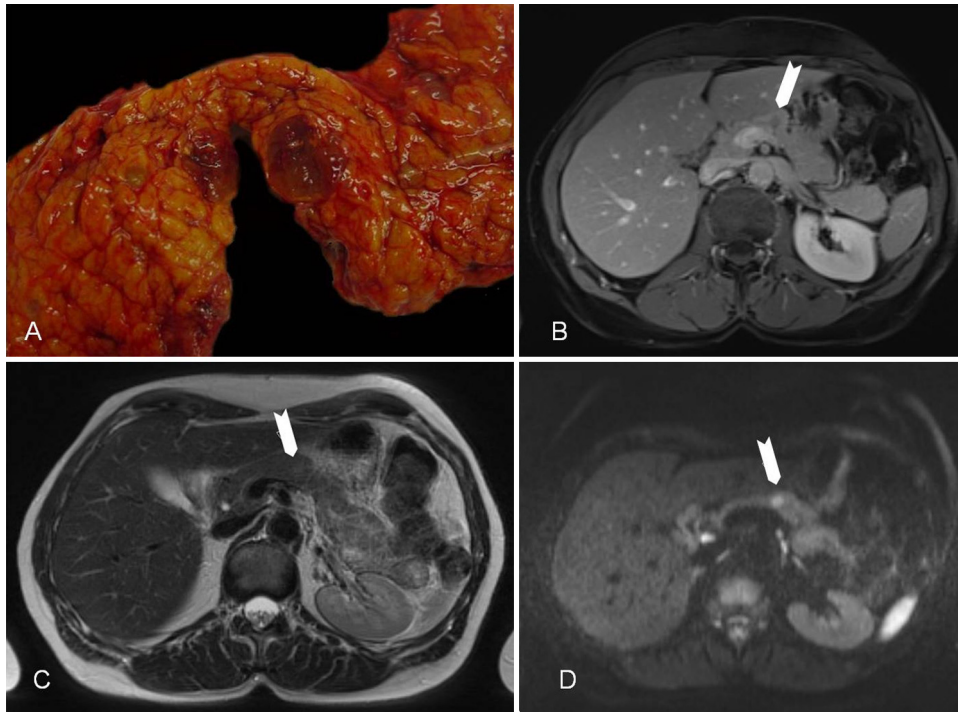


Fig. 6. Perivascular epithelioid cell neoplasm (PEComa) in a 53-year-old woman. (A) Photograph shows gross appearance of the small (1.4 cm × 0.9 cm × 0.5 cm) encapsulated pancreatic tumor. (B) Axial post-contrast fat-suppressed gradient-echo T1-W sequence shows homogeneously hypointense rounded lesion of the pancreatic body (arrow), exhibiting no contrast enhancement. (C) On axial T2-WI, the lesion (arrow) appears hyperintense compared to skeletal muscle. (D) DWI in the axial plane ( $b = 600 \text{ s/mm}^2$ ) shows diffusion restriction of the lesion (arrow).

### 2.7. Primary pancreatic lymphoma

Pancreatic lymphoma can be classified as either primary or secondary lymphoma. Primary pancreatic lymphoma represents only 0.5% of all pancreatic malignancies. Less than 1% of all primary extralymphatic non-Hodgkin lymphoma can be found in the pancreas and most of them are extranodal manifestations of B cell non-Hodgkin's lymphoma [33,34]. Secondary lymphoma results from peripancreatic lymphadenopathy and is more frequent. Symptoms are nonspecific and include, e.g. abdominal pain, weight loss, nausea and vomiting. Morphology of pancreatic lymphoma can be classified as either focal or diffuse.

On MRI, primary pancreatic lymphoma may present as a focal lesion without dilatation of the pancreatic duct or as diffuse enlargement of the pancreas with narrowing of the pancreatic duct [35]. The focal form appears as well-circumscribed homogeneous lesion with low signal intensity on T1-WI and intermediate, more heterogeneous signal intensity on T2-WI. Contrast enhancement is heterogeneous, and less than in the surrounding healthy pancreatic parenchyma [36]. The diffuse form is characterized by mainly decreased signal intensity on T1-WI. On T2-WI, signal intensity is variable. Contrast enhancement is rather homogeneous with or without small spared spots [36,37] (Fig. 7). A hint to pancreatic lymphoma is the combination of a pancreatic mass without dilatation of the main pancreatic duct

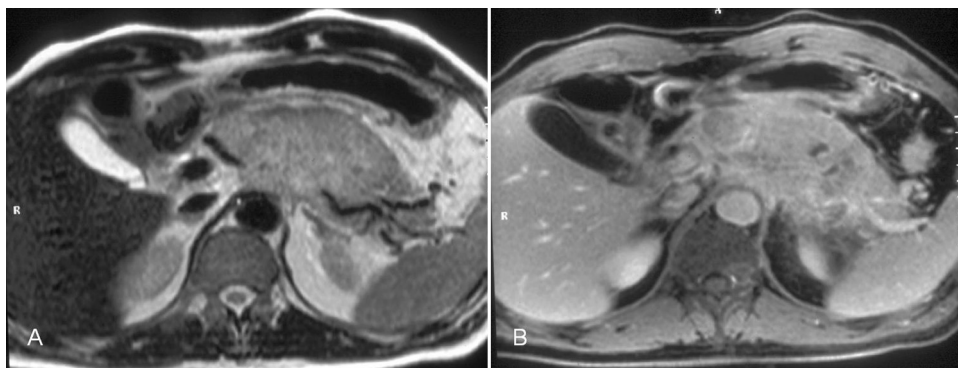


Fig. 7. Primary pancreatic lymphoma in a 62-year-old man. (A) Axial T2-WI shows a diffusely enlarged pancreas with inhomogeneous signal intensity with small bright spots, representing necrotic tissue, next to areas with moderate signal intensity. (B) Fat-suppressed FLASH T1-WI in the axial plane obtained after intravenous administration of gadolinium-chelate shows homogeneous enhancement with small spared spots. Infiltration of the peripancreatic fat is visible around the pancreatic tail.



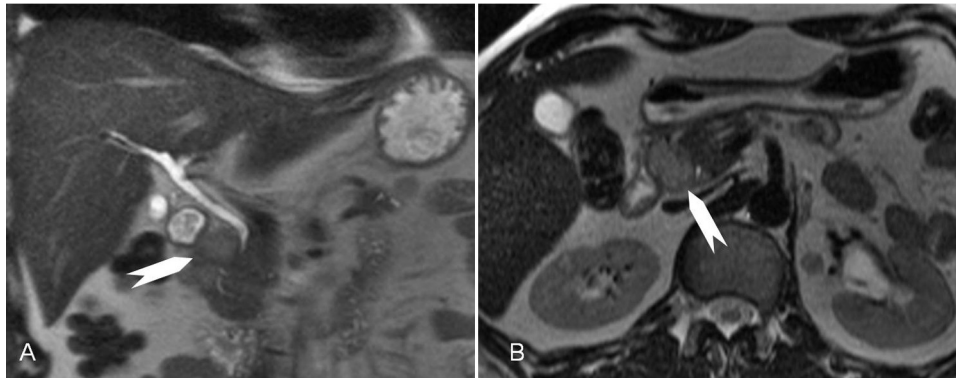


Fig. 8. Widespread metastatic disease in malignant melanoma with pancreatic metastases in a 65-year-old man. (A) Coronal T2-W HASTE sequence shows a well-defined rounded lesion in the pancreatic head with intermediate signal intensity, slightly higher than the surrounding normal pancreas. Another metastasis can be seen inferiorly to the stomach. (B) High resolution T2-WI reveals a hypointense rim around the well-circumscribed, slightly hyperintense lesion. Another metastatic nodule can be found medial to the left kidney.

and peripancreatic lymphadenopathy without involvement of infrarenal levels [38].

## 2.8. Metastases

As the pancreas is a non-encapsulated organ, metastases of various malignant tumors can be found in the pancreas. Primary tumors from the kidney, lung, gastrointestinal tract as well as lymphoma are the most common entities metastasizing to the pancreas [39]. Other frequent entities are tumors of the breast, thyroid gland, bones (osteosarcoma) and skin (melanoma). Still, the incidence of metastases to the pancreas and the peripancreatic lymph nodes is only 3–12% of patients with widespread metastatic disease in autopsy studies and 2–5% in clinical studies, emphasizing their rarity. Often, pancreatic metastases are associated with other extrapancreatic metastases since pancreatic metastases tend to develop rather late in the course of malignant disease [40–43]. Metastases to the pancreas can be found anywhere within the pancreas (head/body/tail) [44]. Clues that may help differentiate metastases from primary pancreatic tumors include a prior history of malignancy, multiplicity of lesions and of course widespread metastatic disease. Pancreatic metastases are usually small and well-defined masses [45].

Due to the variety of entities, appearance on MRI is diverse. In this overview, we would like to present the MR appearance of two of the entities: pancreatic metastases from renal cell carcinoma (RCC) and from melanoma.

Pancreatic RCC metastases show a low signal on T1-WI, while signal intensity is high on T2-WI. On dynamic contrast enhanced studies they show a strong enhancement in the early phase, which may appear ring-like in larger lesions [41].

Pancreatic metastases of melanoma show characteristic signal features on MRI caused by T1 and T2 shortening due to the paramagnetic properties of melanin, resulting in high signal intensity on T1-WI and low to intermediate signal intensity on T2-WI [13] (Fig. 8). As lesions are T1-hyperintense, subtraction imaging can be helpful in identifying contrast enhancement. In the amelanotic subtype of melanoma, due to the lower amount of melanin, T1-signal in pre-contrast images tends to be iso- to hypointense [46].

## 2.9. Other less common pancreatic malignancies

Other less common pancreatic malignancies include primary pancreatic sarcoma, serous cystadenocarcinoma, pancreatoblastoma, solitary fibrous tumor, pancreatic plasmocytoma and desmoplastic round cell tumor.

Serous cystadenocarcinoma are far less frequent than benign serous cystadenoma; only 1–3% of serous cystic neoplasms are malignant. Less than 30 cases have been described in the literature. MRI shows a multicystic lesion with a honeycomb appearance, just as it can be found in serous cystadenoma. For differentiation from serous cystadenoma, detection of local invasion and distant metastases can be helpful as they are suggestive of invasive carcinoma [47].

Pancreatoblastoma is a malignant tumor of childhood—generally occurring before ten years of age—metastasizing to lymph nodes, liver and distant anatomic sites [48]. MRI shows a well-defined lobulated mass which is usually located in the pancreatic head, sometimes with cystic degeneration or calcifications [49]. On contrast enhanced MRI, they usually show enhancement [50].

Solitary fibrous tumor is a very rare mesenchymal tumor of the pancreas with malignant potential [51]. Only 10 cases have been described in the literature so far. Thus, very few is known about MR findings. Imaging findings described imply a well circumscribed mass; tumor size in the reported cases was 3 cm at minimum [52]. The masses may contain cystic parts.

Primary pancreatic sarcoma is an extremely rare entity accounting for less than 0.1% of all pancreatic malignancies. Imaging findings include a large, well-defined mass [53]. The mass can have a contrast-enhancing capsule. In terms of MR-morphology, knowledge is otherwise limited due to the paucity of reports about imaging findings.

Plasmocytoma of the pancreas usually occurs in patients with a history of multiple myeloma or other primary lesions and not as a primary pancreatic lesion. Only two cases of primary pancreatic plasmocytoma have been reported in the literature [54,55]. Imaging shows a well-defined lobulated pancreatic mass which is usually located in the pancreatic head [56].

Desmoplastic small round cell tumors are extremely rare and highly aggressive neoplasms and occur in the pancreas in exceptional cases [57]. Imaging studies show a large lobulated heterogeneous mass [58]. Due to its rarity with only four cases in the English literature, further characteristics on MRI studies are not described.

### 3. Conclusion

A wide range of pancreatic malignancies and pancreatic tumors with malignant potential are known, and several of them are quite rare, so little is known about their appearance on diagnostic imaging. In fact, many of them have characteristic features that are well demonstrated with MRI. MRI and its varieties have the ability to depict soft tissues in detail thus allows excellent evaluation of the internal architecture of a lesion and its relation to the pancreatic parenchyma. However, there are typical and atypical appearances of rare pancreatic malignancies and pancreatic tumors with malignant potential on MRI. Knowing those MRI features according to up-to-date literature facilitates the initial diagnosis to help direct appropriate management in patients with pancreatic lesions.

### Conflict of interest

None of the authors has any potential financial conflict of interest related to this manuscript.

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