H.-J. Brambs

Contrast-Enhanced CT and MRI

Abdominal plain films and chest radiographs play practically no more role in the work-up of pancreatic disorders. Although extensive pancreatic calcifications, which are seen frequently in patients with chronic pancreatitis, are well visualized, there is no additional information to be gained in comparison with cross-sectional imaging methods.

Since the advent and wide availability of endoscopy, the standard upper gastrointestinal series and hypotonic duodenography have also lost most of their importance. They are still required in the work-up of patients in whom significant stenoses of the duodenum due to inflammation or malignancy preclude safe passage of the endoscope.

Angiography still plays a role in the work-up of hemorrhage occurring in pancreatic disease. Otherwise, it has been completely replaced by noninvasive cross-sectional imaging methods such as computed tomography (CT) and magnetic resonance imaging (MRI). Both of these techniques have adequate capabilities for visualizing both arterial and venous vessels and for determining the involvement of these vessels in the patient's underlying inflammatory or malignant disease (Fig. 8.1).

The importance of endoscopic retrograde cholangiopancreatography (ERCP) as a diagnostic method has declined significantly with the development of ultrasound and, in particular, magnetic resonance cholangiopancreatography (MRCP). The invasive method, however, is still indicated whenever a therapeutic procedure, such as papillotomy, stone extraction, or stent implantation is contemplated.

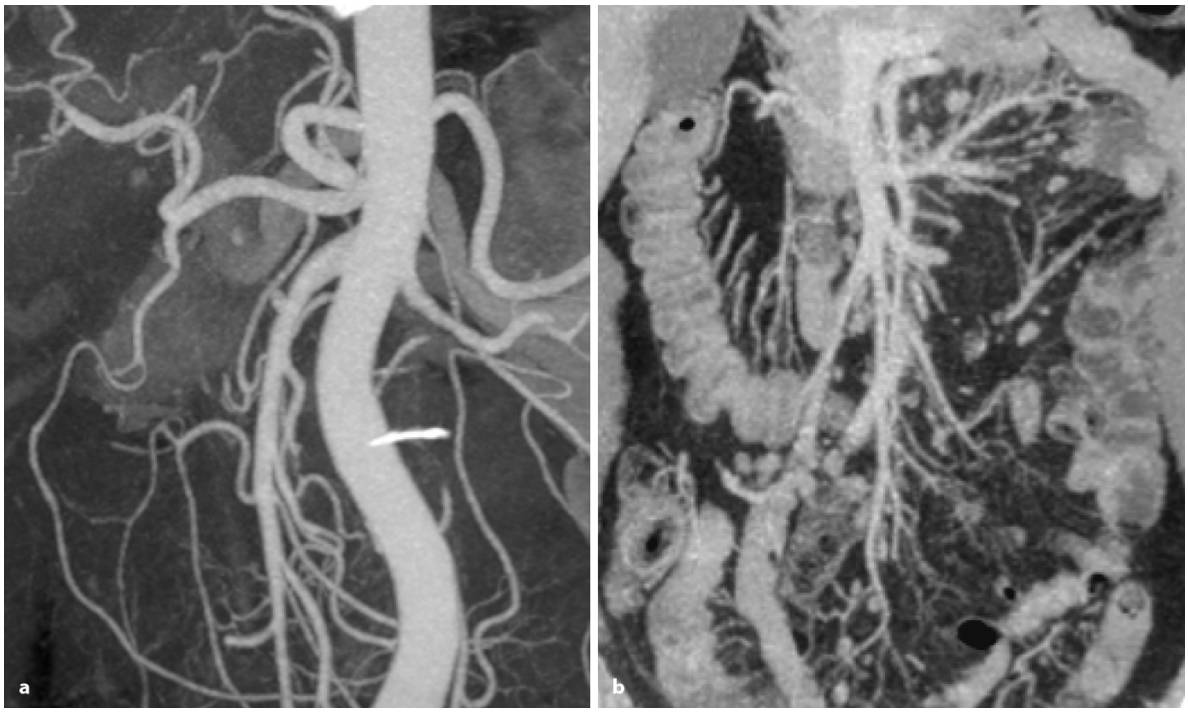


Figure 8.1 a, b

Three-dimensional volume-rendered computed tomography (CT) of the arterial and venous vessels of the abdomen

Diagnostic ultrasound has become the single most important method for visualizing the pancreas and the biliary system. This is especially true in light of the many technical refinements that have been made in recent years. Transabdominal ultrasound depends only partially on the cooperation of the patient and can be repeated rapidly and safely whenever needed. The advantages of endoscopic ultrasound (EUS) include high-resolution imaging and the capability for targeted punctures.

Spiral CT

Spiral CT, especially since the introduction of the newly developed multidetector scanners (MD-CT), has resulted in a significant improvement in resolution when imaging the pancreas [1]. In addition, it has become possible to plan contrast-enhanced studies in detail and, when required, the organ can be studied during more than one contrast medium phase (Fig. 8.2). Depending on the available technology and the clinical question, a more refined examination protocol can be devised to vary the spatial resolution, the phase of contrast enhancement, and, where needed, include more than one phase of contrast enhancement.

A further advantage of multidetector technology is the capability for reconstruction image data (Fig. 8.3). Particularly impressive are the reconstructions along duct formations (Fig. 8.4) and vessels (curved reformations and slab viewing). This can be of great importance in cases of tumor infiltration of vessels and for a more precise visualization of cystic tumors and their connection with the pancreatic duct (Fig. 8.5).

For a qualitative study, it is important that patients drink adequate amounts of liquid immediately before the examination. This helps delineate the stomach and duodenum from the pancreas and for recognizing inflammatory or malignant infiltration. The additional intravenous administration of spasmolytic agents is useful for distending the duodenum. The collapsed duodenum is often difficult to distinguish from pancreatic parenchyma.

High spatial resolution, which includes imaging of the ductal structures, the capability for very rapid reconstruction of arterial and venous structures that is comparable to angiography, and the ability to include the liver and the lungs in the same imaging session makes this method highly suitable for the diagnosis and staging of tumors. It is possible, without subjecting the patient to further studies, to make informed statements regarding the crucial issue of resectability.

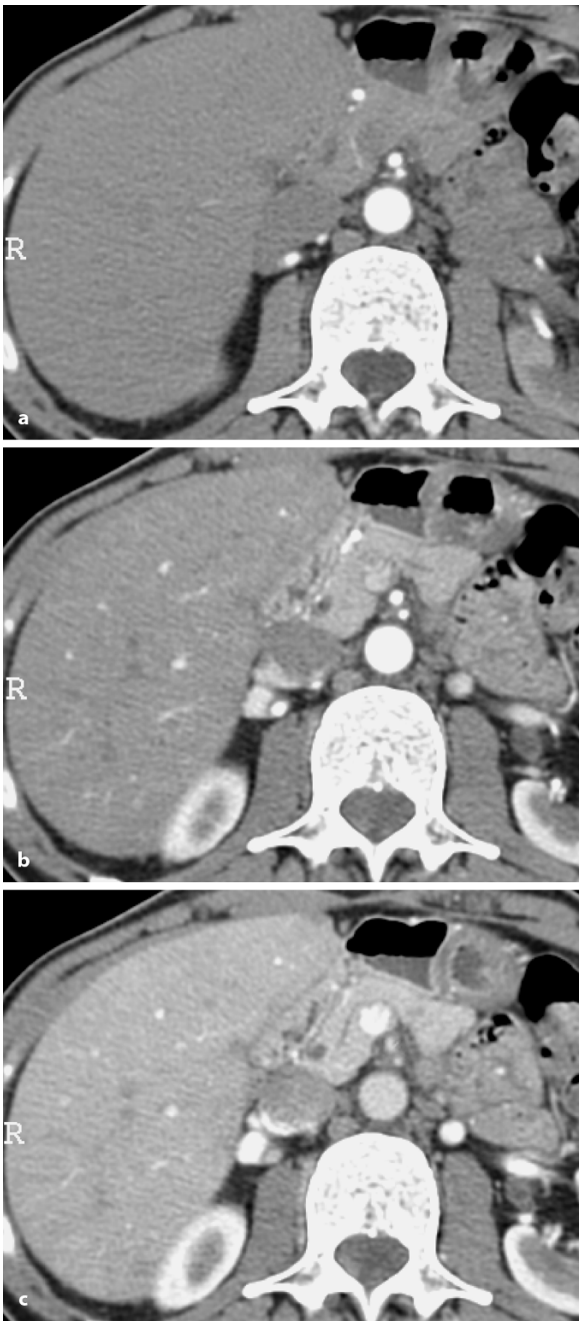


Figure 8.2 a–c

Three-phasic CT of the pancreas including an arterial, parenchymal, and portal-venous phase

The design of the examination depends on the clinical question, but the options are determined by the available technology. This latter factor is dependent on the number of detectors in modern CT units. Although modern multidetector technology allows a reduction in the required contrast medium, it is use-

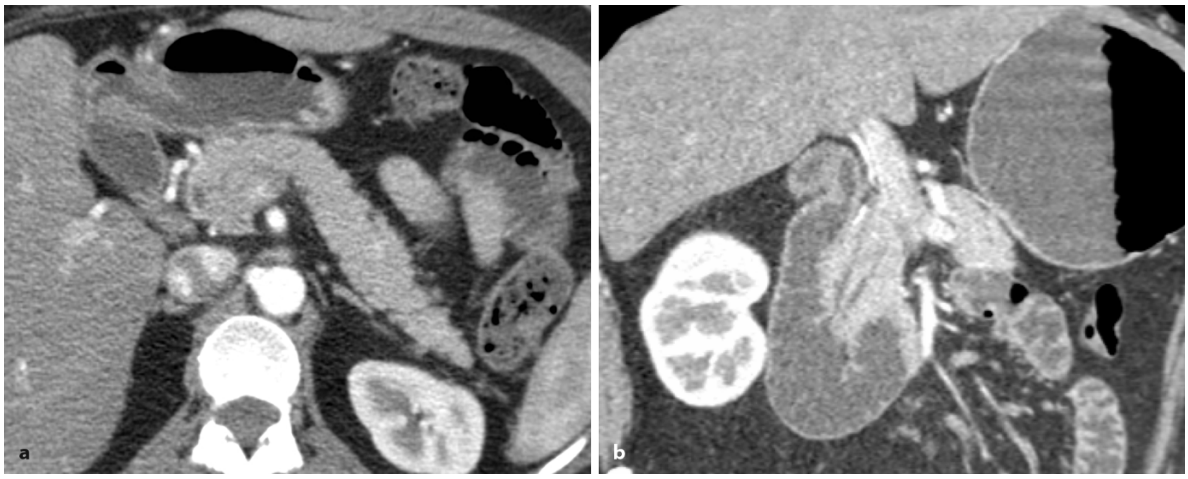
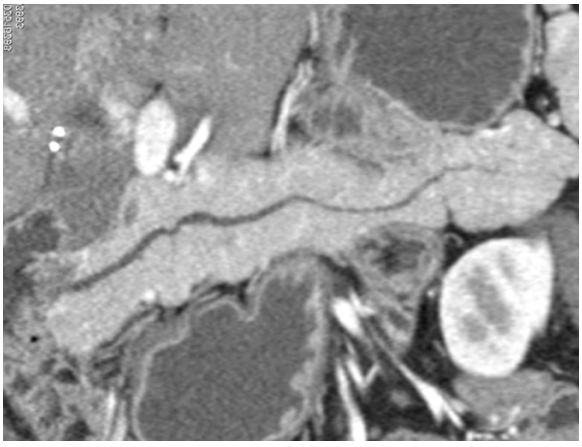


Figure 8.3 a, b

High-resolution CT of the pancreas in the axial plane (a). In the coronal reformation, the pancreatic head is well delineated from the fluid-filled duodenum, showing the normal distal bile duct and pancreatic duct

Figure 8.4

Perpendicular reconstruction along the pancreatic duct



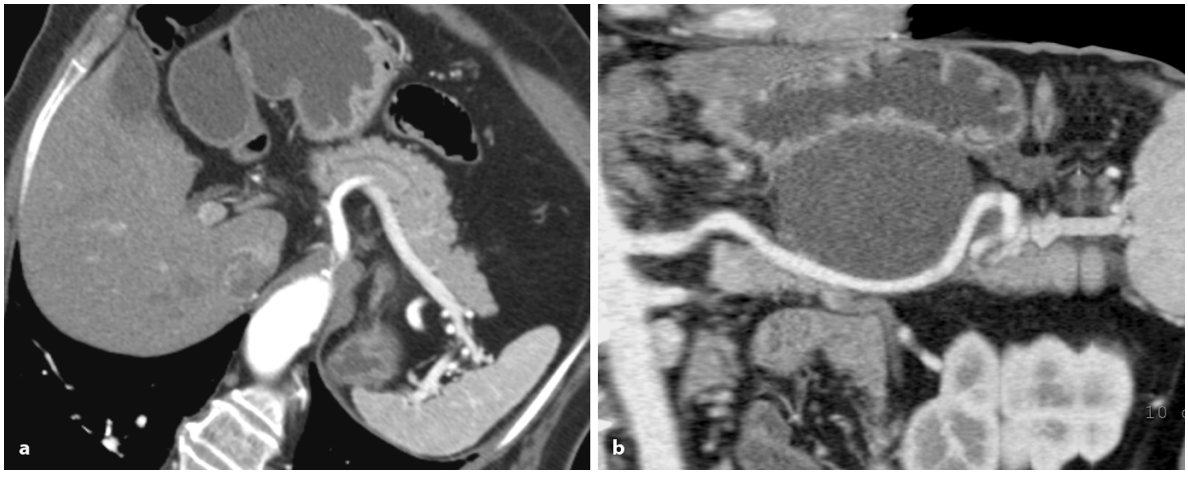


Figure 8.5 a, b

Reformation of a normal pancreas along the splenic artery (a: slab viewing), and of a pancreatic pseudocyst (b: perpendicular)

ful to increase the contrast medium concentration [2]. In most cases, a contrast medium flow of 3–4 ml/s is recommended.

Technical refinements have resulted in a sustained discussion regarding the number of contrast phases that are necessary for adequate assessment of pancreatic disorders as well as regarding which contrast phase permits optimum differentiation between normal and pathological pancreatic tissue [3,4].

The so-called arterial phase (20–25 s following the start of contrast medium injection) often occurs too soon for adequate differentiation between healthy and diseased parenchyma. It is most commonly recommended in cases of suspected endocrine tumors or when special angiographic reconstructions are desired (Fig. 8.2a).

The greatest difference in contrast uptake between normal and pathological pancreatic tissue occurs during the so-called pancreatic phase (30–70 s following start of contrast medium injection, with a maximum at 40 s). The amount and speed of injection affect this phase: larger amounts of applied contrast medium are associated with a longer duration of the phase, while a more rapid injection results in more intense contrast enhancement (Fig. 8.2b).

The portal venous phase (maximum after 60–90 s) is characterized by optimum contrast of the portal and mesenteric veins. In addition, this phase is usually best suited for the detection of hypovascular metastases of the liver (Fig. 2c).

Magnetic Resonance Imaging

MRI has enjoyed increasing acceptance in the diagnosis of pancreatic disorders. It exhibits significant advantages in the work-up of certain entities, such as cystic tumors. The method has the additional advantage that, besides the cross-sectional imaging, MRCP and angiographic sequences can be acquired, making it a well-rounded diagnostic modality that is particularly useful in the diagnosis and staging of tumors. Technical innovations such as phased-array coils have resulted in improvement in both the signal:noise ratio and spatial resolution, facilitating the imaging of the upper abdomen with rapid T1- and T2-weighted sequences in breath-hold technique [5].

In order to better distinguish the pancreas from surrounding bowel loops and the stomach, patients can, as has been recommended with CT, be asked to drink adequate amounts of water prior to the examination. Other positive and negative contrast media have been discussed favorably in the scientific literature, but have not to date gained general acceptance.

Different T1- and T2-weighted sequences in the axial and coronal plane can be used for visualization of the pancreatic parenchyma. On T1-weighted sequences, the normal pancreas shows a moderate level of signal intensity that is most frequently higher than that measured for the liver or spleen (Fig. 8.6a). This is ascribed to the high proportion of proteins in the glandular tissue, the highly developed reticuloepithelial system and the high concentration of paramagnetic ions, such as manganese. This higher signal intensity is even maintained in the presence of significant fatty degeneration of the organ, but decreases gradually with advancing age as a result of the increasing fibrosis of the gland. Signal intensity is decreased in tumors, pancreatitis, and atrophy.

The T1-weighted sequences include turbo spin echo sequences with fat suppression or gradient recalled echo sequences in breath-hold technique. Fat suppression improves visualization of many organs that, like the pancreas, are surrounded by fat tissue and are themselves characterized by a high protein content. In addition, movement artifacts are reduced, as are the so-called chemical shift artifacts that occur at the lipid–water boundary. Fat-suppressed T1-weighted images are especially useful for detecting subtle focal and diffuse changes in the pancreas; they are also suitable for excluding some pancreatic disorders (Fig. 8.6b).

As a rule, the work-up of pancreatic disorders requires intravenous contrast medium, which is administered using an MRI-compatible high-performance injector (Fig. 8.6b). Dynamic, gadolinium-enhanced sequences acquired at different perfusion phases improve the detection and characterization of pancreatic lesions less than 1 cm in diameter. In addition, they permit assessment of vascularization of pancreatic tumors and facilitate the detection and characterization of any hepatic lesions that may be simultaneously present.

T2-weighted sequences are acquired in thin-slice technique with short and long scan times in both axial and coronal planes (Fig. 8.7). Acquisition is performed either with respiratory triggering or during breath-hold. Because these sequences visualize the biliary and pancreatic ducts, they also serve as a basis of MRCP.

Application of manganese-containing contrast medium, originally conceived as a hepatobiliary contrast medium, results in a significant increase in signal intensity in healthy pancreatic parenchyma (Fig. 8.8). The use of this contrast medium, however,

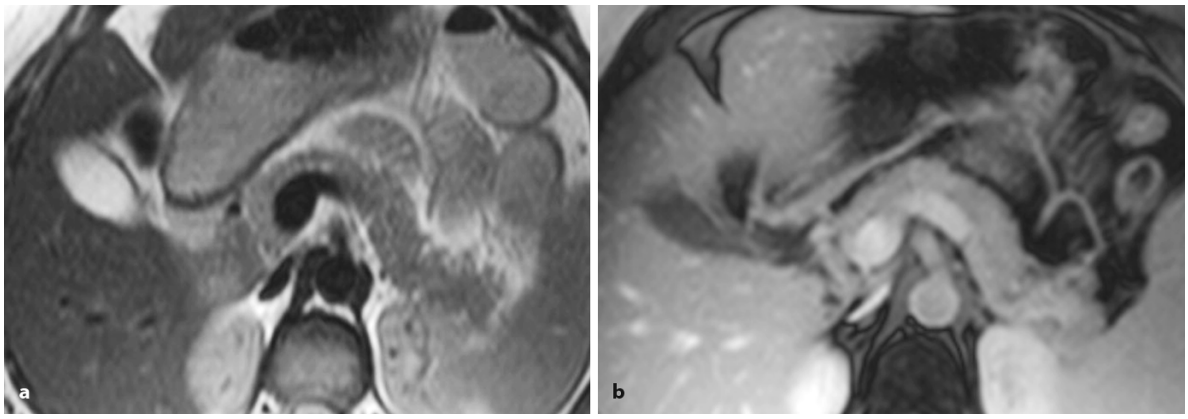
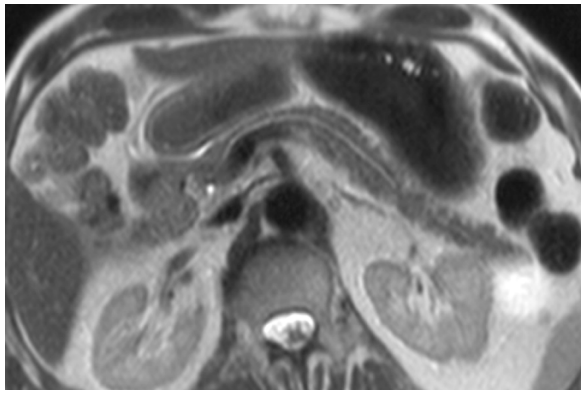


Figure 8.6 a, b

T1-weighted sequence of the pancreas (**a**: native, **b**: after intravenous administration of Gd-diethylene triamine pentaacetic acid using fat suppression)

Figure 8.7

T2-weighted imaging of a normal pancreas with delineation of the pancreatic duct



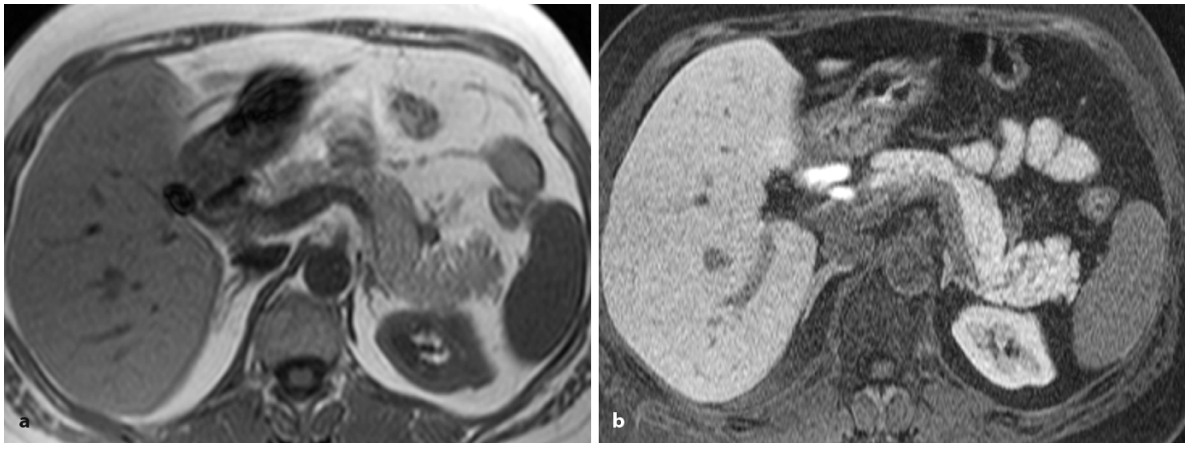


Figure 8.8 a, b

T1-weighted image of the pancreas (**a**: native, **b**: after intravenous administration of Mangan)

has not yet found broad acceptance. One reason is that dynamic studies are impossible. In addition, even with this contrast medium, differentiation between pancreatic carcinoma and chronic pancreatitis remains difficult, since both entities present with a reduced concentration [6]. On the other hand, certain tumors such as acinar cell carcinoma show increased uptake of this contrast medium.

Magnetic Resonance Cholangiopancreatography

A comprehensive work-up of pancreatic disorders includes evaluation of the biliary and pancreatic ducts. This can be done rapidly and with adequate quality using MRCP. Many studies have even shown that, for detection of ductal changes within the pancreas and of extrapancreatic changes of the biliary system, MRCP is equivalent to ERCP. In addition, MRCP can be performed without difficulty in patients with stenoses of the stomach and duodenum, large duodenal diverticula, after gastric surgery and after biliodigestive anastomoses – situations in which ERCP is either impossible or associated with very high failure rates.

MRCP is based on very strong T2-weighted sequences in which standing or very slowly flowing fluids are visualized with high signal intensities. Ideally, very rapid sequences are used, although these are associated with the disadvantage of poorer spatial resolution. As a rule, single and multislice techniques are combined, since these are quite complementary.

Single-slice images can be acquired during brief breath-hold phases in thick slices (20–50 mm). Motion artifacts due to peristalsis and respiration are practically negligible. Additional fat suppression increases the contrast between ductal structures and the background and, even without special postprocessing, yields images that are very comparable to ERCP images (Fig. 8.9).

An important advantage of this technique is the short acquisition time, permitting dynamic evaluation. This can be used for work-up of dysfunctions of the sphincter and for evaluating the secretory performance of the pancreas following intravenous administration of secretin. The disadvantage of this technique is that visualization of ductal structures may be compromised by adjacent, fluid-filled structures and by overlying ascites. In order to reduce such artifacts from the stomach or duodenum, patients should either be fasting or can be given contrast medium containing iron oxide shortly before the examination. This latter measure neutralizes gastric and duodenal secretions prior to imaging.

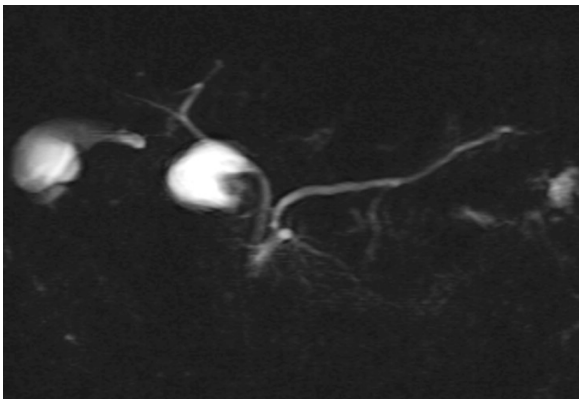


Figure 8.9

Magnetic resonance cholangiopancreatography (MRCP) of a normal ductal system

Multislice techniques generally involve series of slices 3–5 mm in thickness that are acquired with a shorter echo time than with single-slice techniques (100–300 ms). With these settings, both signal-intense fluids and periductal structures are visualized, which is important, especially in cases of malignant obstruction, and can be helpful when artifacts secondary to superposed fluids interfere with diagnosis in single-slice studies. Because the slices are acquired in less than 1 s, motion artifacts do not occur. In addition, image quality is less affected by chemical shift or susceptibility artifacts.

Secretin-Stimulated Dynamic MRCP

The intravenous administration of secretin (1 ml per 10 kg body weight) results in stimulation of water and bicarbonate secretion. This produces better filling of the pancreatic ducts, which is further intensified by a transient contraction of the papilla sphincter that lasts about 5 min. This endogenous "contrast enhancement" permits better evaluation of the main pancreatic duct and often also of the side branches in the head of the pancreas. Here, it is important that with good temporal resolution, both the duodenum and pancreatic duct are visualized over their entire lengths. Good indications include confirmation of pancreas divisum and other ductal variants.

In addition, this method permits dynamic examination of the pancreas (Fig. 8.10), which can be used for semiquantitative estimation of secretory performance and for assessing the exocrine function of the gland [7–9].

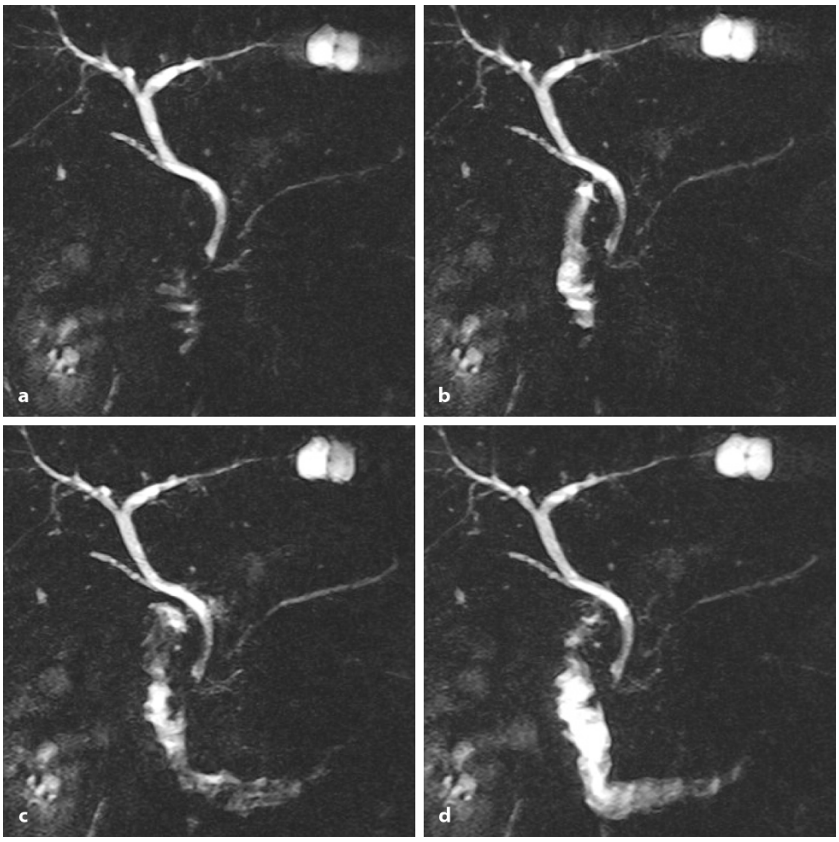


Figure 8.10 a – d

MRCP obtained before and during secretin stimulation slightly improves visualization of the main pancreatic duct and shows an increasing filling of the duodenum due to normal pancreatic secretion

Magnetic Resonance Angiography

Dynamic sequences acquired following intravenous application of gadolinium can be used for assessing arterial and venous vascularization of pancreatic tumors (Fig. 8.11). A three-dimensional gradient echo sequence can also be acquired following gadolinium application for assessing the vascular situation. A novel variation of this technique is the so-called VIBE sequence (volume interpolated breath-hold examination), which provides high resolution and can also be used in hepatobiliary imaging [10].

A Comparison of Methods

Transabdominal ultrasound and EUS have been strongly propagated by internists for the diagnosis of pancreatic disease. Without doubt, transabdominal ultrasound is an outstanding screening method for discovering pancreatic pathology and, in many cases, can be used for follow-up monitoring. If serious therapeutic consequences are expected, EUS is often recommended.

Among radiologists, CT is currently the most frequently recommended method for detecting and characterizing pancreatic diseases. Since the introduction of modern MD-CT scanners, the examination can be performed in a very short time and with very high resolution. A wide range of reconstructions is possible without major time requirements, yielding very useful topographic images. In addition, simultaneous changes involving the lung, liver, adjacent bowel loops, arterial and venous vasculature and lymph nodes can be precisely visualized.

Magnetic Resonance Imaging

As a rule, MRI is not the primary method for diagnosing disorders of the pancreas. This is due in great part to the relatively long examination times, problems of availability, and the relatively high costs of the method. Compared to newer CT technologies, MRI offers less satisfactory resolution, and the previously cited advantages of multiplanar imaging have been met by the at least equivalent performance of MD-CT.

There are, however, a few indications for MRI in the work-up of pancreatic disease:

1. Unsatisfactory or questionable CT results in patients with a high probability of pancreatic disease.

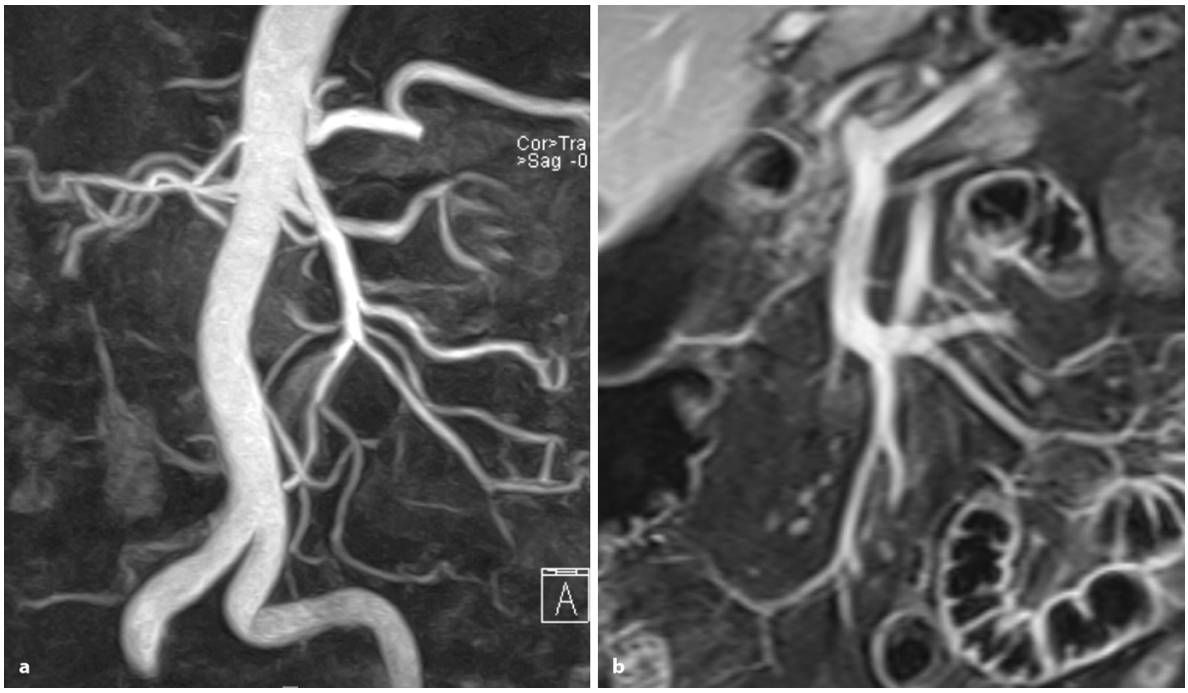


Figure 8.11 a, b

Magnetic resonance angiography of the arterial and venous abdominal vessels

2. Contraindications for iodine-containing contrast media.
3. Patients in whom radiation exposure must be avoided (e.g. pregnancy, children)

The particular strengths of MRI in comparison with other cross-sectional imaging modalities include:

1. Detection of small endocrine tumors.
2. Characterization of questionable parenchymal inhomogeneities at ultrasound or CT (disorders of fat distribution).
3. Cystic tumors of the pancreas.

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