Eur. Radiol. 8, 428–434 (1998) 

**Abdominal radiology**

European Radiology

*Original article*

# Pancreatic adenocarcinoma: combination of MR imaging, MR angiography and MR cholangiopancreatography for the diagnosis and assessment of resectability

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Received 22 August 1996; Revision received 3 June 1997; Accepted 19 August 1997

**Abstract.** The purpose of this study was to determine the possibility of integrating MR cholangiopancreatography (MRCP) and MR angiography (MRA) to conventional MR images in the diagnosis and assessment of resectability of pancreatic adenocarcinoma. Twenty-three patients with pancreatic adenocarcinoma were prospectively examined with MR. Conventional MR images were acquired in all patients. Three-dimensional MRCP and MRA images were acquired in all patients with suspected biliary and vascular involvement. Acquisition time was less than 45 min in all cases. Images were independently evaluated by two radiologists, with final reading decided by consensus among readers. Diagnosis was confirmed with surgery in 16 patients and with percutaneous biopsy in 7. Concordance among readers was high with a kappa value of 0.83. Pancreatic adenocarcinoma was observed in all patients. Correct assessment of unresectability due to vascular involvement was found in 22 of 23 patients. Biliary obstruction was evident in 13 patients, involving the biliary and pancreatic ducts in 9 and the biliary ducts only in 4. Technical advances permit extensive use of MRI in the evaluation of abdominal pathologies. The combination of MR imaging, MRCP, and MRA can provide sufficient information for the diagnosis and assessment of resectability of pancreatic adenocarcinoma, which otherwise would require three different exams.

**Key words:** MR imaging – MR angiography – MR cholangiopancreatography – Pancreatic adenocarcinoma

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## Introduction

Pancreatic carcinoma accounts for 22 % of the deaths due to gastrointestinal carcinoma in Western countries [1]. It is a disease with an extremely poor prognosis: generally less than 20 % of the affected patients survive the first year and only 3 % are alive at 5 years [2]. Ductal adenocarcinoma is the most common neoplasm, comprising 75–90 % of all pancreatic tumors [3]. Abdominal discomfort, back pain, obstructive jaundice, and weight loss are the most common symptoms [4]. Among the different pancreatic neoplasms, ductal adenocarcinoma has the worst prognosis, whereas periampullary carcinomas have a more favorable prognosis, reflecting earlier presentation, with an overall 5-year survival rate of 30–40 % [2]. The only potential cure for pancreatic neoplasms is surgery [5]. Therefore, early diagnosis and assessment of tumor resectability are fundamental to achieve a successful treatment [2, 5, 6]. Although important advances and technical developments now allow higher accuracy in the radiologic diagnosis of pancreatic tumors, still many different exams are generally performed to detect and stage the disease. Staging of pancreatic neoplasms is generally performed with CT, which is also specific in the diagnosis of biliary or vascular involvement [7, 8].

The MRI technique is also proving to be a reliable procedure for the identification of pancreatic carcinomas [9–11]. According to large clinical trials, MRI is slightly inferior to CT in staging this disease [12]. More recently, MRI, following improvements in the equipment, has proven conclusive in inconclusive CT examinations [13, 14]. Furthermore, MR angiography (MRA) and MR cholangiopancreatography (MRCP) have recently been developed and optimized and are now used for routine clinical exams [15–19]. In this study we present our results with MR imaging in the assessment of resectability of pancreatic adenocarcinoma using advanced imaging protocols for the evaluation of vascular structures and biliary tree.

## Materials and methods

A prospective evaluation was conducted in our institution, over a 14-month period, to evaluate the use of MR to assess the resectability of pancreatic adenocarcinoma. Twenty-three consecutive patients with pancreatic adenocarcinoma were examined. The study population consisted of 14 males and 9 females (age range 31–79 years, mean age 57 years). Pancreatic tumor was suspected on the basis of clinical symptoms and transabdominal US findings. The lesion involved the region of the body tail of the gland in 5 patients, and the pancreatic head in 18 patients. In all 18 patients with pancreatic head carcinoma endoscopic retrograde cholangiopancreatography (ERCP) was also performed. In all cases the final diagnosis of pancreatic adenocarcinoma was based on pathological specimens, obtained in 16 cases at surgery and in 7 cases with percutaneous biopsy. All patients underwent MR imaging. Sixteen patients underwent surgery.

Diagnosis was confirmed with percutaneous biopsy in 7 cases and with surgical exploration in 16 cases.

### *MR imaging*

All exams were performed with a 0.5-T magnet (Philips Gyroscan T5-II, Philips, Eindhoeven, The Netherlands) with 15-mT/m gradient power. Five hundred milliliters of tap water were administered to opacify the upper gastrointestinal tract and to better delineate the pancreas. A reduction of the intestinal peristalsis was obtained with an intramuscular injection of 1 ml of scopolamine hydrobromide (Buscopan, Boehringer, Ingelheim, Germany). Respiratory compensation for conventional MR imaging and MRCP and cardiac gating for MRA were applied in all exams. Axial Tl-weighted spin echo (SE) with and without fat saturation (TR/TE = 300/12 ms, matrix 192 × 256, number of excitations (NEX) = 4, Sl.Th. = 10 mm, TA = 4.5 min) and axial T2-weighted turbo-SE (TSE; TR/TE = 3000/120 ms, echo train length = l9, matrix 203 × 256, NEX = 6; Sl. Th. = 10 mm, TA = 2.47 min) sequences were acquired in all patients. The MRA technique was obtained in 16 patients with a double acquisition volume: an arterial phase, with a caudal venous presaturation, and a venous phase with a cranial arterial presaturation. The MRA techniquewas performed in those cases in which morphological images showed a lesion contiguous to a major vascular structure. Cardiac-gated 3D phase contrast, acquired in the axial plane with the following parameters, was employed for MRA: TR/TE = 25/6.8 ms, flip angle (FA) 20°, VENC = 10–50 cm/s, Sl.Th. = 2 mm, NEX = 2, matrix 96 × l28, TA = 7.3 min. The acquisition volume for the venous phase included the superior mesenteric and splenic veins and extrahepatic portal vein, and, for the arterial phase, included the celiac trunk and superior mesenteric artery. Image reconstruction for MRA was performed after completion of the MR study. In 18 patients with pancreatic head lesions MRCP was also performed. For this purpose we utilized a coronal 3D fat-suppressed TSE sequence with the following parameters: TR/TE = 3000/700 ms, NEX = 6, matrix 83 × 128, echo train length = 128, Sl.Th. = 3 mm, number of slices = 20 25, field of view (FOV) = 240, TA = 3–3.4 min. A standard maximum intensity projection (MIP) algorithm was utilized to reconstruct either MRA or MRCP images. The overall acquisition time was less than 40–45 min in all cases in which conventional imaging, MRCP, and MRA were performed.

### *Image analysis*

Two experienced radiologists evaluated all the images. The radiologists were blinded to both US and CT findings. The final reading was determined by consensus reading of the two readers. Interobserver variability was evaluated by the kappa test. The study protocol included assessment of tumor location, with definition of size and local infiltration, involvement of major extrapancreatic vessels and biliary tree, and evaluation for liver metastases. The diagnosis of adenocarcinoma was based on the presence of a hypointense mass, as compared with the normal pancreas, on T1-weighted – particularly on fat-suppressed Tl-weighted – SE images. The type of dilatation of the main pancreatic duct and the contour of the stenosis of the main bile duct, when present, were considered as criteria for diagnosis. Abrupt termination or irregular stenosis of the common bile duct or pancreatic ducts were interpreted as consistent with pancreatic carcinoma. Magnetic resonance angiography images were evaluated examining both 3D reconstructions and source images in order to evaluate the vascular anatomy and encasement or infiltration of the vessels by tumor. Unresectable disease was determined by the observation of encasement and occlusion of a major vessel [particularly superior mesenteric vein and artery (SMV and SMA) and splenic vessels]. Morphological SE images were evaluated in conjunction with MRA images, in the assessment of lesions contiguous to vessels. Encasement was considered as probable when a > 90° contact between tumor and vessel was identified, or streaks of tumor tissue infiltrating the perivascular fat were evident. When the MR angiograms revealed no abnormality or only minor displacement of the major vessels, the disease was regarded as resectable. Tumors of the pancreatic head greater than 4 cm in diameter with subtle angiographic changes were classified as "probably resectable." Biliary duct and pancreatic duct dilatation were evaluated at MRCP. Attention was given to the level and morphology of the obstruction. The type of dilatation was considered as one of the criteria for the differential diagnosis between pancreatic adenocarcinoma and chronic inflammatory processes. The presence of an abrupt or irregular stenosis of the biliary and pancreatic ducts was considered a highly specific but poorly sensitive criterion of pancreatic carcinoma. In patients in whom the stenoses of the main bile duct or pancreatic duct were not clearly malignant, an analysis of the secondary ducts

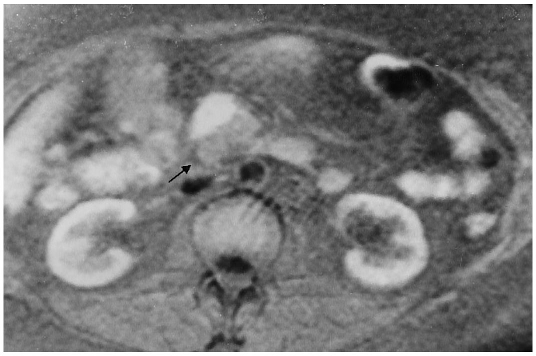

**Fig. 1.** Pancreatic head carcinoma. Fat-saturated Tl-weighted spin-echo (SE) sequence clearly shows a 2-cm hypointense mass *(arrow)* within the markedly hyperintense normal pancreas

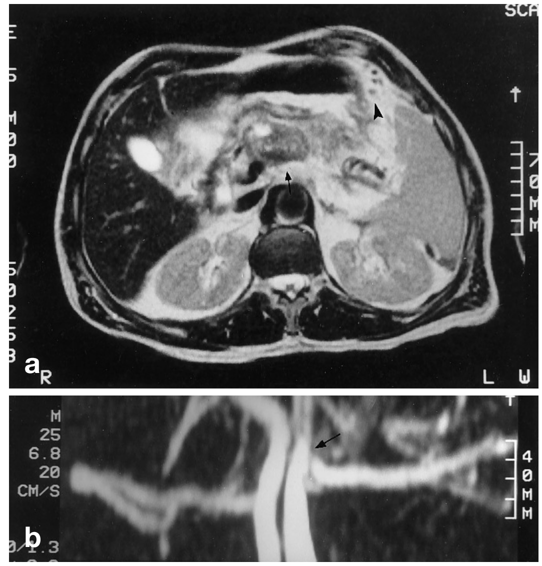


**Fig. 2 a, b.** Pancreatic isthmus adenocarcinoma. **a** T2-weighted turbo-spin-echo (TSE) image shows an inhomogeneously hyperintense lesion *(arrow)* in the body of the pancreas. Note also the ectatic gastroepiploic vein *(arrowhead)*, an indirect sign of splenic vein thrombosis. **b** Venous MRA demonstrates infiltration of the splenic vein *(arrow)* at the junction with the superior mesenteric vein (SMV)

caliber was performed. In particular, the visualization of the secondary ducts and their saccular dilatation were considered criteria for diagnosis of benign lesions.

## Results

The interobserver concordance for the resectability of pancreatic cancer had a kappa value of 0.83.

### *Identification: characterization and local extension*

Pancreatic adenocarcinoma was found in all patients examined, located in the body–tail region in 5 cases, and in the head in 18 cases. Five of the head carcinomas were located in the region of the uncinate process.

Tumors located in the body and tail of the pancreas were large, measuring 4.5–8 cm in diameter (mean 5.8 cm). All tumors were detected and correctly staged. Four of the pancreatic head carcinomas were < 2 cm in diameter. In these patients biliary obstruction was the major symptom. Magnetic resonance images allowed correct identification of these four lesions. They were in fact shown by Tl-weighted SE sequences with and without fat suppression (Fig. 1).

In all remaining neoplastic lesions, the diameter (ranging between 2 and 4 cm) and the signal intensity of the tumor on all sequences were consistent with neoplasms. The local extension and infiltration of the peripancreatic fat planes were defined in all cases, best shown on T1-weighted images.

Local extension of tumor beyond the margin of the pancreas, present in 14 patients, was identified as a contiguous area of extra-pancreatic soft tissue, with a signal intensity similar to that of the primary tumor on all sequences. Extension occurred posterior to the pancreatic tumor mass in 7 patients, into the splenic hilus in 2 patients and anterior to the tumor mass in 5 patients. Confirmation of local extension seen at MR imaging was determined in 9 patients at surgery with palpation and multiple histological specimens. In the remaining 5 patients, MR imaging findings suggested diffuse local extension, diagnostic for unresectability and no need to perform other diagnostic exams to exclude a surgical resection, as also confirmed by clinical follow-up. In 3 cases infiltration of the duodenum was observed which was confirmed at surgery in all cases.

### *Distant metastases*

Liver metastases were present in 3 patients at the time of the MR examination; in 2 cases the primary neoplasm was located in the tail and in 1 case in the head. Peritoneal carcinomatosis was evident in 1 case of pancreatic head carcinoma. All other patients did not present with distant metastases.

**Table 1.** MRA findings of vascular involvement

| | No. of patients | Thrombosis of splenic vein (3 patients) | Encasement of gastroduodenal artery (2 patients) | Encasement of SMV (4 patients) |
|---|---|---|---|---|
| Adenocarcinoma, head | 11 | – | 2 | 3 |
| Adenocarcinoma, body-tail | 5 | 3 | – | – |

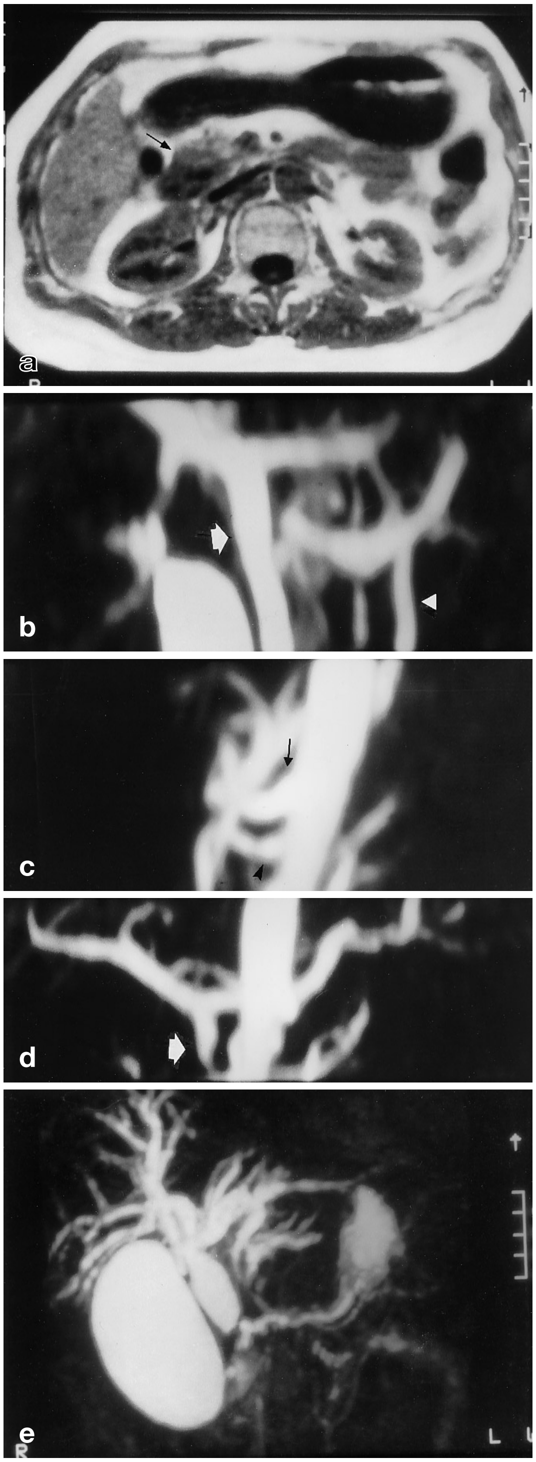

**Fig. 3 a–e.** Pancreatic head carcinoma. **a** Tl-weighted SE image shows a hypointense mass *(arrow)* adjacent to the duodenum. **b** MRA demonstrates patency of the SMV *(arrow)*, splenic vein, and portal vein, with good evaluation also of the inferior mesenteric vein *(arrowhead)*. **c** The arterial phase shows, on a lateral projection, the origin of the celiac trunk *(arrow)* and SMA *(arrowhead)*, which both result patent. **d** A coronal projection allows depiction of the progressive reduction in caliber of the gastroduodenal artery, encased by the tumor *(arrow)*. **e** MRCP shows a marked dilatation of the biliary and pancreatic ducts, with a double duct sign

*Vascular involvement*

The vascular study with MRA was performed in 16 patients with lesions contiguous to major vascular structures, acquiring venous and arterial images. All 5 cases with neoplastic lesions of the body–tail region were considered unresectable, due to splenic vein thrombosis in 3 patients (Fig. 2), and hepatic metastases in 2 patients. In both patients with liver metastases no direct vascular involvement was evident (Table 1).

In the remaining 11 patients, the lesion involved the pancreatic head and periampullary region. Of these 11 patients, 7 underwent surgery. In 2 cases encasement of the gastroduodenal artery (Fig. 3) was detected, which was confirmed at surgery. In 3 patients the neoplasms caused vessel displacement without vascular narrowing or encasement. These three tumors were considered as "probably resectable" and the patients underwent surgery. Two of these tumors were resected, whereas in the third patient the tumor had partially infiltrated the SMV, which did not allow complete surgical resection. In the final 2 cases MRA did not demonstrate vascular abnormalities and these patients underwent successful duodenal cephalo-pancreatectomy

Four patients with pancreatic head lesions did not undergo surgery, due to encasement of the SMV in 3 patients and SMV neoplastic thrombosis in 1 patient. The MRA technique demonstrated these findings which were subsequently confirmed by conventional arteriography.

*Biliary involvement*

The MRCP technique was performed in 18 patients with pancreatic head lesions. In 16 patients no significant difference was evident between ERCP and MRCP images. In 2 cases MRCP demonstrated a "double duct" sign, whereas ERCP did not visualize the pancreatic duct, because this duct could not be cannulated (Fig. 4; Table 2).

Dilatation involving the intra- and extrahepatic biliary ducts and the pancreatic duct was present in 9 cases with abrupt bilio-pancreatic ducts stenosis consistent with ductal adenocarcinoma of the pancreatic head (Fig. 3); in the remaining 4, the duct of Wirsung was normal in caliber (Fig. 5). In 5 cases with cancer of the uncinate process there was no significant biliary dilatation, as demonstrated by MRCP images.

**Table 2.** MRCP/ERCP findings of biliary involvement in 18 patients

| | Intra- and extrahepatic biliary duct dilatation | | Dilatation of Wirsung duct |
|---|---|---|---|
| MRCP | Intra-extra | 9 | |
| | extra | 5 | 18 |
| ERCP | intra-extra | 9 | |
| | extra | 5 | 14[a] |

[a] Cannulation of pancreatic duct was unsuccessful in 4 patients

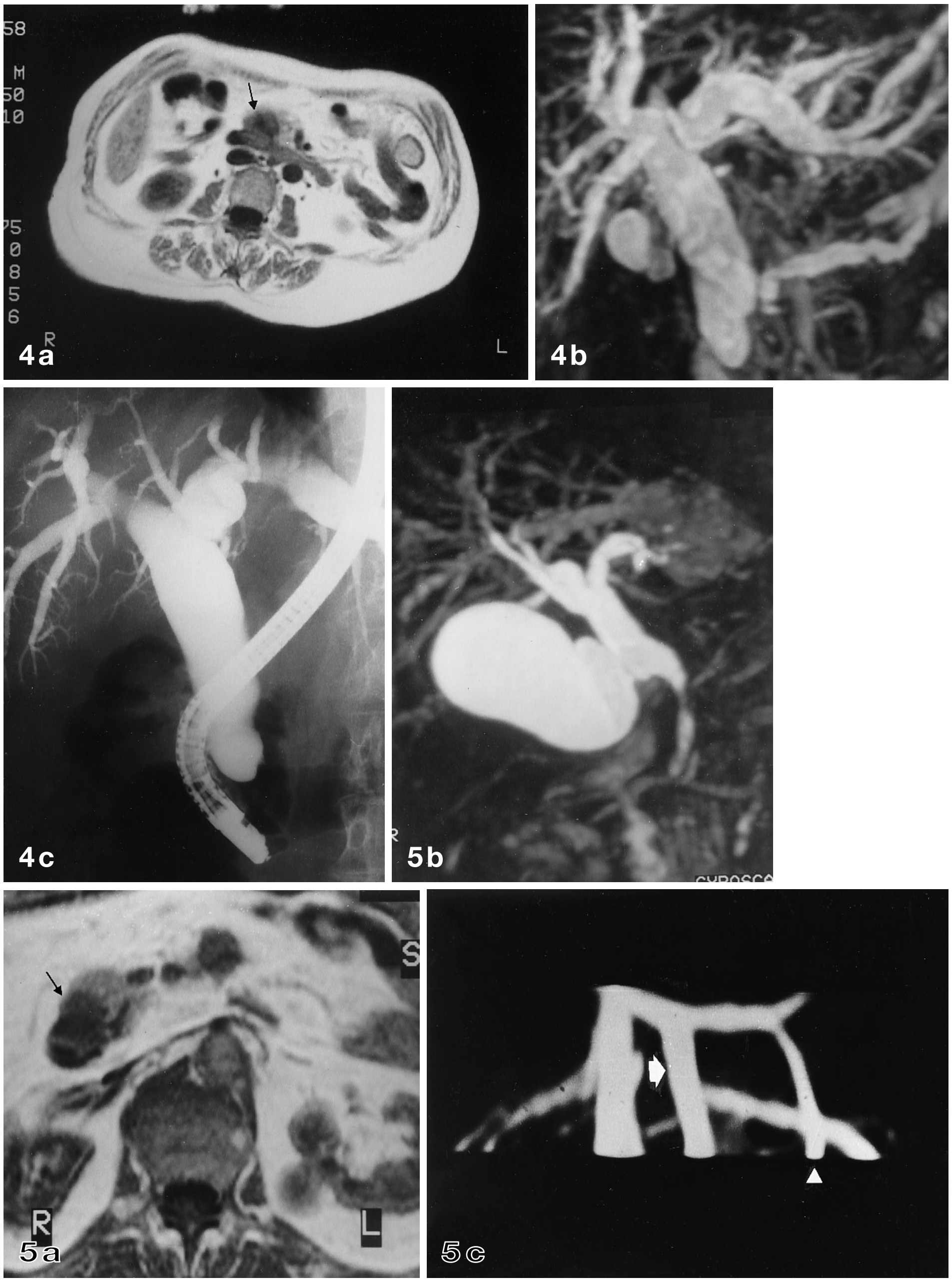


**Fig. 4 a–c.** Pancreatic head carcinoma. **a** T1-weighted SE image shows a reduction in signal intensity of the pancreatic head *(arrow)*. **b** MRCP demonstrates the marked dilatation of the intra- and extrahepatic bile ducts, similarly to ERCP, and the slightly irregular dilatation of the pancreatic duct, with a double duct sign. **c** At ERCP the Wirsung duct could not be cannulated and therefore not opacified

**Fig. 5 a–c.** Pancreatic head carcinoma. **a** Tl-weighted SE image shows the presence of a 2-cm lesion *(arrow)* adjacent to the duodenum. **b** At MRCP the intra- and extrahepatic bile ducts result dilated due to severe stricture of the main bile duct. **c** MRA of venous structures shows patency and regular caliber of the SMV *(arrow)*, splenic vein, and proximal tract of the portal vein. Note also the inferior mesenteric vein *(arrowhead)*

The margins of the dilated pancreatic duct were smooth and tubular in 7 cases, whereas they were beaded and irregular in 2 cases. In 5 of the 18 pancreatic head lesions, dilatation of the pancreatic duct was associated with atrophy of the parenchyma of the body and tail.

## Discussion

Recent studies have shown a superiority of MR over CT in the diagnosis and staging of pancreatic carcinoma, particularly with the use of newer sequences and contrast agent administration [9, 11]. In our series a routine use of fat-suppressed Tl-weighted images and techniques for artifact reduction (respiratory compensation, antiperistaltic agents, increased number of excitations) has permitted routine detection of lesions smaller than 2 cm in diameter, including 2 cases in which CT did not demonstrate any mass lesion. Our results confirm the findings of other recent studies [13, 14]. Respiratory artifact reduction can also be obtained by the use of breath-hold sequences, which appear particularly valuable at high field strength and also allow the use of intravenous contrast agent, as proposed by several authors. On medium-field-strength equipment, conventional sequences acquired with respiratory compensation provide similarly good results for lesion detection, although dynamic studies cannot be performed.

In the evaluation of pancreatic adenocarcinoma, still many different exams are generally performed to confirm the diagnosis and to determine tumor resectability;

among them ERCP and arteriography are commonly considered necessary for a complete evaluation of these patients. The ERCP technique can demonstrate the cause of the biliary obstruction, when present, and help in making a differential diagnosis based mainly on the aspect of the pancreatic and biliary ducts [2, 5]. The diagnostic accuracy of ERCP in pancreatic cancer has been reported as between 92 and 100 % [20, 21]. Recently, MRCP has become available and feasible, not only at 1.5 T, but also at medium field strength, as far as high gradient strength is available, providing excellent images of the dilated biliary tree and the Wirsung duct and consequently a further means for the diagnosis of obstructive pathologies. If ERCP is performed for diagnostic purposes only, without any need of positioning biliary drainages, MRCP can satisfactorily substitute it, with the advantage of being totally noninvasive, much shorter (4–5 min acquisition time) and less expensive. The MRCP images are comparable, and in some cases even superior, to those of ERCP [22]; MRCP always shows the dilated pancreatic duct, which at ERCP is rarely evident unless cannulated. The role of ERCP should be limited to those cases that need biliary drainage through an endoscopically placed stent. Furthermore, MRCP (demonstrating dilated saccular pancreatic secondary ducts) may increase the accuracy of MR imaging in the differentiation between pancreatic adenocarcinoma and focal chronic pancreatitis.

By far, the main index of resectability, in the absence of distant metastases, is the patency and absence of infiltration of the major extrapancreatic vessels. In fact, for most surgeons with extensive experience in pancreatic resection, invasion of the portal-mesenteric vein by cancer is an absolute contraindication to duodenopancreatectomy [2, 5, 8]. As this information is crucial, arteriography is still performed occasionally in some centers, in those patients with doubtful CT findings [23]. Apart from being invasive, arteriography lacks sensitivity (66 %), with an accuracy for predicting resectability of only 54 % [5].

The MRA technique has recently become available for noninvasive vascular imaging [11–13]. The reduction of major artifacts (pulsatility artifacts) has allowed obtainment of excellent images of venous and arterial splanchnic vessels, with good evaluation of vascular anatomy and involvement in patients with abdominal parenchymal neoplasms. Among these, pancreatic adenocarcinoma tends quite rapidly to infiltrate major extrapancreatic vessels.

After having optimized the technique of study, we decided to extensively apply MRA in the preoperative assessment of patients with pancreatic neoplasms. The use of the 3D phase contrast technique with cardiac gating allows avoidance of major artifacts, with optimal visualization of both arterial and venous structures in an acceptable acquisition time (15 min to acquire both volumes). Particularly useful are the images of the veins, in consideration of their more common involvement as compared with arteries, and their often inadequate opacification at arteriography. The evaluation of both reconstructed and source images, as well as the morphological images (both Tl- and T2-weighted), provide information on vessel anatomy and on the relationship of the tumor with the vascular wall. In particular, MRI associated with MRA sequences combines the advantages of angiography and CT. In fact, it provides angiographic images with optimal evaluation of vascular anatomy. At the same time the analysis of single axial slices allows determination of tumoral contiguity to vessels, even in cases in which no direct sign of vascular infiltration, such as encasement, stenosis, and occlusion, is evident.

A limitation of this study is that no comparison has been performed with other techniques, particularly with spiral CT, routinely used for imaging of the pancreas. At the time of the study in our institution spiral CT was not available. Furthermore, the aim of the study was to validate MRI in staging pancreatic adenocarcinoma without comparison with other modalities. Data on the accuracy of spiral CT have been recently described in the literature [13, 14].

The combination of MR imaging, MRCP, and MRA provides comprehensive information needed for the diagnosis and assessment of resectability of the disease, which otherwise can be obtained only by performing three different exams. The overall acquisition time, including conventional, cholangiographic, and angiographic MR images, never exceeded 45 min in our series, a time that is acceptable, even for oncological patients. Using a single procedure to obtain comprehensive information on lesion, vessels, and biliary tree may reduce the expenses and the length of hospital stay, with the additional attractive feature of being completely noninvasive.

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# Book review

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**Kimme-Smith C., Bassett L. W., Gold R. H.: Workbook for Quality Mammography, 2nd edn.** London: Williams & Wilkins, 1997, 240 pages, 100 figures, ISBN 0-683-04612-8, £ 44.00.

This book, dealing with aspects of quality mammography, is written by three authors and comprises 13 chapters. The book is not a diagnostic teaching tool but a manual to help the reader to meet the required standards. The layout is attractive, with each chapter dealing with a specific aspect of quality mammography and including images and comments. Questions and answers at the end of each chapter and at the end of the book are set up in a good pedagogic way.

It is well known that mammography differs substantially from the other radiological examinations. The outcome of a mammography examination is dependent not only on the skills of the radiologist reading the mammograms but to a great extent on the quality of the mammograms. To achieve good-quality mammograms the whole chain of events that lead to the final product, i. e. a mammogram, has to be carefully controlled and optimised. It is not always easy to find solutions to problems related to questionable images if the problems cannot be identified. In this respect this book is an excellent guide to both inexperienced and experienced personnel working with mammography that will help then identify and find solutions to problems encountered in daily practice.

The book points out that while the Mammography Quality Standards Act (MQSA) and the American College of Radiology demand good-quality images, one seldom finds advice on how to look for and solve problems related to these demands. Therefore in the opening pages the authors have covered basic theoretical aspects such as contrast, spatial resolution, anodes, filters, focal spots and radiation dose. At this point the reader might find a need for more details that are not presented in the first chapter. Instead, the abovementioned aspects are dealt with in detail later on in separate chapters, each chapter dealing with one quality assurance aspect. For the reader who wishes to jump to a particular problem the authors suggest reading specific chapters, and this recommendation is available in the first chapter. In addition the authors have taken the trouble to recommend relevant literature at the end of each chapter.

Each chapter starts with a concise presentation of the features pertaining to its title. Thereafter suboptimal images accompanied by comments to assist a reader in finding and/or observing the faults that can be corrected are presented. Side by side with these suboptimal images are better or adequate images of the same mammograms in order to highlight the differences and attainable corrections. There are many artefacts that may disturb a final image. Some of these are illustrated so that one can try to analyse and deal with them appropriately without the need for time-consuming fault detection activities or expensive consultants.

Film processing is one of the extremely sensitive aspects of the production of a mammogram. The authors try to explain the chemistry and various factors that affect the chemical processes. The pathway of a film inside a film processor, be it a daylight loader or a conventional dark room loader, is illustrated. Sensitive daily controls are recommended with appropriate instruments: e. g. 'the thermostat should be checked against an independently calibrated metal or digital medical thermometer (never a mercury thermometer!)'. Also maintenance aspects are presented, since negligence in maintenance will undoubtedly lead to a standstill that will affect the mammography services.

At the end of each chapter there are a few questions and answers that further highlight important features of that chapter. At the end of the book there is a chance to review one's newly acquired knowledge by means of a multiple choice questionnaire comprising 50 questions, each with four or five alternative answers. The correct answers and cross-references to appropriate chapters are given after the questions.

The book is a workbook to be readily available in a mammography suite and it is not bound in a hard cover but as a working manual with good paper and acceptable image quality. The purpose of the 16 blank pages at the end of the book could be questioned. The book should be available in every mammography suite that wants to provide state-of-the-art mammography. The targeted readers should be radiologists and radiographers, but even physicists and other personnel involved in breast imaging should find it an asset.

E. Azavedo, Stockholm