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State of the art MRI and CT imaging of the liver: primary and metastatic neoplasms

S. Thomas, P.R. Ros[1]

Recent advances in hepatic imaging techniques have drawn particular attention to detection and characterization of liver lesions. Optimal imaging diagnosis of hepatic lesions surely depends on the understanding of currently available modalities and its tailored application in consideration of clinical information.

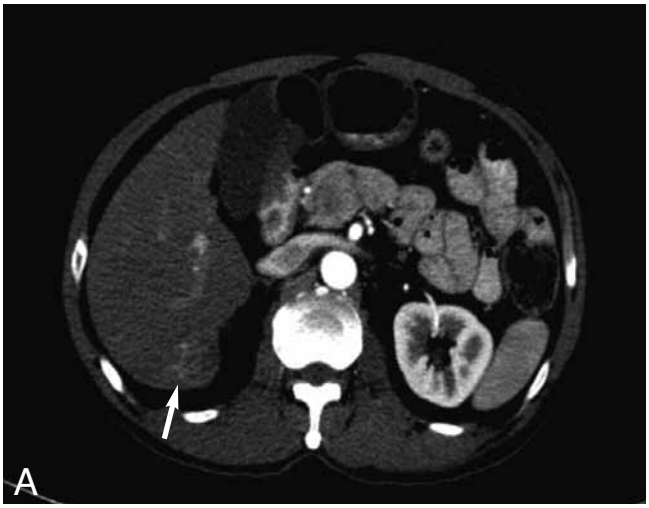
At present CT is the most frequently used modality for imaging the liver. The development of multi detector computed tomography (MDCT), which allows scanning the liver at multiple phases of contrast enhancement, may improve the diagnostic accuracy of hepatic lesions. Some of the recent advances in MDCT technology include three-dimensional (3D) imaging software and volumetric analysis. Dual energy technology attempts to reduce radiation dose by eliminating the non-enhanced phase of imaging. The advantages of MRI as a preoperative imaging modality for liver masses are many fold. MRI with intravenous contrast can be used in patients with allergy to iodine based contrast. The emergence of liver specific MR contrast agents has added a new dimension by effectively discriminating between lesions of hepatocellular origin such as hepatocellular carcinoma (HCC) and focal nodular hyperplasia (FNH) from non-hepatocellular etiology such as metastases and cholangiocarcinoma.

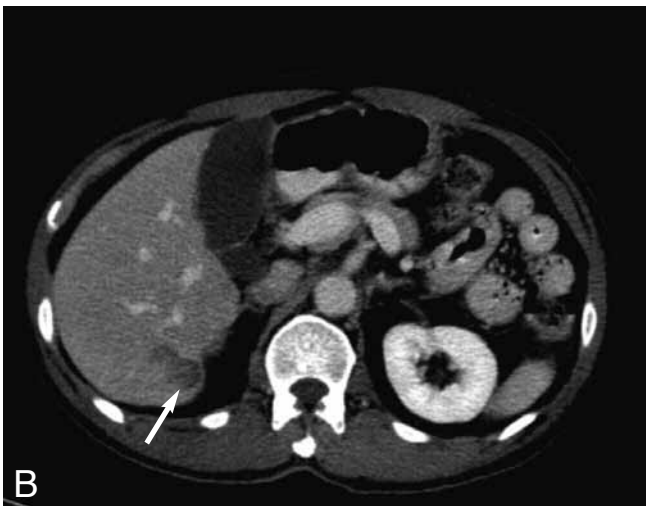
CT of the liver

Non contrast CT imaging (NECT) alone is not routinely performed in clinical practice due to the low inherent attenuation difference between the normal liver parenchyma and lesions. Single phase imaging during the portal venous phase of enhancement is desirable, because ~ 75% of hepatic blood flow is supplied by the portal venous system, and hence better delineation of common hypovascular hepatic focal lesions, such as majority of metastases and cysts against enhanced hepatic background is possible.

A triple pass technique can be performed only on MDCT scanner (Fig. 1). The first imaging pass provides a true (or early) arterial phase and enhancement of hypervascular focal lesions. The second pass corresponds in timing to the initial opacification of the portal venous system and is called late arterial or 'parenchyma phase'. For both primary and metastatic hypervascular neoplasms such as HCC, islet cell tumor, carcinoid and sarcoma, approximately 30% additional lesions are detectable on the late arterial dominant phase than in the delayed hepatic venous phase of enhancement. In the third imaging pass also known as hepatic venous phase, the hepatic veins are enhanced and the enhancement of background hepatic parenchyma is maximized. Acquisition timing corresponds to what has been conventionally labeled as the 'portal venous phase'. Tumors, like HCC which are hyperattenuating on the arterial phase and parenchyma phase may become isoattenuating or hypoattenuating on the hepatic venous phase (1, 2).

The appropriate scan delay for helical CT depends upon the contrast medium injection protocol used. The timing of peak aortic and hepatic contrast enhancement depends primarily on the injection duration. Rapid or low-volume (shorter duration) injections produce earlier peak enhancement, whereas slow or high-vol-





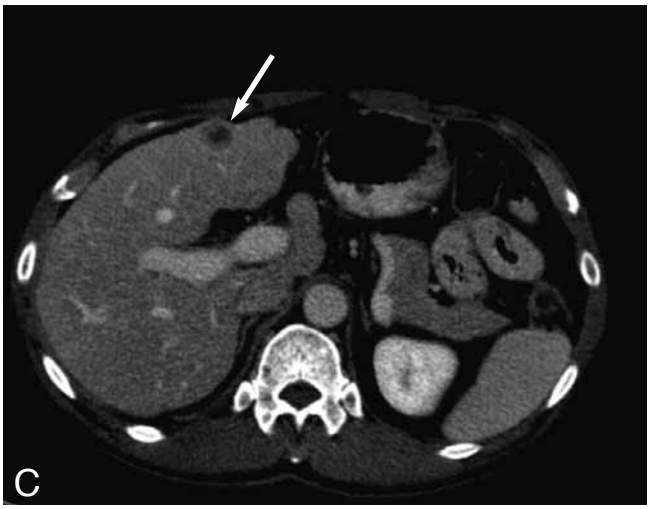


Fig. 1. — Early arterial (A), venous phase (B), and delayed phase (C) images demonstrate a right lobe HCC (arrow on A,B). An additional lesion is seen as a hypodense lesion against an enhanced hepatic background, consistent with multifocal HCC in a non-cirrhotic liver (arrow on C).

Table I. — MDCT Protocol for liver in our practice.

Protocol	Indications	oral	IV rate/vol	Delay (sec)	Area	Collimation (mm)	Feed (mm)	Reconstruction (thk./int.)
Basic liver	Metastatic work up	C+	4/100	70	liver A/P	3.0	15	5/5
Hypervascular liver lesion	Hypervascular, metastasis, HCC, FNH, hemangioma	H2O	4/100	20 40 70	liver liver A/P	3.0	15	5/3

C+: 2.1% dilution of barium sulfate, H2O: water, A/P: abdomen to pelvis, thk: Thickness, int.: interval.

ume (longer duration) injections result in later peak enhancement (3-5).

A typical MDCT protocol includes bolus injection for multipass imaging of 4cc/sec for 25 seconds of 60% nonionic contrast material (30 g iodine). Time to aortic peak is determined from the resultant time attenuation curve and is used as the injection to scan delay for multiphase imaging. Two passes during the arterial phase can be obtained; true arterial phase (10 to 20 seconds after contrast arrives in the abdominal aorta), and parenchyma arterial phase (30 to 40 seconds after the initiation of contrast). A third imaging pass beginning 60 to 70 seconds after the beginning of injection and employing a table speed of 15 mm per second corresponds in timing to the conventional "portal venous phase" to evaluate the remainder of the abdomen (Table I).

Clinical utility

The shorter acquisition time of MDCT provides intense enhancement with intravascular contrast material and improved separation between the phases of contrast enhancement. There is less respiratory misregistration and improved z axis resolution. CT of the liver can be performed routinely with very thin collimation, yielding greater conspicuity of small lesions and improved lesion detection. Use of 2.5-mm-thick sections resulted in a 46% increase in detection rate versus use of 10.0-mm-thick sections and an 18% increase versus use of 5-mm-thick sections (6).

Multiplanar reconstruction algorithm allows complete delineation of normal arterial anatomy and vascular variants, which can be seen in up to 45% of patients (Fig. 2).

In addition, specific arterial etiology such as aneurysm and pseudoaneurysm of the hepatic artery and hepatic infarctions can also be evaluated.

MDCT with dual energy capabilities have been introduced recently. The most current dual-energy technique is based on dual detector capability. There are two layers of detectors on the CT, the upper layer primarily absorbs the lower X-ray energy spectrum, and the lower detector layer absorbs the remainder of the spectrum, mainly in the higher energy range. Data from each layer, corresponding to lower- and higher energies, are independently reconstructed. The ability to process virtual nonenhanced (VNE) images, by subtracting the iodine content of contrast-enhanced CT images using image post-processing techniques, may obviate the need for the nonenhanced imaging phase in multiphase studies. The benefits include shorter scan time and reduced radiation. VNE images can be useful in various clinical settings, such as CT urogram (7, 8).

MRI

MRI allows better detection and characterization of diffuse and focal hepatic parenchymal lesions and the biliary system. Newer contrast agents have provided a new dimension to imaging of the liver.

Technique

MRI of the liver consists of the following elements:

1) Torso coil (phased-array multicoil to improve signal-to-noise ratio (SNR)).
2) Image-intensity correction software to reduce image nonuniformity.
3) "Ghost" control techniques to reduce fat or respiratory motion artifact.
4) T1 and T2 weighted images and contrast imaging.
5) New techniques such as Diffusion weighted imaging (DWI), MR Elastography, MR perfusion imaging, based on availability and clinical relevance.

Tl-weighted imaging

1) Conventional spin-echo pulse sequence (CSE) is used in patients incapable of holding their respiration for breath-hold gradient-echo pulse sequences. Due to prolonged acquisition time, motion artifacts are common.
2) Gradient-echo pulse sequence (GRE) is more common and multi-section spoiled gradient-echo pulse sequences image the entire liver in one or two breath-holds with higher contrast and SNR.
3) Chemical shift imaging uses two T1-weighted gradient-echo pulse sequences with identical parameters except for TE, to produce in-phase and opposed-phase images, thereby aids in the diagnosis of steatosis and detection of microscopic in hepatic neoplasms.

T2-weighted imaging

1) Conventional T2 spin-echo sequences have been practically abandoned due to their long acquisition times (up to 20 minutes) resulting in cardiac flow and particularly respiratory artifacts.

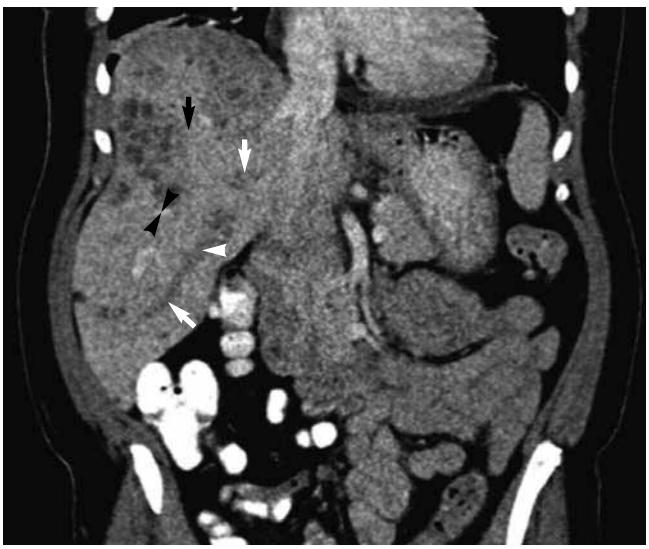


Fig. 2. — Coronal reformatted image demonstrates thrombosis of the right and left branches of portal vein (white arrows) with multiple rim enhancing abscesses (black arrows).

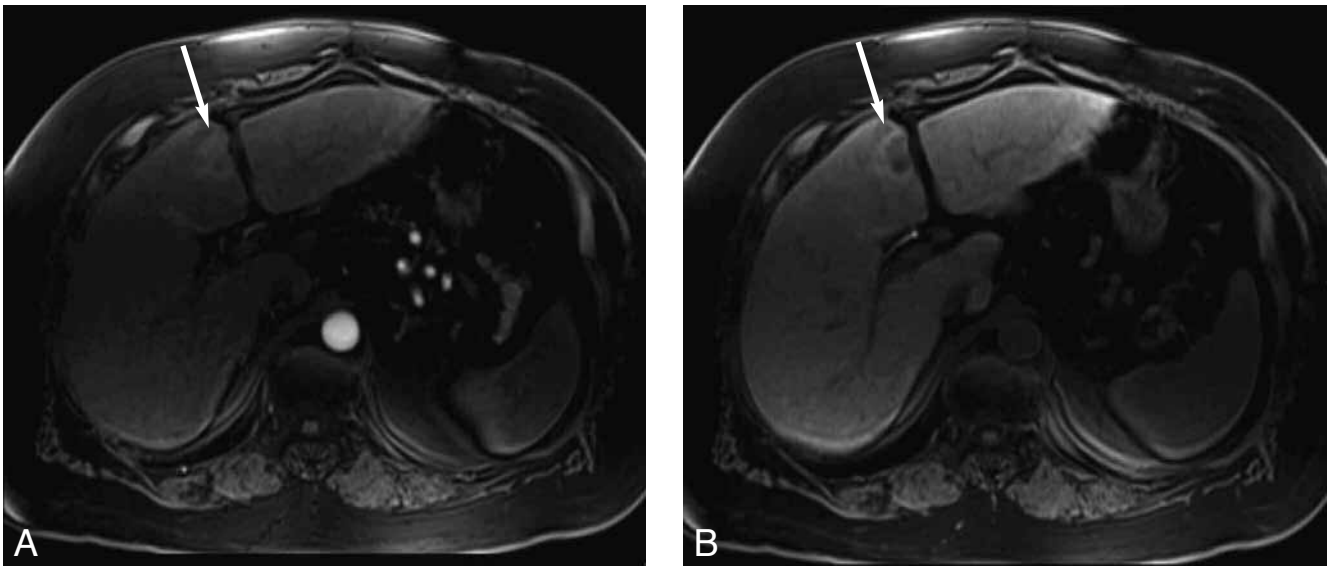


Fig. 3. — MRI of the liver during arterial phase (20 sec) and delayed (15 min) after IV administration of Eovist. The enhancing lesion appears hypointense on the delayed phase, consistent with metastases from thyroid cancer.

2) Fast spin-echo (FSE)
   a. Rapid acquisition with relaxation enhancement (RARE) uses a single excitation pulse followed by a long train of spin-echoes with a different amplitude phase encoding gradient applied for each spin-echo.
   b. Hybrid RARE. Hybrid RARE uses multiple excitation pulses, with each excitation pulse followed by two or more 180° refocusing pulses.

Fast recovery fast spin-echo (FRFSE) is a breath-hold pulse sequence that utilizes additional radiofrequency pulses after each echo-train to drive the recovery. Some breath-hold techniques such as FRFSE show lower lesion-liver contrast and low SNR, which may reduce the detection of solid liver masses requiring additional sequences.

   c. Single short hybrid RARE (SSHR) sequences are termed: 1) half Fourier acquisition single-shot turbo spin-echo (HASTE); and 2) single-shot fast spin-echo (SSFSE).

SSHR allows sub second single-slice imaging, obviating motion artifact reduction measures. While producing high quality abdominal images, the limitations include reduced contrast between solid hepatic lesions and the surrounding parenchyma. However, increasing the sampling rate with enhanced gradient field strength, a higher soft tissue contrast resolution can be achieved (9).

3) Gradient echo pulses sequences have been replaced by SSFSE and FRFSE sequences.

4) Echo-planar Imaging (EPI)

It uses ultra fast T2-weighting which requires enhanced gradients with high bandwidths and good fat suppression due to marked chemical shift artifacts. EPI allows diffusion images that can be used to characterize hepatic masses.

Contrast agents

1. Gadolinium based extracellular contrast (Magnevist, Optimark, Omniscan, ProHance).
2. Currently, in USA, there are two FDA-approved liver-specific MRI contrasts: gadoxetate (Eovist) and gadobenate dimeglumine (MultiHance).

Extracellular agents (Gadolinium DTPA)

After intravenous injection, gadolinium chelate rapidly distribute in the interstitial spaces of the body. In the liver, this happens both in the normal parenchyma and in tumors, but at different rates, resulting in tumor-liver contrast which lasts for a short period of time. Clinically, this implies the use of rapid image acquisition techniques (gradient echo sequences) and a bolus injection. Some patients, who receive GBCAs, appear to be at an increased risk for developing a serious systemic fibrosing disease, Nephrogenic Systemic Fibrosis (NSF). The patients at risk are those with severe renal (kidney) insufficiency (glomerular filtration rate < 30 ml /min/1.73 m^2). NSF causes fibrosis of the skin and connective tissues throughout the body that limits joint mobility. NSF can progress with time and can even cause death. In November 2009, the World Health Organization issued a restriction on use of some GBCA, stating that High-risk gadolinium-containing contrast agents (Optimark, Omniscan, Magnevist) are contraindicated in patients with severe kidney problems, in patients who are scheduled for or have recently received a liver transplant, and in newborn babies up to four weeks of age.

Iron oxide based particles

Superparamagnetic iron oxides (SPIO) and Ultra small super paramagnetic iron oxide (USPIO) are nanoparticles composed of a magnetically active crystalline iron core (magnetic) surrounded by a dextran or starch coating. Because of its long residence in the vascular system, USPIO is considered a blood-pool agent. These reduce the T2 signals of absorbing tissue. Many of the agents, which were previously approved by the FDA including Ferumoxides (Feridex), Sinerem (Combidex), and Resovist (Cliavist), have been taken off the US market.

Hepato-biliary agents

There are two different types of hepato-biliary agents: gadolinium-based and manganese-based.

The gadolinium based agents are often called bimodal contrast agents since they demonstrate both hepatocyte and perfusion imaging properties. These include gadoxetate (Eovist or Primovist, also known as Gd-EOB-DTPA, Bayer) and gadobenate dimeglumine (MultiHance, Bracco, formerly known as Gd-BOPTA). Following a rapid bolus, dynamic T1W GRE sequences are performed similar to those performed with non specific Gadolinium based agents. The enhancement of the liver on T1-weighted images peaks at about 20 minutes for Eovist and lasts for at least 2 hours after injection of the contrast agent. Tumors of hepatocellular origin show enhancement whereas non hepatocellular tumors such as metastases appear hypo-intense on delayed images (10) (Fig. 3).

Magnafodipir trisodium (Tesla scan), withdrawn from US markets is predominantly a T1 shortening agent. The liver is enhanced onT1-weighted sequences from the end of the perfusion to 4 hours later. The free manganese released in the hepatocyte is excreted into the bile and the remnant ligand excreted through the kidneys.

Diffusion Weighted Imaging (DWI)

DWI can be easily added to the current MR I protocol. Some studies have shown higher sensitivity for hepatic lesion

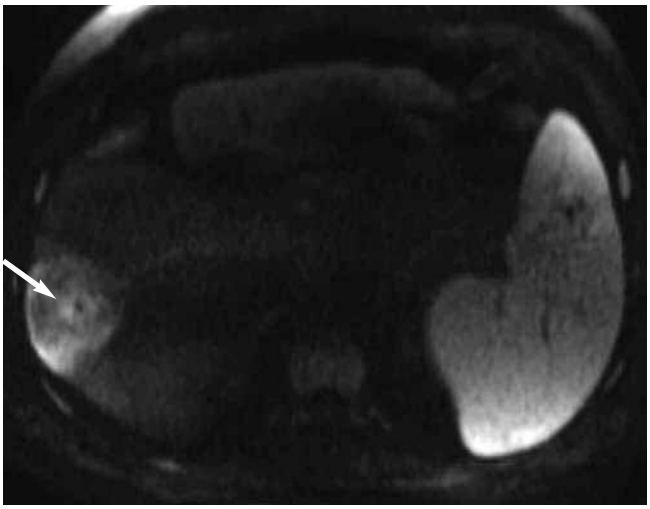


Fig. 4. — DWI demonstrates HCC in the right lobe, which appears bright against dark hepatic background.

detection when compared to T2 –weighted imaging. The liver lesions are detected using low *b* values (below 100 sec/mm^2), providing black-blood images, with high inherent tissue contrast and robust image quality. Higher *b* values (≥ 500 sec/mm^2) can assess of lesion signal intensity qualitatively. Malignant lesions typically demonstrate impeded diffusion and appear bright against a dark hepatic background (11) (Fig. 4).

MR elastography

MR Elastography is a newer technique currently used for evaluating hepatic fibrosis in cirrhosis, based on the viscoelastic properties of the tissue. Determining the viscoelastic characteristics differentiate between dysplastic nodules and HCC may prove to be value in the future (12).

MRI applications

MRI is able to characterize with higher accuracy than CT the following:

1. Hemangioma: In addition to assessing morphology and enhancement pattern like CT, MRI also provides signal intensity characteristics (Fig. 5).
2. FNH: FNH is diagnosed with MRI based not only on the enhancement pattern (including delayed enhancement of the scar), but also on signal characteristics of the tumor and scar (bright in T2) (Fig. 6).
3. Fat containing tumors (hepatocellular adenoma, hepatocellular carcinoma): Using chemical shift imaging MR is able to prove fat in hepatocellular neoplasms with higher sensitivity than CT.
4. Cysts: Hepatic cysts are confidently diagnosed with MRI even if they are sub-centimeter in size, based upon its very high signal intensity and lack of enhancement.
5. Hemorrhage in tumors: The visualization of hemosiderin rings allows characterizing internal hemorrhage within neoplasms.

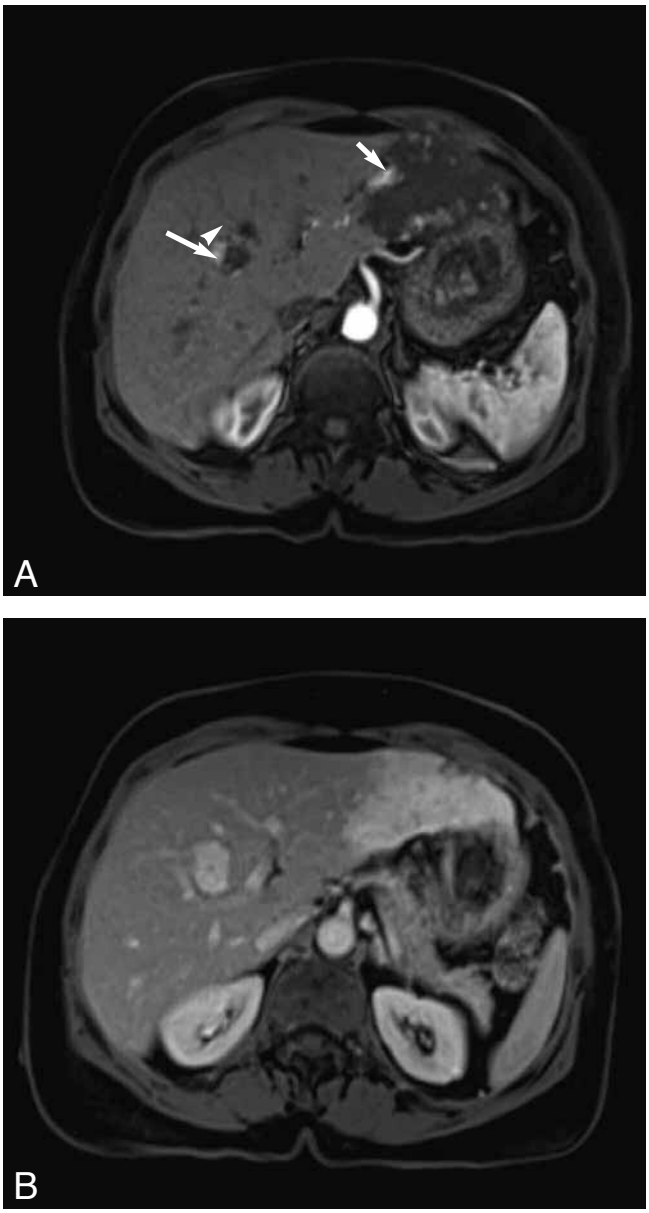


Fig. 5. — MRI of the liver with a (arterial -15 sec) and b delayed (2 min) phases depicts early peripheral nodular enhancement of two Hemangioma with delayed centripetal filling in.

6. Benign versus Malignant Hepatocellular nodules: In the setting of cirrhosis, MR is able to characterize benign (macro regenerative and dysplastic) nodules from nodules of hepatocellular carcinoma. This is based both on enhancement criteria (arterial in malignant nodules and portal in benign nodules) as well as iron byproducts in benign nodules.
7. Metastases: detection of metastases with the use of gadolinium or specific contrast agents has been proven to be higher with MRI than with intravenously enhanced CT. MR with liver specific contrast agents is considered the imagery method of choice pre resection of liver metastases, having rendered CT arterial portography obsolete.

PET/CT and MRI/PET

Positron emission tomography (PET)/CT is a functional imaging modality that has proven useful as a diagnostic tool for staging of a wide variety of cancers. Tumor cells demonstrate increased glucose uptake mediated by glucose transporters (GLUT) and accelerated glycolysis leading to tumor specific high intracellular accumulation of the glucose analog fluorodeoxyglucose (^{18}F-FDG). While PET/CT has demonstrated immense benefit in staging extra hepatic disease in colorectal cancer staging, it role in initial staging and follow up of hepatic metastases is limited. Moreover, the sensitivity of PET in detecting metastases decreases considerably following neoadjuvant chemotherapy (13, 14).

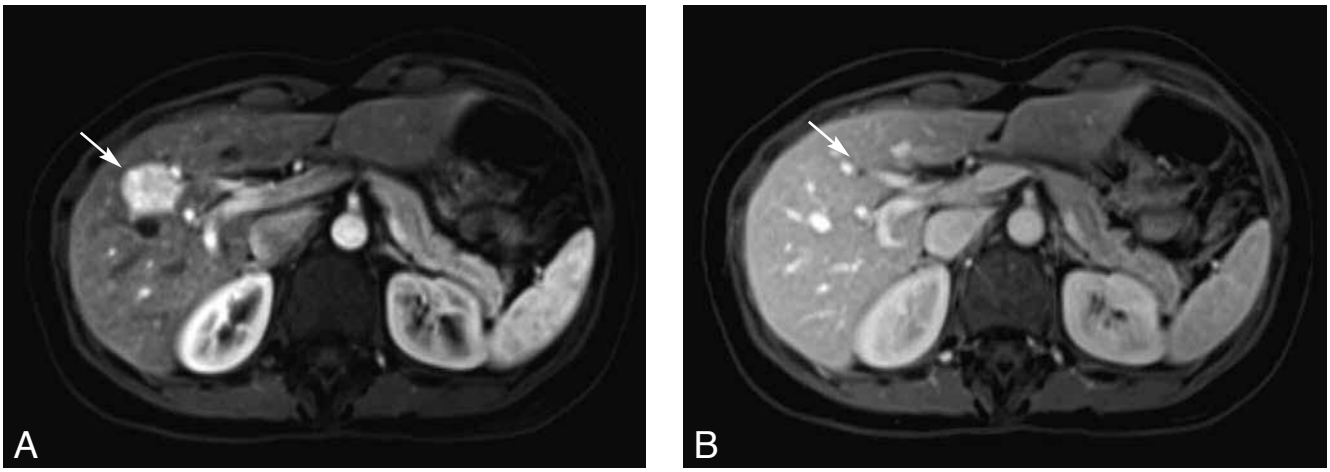


Fig. 6. — Post gadolinium fat suppressed arterial phase T1W I (A) demonstrates a intensely enhancing lesion in segment 5 which becomes isointense to hepatic parenchyma on portal venous phase (B), typical for FNH.

PET/CT has limited role in imaging HCC or other primary liver tumors except lymphoma, but our recent experience has demonstrated that PET maybe helpful in detecting extra hepatic spread of HCC. MRI/PET, with superior imaging MRI characterization of liver lesions, may prove to be beneficial in future in assessing tumor recurrence or residual tumor in post-therapy patients.

Conclusion

Both CT and MRI with continuously evolving technologies are effective in imaging of the liver. MRI allows better characterization of liver lesions, but is expensive as a screening tool. The choice of imaging study should be determined by the clinical indication, with consideration of availability, technical and clinical expertise, cost, and patient tolerance.

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1. Department of Radiology, University Hospitals Case Medical Center, Case Western Reserve University, Cleveland, OH, USA.

Hepatocellular carcinoma: the multi-step process

C. Bartolozzi[1]

The recent availability of different imaging modalities has improved the investigation of the processes taking place during the carcinogenetic pathway towards dysplasia and full malignancy, represented by the alteration of lesion vascular supply (progressive capillarization of the sinusoids and increasing number of muscularized, unpaired arterioles); and to the progressive histological changes (loss of biliary polarization of the hepatocytes and derangement of the microscopic secretory structure) (1).

Imaging cirrhotic patients still remains a challenging issue, especially when a differential diagnosis between pre-neoplastic hepatocellular lesions, such as dysplastic nodules (DNs), and early neoplastic lesions, is requested. Actually, vascular supply to the lesion represents the key pathologic factors for differential diagnosis of nodules in cirrhosis, that can be evaluated by dynamic imaging studies; particularly, changes in lesions' vascular supply, such as the development of new arterial vessels, termed nontriadal arteries, suggest lesions' diagnosis.

If ultrasound (US) examination still represents the first diagnostic approach in the follow-up of cirrhosis, nowadays nodules characterization is demanded to contrast enhanced Multidetector

Computed Tomography (CT) or Magnetic Resonance (MR) (2).

At dynamic studies performed with both techniques, typical HCC shows a clear-cut enhancement on the arterial phase and rapid wash-out on subsequent phases (Fig. 1), while preneoplastic nodules usually have no specific features, because of different intranodular vascular supply. In doubtful cases, MR study, performed with hepatobiliary contrast agents, can furnish an insight on the so called "grey area", in which significant histological changes are already present without an evident arterial supply of the nodule (Fig. 2) (3). Contrast behaviour of HCC after hepatobiliary agents is strictly related to tumor degree of differentiation: whereas moderately or poorly differentiated lesions fail to take up hepatobiliary agents, appearing as hypointense on T1-w.i, well-differentiated tumor may appear as hyperintense, as a result of the uptake and trapping of the agent within the lesion.

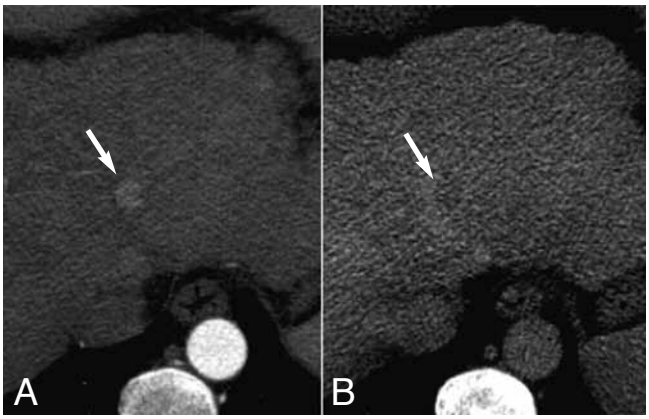

Fig. 1. — On A, a clear cut enhancement of a small nodule within segment IV is appreciable, while on figure B, the nodule shows as hypodense. On the basis of these typical enhancement features, a diagnosis of HCC can be performed.

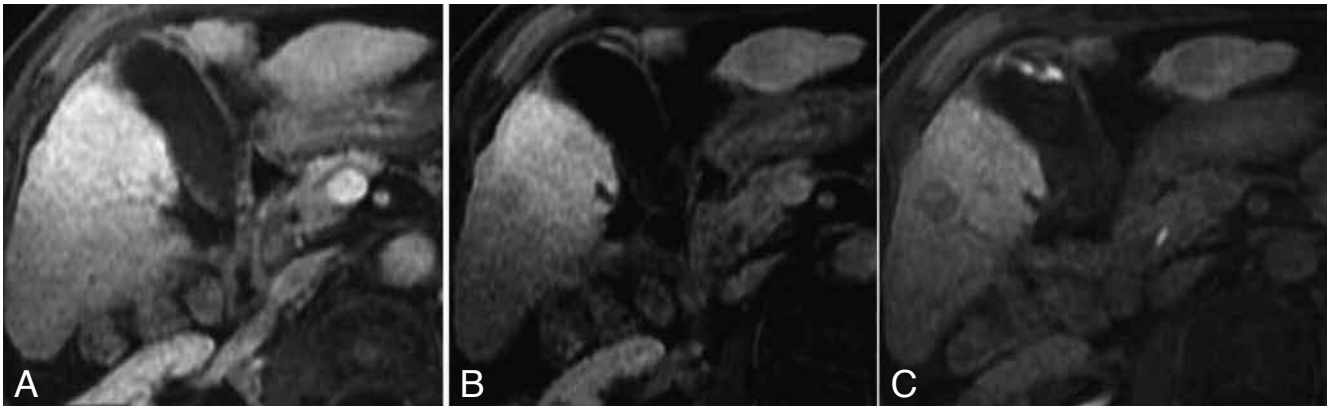

Fig. 2. — Man with HCV related cirrhosis. On segment VI, no nodules are clearly appreciable on the arterial phase (A), while on late dynamic and hepatobiliary phases (respectively B and C), a hypointense nodule is appreciable. A similar nodule is appreciable on segment III. Despite the lack of enhancement on arterial phase, the wash-out on the late phase and the hypointensity on hepatobiliary phase suggest premalignancy of nodules.

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1. Diagnostic and Interventional Radiology, University of Pisa, Pisa, Italy.

Body MRI: fast, efficient, and comprehensive

R.C. Semelka, B.S. Kim[1,2]

The use of fast scanning techniques allows for consistent high image quality and good conspicuity of disease with a decrease of imaging times. Examination time is critical because longer MRI studies may result in worsening of imaging quality due to motion that tends to progress through the course of the study from patient exhaustion. The inability of noncooperative patients to hold their breath impairs the image quality substantially on abdominal MRI. Therefore, it is useful to separate protocols are required for noncooperative patients from a standard cooperative protocol.

Cooperative protocol

T1-weighted sequences

In-phase 2D spoiled gradient echo (SGE) has become a routine part of every liver MR imaging for investigating disease of the abdomen. This sequence is primarily used to know abnormally increased fluid content, presence of subacute blood or concentrated protein, and presence of fat. Out-of-phase SGE sequence is very helpful for the recognization of diseased tissue in which fat and water protons are present within the same voxel. This sequence plays a important role in detecting the presence of fat within liver and lipid within adrenal adenoma. The value of magnetic susceptibility effects to assess the presence of iron using in- and out-of-phase image is also important.

3D GRE is suitable for dynamic contrast-enhanced MR because of thin section acquisition with larger volume coverage, and excellent inherent fat suppression and sensitivity to enhanced tissues. The hepatic arterial dominant phase (HADP) is the single most important data set. Hypervascular liver tumors, especially hepatocellular carcinomas, focal nodular hyperplasia and metastases, are well

recognized as intensely enhancing lesions on HADP. The pancreas demonstrates uniform capillary blush on HADP, which render it markedly high in signal intensity. In general, pancreatic cancer usually appears as a focal hypovascular mass. In the early hepatic venous phase (1-1.5 minute postcontrast), the hepatic parenchyma is maximally enhanced so that hypovascular lesions are more clearly identified as regions of absent or diminished enhancement. Interstitial phase (2-4 minute postcontrast) are helpful to recognize critical late enhancement features such as washout and delayed capsular enhancement with hepatocellular carcinoma and progressive enhancement with mass-forming intrahepatic cholangiocarcinoma.

T2-weighted sequences

The important information that Single-Shot Echo-Train Spin-Echo (SS-ETSE) Sequence provide includes the presence of abnormal increased fluid content in diseased tissue and fluid containing tumors, the presence of chronic fibrotic tissue, the presence of low fluid content lesions, the presence of iron deposition, and the presence of lymph nodes in porta hepatis. Acquiring SS-ETSE sequences both without and with fat-suppression also permit evaluating for fat using T2-weighted sequences.

Motion-resistant protocol

T1-weighted sequences

2D Magnetization-Prepared Rapid-Acquisition Gradient Echo (MP-RAGE) Sequence, for example Turbo-fast low angle shot (FLASH), which operates as a single shot technique, can generate T1-weighted images that are resistant to deterioration from respiratory motion. This sequence can be used to obtain motion-free and moderate quality images with acquisition times as short as 1 second. The MP-RAGE in/out-of-phase images are able to demonstrate the presence of fat, which is necessary to evaluate the liver and adrenal masses in patients who cannot cooperate with 10-20 second breath holds. Water excitation (WE) MP-RAGE should be used to provide fat-attenuated contrast-enhanced T1-weighted images as excitation spoiling fat-attenuation does not work with MP-RAGE due to the length of this preparatory scheme. WE-MP-RAGE at 3T can achieve better image quality and fat-attenuation than 1.5T.

Free-breathing T1 fat-suppressed 3D radial gradient echo sequences provide motion resistant data acquisition. In part this reflect that radial acquisition technique (projection reconstruction) has higher sampling density for central K-space. This technique results in excellent motion control images in noncooperative patients, especially children.

T2-weighted sequences

The SS-ETSE sequence is a breathing-independent technique which is useful both in standard and motion resistant protocols. An additional advantage of this sequence is resistance to susceptibility artifact. As a result, the bowel wall can be clearly demonstrated and susceptibility artifact from metallic devices is minimal. In these settings it is however important to not use fat suppression.

Conclusion

Separation of protocols for cooperative and cooperation-challenged patients is necessary. Fast studies render MRI more cost effective in a progressively more cost contained environment. The clinical MRI study should be performed in a fast, efficient, and comprehensive fashion, and focus on the benefit to the patient and emphasize clinically essential strategies.

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1. Department of Radiology, University of North Carolina at Chapel Hill, Chapel Hill, USA, 2. Department of Diagnostic Radiology, Jeju National University School of Medicine, Jeju, Korea.

Diffusion imaging of the liver

F. Deckers[1]

Magnetic resonace imaging of the liver has been advocated as a highly accurate technique for diagnosing liver lesions since several years. Driven by technological advances, diffusion weighted (DW) sequences for the abdomen have become available on most commercial imagers in recent years.

In higly cellular tissues (eg. neoplasm) the narrowing of interstitial space and the high density of cell membranes restrict the free motion of water molecules. This phenomenon generates the contrast between tissues in DW imaging. Because it reflects underlying cellular density and integrity of cell membranes DW imaging of the liver opens up interesting opportunities for evaluating the effects of antitumoral treatment. DW imaging can be easily implemented in clinical setting as an added sequence in existing protocols. All these factors have contributed to the fast adoption of DW imaging of the liver in the radiologic community.

Diffusion imaging provides both qualitative and quantitative assessment of lesions. ADC maps are automatically generated by most modern MR units and provide a quantitative insight in the degree of diffusion restriction. As most malignant lesions demonstrate impeded diffusion they will show up as areas of lower ADC values. Several authors have described cutoffs for detection of malignant liver lesions (1). However there is important overlap in ADC value between benign and malignant lesions. Furthermore, ADC measurements in the liver suffer a lower reproducibility. As opposed to benign lesions, most malignant lesions will manifest a high residual signal intensity compared with the background liver on images with high b values. By visually comparing the contrast between the liver and the lesion at different b-values a qualitative interpretation of lesions can be performed. Using this qualitative visual approach excellent specificity and sensitivity are obtained (2). Not all lesions that display restricted diffusion are malignant however and DW images should always be interpreted as part of a complete liver MR protocol, inluding conventional T1 and T2 images. For detecting liver lesions DW imaging generates very high sensitivity and specificity, particularly in detecting small metastasis (2, 3). In the investigation of liver metastasis DWI can be used as an alternative to gadolinium enhanced imaging in patients with impaired renal function or who have other contraindications for injection of gadolinium chelates.

When applied to molecular-targeted therapies anatomic measurements can be misleading in the evaluation of response in oncologic patients. In these treatments response is often not reflected in a change in diameter. DW MR of the liver could be an interesting parameter for the follow up of these patients (4).

Lower ADC values have been observed in cirrhotic liver compared with normal hepatic tissue. However, an important overlap exists between measured ADC values in different stages of fibrosis (5).

Reflecting tissue cellularity, DW MR of the liver holds promise as a biomarker in oncologic imaging. Furthermore it has proven to be an excellent technique for the diagnosis of liver lesions. Therefore this attractive technique has become a part of routine liver imaging protocols.

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1. Department of Radiology, GZA Sint-Augustinus Hospital, Wilrijk, Belgium.

Hepatic tumor response after interventional treatment

C. Bartolozzi[1]

Nonsurgical imaging-guided interventional therapies are actually largely applied for the treatment of hepatocellular carcinoma (HCC). Imaging techniques play a key role in all the subsequent steps of ablation treatments, from pre-treatment assessment, passing through the evaluation of technical success, up to the assessment of tumor response to therapy (1).

Complete or partial response, as well as progression of disease after interventional treatments have been re-defined depending on the percentage of enhancing areas appreciable within the treated lesions at the evaluation control (2).

Regarding percutaneous ablation therapies, Contrast-enhanced US (CEUS) is routinely performed during peri-procedural evaluations, allowing both to target areas of residual viable tumor, as well as to monitor first tissue changes depending on the applied ablation modality (Fig. 1). Anyway, dynamic multidetector CT and MR imaging are still considered as the reference techniques to assess technical effectiveness of treatments (3).

On both dynamic imaging studies, residual viable HCC is reliably depicted as it stands out in the arterial phase images against the unenhanced areas of coagu-

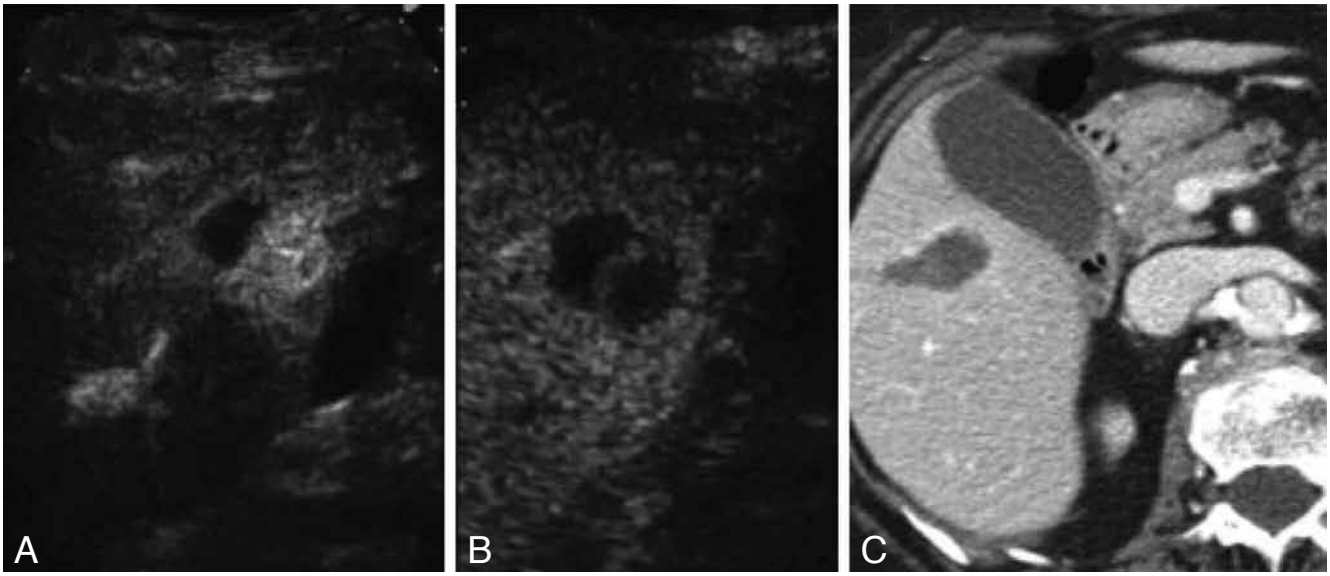

Fig. 1. — Periprocedural evaluation with CEUS a hour after laser ablation assesses the presence of neoplastic persistence within the target nodule (A). The evaluation after a second procedure of laser ablation, performed within two hours shows a complete ablation of the residual tumor (B). Complete response has been confirmed at CT examination after 1 month (C).

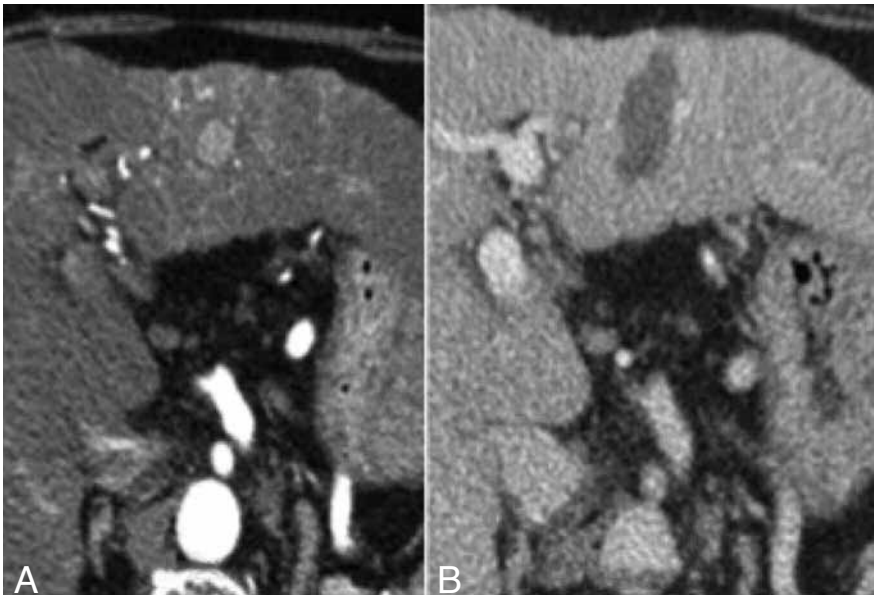

Fig. 2. — CT examination berore treatment did assess the presence of a small HCC within segment III (A). CT evaluation 1 month after microwave ablation did show a complete ablation area, larger that target lesion (B), suggesting complete response to treatment.

lation necrosis, while in cases of complete response, no tumoral enhancement should be appreciable (Fig. 2).

Moreover, MR performed with hepatospecific agents can furnish more information about post-ablation tissue components, revealing useful in doubtful cases, in differentiating periablation hyperemia or artero-venous shunts/thrombosis, from tumoral persistence or recurrence (3).

MDCT and MR must be moreover considered as the reference methods for the evaluation of chemo and radio embolization treatments, usually performed in large, otherwise untreatable HCCs, as well as in patients on waiting list for transplantation as a down-staging approach.

If MDCT can furnish an accurate evaluation of the homogenous distribution of Lipiodol as well as the progressive shrinkage of successfully treated lesions, dynamic MRI study has revealed very accurate in the assessment of residual enhancing viable tumor, thanks to the avoidance of iodinate oil artefacts that largely affect MDCT images (4).

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1. Diagnostic and Interventional Radiology, University of Pisa, Pisa, Italy.

CT/MRI imaging of benign liver tumors

B. Op de Beeck[1]

Today, most benign liver lesions are incidentally diagnosed using ultrasound (US), MDCT, and MRI. Most commonly, a liver tumor will be detected on US because this is the first line imaging examination for the liver. For characterization MDCT and/or MRI will be performed with a higher accuracy for MRI. Detection and characterization of liver lesions with MDCT is based on differences in density (attenuation), mainly during the different phases of dynamic imaging following a rapid bolus infusion of contrast material. Late arterial phase (35-40 sec) is the best for hypervascular tumors (FNH, HCA, small hemangiomas) and portal venous (parenchymal) phase (70 sec) for hypovascular lesions should be obtained in almost all abdominal CT scans. Equilibrium (delayed) phase (2-10 min) can sometimes be of help for characterizing hemangiomas. Detection and characterization with MRI is mainly based on intensity differences on T1- and T2-weighted imaging, DWI and ADC values, vascular enhanced imaging with extracellular gadolinium agents, and eventually reticulo-endothelial enhanced with SPIO or hepatocyte enhanced with Gd-BOPTA or Gd-EOB-DTPA. The use of US or CT-guided biopsy for characterizing benign liver lesions is in the last decade dramatically decreased due to the better non-invasive characterization of these lesions, especially with state-of-the-art MR imaging.

In the group of benign hepatic masses we can distinguish primary benign liver lesions, secondary benign liver lesions, and hepatic pseudolesions. The primary benign hepatic neoplasms are of hepatocellular origin (hepatocellular hyperplasia, most commonly FNH, and hepatocellular adenoma), cholangiocellular origin (hepatic cysts), or mesenchymal origin (most commonly hemangioma). The secondary benign liver lesions are mostly abscesses, and in the group of hepatic pseudolesions we are most commonly dealing with focal steatosis, a focal spared area in a fatty liver or vascular disorders.

Typical imaging findings of these benign hepatic masses will be discussed during the presentation.

1. Department of Radiology, Antwerp University Hospital, Edegem, Belgium.

Imaging of focal splenic lesions

F.M. Vanhoenacker[1,2,3], A. Snoeckx[2]

The learning objectives of this presentation are to discuss the 10 most frequent encountered focal splenic lesions in Europe and to discuss the imaging characteristics of these lesions.

The spleen is regarded as the forgotten and silent organ in the abdomen. Compared to the extensive literature on liver and pancreatic imaging, little has been written on imaging of splenic lesions. However, splenic lesions may be encountered on imaging (ultrasound and computed tomography) done for other reasons. Characterization of splenic incidentalomas may be challenging for the radiologist.

Imaging of focal splenic lesions

Haemangioma

A haemangioma is the most common benign splenic lesion. It is usually solitary, but multiple lesions may occur. The CT appearance is variable. Solid and cystic portions may be seen and the degree and pattern of enhancement may differ on CT and MRI. Rarely, central or curvilinear peripheral calcifications may be seen on CT.

Calcifications

The most frequent causes of splenic calcifications are healed postinfectious granulomas (tuberculosis or histoplasmosis) and phleboliths. Peripheral rim-like calcifications may be seen in cysts. Rare causes of calcifications include old infarcts, splenic hematoma, collagen-vascular diseases, amyloidosis, silicosis, Gamna-Gandy bodies,...

Cystic lesions

Two types of splenic cysts are distinguished along with the presence or absence of an epithelial lining, i.e. true cysts (20% of cases, true epithelial lining) and false cysts (80% of cases, with an absence of an epithelial lining usually due a posttraumatic etiology or old infarcts). The imaging appearance of both types is very similar. The clue to the correct diagnosis is the cystic content on US, CT and MRI. The signal intensity on T1-WI images may – however – be relatively high due to protein content. CT may show subtle wall calcifications (Fig. 1).

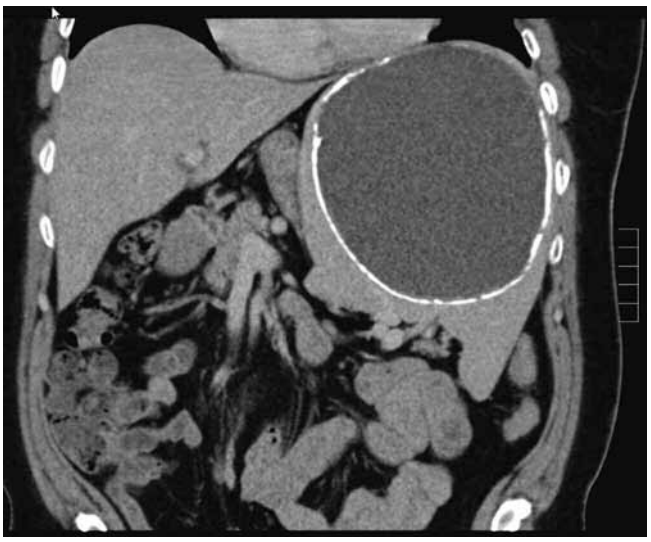

Fig. 1. — Huge splenic cyst with typical wall calcification

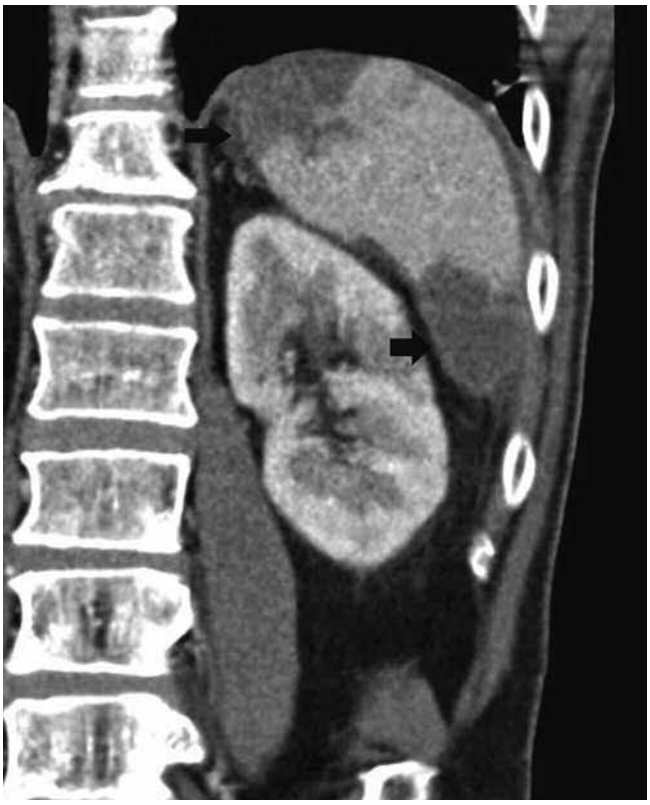

Fig. 2. — Splenic infarcts. Wedge-shaped areas of non enhancement on a contrast enhanced CT (arrows).

Infarcts

The etiology of splenic infarcts is highly variable and most infarcts are symptomatic in the acute stage. A typical wedge-shaped morphology is seen on contrast enhanced CT (Fig. 2.) and MRI. A diffuse pattern of infarction of the spleen may be encountered in systemic diseases (vasculitis).

Sarcoidosis

Splenic sarcoidosis should be considered in the differential diagnosis of multiple focal lesions on US or CT in asymptomatic patients. MRI typically shows multiple lesions with relatively low signal on T2-WI and a delayed enhancement pattern.

Metastasis

The spleen is a rare site of splenic metastasis due to lack of afferent lymphatics. Isolated splenic metastases are very rare. Even in the presence of a known primary malignancy, detection of splenic lesion is not necessarily related to malignant spread. Comparison with previous scans is helpful. Implant metastasis represents another pattern of metastatic spread to the spleen.

Splenic lymphoma

Splenic lymphoma is the most common splenic malignancy. Both Hodgkin and non-Hodgkin disease may involve the spleen. Usually, there is concomitant widespread disease and associated adenopathy. Imaging features include splenomegaly, solitary or multiple focal lesions of variable size and splenic infarctions.

Splenic infection

Splenic infection is relatively rare in Western countries, but may be seen in immunocompromised patients, after chemotherapy and transplantation.

Gamna-Gandy bodies

Gamna-Gandy bodies consist of organized foci of hemorrhage and contain a mixture of hemosiderin, fibrous tissue and calcium. It is associated with long-standing portal hypertension. CT is insensitive for early detection and MRI is the preferred technique. The lesions are of low signal on both pulse sequences and may show blooming on gradient echo imaging.

Miscellaneous

Rare benign and malignant tumor and tumorlike conditions may involve the spleen (hamartoma, litteral cell angioma, Gaucher's disease,...).

Conclusion

Most focal splenic lesions are incidentally found on imaging and are benign. CT is the primary imaging modality for detection of these lesions. MRI may be of additional value in lesion characterization. Although imaging will not always provide a specific diagnosis, the combination of the clinical history, laboratory data and imaging is usually sufficient for characterization. In most clinical scenario's, a wait-and-see policy is preferred.

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1. Department of Radiology, AZ Sint-Maarten, Duffel-Mechelen, 2. Department of Radiology, Antwerp University Hospital, University of Antwerp, Edegem, 3. Faculty of Medicine and Health Sciences, University of Ghent.

Update in abdominal ultrasound

E. Danse, L. Annet, A. Dragean, I. Nica, P. Van Tiggelen, P. Trefois[1]

Ultrasound remains a current imaging procedure still required in many abdominal conditions. The advantages of sonography are a low cost technique, its repeatability, its bedside availability and the lack of radiation and side effects (1). The reason of the "sound" success story is based on permanent technical improvements and access to portable machines at a low cost.

Improvements and innovations are constant in the sphere of B mode sonography, Color Doppler technique, Contrast ultrasound, elastography and volumetric approach, giving more confidence for the ultrasound practitioner.

- the B mode improvements are based on efforts of the companies to increase the number of piezzo-electric elements and development of specific process to reduce artifacts.
- Contrast ultrasound is permanently optimized. New indications are under

evaluation, particularly in the field of evaluation of response to therapy (2).
– Volumetric ultrasound has moved from the obstetrical to the abdominal area, with applications for liver, kidney, bladder and bowel imaging. Volumetric ultrasound has been optimized with the development of matricial probes. Volume imaging is also incorporated in the interventional radiology room, allowing better guidance for difficult biopsies based on the "GPS" philosophy (3).
– Elastography of the liver, initiated with the "Fibroscan" is integrated into our common probe, accelerating the access to liver stiffness evaluation and also new applications, including characterization of focal liver lesions.

High quality portable devices are available, with high quality B Mode image, color Doppler and contrast ultrasound imaging in an easier way, particularly in the critical care and emergency medicine area, with a side effect : ultrasound can not be restricted to radiologists and the battle of "who has to perform ultrasound ?" is still alive (4, 5).

These improvements (volumetric ultrasound and portable device) are an opportunity for a new approach for teaching medicine and radiology at the University: ultrasound is used to give a better anatomical understanding of the human body (6).

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1. Department of Imaging, St Luc University Hospital, Université Catholique de Louvain, Brussels, Belgium.

US of the acute abdomen

J.B. Puylaert[1]

CT has several advantages over US in the diagnosis of the acute abdomen: CT is extremely rapid, the *true costs* of CT are fairly low and probably lower than a time-consuming US examination, CT images are not disturbed by gas and bone, while obesity is even an advantage; producing the CT images is not operator-dependent and CT can be reviewed at a later point in time and even from a distance by means of teleradiology. Finally, CT images are easier understood and accepted by clinicians than US images are.

However, there are also specific advantages of US over CT: US has an image definition in the close range which is much higher. US is more interactive: patient's history as well as painful area or palpable mass can be correlated with the US findings. US shows peristalsis, pulsations and blood flow. US shows the effects of respiration, Valsalva manoeuvre, gravity and compression with the probe, allowing to assess whether organs as bowel and gallbladder are soft or rigid. US allows easy puncture of intraperitoneal fluid and drainage of pus.

US in acute abdomen is performed with graded compression. Compression is necessary to displace or compress bowel, eliminating the disturbing influence of bowel gas and to approach the pathological structure closely. This allows using a high frequency transducer with a better image quality. The compression should be graded to avoid unnecessary pain and to avoid pushing organs out of the US plane.

US examination should be symptom-directed and requires communication with the patient. In patients with an acute abdomen the entire abdomen should be examined, i.e. from the axilla to the groin. The final US report should be integrated with the clinical findings, laboratory data, CT-scan and possible other radiological examinations.

The US images of appendicitis, diverticulitis, intussusception, acute biliary, urological and gynecological conditions, infectious ileocecitis, perforated peptic ulcer, small bowel obstruction, ruptured aneurysm, pancreatitis, Crohn's disease, epiploic appendagitis, omental infarction and perforating malignancy will be demonstrated using illustrative case histories, with emphasis on the specific advantages of US over CT.

1. Department of Radiology, MCH, The Hague.

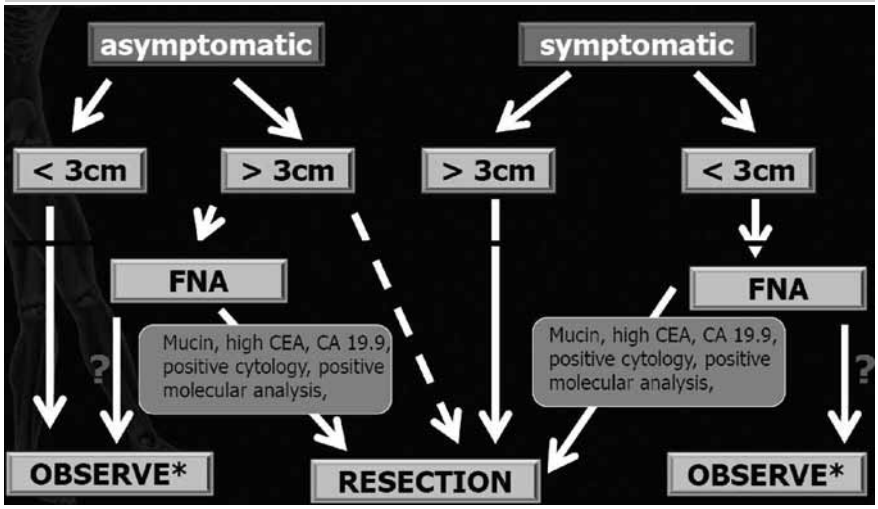
Cystic tumors of the pancreas: imaging and management

K.J. Mortele[1]

Cystic tumors of the pancreas are a diverse group of lesions which vary from benign to pre-malignant to frankly malignant entities. There has been a 20-fold increase in detection of cystic pancreatic lesions over the last 15 years most notably by cross-sectional modalities such as computed tomography (CT) and magnetic resonance imaging (MRI). The true prevalence of pancreatic cystic lesions is unknown but has been previously reported to be around 2.4-16.0%, and they appear to be increasingly detected with increasing age. One study reported a prevalence of incidental pancreatic cystic lesions on MRI to be in the order of 13.5% and showed that the prevalence and cyst size also increased with age. These findings have been corrobated at autopsy with the prevalence of cystic lesions approaching 25%.

Given the fact that the prevalence of pancreatic cystic lesions is increasing

Table I. — Our standardized in-house approach to cystic pancreatic lesions.



Lesion size	Recommended follow-up
< 1 cm	Every 2 years (2x) for a total of 4 years; if still stable then STOP
1-2 cm	Every year for 2 years (2x), then once after 2 years; if still stable then STOP
> 2 cm BUT < 3 cm	Every 6 months for 1 years (2x), then every year for 3 years (3x); if still stable then STOP

due to increased detection by cross-sectional imaging, and the fact that most cystic pancreatic lesions are neoplastic in nature, accurate diagnosis via clinical information, radiological images, +/- endoscopic ultrasound (EUS) with cyst fluid analysis plays an important role. The majority of these lesions, especially when large, have characteristic imaging features at radiology, and accurate differentiation between them is important to help guide future treatment and management. Nevertheless, smaller lesions may appear indeterminate and the management pathways of these may be confusing and variable. The aim of this lecture is to review the histopathologic features and common imaging findings for a vast array of cystic pancreatic neoplasms. These include the relatively common cystic tumors of the pancreas: serous microcystic adenoma, mucinous cystic tumor (MCT), intraductal papillary mucinous neoplasm (IPMN), and solid pseudopapillary tumor (SPT). Uncommon cystic tumors of the pancreas include cystic endocrine tumors, cystic metastases, cystic teratomas, and lymphangiomas. This lecture also aims to provide comprehensive algorithms on how to manage the individual lesions with recommendations on when to reimage patients (Table I).

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1. Associate Professor of Radiology, Harvard Medical School / Director, Division of Clinical MRI / Staff Radiologist, Abdominal Imaging and MRI, Beth Israel Deaconess Medical Center, 330 Brookline Avenue, Ansin 224, Boston, MA 02115, USA.

Imaging of abdominal and retroperitoneal soft tissue tumours: a practical approach

F.M. Vanhoenacker[1,2,3], A. Snoeckx[2], B. Op de Beeck[2]

The learning objectives of this presentation are to describe the imaging features of abdominal and retroperitoneal soft tissue tumours with emphasis on MRI and to define a practical approach for differential diagnosis.

Abdominal and retroperitoneal soft tissue tumours are rare. Since clinical implications and therapeutic strategy vary depending the cause, imaging plays an important role.

Imaging findings

When approaching abdominal or retroperitoneal soft tissue tumours, the initial step in the evaluation is defining the precise localization of the lesion. The next step is to differentiate between cystic and non-cystic masses. Cystic lesions can be classified as neoplastic or nonneoplastic. Neoplastic lesions include cystic lymphangioma (Fig. 1), mucinous cystadenoma, cystic teratoma, cystic mesothelioma, Müllerian cyst, epidermoid cyst, tailgut cyst, bronchogenic cyst, etc. Nonneoplastic lesions include pancreatic pseudocyst, lymphocele, urinoma and hematoma. Non-cystic masses can be classified according to their origin. Lesions of vascular origin are hemangiopericytoma and retroperitoneal lesions associated with angiomatosis. Lesions of neurogenic origin are associated with NF-1 and include neurofibroma, schwannoma, malignant peripheral nerve sheath tumor and duralectasia. Tumours of fibrous origin are desmoids and inflammatory pseudotumor. Liposarcoma (Fig. 2) and GIST are the most common malignant retroperitoneal tumours. Abscesses, iliopsoas bursitis, ischemic fasciitis, endometriosis and cisterna chyliare pseudotumoral lesions that may mimic a retroperitoneal or abdominal mass.

Conclusion

Although abdominal and retroperitoneal soft tissue tumours show many

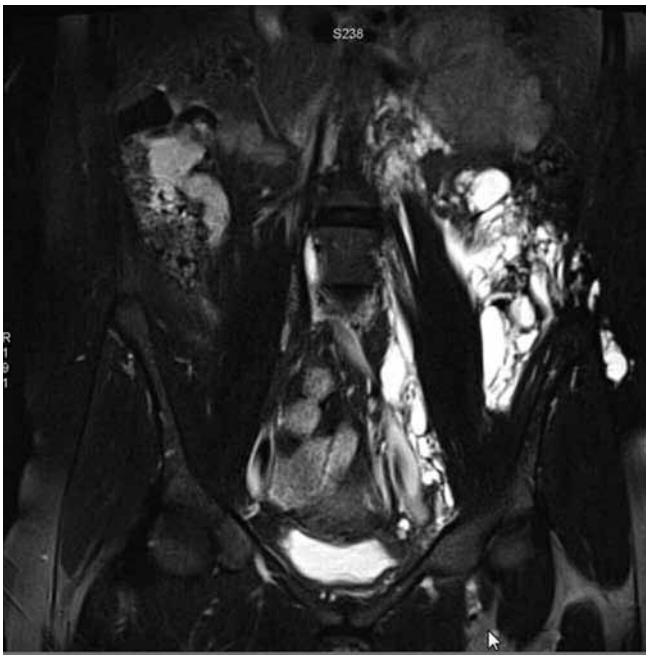

Fig. 1. — Retroperitoneal lymphangioma. Diffuse infiltrating serpiginous lesion at the left flank and abdominal wall on fat-suppressed (FS) T2-Weighted image (WI).

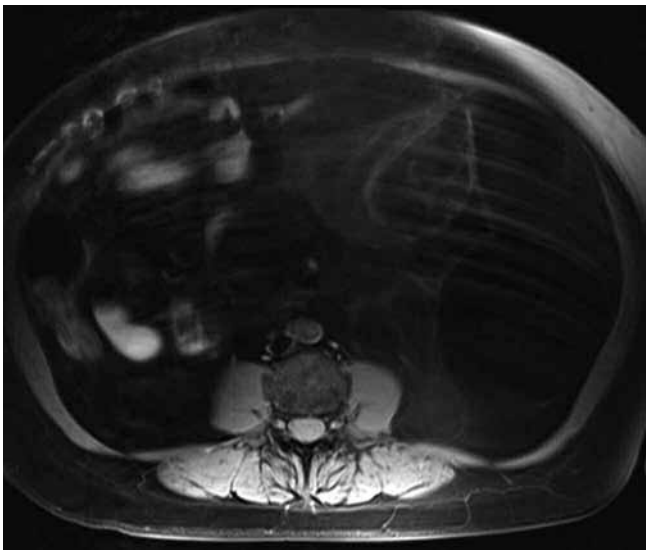

Fig. 2. — Retroperitoneal liposarcoma. Huge retroperitoneal mass containing fatty and nonlipomatous components on a FS T2-WI.

overlapping characteristics, some imaging findings may suggest a specific diagnosis. Whereas CT is the initial imaging technique for detection, MRI can better characterize the tumour and define its extension.

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1. Department of Radiology, AZ Sint-Maarten, Duffel-Mechelen, 2. Department of Radiology, Antwerp University Hospital, University of Antwerp, Edegem, 3. Faculty of Medicine and Health Sciences, University of Ghent.

CT colonography: current status and pitfalls

Ph. Lefere[1]

Current status

Since its introduction as a revolutionary imaging technique for detecting tumoral lesions in the colon, CT colonography (CTC) has gained major interest from both the radiological and gastrointestinal community. After a rather long introductory period with variability of results, CTC is now more and more established as a useful and reliable technique to inspect the colon for colorectal cancer and its adenomatous precursors. Sustained efforts of the CTC community (ESGAR CTC faculty) resulted in the elaboration of a state-of-the-art technique focussing on the important aspects of patient preparation, colonic distension image acquisition and interpretation. The results of recently performed multicentre trials have proven these efforts to be worthwhile.

State-of-the art CTC technique is based on 4 importants pillars: colonic preparation with fecal tagging, adequate colonic distension using an automated CO_2 injector, acquisition with a multi-slice scanner (using (ultra-) low dose in asymptomatic patients), interpretation with dedicated colon software programs by an experienced CTC radiologist. Using this technique very good results of polyp detection have been obtained in several large trials with CTC obtaining a sensitivity of > 80% for adenomas and/or advanced neoplasia 6-9 mm (some studies obtaining > 90%) and > 90% for adenomas ≥ 1 cm. CTC is now an accepted indication after incomplete optical colonoscopy, in case of contra-indications and patient refusal of optical colonoscopy. While the use of CTC for population-based screening is a matter of debate because of an issue of cost-effectiveness, CTC is a good option for individual screening. CTC is a very good indication in the frail and elderly patients. CTC can be considered in patients with symptoms suggestive of colorectal cancer and patients with vague abdominal symptoms. CTC can be used for preoperative mapping of diverticular disease and colorectal cancer and in the posroperative patient for colorectal cancer surveillance. CTC is also an option in patients with endometriosis. CTC is very well accepted by the patient and currently techniques are developed to decrease the intensity the preparation in order to improve patient compliance. Furthermore CTC is a very safe examination with very few and mostly self-limiting complications. Radiation dose is very low with the development of better scanners and new acquisition and postprocessing methods.

Pitfalls in imaging

Pitfalls in imaging are related to the technical aspects of CTC, the anatomical aspect of the colon and two- and three-dimensional imaging.

Technique-related pitfalls are related to the preparation, colonic distension and CTC acquisition. Most problems are solved by preparing the patient with fecal tagging and obtaining optimal colonic distension. Some minor problems may be caused by noise related to the low dose technique and motion artefacts. Anatomy-related pitfalls are more difficult to handle. Some pitfalls occur in any colonic segment: segmental mobility, the flexural pseudotumor and extrinsic impressions. Some pitfalls are related to the colonic segments. As a closed structure the rectum is difficult to examine. The anal margin needs our particular attention because of possible internal hemorrhoids, hypertrophied anal papillae and true polyps. Futhermore the rectal catheter obscures this part of the rectum. The valves of Houston or rectal valves are 3 prominent folds that add more difficulties when inspecting the rectum. In the sigmoid most problems are caused by diverticular disease: diverticular fecaliths, polypoid mucosal prolapse and wall thickening with the issue of chronic diverticulitis vs cancer. The descending colon does not cause a lot of problems. Having a round aspect in the sigmoid, the colonic lumen becomes somewhat more triangular in the descending colon with a typical aspect in case of spasm. In the transverse and ascending colon the lumen becomes frankly triangular with deeper haustal folds. At both the splenic and hepatic flexures, flexural pseudotumors are frequently encountered. Finally the cecum is difficult to examine: first it is a closed structure, second the ileo-cecal valve has several normal appearances mimicking tumors: lipomatous transformation, papillary transformation. Sometimes the ileo-cecal valve is difficult to localize or may be misinterpreted as a tumor. It is also necessary to examine the appendix to exclude a tumor or a mucocele.

Conclusion

CTC is a reliable tool for detecting tumoral lesions in the colon. To be succesful, a meticulous technique and interpretation by an experienced radiologist are mandatory.

1. Department of Radiology, Stedelijk Ziekenhuis Roeselare, Roeselare, Belgium.

US of appendicitis and diverticulitis

J. B. Puylaert[1]

Appendicitis

US is the modality of choice to demonstrate appendicitis. In experienced hands in 90% of patients with appendicitis, the inflamed appendix can be demonstrated. It presents as a hypervascular, aperistaltic, sausage-like, blind-ending, concentrically layered structure, which is not or only moderately compressible.

The inflamed appendix has an average diameter of 9 mms and is often surrounded by hyperechoic, non-compressible, inflamed fat.

In contrast, the diameter of the normal appendix is usually < 7 mms, is well-compressible, more mobile and never surrounded by inflamed fat. A possible pitfall is the demonstration of the normal proximal part of the appendix while the distal inflamed tip is overlooked because it is obscured by bowel gas. Also the diameter of the normal appendix at times may exceed 7 mms, in most cases because the lumen is dilated with fecal material. In children the hypoechoic deep mucosal layer may be very thick due to lymphoid hyperplasia and be responsible for a large diameter, while the appendix is not inflamed. In all of these cases the absence of inflamed fat and the absence of hypervascularity are the clue to the right diagnosis.

A pitfall leading to a false-positive diagnosis is secondary enlargement of the appendix. This maybe due to conditions as cecal carcinoma, Crohn's disease, perforated peptic ulcer and sigmoid diverticulitis. If in these cases the underlying condition is not recognized, an incorrect diagnosis of appendicitis may lead to an unnecessary operation or, in case of a surgical condition, to an inappropriate incision.

If, next to the inflamed appendix, fluid filled, dilated and aperistaltic bowel loops are seen in the right lower quadrant or throughout the abdomen, this indicates localized respectively generalized peritonitis. This means a high chance for perforation and usually it coincides with severe peritonitis, making surgery imperative.

Another pitfall is provided by the phenomenon of "spontaneously resolving appendicitis". These patients are admitted with suspected appendicitis, but after a variable period of time (12-36 hours) they experience rather sudden relief of pain and concomitant symptoms. If examined at that point US is still able to confirm an inflamed appendix which is however not anymore tender on pressure. Repeat US scans show gradual decrease of the appendix diameter over the following days. Conservative management in a large series showed a 40% recurrence rate, usually within one year.

If appendicitis has been present for several days, and the erythrocyte sedimentation rate (ESR) is markedly elevated, while the patient's condition is relatively stable, US will usually denote large hyperechoic fatty masses surrounding the appendix as well as secondary wall thickening of ileum and cecum. These hyperechoic masses, often interspersed with irregular echolucent linear configurations, represent inflamed mesenterial fat and omentum, migrating towards the appendix in an attempt to wall-off the (imminent) perforation. These patients get the clinical diagnosis of "appendiceal mass", which is commonly treated conservatively, because appendectomy is expected to be technically difficult or even impossible due to the large inflammatory mass . When these patients are followed with US, one observes a gradual decrease in size of the inflammatory periappendiceal mass). In case there is doubt whether to operate immediately or to remain conservative, the clinical impression and especially the duration of symptoms and the absence of peritonitis, has generally more weight than the US image. The diagnosis of appendiceal phlegmon can only be made in dialogue between radiologist and clinician, and never on the US or CT image alone. If there is a circumscribed fluid collection, this indicates the presence of an appendiceal abscess.

Appendiceal abscess

The treatment of choice for an appendiceal abscess is percutaneous drainage. However it is important to realize that many appendiceal abscesses disappear spontaneously. The smaller ones are resorbed, the larger ones evacuate itself into neighbouring bowel.

If an abscess causes pain or recurrent fever, or if the patient recovers too slowly, percutaneous drainage is indicated.

Preceding the drainage procedure, CT scan is mandatory to confirm the abscess, to delineate its extent and to establish a safe access route for the puncture. In general it is best to puncture from lateral, but all directions are possible, provided that vital structures as vessels and bowel are avoided. Puncture and insertion of the initial guidewire are best performed under direct US-guidance, subsequent dilatation and insertion of the final drainage catheter are performed using fluoroscopy.

In children, and in adults with frank peritonitis, surgical intervention is indicated.

Diverticulitis

Over all, the diagnosis of diverticulitis is more reliably made by CT than by US. However, since US is often used as a first modality in acute abdomen, it is important to be aware of the US signs of diverticulitis. Besides, in not too obese patients, US may be superior to CT.

US is most useful in early, uncomplicated diverticulitis. Daily, repeated US examinations in patients with diverticulitis has taught us that diverticulitis, in the majority of cases, runs a predictable and benign course.

Initially, there is local wall thickening of the colon with preservation of the US layer structure. Within the inflamed diverticulum a fecolith is present and the diverticulum is surrounded by hyperechoic, non-compressible tissue, which represents the inflamed mesentery and omentum "sealing-off" the imminent perforation.

US follow-up shows evacuation of the fecolith to the colonic lumen, with or without the transient development of a small paracolic abscess, sometimes with disintegration of the fecolith . This process of spontaneous evacuation of pus and fecolith via local weakening of the colonic wall at the level of the original diverticular neck towards the colonic lumen, takes place within one or two days, rarely more.

The residual inflammatory changes remain present for several days after the evacuation, and it is not uncommon to find an empty diverticulum at first presentation. If, in such cases, patients are specifically asked for their symptoms, they invariably declare that "the worst pain is over"...

Whenever diverticulitis takes a complicated course, CT is superior to US, especially in the detection of free air, fecal peritonitis and deeply located abscesses, and in general in obese patients.

Finally, US, if necessary followed by CT, has an important role in the diagnosis of alternative conditions: ureterolithiasis, pyelonephritis, perforated peptic ulcer, appendicitis, Crohn disease, epiploic appendagitis, gynecological conditions, colonic malignancy, pancreatitis, etc.

Right sided colonic diverticulitis in many respects differs from its left sided cousin. Diverticula of the right colon are usually congenital, solitary, true diverticula containing all bowel wall layers. The fecoliths within these diverticula are larger and the diverticular neck is wider. There is no hypertrophy of the muscularis of the right colonic wall. My observations with US and CT in 110 patients with right colonic diverticulitis, clearly show that it invariably has a favorable course and never leads to free perforation or large abscesses. Although relatively rare (left: right = 15:1), it is crucial to make a correct diagnosis, since the clinical symptoms of acute RLQ pain may lead to an unnecessary appendectomy or even right hemicolectomy.

1. Department of Radiology, MCH, The Hague.

Inflammation and obstruction of the urinary tract

J.R. Fielding[1]

What is the appropriate test for the evaluation of painless hematuria in the patient with high risk for TCC?

High risk patients include those over the age of 60 with a smoking history. These patients routinely undergo cystoscopy to exclude a primary bladder cancer. Assessment of the upper tracts is performed to exclude a synchronous tumor or in the case of a negative cystoscopy, a primary site of disease. There are many methods to perform CTU, however, all involve a non-contrast enhanced image of the abdomen to exclude stones and identify renal cortical masses. A second pass through the abdomen and pelvis following injection of 100 cc of contrast material (350 mg I/ml) is performed at 75 seconds. Finally, a third pass performed at 5 to 10 minutes following injection is used to assess the intrarenal collecting systems and ureters. Coronal reformatted images of the delayed phase acquisition are essential and should be reviewed using both soft tissue and bone windows. The use of furosemide, a split bolus of contrast agent and compression bands all increase opacification of the ureters.

What is the appropriate use of MR urography?

MR urography can be a valuable substitute for patients who require evaluation of the kidneys and upper tracts but cannot receive IV contrast agents. Although it lacks the spatial resolution of CT, there is increased contrast resolution theoretically allowing for more accurate identification of soft tissue masses. In those patients who have undergone therapy for TCC, it may replace CTU for follow-up examinations. Despite the perceived complexity of MR urography, it can be performed in a simple fashion. The two most crucial components are the use of hydration (250 ml IV) and diuresis (furosemide 10 mg IV). Once these steps are completed, the acquisition of a thick slab fat saturated T2 weighted coronal image with a large field of view should yield high quality results. Parameters used for MRCP are satisfactory.

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1. University of North Carolina at Chapel Hill, Chapel Hill, NC, USA.

Imaging acute abdomen in the pediatric population

F. E Avni[1]

Abdominal emergencies represent one of the largest parts of the workload in a Paediatric Radiology Department. Emergencies encompass a very wide spectrum of diseases and entities some life threatening while other more benign.

The role of imaging is of utmost importance as in many patients, the origin of the acute symptoms is not obvious. Furthermore some specific entities such as non accidental trauma and child abuse have to be considered and will be suspected through imaging findings only.

Considering abdominal emergencies, ultrasound (US) plays a central role in sorting between the differential diagnoses and therefore, a clinico-radiological triage has to be applied based on age, sex, symptoms, medical history, and sonographic findings.

Imaging techniques

As mentioned, among imaging techniques, ultrasound (US) occupies a central role. The technique is not irradiating, easy to perform (yet operator – dependant) and relatively low cost. The US examination has to be optimized and fitted to the size and age of the patient. Whatever the purpose of the examination, the entire abdomen should be checked. In many cases, color Doppler will provide additional information.

In selected cases, a plain film of the abdomen will help to demonstrate calcifications or confirm intestinal (sub)obstruction. In some others, a CT-scan would provide additional information useful for the proper management of the patient. Whenever performed, the CT technique should be optimized to deliver the lowest possible irradiation. MR Imaging is rarely performed as an emergency procedure, unless an abdomino-pelvic mass is detected. Finally, fluoroscopy has limited indications in emergency abdominal imaging.

Acute abdominal conditions (trauma excluded)

One way of defining the best optimal work up of an acute abdominal condition is to base the approach on the patient's age:

– The principal entities to consider *around birth and up to 6 months* are congenital anomalies, those related to premature birth and hypertrophic pyloric stenosis. Congenital anomalies are frequently detected during obstetrical US examination; yet, some do escape antenatal diagnosis and will be detected after birth only, secondary to symptoms of intestinal (sub)obstruction. Prematurely born babies are at risk for developing digestive complications such as necrotizing enterocolitis. At an early stage, US may demonstrate bowel wall thickening and a small amount of free fluid. Thereafter, free air may dissect the bowel wall and reach the portal vein system. It will be demonstrated as hyperechoic dots within the liver parenchyma. In case with unfavourable evolution, a pneumoperitoneum may develop due to intestinal perforation.

In a 6 week-old vomiting babyboy, a hypertrophic pyloric stenosis is the most probable diagnosis. US is confirmatory as it demonstrates the thickened pyloric muscle. The stomach is distended since food remains trapped for an abnormal long duration.

– *between 6 months and 2 years,* the main diagnoses are intussusceptions, midgut volvulus and inguinal hernia. In classical cases, intussusception has a typical clinical and sonographic appearances. At US, a mass with a target pattern is visualized (above 3 cm diameter). Many small ganglions are usually included within the intussuception. Most All are primary. Some (usually those before the age of 6 months or after 2 years) are secondary to leading lesions (e.g. intestinal duplications, Meckel's diverticulum, lipoma, lymphoma) that can be visualized as persisting masses after the therapeutic reduction.

A midgut volvulus is an acute condition that complicates intestinal malrotation and induces intestinal obstruction. In obvious cases of intestinal malrotation, the mesenteric vein lies to the right of the mesenteric artery; the condition can be complicated by a midgut volvulus where the bowel loops and the mesenteric vessels determine the so-called and characteristic Whirepool sign. Midgut volvulus is a surgical emergency.

An Inguinal hernia corresponds to bowel loops entrapped within the patent inguinal canal. Peristalsis within the herniated loops can be observed. Secondary obstruction may develop. Note worthy, in baby girls, an ovary can be entrapped within the hernia. This condition should be operated rapidly.

– *Between 2 and 12 years,* the spectrum of diseases occurring within this age group is wide and assessing the correct diagnosis is sometimes a real challenge. Still, by frequency, two conditions overpass all others. By far, constipation is the commonest cause for acute and chronic abdominal pain in children. This diagnosis can only be obtained through a careful interrogation of the child (if possible) and of his/her parents. If necessary, a plain film of the abdomen may confirm the condition.

The second most common condition for acute abdominal pain is acute appendicitis which is actually the most commonly diagnosis suspected by the ER physician.

A US diagnosis of acute appendicitis (AA) is based on the demonstration by US of a thickened, swollen, non depressible appendix (above 6 mm diameter). The inflamed appendix is painful under gentle US compression. On color Doppler, the peri-appendicular mesenteric fat appears hypervascularized. An echogenic appendicolith can be visualized. As the disease progresses, perforation may occur and peritonitis develop with abscess formation. The latter may be difficult to delineate and complementary CT may be necessary. Indications of CT include unusual clinical presentation (i.e. infants), clinico-imaging discrepancy and complicated cases (multiple abscesses).

False negative diagnoses of acute appendicitis result from localized inflammation or abnormally located (retrocaecal or retrohepatic) appendix. False positive cases include other causes of appendicular infiltrations or thickening (e.g. carcinoïd tumor, cystic fibrosis, Crohn's disease, ...).

Once acute appendicitis has been excluded, the list of diagnoses widens. For instance, the digestive tract can be involved infectious or inflammatory processes that lead to its thickening and hypervascularization. It can also be involved in auto-immune diseases (e.g Henoch-Schonlein Syndrome, Hemolytic and uremic syndrome...).

Meckel's diverticulum is surely a potential diagnosis and it may be complicated by torsion, abscess formation and rupture.

Biliary lithiasis may occur under various favouring conditions (Sickle cell disease, infections, post-surgery, ...) and detected thanks to typical ultrasound features.

Abdominal tumors may develop at any age and involve any organ. Neuroblastoma, Wilms' tumor and lymphoma are the most frequent in children. Other classical tumors include cystic lymphangioma and teratoma. Both can be retro- or intraperitoneal. Cystic lymphangioma appears as large multiseptated fluid filled masses where as teratoma are usually more complex tumors including solid components and calcifications.In girls, the most common tumors in develop in the ovary. Teratoma (or dermoïd cyst) are the most classical histologic type encountered.

Other entities that may lead to acute abdominal pain include acute pneumonia, acute pyelonephritis, testicular torsion, psoas abscesses or skeletal diseases.

– *Above 12 years,* the list of diseases to be considered resembles the ones occurring in adults as for instance gastritis, gastro-duodenal ulcers or bowel inflammatory diseases and their complications may occur. In adolescent girls, gynaecological diseases have to be considered. Ovarian cysts may develop and torsion is a classical complication. At puberty, gynaecological malformations may become obvious due to hematocolpos.

1. Department of Pediatric Radiology, CHRU-Lille, France.

MRI in fistulizing perianal disease

D. Vanbeckevoort, D. Bielen, V. Vandecaveye, K. Op de beeck, R. Vanslembrouck, E. Mussen, S. Dymarkowski, M. Thijs[1]

Perianal fistulas are an uncommon but major cause of morbidity, occurring in 1/10000 predominantly male persons.

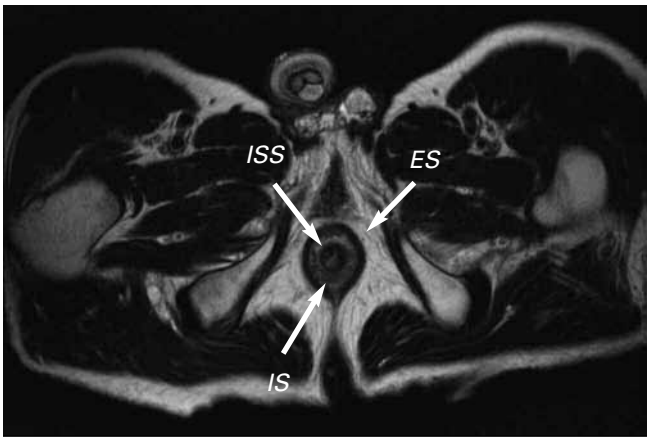

Fig. 1. — Axial T2-weighted MR image shows the normal anatomy of the perianal region: *ES* = external sphincter, *IS* = internal sphincter, and *ISS* = intersphincteric space.

Normal anatomy

The anatomy of the anal region is well demonstrated on MR images (Fig. 1): the involuntary internal sphincter, the intersphincteric space, and the voluntary external sphincter.

Etiology and classification

Perianal fistulas usually arise from infected anal glands, penetrating into the intersphincteric plane, spreading infection down to the skin.

In patients with Crohn disease perianal fistulas arise from inflamed or infected anal glands and/or penetration of fissures or ulcers in the rectum or anal canal.

Using the external sphincter as a reference point, Parks divided perianal fistulas in 5 types: intersphincteric, transsphincteric, suprasphincteric, extrasphincteric, and superficial (1).

Diagnosis

Standard assessment of perianal fistulas combines examination under anaesthesia and imaging with endoscopic ultrasound and/or pelvic MRI.

MRI protocol

Coronal and axial MR images demonstrate fistula tracks in relation to the sphincter complex, ischiorectal fossa, and levator plate.

Sagittal and oblique planes are helpful in anovaginal or presacral disease.

Contrast enhanced and fat suppressed sequences are used to improve contrast and can distinguish inflamed tissue from normal perineal tissues.

Accuracy and application of MR imaging

For surgical treatment (preoperative assessment)

Pelvic MRI may change surgical management in 10%-15% of cases (2).

For medical treatment (measurement of fistula disease activity)

Fistula inflammation and disease activity correspond well with the presence of T2 hyperintensity in fistula. Van Assche et al. have constructed a new MRI based score, taking into account both anatomical and inflammation criteria (3). This score correlates with clinical disease activity and with response to biological therapy.

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1. Department of Radiology, University Hospitals, Catholic University of Leuven, Leuven, Belgium.

Imaging and interventional treatment of benign uterine tumors

Th.J. Kroencke, B. Hamm[1]

Uterine artery embolization (UAE) is a nonsurgical intervention for treating symptomatic uterine leiomyomas and represents an alternative to surgical removal (hysterectomy, moymectomy, hysteroscopic resection). The indication for uterine artery embolization crucially relies on the preinterventional assessment of symptomology and burden of disease. Especially the location, size, and number of leiomyomas are important to determine treatment options of patients. As a rule, both single and multiple fibroids can be treated by UAE. The number and location of the individual tumors (subserosal, intramural, transmural, submucosal) does not affect the approach, technique or outcome of UAE.

MR guided high-intensity focused ultrasound (HIFUS) is a noninvasive treatment option for symptomatic leiomyomata. In contrast to UAE and surgery, it lacks the invasiveness of these procedures since the targeted leiomyoma are ablated by energy transmitted through the skin by focused ultrasound while exact delivery is monitored online by MR imaging. Size, location and number of fibroids are limiting factors for the application of HIFUS.

Magnetic resonance imaging (MRI) is superior to ultrasound in delineating the extent of fibroid disease and excluding other pathologies or disease processes that may mimic fibroid-related complaints.

1. Department of Radiology, Charité-Universitätsmedizin Berlin, Charité Campus Mitte, Berlin, Germany.

MR Imaging of cervical and endometrial cancer

B. Hamm[1]

MR imaging is the method of first choice for staging uterine malignancies. The main criterion for staging endometrial cancer is the depth of myometrial invasion. The diagnostic accuracy can be improved by performing a dynamic contrast-enhanced study in addition to T2-weighted imaging. Recently, it has been shown that DWI gives similar diagnostic information concerning myometrial invasion as dynamic contrast-enhanced imaging. The backbone of staging cervical cancer is T2-weighted imaging with a high spatial resolution performed in sagittal and transverse slice orientation. Invasion of the parametrium can thus be assessed with a high degree of accuracy. Especially in staging cervical cancer, MR imaging can replace numerous other diagnostic tests and thus improve pretherapeutic staging while at the same time reducing costs. In addition, MR imaging is used in planning radiotherapy and following up patients having undergone irradiation. MR imaging is a problem-solving method in patients with post-treatment complications such as assessment of fistulas and detection of recurrent cancer.

1. Department of Radiology, Charité-Universitätsmedizin Berlin, Charité Campus Mitte, Berlin, Germany.

MRI of the prostate

J. Fütterer[1]

Prostate cancer is a major health issue in aging men. No treatment is required in less aggressive prostate cancer but there is consensus that radical treatment is needed in aggressive prostate cancer.

Radical treatment has to start while the tumor is still confined to the gland and has

not spread beyond. Potential side effects of radical treatment, such as impotence and incontinence, have a substantial impact on quality of life. This is of special importance because more than 25% of patients eligible for radical treatment are in the age range of 40 to 65 years.

Conventional anatomical T2-weighted MRI is the mainstay in prostate cancer imaging. On T2-weighted images, normal prostate tissue displays an intermediate to high signal intensity while the transition-zone has lower signal intensity than the peripheral zone. Currently several MR imaging techniques are being explored. These include: 1H-MR spectroscopic imaging, dynamic contrast-enhanced MR imaging, and diffusion weighted imaging. Multiple studies have explored optimal parameter settings for the diagnostic MR-protocol, which allows accurate tumor localization. Although reported accuracies of the different separate and combined MP-MRI techniques vary for diverse clinical prostate cancer indications, MP-MRI has shown promising results and may be of additional value in prostate cancer localization and local staging. To increase MR imaging accuracy for the different clinical prostate cancer indications, one or more functional MR imaging techniques should be combined with T2-weighted MR imaging in a MP-MRI of the prostate. The optimal strength of MP-MRI is yielded by combining the information of the various techniques.

1. Department of Radiology, Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands.

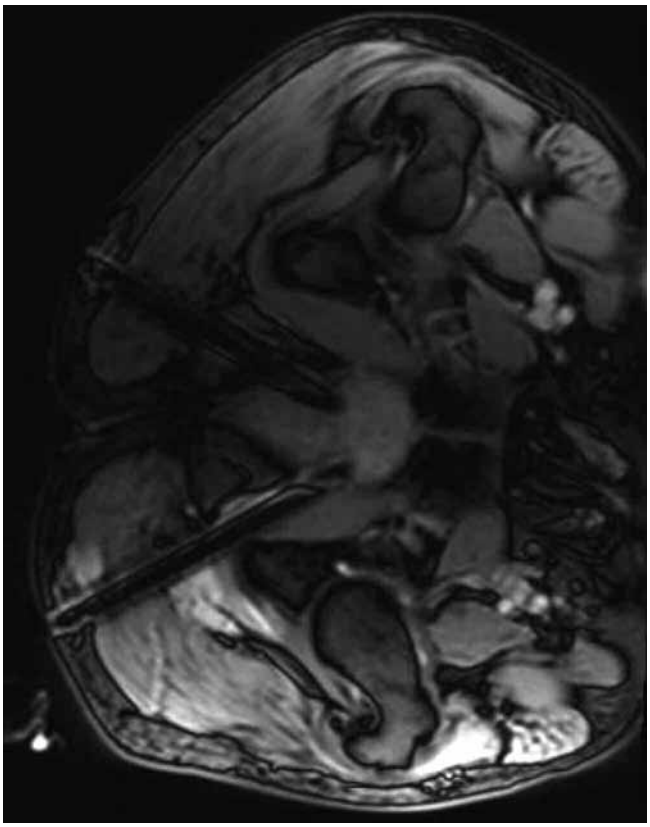

Fig. 1. — MR-guided prostate biopsy - transgluteal approach

MR guided biopsies of the prostate, an update

Th. Vogl[1]

Prostate cancer is the most frequently diagnosed malignancy in the western hemisphere in men aged 50 years and older. Early detection programs for prostate cancer with prostate-specific antigen level testing and an annual digital rectal examination should be performed in men over the age of 50. In this context the incidence of prostate carcinoma increased after the introduction of PSA testing.

Transrectal ultrasound-guided biopsy is recommended as the gold standard to confirm the diagnosis of prostate cancer. This systematic approach is characterized by low sensitivity and high specificity. A large number of patients with elevated and/or rising PSA levels have negative results on initial transrectal ultrasound-guided biopsy. Therefore, repeated biopsies have to be performed to confirm the diagnosis of prostate cancer. Missed prostate cancer at the first transrectal ultrasound-guided biopsy is described in about 25% of the patients.

Magnetic resonance imaging has established itself as a useful diagnostic modality for accurate localization of prostate cancer. It is a complementary reliable imaging technique after negative transrectal ultrasound-guided biopsy.

MR-guided biopsy of the prostate is a promising technique which combines MR imaging and the possibility of a guided biopsy. Initial experience shows promising results using transgluteal, rectal and perineal approaches (Fig. 1).

Manual MR guided-biopsy of the prostate gland with a transgluteal approach in a high-field MR system is feasible, safe and an advantage for prostate cancer detection.

1. Institute for Diagnostic and Interventional Radiology, Johann Wolfgang Goethe University Hospital, Frankfurt University, Frankfurt, Germany.