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CHAPTER FOUR

# MRI of the Hepatobiliary System

**After completing this chapter, the reader will be able to:**

- **Develop a protocol for liver MRI**
- **Identify benign and malignant liver disease processes**
- **Develop protocols for imaging of the biliary ducts and gallbladder**

**MR imaging of the liver** has become an important and relevant diagnostic tool. Liver MRI is most commonly used to evaluate an indeterminate focal hepatic lesion detected on other imaging studies and for imaging patients with contraindications to iodinated contrast media.

## OVERVIEW

Advances in contrast agents, faster pulse sequences, diffusion-weighted imaging, and MR elastography are examples of how liver MRI is becoming more technologically sophisticated and clinically valuable. When imaging the liver, the pancreas and hepatobiliary structures will be included because of their correlation with each other in both function and location (Figures 63 and 64).

In order to perform liver MR well, the technologist must optimize the imaging protocol for the specific MR system used, understand the proper application of several basic MR sequences, and recognize the MR appearance of several common focal hepatic lesions. A

## POINTS FOR PRACTICE

1. What are the components of a basic liver MR protocol?
2. List examples of potential barriers to obtaining high-quality liver MRI.
3. What are the three main methods for timing arterial enhancement for dynamic liver MR imaging?
4. Why is multiphase imaging useful?
5. Why is the discovery and imaging of hemangioma clinically important?
6. How is MRI helpful in diagnosis of secondary liver metastasis?
7. What cancer arises from the liver itself?
8. What are the advantages and disadvantages of MRCP vs ERCP?
9. List some malignant bile duct obstructions.

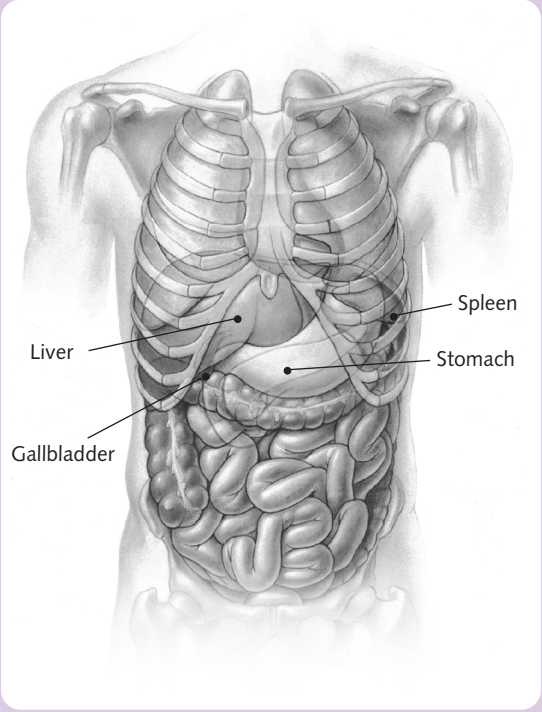


**Figure 63. Anterior view of the abdominal viscera. Liver MRI protocols cover the liver from just above the diaphragm to a point in the mid to lower abdomen, yielding enough coverage to include all of the right liver margin, which can extend up to 20 cm or more.**

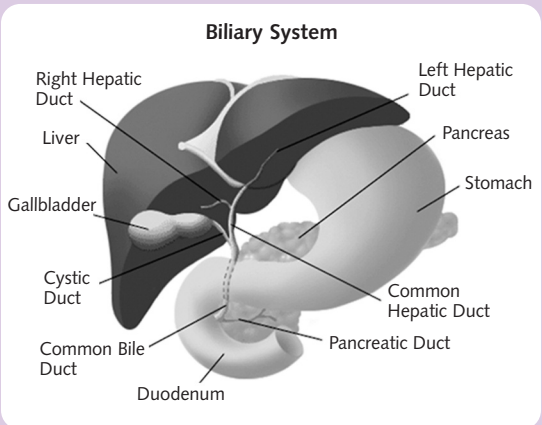


**Figure 64. Anatomy of the hepatobiliary system.** *From biologycorner.com*

basic liver MR protocol involves a good mixture of breath-hold and non-breath-hold sequences to demonstrate and differentiate abdominal tissue. This includes an axial T2-weighted sequence with or without fat saturation through the liver and spleen, an axial **in- and out-of-phase** T1-weighted gradient, and a fat-saturated 3D T1-weighted sequence for dynamic contrast imaging.

MR imaging accurately detects and characterizes focal hepatic lesions. Specific sequences, such as T2-weighted FSE/TSE and inversion recovery sequences are highly sensitive for detecting lesions. Once discovered, lesions often can be accurately characterized as malignant or benign, cyst or solid tumor, etc., based on appearance and relative signal intensity on T1- and T2-weighted sequences. Intravenous contrast media increase the sensitivity and specificity of MRI for detection and characterization of focal hepatic lesions. See Table 5 on page 53 for common indications for liver MRI.

## LIVER MRI PROTOCOL DEVELOPMENT

### Imaging Parameters

High-quality liver MR studies can be challenging to obtain because many external factors can impact image quality. Breath-holding ability, the presence of ascites, language barriers, and anatomical variants are examples of potential challenges that technologists must manage in order to acquire high-quality scans for adequate image interpretation. Well thought out protocols, proper equipment, and patient education are crucial for successful imaging of the liver. Currently, most MR centers have phased-array torso coils with multiple receiver channels that provide better SNR and the capacity for parallel imaging techniques.

## Common Indications for Liver MRI

- Evaluation of an indeterminate lesion
- Contraindication to CT contrast
- Evaluation of therapeutic response to chemotherapy or other therapy
- Normal CT or US but high clinical suspicion of lesion
- Metastatic disease staging
- Evaluation for liver transplant (recipient and living donors)
- Evaluation of the cirrhotic liver

Table 5. **Liver MRI is more sensitive and accurate for detection and characterization of focal lesions than either CT or US.**

Special care should be taken to ensure that the liver and kidneys are placed in the center of the phased-array coil. If the liver is too close to the top edge, signal intensity will drop off and fat saturation will not be optimal. If the patient is poorly positioned, it is prudent to move them so that they are properly centered.

### Patient Education

A good MRI liver protocol provides the patient with an opportunity to catch their breath and relax, especially prior to important breath-hold sequences. Non-breath hold sequences also allow for **contiguous** slices throughout the abdomen without any **misregistration**, which occurs when patients do not hold their breath the same way each time. Instructing patients on how to hold their breath is one of the most important factors when educating patients about their MRI scans. While scanning on expiration allows for the best replication of liver position, most patients are not able to hold their breath for more than 15 to 20 seconds on expiration. If the breath is held after inspiration, it is helpful to instruct the patient to breathe in, breathe out, breathe in again, and then hold their breath after two breaths.

### Imaging Protocols

Liver MR imaging protocols typically use a combination of T1- and T2-weighted images and dynamic post-gadolinium-enhanced imaging. Together they provide complementary information used for image interpretation. No one liver protocol can be used for every clinical situation; depending upon the complexity of the case and the clinical questions asked, additional sequences may

**LIVER PROTOCOL GUIDELINES**

- **Short as possible without compromising image quality**
- **Robust T2 and in- and out-of-phase images**
- **Unenhanced, arterial, portal venous, and equilibrium phase**
- **Arterial phase as early as possible**
- **Good mixture of breath-hold and non-breath-hold sequences**

be needed. Many centers add a diffusion-weighted sequence (**DWI**) for increased detection of a lesion. DWI measures the random motion of water molecules in the body. This free motion of water is inhibited in both the intracellular and extracellular spaces by increased cellularity and intact cell membranes; thus, this technique complements morphological information obtained by conventional MR imaging. Staging for metastatic lesions have been of particular interest since cell membranes in hypercellular tumor tissue serve as barriers to free diffusion in the intracellular and extracellular spaces.

An in- and out-of-phase gradient sequence is essential for detection of adenomas of the adrenal gland and hepatic steatosis. New 3D, 2-point Dixon sequences provide in- and out-of-phase sequences with additional fat-only and water-only sequences. The water-only sequence can be used as a pre-contrast dynamic in-phase, fat-saturated, T1-weighted volume. Obtaining early arterial dynamic contrast enhancement of the liver is crucial for differentiating lesions, and there are several methods for determining the proper timing of contrast, which we discuss later.

## Axial In- and Out-of-Phase Imaging

In- and out-of-phase imaging is a vital tool for characterizing lesions on MR. New gradient echo sequences provide a 3D, 2-point Dixon technique that provides in- and out-of-phase sequences along with water- and fat-only data sets, which are reconstructed once the scan is complete. By adding the raw data sets of the in- and out-of-phase acquisitions, a water-only, T1-weighted image set is obtained that can be used as a pre-contrast dynamic sequence, minimizing the number of breath holds for a patient and thereby reducing the protocol time. If the raw data sets from the in- and out-of-phase vectors are subtracted, a fat-only image is reconstructed, which is useful for detection of small amounts of fat, eg, focal fatty infiltration or hepatic or adrenal adenomas. When using in- and out-of-phase imaging, efforts should be made to use a sequence that allows both echoes to be acquired in the same breath hold so that misregistration of slices is kept to a minimum.

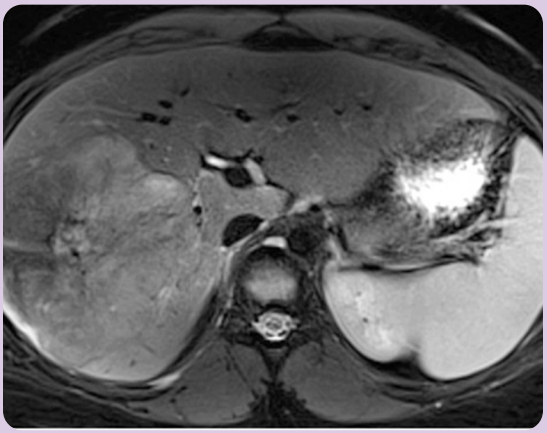

**Figure 65. Axial T2-weighted FSE with fat saturation demonstrates a large fibro-lamellar carcinoma in the right liver lobe.** *Courtesy of Dr. Elmar Merkle, Duke University Hospital.*

## Axial T2-Weighted Fast Spin Echo

T2-weighted FSE or single shot fast-spin echo (**SSFSE**) are routinely used in the liver for lesion detection and characterization (Figure 65). Again, the decision should be made regarding whether or not to breath hold during this scan. This is a good opportunity to use a **respiratory trigger** or **navigator device** to trigger the scans according to a patient's respiratory cycle, especially for patients who have a difficult time holding their breath. Trigger and navigator placement are important for the success of this sequence, with the navigator device placed at the dome of the liver

for optimal tracking. If the decision is made to breath hold the T2s, educating the patient to breathe in the same manner is essential so that misregistration of the liver is kept to a minimum and lesions are not missed because of poor breath holding.

## Dynamic Liver Imaging

Most liver exams require the use of a contrast medium to help differentiate neoplasms. Evaluation of arterial enhancement is crucial for proper diagnosis, and this process can be intimidating when approaching abdominal imaging. There are several methods by which to time the delivery of contrast to the liver, and each diagnostic center decides which is best, based on their own equipment.

### *Bolus timing*

Accurate timing of the arterial (or first) post-contrast phase can be performed by employing a quick circulation-time test prior to the start of the dynamic study. Many imaging centers use this technique for liver and pancreatic MRI. This "test-bolus" technique is commonly used to accurately time gadolinium-enhanced 3D MR angiograms, and for similar reasons it can be performed to better time the arterial phase of contrast enhancement. The disadvantage is some loss of total contrast dose and some background parenchymal enhancement of liver tissue. To perform imaging with test bolus tracking, the technologist obtains a **scout image**, selecting a slice near the celiac artery. The test bolus, approximately 1-2 mL of contrast, is injected with 20 mL saline, and a time-intensity graph is obtained to determine the time of peak intensity and therefore the delay time. The remaining bolus is then administered, and arterial phase imaging is initiated after the calculated time delay.

### *Bolus tracking*

Each manufacturer has different names for bolus tracking or computer-aided detection of contrast media. To perform bolus tracking, the technologist obtains a scout image and selects the region of interest. Imaging starts when the ROI becomes **opacified**. The scan will be auto-triggered when the intensity increases approximately 20% or manually when the technologist initiates a scan. To be successful, this method relies on proper placement of the bolus detection device.

### *Multiphase dynamic imaging*

Multiphase dynamic imaging employs a lower spatial resolution sequence with several dynamic phases, using a 3D T1-weighted, fat-saturated, fast-spoiled gradient sequence taken in rapid succession. For example, there might be three phases or acquisitions—one every six to eight seconds. Within one of these phases, the early arterial phase at its peak will be captured, as well as a late arterial phase that may be best suited for the detection and characterization of focal liver lesions. While it can be a fairly long breath hold, one or two phases should be sufficient for diagnosis if a person cannot hold their breath for 24 seconds. The dynamic timing of contrast is straightforward: if a patient is under 60 years of age, use a scan delay of 15 seconds; if they are over 60 years of age, use a scan delay of

**The dynamic timing of contrast is straightforward: if a patient is under 60 years of age, use a scan delay of 15 seconds; if they are over 60 years of age, use a scan delay of 20 seconds.**

20 seconds. While this scan is often of lower spatial resolution, multiphase dynamic imaging is foolproof for obtaining excellent arterial contrast timing.

While proper dynamic enhancement is essential for accurate diagnosis of liver lesions, capturing high-resolution images of the hepatic vasculature system and subsequent parenchymal enhancement is important as well. Once the initial arterial scan is complete, the next scan should be set up and ready to apply as soon as possible. Portal vein enhancement occurs approximately 45-75 seconds post-injection, so the window of opportunity is small. The equilibrium state of the liver occurs approximately 90-120 seconds after administration of contrast. The fast perfusion of the liver with contrast requires a patient to do quite a bit of breath holding, emphasizing the importance of using non-breath-hold sequences prior to the strenuous series of breath holds that the patient must perform to acquire good dynamic images (Figure 66). See Sample Liver Protocol (Table 7) and Optional Liver Sequence (Table 8) at the end of this chapter.

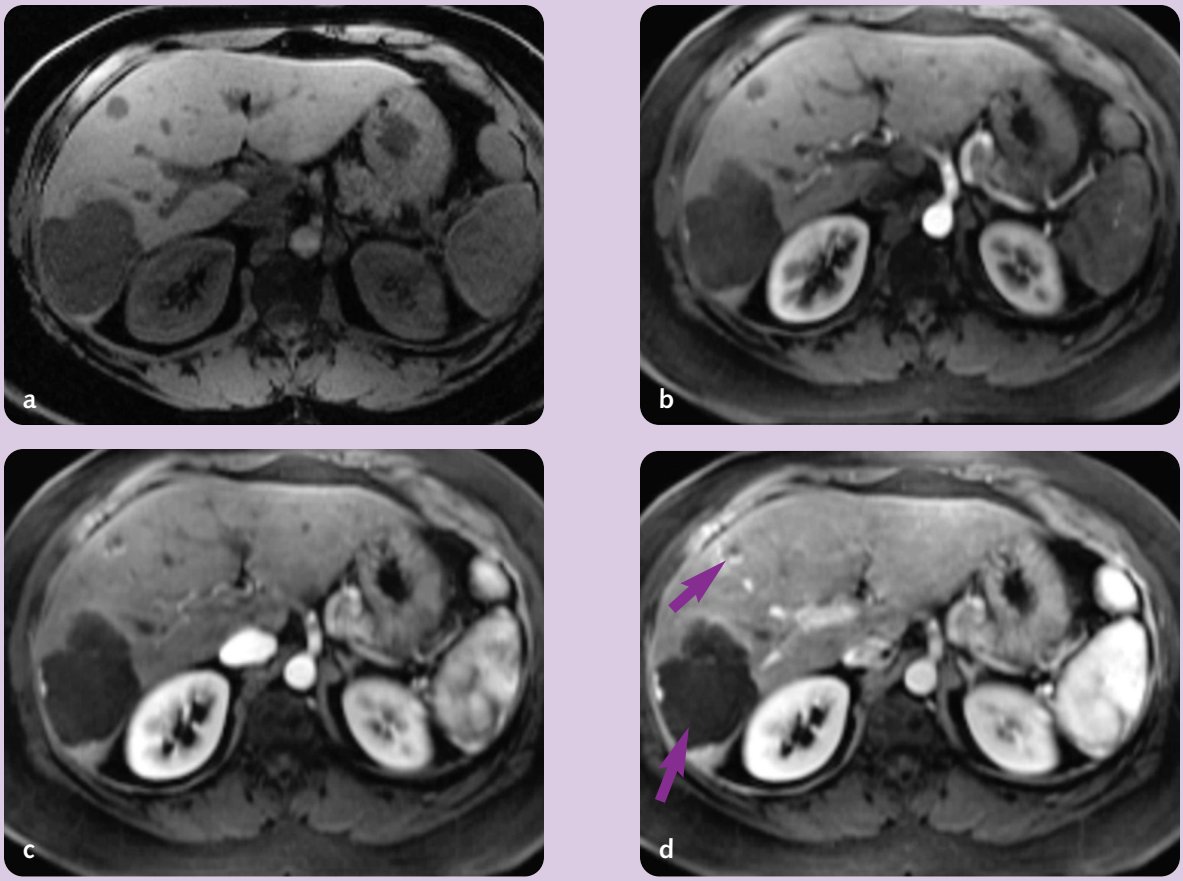


**Figure 66. Multiphase dynamic imaging. (a) Pre-contrast. (b) First arterial phase. (c) Second arterial phase. (d) Third arterial phase. Two hemangiomas are seen in the right hepatic lobe (arrows).** *Courtesy of Dr. Elmar Merkle, Duke University Hospital.*

## MRI FINDINGS

The liver is imaged to detect and characterize either **focal** diseases or **diffuse** processes. These can easily be separated into benign and malignant lesions or primary and secondary lesions. Most commonly encountered focal diseases include hemangiomas, cysts, focal nodular hyperplasia, hepatic adenoma, hepatocellular carcinoma, and metastatic neoplasms. Most common diffuse processes include cirrhosis, hemochromatosis, hemosiderosis, and hepatic steatosis.

### Benign Disease Processes

#### Hemangiomas

**Hemangiomas** are common benign lesions that are clinically important only because they can be easily mistaken for malignant processes. Hemangiomas themselves seldom cause clinical problems, with the exception of giant hemangiomas, which can occasionally cause symptoms of pain or other discomfort when they become larger than 5.0 cm.

Hemangiomas are characteristically very high in signal intensity and sharply circumscribed on T2-weighted images. The primary diagnostic criterion is the very characteristic pattern of contrast enhancement exhibited by hemangiomas following gadolinium administration. Hemangiomas depict characteristic discontinuous peripheral nodular enhancement with eventual complete or partial fill-in of the remainder of the lesion following contrast administration. The entire enhancement process may take less than one minute in some cases or several minutes for larger lesions; therefore, at least three to four post-contrast data sets are quickly acquired immediately following contrast administration. The first two should be performed to coincide with the arterial and portal-venous phases of perfusion (Figure 67).

#### Cysts

Liver cysts, like hemangiomas, are benign lesions that are only occasionally of importance but can be confused on some studies because they can mimic neoplasms if not

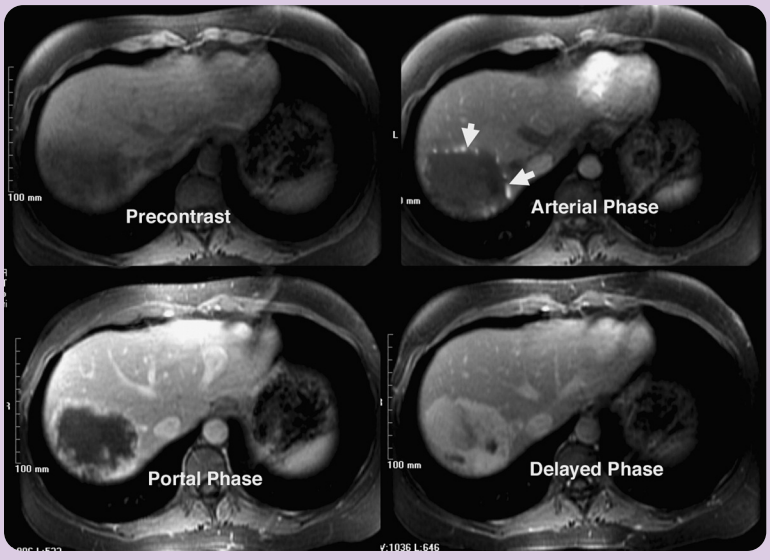


**Figure 67. Dynamic pre- and postgadolinium-enhanced images of a liver hemangioma. The primary diagnostic criterion for liver hemangioma is this very characteristic pattern of discontinuous peripheral nodular enhancement with eventual complete or partial fill-in of the remainder of the lesion following gadolinium administration (arrows).**

imaged correctly. Like hemangiomas, they are very bright on T2-weighted sequences and very sharply circumscribed. Liver cysts usually can be characterized without contrast enhancement, but when contrast is used, the cysts will not enhance. Occasionally the adjacent liver tissue appears to enhance slightly more than the remainder of the liver parenchyma. This is not the cyst enhancing but may represent compressed normal liver appearing to enhance differently than the adjacent liver.

## Focal Nodular Hyperplasia

**Focal nodular hyperplasia (FNH)** is a benign and commonly encountered liver lesion. FNH is a collection of benign **hepatocytes** that derive most of their blood supply from the hepatic artery, while the remainder of the liver receives its supply predominantly from the portal vein. Because these lesions are comprised of normal hepatic tissue, they are often very subtle on unenhanced images, having T1 and T2 properties similar to normal hepatic parenchyma. In some lesions, there may be a central region, called a **central scar** or **fibrovascular core**, which may be slightly darker than the liver on T1 images and slightly brighter on T2 images. Following gadolinium administration, FNH characteristically hyperenhances on the arterial phase and eventually **equilibrates** with the remainder of the liver on later phases of enhancement. Using a contrast agent with hepatocellular properties can help characterize FNH lesions as FNH typically demonstrates a popcorn-like enhancement pattern on delayed imaging (Figure 68).

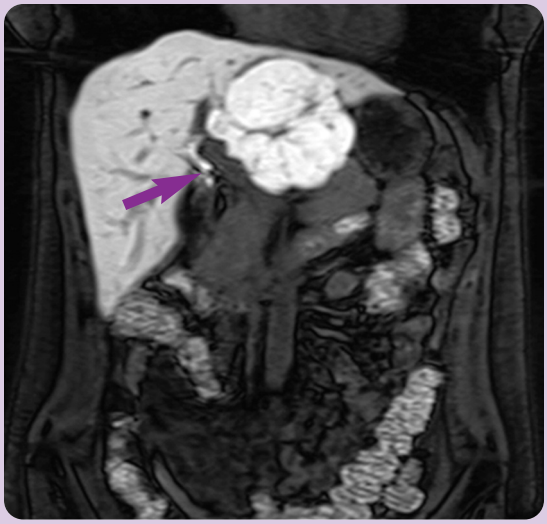

Figure 68. **Coronal T1-weighted fat-saturated 3D gradient echo image acquired 20 minutes post-administration of hepatocellular-specific contrast agent. A large FNH is seen in the left hepatic lobe, which is hyperintense compared to the rest of the liver. Note also the biliary excretion of the GBCA (arrow).** *Courtesy of Dr. Elmar Merkle, Duke University Hospital.*

## Hepatic Adenomas

**Hepatic adenomas** are benign lesions that are clinically important because they tend to bleed on occasion and cause symptoms; in rare instances, they can be serious. Hepatic adenomas are comprised of benign liver cells

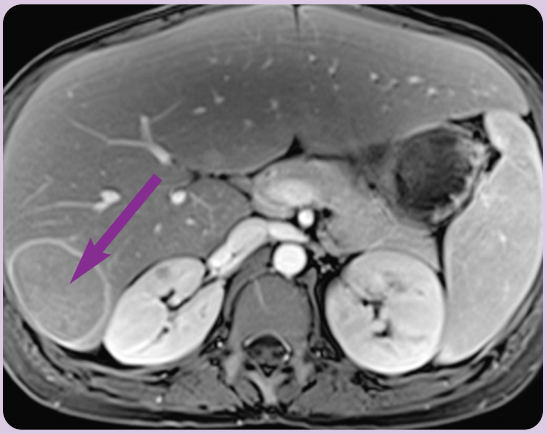

Figure 69. **Hepatic adenoma demonstrates capsular enhancement (arrow).** *Courtesy of Dr. Elmar Merkle, Duke University Hospital.*

but tend to be much more disorganized than FNH and therefore are more heterogeneous than FNH on both unenhanced and enhanced images. Although some adenomas may appear exactly the same as FNH, they sometimes contain blood or blood products, making them more detectable on MR and therefore more likely to be diagnosed. In a minority of cases, multiple hepatic adenomas, sometimes more than 10 or 20, appear simultaneously in a condition known as hepatic **adenomatosis** (Figure 69).

### Hemochromatosis and Hemosiderosis

**Hemochromatosis** and **hemosiderosis** are both conditions where the liver contains too much iron. The iron causes T2* effects, leading to liver signal loss on all pulse sequences with the effect most pronounced on gradient echo images due to the lack of a refocusing pulse. Hemochromatosis is a genetic disease in which the liver, pancreas, heart, and other organs collect too much iron, which can lead to the development of **hepatocellular carcinoma (HCC)** in the liver.

Hemosiderosis is caused by too many blood transfusions or by blood disorders where the red blood cells are abnormal. Iron released by the blood cells is ingested by cells of the reticuloendothelial cell system (**RES**). The RES cells reside in the liver, spleen, and bone marrow, and thus these areas appear dark on MR imaging. The best "routine" pulse sequence to look for iron storage is the gradient dual echo in- and opposed-phase series where the signal intensity in the liver is markedly lower on the images with the longer echo time.

### Hepatic Steatosis

**Hepatic steatosis** is a condition where fat is stored in the liver. Steatosis, also known as fatty infiltration of the liver, has many appearances, ranging from only a small focal area of liver involvement to regional or geographic involvement, then lobar, and all the way to complete parenchymal involvement. There are many causes of hepatic steatosis, and it is a very common entity in the USA. Occasionally, focal fatty infiltration or focal areas of normal liver that are spared from fatty infiltration in an otherwise fatty liver may be misdiagnosed as a focal **neoplasm** or other disease. The fatty areas have higher signal intensity on non-fat-saturated T1 and FSE T2 images. Because the liver in the region of fat has an intracellular mixture of fat and water, it loses a substantial amount of signal intensity on opposed-phase MR imaging techniques. This is an excellent indication for using the 3D 2-point Dixon gradient-echo sequence described earlier.

## Malignant Disease Processes

Metastatic disease to the liver is common for many primary neoplasms, such as colon, breast, lung, and renal cancer. Liver MRI is performed to stage the liver in order to both detect and characterize metastases that exist or to differentiate benign lesions from metastatic disease. Metastases are typically bright on T2-weighted images and darker than normal liver on T1-weighted images. Unlike hemangiomas or cysts, metastases are normally only moderately high in signal intensity and may be very heterogeneous in appearance, sometimes having a "target" or "bull's-eye" appearance of higher central signal and layers of peripheral lower signal intensity on T2-weighted images. Following gadolinium administration, metastases may completely enhance very quickly on the arterial phase, or they may show a ring of complete peripheral enhancement followed by partial or complete fill-in on delayed views.

**Hepatocellular carcinoma (HCC)**, or hepatoma, is a primary malignancy that arises from the liver itself. HCC is most commonly seen in patients with cirrhosis but occasionally arises in an otherwise normal liver. On imaging, HCC has varied appearances. Typically, these are solid masses that have a moderately high T2 signal intensity, and they enhance relatively quickly and heterogeneously following contrast administration. Following gadolinium administration, the arterial phase images are of critical importance as some HCCs will only be evident on this phase and not detectable on any other phase of perfusion or on unenhanced images. HCCs may have a well circumscribed capsule that can be visualized on MR; they occasionally contain fat and frequently have "daughter" lesions that are small HCCs along their margins (Figure 70).

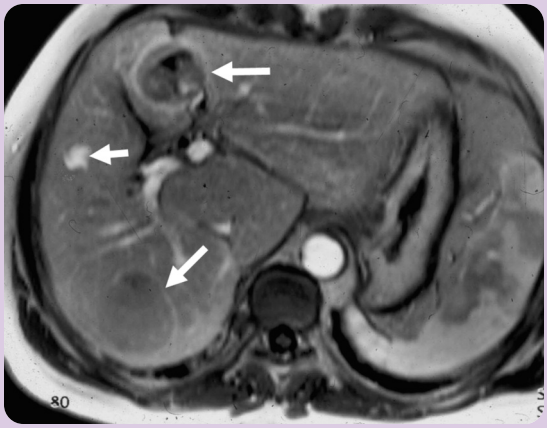

**Figure 70. Hepatocellular carcinomas have numerous appearances on MRI. This gadolinium-enhanced T1 GRE image shows three HCCs (arrows), each with a slightly different morphology. HCCs can be small and hypervascular, solid and homogeneous, encapsulated, necrotic, diffusely infiltrating, contain fat, or have small "daughter" HCCs along their margin.**

### Cirrhosis

**Cirrhosis** is a disease that arises because of continuous and prolonged injury to the liver. Common causes include chronic hepatitis B or C, alcohol abuse, or autoimmune diseases. Because of the repeated injury, the liver must continuously repair itself, creating many areas of **fibrosis** and regeneration of **hepatocytes**, which typically leads to a nodular pattern throughout the liver. The right lobe tends to atrophy while the caudate lobe becomes larger. Cirrhosis is often associated with the development of **ascites**, enlargement of the spleen, development of larger collateral blood vessels throughout the abdomen (varices), and reversal of blood flow in the portal vein. Imaging patients with cirrhosis can be a challenge because their breath-holding abilities may not be as good as in healthier patients. The ascites associated with cirrhosis can cause imaging artifacts, particularly on T2-weighted images. Finally, the liver eventually becomes quite small, making it more difficult to image and detect lesions.

## MR CHOLANGIOPANCREATOGRAPHY

### MRCP vs ERCP

Magnetic resonance cholangiopancreatography (**MRCP**) is a noninvasive test for evaluation of the bile ducts, gallbladder, and pancreatic duct. By using heavily T2-weighted sequences, the signal of static or slow-moving fluid-filled structures such as the bile and pancreatic ducts is greatly increased, resulting in increased duct-to-background contrast. MRCP is comparable to invasive endoscopic retrograde cholangiopancreatography (**ERCP**) for diagnosis of extrahepatic bile duct and pancreatic duct abnormalities, such as stones, malignant obstruction, congenital anomalies, and chronic pancreatitis.

In most institutions, MRCP has become the first-line imaging tool for the biliary system, with ERCP reserved for therapeutic indications as ERCP is not without risk. Some ERCP patients contract pancreatitis due to contrast injection into the pancreatic duct, which can result in hospitalization and occasionally serious complications.

## Indications for and Benefits of MRCP

Indications for MRCP include unsuccessful ERCP, contraindication to ERCP, or a low index of suspicion that disease requiring endoscopic intervention is present. Although ERCP is still the standard of reference for imaging the biliary system, there are specific advantages of MRCP over ERCP. MRCP is noninvasive, less expensive, uses no radiation, requires no anesthesia, is less operator-dependent and allows better visualization of ducts proximal to an obstruction and detection of extraductal disease. Therefore, MRCP continues to grow as a diagnostic procedure (Table 6).

## Imaging Parameters

While MRCP has become a very important imaging tool in recent years, protocols vary between MR manufacturers and institutions. In general, MRCP is performed with ultrafast, heavily T2-weighted sequences using both 2D thick slab (single section) and 2D thin slice in axial or coronal planes and coronal thin slice 3D respiratory triggered fast-spin echoes. The thick section coronal plane provides a cholangiographic display that mimics the appearance of the bile ducts on ERCP. One orthogonal coronal slab and two slabs angled plus or minus 20° is helpful in demonstrating the biliary anatomy. By examining these thick slab sequences, a determination can be made as to which slab best demonstrates the junction of the common bile duct and the pancreatic duct. Next, thin section sequences can be set up to best evaluate the pancreatic duct and distal common bile duct. Especially in patients who are not able to hold their breath, 3D respiratory triggered sequences in a coronal plane can be very useful in MRCP evaluation.

| | MRCP | ERCP |
|---|---|---|
| **Indications** | Unsuccessful or contraindication to ERCP | Aids in diagnosis of extrahepatic bile ducts and pancreatic abnormalities |
| | Low suspicion for disease requiring endoscopic intervention | |
| **Advantages** | Noninvasive, less expensive, and uses no radiation | Patient is generally sedated and cooperative |
| | Allow for better visualization of ducts proximal to an obstruction and extraductal disease. | Allows for therapeutic intervention of obstructed bile ducts |
| | Done without contrast | Generally less expensive |
| **Disadvantages** | Claustrophobia | Patient can contract pancreatitis from contrast |

Table 6. MRCP vs ERCP

## Thick Slab MRCP

While the thick slab images more closely resemble conventional cholangiograms and are familiar to many clinicians, spatial resolution is degraded because of **volume averaging** effects. These single shot fast-spin echoes (SSFSE, HASTE, etc.) are a more rapid MRCP sequence performed in a single breath hold, thereby significantly reducing motion artifacts and increasing image quality. Because of less motion artifact with SSFSE, SNR increases compared with that of fast-spin echo MRCP. The use of a breath-hold technique helps reduce artifacts from respiratory motion and section misregistration. The combination of rapid sequences and the torso phased-array coil or one of the newer 8-channel array coils makes it possible to visualize ducts as small as 1 mm in diameter. In addition, owing to the shorter spacing of the RF pulses, susceptibility artifacts from the intestine, surgical clips, catheters, and stents, for example, are reduced with the single shot fast-spin echo sequence (Figure 71).

## Thin Slice MRCP

3D, respiratory triggered, thin slice acquisitions provide greater spatial resolution than thick slabs. The source images can be scrutinized to not overlook small filling defects and strictures easily missed on thick slab images. These 3D acquisitions can be post-processed and MIP images obtained for 360° rotations of the entire biliary system. Proper respiratory triggering is essential for clear, high-resolution images. When using a navigator device, care should be taken to ensure placement at the dome of the liver. If using a respiratory belt, it is important that the waveform is reliable before starting the sequence. When using 2D thin slice imaging, patient education about proper breath hold techniques is important. Misregistration is a common problem, as contiguous slices through the pancreas and gall bladder are preferable. See Table 9 on page 66 for additional sequences for MRCP protocols.

# MRI FINDINGS

## Choledocholithiasis

**Choledocholithiasis** (bile duct stones) is a common indication for MRCP. MRCP is comparable to ERCP in detection of bile duct stones and superior to CT or US. Up to 25% of patients with acute **cholecystitis** (gallbladder stones and inflammation) have bile duct stones, and MRCP is often performed as part of the preoperative workup. Bile duct stones are readily identified as dark filling

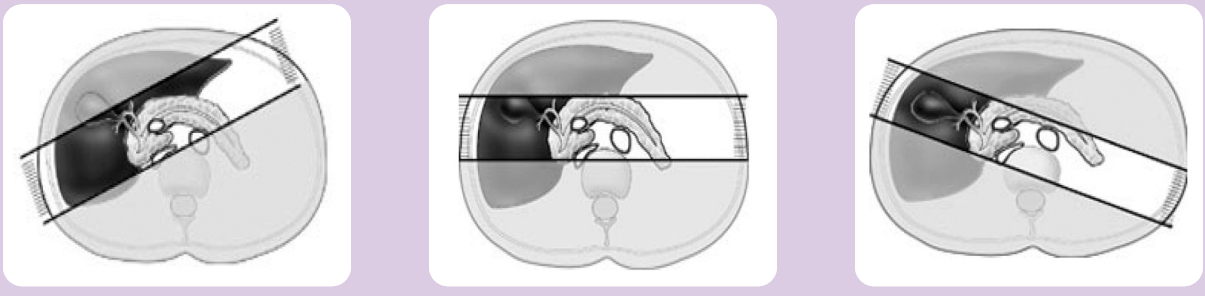

**Figure 71. Thick slab. This series shows how the slices should be prescribed for thick slab SSFSE.** *Courtesy of www.mrprotocols.com*

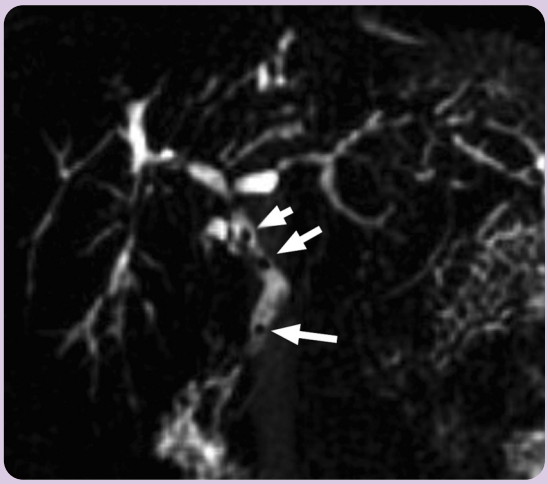

**Figure 72.** Multiple common bile duct stones are depicted on this coronal thick section T2-weighted SSFSE MRCP image (arrows).

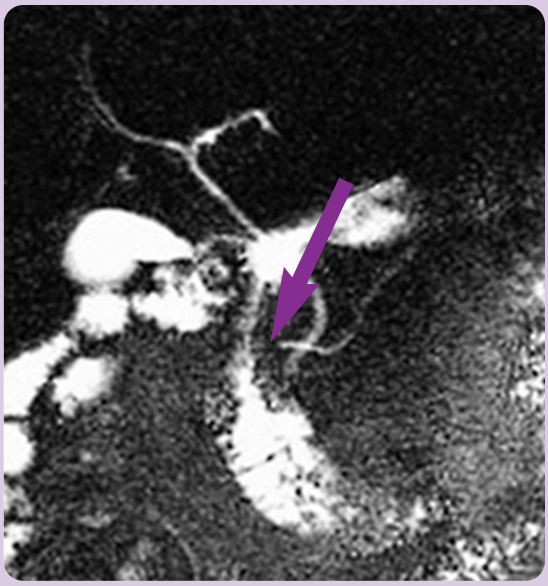

**Figure 73.** Pancreatic divisum. Depicts the dorsal and ventral pancreatic ducts of the body and tail draining through the minor papilla (arrow).

defects within the high-signal intensity bile fluid on MRCP (Figure 72). Stones as small as 2 mm in diameter can be visualized. The accuracy of stone detection is improved with SSFSE techniques due to reduction of motion and susceptibility artifacts. Small stones may not cause secondary **dilatation** of the ducts and are best seen on source images. The differential diagnosis of filling defects in the bile ducts most commonly includes stones and air bubbles; however, neoplasms, blood clots, concentrated bile, metallic stents, flow voids, and susceptibility artifact from surgical clips must be ruled out.

## Benign Strictures

Benign strictures are most commonly seen after an injury to the extrahepatic bile ducts during cholecystectomy, although other causes include infection, pancreatitis, stone passage, trauma, and primary **sclerosing cholangitis**. MRCP is comparable to ERCP for demonstrating the location and extent of strictures of the extrahepatic bile duct.

## Congenital Anomalies

Congenital anomalies involve variations of the bile ducts from the commonly described anatomic pattern. MRCP is accurate in diagnosis of aberrant hepatic ducts and cystic duct variants. Anatomic variants have high potential for injury during gallbladder removal. The most common anomalies are an aberrant right hepatic duct with insertion into the common hepatic duct or cystic duct, a long intramural cystic duct parallel to the common hepatic duct, or a cystic duct inserting medially on the common bile duct. **Pancreas divisum**, the most common anatomic variant of the pancreas, results from failure of fusion of the dorsal and ventral pancreatic ducts and may be associated with an increased prevalence of acute pancreatitis. MRCP has been shown to have up to 100% accuracy for detection of pancreas divisum (Figure 73).

## Malignant Bile Duct Obstruction

Malignant bile duct obstruction is usually due to pancreatic neoplasms. Other causes include **cholangiocarcinoma (**bile duct cancer), metastases, and **lymphadenopathy**. Most malignant pancreatic neoplasms are **adenocarcinomas** that present as a focal mass in the pancreatic head. With MRCP, dilatation of both the pancreatic and bile ducts (the **double duct sign**) is highly suggestive of a pancreatic head malignancy. The addition of T1- and T2-weighted sequences to MRCP improves specificity by allowing visualization of extraductal structures.

### Chronic pancreatitis

**Chronic pancreatitis** is a chronic inflammatory process of the pancreas that results in irreversible dysfunction and **morphologic** changes. The hallmark of this disease process is dilated side branches of the main pancreatic duct. Pancreatic **pseudocysts** are encapsulated collections of pancreatic fluid that can occur in association with acute or chronic pancreatitis. MRCP is more sensitive than ERCP in detection of pseudocysts because less than 50% of pseudocysts fill with contrast material at ERCP. However, MRCP is less sensitive than ERCP in demonstrating the site of communication with the pancreatic duct. Close scrutiny of the source images is necessary so that strictures or filling defects not be overlooked, since the high-signal intensity pseudocysts may obscure portions of the pancreatic and bile ducts.

## SUMMARY

MR abdominal imaging continues to be a dynamic field. With significant advances in software and hardware, coils with higher receiver channels, and new hepatobiliary-specific contrast agents, the quality of liver and pancreatic imaging has improved and is rapidly becoming the standard of care. With state-of-the-art scanners and parallel imaging techniques, the acquisition times for most body sequences are short enough to be performed with breath holds, resulting in completed exams in less than 30 minutes and making abdominal imaging a cost-effective way to safely evaluate the hepatobiliary system.

Table 7.

**SAMPLE LIVER MRI PROTOCOL (1.5 T)**

| Parameter | 3-Plane Localizer | Coronal SSFSE | Axial T2 Fat Sat* | Axial in/out phase 2D | Axial FSPGR Triple Phase Fat Sat Dynamic | Axial FSPGR Fat Sat Portal Venous | Axial FSPGR Fat Sat Equilibrium |
|---|---|---|---|---|---|---|---|
| **Imaging Parameters** | | | | | | | |
| Pulse Sequence | Gradient | Single Shot Fast Spin Echo | Fast Spin Echo | Gradient | Fast Spoiled Gradient | Fast Spoiled Gradient | Fast Spoiled Gradient |
| Echo Time (TE) | min | 140 | 80-100 | IP = 2.1ms<br>OP = 4.2ms | min | min | min |
| Repetition Time (TR) | min | min | 3-6,000ms | 150-250ms | min | min | min |
| Flip Angle (FA) | | | | 80 | 12 | 12 | 12 |
| Options | | Fast, SS, ASSET | FC, TRF, RT, Fast | ASSET | Zipx2, ASSET | Zipx2, ASSET | Zipx2, ASSET |
| Slice Thickness (mm) | 10 | 6 | 6mm | 2D = 6mm | 4-8mm | 3-6mm | 3-6mm |
| Slice Spacing (mm) | 0 | 2 | 2D=1.5mm | 2D=1.5mm | 0 | 0 | 0 |
| Sat Bands | | | S, I, F | S, I | F | F | F |
| Matrix | 256 x 128 | 256 x 192 | 320 x 224 | 256 x 192 | 256 x 160 | 256 x 160 | 256 x 160 |
| Number of Excitations | 1 | 1 | 2 | 1 | 1 | 1 | 1 |

* Use respiratory triggering or a navigator to assist with respiratory artifact. Scan can be done breath held. See Optional Liver Sequences.

Table 8.

## OPTIONAL LIVER MRI SEQUENCES (1.5T)

| Parameter | 3D Gradient In/Out 2 Point Dixon* | Axial Diffusion** Non-Breath Hold | Axial T2 Breath Hold |
|---|---|---|---|
| **Imaging Parameters** | | | |
| Pulse Sequence | Gradient | DW EPI | Fast Spin Echo |
| Echo Time (TE) | TE1=2.3, TE2=4.6 | Min | 80-100 |
| Repetition Time (TR) | Min | 3500 | 2000-4000 |
| Flip Angle (FA) | 12 | 90 | 90 |
| Options | ASSET | ASSET, EPI, Diff | TrF, Fast, ASSET, FR |
| Slice Thickness (mm) | 4 | 6mm | 6mm |
| Slice Spacing (mm) | 0 | 1.5mm | 1.5mm |
| Sat Bands | | | S, I, Fat |
| Acquisition Matrix Frequency | 256 x 160 | 132 x 160 | 256 x 192 |
| Number of Excitations | 1 | 10 | 1 |

* Reconstructs in- and out-of-phase images, as well as fat and water only images.
** Ramp Sampling = 1 B-Value = 50,800 Diffusion Direction = S > I

Table 9.

## ADDITIONAL SEQUENCES FOR MRCP PROTOCOL (1.5T)

| Parameter | Coronal Haste 3D Thick Slab | Haste 3D Thick Slab +20 Degrees | Haste 3D Thick Slab –20 Degrees | Coronal 3D FSE* | Coronal 2D Thin Slice** |
|---|---|---|---|---|---|
| **Imaging Parameters** | | | | | |
| Pulse Sequence | Single Shot Fast Spin Echo | Single Shot Fast Spin Echo | Single Shot Fast Spin Echo | Fast Spin Echo, Fast Rec. | SSFSE |
| Echo Time (TE) | 700-800ms | 700-800ms | 700-800ms | Min ~ 700ms | 350ms |
| Repetition Time (TR) | Min | Min | Min | 2-3 R to R | 2000 |
| Sat Bands | Fat | Fat | Fat | Fat | Fat |
| Options | Fast, SS | Fast, SS | Fast, SS | Zipx2, ASSET, RT, EDR, FR, MRCP | Fast, SS |
| Slice Thickness (mm) | 40-60mm | 40-60mm | 40-60mm | 1-1.4mm | 3-4mm |
| Slice Spacing (mm) | 0 | 0 | 0 | 0 | 0 |
| Acquisition Matrix Frequency | 288 x 288 | 288 x 288 | 288 x 288 | 256 x 256 | 288 x 192 |
| Number of Excitations | 1 | 1 | 1 | 1 | 1 |

* Respirator triggering—use respiratory bellows or a navigator.
** LOC before pause—Split series into reasonable breath holds for patient.

## POINTS FOR PRACTICE

**1. What are the components of a basic liver MRI protocol?**

A basic liver MRI protocol involves a combination of breath-hold sequences and pulse sequences to demonstrate and differentiate abdominal tissue.

- Short as possible without compromising image quality
- Robust T2 and in- and out-of-phase images
- Unenhanced, arterial, portal venous, and equilibrium phase
- Arterial phase as early as possible
- Good mixture of breath-hold and non-breath-hold sequences

**2. List examples of potential barriers to obtaining high-quality liver MRI.**

- Patient's breath-holding ability
- The presence of ascites
- Anatomical variants
- Language barriers

**3. What are the three main methods for timing arterial enhancement for dynamic liver MR imaging?**

- Test bolus – employs a quick circulation time test by selecting a slice near the celiac artery and injecting 1-2 mL of contrast and creating a time-intensity graph to determine the time of peak intensity and therefore the delay time
- Bolus tracking – computer-aided contrast detection of contrast media
- Multiphase dynamic – utilizes a lower resolution multiphase dynamic and set time scan delays

**4. Why is multiphase imaging useful?**

This type of imaging is excellent for obtaining arterial contrast timing. It employs a lower resolution with three dynamic phases, using a 3D T1-weighted, fat-saturated, fast-spoiled gradient sequence in rapid succession. It also uses a fixed timing for scan delay, facilitating the proper timing for arterial enhancement.

**5. Why is the discovery and imaging of hemangioma clinically important?**

These common benign lesions can be easily interpreted as malignant processes.

**6. How is MRI helpful in diagnosis of secondary liver metastasis?**

Colon, breast, lung, and kidney cancers often metastasize to the liver, and MRI is helpful in characterizing lesions to determine benign versus malignant.

**7. What cancer arises from the liver itself?**

Hepatocellular carcinoma (HCC), also known as hepatoma, is a primary liver cancer. HCC is most often seen in patients with cirrhosis but can also be found in the normal liver.

## POINTS FOR PRACTICE

**8. What are the advantages and disadvantages of MRCP vs ERCP?**

MRCP is non-invasive, less expensive than ERCP, requires no anesthesia, and uses no ionizing radiation. MRCP allows for better visualization of ducts proximal to an obstruction and extraductal disease. The disadvantage is that the patient may be uncomfortable or become claustrophobic while lying in the magnet bore.

**9. List some malignant bile duct obstructions.**

Malignant bile duct obstructions are usually due to pancreatic neoplasms, but other causes are cholangiocarcinoma, metastases, and lymphadenopathy.

Notes