MRI of the Liver

MRI provides comprehensive information on the full range of liver diseases, including congenital abnormalities, benign and malignant focal liver lesions, and diffuse liver disease. We employ a protocol incorporating various types of T_1-and T_2-weighted sequences, including transverse and coronal data acquisition, and the routine use of intravenous gadolinium.

LIVER IMAGING

BASIC PROTOCOL

The high signal-to-noise ratio (SNR) obtained at high field strength makes it possible to image the entire liver during a single breath-hold sequence. The sequences described herein are based on the authors' experience with a Siemens 1.5 T Vision scanner, but are expected to be equally applicable to machines from other manufacturers.

Scanning a patient or volunteer is a joint effort among technologists, nurses, and physicians, with the technologist normally responsible for following proper scanning protocols and techniques. Unless otherwise specified, in what follows the person to whom directions are given is assumed to be the technologist. Table A15.1.1 lists the hardware necessary to perform the procedure, along with appropriate parameters.

The following ten sequences comprise the liver imaging protocol. This protocol employs multiple data acquisitions and early and late post-gadolinium imaging. However, most sequences are acquired in a single breath hold and the entire exam time is less than 15 min. Most sequences require the patient to be able to suspend respiration for ~25 sec. It is imperative that there be clear communication between the technologist and the patient throughout the exam. This protocol results in consistent, reproducible image quality that is effective for evaluating the full spectrum of liver diseases.

NOTE: Be sure that technologists and nurses have immediate access to any emergency equipment that may be relevant to a given study, or that may be needed for a particular patient, such as crash carts or oxygen.

Materials

Normal saline (0.9% NaCl), sterile, 40 ml minimum
Extravascular contrast agent (e.g., Magnevist, Omniscan, or Prohance), volume by patient weight

Table A15.1.1 Equipment Specifications for Imaging of the Liver

Coil type	Circular polarized body phased array coil
Field strength	1.5 T
Gradient strength	24 mT/m (or whatever the system permits, but minimum of 24 mT/m for sequences 2 and 4)
Knee cushion	Yes
Use of contrast agents	Yes
Pulse oximeter	If patient requires sedation
Power injector	Yes
Normal saline	Yes
35-in. extension tubing	Yes

Contributed by Laurie Fisher, Richard Semelka, and Kathy Wilber
Current Protocols in Magnetic Resonance Imaging (2001) A15.1.1-A15.1.14

Set up equipment and patient

1. Interview (screen) the patient to assess for contraindications such as cardiac pacemaker, implanted mechanical devices, and/or ferromagnetic materials. Also, determine if the patient has any health conditions that may require the presence of special emergency equipment during the scanning procedure, or if he or she will need sedation medication necessitating the use of appropriate monitoring equipment.

   Generally standard screening forms are used for all patients scanned in a magnetic resonance system.

   The presence of any ferromagnetic metals may be a health hazard to the patient when he or she is inside the magnet, and will also affect the imaging. If in doubt as to the exact composition of the items, it is best to exclude patients with any metal implants; see Shellock (1996) for discussion of what implants may be safely scanned using magnetic resonance.

   The presence of ferromagnetic materials in the globe of the eye is contraindicated for MRI. Patients with prior metal exposure to the eye should have plain X rays of the orbital area to ensure that all metal has been removed, prior to placing them in the magnetic field.

   Patients may be accompanied into the magnet room by a friend or family member, who can sit in the room during the scan and comfort the patient as needed. This companion must be screened as well to ensure the absence of loose metal objects on the body or clothing.

2. Explain the procedure to the patient and record relevant clinical history. Ensure that the patient understands what is expected and ask if there are any questions; answer appropriately. If the procedure is a research protocol, have the patient sign any necessary consent form.

3. Request that the patient change into a gown to eliminate any metal that might be found in clothing. Ask the patient to remove all personal effects such as jewelry, hearing aids, glasses, etc., prior to entering the MRI scan room.

   All personal belongings should be secured during the examination.

4. Fill a 20-ml syringe with normal saline and attach to saline filled extension tubing (35-in.). Obtain intravenous (i.v.) access utilizing a 22-G angiocatheter and attach saline-prepared extension tubing and syringe. This will allow you to flush the extension tubing with ~10 ml of saline while the patient waits to be imaged, and, in cases in which a power injector is not available, this will allow preparation for bolus injection (see Note below). Secure the position of the angiocatheter with tegraderm or tape.

   Obtaining i.v. access prior to entering the scan room will promote patient throughput and eliminate "dead" time of starting the i.v. while the patient is on the exam table. Follow power injector manufacturer guidelines with regard to appropriate gauge needle/angiocatheter to be used; this will depend on chosen injection/flow rates.

   NOTE: *If you do not have access to a power injector you will still be able to perform dynamic liver imaging, as the extension tubing will allow the saline syringe to be placed at the foot of the patient table during precontrast imaging. In this case, you will need to draw up the contrast agent in another syringe. When you are ready to bolus-inject the contrast agent, simply disconnect the saline syringe and connect the syringe filled with contrast agent; once you have injected the bolus of contrast agent, reconnect the saline syringe and bolus an appropriate volume of flush, usually ~10 ml. Alternatively, to eliminate the need of switching syringes, incorporate the use of a 3-way stopcock.*

5. Set up the exam room by securing the circularly polarized (CP) body array coil onto the table and providing a clean exam table.

6. Set up the power injector as specified by the manufacturer.

   A minimum of 40 ml normal saline should be drawn up to ensure sufficient saline is available to keep the vein open (KVO) throughout the exam. To determine the amount of

contrast agent to be used, reference the contrast agent packet insert and draw up the amount indicated per kg of patient weight. There is no need to double dose.

7. Escort the patient to the MR examination room and ask the patient to lie down accordingly with respect to the exam to be performed. Help the patient mount onto the table. Either before or right after the patient lies down, set up any triggering devices or other monitoring equipment that is to be used.
8. Connect the extension tubing, secured to the syringe, to the power injector extension tubing.
9. Inform the patient about what will occur during the procedure, what he or she will experience while in the magnet, and how to behave, including the following:
   a. If earphones or headphones are used to protect the ears from the loud sounds produced by the gradients, the patient will be asked to wear these, but will be able to communicate with you at any time during the imaging.
   b. The patient will be given a safety squeeze-bulb or similar equipment to request assistance at any time (demonstrate how this works).
   c. For good results the patient should not talk, and should avoid or minimize swallowing or other movement, during each scan—i.e., as long as the banging sounds continue. Between scans, talking and swallowing are allowed in most cases, but should be avoided when comparative positional studies are being performed; the patient will be informed when this is the case.

      Additionally, review breath-holding instructions with the patient, and provide the patient with an approximate time that the examination will take.

   d. Nevertheless, the patient may call out at any time if he or she feels it necessary.
10. Secure the top portion of the CP-body array coil to prevent it from moving side-to-side during breath-holding imaging sequences.

    Usually the manufacturer provides straps that are directly attached to the coil.

11. If needed, place a pillow or other support under the knees to make the patient more comfortable.
12. Use the laser light to position the patient, and to center the coil (see Table A15.1.2). Then, advance the patient table to isocenter.

    Once this step has been performed, so long as the patient does not move on the table, the table itself can be moved and then replaced in the same position as before without jeopardizing the positioning of one scan relative to another.

13. If the patient is unable to hold still, provide an appropriate sedative.
14. Program the power injector for a contrast agent and saline injection rate of 2 ml/sec. Total volume of saline following contrast agent injection should be programmed for 10 ml. Program a scan delay of 18 sec (contrast agent is injected, scan is initiated 18 sec after contrast and saline are delivered). Arm the power injector and keep the vein open.

    Do not inject the contrast agent at this time!

Sequence 1: Three-plane positioning scout

15. To validate the patient's position and to have a reference to prescribe successive imaging sequences, acquire a three-plane orthogonal scout sequence. See Table A15.1.2 for specific parameters.

Most MR scanners can be programmed to acquire the scout automatically after coil tuning or after the patient has been placed in isocenter (for systems that do not require tuning).

Sequence 2: Half-acquisition (partial Fourier) turbo spin echo coronal

16. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.3. Position slices to center of the transverse scout, ensuring that the entire liver is covered.

17. Instruct the patient to remain motionless and to breathe normally, as the scan will begin and last for ~40 sec.

Sequence 3: Gradient echo coronal

18. Duplicate the setup in step 17. Change imaging parameters to those listed in Table A15.1.4. Position slices to center of the transverse scout, ensuring that the entire liver is covered.

19. Instruct the patient to take in a deep breath and exhale, take in another deep breath, and hold it. Initiate the scan.

Sequence 4: Half-acquisition turbo spin echo transverse with fat saturation (fat suppression)

20. Display both the coronal and transverse scout images in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.5. Position slices to middle of liver on coronal scout, ensuring that the entire liver is covered.

    Perform system shim as recommended by manufacturer as this is a fat saturation sequence.

21. Instruct the patient to remain motionless and to breathe normally, as the scan will begin and last for ~40 sec.

Sequence 5: Turbo inversion recovery transverse

22. Display the midline slice of the gradient echo coronal image (sequence 3) and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.6. Position slices to cover from the top of the liver through mid liver. This sequence will need to be repeated in order to obtain coverage through the entire liver.

    It is imperative that the slices be prescribed off of the breath-hold gradient echo coronal image, as this is also a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

23. Instruct the patient to take in a deep breath and exhale, take in another deep breath and hold it, and initiate the scan.

24. Scan the slices inferiorly to cover the remaining liver that was not imaged, making it the second run. You should overlap the slices by at least one slice to ensure complete coverage. Repeat step 23.

Sequence 6: Gradient echo transverse (out-of-phase)

25. Display the midline slice of the gradient echo coronal image (sequence 3) and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.7. Position slices to cover entire liver.

Table A15.1.2 Imaging Parameters for Three-Plane Positioning Scout (Sequence 1)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal, transverse, and coronal
Central slice or volume center	Laser light centered approximately one hand width above the inferior rib margin
Echo time (T_E)	6 msec
Repeat time (T_R)	15 msec
Flip angle (FA)	30°
Fields of view (FOV_x, FOV_y)	450 mm, 450 mm
Resolution (Δx, Δy)	1.76 mm, 3.52 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	10 mm
Number of slices	3
Slice gap	Not applicable
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Not applicable
Saturation pulses	Not applicable
Scan time	16 sec

Table A15.1.3 Imaging Parameters for Half-Acquisition Turbo Spin Echo (Sequence 2)

Patient position	Supine
Scan type	Half acquisition turbo spin echo
Imaging plane (orientation)	Coronal
Central slice or volume center	Slices posted on transverse scout; center to liver
Echo time (T_E)	90 msec
Repeat time (T_R)	4.4 msec (note: the true T_R is infinite, 4.4 msec represents the echo spacing)
Delay time (T_D)	1500 msec
Flip angle (FA)	150°
Fields of view (FOV_x, FOV_y)	400 mm, 400 mm
Resolution (Δx, Δy)	1.56 mm, 2.08 mm
Number of data points collected (N_x, N_y)	256, 192 (using half Fourier)
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	40 sec

Table A15.1.4 Imaging Parameters for Gradient Echo Coronal (Sequence 3)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Coronal
Slice or volume center	Slices posted on transverse scout; center to liver
Echo time (T_E)	4.1 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	400 mm, 400 mm
Resolution (Δx, Δy)	1.56 mm, 3.12 mm
Number of data points collected (N_x, N_y)	256,128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	18 sec

Table A15.1.5 Imaging Parameters for Half-Acquisition Turbo Spin Echo with Fat Saturation (Sequence 4)

Patient position	Supine
Scan type	Half acquisition turbo spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	90 msec
Repeat time (T_R)	4.4 msec (note: the true T_R is infinite, 4.4 msec represents the echo spacing)
Delay time (T_D)	1500 msec
Flip angle (FA)	150°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 1.37 mm
Number of data points collected (N_x, N_y)	256, 192 using half Fourier
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	Yes, superior and inferior to slices
Fat suppression	Yes
Slice series	Interleaved
Scan time	40 sec

Table A15.1.6 Imaging Parameters for Turbo Inversion Recovery (Sequence 5)

Patient position	Supine
Scan type	Echo train inversion recovery
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices centered upper liver
Echo time (T_E)	76 msec
Repeat time (T_R)	5110 msec
Inversion time (T_I)	170 msec
Flip angle (FA)	160°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.65 mm
Number of data points collected (N_x, N_y)	256, 99
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	13
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice locations	First slice above top of liver (first run); mid liver down (second run)
Saturation pulses	No
Slice series	Interleaved
Scan time	20 sec

Table A15.1.7 Imaging Parameters for Gradient Echo Out-of-Phase (Sequence 6)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	2.2 msec
Repeat Time (T_R)	140 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	19 sec

It is imperative that the slices be prescribed off of the breath-hold gradient echo coronal image, as this is also a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

26. Instruct the patient to take in a deep breath and exhale, to take in another deep breath and hold it, and initiate the scan.

Sequence 7: Gradient echo transverse

27. Display the midline slice of the gradient echo coronal image (sequence 3) and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.8. Position slices to cover entire liver (Fig. A15.1.1).

Table A15.1.8 Imaging Parameters for Gradient Echo Transverse (Sequence 7)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	4.5 msec
Repeat time (T_R)	140 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Slice thickness (Δz)	8–10 mm
Number of slices	18
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice locations	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	18 sec

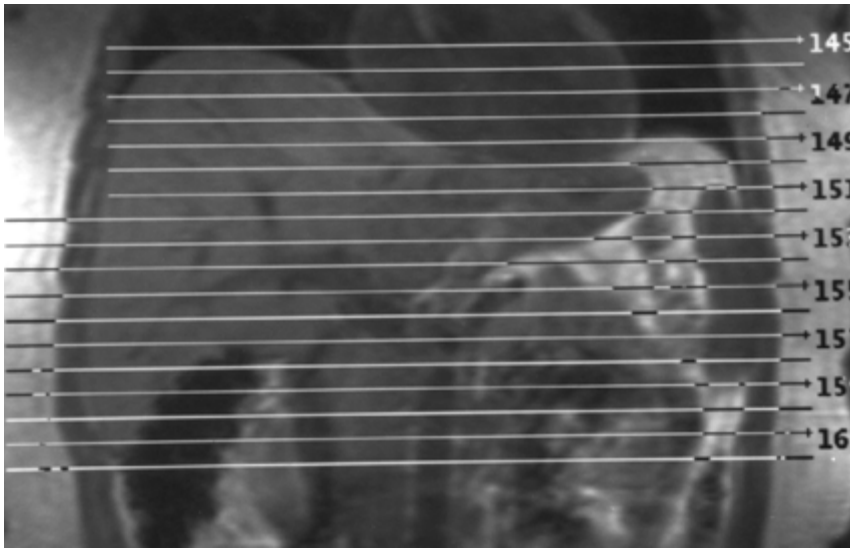

Figure A15.1.1 Coronal breath-hold image used to plan transverse breath-hold sequences.

It is imperative that the slices be prescribed off of the breath-hold gradient echo coronal image, as this is also a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

28. Instruct the patient to take in a deep breath and exhale, to take in another deep breath and hold it, and initiate the scan.

Sequence 8: Gradient echo transverse—immediate post contrast

NOTE: See patient setup section for specific instructions on preparation for contrast injection. This preparation must be done prior to placing the patient in the scanner.

29. Repeat step 27.

It is imperative that the slices be prescribed off of the breath-hold gradient echo coronal image as this is also a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breath-held image is used.

30. Explain to the patient that you will now be injecting the contrast agent and he or she may feel a cool sensation in his or her arm. Initiate the injection. Do not begin scanning until the 18-sec scan delay has expired. However, breathing instructions should be delivered when 10 sec of delay are remaining (see step 31).

If you do not have access to a power injector and are "hand" injecting, follow step 30. However, after you have completed the bolus contrast injection, reattach the saline-filled syringe and flush with 10 ml of saline. Begin breathing instructions after 5 ml of the saline has been injected, then proceed to initiate the scan. The process of switching syringes must be completed as quickly as possible and thus, the suggestion of incorporating the use of a 3-way stopcock.

31. When there are 10 sec of delay remaining, instruct the patient to take in a deep breath and exhale, then take in another deep breath and hold it Initiate the scan

Table A15.1.9 Imaging Parameters for Gradient Echo with Fat Saturation—90 Sec Delay (Sequence 10)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	4.1 msec
Repeat time (T_R)	147.2 msec
Flip angle (FA)	80°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	20
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Fat saturation	Yes
Slice series	Interleaved
Scan time	19 sec

Sequence 9: Gradient echo transverse (45-sec delay after sequence 8)

32. Repeat step 27 (see sequence 7).

33. Once 45 sec has expired, instruct the patient to take in a deep breath and exhale, then take in another deep breath and hold it. Initiate the scan

Sequence 10: Gradient echo transverse with fat saturation (90 sec delay after injection)

34. Display the midline slice of the gradient echo coronal image (sequence 3) and the transverse scout image in two separate quadrants on the scan monitor. Change imaging parameters to those listed in Table A15.1.9. Position slices to cover entire liver (Fig. A15.1.1).

It is imperative that the slices are prescribed off of the breath-hold gradient echo coronal image as this is also a breath-held imaging sequence. Otherwise, the slice location will not be accurate relative to the reference image if a non-breathheld image is used.

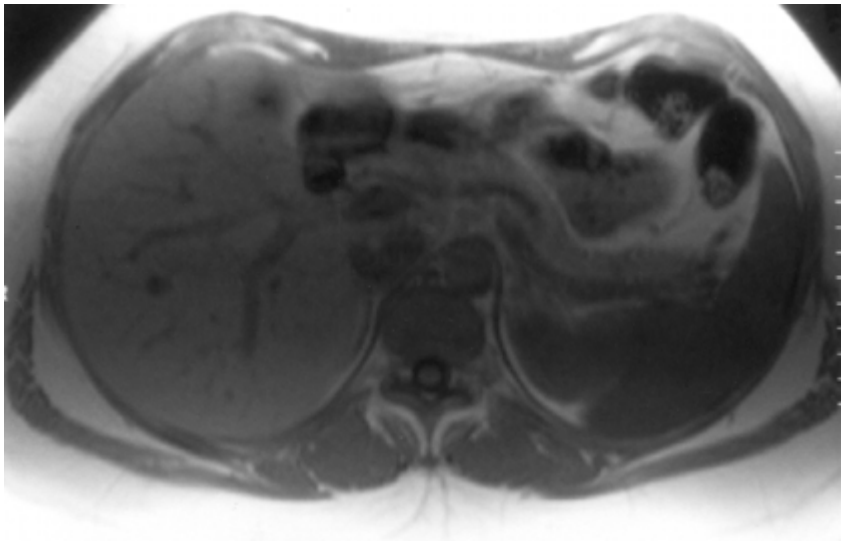

Figure A15.1.2 Unenhanced transverse spoiled gradient echo image.

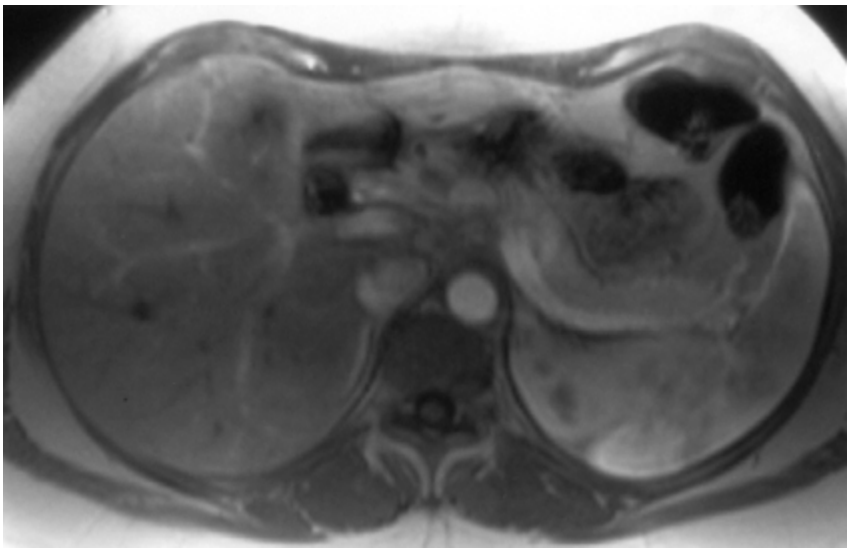

Figure A15.1.3 Immediate post-gadolinium spoiled gradient echo image (arterial phase) demonstrates the absence of gadolinium in hepatic veins and the presence of gadolinium in the hepatic arteries and portal veins.

35. Once 90 sec has expired, instruct the patient to take in a deep breath and exhale, then take in another deep breath and hold it. Initiate the scan.

COMMENTARY

Background Information

By using multiple data acquisitions and early and late post-gadolinium images (Figs. A15.1.2 through A15.1.5), accurate evaluation of liver disease can be made (Semelka et al., 1992, 1993, 1994, 1997, 1999; Low et al., 1993, 1999; Whitney et al., 1993; Larson et al., 1994; Oi et al., 1996; Semelka and Kelekis, 1997; Yamashita et al., 1996; Rofsky et al., 1999;). At the same time, we consider it imperative that each individual sequence be short, such that it can be acquired in a breath hold. This ensures that the entire study can be performed in 15 min or less (Semelka et al., 1999). Short study times permit good patient throughput and ensure that imaging quality will be good throughout the entire study. We have found that patient cooperation diminishes over the time course of

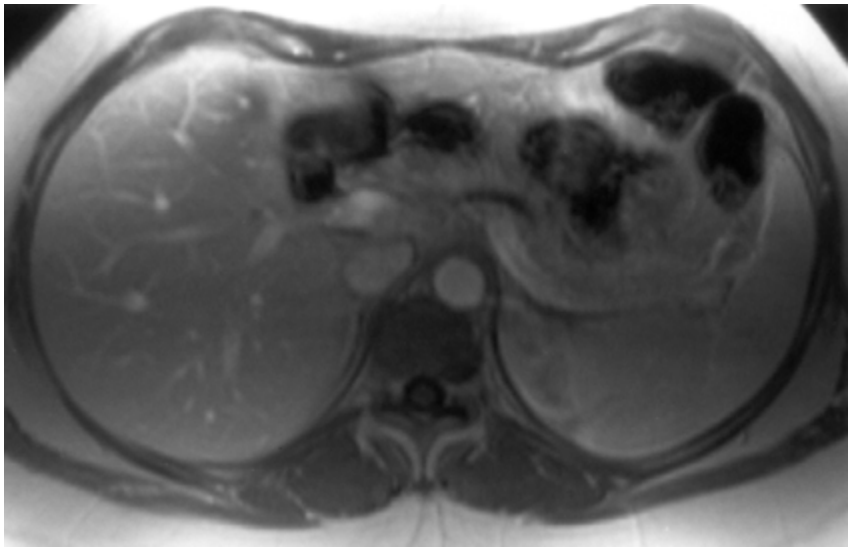

Figure A15.1.4 1-min post-gadolinium spoiled gradient echo transverse image (portal-phase) demonstrates maximal hepatic enhancement.

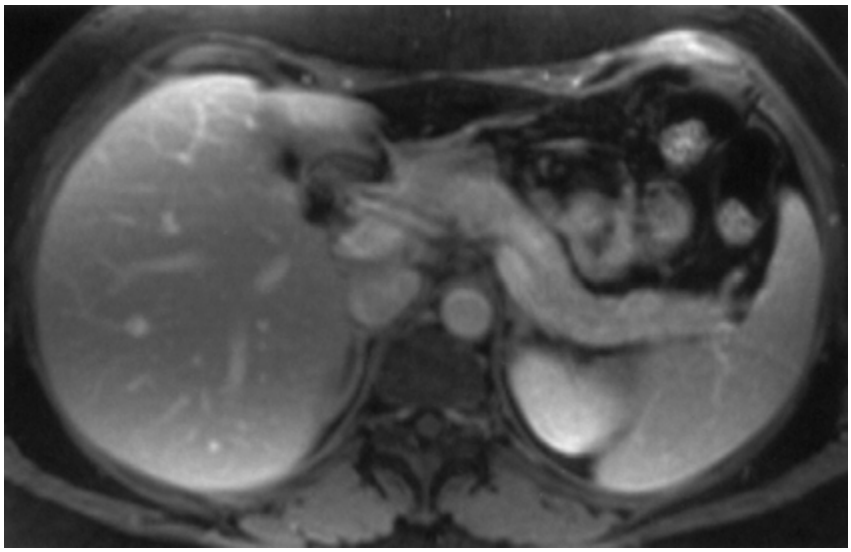

Figure A15.1.5 2-min post-gadolinium fat-suppressed spoiled gradient echo transverse image (equilibrium-phase) demonstrates delayed contrast enhancement.

Table A15.1.10 Imaging Parameters for Non-Slice Selective Turbo Flash[a]

Patient position	Supine
Scan type	Inversion recovery prepared snap shot gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	4.2 msec
Repeat time (T_R)	11 msec
Inversion time (T_I)	360 msec
Delay time (T_D)	4900 msec
Flip angle (FA)	15°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	21
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	2 min, 20 sec

[a]Use pre-contrast for patients unable to breath-hold.

Table A15.1.11 Imaging Parameters for Slice Selective Turbo Flash[a]

Patient position	Supine
Scan type	Inversion recovery prepared snap shot gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Slices posted on coronal; center to liver
Echo time (T_E)	4.2 msec
Repeat time (T_R)	11 msec
Inversion time (T_I)	300 msec
Delay time (T_D)	2 msec
Flip angle (FA)	15°
Fields of view (FOV_x, FOV_y)	350 mm, 263 mm
Resolution (Δx, Δy)	1.37 mm, 2.05 mm
Number of data points collected (N_x, N_y)	256, 128
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	8–10 mm
Number of slices	21
Slice gap	1.6–2 mm
Number of acquisitions (N_{acq})	1
Swap read and phase encoding	No
Slice location	Centered to cover entire liver
Saturation pulses	No
Slice series	Interleaved
Scan time	36 sec

[a]Use post-contrast for patients unable to breath hold.

longer examinations, and therefore image quality deteriorates. A set protocol also makes it possible to perform studies at any time during the operation of the MR center without the requirement of close physician supervision. This above-described protocol results in fast examination times and consistent, reproducible image quality that is effective for evaluating the full spectrum of liver diseases.

Critical Parameters and Troubleshooting

One of the most critical aspects of this protocol is to ensure that the initial scan performed after gadolinium administration is timed appropriately. We use the presence of contrast in the hepatic arteries and portal veins with the absense of contrast in the hepatic veins as a check for optimal enhancement (Semelka et al., 1992, 1993, 1997; Low et al., 1993; Larson et al., 1994; Semelka and Kelekis, 1997). It is also important that the spoiled gradient echo sequence have a sufficient number of images (at least 14) to encompass the entire liver in one breath hold for the data acquisition immediately following contrast administration.

The two major potential problems with this protocol are that patients may not be able to suspend respiration, and that timing of gadolinium administration may be incorrect. The first problem can be addressed by substituting snapshot T_1-weighted sequences (e.g., inversion recovery prepared snapshot gradient echo; see Table A15.1.10 and Table A15.1.11) for the breath hold T_1-weighted spoiled gradient echo. Fast acquisition of the first and second post-gadolinium spoiled gradient echo sequences compensate for the second problem. Alternatively, other investigators have described using a test dose of gadolinium to determine timing (Rofsky et al., 1999).

Anticipated Results

Accurate detection and characterization of focal liver lesions and a positive effect on patient management can be expected with this protocol (Semelka et al., 1997). The greatest advantages over computed tomography (CT) are in the investigation of hypervascular lesions such as hepatocellular carcinoma (Oi et al., 1996; Yamashita et al., 1996; Semelka and Kelekis, 1997) and hypervascular metastases.

Employing this MR protocol, superior results for lesion detection and characterization comparable to spiral CT have been demonstrated (Semelka et al., 1997). In particular, immediate post-contrast spoiled gradient echo is superior to dynamic sequential or spiral CT techniques (Semelka et al., 1992, 1993, 1997; Low et al., 1993; Larson et al., 1994; Oi et al., 1996, Yamashita et al., 1996).

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Key References

Shellock 1996. See above.

Covers a number of important patient management issues related to MR imaging, including recommended safety procedures, a list of metallic implants that have been tested for MR compatibility, and a list of other sources on MR safety.

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