MRI Techniques in Diagnosis of Non-neoplastic Fat Containing Liver Lesions and Pseudolesions

Poster No.: C-1993
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Abdomen, Liver, MR physics, MR, Physics, Tissue characterisation
DOI: 10.1594/ecr2015/C-1993

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Learning objectives

1. Imaging characteristics and differential diagnosis of non-neoplastic fat-containing liver lesions and pseudolesions.

2. Pertinent magnetic resonance imaging (MRI) physics and MRI sequences for lipid detection.

3. Understanding of these non-neoplastic fat containing entities and the available MRI techniques for lipid detection will facilitate correct diagnosis and exclusion of truly neoplastic pathology.

Background

A multitude of hepatic lesions may contain fat. These range from highly malignant pathology to benign incidental findings. While the possibility of lipid within certain neoplastic and potentially neoplastic lesions of the liver, e.g. hepatocellular carcinoma and adenoma, is often discussed, other non-neoplastic entities, with the notable exception of steatosis, are less prominent in the literature.

Outline of Presentation

I. Steatosis
   A. Technique
      1. STIR
      2. CHESS
      3. In/Out phase
      4. Modified Dixon
      5. Selective water excitation
      6. SPIR, SPAIR
      7. Magnetization Transfer Imaging
      8. MR Spectroscopy- Quantification
B. Causes

C. Types

1. Diffuse
2. Focal (in usual and unusual locations)
3. Focal sparing
4. Geographic, multi-focal nodular mimicking metastasis

D. Associated with pancreatic insufficiency / pancreatectomy

II. Pseudolipoma of the Glissen capsule

III. Lipiodol

IV. FNH

V. Focal fat adjacent to intrahepatic IVC

VI. Hydatid cyst, omental packing

VII. AML

VIII. Other

Findings and procedure details

I. Steatosis

A. Technique

The high specificity and sensitivity of MRI for detecting lipid make it the most accurate imaging method for detecting and quantifying hepatic steatosis.

Specific MRI techniques for fat detection Table 1 on page 9:

1. Short tau inversion recovery (STIR)
2. Frequency selective fat suppression imaging (CHESS)
3. In and Out of phase
4. Modified DIXON
5. Selective water excitation
6. Spectral presaturation with inversion recovery (SPIR)/ Spectral presaturation attenuated inversion recovery (SPAIR)
7. Magnetization Transfer
8. MR spectroscopy (MRS)

1. STIR

An initial inversion of the longitudinal magnetization occurs with the 180 degree RF pulse prior to the regular spin-echo pulse sequences. The magnetization of different tissue will recover back at different rates. A 90 degree RF pulse is applied right as the signal from fat protons are crossing the null point. This time interval between the 180 degree and the 90 degree pulse is the inversion time (TI). As fat proton spins relax relatively quickly, the 90 degree pulse rotates signals from other protons (mainly water) into the transvers plane and can be detected. Fat proton signal is nulled and the resulting image is fat suppressed Fig. 1 on page 11 [1].

- Primarily used for T2 weighted and proton density weighted imaging.
- Advantage (Adv): homogeneous fat suppression because of the insensitivity to magnetic field inhomogeneity [2].
- Disadvantage (Disadv): possibility to suppress signal from non-fatty tissues with similar T1 values, such as blood products or gadolinium-enhanced tissues because of the nonspecific nature of the sequence [2].

2. CHESS

Chemical shift selective suppression (CHESS) uses the chemical shift between water and fat to perform fat suppressed imaging. In this technique a proton resonance frequency selective fat saturation pulse is used to suppress the signal from macroscopic fat [2].

- Helps to increase image contrast resolution and distinguish the lesions.
- Primarily used for T1 weighted contrast enhanced MR imaging.
- Adv; not affected with tissue T1 value as STIR that enables the usage in contrast enhanced images.
- Disadv; susceptible to magnetic field inhomogeneities (foreign bodies, tissue interfaces), affected by heterogeneity of RF pulse field ($B_1$ field inhomogeneity), not useful in small amount of fat within a voxel- microscopic fat Fig. 2 on page 11.

3. In and Out of Phase

Dual echo technique utilizes the precessional frequency differences between water and lipid protons. After the initial excitation, the phase of water and lipid protons relative to each other changes with time. In-phase and out-of-phase conditions occur twice per cycle. For example, in a 1.5T magnet, the protons are in phase at time 0, 4.4 msec, 8.8 msec, etc. and are out of phase at 2.2 msec, 6.6 msec, 11.0 msec, etc. The signal is
additive when lipid and water protons are in phase with each other. When out of phase, lipid and water signals cancel each other Fig. 3 on page 12.

- The areas with significant signal drop on out-of-phase images contain microscopic (intracytoplasmic) fat.
- Paired gradient echo (GRE) images with two different TE values.
- The condition occurs every 2.2 msec at 1.5T and every 1.1 msec at 3.0T.
- Adv; the ability to demonstrate small amount of fat and water-fat mixtures. Independent of static field inhomogeneity [3].
- Disadv; does not suppress macroscopic fat.

4. Modified DIXON

The technique originally described by Dixon [4] utilized the principle that the sum of in-phase and out-of-phase images produces a pure water image; the difference between these images produces a pure lipid image.

- Disadv; two data acquisitions susceptible to static field inhomogeneities.

The modified technique corrects the static field inhomogeneity and phase errors with three-point method with an addition of a third imaging phase [5].

- Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) is another modification of Dixon technique which obtains in-phase, out-of-phase, water only, fat only images during a single acquisition. It provides uniform and reliable fat suppression throughout the body Fig. 4 on page 13 [6].

5. Selective water excitation (Spectral-Spatial Imaging)

Combination of selective radio-frequency (RF) pulses are used to excite only water; lipid spins are left in equilibrium and thus produce no signal.

- Adv; faster than fat saturation or inversion-recovery techniques.
- Disadv; susceptible to static (B₀ magnetic) field inhomogeneities [7].

6. Spectral presaturation with inversion recovery (SPIR)/ Spectral presaturation attenuated inversion recovery (SPAIR)

SPIR and SPAIR are combined techniques of inversion recovery and chemical shift.

- SPIR and SPAIR selectively suppress fat, less sensitive to B₀ field inhomogeneity.
- SPIR sequences are sensitive to B₁ inhomogeneity, SPAIR sequences are insensitive [2,8].

7. Magnetization Transfer
Water protons exchange magnetization with protein and membrane phospholipid protons but not with triglycerides and fat protons. In this technique, the signal from protein and phospholipid protons is presaturated, resulting in partial saturation of the water proton signal. If then an image is obtained, it will contain only a portion of the water signal and the entire fat signal. Subtracting this image from the standard image yields a fat-subtracted image [2].

- Adv; fat signals are removed irrespective of their chemical shift, insensitive to B0 or B1 inhomogeneities.
- Disadv; small reduction of signal from water, increase in scan time, possible misregistration between the images for subtraction [9].

8. MR spectroscopy (MRS)

MR spectroscopy provides information about the chemical composition in an organ and chemical changes in the progression of a disease. This technique can be used to quantify the amount of hepatic triglyceride content [10].

B. Causes of Steatosis

Hepatic steatosis involves the excessive deposition of lipid within hepatocytes. The common causes are:

- Excessive alcohol consumption
- Non-alcoholic fatty liver disease (NAFLD)
- Excessive body weight
- Insulin resistance (type 2 diabetes)
- High levels of triglycerides in the blood
- Drugs
- Hepatitis
- Pancreatic insufficiency / pancreatectomy

C. Types of Steatosis

- Diffuse Fig. 5 on page 14
- Focal (in usual locations Fig. 6 on page 15 and in unusual locations Fig. 7 on page 16, Fig. 8 on page 17)
- Focal sparing Fig. 9 on page 18, Fig. 10 on page 19
- Geographic, multi-focal, nodular mimicking metastasis Fig. 11 on page 20, Fig. 12 on page 21, Fig. 13 on page 22, Fig. 14 on page 23, Fig. 15 on page 24, Fig. 16 on page 25
D. Associated with pancreatic insufficiency / pancreatectomy

Patients with pancreatic insufficiency including those who have undergone pancreaticoduodenectomy may frequently develop fatty liver, which was associated with pancreatic exocrine and endocrine dysfunction Fig. 17 on page 26, Fig. 18 on page 27 [11].

II. Pseudolipoma of the Glisson capsule

Pseudolipoma of Glisson capsule is a well-circumscribed encapsulated lesion, which is thought to arise from a detached epiploic appendage, enveloped by liver capsule. This macroscopic fat containing lesion has characteristic chemical shift induced peripheral dark boundary (india ink- etching) artifact in addition to the fat signal intensity on MR sequences Fig. 19 on page 28 [2,12].

III. Lipiodol

Transarterial chemoembolization (TACE) is an accepted treatment method for HCC and TACE has been performed using iodinized oil (Lipiodol; Gurebet, Villepinte, France) as a carrier of antitumor agents with a fairly good therapeutic results [13]. The effects of lipiodol retention on MRI signal intensity can determined by lipid detection techniques Fig. 20 on page 29.

IV. FNH (Focal Nodular Hyperplasia)

The presence of steatosis within FNH lesions has been reported to be anywhere between 22-85% on pathology [14,15,16]. Detection of fat on imaging is rare, however, and if seen will be signal loss on out of phase. This may be heterogeneous and of varying extent depending on the amount of fat Fig. 21 on page 30 [14].

The typical imaging findings of FNH are:

- peripheral lobulation
- iso- or slightly hypointense on T1W
- iso- or slightly hyperintense on T2W
- hyperintense central scar on T2W
- strong homogeneous enhancement on arterial phase postcontrast T1W
- lack of washout on portal venous and delayed phases
- hyperintense on hepatobiliary phase with gadoxetic acid
• enhancement of the central scar on later phases

Sometimes in the setting of hepatic stetosis differentiation of FNH from other liver lesions, especially adenoma can be problematic. This is because the signal from background liver fat confounds the interpretation of the signal of the lesion relative to the background liver. For example, FNHs should be classically nearly isointense to background liver on all pulse sequences except for the arterial post contrast sequence. However, in the setting of steatosis, the background liver signal is decreased on fat suppressed images and the FNH (which may not contain fat) appears relatively hyperintense, including on later post-contrast phases.

V. Focal fat adjacent to intrahepatic inferior vena cava (IVC)

Focal fat adjacent to the intrahepatic portion of IVC has been described as a normal variant [17], which can be seen frequently with cirrhosis. The fat is extrahepatic and located medial to the IVC at or above the level of confluence of the hepatic veins and the IVC Fig. 22 on page 31 [17]. Knowledge of this entity is important so that it is not mistaken for an abnormality as it may mimic thrombus or a fat-containing liver lesion.

VI. Hydatid cyst, omental packing

Hydatid disease is a parasitic infestation by Echinococcus. Hydatid lesions in liver are cystic. If the lesion contains fat droplets, which can be detected on MRI Fig. 23 on page 32, it has been suggested to represent communication with biliary tract [18]. Furthermore, the surgical treatment of hydatid cysts with omental packing can mimic a fatty liver lesion [19].

VII. AML

Angiomyolipoma (AML) is an uncommon benign hamartomatous hepatic lesion with composed of various proportions of lipomatous, myomatous and angiomatous tissue. There can be association with tuberosclerosis and renal AML. The imaging features depend on the predominance of the each tissue. MRI is considered to be the best modality to detect these components of the tumor, especially the fat component Fig. 24 on page 33 [20].

VII. Other

Other entities that can be classified as non-neoplastic fatty liver lesions and pseusolesions are:
• Lipopeliosis
• Focal hepatic extramedullary hematopoiesis
• Lipoma
• Xanthoma
• Adrenal rest tumor

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Table 1: Summary table of MRI techniques for lipid detection

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**Fig. 1:** (a) Diagram of a STIR sequence 180 degree pulse followed by a 90 degree pulse after specific time for fat (TI: 130-170 sec for 1.5 T)= no signal from lipid protons
(b) Example of a STIR axial image abdomen MR demonstrates homogeneous fat suppression, for example of subcutaneous fat tissue
### CHESS

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**Fig. 2:** (a) Diagram of chemical shift selective fat suppression imaging (CHESS). Example of T1W fatsat (b) and post-contrast T1W fatsat (c) image on axial abdomen MR examination (f: frequency)
**Fig. 3:** (a) Diagram of two waves with different frequencies. When out-of-phase, the magnitudes of the two waves oppose each-other. When in-phase, the magnitudes are additive. (b) Coronal out of phase image shows dark contour around the visceral organs due to the india ink (etching) artifact, which is signal drop out in voxels that contain both fat and water components. No definite suppression in subcutaneous adipose tissue due to predominance of lipid and minimal water. (c) Coronal in-phase abdomen MR
**Fig. 4:** Dixon technique for lipid detection. Addition and subtraction of the in phase and out of phase images produce water only and fat only images, respectively
**Fig. 5:** 56 year old female abdomen MR demonstrates diffuse signal drop of the liver on out of phase image (a) compare with in phase image (b) indicating diffuse hepatic steatosis.
Fig. 6: Focal fat in usual liver locations: (a,b) near gall bladder fossa, on the background steatosis, (c,d) near falciform ligament as signal drop on out of phase images (a,c arrow)
Fig. 7: Examples of focal fat in unusual locations (arrows); (a-c) focal fat in caudate lobe and in another case (d-g) focal fat in segment 3 appears hypodense on CT and signal drop on out of phase images.
Fig. 8: 77 year old male with indeterminate hypoattenuating liver lesion on CT (a, arrow). Follow-up MRI demonstrated isointensity on T2 weighted image (b) and signal drop on out of phase image (c, arrow) relative to the in phase image (d). Focal fat was diagnosed
**Fig. 9:** Focal fat sparing (arrows) near portal vein appears as a relative hyperdensity on CT (a). It is hyperintense on out of phase image (b) compared with fatty liver which is hypodense on CT (a) and shows signal loss on out of phase MR image (b)
**Fig. 10:** Severe diffuse hepatic steatosis with focal lesion (arrows) near the gallbladder fossa which is hyperdense on postcontrast CT (a) and hyperintense on T1 weighted images (d,e). There is relative increased uptake seen on prior FDG PET CT (b) that was obtained for the evaluation of possible metastatic disease in a patient had an extrapleural chest mass. The liver lesion is hyperintense on out of phase image (f) relative to the background liver which shows loss of signal. The liver lesion showed stability on multiple follow up examinations and likely represent fatty sparing. The lung lesion was diagnosed as benign process on excisional pathology.
Fig. 11: Geographic fatty infiltration (arrows) seen as hypodense areas with indefinite borders on postcontrast CT (a), hypointense on postcontrast T1W image (b) and signal drop on out of phase image (c) compared with in phase image (d)
Fig. 12: Diffuse nodular steatosis pattern demonstrated as nodular signal drop on out of phase image (a) compared with in phase image (b) in a nonalcoholic steatohepatitis (NASH) patient with cirrhosis.
Fig. 13: Hyperechoic mass-like geographic fatty infiltration on US (a). The area is slightly hypointense on postcontrast T1 fatsat image (b), and shows signal drop on out of phase image (c)
Fig. 14: Multi-focal mass-like steatosis in a 37 year old male with ETOH abuse and alcoholic hepatitis. (a) Hypodensities on CT are hyperechoic on US (b) appear to have mass effect, but have vessels running through. (c,d) Signal loss on out of phase (c) image measured with ROI (region of interest)
Fig. 15: 60 year old female with severe nonalcoholic steatohepatitis. Liver demonstrates pseudomasses (circled) in a background fatty liver. These pseudomasses have two components. The central component (arrowhead) has relative hypointense T1 signal (as seen on in phase imaging (a)) and increased signal on T2 fat sat image (c) due to fatty sparing. The peripheral components (arrows) are hyperintense on T1 in phase image and hypointense on T2 fat sat. This is because of macroscopic fat deposition in these areas. Note the india ink artifact around the macroscopic fat on out of phase image (b, arrow). Post-contrast image (d) shows apparent relative hyperenhancement of the central area of fatty sparing (arrowheads)
**Fig. 16:** 60 year old woman with primary biliary cirrhosis. Patchy periportal liver steatosis (arrows), hypointense on postcontrast T1FS (b) and loss of signal intensity on out of phase image (c)
**Fig. 17:** Patchy fatty liver disease in a patient who is status post pancreatectomy for chronic pancreatitis. There is heterogeneous signal drop on out of phase image (a) compared with in phase image (b)
Fig. 18: Patchy focal fat (arrows) after partial pancreatectomy (Whipple) in a patient diagnosed with pancreatic cancer. The liver parenchyma is homogenous on preoperative exams (a,b,c). It demonstrates heterogeneously hypodense areas on postoperative CT exam (d). These areas show signal loss on out of phase image (e)
**Fig. 19:** Subcapsular fatty nodular lesion is hyperintense on axial T2W (a) and coronal HASTE (e) images. There is signal loss at the periphery (India ink artifact) on axial out of phase (b) and coronal TruFISP image (d), caused by phase cancellation artifact present at the interfaces between fatty and non-fatty tissue. This was diagnosed as pseudolipoma of the Glisson capsule given the sub-capsular location and appearance.
Fig. 20: Signal loss (arrows) post lipiodol on out of phase (a) in a 36-year-old woman with history of metastatic appendiceal carcinoid tumor post chemoembolization.
**Fig. 21:** Slightly T2 hyperintense (a,b), strongly arterially enhancing lesion (f) in right liver lobe. The lesion is isointense on precontrast T1W fat saturated image (e). The nodular lesion looks low signal intensity on in phase (d) and high signal intensity on out of phase (c) image compared with the background fatty liver that shows signal loss on out of phase image (c). FNH was diagnosed on excisional biopsy.
Fig. 22: Two cases of paracaval fat (a and b; c) (arrows). Hypodense fatty tissue near vena cava on postcontrast axial abdomen CT (a and c) and coronal reconstruction (b). Awareness of this lesion is important as it is frequently seen with cirrhosis and can mimic a thrombus.
Fig. 23: 36 year old female with a previous history of surgical treatment with omental packing (arrow head) for a hydatid cyst in right liver lobe. The packed fatty omental tissue is hypodense on postcontrast CT images (a,b) and has signal characteristics of fat on all MR images (c-h). Patient has giant hydatid cystic lesion on the left liver lobe which displaced the stomach. The giant cystic lesion (asterisk) is hypodense on CT images (a,b), hypointense on T1W (c), hyperintense on T2W (d,e,f) images and does not enhance on postcontrast coronal T1W image (h). The fatty nodular droplet (arrow) within the cyst, which shows signal characteristics of fat on MR images suggests communication of the hydatid cyst lesion with biliary system.
**Fig. 24:** 45 year old female with multiple AML (arrows) on liver parenchyma. Lesions have macroscopic fat which are hyperintense on nonsuppressed images (a,d) and suppressed with fat suppression techniques (b,c,d). The etching artifact is seen on out of phase image (c). Biopsy of one of these lesions was consistent with angiomyolipoma.
Conclusion

Non-neoplastic fat containing liver lesions and pseudeolesions can have varied appearances and should be kept in mind when evaluating the liver. MRI is the modality of choice to specifically detect fat. Its use continues to increase as new techniques and sequences are developed to facilitate the detection and quantification of fat.

Personal information

References


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