MRI of liver, biliary system, pancreas and spleen

NATTHAPORN TANPOWPONG, MD
DEPARTMENT OF DIAGNOSTIC RADIOLOGY
FACULTY OF MEDICINE
CHULALONGKORN UNIVERSITY

Contents
- MRI sequences and clinical application
- How to approach common liver lesion
- Biliary system evaluation and common disease
- Pancreas
- Spleen

MR sequences
- Dual echo FSPGR T1W
- IDEAL IQ
- 3D SPGR T1W Pre- and post contrast
- T2W with FS
- Heavy T2W with FS
- Diffusion

MR sequences
- Dual echo FSPGR T1W
- Detect intracellular lipid
- Identify paramagnetic effects associated with iron loss of tissue signal on longer second echo images
- Proton density fat fraction (PDFF = F/W+F)
- R2* map
- Enhancement pattern
- Subtraction

Dual echo FSPGR T1W
- In phase
  - Water + Fat
  - Echo time: every 4.6 ms (1.5T), 2.3 ms (3T)
- Opposed phase
  - Water - Fat
  - Echo time: every 2.3 ms (1.5T), 1.15 ms (3T)
Fat fraction assessment about 2.6% → no fatty change
Fatty liver → fat fraction >5.5-6.0%

Fat fraction assessment about 12.8% → hepatic steatosis grade II

Iron deposition

Iron deposition disease

MRI is the most sensitive imaging modality for the diagnosis of hemochromatosis, and is also able to estimate iron concentration within the liver.

Intracellular iron → superparamagnetic → reduce T2 and T2* relaxation times → diminish SI on both T1W and T2W

Longer second echo image → darkening of liver

Greatest sensitivity → GRE T2*W

Internal reference → skeletal muscle

Quantitative assessment of liver iron concentration using both SGE and spin echo sequences, relying on measurement of T2* and T2 decay

Primary Hemochromatosis

- Inappropriately regulated small bowel increased uptake of iron → excess to total body iron accumulation
- Accumulation of iron
  - Hepatocytes → cirrhosis
  - Islet cells of pancreas → DM
  - Pituitary gland → impaired function
  - Heart → cardiac arrhythmia and congestive heart failure

Primary hemochromatosis

T2* = 1.9 msec
Secondary hemochromatosis

- Exogeneously derived red cells as a result of blood transfusion therapy
- Taken up by RE system → Kupffer cells (liver), spleen, bone marrow and lymph nodes → less clinical significance
- Underlying red cell or bone marrow abnormalities (thalassemia, mastocytosis or myelofibrosis)
- Endogeneous derived excess iron from red cell turnover → polycytemia rubra vera, myoglobin in rhabdomyolysis or siderosis related to alcohol liver disease

2nd hemochromatosis in Thalassemia

Liver cirrhosis

Diffusion weighted

Low b-value
- suppressed background signal of vessels in liver
- allow for lesion detection, esp. metastasis, hemangioma

High b-value
- diffusion information → lesion characterization

Liver metastasis
Liver fibrosis

- A common feature of almost all causes of chronic liver disease
- Dynamic process with potential for regression
- Causes: viral hepatitis, alcohol, NASH and etc.
- Standard of reference for diagnosis and staging → liver biopsy
- Limitation of liver biopsy
  - Invasive
  - Possible complications → hemorrhage, hospitalization and fatality
  - Sampling variability
  - Subjectivity

Conventional MRI

- Characteristic morphologic alteration
  - Surface nodularity
  - Widening of fissures
  - Expansion of gallbladder fossa
  - Notching of right hepatic lobe
  - Atrophy of right hepatic lobe and relatively enlargement of lateral segment of left hepatic lobe and caudate lobe
- High specificity but low sensitivity
- Advanced fibrosis → fibrotic septa and bridges seen as low SI reticulations on T1W and high SI reticulations on T2W
MRI-based techniques for assessment of liver fibrosis

MR elastography
- Noninvasively quantifies the stiffness of the liver by analyzing the propagation of mechanical waves through tissue
- Stiffness of hepatic parenchyma increases as fibrosis advances
- Measuring hepatic stiffness
- Gradient-echo sequence as the waves propagate through the liver
- Velocity and wavelength increase with greater tissue stiffness
- Propagating mechanical waves → special algorithm → generate quantitative stiffness maps (elastograms)

Liver fibrosis stage IV

Liver cirrhosis

MRI findings
- Morphologic change
- Nodular hepatic surface
- Regenerative nodules
- Mild degree of iron deposition
- Fibrosis
- Expanded gallbladder fossa sign
- Dilatation of right inferior phrenic artery
- Portal hypertension
Liver cirrhosis

Morphologic changes
- Hypertrophy of lateral segment of left hepatic lobe and caudate lobe
- Atrophy of medial segment of left hepatic lobe and right hepatic lobe

Regenerative nodules
- Variable intensity on T1W
- Iso- or hypointensity on T2W
- Not hyperintense on hepatic arterial phase gadolinium enhanced images
- Maximally enhanced on portovenous phase

Liver cirrhosis

Siderotic nodules

Portal hypertension
- Portosystemic collaterals: increased size and number of retroperitoneal vessels in
  - splenic hilum
  - gastrohepatic ligament
  - paraoesophageal region
  - splenorenal shunt
  - canalization of paraumbilical vein
- Ascites

Confluent hepatic fibrosis
Characteristics
- Wedge-like or geographic shape with straight or concave borders
- Radiate from portal hilum to contact liver surface
- Retract the overlying hepatic capsule
- Associated with progressive volume loss
- Persistent enhancement into the late phases
Liver lesion characterization

- MRI characterized over 95% of detected liver lesion
- Greater contrast resolution
- Variety of different soft tissue contrast achieved through implementation of multiple sequences
  - Cystic lesions ➔ high SI on T2W and heavy T2W
  - Fat containing lesions ➔ drop SI on fat suppressed image or opposed phase GRE T1W
  - Enhancement pattern: hypo-enhancing, arterial enhancing and delayed enhancing

Hyposignal intensity on T2W lesions

- Iron deposit lesion
- Calcification
- Regenerative nodules
- AVM (high flow)
- Fibrosis
- Non-acute hemorrhage, hemorrhagic metastases
- Post alcohol injection or thermal ablation

Hyposignal intensity on T1W

- Fat
- High protein
- Methemoglobin
- Paramagnetic substance: Gadolinium, Melanin

Cystic liver lesions

**Cysts**

- Most common benign lesion
- Well defined margin, low SI on T1W, high SI on T2W and no enhancement on Gd-enhanced images
- May appear slightly complicated ➔ ablation of border, septations, elevated signal on T1W in association with protein or prior hemorrhage

**Lipiodol staining nodule**

**Ablation treated nodule**

**Siderotic nodules**

**Regenerative nodules**

**Lipiodol stained cyst**

**Ablation treated cyst**

**Cysts**

- Most common benign lesion
- Well defined margin, low SI on T1W, high SI on T2W and no enhancement on Gd-enhanced images
- May appear slightly complicated ➔ ablation of border, septations, elevated signal on T1W in association with protein or prior hemorrhage

**Melanoma metastases**

**Bleeding hepatic adenoma**

**Fibrosis**

**Non-acute hemorrhage, hemorrhagic metastases**

**Post alcohol injection or thermal ablation**

**Siderotic nodules**

**Regenerative nodules**
Cystic liver lesions
Bile duct hamartoma (Von Meyenburg complex)
- Relatively common, 3% of population
- Frequently peripheral, multiple and less than 1-1.5 cm in size without communicate with biliary tree
- Similar SI to fluid
- Thin rim enhancement on Gd-enhanced image → compressed liver parenchyma

Cystic liver lesion
Biliary cystadenoma/carcinoma
- Rare, arising from biliary epithelium
- Predominantly in middle-aged women
- Symptoms → related to mass effect of lesion
- Variable in size
- Typically → large well defined, homogeneous or heterogeneous, complex cystic mass with septations and nodularity
- Fine mural or septal calcifications → common
- Dilatation of IHHBDs due to mass effect
- Enhancing mural nodules → malignancy

Liver lesion characterization
Fat containing liver lesions
- Chemical shift imaging with opposed GRE sequences
- Fat suppression sequence

Liver lesions containing intracellular fat

<table>
<thead>
<tr>
<th>Type of lesion</th>
<th>Only fat</th>
<th>Fat + soft tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>Focal steatosis, Adenoma</td>
<td>Focal nodular hyperplasia, Angiomyolipoma</td>
</tr>
<tr>
<td>Malignant</td>
<td></td>
<td>Hepatocellular carcinoma</td>
</tr>
</tbody>
</table>

Liver lesions containing macroscopic fat

<table>
<thead>
<tr>
<th>Type of lesion</th>
<th>Only fat</th>
<th>Fat + soft tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>Lipoma, Postoperative packing material</td>
<td>Adenoma, Angiomyolipoma</td>
</tr>
<tr>
<td>Malignant</td>
<td>Liposarcoma</td>
<td>Hepatocellular carcinoma, Liposarcoma</td>
</tr>
</tbody>
</table>
Fat containing liver lesions

**Adenoma**
- Benign encapsulated neoplasm
- Propensity to frequent hemorrhage and rare malignant change
- Risk factor
  - Oral contraceptives
  - Type I glycogen storage disease
  - Anabolic steroids
- Solitary 70-80%
- Adenomatosis → multiple (more than 4 lesions), predominantly associated with glycogen storage disease

35-77% demonstrate steatosis at chemical shift MRI, depend on fat content in lesion
- T1W → varies among hypointense, isointense and moderately hyperintense
- T2W → mild hyperintense, isointense
- Contrast enhanced image → heterogeneous arterial enhancement, fade to near isointense on equilibrium phase
- Liver specific contrast enhanced → Hypointense

**Lipoma**
- Extremely uncommon
- Characteristic fatty lesion, SI similar to subcutaneous fat

Yunus ANK, Saffiye Samer DERELI BULUT. Turk Onkoloji Dergisi 2009; 24 (4): 181-4

**Angiomyolipoma**
- Benign, unencapsulated mesenchymal tumor
- Composed of vary proportions of three elements: smooth muscle cells, thick-wall blood vessels and mature adipose tissue
- 50% lack considerable fat content

**Hepatocellular carcinoma**
- Small well differentiated HCC often associated with a diffuse-type fatty change
- Larger tumor → patchy fatty metamorphosis
- Hyperintense on T1W, drop SI on chemical shift image
Characterization lesions: enhancement pattern

- Arterial enhancing lesions
  - FNH
  - HCC
- Hypoenhancing lesions
  - Metastasis
- Delayed enhancing lesions
  - Hemangioma
  - Cholangiocarcinoma

Arterial enhancing lesions

<table>
<thead>
<tr>
<th>Central scar</th>
<th>Focal nodular hyperplasia</th>
<th>Fibrolamellar HCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>No central scar</td>
<td>Transient hepatic intensity difference (THID)</td>
<td>Adenoma</td>
</tr>
</tbody>
</table>

Arterial enhancing lesions with scar

Focal nodular hyperplasia

- Second most common benign liver tumor
- Most frequently in adult women, 2:1 female predilection
- T1W – mildly hypointense to isointense
- T2W – mildly hyperintense to isointense
- Contrast enhancement – marked, nearly uniform arterial phase enhancement and lessen on subsequent phases
- Hepatobiliary phase – hyperintense or isointense; heterogeneous, peripheral or heterogeneous
- Scar
  - Characteristically hyperintense on T2W
  - Low SI on arterial phase and gradually enhanced to hyperintense to the rest of lesion on delayed phase

Fibrolamellar HCC

- Uncommon type of HCC
- Usually seen as a large, well circumscribed focal lesion
- T1W – hypointense
- T2W – hyperintense
- Contrast enhancement – early heterogeneous contrast enhancement, fade on subsequent images
- Hepatobiliary phase – hypointense (not uptake)
- Scar
  - Seen in 80%
  - Low SI on T2W
  - Minimal or no enhancement

Arterial enhancing lesions with scar

- Central scar
- Fibrolamellar HCC
- No central scar
- Transient hepatic intensity difference (THID)
- Adenoma
- Hepatocellular carcinoma
- Hypervascular metastases

Arterial enhancing lesions

- Central scar
- Fibrolamellar HCC
- No central scar
- Transient hepatic intensity difference (THID)
- Adenoma
- Hepatocellular carcinoma
- Hypervascular metastases

Transient hepatic intensity difference (THID)

- Patchy wedge shaped area of enhancement involving a hepatic subsegment
- Transiently immediately after contrast material administration with fading on subsequent image
- Unknown cause
- Imbalance between hepatic arterial and portal venous supply to affected subsegments → increased hepatic arterial blood flow in the presence of portal vein obstruction
Hepatocellular carcinoma

- Most common primary malignant hepatic neoplasm
- Predominant causal factors → cirrhosis from alcoholism, viral hepatitis and toxin exposure
- T1W → often hypointense relate to liver; hyperintense → fat, copper, protein or blood secondary to intralesional hemorrhage
- T2W → hyperintense; well differentiated lesion → isointense
- Contrast enhancement → intense enhancement on arterial phase
- Large HCC → mosaic pattern, tumor capsule, extracapsular extension with satellite nodules, vascular invasion and extrahepatic dissemination

Arterial enhancing lesions in cirrhosis

- T2W
- High SI nodule
- Hypo SI nodule
- No abnormal SI
- HCC
- Dysplastic nodule
- THID/perfusion abnormality

Hepatocellular carcinoma

Arterial enhancing lesions

- Hypervascular metastases
  - Neuroendocrine tumor (islet cell tumor, pheochromocytoma, carcinoid)
  - Breast cancer
  - Melanoma
  - Thyroid cancer
  - Renal cell carcinoma
  - Choriocarcinoma
  - Best seen during the arterial phase contrast enhanced image and washout on delayed phase
  - Most have hyperintense on T2W

- Hypovascular metastases
  - Lymphoma

- Hypoenhancing lesions
  - Regenerative and dysplastic nodules
    - Dysplastic nodule
    - T1W - hypointense or more commonly hypointense
    - T2W - iso or hypointense, never hyperintense
    - Contrast enhancement – usually not enhanced on arterial phase
  - Hypovascular metastases
  - Lymphoma
Hypoenhancing lesions

Hypovascular metastases
- colorectal cancer
- lung cancer
- gastric cancer
- urothelial cell carcinoma
- T1W – hypointense
- T2W – hyperintense
- Contrast enhancement – delayed enhancement, early ring enhancement

Colorectal metastasis

Delayed phase enhancing lesions

Hemangioma
- Most common benign liver neoplasm, prevalence up to 20%
- Usually incidental finding in patients at any age, 5 times more common in women
- Solitary or multiple lesions

Hemangioma
- Well-delineated lesion
- Round shape (small), lobular border (larger)
- T1W – low SI
- T2W and heavy T2W – high SI, giant hemangioma → central area of either bright, dark or mixed SI and a network of multiple fibrous septae of low SI
- Contrast enhancement – 3 patterns
**Hemangioma: enhancement pattern type 2**
Peripheral, discontinuous nodular enhancement on A-phase with centripetal progressive enhancement on PV phase and homogeneous fill-in on delayed.

**Hemangioma: enhancement pattern type 3**
Same enhancement pattern as type 2 during dynamic contrast enhanced images, but failure to completely fill and no enhancement of central scar on delayed phase.

**Delayed enhancing liver lesion**
Mass forming type cholangiocarcinoma
- Intrahepatic cholangiocarcinoma
- Thin irregular peripheral enhancement with heterogeneous gradual centripetal enhancement
- Delayed contrast retention (Central fibrosis)
- Vascular encasement or compression
- Retraction of liver capsule
- Lobar atrophy
- Satellite nodules
- Segmental duct obstruction

**Mass forming cholangiocarcinoma**

**MRCP**
- A non-invasive imaging technique to visualize intra and extrahepatic biliary tree and pancreatic ductal system
- Fluid in the biliary and pancreatic ducts → a contrast agent by acquiring the images using heavily T2 weighted sequences
- Technique and protocol
  - Fasting at least 4 hours
  - All protocols obtain heavy T2W sequences and acquired images are reformatted in different planes using multiplanar reconstruction (MPR) and maximum intensity projection (MIP)
  - Negative oral contrast to 'null' the duodenum: commercially available agents or natural products such as pineapple juice which is rich in manganese and shortens T2 relaxation time
Choledocholithiasis

- Stone within bile duct
- MRCP largely replaced ERCP as the gold standard for diagnosis (similar sensitivity and specificity without ionizing radiation, intravenous contrast, or the complication rate inherent in ERCP)

MRCP 
- MRCP 
  - largely replaced ERCP as the gold standard for diagnosis (similar sensitivity and specificity without ionizing radiation, intravenous contrast, or the complication rate inherent in ERCP)

MRCP

- Filling defects are seen within the biliary tree on the cross-sectional T2W Appearance of stones:
  - T2W: all are dark
  - T1W:
    - low or intermediate: cholesterol stone
    - high: pigment stone
- MRCP
  - Achieve accuracy of source images
  - Limitation for stones <3 mm

Gallstone (cholelithiasis)

- Occurs in ~10% of the population with a predominance in women (F:M = 2:1)
- 3 types:
  - Cholesterol stone (10%)
  - Mixed (80%)
  - Pigment stone (10%)
- MRI:
  - T2W: all stones are hypoSI
  - T1W:
    - Pigment stone: hyperSI
    - Cholesterol stone: hypoSI

Choledocholithiasis

- Fill defects are seen within the biliary tree on the cross-sectional T2W Appearance of stones:
  - T2W: all are dark
  - T1W:
    - low or intermediate: cholesterol stone
    - high: pigment stone
- MRCP
  - Achieve accuracy of source images
  - Limitation for stones <3 mm

Cholangiocarcinoma

- 2nd most common primary malignancy of liver
- Incidence 1.2 per 100,000
- Represents 3% of all GI cancers
- 10-fold increase in incidence in patients >80 years old
- At least a third of patients present with unresectable disease
- Preoperative evaluation important
- Complete surgical excision offers the best hope for improved survival
- Treatment goal is complete excision with negative margins

Cholangiocarcinoma

- Imaging:
  - US: Primary test for biliary obstruction
  - CT: Most common exam for staging
  - MR: One-stop shop for parenchymal (MR), biliary (MRCP), and vascular (MRA) imaging
- Cholangiography:
  - ERCP: Allows bile sampling, brush cytology, biopsy, stent placement
  - PTC: Can be used when ERCP fails
  - MRCP: Non-invasive visualization of bile ducts
Cholangiocarcinoma

- **Morphologic classification**
  - Mass forming type / nodular
  - Periductal infiltrating type / sclerosing
  - Intraductal growth type / papillary

- **Anatomic Classification**
  - Intrahepatic 10-15%
  - Perihilar 60-70%
  - Extrahepatic 20-30%

**Intrahepatic Cholangiocarcinoma**

- 10-15%
- Arise from intrahepatic bile ducts distal to the second order branches
- Mass forming type
- Periductal infiltrating type
- Intraductal type

**Intrahepatic Cholangiocarcinoma**

- Intrahepatic 10-15%
- Perihilar 60-70%
- Extrahepatic 20-30%

**Periductal Infiltrating cholangiocarcinoma**

- Growth along a dilated or narrowed bile duct without mass formation
- Eccentric, elongated, spiculated, or branch like abnormality
- Diffuse periductal thickening and increased enhancement
- Rare, combination of periductal and mass-forming types is more common than pure periductal infiltrating lesion

**Intrahepatic Cholangiocarcinoma**

- Intraductal growing type
  - Polypoid expansile tumor
  - Limited to mucosa and lumen
  - No invasion of bile duct wall
- Imaging patterns
  - Diffuse and marked duct ectasia with a grossly visible papillary mass
  - Diffuse and marked duct ectasia without a visible mass
  - An intraductal polypoid mass within localized duct dilatation
  - Intraductal castlike lesions within a mildly dilated duct
  - A focal stricture-like lesion with mild proximal duct dilatation

**Intraductal growing type intrahepatic cholangiocarcinoma**

- Duct ectasia with grossly visible papillary mass
- Localized ductal dilatation with an intraductal mass
Cholangiocarcinoma

- Hilar and extrahepatic cholangiocarcinoma usually spread circumferentially along the bile ducts which is presenting as circumferential wall thickening, less commonly pattern presents as a small mass like lesion
- MRCP →
  - morphology and length of stricture
  - present of intraductal stone
  - degree of ductal dilatation
  - ducts both caudal and cephalad to the stricture
- Tumor appears hypo to iso SI on T1W, iso to mild hyperSI on T2W, hypovascular on immediate contrast images and progressive heterogeneous enhancement on delayed imaging.

Pancreas

Pancreatic adenocarcinoma

- On unenhanced MR images, small tumors are best detected on T1W breath-hold fat-suppressed GRE images as hypointense masses
- If tumours involve the peripancreatic tissues, fat-suppressed T1w GRE images lack contrast between low-signal intensity tumour and suppressed fat signal of the peripancreatic fat
- Delineation of tumors is difficult on T2w images, as they may appear iso- or only mildly hyperintense
- To improve tumor detection, administration of contrast agents is mandatory
- AdenoCA → hypointense after contrast media administration
Pancreatitis

- Acute inflammation of the pancreas
- Contrast-enhanced MRI is equivalent to CT in the assessment of pancreatitis
- Advantages for using MRI
  - No radiation hazard
  - Useful in patients who cannot receive iodinated contrast material (allergy or other contraindications)
  - MRCP has the unique capability of providing noninvasive images of pancreatic parenchyma and pancreatic duct integrity, and it has the advantage of demonstrating possible communication of a pancreatic pseudocyst with pancreatic ducts
  - MRI has a potential advantage over CT in detecting bile duct lithiasis and pancreatic hemorhage of pseudocysts or pseudoaneurysms, which can help plan surgery
  - Early assessment of severity and prognosis of acute pancreatitis
- Non-enhanced MRI is superior to CT for depiction and confirmation of mild forms of acute pancreatitis.

Limitations for using MRI
- Requires patient cooperation and breath holding
- On MRCP, pancreatic duct visibility can be decreased by the overlap of fluid-containing organs (e.g. stomach and duodenum)
- MRI is time-consuming and relatively expensive with comparison to US or CT
- MR contrast media (e.g. gadolinium) have a potential risk of developing nephrogenic systemic fibrosis in patients with severe acute pancreatitis associated with renal insufficiency after performing MR enhancement.

Pancreatic cystic lesions

- Advantage of MRI
  - Microcystic lesion mimic solid mass on US and CT
  - Demonstrable connection between lesions and pancreatic duct
  - IPMN and pseudocyst
Intraductal papillary mucinous neoplasm

Mucinous cystic neoplasm

Von Hippel-Lindau syndrome

Spleen

- The largest lymphatic organ
- Shape
  - Convex – superolaterally
  - Concave – inferomedially
- Size
  - Average length 12 cm, breadth 7 cm and thickness 3-4 cm, weight ~ 150 grams
  - Decreased size and weight with advanced age
- CT: Imaging modality of choice for evaluation of spleen in acute setting (trauma or pain)
- MRI: Additive evaluating splenic mass and some metabolic diseases (Hemochromatosis)
Secondary hemochromatosis

Lymphangioma

- A multicystic lesion, although some of the cysts may be hyperintense on T1-weighted images because of their proteinaceous or hemorrhagic content.

Hemangioma

- The most common primary benign neoplasm of the spleen.
- Composed of endothelium-lined vascular channels filled with blood.
- Hypointense to the spleen on T1W and hyperintense on T2W.
- After contrast material administration → early nodular centripetal enhancement and uniform enhancement at delayed imaging.

Infarction

- Peripheral wedge-shaped defects that exhibit decreased signal intensity on both T1- and T2-weighted MR images.
- No enhance after intravenous contrast material administration.

Thank you for your attention.