MRI problem solving in the liver, pancreas, kidneys, and adrenal glands

John R. Leyendecker
Associate Professor, Abdominal Imaging
Clinical Director, MRI
Wake Forest University School of Medicine

Outline

Part 1: Tools and Techniques
- MRI tools for problem solving in the abdomen and creation of an abdominal MRI protocol

Part 2: Distinguishing good from bad
- How to distinguish between common benign liver lesions and their malignant look-alikes with MRI
- How MRI can help manage pancreatic cystic masses
- How to distinguish between benign and malignant solid renal neoplasms with MRI
- How to distinguish between adrenal adenoma and its mimics

Disclosures
- Bracco, Speaker
- Bracco, Research grant
- Bayer, Speaker

I will discuss off-label applications of gadolinium-based contrast agents
**Other substances bright on T1**
- Melanin
- Protein
  - Most evident in fluid collections or cystic masses
- Manganese
  - Fruits and vegetables
  - Mn-DPDP
- Some gallstones

**Bright on T2**
- Fluid (urine, bile, ascites, CSF, etc.)
- Pus
- Necrosis
- Mucin
- Myxomatous tissue
- Hyaline

**Dark on T2**
- Smooth muscle
- Papillary RCC
- Blood products
- Iron

**Renal Angiomyolipoma with Hemorrhage**

**Fatty Tumors**
- Lipoma (or pseudo-)
- Liposarcoma
- Myelolipoma
- Angiomyolipoma
- Cystic teratoma
- Lipoleiomyoma
- Epiploic appendagitis
- Omental infarction
- Mesenteric panniculitis
- Surgical omental packing
- Hepatic adrenal rest
- HCC (rare)
- Hepatic adenoma (rare)
Chemical Shift Imaging

Hepatic Steatosis

Microscopic Fat (Intracellular Lipid)
- Parenchymal fatty infiltration
- HCC
- Hepatic adenoma
- FNH (rare)
- Adrenal adenoma
- Adrenal cortical carcinoma
- Clear cell carcinoma of kidney

Focal Fat (r/o mets, lesion on CT)

No T2W abnormality (unless related to fat) and no abnormal enhancement

In and Opposed Phase (CSI)
Imaging isn’t just for Lipid

In Phase: Susceptibility
- Gas collections: e.g. Pneumobilia
- Metallic surgical clips
- Remote hemorrhage (hemosiderin)
- Concentrated gadolinium-based contrast material
- Iron

Susceptibility Artifact
Surgical Clip

Duodenal Diverticulum

Iron

Dynamic Enhanced Imaging
- Aids in lesion detection
- Aids in lesion characterization

HCC

Metastases
Liver Specific Contrast Agents

- Target either
  - Functioning hepatocytes
  - Functioning RES cells (Kupffer cells)

- Distinguish normal liver and tumors composed of normal liver cells from nonhepatocellular neoplasms

- Some malignant tumors (most commonly HCC) will accumulate these agents

Liver Specific Contrast Agents

- Superparamagnetic iron oxide (SPIO, Feridex)
  - Small iron particles taken up by reticuloendothelial (RES) cells of liver (Kupffer cells).
  - Liver appears dark on T2 and T2*-weighted images.
  - Tumors without Kupffer cell activity appear brighter than background liver.
  - Most FNH and some HCC can accumulate SPIO

Liver Specific Contrast Agents

- Mn-DPDP (Teslascan, Mangafodipir)
  - Manganese based agent
  - Taken up by functioning hepatocytes and excreted in the bile
  - Makes normal liver appear bright on T1-weighted images
  - Avidly accumulated in FNH (bright) but not most metastases (dark)
  - Uptake by some HCC and neuroendocrine tumors has been reported
  - No longer marketed in the U.S.

Liver Specific Contrast Agents

- Gadobenate (Gd-BOPTA, MultiHance)
  - Combined hepatocellular, extracellular gadolinium-based contrast agent
  - Approximately 3-5% biliary elimination
  - Hepatobiliary phase at 1 hr (up to 3 hr)
  - FNH avidly accumulates agent
  - A few HCCs can accumulate agent
  - Mets and adenomas typically do not accumulate agent
  - High relaxivity
  - Not currently approved for liver in the U.S.

Liver Specific Contrast Agents

- Gadoxetate (Eovist, Gd-EOB-DTPA, Primovist)
  - Combined hepatocellular, extracellular gadolinium-based contrast agent
  - Approximately 50% biliary elimination
  - Hepatobiliary phase at 20 min. (up to 2 hr)
  - FNH avidly accumulates agent
  - A few HCCs can accumulate agent
  - Mets and adenomas typically do not accumulate agent
  - High relaxivity: 0.025 mmol/kg body wt.

Diffusion

- Diffusion refers to the microscopic motion of water molecules
- Focal changes in water proton diffusion, or diffusivity, within an organ may signal an alteration in tissue cellularity, permeability or organization indicative of disease.
Part 2
How to tell good from bad

Disclaimer: There are exceptions to every rule

Common Benign Liver Lesions and their Mimics

Generic (Core) Abdomen Protocol
- Fast coronal T2 localizer
- ssFSE, ssTSE, HASTE
- (Fat-suppressed) T2
- In and opposed-phase T1
- Dynamic contrast-enhanced fat-suppressed T1
- Optional (using more and more):
  - RARE sequences (MRCP, MRU)
  - Liver specific agents (mets, FNH)
  - DWI (abdominal cancers and infection)

Metastatic colon cancer

Areas of restricted diffusion are bright

Metastatic liposarcoma

1000
500
50

$\textit{b} \text{ value}$
Common Benign Liver Lesions We Typically Ignore

- Cyst
- Hemangioma
- FNH
- Focal fat

Hemangioma

- Lobulated, well-defined margin
- Very bright on T2WI
- Low SI on T1WI
- Nodular peripheral discontinuous enhancement that progresses toward the center
- Enhancement SI parallels vessels
- Central scar OK

GIST

- Doesn’t progress
HEMANGIOMA

Metastasis (breast)

Patchy, ill-defined progressive enhancement

Not as bright on ssFSE

Neuroendocrine Metastasis

Continuous, rim enhancement

Peripheral Washout = Bad

Good

- Very bright on T2WI
- Nodular, peripheral, discontinuous enhancement that progresses centrally

Bad

- Continuous rim enhancement
- Irregular enhancement that doesn’t progress from periphery to center
- Peripheral washout

FNH
FNH

- Slightly hypo- to isointense to liver on T1WI (stealth tumor)
- Iso to slightly hyperintense to liver on T2WI
- Bright central scar
- Scar enhances after arterial phase (except gadoxetate)
- Lesion enhances avidly early (radiating septa)
- Lesion becomes iso- to slightly hyperintense during portal phase
- Lobulated margin without a capsule

- Retains gadobenate, gadoxetate, mangafodipir
- Uptake of SPIO

Mimics of focal nodular hyperplasia (FNH)

- Nearly isointense to liver
- Bright central scar
- Lobulated margin
- Slightly hyperintense to liver
- Central scar enhances
- Brisk enhancement

Metastatic GIST

- Central scar never enhances
- Lesion is serosal in location
<table>
<thead>
<tr>
<th>Mimics of focal nodular hyperplasia (FNH)</th>
<th>T2WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNH</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal stromal tumor metastasis</td>
<td></td>
</tr>
<tr>
<td>Colon cancer metastasis</td>
<td></td>
</tr>
<tr>
<td>Neuroendocrine metastasis</td>
<td></td>
</tr>
<tr>
<td>Well-differentiated HCC</td>
<td></td>
</tr>
<tr>
<td>Hemangioma</td>
<td></td>
</tr>
</tbody>
</table>

**Rim enhancement.**
Lesion very low SI

**FNH**

**No enhancement of central scar**

**Very conspicuous on T2WIs**

**Well differentiated HCC**
**Fibrolamellar HCC**

- Can sometimes see pseudocapsule with FNH

---

**Characterization of focal liver lesions by ADC measurements using a respiratory triggered diffusion-weighted single-shot echo-planar MR imaging technique**

- Inconspicuous on T1 and T2 and...
- Bright central scar on T2 and...
- Arterial enhancement with mildly delayed enhancement of scar (except with gadoxetate)
- Retention of liver specific contrast agents

---

**Focal Fatty Infiltration**

- Slightly increased SI on non-fat-suppressed T1WI
- Signal loss on opposed phase images
- No distortion of liver contour
- No mass effect
- No displacement or compression of vessels
- Enhancement no more than normal liver
- Normal uptake of liver specific contrast agents
- Rapid changes over time
- Typical locations
Focal fatty infiltration

Problem Solving in Abdominal Imaging with CD-ROM / Neal C. Dalrymple, John R. Leyendecker, Michael Oliphant. -- 1st ed. Elsevier

Mimics of Focal Fatty Infiltration

Hepatic Adenomatosis

Liposarcoma metastases

HCC

Lesions grow

Abnormal enhancement

Distortion of liver contour and displacement of vessels

Abnormal SI on T2

Liver contour distorted
Good
- Typical location near gallbladder, porta hepatis, falciform lig.
- Normal vessels run through
- Normal organ contour
- Resembles liver on other sequences

Bad
- Displaces vessels
- Distorts contour
- SI different from normal liver on other sequences
- Enhances differently than liver
- Restricted diffusion

Pancreatic Cystic Masses

Duodenal Diverticulum

4 cystic masses you need to know
- Microcystic adenoma (serous cystadenoma, microcystic cystadenoma)
- Mucinous cystic neoplasm (MCN, macrocystic cystadenoma)
- Intraductal papillary mucinous neoplasm (IPMT, IPMN)
- Pseudocyst

Table 14-4 Pancreatic Cystic Neoplasms and Their Aliases

<table>
<thead>
<tr>
<th>Tumor</th>
<th>Also Known As</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcystic adenoma*</td>
<td>Serous microcystic adenoma</td>
</tr>
<tr>
<td>Mucinous cystic neoplasm</td>
<td>Serous macrocystic adenoma</td>
</tr>
<tr>
<td>Intraductal papillary mucinous neoplasm</td>
<td>Solid pseudopapillary neoplasm</td>
</tr>
<tr>
<td>Pseudocyst</td>
<td>Solid pseudocyst tumor</td>
</tr>
</tbody>
</table>

4 lesions
27+ names!!!
Distinguishing Pancreatic Cystic Lesions

- Patient demographics
- Location
- Size/number of cysts
- Shape (round, tubular, lobulated)
- Enhancement
- Communication with pancreatic duct

Patient Demographics

- Moderately useful
- **Young woman**
  - Solid pseudopapillary tumor (SPEN)
- **Middle aged woman**
  - Mucinous cystic neoplasm
- **Older woman or vHL**
  - Microcystic adenoma (serous cystadenoma)
- **Older man**
  - Intraductal papillary mucinous neoplasm
- History of or risk factors for pancreatitis
  - Pseudocyst

Cystic and Papillary Epithelial Neoplasm

- Not very useful
- **Head**
  - IPMN (uncinate)
  - Microcystic (serous) adenoma
  - Duodenal diverticulum
- **Body/Tail**
  - Mucinous cystic neoplasm

Microcystic (serous) adenoma

- Moderately useful
  - > 1.5 cm in size, < 6 in number
    - Mucinous cystic neoplasm
    - Oligocystic serous cystadenoma
    - Pseudocyst
  - < 1.5 cm in size, > 6 in number
    - Microcystic (serous) adenoma
- **Diffuse, multiple**
  - IPMN, vHL

Beware the oligo- (macro) cystic microcystic adenoma
Mucinous cystic neoplasm (MCN)

Microcystic (serous) adenoma

Cysts few and large

Cysts small and numerous

Diffuse, multiple

Intraductal papillary mucinous neoplasm (IPMN)

Von Hippel Lindau

Shape

- Moderately useful
- Round, smooth
  - Epithelial cyst
  - Mucinous cystic neoplasm
  - Pseudocyst
- Lobulated
  - Microcystic (serous) adenoma
  - IPMN (branch duct)
- Tubular
  - IPMN (main duct)

IPMN: Main Duct Variety

Microcystic (serous) adenoma

MCN

Lobulated

Smooth
Enhancement

- Moderately useful
- No internal enhancement
  - Epithelial cyst
  - Pseudocyst
  - MCN
- Enhancing thin septa, central scar
  - Microcystic (serous) adenoma
- Enhancing septa and nodules
  - MCN (esp. malignant)

Epithelial cyst

Pseudocyst

MCN

MCA

Communication with duct

- Moderately useful
- MRCP helpful
- Pseudocyst
- IPMN

Chronic Pancreatitis
Cystic Pancreatic Masses

**Bad (consider surgery)**

- Thick or irregular septa
- Mural nodules or solid enhancing component(s)
- Cyst/mass ≥ 3 cm (unless suspect pseudocyst or microcystic adenoma)
- Invasion or encasement

**Cystic Pancreatic Masses**

**Consider Follow-up**

- Mass with many tiny cysts, central scar, and lobulated margins in an elderly woman
- Tubular or multicentric mass that communicates with the pancreatic duct (duct < 1 cm) in an elderly patient
- Suspected pseudocyst
- Simple cyst ≤ 1 cm

---

The radiologists were correct (#1 diagnosis) < 50%

- 37% malignant
- 30% premalignant
- 34% benign

The problem: Only surgically proven lesions were considered. Follow-up lesions were not considered. Only 13 MRI scans

70 cystic pancreatic masses
48 CT scans
13 MRI scans
Cystic Pancreatic Masses

Further evaluate (aspiration, EUS, ERCP)

• Everything else, including a simple appearing cyst

Incidental Pancreatic Cyst

Solid Lesions of the Kidney

Fat/Lipid
Enhancement
Signal Intensity
Diffusion

Does the lesion contain fat?

- Macroscopic fat
  - AML likely
  - Consider partial nephrectomy site

Looking for fat early avoids embarrassment (or worse) later

Macroscopic Fat

- Bright on T1WI
- Signal loss with fat suppression techniques (large foci of fat)
- Opposed phase GRE images
  - India Ink artifact
  - Significant signal loss
Angiomyolipoma

Fat suppression

Angiomyolipoma

RCC (clear cell) AML

Renal sinus fat

Clear Cell RCC

Remember

Macroscopic fat is not 100% specific for AML

But it’s pretty darn close

Curry et al. AJR 1990;154:307
Helenon et al. RadioGraphics 1997;17:129
Prando. AJR 1991;156:871
Also remember

Not all AMLs contain detectable macroscopic fat

AML with no detectable fat on NCCT
% SI drop between in/out phase
Sensitivity = 93%
Specificity = 96%
For AML using a signal intensity index threshold of 25%

Clear cell carcinoma

Subtraction imaging can help

Microscopic Fat

- Clear RCC  
- AML with minimal fat  
  Kim et al. Radiology. 2006;239:174

Clear Cell Carcinoma

Enhancement

- An enhancing mass without macroscopic fat is usually bad (RCC)
Is this enhancing?

Pre T1 | Post FS T1
---|---
Papillary RCC

Is this enhancing?

Hemorrhagic cyst

Not all enhancing masses without fat are malignant

Cortical adenoma | Oncocytoma

Enhancement patterns can improve specificity for RCC subtypes

What about signal intensity?

- Dark on T2
  - RFA site
  - Bright on T1
  - No enhancement
- Hemorrhagic cyst
  - Bright on T1
  - No enhancement
- Fluid level
- Papillary RCC
  - Intermediate on T1
  - Mild enhancement
- AML with minimal fat
  - Looks like papillary RCC
What about diffusion-weighted imaging?

Table E1. ADC Values for 109 Renal Lesions (and Cortex and Medulla) in 64 Patients, for Three Sets of b Values

<table>
<thead>
<tr>
<th>Lesion and Nodule Type</th>
<th>ADC (x 10^-3 mm^2/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b = 0, 400 sec/mm^2</td>
</tr>
<tr>
<td>Cystic (n = 25)</td>
<td>2.0 ± 0.43</td>
</tr>
<tr>
<td>Cystic (n = 20)</td>
<td>2.1 ± 0.47</td>
</tr>
<tr>
<td>Cystic (n = 15)</td>
<td>2.1 ± 0.47</td>
</tr>
<tr>
<td>AML (n = 20)</td>
<td>1.6 ± 0.36</td>
</tr>
<tr>
<td>Clear cell RCC (n = 10)</td>
<td>2.2 ± 0.31</td>
</tr>
<tr>
<td>Papillary RCC (n = 9)</td>
<td>2.0 ± 0.22</td>
</tr>
<tr>
<td>Normal cortex (n = 64)</td>
<td>1.4 ± 0.15</td>
</tr>
<tr>
<td>Normal medulla (n = 60)</td>
<td>1.4 ± 0.15</td>
</tr>
</tbody>
</table>
**Lymphoma**

**DWI**

**ADC**

**Renal Abscess**

**Papillary carcinoma**

**Adrenal Adenoma and its Mimics**

**Adenoma**

**Adrenal Adenoma**

- Variable T2W SI
- Intermediate T1W SI
- Signal loss on opposed phase images
  - Best when homogeneous
- Modest early enhancement and washout

**Fatty infiltration of liver**
Relative Utility of MRI for Adrenal Adenoma

Unenhanced CT < Chemical Shift MRI < Enhanced CT

Chemical shift MRI may be helpful for adrenal lesions 10 – 30 HU on unenhanced CT

Enhanced CT with washout calculations may be helpful for adrenal lesions that don’t drop 16.5 – 20% on chemical shift MRI

Park et al. Radiology 2007;243:716
Jhaveri et al. AJR 2006;187:1303
Haider et al. Radiology 2004:231:711

Enhancement

Adenoma  RCC metastasis

Metastatic Clear Cell Carcinoma

Enhanced CT

Metastatic HCC

Adrenal cortical carcinoma
Adrenal cortical carcinoma invading the liver

Myelolipoma

Collision Tumor

Adenoama and lung cancer metastasis
Collision Tumor (esoph ca)

Collision Tumor (lung ca)

Collision Tumor?

Adenoma with Hemorrhage

Conclusions

- MRI is a powerful tool for characterizing lesions of the liver, pancreas, kidneys, and adrenal glands
- MRI does not always provide a definitive diagnosis, but it often provides valuable information to guide management
- Careful attention to detail and knowledge of various pitfalls and mimics can help in improving diagnostic accuracy

When to think twice about adrenal adenoma

- Known primary malignant tumor (lipid rich primary)
- Progressive prolonged enhancement
- Focal, mass-like area of differing SI and enhancement that does not lose SI on opposed phase images
- Large size (cortical carcinoma)
- Evidence of invasion