Chemical Shift Imaging in the Detection and Characterization of Neoplasms in the Abdomen and Bone Marrow

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• Lecturer
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Who are you?

1. Radiologist
2. Physicist
3. Technologist
4. Ogopogo
5. None of the above
How many years have you been in practice?

1. 1-5
2. 6-10
3. 11-15
4. 16-20
5. 21-25
6. > 25
How often do you perform dual echo chemical shift imaging (CSI) for Body MR exams?

1. All
2. Most
3. Some
4. None
5. What is dual echo CSI?
Chemical Shift

• Difference in Behavior Between Hydrogen Protons in Lipid and Water Environment

• Chemical Shift = 3.5 ppm (parts per million)
  – Lipid H protons precess 1,000,000 Hz
  – Water H protons precess 1,000,003.5 Hz
Chemical Shift

- Larmor Equation: \( \omega \) (MHz) = 43 \( B_0 \) (Tesla)
- 1.5 Tesla - \( \omega \) (MHz) = 42.5 \( \times 1.5T = 63 \) MHz
  - 63 MHz \( \times 3.5 \) hz / MHz → 220 Hz
  - 4.4 msec and 2.2 msec
Chemical Shift Imaging Techniques: 1.5 T

Chemical Shift

- Difference in Behavior Between Protons in Lipid and Water Environment
- Chemical Shift $= 3.5$ ppm

- $1.0 \text{ T: } 42 \text{MHz} \rightarrow 147 \text{ Hz}, \ 6.6 \text{ and } 3.3 \text{ msec}$
- $1.5 \text{ T: } 63 \text{ MHz} \rightarrow 220 \text{ Hz}, \ 4.4 \text{ and } 2.2 \text{ msec}$
- $3.0 \text{ T: } 126 \text{ MHz} \rightarrow 440 \text{ Hz}, \ 2.3 \text{ and } 1.15 \text{ msec}$
Chemical Shift Imaging Techniques

• T1-Weighted Images
• Technique
  – Gradient Echo
  – Dual Echo
• In-Phase and Opposed-Phase
Chemical Shift Imaging Techniques

- ↓ Signal Intensity on an Opposed Phase Image Compared to an In-Phase Image
  - Lipid and Water in the Same Voxel
  - You are the pathologist
Chemical Shift Imaging and Tissue Specific Diagnosis

Liver
Adrenal
Kidney
Pancreas
Bone Marrow
T1-WI  Hepatic Lesion Characterization: Loss of SI on Chemical Shift Imaging

• Diagnostic For Lipid and Water in the Same Voxel
• Specific for Hepatocellular Tissue
• Exclude Cysts, Hemangiomas and most Metastases
Lipid Containing Hepatic Lesions: The Top 4

- Focal Steatosis
- Hepatic Adenoma
- Regenerating Nodules
- Hepatocellular Carcinoma
Subtraction: In Phase - Opposed Phase
Pre and Post Dynamic Gadolinium Contrast
The lesion most likely represents

1. Focal Nodular Hyperplasia
2. Hepatic Adenoma
3. Hepatocellular Carcinoma
4. Regenerative Nodule
The lesion represents a hepatic adenoma. Which subtype is most likely?

1. β-Catenin Mutated
2. HNF 1-α Mutated
3. Inflammatory
4. You talkin’ to me?

Hepatic Steatosis

- Two forms of hepatic steatosis
  - Non Alcoholic Fatty Liver Disease (NAFLD)
  - Non Alcoholic Steatohepatitis (NASH)
- Metabolic Syndrome
  - Obesity
  - Insulin Resistance
  - Steatosis
Do you use MR elastography in your practice?

1. Yes
2. No
3. Not sure

33% 33% 33%
Adrenal Masses

- Adrenal Adenomas
  - Intracellular cholesterol
- Adrenal Myelolipoma
  - Mature Fat
  - Hematopoietic elements
- Adrenal Cortical Carcinoma
  - 50% - focal intracellular lipid
Adrenal Cortical Adenomas

- Cross-Sectional Imaging – 5%
- Most are Non-Hyperfunctioning
- Hyperfunctioning Cortical Adenomas
  - Cushing Syndrome
  - Conn Syndrome

The incidental adrenal mass on CT: prevalence of adrenal disease in 1,049 consecutive adrenal masses in patients with no known malignancy
In phase Opposed phase

Subtraction: In phase – Opposed Phase

Electron Density Weighted $\text{HU} = 3$
Adrenal Myelolipoma

• Uncommon Benign Adrenal Neoplasm
• Mature Fat and Hematopoietic Tissue
• Imaging Diagnosis: Macroscopic Fat
• Surgery
  – Symptomatic Lesions (Uncommon)
  – Prevent Hemorrhage (Large Lesions)
  – Most Myelolipomas: Leave Alone
MR Diagnosis Fat vs. Lipid and Water

- **Macrosopic Fat**
  - T1-WI with and without Fat suppression
  - Loss of Signal $\rightarrow$ Fat Present

- **Intracellular Lipid**
  - T1-W IP and OP
  - Loss of Signal $\rightarrow$ Lipid and Water In Same Voxel
Macroscopic Fat and Intracellular Lipid: In-Phase and Opposed Phase

- **IP** 100: 50% Lipid, 50% Water
  - Adrenal Adenoma, Steatosis

- **OP** 0: 95% Lipid, 5% Water
  - Subcutaneous Fat, Lipoma
Macroscopic Fat and Intracellular Lipid: In-Phase and Fat Sat

IP    FS     IP       FS
50% Lipid 50% Water   95% Lipid, 5% Water
Adrenal Adenoma, Steatosis  Subcutaneous Fat, Lipoma
In Phase

Opposed Phase

Fat Suppressed T1

Electron Density weighted
Adrenal Cortical Carcinoma

• Rare, Incidence = 1 / Million / Year
• M = F, 4th – 5th Decades
• Large, Infiltrative, Aggressive, Poor Px
• Chemical Shift MR: Some Tumors Focally Lose Signal
Coronal and Sagittal T2 FSE
In Phase TE = 4.6  
Opposed Phase TE = 2.3

Subtraction: In phase – Opposed Phase
In Phase TE = 4.6

Opposed Phase TE = 2.3

Subtraction: In phase – Opposed Phase
Renal Neoplasms

- Clear Cell Renal Cell Carcinoma
  - Glycogen
  - Lipid
- Renal Angiomyolipoma
  - Smooth Muscle
  - Vascular Elements
  - Fat
Histological Subtypes of RCC

- Clear Cell: 75%
- Papillary: 15%
- Chromophobe: 5%
- Oncocytoma: 2%
RCC: MR Findings

- **Clear Cell RCC**
  - Loss of SI on Chemical Shift
  - Variable Enhancement
  - Some restricted diffusion

- **Papillary RCC**
  - No Loss of SI on Chemical Shift
  - Less enhancement than CC RCC
  - Peripheral Location, Low T2 SI
  - Greater restriction of diffusion
Angiomyolipoma

• Benign Hamartoma
  – Fat
  – Smooth Muscle
  – Blood Vessels

• Sporadic – 80%

• Tuberous Sclerosis (TS) – 20%
Angiomyolipoma: Treatment

• AML < 4 cm – No Rx
• AML > 4 cm
  – Embolization, RF Ablation, Resection
  – Prevent Intratumoral Bleeding
• No Malignant Degeneration in Sporadic
• Rare Malignant Epithelioid AML in TS
Angiomyolipoma: MR Diagnosis

- Intratumoral Fat
  - T1-WIs Before and After Fat Suppression – Fat Saturation
  - Loss of SI → Fat is Present
- Suggestive Imaging Features
  - Extrarenal > Intrarenal Growth
  - Absent “Claw Sign”
Pancreatic Lesions

• Focal Fatty Change
  – Adipocytes admixed with parenchyma
  – Mimic of Tumor on Enhanced CT
• Metastatic Clear Cell RCC
Focal Fatty Change

• ↓ Attenuation mass on CT
• “Everything is Illuminated” with CSI
• Pancreatic head
• Related to duct drainage?
• “Don’t touch me” pseudolesion

• AJR 2007;188:429 Focal fatty replacement of the pancreas: Usefulness of chemical shift MRI
• AJR 1999;173:1263 Focal fatty infiltration of the pancreas: MR characterization with chemical shift imaging
Enhanced CT

Enhanced Fat Suppressed T1-WI
T2-Weighted FSE
In phase TE = 4.2

Opposed Phase TE = 2.1
Metastatic Clear Cell RCC

- Intracellular lipid within primary RCC
- RCC can metastasize to pancreas
- Similar imaging findings as primary
Fat Suppressed T2-WI
In phase TE = 4.2

Opposed Phase TE = 2.1

Subtraction: In Phase – Opposed Phase
Bone Marrow

- **Erthyropoietic Marrow**
  - High signal intensity on fat sat T2 and STIR imaging
  - Poorly marginated

- **Hemangiomas**
  - Variable amounts of fat

- **Metastatic Disease**
  - Absent fat / lipid
T1 In Phase

T1 Opposed Phase

Fat Sat T1

CT
T1 In Phase

Fat Sat T1

T1 Opposed Phase

T2* weighted image
Are you more likely to incorporate chemical shift imaging in your Body MR protocols?

1. Maybe
2. No
3. Yes