ADRENAL MR: PEARLS AND PITFALLS

Frank Miller, M.D.
- Lee F. Rogers MD Professor of Medical Education
- Chief, Body Imaging Section and Fellowship
- Medical Director, MR Imaging
- Professor of Radiology
Northwestern University, Feinberg School of Medicine
Chicago IL
DISCLOSURES

• Research grant from Siemens Health Systems
OBJECTIVES

• Discuss pearls and pitfalls of adrenal MR
• Strengths and limitations of MR
• Problem-based approach with variety of interesting cases
ADRENAL MASS

• MR of adrenal gland used to characterize adrenal masses
• Incidental mass most frequently benign adenoma
• Malignant causes include adrenal cortical carcinoma and metastasis
• Other causes-pheochromocytoma, benign causes-cyst, hemorrhage, myelolipoma
ADRENAL PROTOCOL

• In and opposed phase T1-GRE-axial and coronal
  – Most important sequence to assess for lipid seen in adenomas
  – Consider subtraction imaging (in-opposed phase)
• HASTE (SSFSE) T2-axial and coronal
• T1 FS GRE
• Optional: Dynamic postgad T1FS
CHEMICAL SHIFT IMAGING

• Special sequences to assess for fat
• In and out of phase (opposed phase) images
• Based on fat and water protons precessing differently
• On in phase images, water and fat signal in same voxel are additive
• On opposed phase images, fat and water are out of phase and cancel and appear dark and therefore adenomas are dark
CHEMICAL SHIFT IMAGING

- At 1.5 T: Fat and water are out of phase at TE 2.1 (and odd multiples of 2.1)
- In phase at TE 4.2 (even multiples of 2.1)
- At 3T, occurs at multiples of 1.1 msec (out of phase odd multiples- 1.1 3.3, 5.5 and in phase; in phase 2.2, 4.4, 6.6 msec)
- Want earliest possible echo times with opposed phase before the in phase
- Want both acquired in single breath hold to ensure accuracy
ADRENAL ADENOMA

- Incidence of 2-8%
- Challenging in oncology patient if metastasis or adenoma
- Also many patients have CECT not NCCT
- NCCT <10 HU 71% sensitive; 98% specific; want highest specificity
  - Boland et al. AJR 1998; 171: 201-204
In Phase GRE T1  TE = 4.2 ms

Opposed Phase GRE T1  TE = 2.1 ms
ADRENAL MASS

- Noninvasive characterization of adenoma is more important than diagnosis of metastases
- Critical that diagnosis of adenoma is very specific so patient with metastases do not have curative therapy of neoplasm

Korobkin et al Radiology 1995
Opposed Phase
UTILITY OF SUBTRACTION IMAGE
ADRENAL IMAGING-DOGMA

• MR can distinguish adrenal adenomas from metastases
• Based on presence of lipid in adenomas and not in other lesions (same principle as unenhanced CT)
• Signal dropout on opposed-phase imaging is highly specific for adenoma
MY PERSPECTIVE

- Adenomas sometimes easier to diagnose on MR
- Drop in signal on opposed phase images may be easier to identify on MR than low density on CT
- Does not require radiation; more sensitive for lipid
- Patients may be more accepting of not having the “same test” again
ADRENAL ADENOMAS: CHEMICAL SHIFT MRI

• Quantitative assessment

- Adrenal signal intensity index ASII =
  \[
  \frac{(\text{lesion intensity in - phase }) - (\text{lesion intensity opposed - phase })}{(\text{lesion intensity in - phase })} \times 100
  \]

- Adrenal to spleen ratio ASR =
  \[
  \frac{(\text{lesion intensity opposed - phase })/(\text{spleen intensity opposed - phase })}{(\text{lesion intensity in - phase })/(\text{spleen intensity in - phase })}
  \]
ADRENAL ADENOMAS: CHEMICAL SHIFT MRI

Cut-off values for diagnosing adenoma:
- ASII > 16.5%
- ASR < 0.71
Adrenal Adenomas - MRI

- T1W & T2W sequences are not helpful in differentiating adrenal tumors
  - generally higher T2W signal, rapid enhancement and delayed washout are consistent with malignant lesions, but considerable overlap so unreliable

- Diffusion-weighted imaging – not reliable
  - significant overlap between ADC values of adenomas and malignant tumors

- Chemical shift imaging – sensitivity 80-100%, specificity 94-100% for diagnosing adenomas
  - MRI is comparable to washout CT for hyperattenuating lesions measuring 10-30HU, with sensitivity of 89%2
  - 76.2% of lesions that are lipid-poor on NCCT measuring 10-30HU are lipid-rich on chemical shift MR, but 66.6% of lesion >30HU remain indeterminate after MR3

HX LUNG CANCER: ADRENAL HU 25
ADRENAL MYELOLIPOMA: MR

• Rare tumor with mature fat tissue and hematopoietic elements-benign
• Adrenal myelolipoma-macroscopic fat-easy diagnosis on CT
• MR need to look at T1 in phase and frequency selective T1FS images not just in phase and opposed phase
  – macroscopic fat-may not suppress on opposed phase (more sensitive for microscopic fat of adenomas)
  – Look for “India Ink” artifact on opposed phase images
61 YEAR OLD WOMAN WITH LESION RIGHT ADRENAL GLAND
61 YEAR OLD WOMAN WITH LESION RIGHT ADRENAL GLAND
India ink artifact with adrenal
ADRENAL MYELOLIPOMA

- In this patient, lesion may be collision tumor (adrenal adenoma and myelolipoma) or myelolipoma (lipid-rich and lipid-poor regions)
- No further work-up
NEXT STUDY
45 YEAR OLD FEMALE PRESENTED TO ER RIGHT LOWER QUADRANT PAIN
ANSWER
ADRENAL MYELOLIPOMA MIMICKER-LIPOSARCOMA
RECOMMENDED FOLLOWUP - FELT ADRENAL MYELOLIPOMA BUT CANNOT EXCLUDE LIPOSARCOMA - MR 6 MONTHS LATER - DOUBLED TO 8 CM
DISTINCTION OF MYELOLIPOMA FROM LIPOSARCOMA AND AML

• Large predominately fatty mass near adrenal may be difficult to identify if from adrenal or liposarcoma or AML
• Multiple planes help: if from kidney may see defect
• Liposarcoma may engulf or displace adrenal
• If normal adrenal excludes myelolipoma
  – Davarpanah AH, Israel GM. RCNA 42 (214) 792.
ADRENAL CELL CARCINOMA
BY BIOPSY

• Not typical for adenoma (lipid rich): fails to suppress on opposed phase imaging
• Differential diagnosis of adrenal mass (without liver mass): atypical (lipid poor) adenoma, adrenal cell carcinoma, metastasis, pheochromocytoma
PEARLS

- Chemical shift MR imaging is helpful in identifying adrenal adenomas
- Basis of distinction is the presence of abundant intracytoplasmic lipid in adenomas
- MR criterion for adenoma is COMPLETE suppression-subjective or quantitative
T1 Weighted In Phase (TR/TE=130/4.1)

Out of Phase (TR/TE=130/2.2)
EXCEPTIONS

• Observation that some lesions demonstrate heterogeneous, incomplete suppression

• Appearance is not typical for an adenoma nor for a metastasis
“ATYPICAL” Adenomas

- 34 of 242 patients (14%) had adrenal lesions with heterogeneous suppression
- Combination of interwoven lipid rich cells and compact lipid poor cells
- Percentage of lipid rich cells varied from 20-80%

Gabriel H, Pizzitola V, McComb EN, Wiley E, Miller FH. Adrenal Lesions with Heterogeneous Suppression on Chemical Shift Imaging: Clinical Implications. JMRI 2004; 19:308-316
PATHOLOGY CORRELATION

• Amount and distribution of the cell types likely correlates with the MR imaging findings
• All patients with heterogeneous suppression were benign
• Patients with heterogeneous suppression and without history of malignancy may potentially be managed conservatively with follow up
RARE PITFALLS
54 YR OLD WOMAN CHEST CT FOR PULMONARY NODULES
6 YEARS LATER: CHEST CT R/O PE: SECOND ADRENAL MASS WITH PUNCTATE PERIPHERAL CALCIFICATIONS
CHEMICAL SHIFT

T1 In Phase  T1 Opposed Phase
GADOLINIUM-ENHANCED
BIOPSY SPECIMEN
ANSWER
• Collision tumor due to adrenal adenoma and hemangioma

COLLISION TUMORS

- Extremely rare; prevalence unknown
- Refer to 2 different types of adrenal lesions that coexist, may be benign or malignant
- Imaging appearance is combination of adenoma and hemangioma
- Suspect if 2 types of focal lesions, atypical adenoma grows, changes in appearance or somewhat large and heterogeneous with known malignancy
ADRENAL HEMANGIOMA-ADENOMA COLLISION TUMOR

• Adrenal hemangiomas – rare with less than 50 reported cases
• Women 50-70 yr old, usually asymptomatic and very large
• Similar to liver hemangiomas may be hypointense T1WI, hyperintense-T2WI, peripheral nodular enhancement less common due to prominent areas of necrosis and fibrosis
ANOTHER PITFALL
SIGNAL DROP IN ADRENAL AND LIVER
CORONAL CHEMICAL SHIFT SUBTRACTION (IN-OPPPOSED PHASE)

ADRENAL ADENOMA? (Note absent left kidney)
4 MONTHS LATER

2.7 x 1.8 CM

3.5 x 2.3 CM
SIGNAL DROP - BIOPSY PROVEN CLEAR CELL CARCINOMA MET
PITFALL OF ADRENAL ADENOMAS-CLEAR CELL RENAL CELL CARCINOMA

- Clear cell and less commonly granular cell carcinomas can have loss of SI on out of phase MR due to microscopic fat
- In kidney mimics AML with microscopic fat or in case of adrenal lesion, adrenal adenoma
- Similar finding may be due to hepatocellular carcinoma metastasis to adrenal gland

Outwater EK. Radiology 1997; 205: 103-107
Hypervascular metastases can show washout on adrenal protocol CT similar to adenomas (ie clear cell RCC, HCC—same issues as fat with MR)
45 YR OLD MAN W CLEAR CELL RCC; INDETERMINATE 3 CM MASS ON CT
SUBTRACTION IMAGE (IN-OPPOSED)
CLEAR CELL RENAL CELL CARCINOMA

• Need to recognize that dogma that lesions that contain fat are not all adenomas: exceptions include RCC and HCC metastases
• Patients with history of RCC or presence of mass suspicious for RCC, adrenal metastasis must be considered even if adrenal shows a drop in signal on opposed phase images
• General population without history of malignancy, mass with signal loss should be considered adenoma
60 YEAR OLD MALE
39 YR OLD FEMALE WITH CUSHING
ADRENAL CORTICAL CANCER

• Can have fat as arise in adrenal cortex like adenoma
• Note that the mass however is large and generally heterogeneous
• Invades IVC and adjacent organs
IVC INVASION
34 YR OLD ORTHOPEDIC SURGEON: ABDOMINAL PAIN
<table>
<thead>
<tr>
<th>HX - HEMATURIA AND L FLANK PAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EARLY POST GAD</strong></td>
</tr>
<tr>
<td><strong>DELAYED POST GAD</strong></td>
</tr>
<tr>
<td><strong>CORONAL HASTE</strong></td>
</tr>
<tr>
<td><strong>DELAYED POST GAD</strong></td>
</tr>
</tbody>
</table>
ADRENAL CORTICAL CARCINOMA

- Extremely rare
- Usually large at diagnosis, majority >6cm
- Approximately 10% bilateral
- Usually present with pain and palpable mass, >50% with endocrinopathy
- Suspect if adrenal lesion with vascular invasion
ADRENAL CORTICAL CARCINOMA

• Often intermediate SI on T1WI, mixed intermediate and high SI on T2WI, larger lesions often have central necrosis
• Some may have small foci of lipid and lose signal on opposed phase images but generally they are larger lesions (>5 cm) than adenomas and more infiltrative
• Gadolinium helpful for vascular invasion
NEXT STUDY
HEPATIC ARTERIAL BLOOD SUPPLY
THOUGHT BE HEPATIC ADENOMA GIVEN FAT AND SURGERY PERFORMED
ANSWER
HART: HEPATIC ADRENAL REST TUMOR

- Originates from adrenal rest from aberrant adrenocortical tissue
- Round, well demarcated mass in posterior segment hepatic lobe in subcapsular region; has hepatic arterial blood supply but contiguous with adrenal gland
- Include in differential of solid hypervascular or fat-containing hepatic tumor in characteristic location; often not diagnosed preoperatively
  - Mimic HCC, adenoma and angiomyolipoma

Tajima JCAT 2001 25: 98-101
DIFFUSION WEIGHTED MR

• Diffusion-weighted MR has been used to detect and characterize various abdominal lesions
• “Dogma” is malignant lesions have restricted diffusion and low apparent diffusion coefficients (ADC) while benign lesions do not
PURPOSE

- Evaluate diffusion MR ADC values to distinguish benign and malignant pathologies and see if correlation of signal intensity (SI) decrease on chemical shift sequences

SUBJECTS AND METHODS

- Retrospectively reviewed 160 lesions
  - 118 adenomas, 9 myelolipomas, 9 cysts, 4 adrenal hemorrhages, 1 angiolipoma
  - 11 metastases, 4 adrenal cortical carcinomas, 3 pheochromocytomas, 1 neuroblastoma
ADRENAL CYSTS: ADC 3.0

- Adrenal cysts had statistically higher ADC values compared to the remaining adrenal lesions due to free water
RESULTS

- ADC values: Median; (interquartile range) - same
  - adrenal malignancies: 1.67
  - benign lesions: 1.61
- Difference in the percentage SI decrease was greater in benign compared to malignant adrenal masses (P<0.05)
- The median (interquartile range) size of malignant lesions was 4.9 cm (2.8 to 8.5), which was greater than that of benign lesions 2.0 cm (1.6 to 2.6)
ADRENAL ADENOMA

- Diffusion-weighted MR could not distinguish lipid rich from lipid poor adenomas
- For adrenal adenomas, there was no relationship between ADCs and percentage SI decrease at chemical shift MR imaging (p>0.05)
RESULTS: ADCs of adrenal lesions

- Myelolipoma: 1.16 x10^-3 mm^2/s
- Hemorrhage: 1.75 x10^-3 mm^2/s
- Adenoma: 1.60 x10^-3 mm^2/s
- Cyst: 2.93 x10^-3 mm^2/s
- Carcinoma: 1.55 x10^-3 mm^2/s
- Pheochromocytoma: 1.84 x10^-3 mm^2/s
- Metastasis: 1.64 x10^-3 mm^2/s
ADENOMA: ADC 2.78
ADENOMA:
ADC 2.78 / SI DECREASE 91%
ADRENAL ADENOMA

• For adrenal adenomas, there was no relationship between ADCs and percentage SI decrease at chemical shift MR imaging (p>0.05)
ADENOMA:
ADC 0.64 / SI DECREASE 46%
CARCINOMA: ADC 0.99

- Mean of carcinomas was 1.47 without difference from other lesions except cysts being higher.
PHEOCHROMOCYTOMA: ADC 1.68
DIFFUSION

- Dogma that diffusion MR can distinguish benign from malignant lesions does not work in adrenal gland due to overlap.
- Benign lesions such as adenomas had restricted diffusion; only less common adrenal cysts had higher values.
- Chemical shift MR imaging still best.

Tsushima Y JMRI 2009; Miller FH AJR 2010; Sandrasegaran K AJR 2011; Halefoglu AM 2012.
ANSWER
ANSWER

- Received parenteral IV iron therapy
- Iron deposition in adrenal and lymph nodes
ADRENAL SUMMARY

• MR can detect and characterize most adrenal masses
• Chemical shift imaging is sensitive for microscopic fat and can characterize lipid-rich adrenal adenomas
• Clear cell renal cell and HCC metastasis can have microscopic fat and mimic adrenal adenoma
• Myelolipoma diagnosed when macroscopic fat using T1 frequency selective fat suppression and chemical shift artifact
ADRENAL SUMMARY

- Adrenal cell carcinoma-suspect with large heterogeneous mass with vascular invasion
- Diffusion weighted MR-did not help distinguish lesions
CONCLUSION

- MR can be used as primary diagnostic test and not just problem solving
- Plays an integral role in evaluation of adrenal diseases
- Any questions: fmiller@northwestern.edu