Diagnostic Imaging of Thoracic-Abdominal-Pelvic Diseases – The Role for MRI as a High Diagnostic Yield, Safe and Cost-Effective Alternative to CT

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Why use MRI?

Over the past 10 years there has been growing published peer-reviewed evidence for the use of thoraco-abdominal-pelvic MRI in applications spanning neoplastic to non-neoplastic and acute to chronic conditions. In many instances, this evidence may be used to support transition of one's practice to further introduce or expand appropriate use of MRI and reduce use of other tests – such as CT – to provide patients with minimized exposure to ionizing radiation, the fewest number of tests, fast time to correct diagnosis, and optimized therapeutic management.

The soft tissues of the chest, abdomen, and the pelvis represent the most radiosensitive tissues, an important factor when considering that imaging wisely implies balancing cost and availability with using the most diagnostic test that minimizes or avoids exposure to the ionizing radiation from CT scanning.

For many clinical problems in which CT has been used to evaluate soft-tissue disorders, body MRI provides an acceptable or favorable alternative. Diagnostic performance and value – defined as outcome divided by overall cost to achieve that outcome - of MRI has been tested and shown to be equal or favorable for most of the common and important diseases affecting the solid and hollow organs of the abdomen and pelvis.

The Challenges in Implementing Body MRI

MRI protocols can be confusing due to the large number of potential variations in sequences available and in the settings used to optimize each of these sequences. All the major MRI manufacturers have been improving the user controls in order to simplify the methodology for body MRI applications. New advances are making the imaging more robust and resistant to problems related to patient motion or from variations introduced by differences in operator experience. Suggested protocols can be found at each of the major manufacturers' websites (recommendation: search for your corresponding vendor MRI website and navigate to protocols). A universal educational site for protocols specific to each of the most common types of MRI, by manufacturer, can be found here:

http://imagingeducation.com/

A general educational reference on MRI nuts-and-bolts can be found here:

http://mriquestions.com/dynamic-ce-imaging.html

There may be reluctance to using a technique that is considered expensive. However, the actual cost of operating an MRI scanner is only incrementally greater than the operating cost for CT. Also, a growing body of published evidence shows that body MRI, when used appropriately, can be performed efficiently, reliably, and adds value by reducing the overall cost of patient care.

Body MRI Applications

Chest: MRI may be used as a first-line test for assessment of mediastinal, pleural, and chest wall soft tissues; chest MR Angiography (MRA) to study the aorta, branch vessels; and pulmonary MRA to detect large to medium size pulmonary emboli. Metastatic disease evaluation can be performed in association with abdominal-pelvic examinations for comprehensive staging, and pulmonary nodules may now routinely be imaged down to 2 to 3mm. Breast and cardiac functional and myocardial perfusion/scan imaging are established applications, and MRI and MRA is a frontline modality for congenital heart disease evaluation in pediatrics. See [MRI of the Chest] or Cardiac MRI (http://www.radiologyinfo.org/en/gallery/index.cfm?video=1266) at RadiologyInfo.org.

There is a growing body of published evidence indicating that MRI/MRA can be used for acute pulmonary embolism imaging as an alternative to contrast enhanced CT, particularly for younger patients where ionizing radiation to the chest and to the breast tissues should be avoided when possible; this is especially true for young women. Earlier reports raised controversy with critical reviews supporting the point that this application should be reserved only for centers with expertise until further improvements became widespread. See Why Can't Magnetic Resonance Imaging Reliably Diagnose Pulmonary Embolism? MRI of the chest and lungs remains an area of considerable potential for further development. Learn more at http://www.mr-tip.com/serv1.php?type=db1&dbs=Lung%20Imaging. For more detailed reading, an extensive reference list is provided below with several more recent reports from various centers showing much improved results for detection of acute pulmonary embolism using the latest MRA techniques.

Abdomen: MRI may be considered a replacement for CT or first-line diagnostic test for focal and diffuse diseases of the liver, bile ducts and gall bladder, pancreas, kidney solid and cystic masses, adrenal glands, peritoneum and retroperitoneum, including angiographic examination. MRI provides greater diagnostic specificity than CT for most solid masses due to soft tissue contrast achievable on MRI. Learn more at MedlinePlus: http://www.nlm.nih.gov/medlineplus/ency/article/003796.htm.

Pelvis: Soft tissues of the pelvis generally produce only a small range of image densities on CT, leading to low contrast between structures, which makes it difficult to recognize and diagnose disease. MRI (along with ultrasound) provides the frontline diagnostic evaluation for pelvic soft tissue disease including the gynecological, prostate, ureters, and bladder. CT should *not be considered* as a frontline test for most cases of pelvic soft tissue disease imaging. For example, the use of MRI in patients with prostate cancer has advanced our ability to better diagnose and treat this common and important disease. MRI, combined with Ultrasound, is revolutionizing our accuracy for prostate cancer diagnosis. The use of MRI for radiation treatment planning has been shown to significantly improve outcomes and reduce the incidence of radiation side effects, including impotence, incontinence, and chronic bladder or rectal inflammation. This is because MRI has a superior capability for showing the pelvic soft tissues. Learn more at:

http://www.radiologyinfo.org/en/search/gsa-iframe.cfm?q=prostate+mri&btnG=&site=RadioInfo_en&client=RadioInfo_en&output=xml_no_dtd&proxystylesheet=RadioInfo_en&excludeapps=1&filter=0&getfields=*&proxyreload=1.

This is true for female pelvic disorders as well. For example, MRI can even be used to study the dynamic "moving" pelvis, without the risks of ionizing radiation, as a method for studying pelvic floor instability; a condition of women who have had multiple vaginal pregnancies and which can lead to problems of defecation and urination. Learn more at:

http://www.radiologyinfo.org/en/info.cfm?pg=dynamic-pelvic-floor-mri.

Bowel: In centers with experience, MRI is a first-line test for inflammatory bowel disease, including Crohn's disease. It has been shown that CT findings of Crohn's disease do not correlate well with disease activity. Feasibility for using MRI for evaluation of Crohn's and for determination of disease activity has been demonstrated. Use of gadolinium enhanced gradient echo, in combination with fat-suppressed, single-shot, echo-train T2 imaging, may yield information that correlates with the degree of active inflammation in and around the involved bowel segments, complementing results from endoscopic techniques. Feasibility for the use of MRI for the investigation of other acute gastrointestinal disease also has been demonstrated, such as for acute appendicitis. It has been now well-established in peer-reviewed publications that, in young adults and in pediatric age groups, MRI can be used as a primary imaging modality for evaluation of acute appendicitis, and for other acute abdominal and pelvic disorders.

The Pregnant Patient: Excellent depiction of a full range of disease processes and safety due to lack of radiation make MRI the ideal modality for evaluating the pregnant patient. Although Ultrasound is a similarly safe imaging modality, it is less reliable for demonstrating maternal acute disease processes beyond the uterus and adnexa, and cannot provide the overall topographical display. MR also depicts complex congenital diseases and is an important adjunct to ultrasound.

Whole Body Scanning: Until recently, MRI systems have been utilized to evaluate disease processes limited to one or a few body regions or organ systems, while CT systems can be used to scan the entire chest, abdomen, and pelvis during a single breath hold. Newer engineering developments in MRI systems are being introduced which facilitate more rapid imaging of larger body regions and for efficiently combining the imaging of multiple stations, including a rapidly acquired examination of the chest, abdomen, and pelvis. Recent studies have shown the feasibility of imaging the entire body using MRI as a method for tumor evaluation and staging, or for whole body MR angiography.

Recommendations for the Practicing Radiologist: When and How to Use MRI

CT is an excellent modality for investigating many disease processes. However, there are two major reasons to migrate from CT to MRI for several fundamental indications for diagnostic body cross-sectional imaging. First, there is a growing awareness of the potential risk of radiation exposure, particularly with the drive towards more diagnostic multiple-pass dynamic enhanced scans and higher resolution imaging. Second, but just as important, is the recognition that MRI should be a primary diagnostic method for a growing number of common indications; particularly for liver, pancreas, kidney, bowel, gynecological, prostatic and vascular diseases. The improved diagnostic yield of optimized MRI is expected to be proved cost-effective in appropriate use where favorable impact can be determined by demonstrating that the total number of exams, time to correct diagnosis, number of unnecessary invasive diagnostic procedures, and inappropriately guided therapies are reduced through superior diagnostic sensitivity and specificity.

Indications for which CT should be considered a primary diagnostic method include; patients with severe trauma, the detection of renal and ureteric calculi, delineation of gastrointestinal perforation, interventional procedure guidance, and high resolution depiction of interstitial lung disease.

Current practice for imaging patients with known or suspected intracranial or spinal neurological disorders has been increasingly oriented to using MRI as a primary imaging technique. A large potential impact on practice patterns would be expected from evaluating body imaging indications. Examples of common indications where alternatives to body CT should be recommended routinely include patients with known or suspected hepatobiliary, pancreatic, adrenal, and renal disease, except for renal calculi. For example, patients who have had an unenhanced or single-phase enhanced CT scan for initial assessment of disease and were found to have a non-specific hepatic or pancreatic lesion, a multi-phase gadolinium-enhanced MRI should be preferred to a multi-phase CT study. Patients with right upper quadrant pain may be initially screened using abdominal ultrasound, and if non-diagnostic, a gadolinium enhanced abdominal MRI recommended. Similarly, female patients with gynecological or obstetrical concerns should be first imaged by ultrasound, followed by MRI if the sonographic examination is non-diagnostic.

Related Links for Reference and Educational Opportunities

General Reference

http://www.medscape.com/viewarticle/511853_2

http://www.nlm.nih.gov/medlineplus/ency/article/003796.htm

http://www.radiologyinfo.org/en/info.cfm?pg=bodymr

MRI Protocols

http://imagingeducation.com/Default.aspx

Educational Opportunities for Radiologists

American College of Radiology – Classroom of the Future – Body MRI Mini-Fellowship Practicum

http://www.acr.org/EducationCenter/ACRFutureClassroom/details-bodymr.aspx

MRI Contrast Safety

FDA gadolinium based contrast agent safety warning update 9.2010

http://www.fda.gov/Drugs/DrugSafety/ucm223966.htm

http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm225286.htm

Additional Related Reading

Scientific Publications

Value-Testing of MRI for Acute Thoraco-Abdominal-Pelvic Diseases

- *Use of MRI allowed cost savings (55K-72K euro) from unnecessary hospitalization and laparoscopy*

  Cobben L, Groot I, Kingma L, et al. A simple MRI protocol in patients with clinically suspected appendicitis: results in 138 patients and effect on outcome of appendectomy. European radiology 2009; 19(5): 1175-83.

- *Cost savings (2335 euro) from MRI in patients with equivocal clinical findings for appendicitis*

  Heverhagen J, Pfestroff K, Heverhagen A, et al. Diagnostic accuracy of magnetic resonance imaging: a prospective evaluation of patients with suspected appendicitis (diamond). J Magn Reson Imaging 2012; 35(3): 617-23.

- *Compared diagnostic lap, CT and MRI following indeterminate US in pregnant patients*
- *MRI most cost effective, $6767 per QALY relative to CT*

  Kastenberg ZJ, Hurley MP, Luan A, et al. Cost-effectiveness of preoperative imaging for appendicitis after indeterminate ultrasonography in the second or third trimester of pregnancy. Obstetrics and gynecology 2013; 122(4): 821-9.

- *CT colon showed similar life years and QALYs per individual compared with optical colonography, and substantially lower cost*

  Gomes M, Aldridge RW, Wylie P, et al. Cost-effectiveness analysis of 3-D computerized tomography colonography versus optical colonoscopy for imaging symptomatic gastroenterology patients. Applied health economics and health policy 2013; 11(2): 107-17.

- *Using MRI over CT until age 50 resulted in:*

  (1) incremental cost effectiveness ratio of $58,022-$62,648/life year gained
  (2) $84,250-$90,982 per QALY

  Cipriano LE, Levesque BG, Zaric GS, et al. Cost-effectiveness of imaging strategies to reduce radiation-induced cancer risk in Crohn's disease. Inflammatory bowel diseases 2012; 18(7): 1240-8.

- *When contrast-enhanced MRI used as initial staging modality, net savings of 1,044 euro compared to starting with CT*
- *Further imaging required in 8.6% of MRI and 23.5% of CT*

  Zech CJ, Grazioli L, Jonas E, et al. Health-economic evaluation of three imaging strategies in patients with suspected colorectal liver metastases: Gd-EOB-DTPA-enhanced MRI vs. extracellular contrast media-enhanced MRI and 3-phase MDCT in Germany, Italy and Sweden. European radiology 2009; 19 Suppl 3: S753-63.

- *Assess direct costs of utilizing CT versus MRI for staging of rectal cancer*
- *Substantial cost savings for MRI (711 euro) versus CT (1035 euro) for workup and staging*

  Huppertz A, Schmidt M, Wagner M, et al. Whole-body MR imaging versus sequential multimodal diagnostic algorithm for staging patients with rectal cancer: cost analysis. RoFo : Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin 2010; 182(9): 793-802.

- *469 second opinion reviews of MRI for gynecological cancer*
- *Approximately 20% of second subspecialty interpretation changed management and surgical decisions, and were confirmed with pathology*

  Lakhman Y, D'Anastasi M, Micco M, et al. Second-opinion interpretations of Gynecologic-oncologic MRI exams by sub-specialized radiologists: influence on patient care. European radiology 2016; 26(7): 2089-98.

Publications Comparing CT vs MRI Diagnostic Precision and Value

- *CT, MRI: general liver lesion characterization*

  Semelka R, Martin D, Balci C, Lance T. Focal liver lesions: comparison of dual-phase CT and multisequence multiplanar MR imaging including dynamic gadolinium enhancement. J Magn Reson Imaging 2001; 13(3): 397-401.

- *CT, MRI: HCC*

  De Ledinghen V, Laharie D, Lecesne R, et al. Detection of nodules in liver cirrhosis: spiral computed tomography or magnetic resonance imaging? A prospective study of 88 nodules in 34 patient. Eur J Gastroenterol Hepatol 2002; 14(2): 159-65.

- *CT, MRI: HCC*

  Onishi H, Kim T, Imai Y, et al. Hypervascular hepatocellular carcinomas: detection with gadoxetate disodium-enhanced MR imaging and multiphasic multidetector CT. Eur Radiol 2012; 22(4): 845-54

- *CT, MRI: HCC*

  Pitton M, Kloeckner R, Herber S, et al. MRI versus 64-row MDCT for diagnosis of hepatocellular carcinoma. World J Gastroenterol. 2009; 15(48): 6044-51.

- *CT, MRI, explant histology: CRC*

  Kasuya K, Oshiro H, Saito K, et al. Comparison of preoperative images with gross and histopathological findings of liver slices in patients with liver metastases from colorectal cancer after chemotherapy. Hepatogastroenterology 2012; 59(116): 981-85.

- *CT vs MRI: Pancreatic CA*

  Motosugi U, Ichikawa T, Morisaka H, et al. Detection of pancreatic carcinoma and liver metastases with gadoxetic acid–enhanced MR imaging: comparison with contrast-enhanced multi–detector row CT. Radiology 2011; 260(2): 446-53. Epub 2011 Jun 21.

- *CT vs MRI: CRC*

  Van Kessel C, van Leeuwen M, van den Bosch M, et al. Accuracy of multislice liver CT and MRI for preoperative assessment of colorectal liver metastases after neoadjuvant chemotherapy. Dig Surg 2011; 28(1): 36-43. Epub 2011 Feb 4.

- *US, CT, FDG PET, MRI: CRC*

  Floriani I, Torri V, Rulli E, et al. Performance of imaging modalities in diagnosis of liver metastases from colorectal cancer: A systematic review and meta-analysis. J Magn Reson Imaging 2010; 31(1): 19-31.

- *PET CT vs CE PET CT vs MRI: CRC*

  Cantwell C, Setty B, Holalkere N, et al. Liver lesion detection and characterization in patients with colorectal cancer: a comparison of low radiation dose non-enhanced PET/CT, contrast-enhanced PET/CT, and liver MRI. J Comput Assist Tomogr 2008; 32(5): 738-44.

- *MRI, US, CT: general liver lesion characterization*

  Shah A, Parsons B, Pope I, et al. The clinical impact of magnetic resonance imaging in diagnosing focal hepatic lesions and suspected cancer. Clin Imaging 2009; 33(3): 209-12.

References on MR Angiography – Pulmonary Embolism

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- Ohno Y, Koyama H, Yoshikawa T, et al. Contrast-enhanced multidetector-row computed tomography vs. Time-resolved magnetic resonance angiography vs. contrast-enhanced perfusion MRI: assessment of treatment response by patients with inoperable chronic thromboembolic pulmonary hypertension. J Magn Reson Imaging 2012; 36(3): 612-623
- Kalb B, Sharma P, Tigges S, et al. MR imaging of pulmonary embolism: diagnostic accuracy of contrast-enhanced 3D MR pulmonary angiography, contrast-enhanced low-flip angle 3D GRE, and nonenhanced free-induction FISP sequences. Radiology 2012; 263(1): 271-278
- Revel MP, Sanchez O, Lefort C, et al. Diagnostic accuracy of unenhanced, contrast-enhanced perfusion and angiographic MRI sequences for pulmonary embolism diagnosis: results of independent sequence readings. Eur Radiol 2013; 23(9): 2374-2382
- Ersoy H, Goldhaber SZ, Cai T, et al. Time-resolved MR angiography: a primary screening examination of patients with suspected pulmonary embolism and contraindications to administration of iodinated contrast material. AJR 2007; 188(5): 1246-1254
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- Yilmaz E, Akkoclu A, Degirmenci B, et al. Accuracy and feasibility of dynamic contrast-enhanced 3D MR imaging in the assessment of lung perfusion: comparison with Tc-99 MAA perfusion scintigraphy. Clinical Radiology 2005; 60: 905-913.
- Ohno Y, Higashino T, Takenaka D, et al. MR angiography with sensitivity encoding (SENSE) for suspected pulmonary embolism: comparison with MDCT and ventilation-perfusion scintigraphy. AJR, 2004; 183: 91-98.
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Books

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