MRI in the Emergency Room

Rapid MRI Protocols and Acquisitions for Emergency Patients

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Target Audience

Clinicians seeking to implement and improve Body MRI protocols for patients in an emergency room setting.

Objectives

Review common indications and types of Body MRI exams in the ER.

Review strategies to get patients to the MRI scanner and through the MRI study in a safe and rapid way to answer the clinical question asked.

Review common rapid sequences and strategies to obtain T1-weighted, T2-weighted, diffusion-weighted, balanced coherent steady state imaging, and flow-related images.

Show examples of common protocols related to indications for rapid Body MRI study acquisitions and relevant cases.

Discussion

While MRI is often not the first exam choice in patients presenting to the emergency room with problems referable to the chest, abdomen, and pelvis where a body MRI protocol would be used, it can often be a second line study after ultrasound. The most common example of this currently is in pregnant and pediatric patients with right lower quadrant pain where there is concern for appendicitis. When ultrasound does not find the appendix or is otherwise equivocal, MRI can evaluate the appendix quickly and has been shown to have excellent sensitivity (> 90%) and specificity (>95%) in diagnosing acute appendicitis.[1] Other common indications where body MRI follows ultrasound when it is not completely diagnostic in the emergency setting include evaluation for choledocholithiasis (such as in right upper quadrant pain) and for ovarian torsion or other acute gynecological pathology in women with pelvic pain. MRI also is commonly used in place of CT in patients with contrast allergies or renal dysfunction such that they cannot receive iodinated contrast. This has become common when evaluating for pulmonary embolism and acute aortic pathology, such as aortic dissection. Other uses include in evaluation of mesenteric ischemia and acute venous thrombosis. MRI is also used instead of CT when radiation exposure is a concern such as in the children, pregnant women, and patients who get frequent imaging such as patients with Crohn's disease. With the latter, this usually in the evaluation of the bowel and peritoneal cavity during acute flare's when perforation is not a

concern or in evaluation of pelvic abscess in perianal fistulous disease, but in pediatric and pregnant patients the use of MRI in the emergency setting is becoming more widespread including in evaluation for small bowel obstruction, pancreatitis, pyelonephritis, and cholecystitis.

More time usually passes between when a clinician wants to order an emergent MRI and when the patient gets on the scanner than the time that the patient is on the scanner. To expedite the process prior to getting the patient on the scanner, it is best to create specific orders for each of the most common MRI studies ordered by the emergency room physicians (e.g., MRI Appendicitis, MRA Pulmonary Arteries) and to have MRI screening forms in available for the emergency room so that it can start being filled out as soon as the decision to order an MRI is made. The screening form should be reviewed by level 2 MRI personnel as soon as it is completed so that any issues, such as obtaining information on an implanted medical device, can be dealt with quickly. Policies should be in place that direct clearly the processes for the most common safety issues that arise (e.g., implanted medical device clearance, gadolinium-based contrast agent [GBCA] administration, MRI in pregnancy). Consent forms should be readily available for situations when they are needed (e.g., MRI in pregnancy, GBCA administration in patients with severe renal dysfunction). The process should be laid out clearly for freeing up an MRI scanner for emergent cases and for mobilizing MRI technologists to prepare and scan the patient. A discussion should occur between a level 2 MRI personnel and the emergency room team about what patient monitoring and support devices will be needed during the scan so that this can be planned safely. If a GBCA is to be given, a recent serum creatinine should be confirmed to assess renal function. Also, so that the patient can be as comfortable as possible during the scan, plans should be made for the administration of pain or other medications, particularly if the patient will need sedation. A radiologist must be available during the process prior to imaging to answer safety and scheduling questions, while imaging to troubleshoot and optimize the scan if needed, and after imaging to interpret the study.

For many sequences in the abdomen and pelvis, imaging is performed ideally when the patient is breath holding, so it is important to assess the potential need for oxygen supplementation and to prepare the patient for breath holding optimally and regularly. It is helpful to have a device that monitors the respiratory cycle while in the scanner to aid in optimizing breath hold imaging, knowing when the patient has not been able to hold breath or is drifting, and in performing respiratory triggered sequences if needed. ECG or pulse gating may be desired for certain MRA/MRV studies, so these should be set up in appropriate circumstances.

Sequence Overview:

T1-weighted imaging – The most common 2D in- and out-of-phase imaging uses spoiled gradient echo imaging (SPGR, FLASH, T1-FFE) and is performed in a breath hold usually. 3D SPGR imaging can also be used for in- and out-of-phase imaging, but usually needs parallel imaging to be performed in a breath hold, has more blurring and artifacts, and has less T1 contrast. However, for GBCA-enhanced imaging, 3D SPGR methods are usually preferred and often employ chemical fat saturation (LAVA, VIBE, THRIVE) or a Dixon-based fat/water separation (LAVA Flex, VIBE Dixon, mdixon).

Ultrafast gradient echo imaging (TurboFLASH, Fast-SPGR, TFE) can be used in patients who cannot breath hold successfully to obtain in- and out-of-phase imaging as well as GBCA-enhanced imaging quickly and with usually reasonable image quality given the lack of breath holding.

T2-weighted imaging – While in the pelvis, standard Fast or Turbo Spin Echo (FSE, TSE) imaging can be used without corruption by breathing motion frequently, this is usually not the ideal choice in the abdomen, though with regular breath holders fat suppressed FSE/TSE images in 1 or 2 breath holds can yield reasonable image quality. Respiratory triggering or navigator techniques can also be used to obtain fat suppressed FSE/TSE images, however at a time penalty of several minutes. Single-shot techniques are the standard for T2wi (SSFSE,HASTE, SSTSE) both without and with fat suppression. Low b-value EPI-based DWI is also used for fat-suppressed T2wi. 3D T2wi, as is commonly used in MRCP, can be performed in a breath hold with limited coverage and with respiratory triggering or navigator techniques for larger coverage with higher resolution.

Balanced coherent steady state imaging – Known as TrueFISP, FIESTA, and balanced FFE, these have become a mainstay of rapid imaging in the abdomen and pelvis, particularly for enterography and vascular imaging but also for pancreaticobiliary and urographic imaging because of their excellent contrast between fluid-filled structures and soft tissue. They are relatively motion insensitive because they are rapid and thus can be used in patients who cannot breath hold successfully. Fat suppression can be used and, while primarily 2D sequences are employed, 3D techniques can also be used.

Flow-related imaging – While GBCA-enhanced T1wi sequences are used primarily to assess the vasculature in MRA/MRV protocols, other sequences can be helpful, particularly in patients who cannot receive GBCAs. Bright-blood imaging with balanced coherent steady state sequences can provide both luminal and mural information in a breath hold using 2D and 3D techniques, though with limited coverage for the latter. 3D balanced coherent steady state imaging can also be used with respiratory triggering or navigator techniques for larger coverage and produce particularly good image quality when used in conjunction with inflow related enhancement techniques and background suppression (IFIR, NATIVE, B-TRANCE). Gated 3D FSE/TSE techniques have also become possible. Dark-blood techniques using single-shot T2wi can help assess vessel walls and depict thrombus in a breath hold. 2D time-of-flight (TOF) and phase contrast imaging can assess luminal patency and provide flow information of limited coverage in a breath hold.

Example Protocols for Rapid Body MRI in the Emergency Room:

All protocols use GE sequence names; see above for relevant Siemens and Philips names

MRA Pulmonary Arteries – rule out pulmonary embolus

1. 3-Plane Localizer

2. Coronal SSFSE (through entire lungs)
3. Axial 2D Non-gated FIESTA
4. Axial LAVA XV pre-contrast – through pulmonary tree
5. Inject GBCA
6. Axial LAVA XV post-contrast x 2
7. Coronal LAVA XV

MRA Thoracic Aorta – rule out dissection

1. 3 Plane Localizer
2. Coronal Black Blood SSFSE, EKG-triggered
3. Axial Black Blood SSFSE, EKG-triggered
4. Axial 2D Gated FIESTA
5. Axial 2D Cine Gated FIESTA, single slices through
   A. Top of Aortic Arch
   B. Proximal Ascending Aorta
   C. Aortic Root
   D. Mid-Descending Aorta
6. Oblique Sagittal 3D T1 SPGR pre-contrast
7. Inject GBCA
8. Oblique Sagittal 3D T1 SPGR post-contrast x 2

MRCP – rule out choledocholithiasis

1. 3-Plane Localizer
2. Axial SSFSE
3. Coronal 3D MRCP (Respiratory Triggered, 2mm thin slab)
4. Coronal SSFSE
5. Coronal Thick Slab SSFSE (5 slice pin-wheel around CBD)
6. Axial DWI (b50, b600)
7. Axial T1 In and Out-of-phase

MRI Appendicitis – rule out appendicitis

1. 3-Plane Localizer
2. Sagittal SSFSE
3. Coronal SSFSE
4. Axial SSFSE
5. Axial Fat Saturated SSFSE
6. Axial T1 In and Out-of-phase
7. Axial 2D TOF
8. Axial DWI (b50, b600)

References

1. Blumenfeld YJ, Wong AE, Jafari A, Barth RA, El-Sayed YY. MR imaging in cases of antenatal suspected appendicitis--a meta-analysis. J Matern Fetal Neonatal Med. 2011 Mar;24(3):485-8.