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Recognition and Appropriate Use of Magnetic Resonance Imaging for Emergent Neuroradiology

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The use of magnetic resonance imaging (MRI) for the diagnosis of emergent life-threatening neurologic conditions and what are considered "do not miss" pathologies has dramatically increased over the past 10 years due to its increasing importance in the emergency department. Although computed tomography is likely to remain the more significantly used imaging modality due to lower cost and faster speeds, continuing technological advances in MRI have made its use more mainstream. Knowledge of specific clinical signs and symptoms as well as the technical limitations of MRI should help to guide emergency department clinicians with both the recognition and the appropriate use of emergent MRI.
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Recognition and Appropriate Use of MRI for Emergent Neuroradiology

The use of magnetic resonance (MR) imaging (MRI) for the diagnosis of emergent life-threatening neurologic conditions and what are considered "do not miss" pathologies has dramatically increased over the past 10 years due to its increasing importance in the emergency department (ED). This can be partly attributed to both the heightened availability as well as greatly improved speed of high-resolution MR scanners. Furthermore, ED physicians are progressively being held to a higher standard of care for undiagnosed or missed life-threatening conditions leading to a difficult balance between quality patient care and appropriate resource use.[1] The intent of this article is to present a compilation of emergent brain, head and neck, and spine disease processes that warrant the appropriate use of emergent MRI. Presenting clinical signs and symptoms as well as the radiological findings for each disease process will be provided through case-based examples. Case discussions include disease background, imaging characteristics, and logistics for the use of emergent MRI.

Emergent neuroradiology has become key in the evaluation and appropriate triage of fairly common presenting chief complaints such as headache, dizziness, weakness, back pain, altered mental status, numbness, and generalized trauma. Though more often than not most of these subjective chief complaints result in negative radiologic findings, it is critical to both rapidly and accurately prioritize patients who require emergent neurologic interventions from those who are clinically more stable.

Most emergent diagnoses, such as traumatic intracranial hemorrhage, skull or spinal fractures, acute intracranial thromboembolic disease, and ruptured aneurysm, can be accurately diagnosed with computed tomography (CT). For this reason, CT is now and will likely continue to be the far more used imaging modality for emergent neuropathology.[2] This is not to say that MRI is any less important. In fact, MRI is independently paramount for its ability to image both head and spine soft tissue pathologies that CT would otherwise not be able to accurately detect.[3] This is mainly due to the physical difference in how images are acquired or produced on an MRI scanner. Though it is not the intent of this article to describe in any length the complicated physics behind MRI, a small introduction will be provided to understand its importance.

Technological Basics of CT vs MRI

CT and MRI are both cross-sectional imaging modalities that produce grayscale images with an average resolution

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of 512 × 512 pixels. The main difference between the 2 technologies lies in the method of which the images are produced. Pertaining to CT, X-rays (a form of ionizing radiation) are applied to the patient and rotated about a central axis while a detector acquires image data from all different angles. These data are then pieced together in a computer to form multiple 2-dimensional cross-sectional slices.[4]

The advantages to modern CT are numerous, particularly its very fast acquisition time. With the advent of multislice detectors and subsecond rotations, whole CT scans of the head, chest, and abdomen can be acquired under 1 minute, which is particularly useful for emergent diagnoses. CT is not without its disadvantages, particularly its use of ionizing radiation. Additionally, because CT is based on the same physical principles as X-ray imaging, CT is highly sensitive for the detection of bone or osseous pathology. It is limited in its ability to distinguish soft tissues and fluid with only slight differences in density. This is where MRI becomes most useful.

An MR machine is essentially a giant magnet with a magnetic strength averaging between 1.5 and 3 T. Initially used for the analysis of chemical samples, nuclear MR was eventually adapted into a larger bore machine in the 1970s and the "N" (Nuclear) was dropped to make the machine soundless threatening to the public. Thus, MRI as a diagnostic imaging tool was born.[5]

Once a patient is placed within the MR machine, the dipole molecules of their body, most importantly hydrogen, align with the magnetic field within the bore of the machine. The machine then applies a variable radiofrequency current to flip the spins of the hydrogen nuclei. Once the radiofrequency current is removed, the nuclei eventually return to their normal spin. This process is called precession. Given that different nuclei will respond at different speeds depending on the tissue composition, the machine can measure these varying differences in nuclei precession and output the information into a computer, which converts raw data into an image.[6]

With these basic concepts, one can understand the significance for MRI and how it is used differently than CT. MRI is able to very sensitively image tissues, which carry water and differentiate between them with different computed sequences such as T1-weighted, T2-weighted, fluid attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI) and apparent diffusion coefficient, gradient echo, and short tau inversion recovery. The combination of imaging characteristics within these different sequences allows for very specific differential diagnoses to be determined or excluded.

Technical Limitations of MRI

One could ask the question, "Why not use MRI for every patient who presents to the ED with a neurologic emergency?" The answer is that MRI carries several technical limitations that prevent its use from ever becoming as rapid or even ubiquitous as CT. For starters, MRI is markedly expensive, both the initial cost of the machine and its constant and complicated maintenance. For this reason, the cost is reflected onto the patients or their insurance company in the form of high medical bills, sometimes 3-4 times the average CT scan. Secondly, MRI is nowhere near as fast as CT. The average MRI scan can take between 20-40 minutes, a far cry from the 30-60 seconds that modern CT scanners have achieved.

The technical limitations of MRI are numerous, but this does not indicate that MRI should be avoided in the ED altogether. More specifically, MRI should be reserved for the right clinical setting. What determines the right clinical setting depends considerably on the ED clinician and their suspected diagnosis either before or even after CT has already been used.

MRI Safety

Despite meeting the appropriate clinical criteria for its emergent use, not every patient is a candidate for MRI. Aside from the technical limitations, there are significant safety issues that must be taken into consideration. MRI uses an incredibly powerful magnet, most commonly either 1.5 or 3 T or approximately 30,000 times the strength of the magnetic field of the earth. One must remember that the magnet is always on, creating the potential for serious injury or even death from external metallic projectiles such as oxygen tanks, wheelchairs, and stretchers. Safety issues related to projectiles are generally well understood by clinicians outside the radiology field. There are, however, several specific concerns that cause frequent consultation, and this mainly centers around the presence or absence of metallic foreign bodies, and implantable devices such as cerebral aneurysm clips, pacemakers, automatic-internal cardiac defibrillators, spinal cord stimulators, and cochlear implants. Though we will not go into detail in this article regarding the MR safety of each of these devices, it is important to at least understand that a proper medical history for the presence or absence of either metallic foreign bodies or implantable devices must be obtained before MRI. Without this history or the ability to screen patients for the presence of these objects, MRI must be avoided.

The Use of Emergent MRI for Pathologies Pertaining to the Brain

Case 1—Headache, Seizure, Altered Mental Status, and Hypertensive

A 16-year-old pregnant patient presented to the ED for symptoms of severe nausea, vomiting, and headache. She had obtained limited prenatal care. On arrival to the ED, she was found to be hypertensive to 193/109 mm Hg. She also was witnessed to have seizure activity shortly into her admission. She was taken to the operating room and emergent C-section was performed for suspected eclampsia. However, postoperatively the patient complained of left-sided weakness and horizontal nystagmus. She was also not oriented to place, date, or time and was found to have altered mental status.