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Putting dangerous things in magnets: a risk-benefit approach.

Arguably the most dangerous implanted devices in the MR environment are implanted electrical/conducting devices. These include cardiac pacemakers, automatic implanted defibrillators, nerve stimulators, and implanted pumps. In addition to the typical risks associated with any metallic device which include production of significant artifact, torque or movement within the magnetic field and heating, these devices have several additional risks. These risks include induced currents within the device which might produce stimulation of cardiac or nerve tissue, potential failure or inappropriate dosing with implanted pumps and the risk of damage to the device necessitating removal or replacement with the added risk of surgery and anesthesia. The devices have clear patient benefit, but in some cases may be at the added risk of the inability to receive state-of-the-art diagnostic imaging. The majority of these devices can be scanned safely under clearly specified conditions. Further, occasionally in specific situations the benefit or need of the patient may outweigh the potential risks and for MR imaging.

At the time of writing this syllabus, all presently available cardiac pacemaker and automatic implanted cardiac defibrillator (AICD) devices approved by the FDA are contraindicated for use inside the MR. The primary risks associated with the devices are induced currents potentially causing arrhythmia, heating of the leads leading to the injury of cardiac tissue and damaged the device itself. There are literature reports of significant injury and death in patients who have been scanned with pacemakers and AICD devices. On the other hand, there are numerous literature reports which have demonstrated no significant injury to the patient following scanning devices in place. Many of the published reports do however discuss changes in capture voltage necessary for pacing following MRI. This may reflect potential heating and/or damage to cardiac tissue. Despite the potential risks there may be situations in which the risk-benefit ratio may sway practitioners to scan patients with pacemakers in place. Typically, these patients are not pacer dependent. Further, appropriate monitoring and personnel at the scanner during imaging for these patients is likely required. This would include trade anesthesia and cardiology personnel who can monitor the patient interrogate the pacemaker before and after imaging. It is likely that the issue of pacemakers may become less difficult in the future as there is at least one MR compatible pacemaker that should be available in the near future.

Nerve stimulators including vagal nerve stimulators, spinal stimulators, and deep brain stimulation devices are approved for scanning under very specific imaging conditions. There are literature reports of injury related to imaging of these devices, however, this is typically in situations where the guidelines for imaging were not followed. In most cases these devices are labeled as safe for imaging the brain only with a transmit/receive head coil and very specific SAR limitations. More recent papers had suggested that safe imaging can be performed with deep brain stimulators outside of these guidelines. A recent large study looking at over 1300 cases using a fairly wide variety of imaging techniques, showed no definite episodes of injury secondary to MR imaging. The safety of imaging body parts other than the brain or use receive only coils which rely on the body coil of the magnet to send remained unclear. Imaging devices in place has the potential to improve our understanding of device function. Recent studies using functional MRI and functional connectivity has shown significant changes within

the brain following deep brain stimulation. Further, studies have also demonstrated the value of using MRI for potential interactive placement of deep brain stimulators. Imaging has the potential to improve the therapeutic efficacy of these devices provided the safety issues can be overcome.

Implanted pump systems can typically be imaged under specific manufacturer guidelines. The guidelines for imaging have changed over the last several years. The newer pump systems appear to be relatively resilient to imaging with fewer composed protections. (1-30)

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