MRI Safety and Cardiac Pacemakers/ICDs

Karl K. Vigen[1], Kurt S. Hoffmayer[2], and Scott B. Reeder[1,3]

[1]*Radiology, University of Wisconsin-Madison, Madison, WI, United States,* [2]*Medicine, University of Wisconsin-Madison, Madison, WI, United States,* [3]*Medicine, Medical Physics and Biomedical Engineering, University of Wisconsin-Madison, WI, United States*

Target Audience Scientists and clinicians interested in MRI in patients with pacemakers and ICDs.

Purpose In recent years, the rate at which cardiac devices such as pacemakers (PMs) and implantable cardioverter-defibrillators (ICDs) are being implanted into patients has continued to increase. Many patients with these devices will require an imaging study at some point. However, MRI has traditionally been contraindicated due to the potential for device malfunction and lead heating due to the magnetic and RF fields used in MRI. Device companies have recently introduced MRI-conditional pacemakers and ICDs; a number of these are approved for use in Europe and the United States. In addition, there is a large body of literature reporting MRI in patients with conventional PMs and ICDs. The purpose of this exhibit is to review procedures and challenges for the use of MRI in patients with both approved and non-approved pacemakers.

Outline of Content Patients who have a pacemaker or ICD have traditionally not been allowed to obtain an MRI due to a number of potential effects. These effects include magnetic force on the device itself or on the magnetically-activated reed switch; malfunction due to RF interference with electronic components of the device; and the induction of current in the device leads which could lead to heating, particularly at the lead tips. This last effect, in addition to tissue destruction, could cause adverse effects on measured lead impedance, sensing, and pacing capture thresholds [1].

Recently, several device companies have introduced MRI-compatible PM's and ICDs. These include devices approved in Europe (Medtronic; Biotronik; St. Jude), and approved by the FDA in the US (Medtronic); with approvals also in other countries and more devices in the approval pipeline (Boston Scientific). Approved devices are conditional for MRI, with conditions including field strength limitations (typically to 1.5T), SAR restrictions, and imaging only specific device and lead configurations; several conditions are similar to those for other devices such as nerve stimulators in patients undergoing MRI. Notably, US-approved pacemakers currently carry a condition that precludes centering the imaging FOV between the C1 and T12 vertebral body levels. This limitation may be problematic for neck, cervical spine, thoracic and upper abdominal imaging. However, certain prescription tricks can be employed to allow imaging these areas (Fig. 1).

Patients with conventional pacemakers and ICDs often have compelling indications for MRI exams, particular if diagnostic information cannot be obtained in other ways (e.g. staging of brain tumor). Removal or replacement of devices or leads carries significant risk, and MRI with such devices is likely to be safer, particularly with devices manufactured since 2000 [2]. Many investigators have reported MRI in patients with conventional pacemakers and ICDs; a recent search of the literature finds 2200 patients (1672 PM, 528 ICD) imaged with 2670 MRI exams, and several centers have reported imaging somewhat large numbers of patients with conventional pacemakers [3,4]. A large clinical trial (the MagnaSafe Registry) is seeking to document the safety of MRI in patients with PMs/ICDs, and is now underway [5]; early reports are promising. Strict imaging protocols are typically followed for such studies, and include imaging with appropriate personnel present; placing the device in specific (generally asynchronous) modes; device interrogation/reprogramming following MRI; and clinical follow-up.

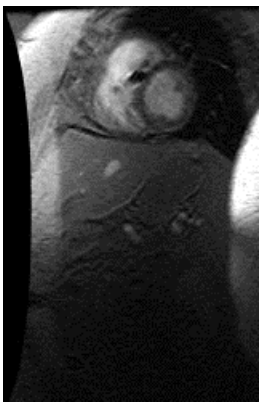

Figure 1 By slightly enlarging the FOV and centering below T12, cardiac MRI can be performed with a pacemaker present, even with positioning restrictions. (Oblique Cor/Sag prescription; fast segmented gated SPGR acq.) Artifact in RV is due to pacemaker lead. Similar adjustments can be made for neck/c-spine imaging.

Summary Patients with conventional PMs and ICDs have traditionally been contraindicated for MRI. Device manufacturers have begun to introduce MRI-conditional pacemakers and ICDs, which allow most standard MRI exams. In addition, several studies have reported imaging patients with conventional pacemakers and ICDs. We will review the available literature and commonly used algorithms for scanning patients with conventional and approved pacemakers and ICDs, and provide suggestions for organizing the appropriate personnel, consent process, and necessary protocol changes for these studies.

References [1] Shinbane JS, et al, *J Cardiovasc Magn Reson* **13:**63 (2011). [2] Roguin A, et al., *Circulation* **110:**475-82 (2004). [3] Nazarian S, et al., *Ann Intern Med* **155**:415-424 (2011). [4] Friedman HL, et al, *PACE* **36:**1090-95 (2013). [5] Russo RJ, *Am Heart J* **165**:266-72 (2013).