Imaging of Patients with Pacemakers and ICDs

Harold Litt MD-PhD
Associate Professor of Radiology and Medicine
Chief, Cardiovascular Imaging Section, Department of Radiology
Perelman School of Medicine of the University of Pennsylvania
Disclosures and Acknowledgements

- I have no conflicts of interest with respect to this presentation
- Performing MRI on patients with most implanted pacemakers and all defibrillators is an off-label use for both the MRI system and device
- Use of gadolinium contrast for cardiac MRI is an unapproved indication
Outline

• What we know
  • The problem
  • Interactions between PM/ICD and MRI
  • Safety evidence

• What you need to know: the HUP program
  • Risk/benefit assessment
  • Minimizing risk and consent
  • Scanning

• Other issues
  • MR compatible pacemaker
  • Effects of CT on pacemakers
What we know

• Number of PM/ICD patients is increasing

• Number of patients needing MR also

• 50% of PM patients will have MR indication within 2 yrs of placement, 75% over lifetime

• 200,000 pts per year not being scanned
Potential Risks

- Direct effects on device
- Lead heating
- Electrophysiologic interference
Effects on Device

- Direct effects of energy absorbed by device
- Temporary or permanent malfunction
- Probably SAR related
- Seems to be very rare
  - Pre-2000 pacemakers may undergo electrical reset
  - ICD permanently damaged by intentional high SAR scanning in animal model
  - 2 older ICDs permanently damaged after MRI
  - Battery voltages will dip transiently after MRI
- Risk to pacer dependent and ICD patients
Lead Heating

- RF energy absorbed by leads, leading to heating at lead tip myocardial interface

- 20°C *in-vitro*, less than 2°C *in-vivo* (endocardial, what about epicardial?)

- Also SAR dependent, but better at 3T
  - \(1.5 \text{T } \lambda/2 = 26 \text{ cm}, \ 3\text{T } \lambda/2 = 13 \text{ cm}\)
  - PM leads 30-40 cm, so less efficient antenna 3T

- Effects
  - Edema/scarring at lead tip-myocardial interface
  - Increase in pacing thresholds, may need to increase output
  - 3-9% incidence in published studies
Electrophysiologic Interference

- It’s complicated, but few basic principles
- ICD will interpret gradients as VT/VF
- Pacer can interpret RF or gradients as beats
- Can lead to inappropriate or lack of appropriate pacing
- You don’t want a paced beat at the same time as a natural beat - arrhythmogenic
- Pacemakers have lots of additional features, which should be turned off for MRI
RF and Gradients Interpreted as VT/VF

The Evidence

Strategy for Safe Performance of Extrathoracic Magnetic Resonance Imaging at 1.5 Tesla in the Presence of Cardiac Pacemakers in Non–Pacemaker-Dependent Patients: A Prospective Study With 115 Examinations
Torsten Sommer, Claas P. Naehle, Alexander Yang, Volkert Zeijlemaker, Matthias Hackenbroch, Alexandra Schmiedel, Carsten Meyer, Katharina Strach, Dirk Skowasch, Christian Vahlhaus, Harold Litt and Hans Schild
*Circulation 2006;114;1285–1292; originally published online Sep 11, 2006;

Safety of Brain 3-T MR Imaging with Transmit-Receive Head Coil in Patients with Cardiac Pacemakers: Pilot Prospective Study with 51 Examinations

Magnetic Resonance Imaging at 1.5-T in Patients With Implantable Cardioverter-Defibrillators
Claas P. Naehle, MD,* Katharina Strach, MD,* Daniel Thomas, MD,* Carsten Meyer, MD,* Markus Linhart, MD,† Sascha Bitaraf, MD,‡ Harold Litt, MD, Ph†D,$ Jörg Otto Schwab, MD,† Hans Schild, MD,* Torsten Sommer, MD||
Bonn, Koblenz, and Neuwied, Germany; and Philadelphia, Pennsylvania

[Note: The above text contains multiple articles and references that are not fully visible in the image.]
The Evidence: Summary

• Published reports of ~1000 PM and 500 ICD patients scanned intentionally, no severe adverse events

• Most haven’t scanned the chest

• Pacemaker dependent ICD pts special prob
  • Some devices won’t pace asynchronously
  • You may not want to anyway

• AHA and ESR statements published
  • Not safety guidelines
  • “If you want to do it, this may be how”
Current Status

- Some sites in US with experience/programs
  - Johns Hopkins
  - Oklahoma Heart Institute
  - Parkwest Hospital, Nashville TN
  - Scripps Institute, La Jolla
  - University of Pennsylvania
- Total of ~4000 PM 1500 ICD pts worldwide
- "We have turned a once exceptional procedure into one that is now a routine at Hopkins," Henry Halperin, JHU Nov. 2006
But ..... 

- “They are flying on a wing and a prayer” Dudley Pennell, Royal Brompton
- FDA editorial Circulation Nov 2006
  - Promising evidence, but not approved yet
  - Only in experienced centers
- CMS memo 10/2009
  - In response to Medtronic petition to have device exclusion removed for FDA approved MRI compatible pacemaker (more at the end)
  - MRI in patients with PM/ICD (and vascular clips) does not improve pt outcomes
  - New standard for imaging coverage decisions?
- Blanket noncoverage NCD unchanged
- FDA sponsored registry underway - run by Scripps
The HUP Program

- About 800 patients thus far
- 350 ICD
- Mostly neuro and CVI
- Some ortho, body, and breast
- First patient has now been scanned 14 times
- One pt. scanned twice in 24 hrs
Minimizing Risk: Patient Screening

• Attending radiologist agrees
  • No other acceptable diagnostic modality
  • Information gained will have considerable impact upon patient treatment or prognosis

• Gather information
  • Pacemaker make and model, year of placement
  • Is pt. pacer dependent? Is there an ICD? Abandoned or capped leads?
  • If ≥2000, no, no, and no, study can be performed at low risk
  • If <2000, or yes, higher risk study, discuss with EP
Minimizing Risks: Prior to the Study

• Adjust pacemaker settings
  • Asynchronous pacing for pacer dependent (V00)
  • Turn off pacer or change support rate for non-dependent, manufacturer specific (VVI 80 bpm)
  • Turn off extra features to limit interference

• Turn off ICD sensing and therapy
  • VVI 40 bpm for non-pacer dependent with ICD
Minimizing Risks during the Study

- Consent patient - risks:
  - Damage to device needing replacement - rare
  - Lead heating leading to scar in heart requiring pacer reprogramming - 3-9%
  - Difficulty treating arrhythmia in magnet (more an issue for ICD/pacer dependent pts)

- Minimize SAR if possible
  - T/R coil if possible - except for chest scanning
  - Adjust sequences if possible

- Monitor patient during study
  - Watch pulse ox for heart rate, ECG too noisy
  - Alert EP if change from electrical reset, i.e. 80 to 65, 80 to 85, or other problems
MR Compatible Pacemaker

- Medtronic Revo SureScan
  - “MRI conditional” 1.5T only, no T/R coils over generator
- FDA approved 3/2010
- Only generator/lead pair
- Isocenter can’t be from Cl-T12 - no hearts 😞
- Normal SAR mode scanning only (<2 W/kg)
- Electrical isolation mode for generator
- Leads better insulated
- Ongoing trials of newer models, no anatomy restrictions
Pacemakers and CT

• Pacemakers can sense time varying x-ray intensity as cardiac activity (oversensing)
• Can lead to transient inhibition of output
  • Only when beam is directly over device
  • A few seconds at most
  • No permanent changes in programming
• Theoretically could be interpreted as VT
• Problem for ICD pts?
• Consider turning of ICD during study
Conclusions

- MRI in non-dependent PM patients seems to be quite safe
- PM Dependent and ICD patients have issues
- Have a process for performing MRI in pts with devices
  - All radiologists performing MRI are a part of the process, with EP physicians
- “MRI Compatible” pacemaker available
- No help for those currently with devices
- CT does effect devices but not usually clinically relevant