2014 AAPM 56th Annual Meeting

SAM – Diagnostic Radiology

MR Safety

- Deep Brain Stimulator and Other Neurostimulators

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Outline

- Background of Neurostimulator
- Neurostimulator and MRI
- MRI Safety factors
- Safety procedure for MRI scanning
- SAM questions

Background of Neurostimulator

Background of Neurostimulator

- Neurostimulation have been proven to be an effective therapeutic method for a variety of neurological disorders likes tremor, pain, and dystonia etc.
- Since 1997, more than 100,000 patients worldwide have received neurostimulation therapy.
- It has been estimated that each year more than 10,000 neurostimulation system are implanted in the U.S.
- New applications and treatment targets continue to emerge as technology advances.

Types of Neurostimulator

- Deep brain neurostimulation for movement disorder like essential tremor, Parkinson's disease and dystonia

medgadget.com

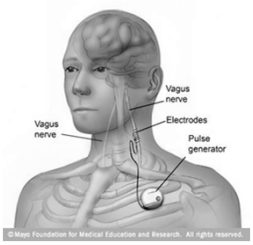
Types of Neurostimulator

- Spinal cord stimulator for chronic pain

Spinal cord stimulator for better chronic pain management.
Photo courtesy of St Jude Medical NMD Division

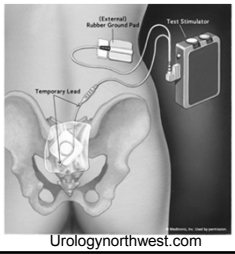
Types of Neurostimulator

- Vagus nerve stimulator for epilepsy and depression management



Types of Neurostimulator

- Sacral nerve stimulator for bladder control and urinary retention



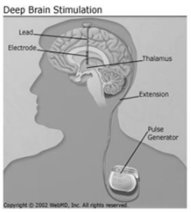
Urologynorthwest.com

Types of Neurostimulator

- Deep brain neurostimulation for movement disorder like essential tremor, Parkinson's disease and dystonia
- Spinal cord stimulator for chronic pain
- Vagus nerve stimulator for epilepsy and depression management
- Sacral nerve stimulator for bladder control and urinary retention

Components of Neurostimulator

- In deep brain stimulation, leads and electrodes are connected by extension cable to a type of pacemaker device (called an impulse generator, or IPG) implanted under the skin of the chest, below the collarbone.
- Once activated, the device sends continuous electrical pulses to the target areas in the brain, blocking the impulses that cause tremors.



Webmd.com

Components of Neurostimulator

- The implanted pulse generator (IPG) - a battery-powered neurostimulator encased in a titanium housing, which sends electrical pulses.

Medtroncis.com

Components of Neurostimulator

- The lead is a coiled insulated wire with four electrodes and is placed in areas of the brain.
- The lead is connected to the IPG by the extension, an insulated wire that runs from the head, down the side of the neck, behind the ear to the IPG

Medtroncis.com

Neurostimulator and MRI

Neurostimulator and MRI

- Currently, MRI exams are used routinely for diagnostic and clinical care.
- MRI is clinically important for postoperative evaluation and for ruling out possible complications like hemorrhage or edema.
- It is very likely that a patient with chronic pain, spinal disease, neurological and orthopedic disorders will require an MRI scan after the neurostimulator is implanted.

MRI Safety Factors

MR Safety Factors

- The risks of performing MRI on patients with neurostimulators are related to the three electromagnetic fields generated by the MRI scanner.
  - Static Magnetic field – The main magnetic field is always on.
  - Gradient Magnetic field – The low frequency pulsed magnetic field that is only on during the scan.
  - RF field – produced by RF coils, which can induce heating

MRI interactions with DBS

- Static field interaction
  - The magnetic field create displacement force and torque on the IPGs.
  - The interaction can cause movement of the generator or bending of the leads.
  - The counterforces provided by sutures or tissue in-growth can effectively prevent the implant from being a substantial risk or hazard to the patient.

MRI interactions with DBS

- Gradient field interaction
  - The gradient pulses may induce voltage onto the lead system which can cause unwanted stimulation.
  - The voltage is proportional to the rate of change (dB/dt).
  - It is also related to the lead positioning and configurations.
  - Normal mode limits dB/dt to 20T/sec

MRI interactions with DBS

- RF pulses
  - The primary MR safety concern.
  - RF pulses induced currents in the implants can produce unwanted heating effects.
  - As the RF energy couples with the implants, the induced currents concentrate at the tips of the leads and generate significant local heating.
  - The local temperature rise can potentially damage surrounding tissues.

RF heating

- Controlled phantom experiments showed local RF heating at the electrode on the order of 25 ºC above baseline with a gel phantom model using the body transmit coil at 1.5T.
- A patient with bilateral DBS for PD had a lumber scan at 1.T with body transmit coil. It caused thermocoagulation of brain tissue around one of the tip of the electrode. The patient was permanent
- Transient dystonia dev
  externalized lead disco
  MRI scan with the T/R head coil.

Both cases are "atypical" configurations!!

RF heating Control

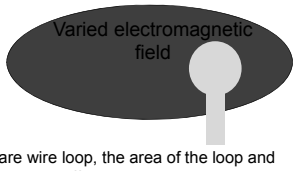
- Scanner SAR level
- Lead configuration
- Patient landmark location
- Coil Type

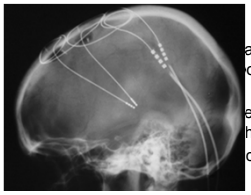
RF heating Control

- Scanner SAR level
  - SAR is a measure of the absorption of electromagnetic energy in the body (typically in W/kg).
  - SAR ∞ field strength^2 and flip angle^2 **(DBS 1.5T only)**
  - An international standard dosimetric term to characterize the themogenic aspects of MRI.
  - Manufactures adapted this value as index of RF power and used it in the guidelines.
  - For DBS, the current SAR limit is **0.1W/kg**.

RF heating Control

- Lead Configuration





are wire loop, the area of the loop and
oops can affect the local head

e scenario was to use body coil and
he lead in the pocket of IPG.
ctice is to loop the excess lead around

Neurosurgery, 57: ONS-392-7, 2005

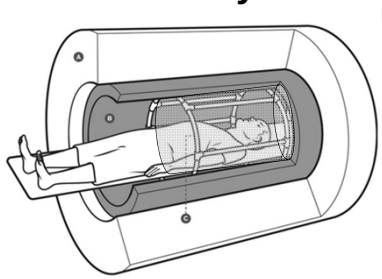
RF heating Control

- Patient landmark location
  - With a whole body coil, study shows the change in temperature varies with the landmark location*.
  - The closer the landmark position to the DBS contact, the greater temperature change was observed*.
- T/R head coil vs. body coil
  - The transmit/receive head coil can limit the RF energy deposition only in the head region.

*Baker, JMRI, 20: 315-320, 2004

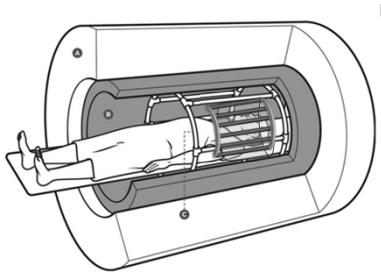
RF heating Control

Whole body coil



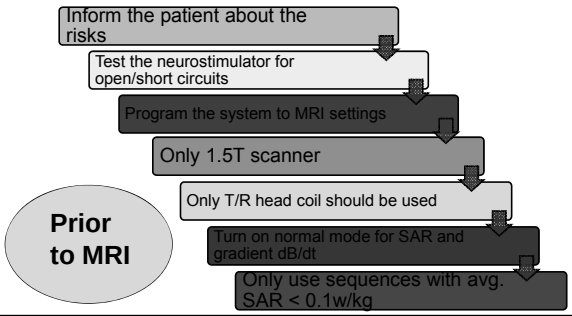
RF heating Control

T/R head coil

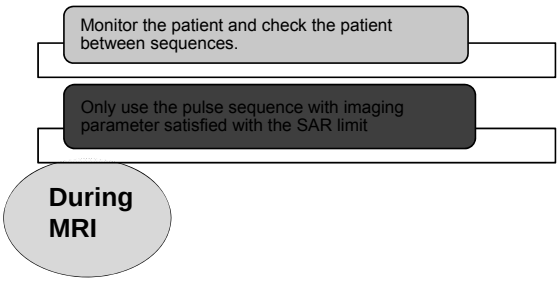


Safety procedures for MRI scanning - Deep Brain Stimulator

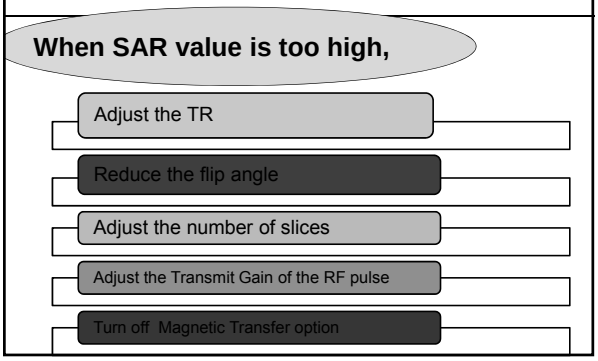
Safety procedures for MRI scanning



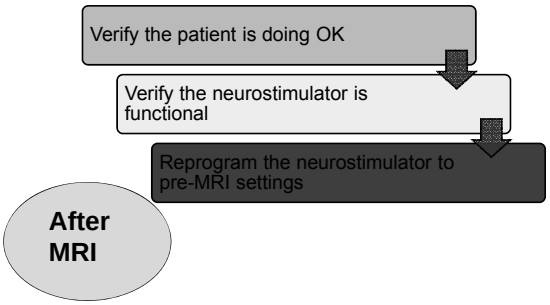
Safety procedures for MRI scanning



Safety procedures for MRI scanning



Safety procedures for MRI scanning



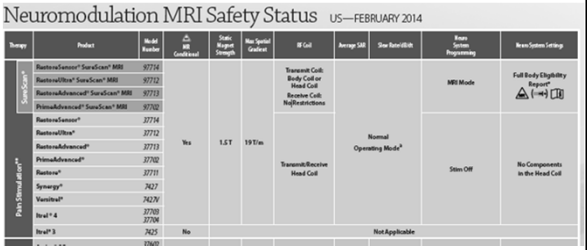
Safety procedures for MRI scanning - other types of neurostimulators

Spinal Cord Neurostimulator for Pain

- Spinal cord stimulation has become a standard treatment for patients with chronic pain in their back and/or limbs.
- It is important to identify the manufacture and model number of the stimulator to check the MRI safety status.
- http://professional.medtronic.com/wcm/groups/mdtcom_sg/@mdt/@neuro/documents/documents/mri-safety-status-us.pdf

www.spine-health.com

Spinal Cord Neurostimulator for Pain


Neuromodulation MRI Safety Status US—FEBRUARY 2014

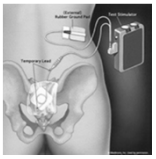
http://professional.medtronic.com/wcm/groups/mdtcom_sg/@mdt/@neuro/documents/documents/mri-safety-status-us.pdf

Spinal Cord Neurostimulator for Pain

http://professional.medtronic.com/wcm/groups/mdtcom_sg/@mdt/@neuro/documents/documents/mri-safety-status-us.pdf

Sacral Nerve Neurostimulator

- Sacral Nerve Neurostimulator is used to control the bowel, rectum and bladder.
- MR safety guidelines(for Medtronics products)
  - Stimulator Off
  - 1.5T scanner
  - T/R coil only
  - Normal SAR mode



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Vagus Nerve Stimulator

- Vagus Nerve Stimulator is used to treat epilepsy and depression.
- MR safety guidelines (for cybersonics products)
  - Stimulator Off
  - 1.5T/3T scanner
  - T/R coil only
  - SAR level of 3.2W/kg can Cause less than 2°C temp rise.

Cybersonics.com

Summary

- The demands and applications for neurostimulators continue to increase as the technology advances.
- MRI is an important diagnostic tool for postoperative evaluation and potential future workup.
- The presence of the neurostimulator poses potential safety risks in the MR scanning environment.

Summary

- By observing certain precautions, MRI can be performed with an extremely low risks.
- It is important to follow the manufactures' MRI guidelines to ensure the safety of the patients and continuous functioning of the device.