Background of Neurostimulator

- Neurostimulation have been proven to be an effective therapeutic method for a variety of neurological disorders like 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 systems 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
- Spinal cord stimulator for chronic pain
Types of Neurostimulator

- Vagus nerve stimulator for epilepsy and depression management

- Sacral nerve stimulator for bladder control and urinary retention

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Components of Neurostimulator

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

- 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.
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

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.

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 1.5T with body transmit coil. It caused thermocoagulation of brain tissue around one of the tip of the electrode. The patient was permanently disabled.
• Transient dystonia developed in another patient with externalized lead disconnected from an IPG and had a 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 strength² and flip angle² (DBS 1.5T only)
  – An international standard dosimetric term to characterize the thermogenic 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

• 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

T/R head coil

Safety procedures for MRI scanning - Deep Brain Stimulator

- Deep Brain Stimulator

Inform the patient about the risks

Test the neurostimulator for open/short circuits

Program the system to MRI settings

Only 1.5T scanner

Only T/R head coil should be used

Normal mode for SAR and gradient dB/dt

Only use sequences with avg. SAR ≤ 0.1w/kg

Safety procedures for MRI scanning

Safety procedures for MRI scanning

Monitor the patient and check the patient between sequences.

Only use the pulse sequence with imaging parameter satisfied with the SAR limit

Safety procedures for MRI scanning

Safety procedures for MRI scanning

When SAR value is too high,

- Adjust the TR
- Reduce the flip angle
- Adjust the number of slices
- Adjust the Transmit Gain of the RF pulse
- Turn off Magnetic Transfer option

During MRI
Safety procedures for MRI scanning

Verify the patient is doing OK
Verify the neurostimulator is functional
Reprogram the neurostimulator to pre-MRI settings

After MRI

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.

Sacral Nerve Neurostimulator

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

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 risk.
- It is important to follow the manufactures MRI guidelines to ensure the safety of the patients and continuous functioning of the device.