

MR Imaging

Bioeffects and Safety

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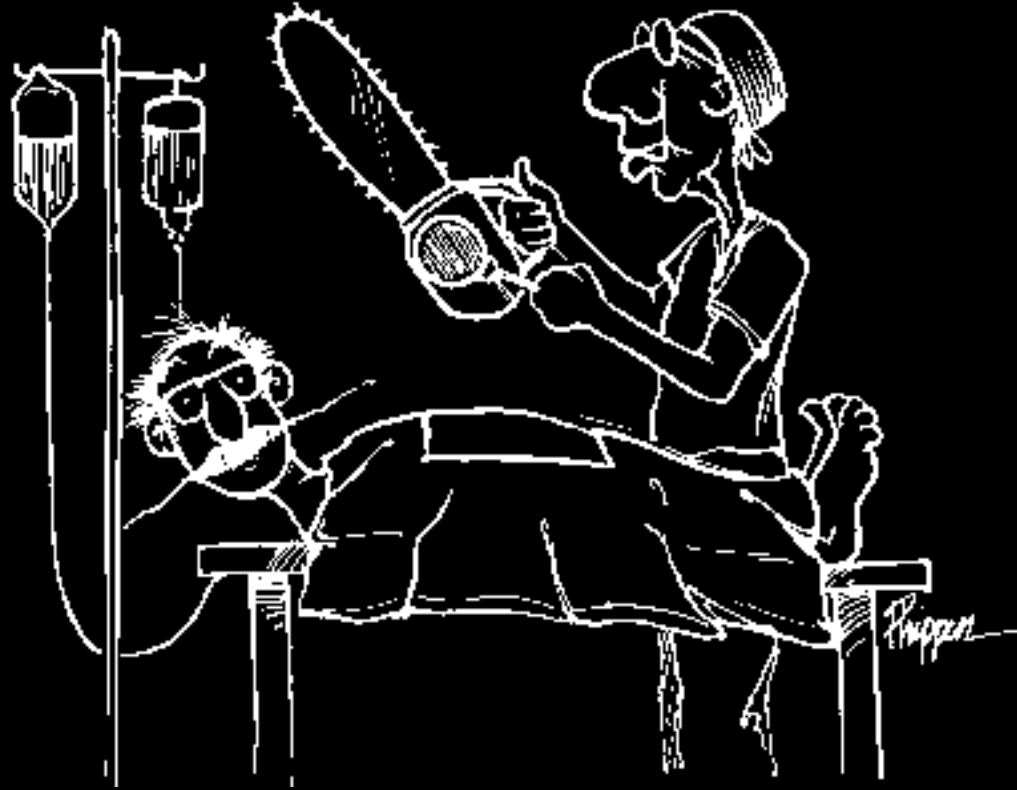
MRI Safety Issues

- **MRI bioeffects**
- **MRI safety & protection**

Bioeffects

- **Is MRI harmful?**
- **Try not to be scanned?**
- **Should I change my job?**

Is MRI This Dangerous?



Let's just take a look at your heart ... briefly

Generation of MRI

- **M : source of signals**
- **R : excitation & detection**
- **I : turning signals into images**
- **What equipments do we need?**

MRI Hardware

- **M : strong magnetic field**
- **R : RF coils**
- **I : gradient coils**

MRI Hardware

- M : strong magnetic field
- R : RF coils
- I : gradient coils
- Are they harmful ?

MRI Bioeffects

- **Strictly personal opinion:**
- **Minimal, or none**
- **Soon recoverable even if yes**

But I Often Encounter ...

- “I don’t believe you ...”
- “There must be something ...”

MRI Hardware

- **M : strong magnetic field**
- **R : RF coils**
- **I : gradient coils**

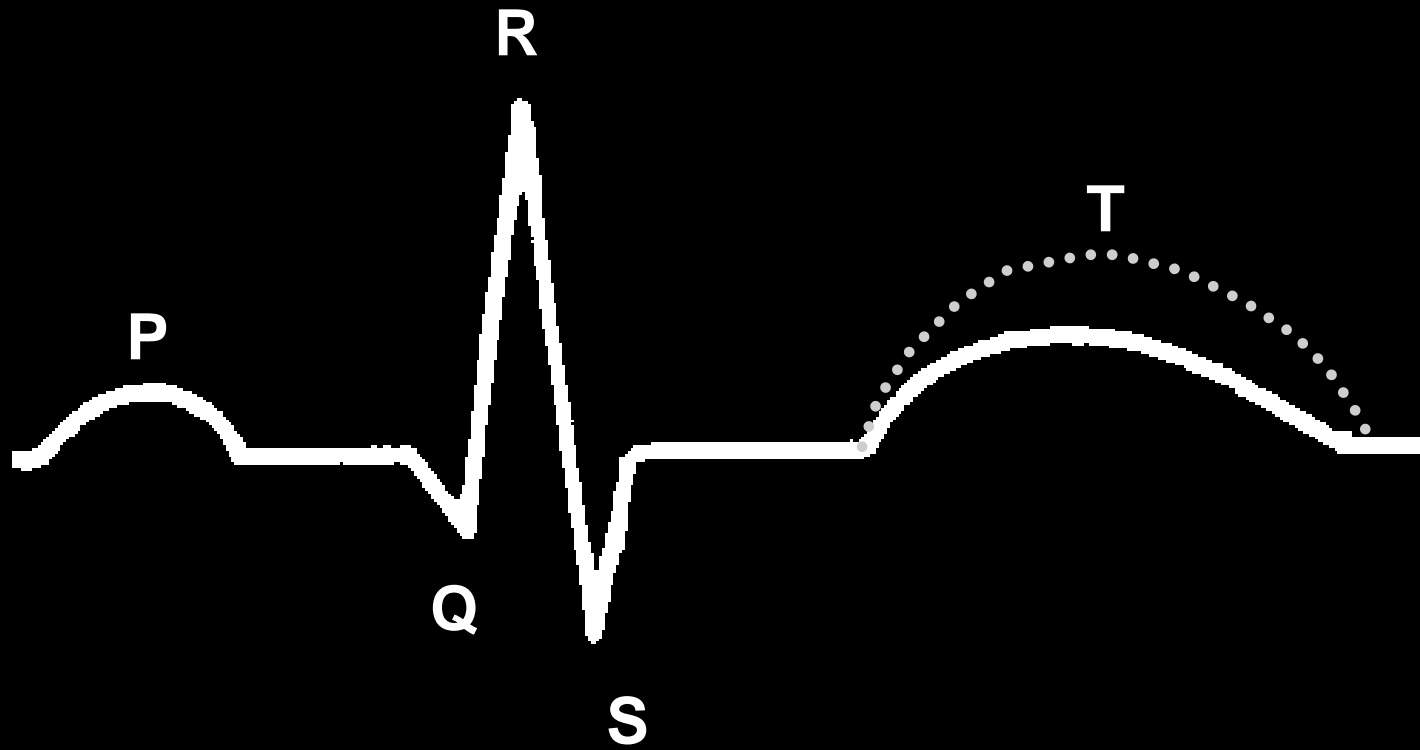
MRI Hardware

- **M : strong magnetic field**
- **R : RF coils**
- **I : gradient coils**

Bioeffects of Main Field

- Always going toward north?
- Reduced reproductive ability?
- Abnormal (mitotic) cell division?
- Enhanced T-wave in ECG ?

Enhanced T-wave in Electrocardiogram

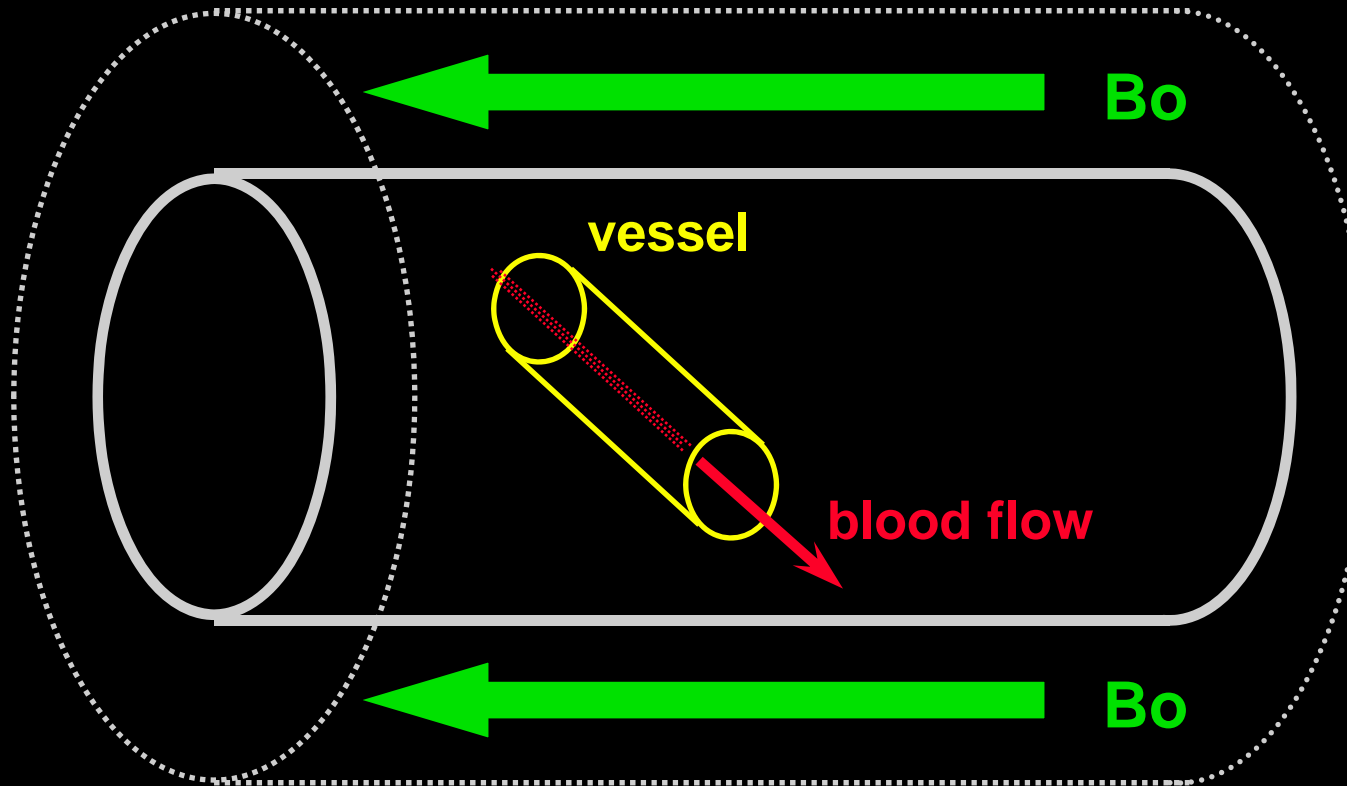


A known effect from MRI main field

Enhanced ECG T-wave

- **Magneto hydrodynamic effect**
- **Blood is electrically conductive**
- **Electrical induction from moving conductor in magnetic field**
- **Detected by ECG surface electrodes**

Magneto hydrodynamic Effect



Electrical induction from moving conductor

Is It Dangerous?

- **Perhaps not for the patients**
- **Gating error (mistaken as R wave)**
- **Also a sign for cardiac infarction**
- **Check ECG before/after MRI**

Research on Bo Bioeffect

- **Sickle cells aligned?**
- **Cone/rod cells aligned?**
- **Change in BBB permeability?**
- **Increased phantom limb pain?**

Bo Bioeffects

- **None from research so far**
- **Or highly debatable**
- **Are there real examples?**

Klitzing (1986) at 0.35 T

- Alterations in somatosensory evoked potential in brain stem
- Against by four research papers
 - Hong (1990), Muller (1990), Vogl (1991), Buettner (1992)

Other Bio Bioeffects

- **Bed oriented along north/south to be parallel with earth magnetic field?**
- **Magnet under pillow for mental stabilization?**
- **Health magnetic belt for slim body?**
- **Magnetic field from rock crystal improves your working environment?**

Bioeffects of Bo

- **Do you believe in scientific research or commercial advertisement?**
- **Give it a try without loss?**

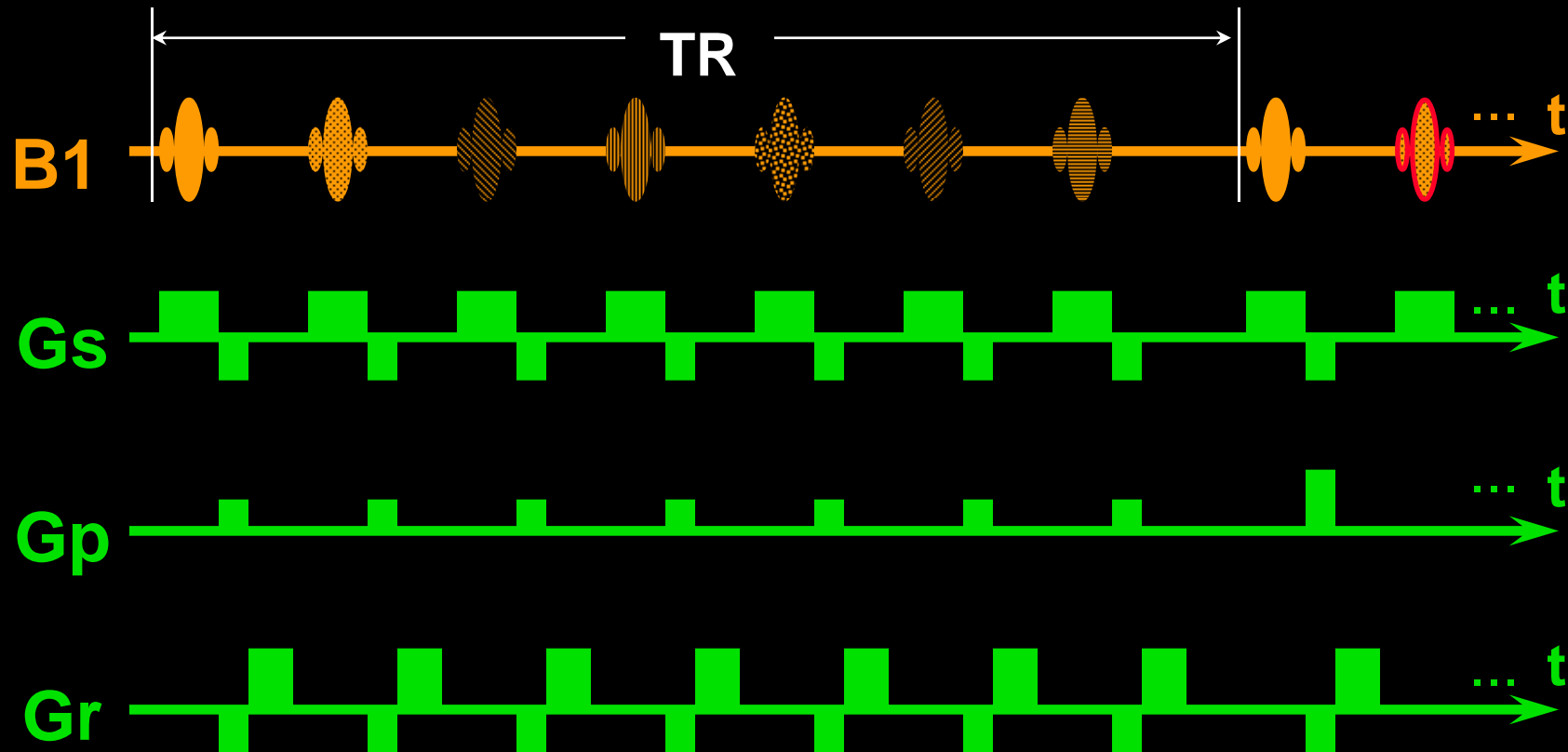
MRI Hardware

- M : strong magnetic field
- R : RF coils
- I : gradient coils

RF Bioeffects

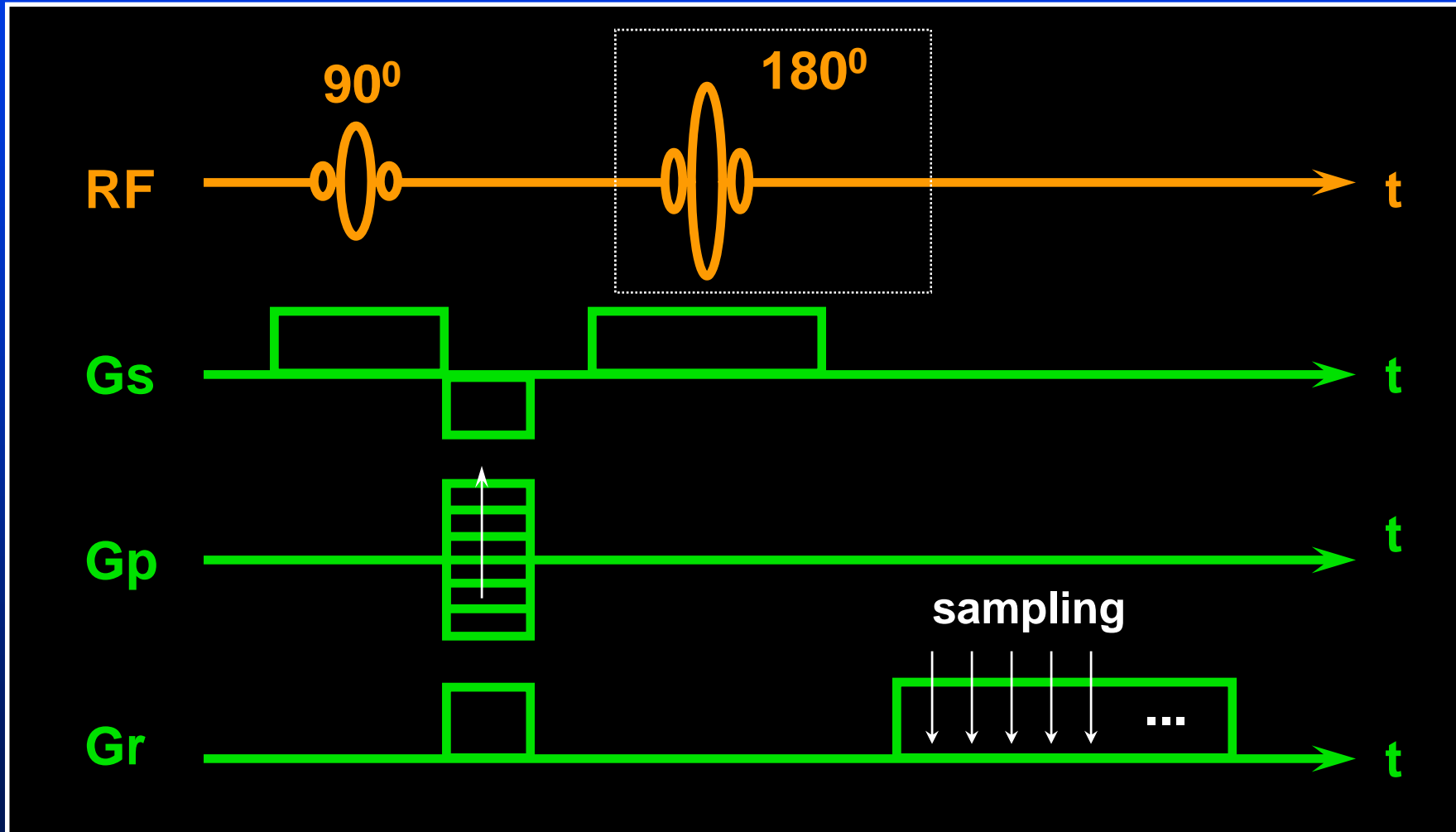
- **Is RF excitation like microwave?**
- **RF is like radio broadcasting**
- **Local temperature increases with too much RF**

Multi-Slice Gradient-Echo



Several slices excited in one TR (lots of RF)

Multi-Slice Spin-Echo



RF Bioeffects

- **Worry? No! FDA SAR limits:**
 - **Mean < 3.2 W/Kg in head**
 - **Mean < 0.4 W/Kg whole-body**
 - **Mean < 8.0 W/Kg locally**

Heating Effects from RF

- **Homeostasis for maintaining body temperature in human**
- **Blood flow carries away the heat**

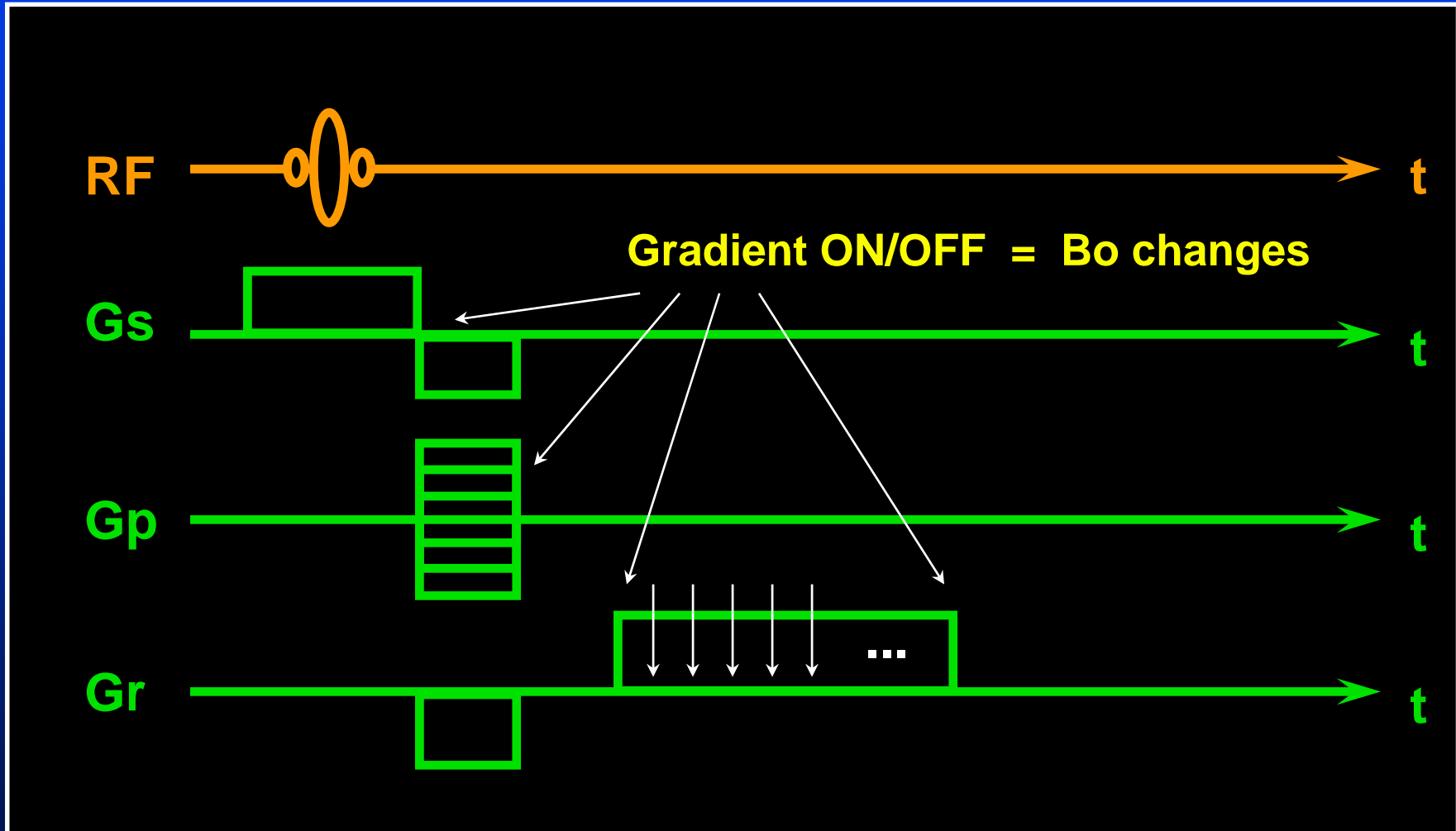
MRI Hardware

- M : strong magnetic field
- R : RF coils
- I : gradient coils

Gradient Bioeffects

- **Rapid Bo change on conductive human body ...**
 - **Electrical induction?**
- **Electric shock on patient?**
- **Electrophysiology disturbed?**

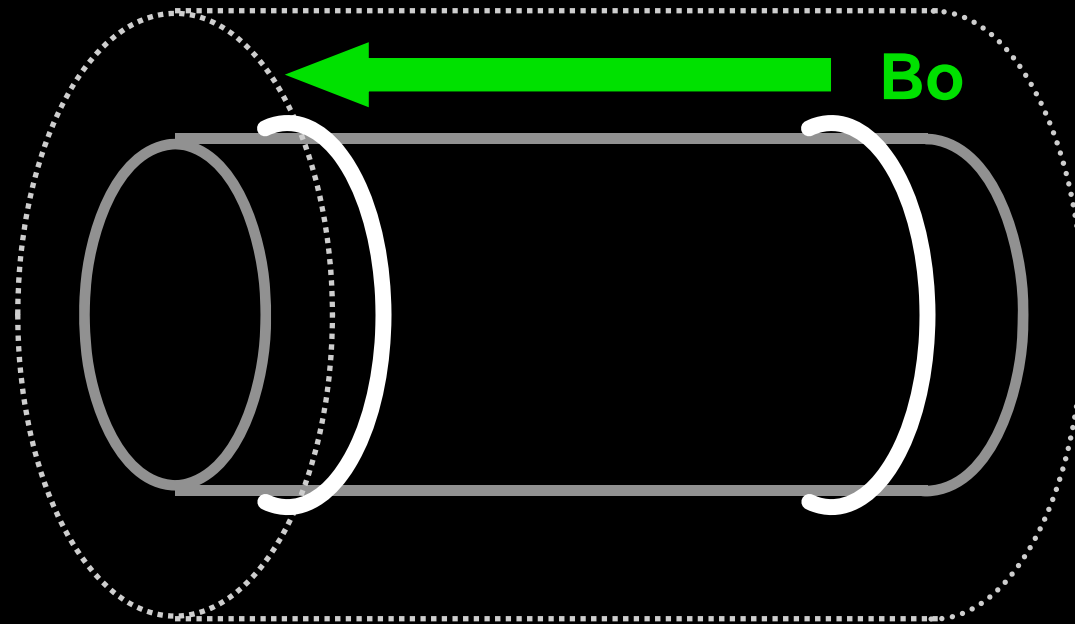
Gradient Echo



Magnetophosphene

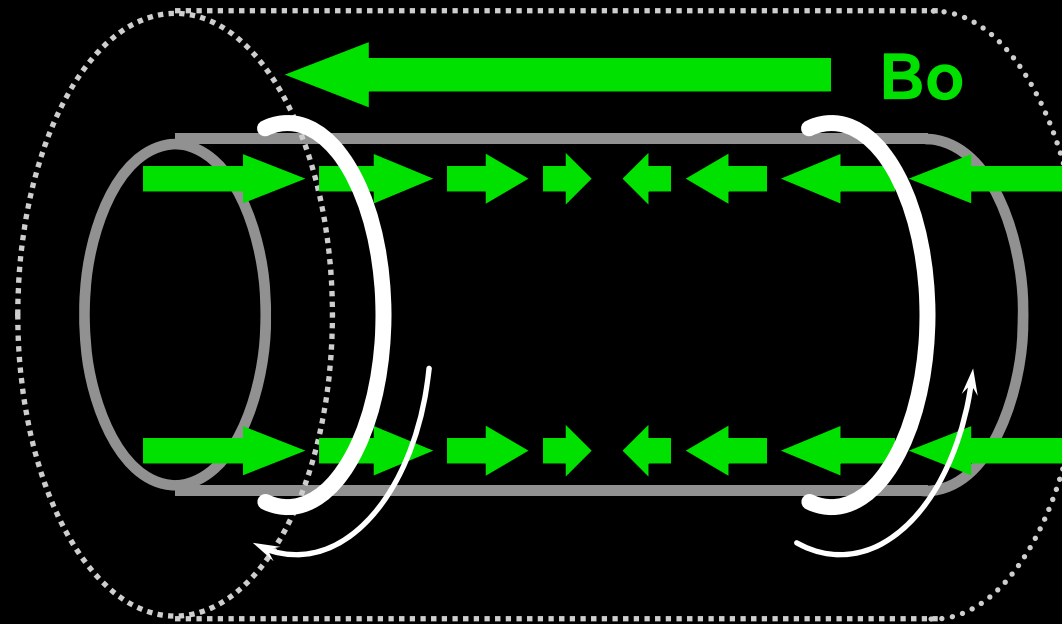
- **Electric induction due to fast dB/dt**
- **Flash-like vision when optic nerves fire action potential**
- **Peripheral nerve stimulation**
- **Smaller effects near MRI isocenter**

z Gradient OFF



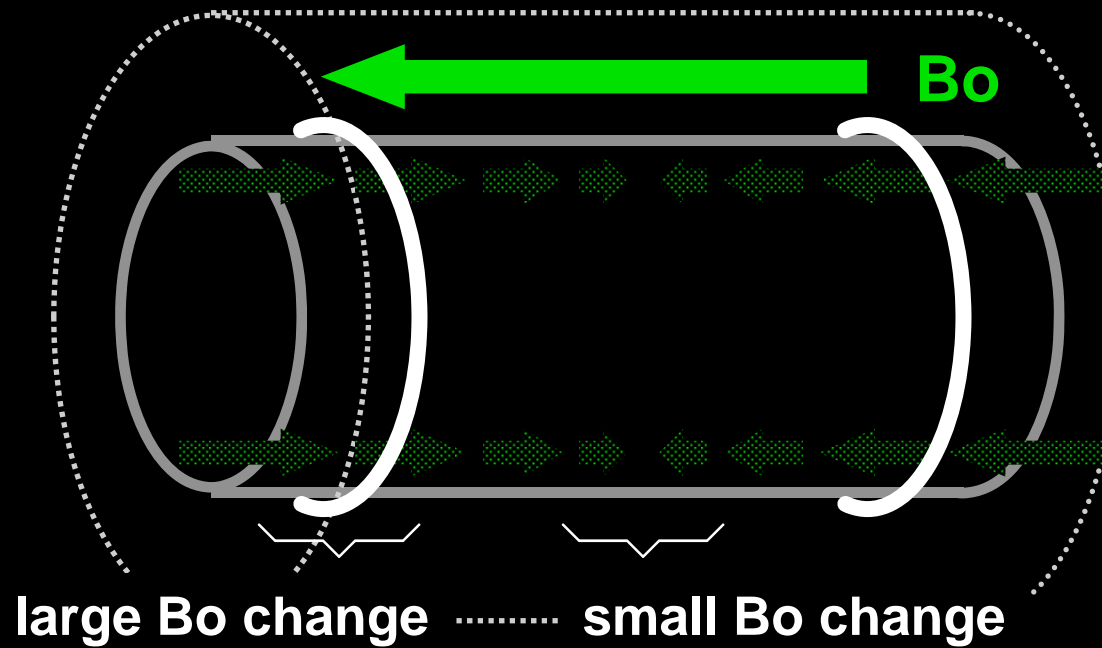
Maxwell pair

z Gradient ON



B_0 changed rapidly everywhere

z Gradient OFF Again

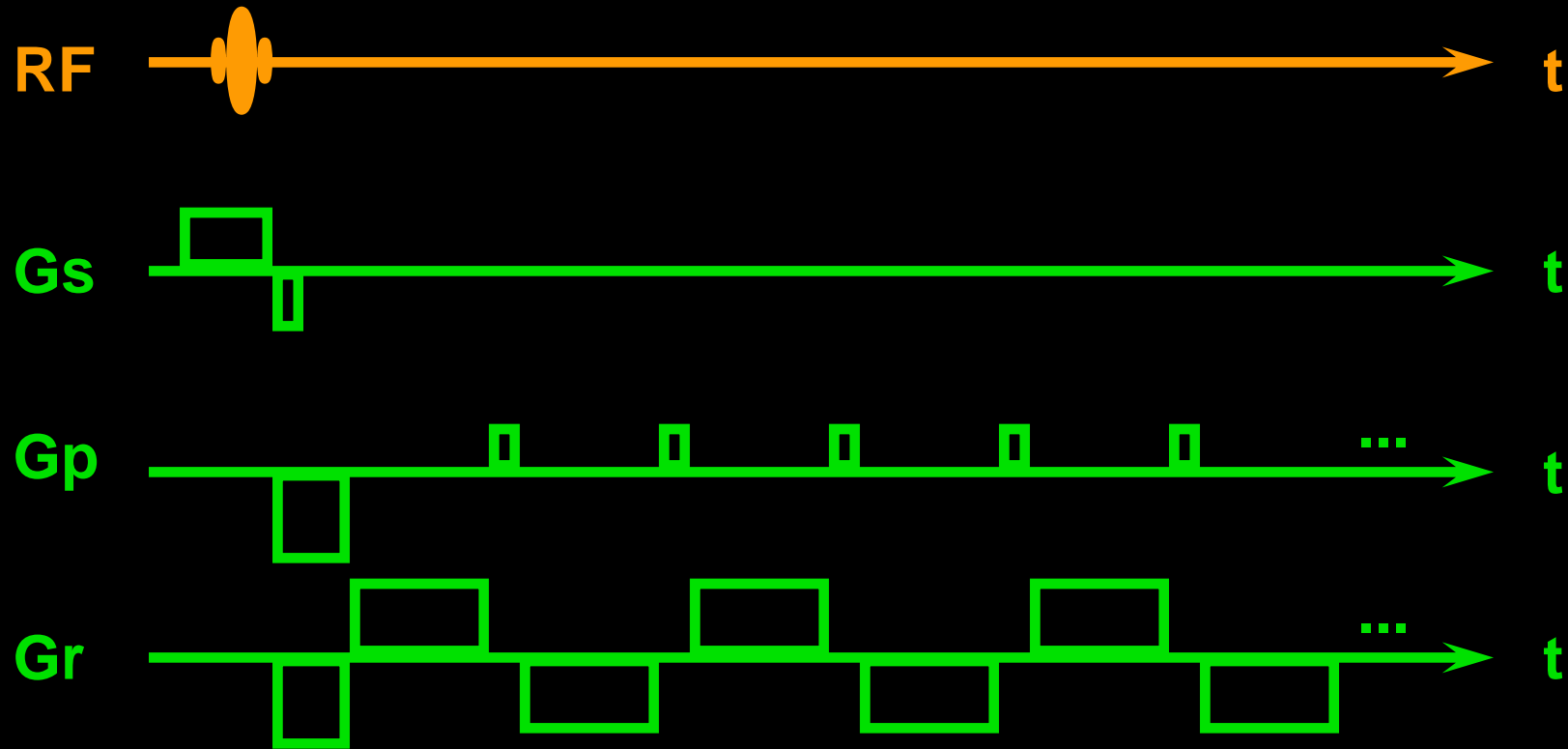


Smaller effects near MRI isocenter

Magnetophosphene

- **Peripheral nerve stimulation**
- **Response gone after scan stops**
- **Optic nerves unharmed**
- **Present in EPI scan only**

EPI Pulse Sequence



Echo Planar Imaging

PNS Issues

- **Eyes: scary although harmless**
- **Myocardium excited as well?**
- **At least 10 times larger intensity for myocardium**

Summary: MRI Bioeffects

- **Increased T-wave amplitude (Bo)**
- **Local temperature increase (RF)**
- **Magnetophosphene (gradient)**

Summary: MRI Bioeffects

- **Patient, clinician, technologist:
all basically harmless**
- **No worry under normal operation**

Well, after class ...

- You may say ...
- “Believe it or not, it is up to me.”

Dr. Chung You're Wrong!

- **My friend said that her eyes hurt after the MRI scan ...**
- **Is it really due to MRI?**
- **You still don't believe me?**

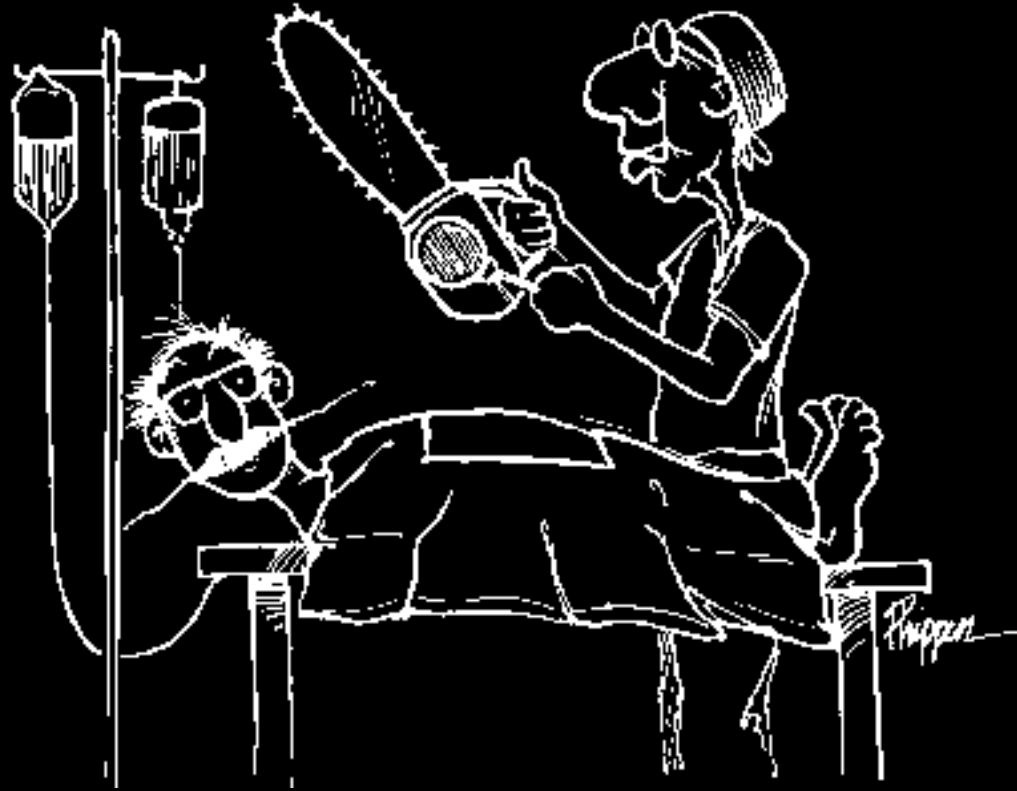
Let's Ask This Question:

- **Is TaiPower Company willing to build nuclear power plant in their backyard?**
- **Are clinicians willing to get X-ray exams frequently?**
- **Is Dr. Chung willing to get MR scans?**

Risk vs. Benefit

- **Patient: better diagnosis**
- **Technologist: work environment without ionizing radiation**
- **Clinician: tomographic vision**
- **Dr. Chung: source of \$ income**

Is MRI This Dangerous?



Let's just take a look at your heart ... briefly

Are You Afraid of MRI?

- Go ahead & quit your job
- Don't force yourself

MRI Safety Issues

- MRI bioeffects
- MRI safety & protection

Protection for MRI Safety

- **What a hell of protection do we need if MRI is so safe?**

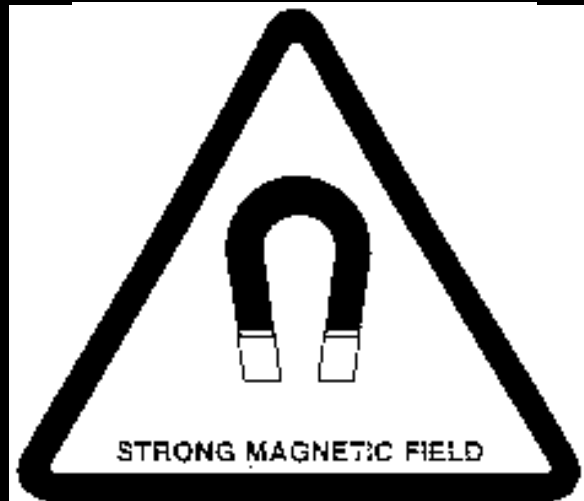
MRI Safety

- No worry under normal operation
- Abnormal operation can be

extremely dangerous!

Warning Sign Near MR Scan Room

WARNING !



**NO PACEMAKERS
NO METALLIC IMPLANTS
NO NEUROSTIMULATORS**

Persons with pacemakers, neurostimulators, or metallic implants must not enter this area. Serious injury may result.



NO LOOSE METAL OBJECTS

Iron, steel and other ferrous materials must not be taken into this area. Serious injury or property damage may result.

The Strong MRI Magnet

- **Earth field: 0.5 Gauss**
- **Toy magnets: ~ 50 Gauss**
- **MRI magnet: 15,000 Gauss**

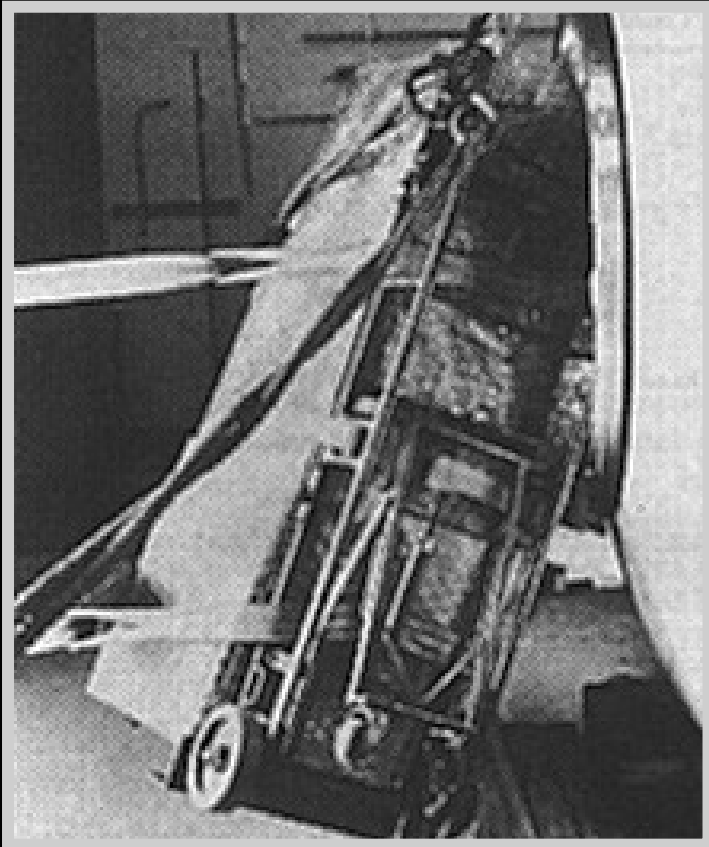
Compare Magnetic Field

- **0.5 Gauss: compass**
- **50 Gauss: paper clips**
- **15,000 Gauss: television?**
- **MRI weight: 4~9 tons**

Danger of Strong Bo

- **Huge attractive force for appliance!**
 - **Nail, scissors, tweezers, ...**
 - **Wrench, screwdriver, hammer, ...**
 - **Computer, chair, oscilloscope, ...**

Danger of Ferromagnetic Object in MRI



Power amplifier



De-humidifier

Danger of Ferromagnetic Object in MRI

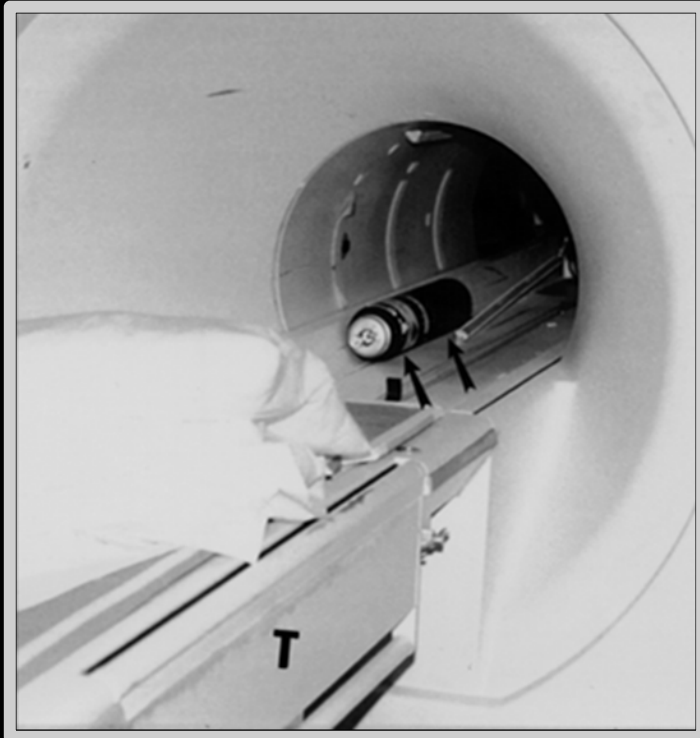


Chair

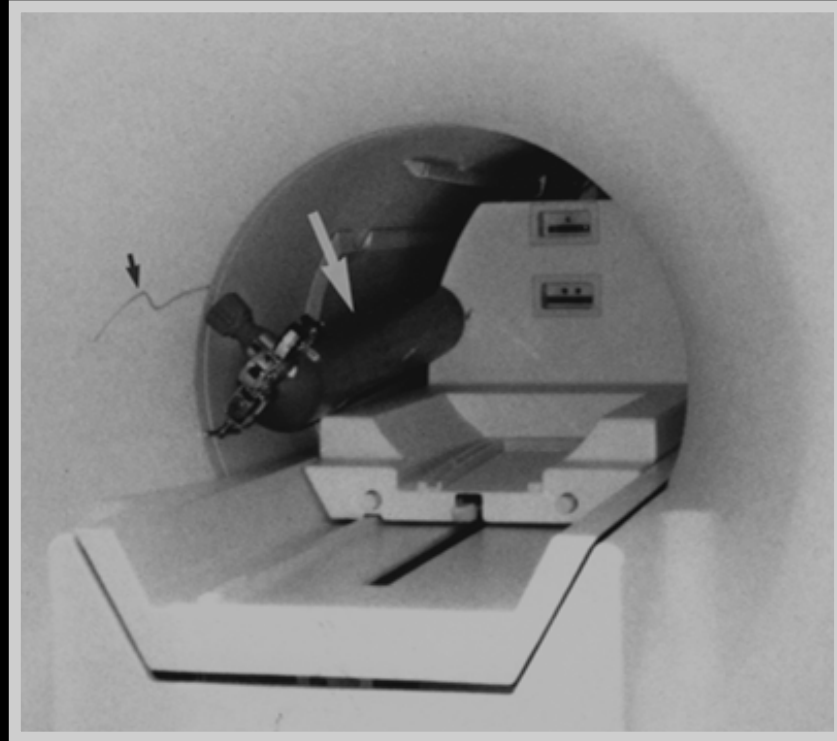


Buffer

Danger of Ferromagnetic Object in MRI



Nitrous oxide tank



Oxygen cylinder

Danger of Ferromagnetic Object in MRI



Vacuum cleaner



i.v. injector

MRI Safety Film

- **If the classroom is like a movie theater ...**
 - **From GE education video**
- **Kids, don't do this at home!**

Danger of Ferromagnetic Object in MRI



Danger of Strong Bo

- **MRI: 4~9 tons in weight**
- **Heavy ferromagnetic objects become lethal weapons!**

Other Dangerous Stuff

- **Cardiac pacemaker**
- **Dysfunction in strong magnetic field**
- **At least one death reported (1990)**
- **Not only patients, but also accompanying family members**

About Pacemakers

- **Highly depend on manufacturer and year of production**
- **Circ '04: safe → Circ '05: 3 letters**
- **Follow new investigations!**
- **Better be careful**

Other “Bad” Things

- **Metal or magnetic stuff**
 - **Implants**
 - **Carry-on**
- **Discomfort or image distortions**

Metal Implants

- **Surgical clips**
- **Cochlear implants**
- **Injection pump**
- **Prosthesis ...**

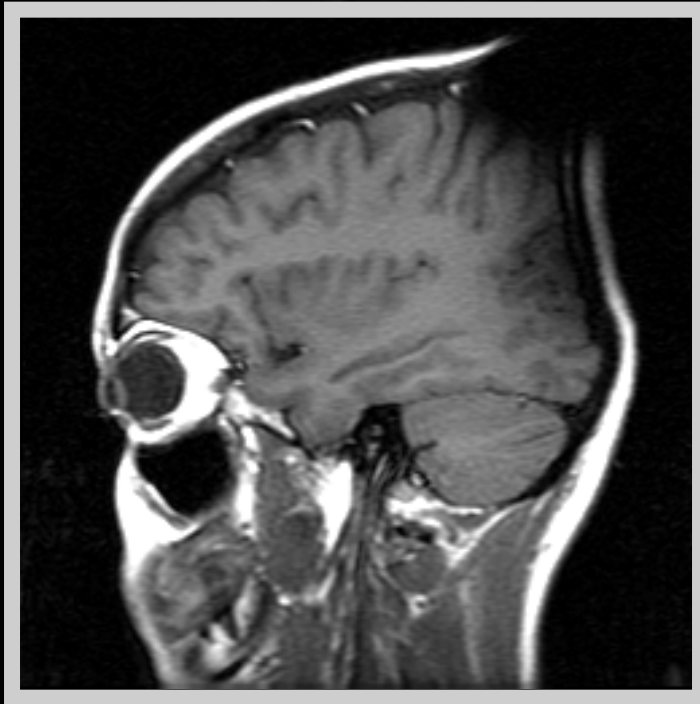
Metal Carry-on

- **Dental work**
- **Leather belt**
- **Make-up (eye shadow)**
- **Hair pin ...**

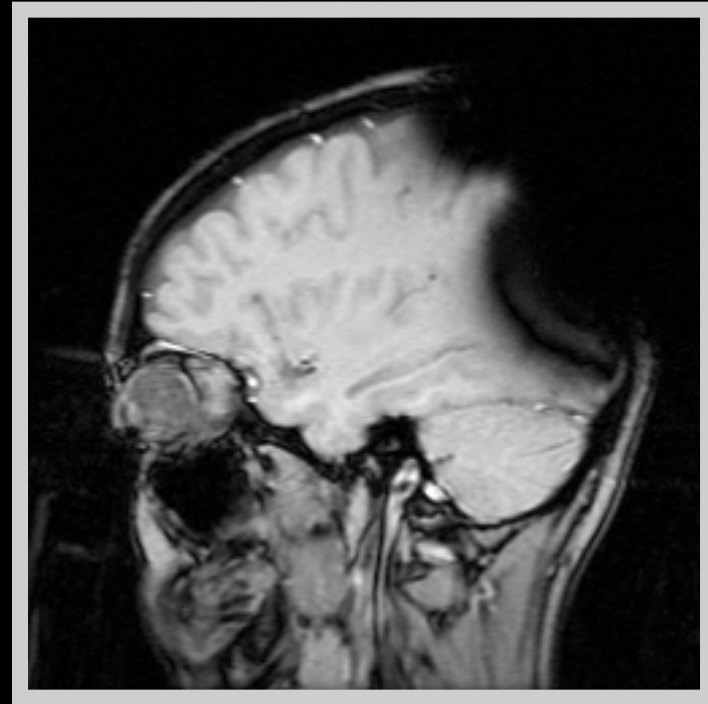
Some Known “Bad Things”



Iron Hair Pin MRI



Spin echo



Gradient echo

Importance of Prevention

- **No disorganized stuff near MRI**
- **Routine query pt's on implants**
- **Remove carry-on, change clothes**
- **No entrance unless admitted!**

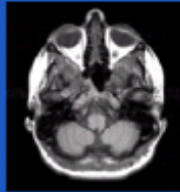
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Search THE LIST

Fill The Search Form

Object Name:

Result Status:

Hold the SHIFT key down
in order to make multiple
selections.

- All
- Safe
- Unsafe 1
- Unsafe 2
- Conditional 1

**Manufacturer
Name:**

Object Category:

Hold the SHIFT key down
in order to make multiple
selections

- All
- AccuRx Constant Flow Implantable Pump
- Activa (Neurostimulation) System (Med
- Aneurysm Clips
- Bioeffects of RF Energy
- Biopsy Needles, Markers and Devices
- Bone Fusion Stimulator

Number of Hits per

In An Emergency

- **Patient life threatened:**
 - **Discomfort: leave MRI at once**
 - **Stuck: emergent quench**
- **Life not threatened: report to manufacturer honestly at once**

Emergent Quench

- **Quench: turn off superconductivity**
- **Magnet “may” be destroyed**
- **Don’t do it unless life threatening!**
- **Don’t hesitate when necessary!**

Quench

- Helium & nitrogen boil off
- Oxygen expelled (asphyxia)
- Ramp up needed afterwards
- Time ~ 2 weeks, \$ ~ million

Quench of an NMR Spectrometer



Starting ...



A while later

MRI Quench Film

- **If the classroom is like a movie theater ...**
- **Pirated without copyright**

From “The One” Starring Jet Li



RF Burns

- **RF + wire ~ point discharge?**
 - ECG leads
 - Meter needle pointer ...
- **(Coil) decoupling circuit broken**

Avoiding RF Burns

- **Follow instructions & use only MR-compatible accessory**
- **Handle RF coils carefully**

MRI & Pregnancy

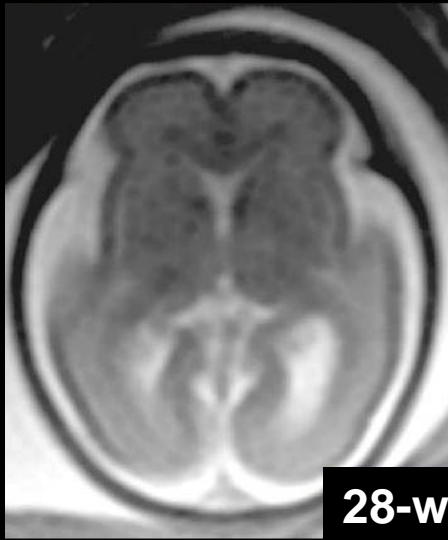
- Believed harmless to fetus, but ...
- Nobody dared to start until '95
- More & more at 2~3 trimesters
 - 1st trimester: cell differentiation
- Especially with uncertain ultrasound

... Including My Own Son

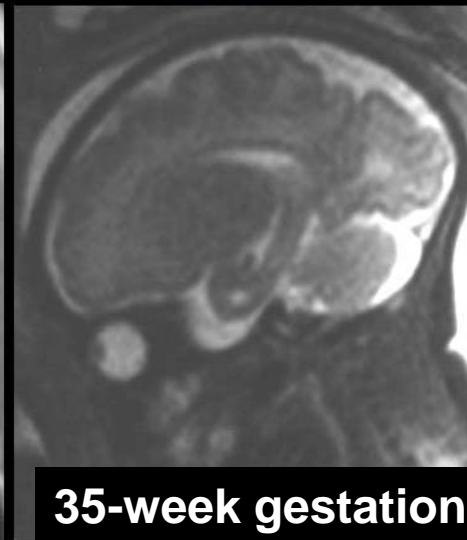
5-month photo



Future look?



28-week gestation



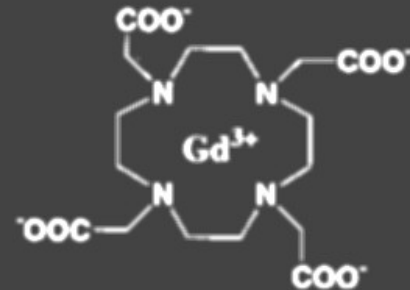
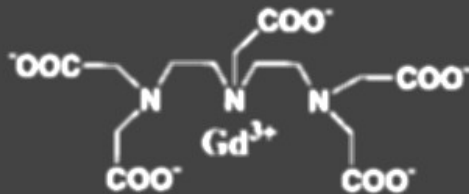
35-week gestation

Courtesy Cheng-Yu Chen, M.D., Tri-Service General Hospital

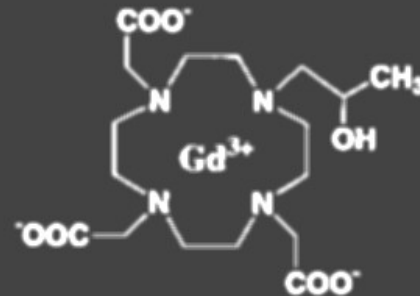
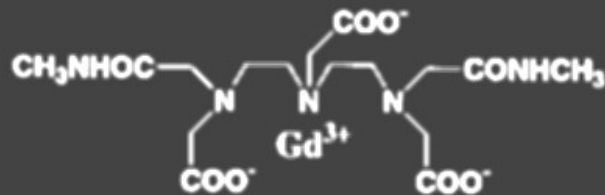
MRI Contrast Agents

- **Magnevist, Gadovist (Schering)**
- **ProHance (Bracco)**
- **OmniScan (Nycomed → GE)**
- **Dotarem (Guerbet)**
- **Optimark (Mallinckrodt)**

Some FDA Approved Gd Chelates



Gd-DTPA (Magnevist) Gd-DOTA (Dotarem)



Gd-DTPA-BMA (Omniscan) Gd-HP-DO3A (Prohance)
Still large compared capillary permeability

Contrast Agent Safety

- **Stability: chelate does not degrade within human body**
- **Excreted (urine) before degrading**
- **LD₅₀ study before commercialized**
 - **Dosage at which 50% mice die**

LD₅₀ Study

Dose at which half mice die (mmol/Kg)

Gd-DTPA	Magnevist	10
Gd-DOPA	Dotarem	>10
Gd-DTPA-BMA	Omniscan	34
Gd-HP-DO₃A	ProHance	12
GdCl₃		0.2~0.5
Gd(OH)₃		0.1

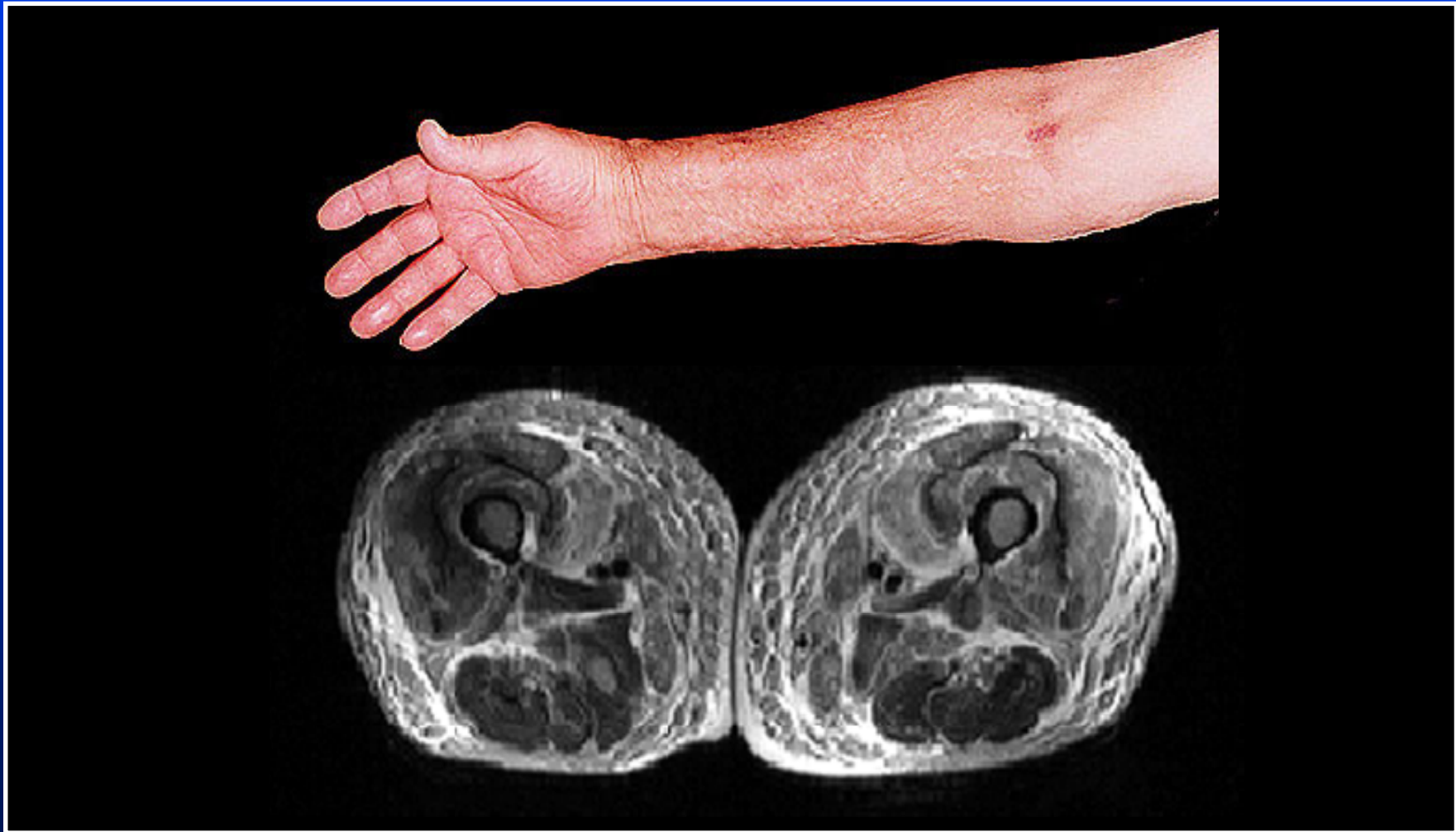
Intravascular Injection

- **Generally safe**
- **Allergy cases reported (1994) :**
 - **Magnevist: 13 in 5,900,000**
 - **One death, one coma**
 - **6 deaths unproven to be due to Gd**

Contrast Agent Safety

- **LD₅₀ is just overall toxicity**
- **Not for kidney dysfunction!**
- **Evolving case: Gd-agents & NSF**
 - **Nephrogenic systemic fibrosis**

Nephrogenic Systemic Fibrosis



Possible Reasons

- **All NSF patients had CE-MR & kidney dysfunction (not the opposite)**
 - **Contrast excretion route altered**
 - **Gd found from skin biopsy**

Possible Reasons

- **Gd has not been proven as the actual origin (perhaps the chelate?)**
- **Evidence all points on Gd agents**
- **Worldwide warning (RSNA, ISMRM, FDA, Dept. of Health ...)**
- **Follow-up warranted**

MRI Acoustic Noise

- **Origin: gradient coil ON/OFF**
- **Often louder (or higher pitch) for faster scan**
- **Give ear plugs**

Claustrophobia

- **Psychological fear (closed space)**
- **Patients afraid of entering MRI**
- **Explain MRI being harmless**
- **Calm down without forcing**

Summary: MRI Bioeffects

- **Some, believed to be harmless**
- **Dr. Chung is not worried**
- **Readers do not have to obey me**

Summary: MRI Protection

- **No ferromagnetic objects**
- **Avoid RF burns**
- **Pay attention to patient comfort**
- **Careful attitude without fear**

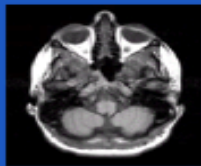
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Safety Information

- ▶ 3.0-Tesla MR Safety Information for Implants and Devices
- ▶ Accessories and Equipment For the MR Environment
- ▶ AccuRx Constant Flow Implantable Pump and Duracath Intraspinal Catheter
- ▶ Acoustic Noise and MR Procedures
- ▶ Activa (Neurostimulation) System (Medtronic, Inc., Minneapolis, MN)
- ▶ Aneurysm Clips
- ▶ Bioeffects of Gradient Magnetic Fields
- ▶ Bioeffects of RF Energy
- ▶ Bioeffects of Static Magnetic Fields
- ▶ Biopsy Needles, Markers and Devices
- ▶ Body Piercing Jewelry and MRI Safety
- ▶ Bone (Spinal) Fusion Stimulator
- ▶ Breast Tissue Expanders and
- ▶ IsoMed Implantable Infusion Pump (Medtronic, Inc., Minneapolis, MN)
- ▶ Kinetra Dual Program Neurostimulator for Deep Brain Stimulation, Model 7428
- ▶ M2A Capsule Endoscopy Device
- ▶ Magnetically Activated Implants and Devices
- ▶ Medical Devices and Accessories for the MR Environment
- ▶ Medtronic MiniMed 2007 Implantable Insulin Pump System
- ▶ Metallic Foreign Bodies and Screening
- ▶ Miscellaneous Implants and Devices
- ▶ "Missile Effect" Accidents and Prevention
- ▶ Monitoring Patients in the MR Environment
- ▶ MR Procedures: Implants and

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Serving with Compassion

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MRI

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A teaching hospital affiliated with the University of Toronto

MRI: MRI Safety

Prior to booking an MRI examination, please ensure that the MRI Screening Questionnaire is completely filled out and sent to the MRI Department. The following represents a list of contraindicated and MRI compatible devices. Please note, this is not a complete list but should serve as a guideline. If you require more information, please check with the MRI staff at 416 360-4000 Ext. 2134 or visit the following website:
www.mrisafety.com

Summary: MRI Safety

- No worry under normal operation!

MR Imaging

Bioeffects and Safety

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