

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

## Nov 8<sup>th</sup>, 1895: The Birth of Radiology

- Radiographs
  - 11/8/95 Wilhelm Conrad Röntgen produces "X-rays"
  - 12/28/95 Röntgen presents: "On a New Kind of Rays"
  - 2/11/96 Jones publishes: "The Discovery of a Bullet Lost in the Wrist by Means of the Roentgen Rays"

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety Ⓢ  
Hardware



First Radiograph  
Röntgen's wife



1901: Röntgen wins 1<sup>st</sup>  
Nobel prize in physics

www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## X-rays as Diagnostic Tool

- Radiographs

**Can see:**

- Bones
  - ✓ Fractures
- Joint width, surfaces
  - ✓ Arthritis
    - ❖ Osteophytes
    - ❖ Erosions

**Can't see:**

- Inside skull
  - ✓ Can't see the brain
- Inside joints
  - ✓ Can't see tears
    - ❖ Ligaments, Tendons
    - ❖ Menisci, Cartilage

**Radiographs: 2D projection of 3D patient**

- Radiographs flatten everything
  - ✓ Can't tell what's in front, what's behind
- With radiographs: **NEED MULTIPLE VIEWS!**

● "One view = No views" ●


www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## "One view = No views"

- Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety Ⓢ  
Hardware



www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD




The Evolution of Radiology Focus on Musculoskeletal MRI

## Need Multiple Views

- Radiographs

Small finger

- Not a subtle fracture
- Fragment overlap each other so perfectly on PA view, are undetectable

PA Obl Lat

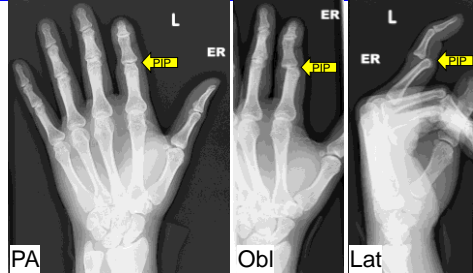
www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## For Joints: Need 3 Views!

- Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety Ⓢ  
Hardware



www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## CT: Giant Leap Forward


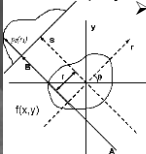

- Radiographs

**CT: Computed Tomography** (*Tomography* [Gr]: part, slice)

**CAT: Computed Axial Tomography**

1917 Johann Radon, Austrian mathematician, proved image of a 3D object could be reconstructed from an infinite number of 2D projection images of the object.

- Had to await the advent of main-frame computers in the 1970's.

www.schreibman.info www.wikipedia.com  
© 2014 Ken L Schreibman, PhD/MD

# Evolution of Radiology: Focus on MSK MRI

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Hounsfield & EMI Brain Scanner

**Radiographs** 1972: Godfrey Hounsfield, a British electrical engineer at EMI Laboratories, developed EMI Brain Scanner.  
 > **Finally, could see through the skull into the brain!**  
 ✓ Awarded Nobel Prize for Medicine 1979; Knighted 1981.  
 ✓ "Hounsfield Units" is the scale we use to measure CT density.  
 > EMI: "Electric and Musical Industries" **EMI**

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) [www.sciencemuseum.org.uk](http://www.sciencemuseum.org.uk) Jump to last slide viewed Jump to next slide Slide 7 of 84  
 © 2014 Ken L Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Why CT is So Great

**Radiographs** **Can see the brain**  
 > Strokes, bleeds, tumors  
**Can see organs (lungs, liver, bowel)**  
 > Tumors, trauma, acute/chronic diseases  
**Can see fractures otherwise missed**  
 > Cervical spine, pelvis  
**And now with ultra-fast, multi-slice...**  
 > Can scan the heart in a single beat!  
 ✓ Can see coronary arteries, pulmonary emboli  
**Hospitals have CT scanners in the ER**

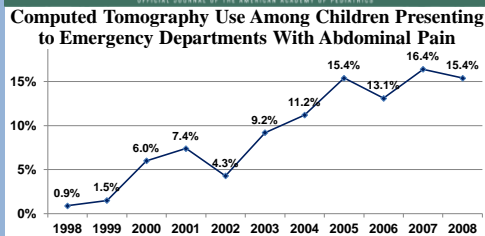
[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 8 of 84  
 © 2014 Ken L Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### CT Usage Increasing in ERs

**Radiographs** *Pediatrics* Nov 2012 Vol 130, # 5, p 1-7 **PEDIATRICS** Published online October 8, 2012  
 SPECIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) [pediatrics.aappublications.org](http://pediatrics.aappublications.org) Jump to last slide viewed Jump to next slide Slide 9 of 84  
 © 2014 Ken L Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Biggest Problem with CT

**Radiographs** **High radiation dose**  
 We are exposed to low levels of radiation every day, "Background Radiation"  
 > Earth: naturally occurring radionuclides  
 ✓ Uranium-238, potassium-40  
 > Atmosphere: Radon-222 (from U-238)  
 ✓ 2<sup>nd</sup> leading cause of lung cancer after smoking  
 > Space: cosmic rays  
 ✓ Airline crews, who spend a lot of time in the upper atmosphere, receive 2x typical background dose.  
**Ave background dose ≈ 2.4mSv/year**

[www.schreibman.info](http://www.schreibman.info) [www.wikipedia.com](http://www.wikipedia.com) Jump to last slide viewed Jump to next slide Slide 10 of 84  
 © 2014 Ken L Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Radiation from Diagnostic Imaging

**Radiographs** **Ave background dose ≈ 2.4mSv/year**  
 Chest Radiograph ≈ 0.06mSv  
 > ≈ 1 week of background radiation  
 Chest CT ≈ 7.0mSv  
 > ≈ 3 YEARS of background radiation  
**How much radiation is too much?**

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware

"Risks of medical imaging at effective doses below 50 mSv for single procedures or 100 mSv for multiple procedures over short time periods are too low to be detectable and may be nonexistent."

[www.schreibman.info](http://www.schreibman.info) [www.aapm.org](http://www.aapm.org) Health Physics Society Jump to last slide viewed Jump to next slide Slide 11 of 84  
 © 2014 Ken L Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Other Problems with CT

**Radiographs** **Usually requires IV contrast**  
 > 1% patients are allergic to CT contrast  
 > Can affect renal function  
**Costs more than radiographs**  
 > Knee radiographs (4 views): \$154  
 > Knee CT (no contrast): \$1,200  
**Can't see structures inside joints**  
 > Knee: ☞ Menisci, ☞ Ligaments, ☞ Cartilage  
 > Shoulder: ☞ Rotator Cuff, ☞ Labrum  
 > Spine: ☞ Disks, ☞ Spinal Cord

[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 12 of 84  
 © 2014 Ken L Schreibman, PhD/MD

# Evolution of Radiology: Focus on MSK MRI

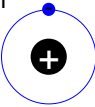
The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI: Giant Leap Sideways

**Radiographs** MRI doesn't rely on X-rays to see projected shadows of patients  
 > Unlike radiographs, tomography, CT

**CT**  
 • **MR**  
 Signal Sequences  
 Coils  
 Magnets  
 Safety Ⓢ  
 Hardware

**MRI sees tissues based upon sub-atomic characteristics**  
 > Proton nucleus of Hydrogen  
 "NMR"  
 > "Nuclear Magnetic Resonance"  
 > "No More Radiologists"  
**MRI**  
 > "Magnetic Resonance Imaging"



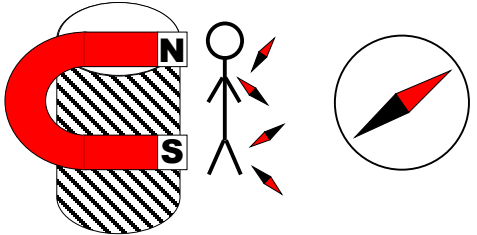
[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 13 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI Scanner: 2 Components

**Radiographs** **THE MAGNET**

**CT**  
 • **MR**  
 Signal Sequences  
 Coils  
 Magnets  
 Safety Ⓢ  
 Hardware



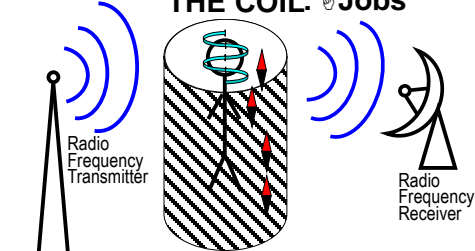
[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 14 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI Scanner: 2 Components

**Radiographs** **THE COIL: 2 Jobs**

**CT**  
 • **MR**  
 Signal Sequences  
 Coils  
 Magnets  
 Safety Ⓢ  
 Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 15 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## How MR Scanner Works

**Radiographs** **Magnet**  
 > Aligns spins of protons in hydrogen nuclei  
 ✓ Align in direction of magnetic field,  $B_0$

**Coil**  
 1) Sends RF pulse to flip spinning protons  
 ✓ After RF pulse is off, protons realign to  $B_0$   
 ✓ As protons realign, resonate RF energy  
 2) Measures strength of resonant RF echo  
 ✓ At a specific time,  $T_E$ , "Echo Time"  
 Steps 1&2 repeated many times / image slice  
 ✓ At a specific "Repetition Time",  $T_R$

[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 16 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Key to MRI

**Radiographs** **Specific tissue types have specific resonant echoes ( $T_1$ ,  $T_2$ ) depending upon specified  $T_R$  &  $T_E$**

**CT**  
**MR**  
 • **Signal**  
 Sequences  
 Coils  
 Magnets  
 Safety Ⓢ  
 Hardware

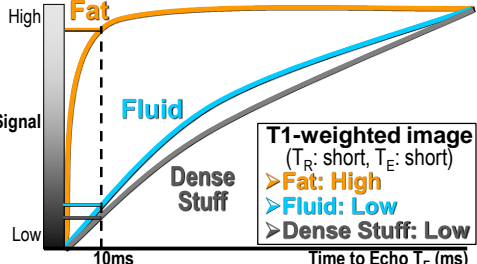
- > **Fluid (Hydrogen protons in  $H_2O$ )**
  - ✓ Cysts
  - ✓ Joint effusions
  - ✓ Edema (in soft tissues, in bone marrow)
- > **Fat (Hydrogen protons in fat)**
  - ✓ Sub-cutaneous fat
  - ✓ Fatty yellow bone marrow
- > **Dense Stuff (with few Hydrogen protons)**
  - ✓ Cortical bone
  - ✓ Ligaments, tendons
  - ✓ Menisci

[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 17 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## T1 Recovery Curve ( $T_R \sim 500ms$ )

**Radiographs**

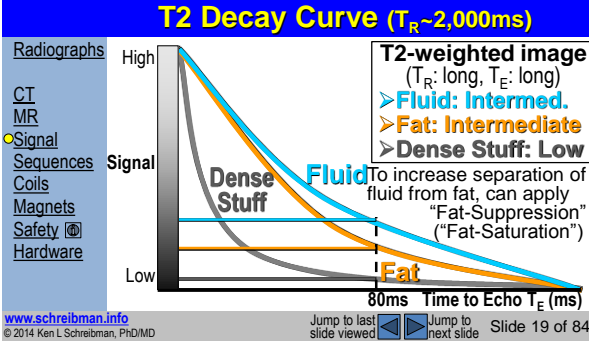


**T1-weighted image**  
 ( $T_R$ : short,  $T_E$ : short)  
 > **Fat: High**  
 > **Fluid: Low**  
 > **Dense Stuff: Low**

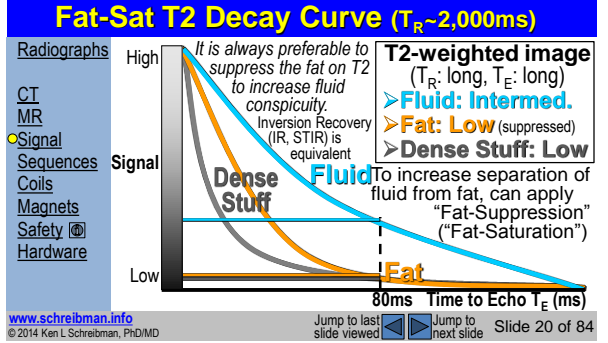
[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L. Schreibman, PhD/MD  
 Jump to last slide viewed | Jump to next slide | Slide 18 of 84

# Evolution of Radiology: Focus on MSK MRI

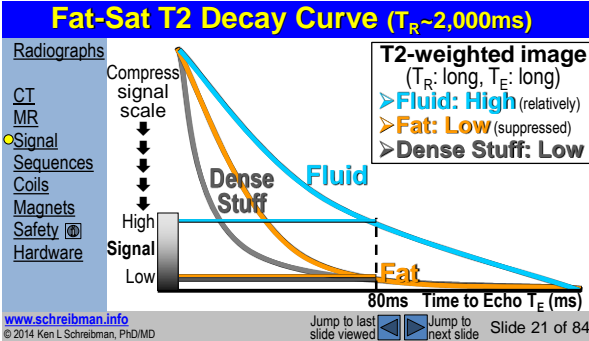
## The Evolution of Radiology Focus on Musculoskeletal MRI



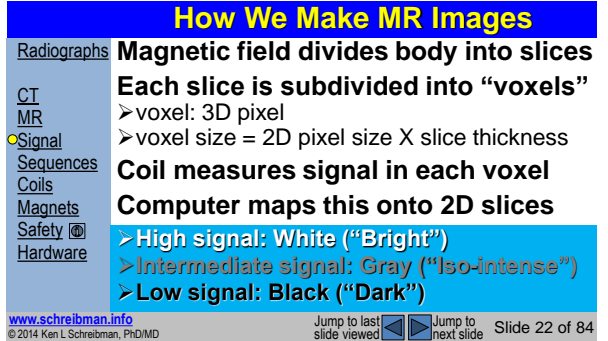
## The Evolution of Radiology Focus on Musculoskeletal MRI



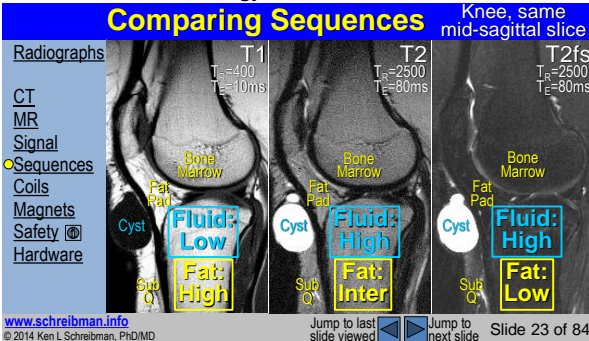
## The Evolution of Radiology Focus on Musculoskeletal MRI



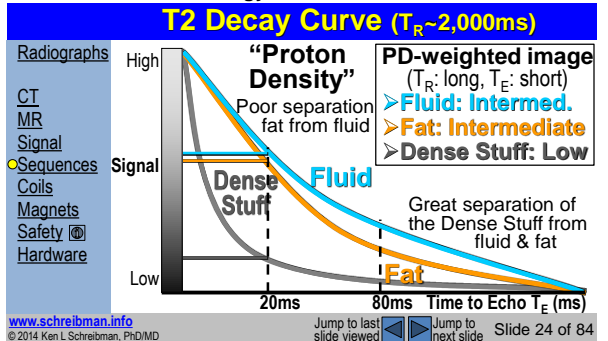
## The Evolution of Radiology Focus on Musculoskeletal MRI



## The Evolution of Radiology Focus on Musculoskeletal MRI



## The Evolution of Radiology Focus on Musculoskeletal MRI



# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

## Comparing Sequences

Knee, same mid-sagittal slice

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 25 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI: Need Multiple Sequences

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

**T1 shows Fat best**

- Most normal anatomy surrounded by fat
- In essence, T1 shows anatomy best

**T2 shows Fluid best**

- Most pathology contains fluid (edema)
- In essence, T2 shows pathology best
  - ✓ Fat-suppression makes fluid more conspicuous

**PD shows Dense Stuff best**

- Good for meniscal and tendon tears
- Used mostly for MRI of joint pain

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 26 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Limitations of MRI

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

**Limited Field of View (FOV)**

**Image resolution related to voxel size**

- Smaller FOV = smaller voxels
- Smaller voxels = higher resolution
- To maximize resolution, try to limit FOV

**Can only image inside the coil**

- Requires an assortment of different coils for different body parts

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 27 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Knee Coil

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 28 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Knee Coil for the Ankle

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 29 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Foot Coil

Radiographs  
CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety  
Hardware

www.schreibman.info © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed Jump to next slide Slide 30 of 84

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

**Elbow Coil**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 31 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Wrist Coil**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 32 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**2 Part Torso Coil**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 33 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Many Coils are Needed**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 34 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**MRI Scans are Expensive**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware

- Coils are expensive: >\$25,000 EACH!
- Scanners are expensive: >\$2,000,000
- Specialty trained technologists are expensive
- **MR scans take 30-60 minutes**
  - ✓ Run several sequences in several planes
  - ✓ Can scan only a limited number of patients per day
  - ✓ Have to charge a lot per scan

Knee Radiographs (4 views): \$154  
Knee CT (no contrast): \$1,200  
Knee MR (no contrast): \$2,400

**Don't order MSK MR before getting Radiographs!**

[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 35 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI


**MR Scans are Long**

Radiographs

CT  
MR  
Signal Sequences  
● Coils  
Magnets  
Safety Ⓢ  
Hardware

**MR scans take 30-60 min**

- Patient's need to lie still... like a statue... for the entire time.
- If the patient is ill the day of the scan and can't stop coughing or sneezing, should reschedule.
- Patients who can't lie flat, severe heart failure (CHF), can't get MRI.



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 36 of 84

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

**Scanners**

Radiographs **A CT scanner... is a doughnut**

CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreiber, PhD/MD


Jump to last slide viewed | Jump to next slide | Slide 37 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Scanners**

Radiographs **A CT scanner... is a doughnut** **An MR scanner... is a cannoli**

CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreiber, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 38 of 84

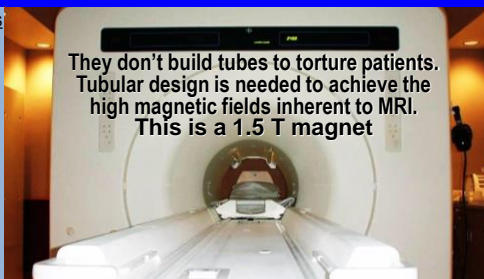
The Evolution of Radiology Focus on Musculoskeletal MRI

**MR Scanner is a Tube**

Radiographs

CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware

**They don't build tubes to torture patients. Tubular design is needed to achieve the high magnetic fields inherent to MRI. This is a 1.5 T magnet**



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreiber, PhD/MD

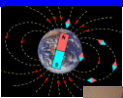
Jump to last slide viewed | Jump to next slide | Slide 39 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Tesla: Measure Magnetic Field Strength**

Radiographs **Earth's magnetic field:**


- > 30  $\mu\text{T}$  ( $3 \times 10^{-5}$  T)



CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware

**Typical refrigerator magnet:**

- > 3 mT ( $3 \times 10^{-3}$  T)



**High Field MRI scanner:**

- > 1.5 – 3 T
- > 1,000 times the strength refrigerator magnet
- > 100,000 times the Earth's magnetic field

[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreiber, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 40 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**"Open" MRI = Low Field**

Radiographs **Favored by commercial stand-alone MRI sites**

CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware

Our MRI scanner is open on all four sides; that's a major advantage for large people who find a tunnel too confining, for children who might become frightened inside a tunnel, and for anyone with a touch of claustrophobia.



[www.schreibman.info](http://www.schreibman.info) [open-mri-inc.com](http://open-mri-inc.com) © 2014 Ken L Schreiber, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 41 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

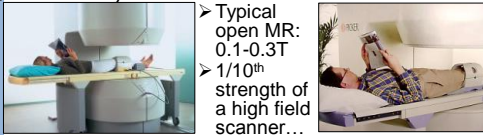
**"Open" MRI = Low Field**

Radiographs **Favored by commercial stand-alone MRI sites**

CT  
MR  
Signal Sequences  
Coils  
Magnets  
Safety  
Hardware

- > Typical open MR: 0.1-0.3T
- > 1/10<sup>th</sup> strength of a high field scanner...
- > 1/10<sup>th</sup> image resolution of a high field scanner.
- > Costs 1/10<sup>th</sup> the price to buy low field scanner...
- > They charge the same price as a high field scan.

**Diagnostic value of low field MR is inferior to that of high field MR.**



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreiber, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 42 of 84

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

## UW Experience with Open MR

Radiographs

CT

MR

Signal


Sequences

Coils

● Magnets

○ Safety

○ Hardware



**0.7 T "Mid Field"**

- This is highest field open scanner made

**Our accuracy: Knee**

- In 1.5 T MR: ≈ 95% ☺
- In this scanner: 75% ☹
- ✓ Same UW radiologists
- ✓ Same UW protocols

**Diagnostic value of low field MR is inferior to that of high field MR.**

Jump to last slide viewed

Jump to next slide

Slide 43 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## UW Experience with Open MR

Radiographs

CT

MR

Signal


Sequences

Coils

● Magnets

○ Safety

○ Hardware



Our surgeons refused to schedule patients in our open scanner.

- Ran it only 2 days/week
- Primarily: Obese patients
- As bad as this scanner was, it did a particularly poor job with... obese patients.
- Got rid of it for a 3 T ☺!

Jump to last slide viewed

Jump to next slide

Slide 44 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## My Recommendations

Radiographs

CT

MR

Signal

Sequences

Coils

● Magnets

○ Safety

○ Hardware

**For yourself or your patients:**

- Don't use open low field scanners
- Always want to use at least a 1.5 T scanner
- **Go to a 3 T if available!**

**What about obese patients?**

- Patients who don't fit in the standard 1.5 T?
- **We now have an alternative to low field open scanners for the "Wisconsin-sized" patient...**

Jump to last slide viewed

Jump to next slide

Slide 45 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## Wide Bore 1.5T

Radiographs

CT

MR

Signal


Sequences

Coils

● Magnets

○ Safety

○ Hardware



**It's still a tube...  
But it's a much wider tube**

**Same size opening as a CT scanner  
Table can hold up to 500 lbs!**

Jump to last slide viewed

Jump to next slide

Slide 46 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## Wide Bore 1.5T, also Short Bore

Radiographs

CT

MR

Signal


Sequences

Coils

● Magnets

○ Safety

○ Hardware



**Wide bore + short bore = less "closed in" feeling**

Jump to last slide viewed

Jump to next slide

Slide 47 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## MR scanner is a tube

Radiographs

CT

MR

Signal

Sequences

Coils

● Magnets

○ Safety

○ Hardware



**Claustrophobia**

**Don't make patients claustrophobic**

- Things I've seen clinicians write:
  - ✓ I told my patient how traumatic an MR scan is
  - ✓ I told my patient it's like laying inside a **COFFIN**
  - ✓ I told my patient it's like laying in a **SEWER PIPE**

Jump to last slide viewed

Jump to next slide

Slide 48 of 84

[www.schreibman.info](http://www.schreibman.info)  
© 2014 Ken L Schreibman, PhD/MD



# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

**MR scanner is just a tube**

Radiographs **Nothing happens inside the tube**

- Nothing moves
- Nothing crushes
- Open at both ends
- Plenty of air
- No radiation
- No X-rays
- No flashing lights

*If it didn't make any noise you wouldn't even know anything was happening.*

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 49 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**MR scanners make lots of noise**

Radiographs **We protect the patient's ears**

- Ear plugs
- Headphones
  - ✓ Can play radio station
  - ✓ or CD
  - ✓ or patient's iPod

**Our goal is to make patient relaxed**

- We get our best pictures of people sleeping

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 50 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**If your patient is still anxious**

Radiographs **Can take something mild as an outpatient**

- Valium (Diazepam)
- Ativan (Lorazepam)
- Cocktail? (not all 3)
- **Patient should not drive!**

**If patient is really problematic**

- We can provide conscience sedation at hospital
- ✓ Not at outpatient facility

**If patient is really really problematic**

- General anesthesia can be arranged (It rarely comes to that)

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 51 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**The Big Problem with MRI**

Radiographs

**It's a Big Magnet  
It's Always On**

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 52 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Why is it Always On?**

Radiographs **Isn't it an electromagnet?**

- Can't we just flick a switch and turn it off?
- It's not that simple...
- Yes, it's an electromagnet.
- Yes, it works by passing current through wire

**To achieve 1.5T, need to pass A LOT of current through wire**

- Requires low resistance wire...
- ...super-conducting wire
- Super-conducting materials operate at CRYOGENIC TEMPERATURES!
- Can't turn off magnet with venting cryogens.

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 53 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

**Occasionally Replenish Cryogens**

Radiographs

www.schreibman.info © 2014 Ken L. Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 54 of 84

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

**MRI Safety**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware

**Everyone in the entire medical center needs to respect MRI safety**

**Can't bring into the scanner room anything that is:**

- Ferromagnetic
- Electronic

**that is not certified MRI compatible.**



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 55 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

**Safety Videos**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) [www.patency.com/mri-safety](http://www.patency.com/mri-safety) Jump to last slide viewed Jump to next slide Slide 56 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

**Things Stuck in Magnets: Floor Buffer**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware



[www.MRImetalDetector.com](http://www.MRImetalDetector.com)

[www.schreibman.info](http://www.schreibman.info) [www.MRImetalDetector.com](http://www.MRImetalDetector.com) Jump to last slide viewed Jump to next slide Slide 57 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

**Things Stuck in Magnets: Gas Tank**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) [www.simplyphysics.com](http://www.simplyphysics.com) Jump to last slide viewed Jump to next slide Slide 58 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

**Things Stuck in Magnets: ICU Bed**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) [www.MRImetalDetector.com](http://www.MRImetalDetector.com) Jump to last slide viewed Jump to next slide Slide 59 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

**Things Stuck in Magnets: Chair**

Radiographs

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
● Safety Ⓢ  
Hardware



[www.schreibman.info](http://www.schreibman.info) [www.simplyphysics.com](http://www.simplyphysics.com) Jump to last slide viewed Jump to next slide Slide 60 of 84  
© 2014 Ken L Schreibman, PhD/MD

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

## Things Stuck in Magnets: Drug Cart

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD


Jump to last slide viewed | Jump to next slide | Slide 61 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Warning Signs

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 62 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Warning Signs

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



Warnzeichen: NMR - Magnetfeld  
Signal attention: Champ Magnétique RMN  
Warning sign: NMR - Magnetic Field

Warnzeichen: Hochfrequenzfeld  
Signal attention: Champ Haute Fréquence  
Warning sign: High Frequency Field

[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 63 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## Metal Objects May Become Airborne

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 64 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI Safety in China

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 65 of 84

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI Safety in China

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) © 2014 Ken L Schreibman, PhD/MD

Jump to last slide viewed | Jump to next slide | Slide 66 of 84

# Evolution of Radiology: Focus on MSK MRI

The Evolution of Radiology Focus on Musculoskeletal MRI

## Limit Access to MR Suite

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 67 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## A True Tragedy

Radiographs New York Daily News Online Tuesday, July 31, 2011

### Freak MRI Accident Kills Westchester Boy Magnet send canister flying into him



6-year-old boy undergoing an MRI exam at a Westchester hospital died after the machine's powerful 10-ton magnet turned an oxygen canister **into a missile** that **smashed his skull**, officials said yesterday.



[www.schreibman.info](http://www.schreibman.info) [mimetaldetector.com](http://mimetaldetector.com) Jump to last slide viewed Jump to next slide Slide 68 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## MRI Safety


Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware

**Everyone in the entire medical center needs to respect MRI safety**

**Can't bring into the scanner room anything that is:**

- Ferromagnetic
- Electronic that is not certified MRI compatible.



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 69 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

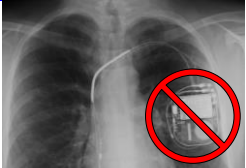
## No Implanted Electronics

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware

**No pacemakers**

- Magnet won't suck pacer out of chest
- But magnet may...
  - ✓ Drain the battery
  - ✓ Make pacer fire erratically
  - ✓ Scramble electronics
  - ✓ May even reprogram pacer



FDA approves first MRI-compatible pacemaker  
February 09, 2011  
by Sarah Valeri, DofMed News  
The U.S. Food and Drug Administration Tuesday approved a pacemaker compatible with magnetic resonance imaging. The device is the first of its kind in the United States, and will allow patients with pacemakers to safely undergo the exam.

[www.schreibman.info](http://www.schreibman.info) [www.doimed.com](http://www.doimed.com) Jump to last slide viewed Jump to next slide Slide 70 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

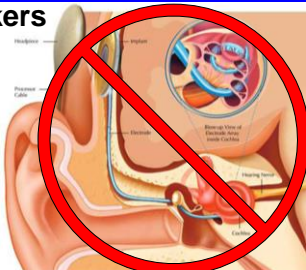
## No Implanted Electronics

Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware

**No pacemakers**

**No cochlea implants**



[www.schreibman.info](http://www.schreibman.info) [www.advancedbionics.com](http://www.advancedbionics.com) Jump to last slide viewed Jump to next slide Slide 71 of 84  
© 2014 Ken L Schreibman, PhD/MD

The Evolution of Radiology Focus on Musculoskeletal MRI

## No Implanted Electronics


Radiographs

- CT
- MR
- Signal
- Sequences
- Coils
- Magnets
- Safety
- Hardware

**No pacemakers**

**No cochlea implants**

**No neuro-stimulators**



[www.schreibman.info](http://www.schreibman.info) [memory-alpha.org](http://memory-alpha.org) Jump to last slide viewed Jump to next slide Slide 72 of 84  
© 2014 Ken L Schreibman, PhD/MD

# Evolution of Radiology: Focus on MSK MRI

## The Evolution of Radiology Focus on Musculoskeletal MRI

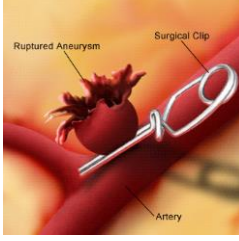
### Metal Inside Patients

**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware

**Safety Issues**

- Metal that can't move is not a safety issue
- ✓ Fillings in the teeth
- ✓ Orthopedic hardware
- Need to worry about metal that CAN move
- ✓ **Metal in/around eyes**
  - ❖ Welding equipment
  - ❖ Grinding equipment
  - ❖ Fire guns w/o protection
  - ❖ People who've been shot
  - ❖ Old aneurysm clips



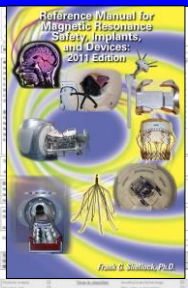
[www.schreibman.info](http://www.schreibman.info) [from patient blog](#) Jump to last slide viewed Jump to next slide Slide 73 of 84  
© 2014 Ken L. Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### New UW Screening Sheet

**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware



Have you had a <b>surgery</b> ?	Yes	No	If yes, date:	Fracture?	Yes	No
Heart Surgery	Yes	No		Facemask	Yes	No
Head/Brain Surgery	Yes	No		Brace/Chest Implant	Yes	No
Ear Surgery	Yes	No		Prosthetic/Implant	Yes	No
Ear Surgery	Yes	No		Tissue Expanders	Yes	No
Back Surgery	Yes	No		Prosthetic/Implant	Yes	No
Colonoscopy/Endoscopy/enteroscopy	Yes	No		Neurostimulator	Yes	No
Other Surgery/Procedure	Yes	No		ICD	Yes	No
				Stents	Yes	No
				Stents	Yes	No
				Brain Aneurysm Clip	Yes	No
Gun Shot, BB's, Shotgun	Yes	No		Other	Yes	No
Headed from an Accident	Yes	No				
Knife/Torn Surgery	Yes	No				
Bleed/Strabismus	Yes	No				
Seen had metal in your eyes	Yes	No				
If "no" to any of above, explain:						

[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 74 of 84  
© 2014 Ken L. Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### An actual case...

**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware

We're screening the patient to see if he's MR compatible.

We ask the patient if he has any metal in his body.

He replies, "... yeah... I think I was shot in the head once."


**Is this patient MR compatible?**

Maybe yes, maybe no.

We get a skull radiograph...

**What do you say now?**

"One view = no views"



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 75 of 84  
© 2014 Ken L. Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Need to have Multiple Views

**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware

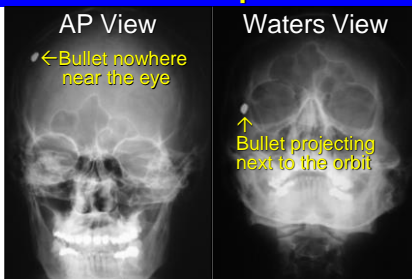
What's the answer?

**AP View**

← Bullet nowhere near the eye

**Waters View**

↑ Bullet projecting next to the orbit



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 76 of 84  
© 2014 Ken L. Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Need to have Multiple Views

**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware

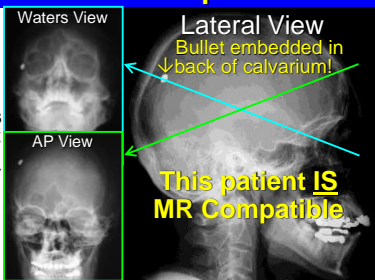
Here's the answer on the lateral view!

On the Waters view the bullet just happened to project over the eye.

**Lateral View**

Bullet embedded in back of calvarium!

**This patient IS MR Compatible**



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 77 of 84  
© 2014 Ken L. Schreibman, PhD/MD

## The Evolution of Radiology Focus on Musculoskeletal MRI

### This Patient is NOT MR Compatible

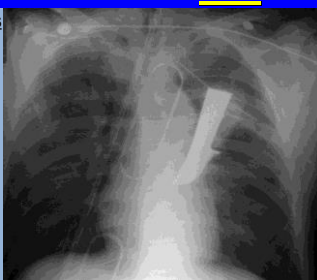
**Radiographs**

CT  
MR  
Signal  
Sequences  
Coils  
Magnets  
Safety   
Hardware

Don't want this knife blade to move from its current position.

History?

**"Stabbing Chest Pain"**



[www.schreibman.info](http://www.schreibman.info) Jump to last slide viewed Jump to next slide Slide 78 of 84  
© 2014 Ken L. Schreibman, PhD/MD

# Evolution of Radiology: Focus on MSK MRI

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Metal Inside Patients

Radiographs	Safety Issues	Imaging Issues
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>	<ul style="list-style-type: none"> <li>☞ No implanted electronics</li> <li>☞ No metal that can move</li> <li>☞ OK: Orthopedic hardware</li> <li>☞ OK: Modern aneurysm clips</li> <li>☞ OK: Modern heart valves</li> <li>☞ OK: Vascular stents</li> <li>☞ OK: IVC filters</li> </ul>	<ul style="list-style-type: none"> <li>➢ Metal can affect the magnetic field</li> <li>✓ "Susceptibility artifact"</li> <li>➢ May limit diagnostic value of the scan...</li> <li>➢ But often the scans come out just fine.</li> <li>✓ As long as the patient is MR safe, we're willing to try.</li> <li>✓ If we can't get useful images, cancel all charges</li> </ul>

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 79 of 84

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Metal Example: Femoral Rod

Radiographs	Patient with lots of metal	T1
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>	<p><i>Is it unsafe to put this patient in the magnet?</i></p> <p><b>Of course not!</b></p> <p>Patient has unexplained knee pain.</p>	<p>Even in retrospect this fracture cannot be seen on the radiograph.</p>

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 80 of 84

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Metal Example: Interference Screws

Radiographs	T2fs Coronal	T2fs Sagittal
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>		

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 81 of 84

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Metal Example: Interference Screws

Radiographs	PD Sagittal Medial	PD Sagittal	T2fs Sagittal
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>			

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 82 of 84

## The Evolution of Radiology Focus on Musculoskeletal MRI

### What to Order When (WOW)

Radiographs	Should always start with radiographs
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>	<ul style="list-style-type: none"> <li>➢ Least expensive study</li> <li>➢ May show the answer</li> <li>➢ Needed for planning other studies</li> </ul> <p><b>CT (MSK)</b></p> <ul style="list-style-type: none"> <li>➢ Used in ER for fracture detection (spine)</li> <li>➢ Used for surgical planning of known fractures</li> <li>➢ Best ordered by treating specialist</li> </ul> <p><b>MRI</b></p> <ul style="list-style-type: none"> <li>➢ Used for tears, occult fractures, infections, ...</li> <li>➢ Best ordered by treating specialist</li> </ul>

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 83 of 84

## The Evolution of Radiology Focus on Musculoskeletal MRI

### Any questions about anything?

Radiographs	MRI
<ul style="list-style-type: none"> <li>CT</li> <li>MR</li> <li>Signal</li> <li>Sequences</li> <li>Coils</li> <li>Magnets</li> <li>Safety </li> <li>Hardware </li> </ul>	

[www.schreibman.info](http://www.schreibman.info)    © 2014 Ken L Schreibman, PhD/MD    Jump to last slide viewed    Jump to next slide    Slide 84 of 84