Slide 1

12.3 MRI Registry Review

Part III
Data Acquisition and Processing
&
Physical Principles of Image Formation

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Slide 2: Outline

- Data Acquisition and Processing
  - Pulse sequences
  - Parameters
- Physical Principles of Image Formation
  - Instrumentation
  - Image acquisition

Slide 3: Objectives

Upon completion of this course, the attendee should…

1. Understand Data Acquisition and Processing?
   - Learn aspects of Pulse sequences
   - Understand Parameters and their affect on SNR, CNR, image contrast and scan time.
2. Understand Physical Principles of Image Acquisition and Image Formation.
3. Learn MR Instrumentation of MRI

Slide 4: Categories of Questions

CONTENT SPECIFICATIONS FOR THE EXAMINATION IN MAGNETIC RESONANCE IMAGING

Publication Date: November 2005
Implementation Date: January 2006

	Content Category	Number of Questions[2]
A.	Patient Care	30
B.	Imaging Procedures	62
C.	Data Acquisition and Processing	65
D.	Physical Principles of Image Formation	43
		200

Part III

1. A special debt of gratitude is due to the hundreds of professionals participating in this project as committee members, survey respondents, and reviewers.
2. Each exam includes an additional 20 unscored (pilot) questions. On the pages that follow, the approximate number of test questions allocated to each content category appears in parentheses.

Slide 5: Physical Principles of Image Formation

- Physical Principles of Image Formation Questions
- What could they ask?
  - –Only 43 total questions
  - –Review content specs
- Study
  - –Instrumentation
  - –Fundamentals
  - –Artifacts
  - –QC
- Study guides
  - –Review books
  - –Videos (on-line courses)
  - –Live Courses

D. PHYSICAL PRINCIPLES OF IMAGE FORMATION (43)

1. **Instrumentation (14)**
   a. Electromagnetism
      1. Faraday's law
      2. types of magnets (superconductive, permanent, resistive)
      3. magnetic field strength
   b. Radiofrequency System
      1. coil configuration
      2. transmit & receive coils
      3. transmit & receive bandwidth
      4. pulse profile
      5. phased array
   c. Gradient System
      1. coil configuration
      2. slew rate
      3. rise time
      4. duty cycle
2. **Fundamentals (17)**
   a. Nuclear Magnetism
      1. Larmor equation
      2. precession
      3. gyromagnetic ratio
      4. resonance
      5. RF pulse
      6. equilibrium magnetization
      7. energy state transitions
      8. phase coherence
      9. free induction decay (FID)
   b. Tissue Characteristics
      1. T_1 relaxation
      2. T_2 relaxation
      3. T_2^* (susceptibility)
      4. proton (spin) density
      5. flow
      6. diffusion
      7. perfusion
   c. Spatial Localization
      1. vectors
      2. X, Y, Z coordinate system
      3. physical & logical gradient
      4. slice select gradient
      5. phase-encoding gradient
      6. frequency (readout) gradient
      7. k-space (raw data)
3. **Artifacts (6)**
   a. Cause & Appearance of Artifacts
      1. aliasing
      2. Gibbs, truncation
      3. chemical shift
      4. magnetic susceptibility
      5. radiofrequency
      6. motion & flow
      7. partial volume averaging
      8. crosstalk
   b. Compensation for Artifacts
4. **Quality Control (6)**
   a. Slice Thickness
   b. Spatial Resolution
   c. Contrast Resolution
   d. Signal to Noise
   e. Center Frequency
   f. Transmit Gain
   g. Geometric Accuracy
   h. Equipment Inspection (e.g., coils, cables, and door seals)

Slide 6: Magnetic System Components

- The Main Magnet (B_0)
- The Shim Magnet
- The Gradient Magnet
- The RF Magnet (B_1)

Image courtesy of Philips Medical

- And you thought that there was only one magnet in the MR Imager!

Magnet Configurations

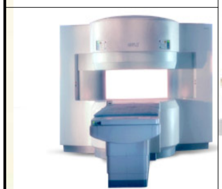


Image courtesy of Hitachi Medical

Permanent Magnet
0.3T


Image courtesy of Philips Medical

Resistive Magnet
0.3T


Image courtesy of Siemens Medical

Superconducting Magnet
1.5T

Magnetic Field Strength

- Tesla (T)
  - Within the bore
- Gauss (g)
  - Outside the imager
- 1T = 10,000 g

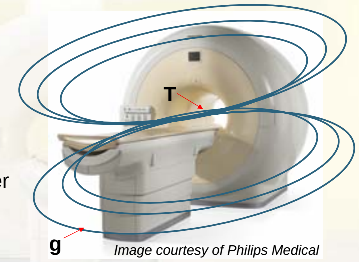


Image courtesy of Philips Medical

Magnetic Field Shielding

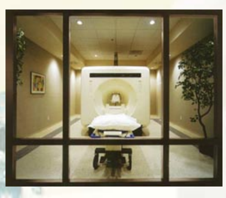


Image courtesy Lindgren

- Passive
  - -Metal in scan room walls
- Active
  - -Implies current
  - -Other magnets within
- 5 g within the wall

Simple Permanent Magnet Configurations

- Horseshoe Magnets
- Face – to- face
- Vertical field
- "Open"

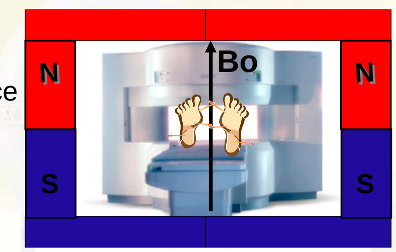
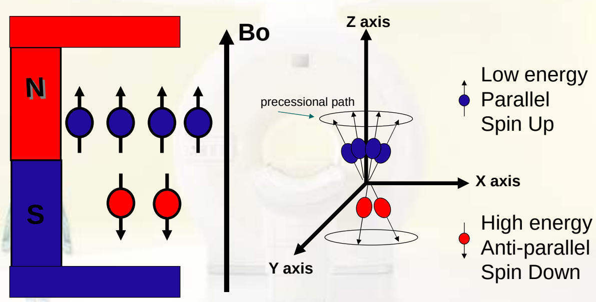


Image courtesy of Hitachi Medical

Cartesian Coordinate System



Larmor Frequency

In order to calculate the precessional (Larmor) frequency
- The magnetic moment of the proton
- The spin angular momentum of the proton

  Gyro-magnetic ratio = γ
  Magneto-gyric ratio = γ

- The field strength of the magnet

  Magnetic field strength = Bo

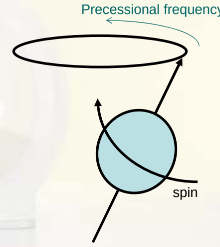
This is known as the Larmor equation

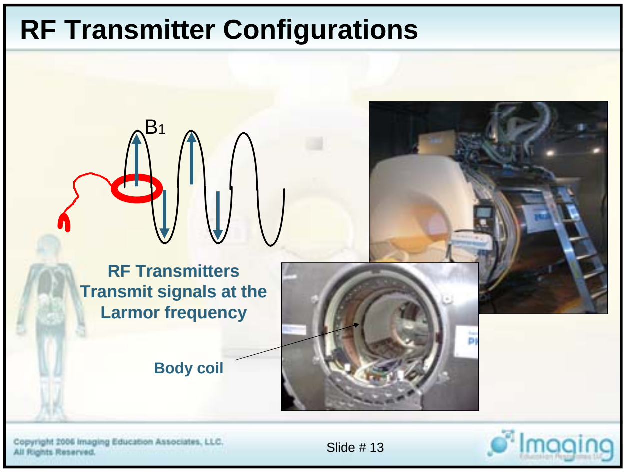
$$\omega_o = B_o \gamma$$

Larmor or Precessional Frequency = ω_o

Magnetic field strength = B_o

Gyro-magnetic ratio = γ
Magneto-gyric ratio = γ




RF Transmitter Configurations
B1
RF Transmitters
Transmit signals at the
Larmor frequency
Body coil
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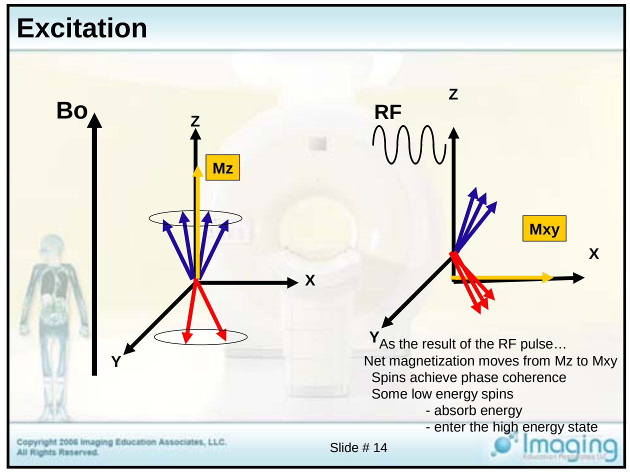
Slide # 13
Imaging


Excitation
Bo
Z
Mz
X
Y
RF
Z
Mxy
X
Y
As the result of the RF pulse…
Net magnetization moves from Mz to Mxy
Spins achieve phase coherence
Some low energy spins
- absorb energy
- enter the high energy state
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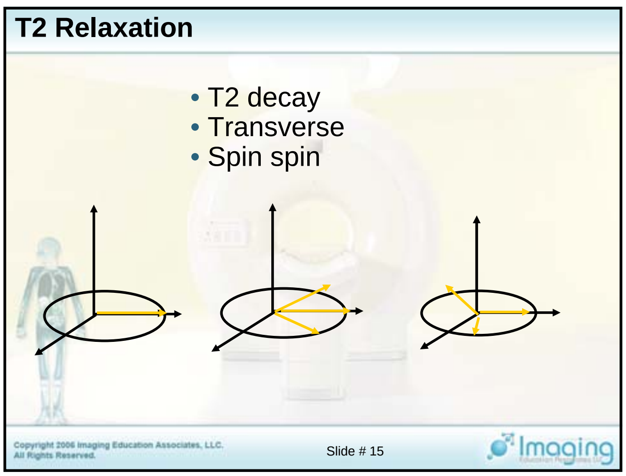
Imaging


T2 Relaxation
• T2 decay
• Transverse
• Spin spin
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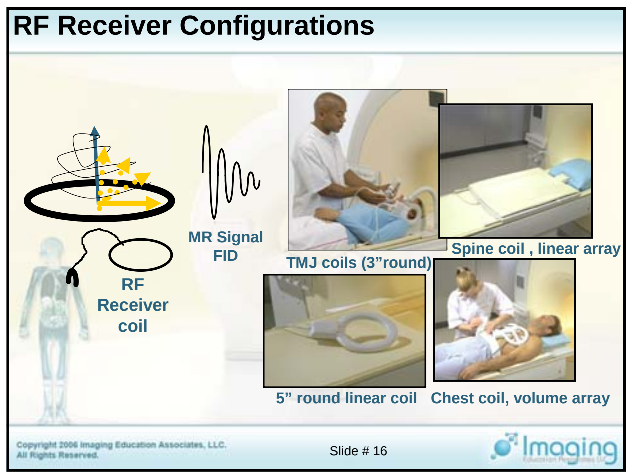
Slide # 15
Imaging


RF Receiver Configurations
MR Signal
FID
RF
Receiver
coil
TMJ coils (3"round)
Spine coil , linear array
5" round linear coil
Chest coil, volume array
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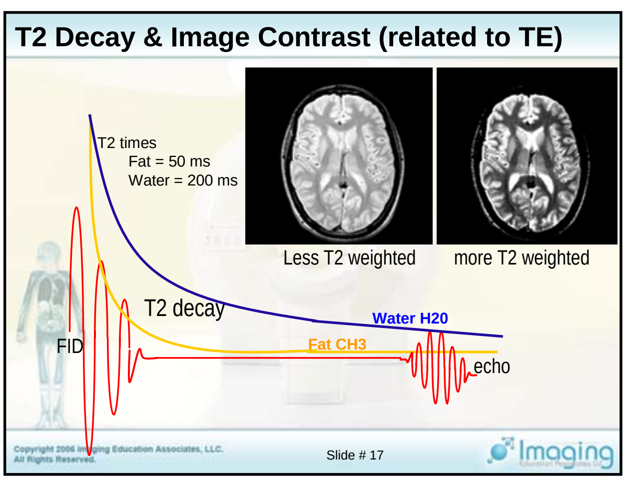
Imaging


T2 Decay & Image Contrast (related to TE)
T2 times
Fat = 50 ms
Water = 200 ms
Less T2 weighted
more T2 weighted
T2 decay
Water H20
Fat CH3
FID
echo
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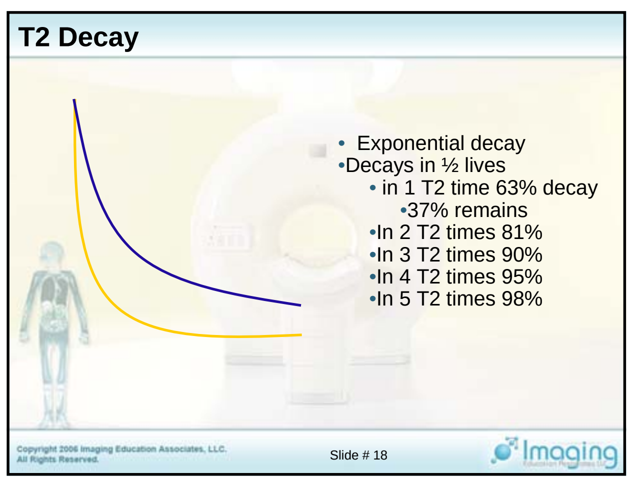
Imaging


T2 Decay
• Exponential decay
•Decays in ½ lives
• in 1 T2 time 63% decay
•37% remains
•In 2 T2 times 81%
•In 3 T2 times 90%
•In 4 T2 times 95%
•In 5 T2 times 98%
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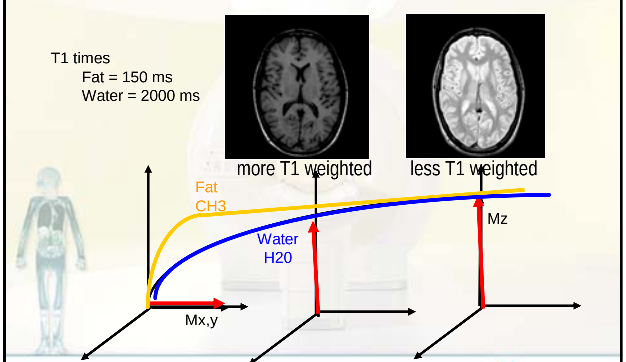
Imaging

T1 Recovery and Image Contrast (related to TR)

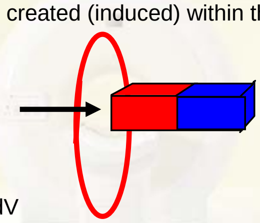


T1 Recovery

- Exponential recovery
- Recovers in ½ lives
  - in 1 T1 time 63% recovery
    - 37% remains
  - In 2 T1 times 81%
  - In 3 T1 times 90%
  - In 4 T1 times 95%
  - In 5 T1 times 98%

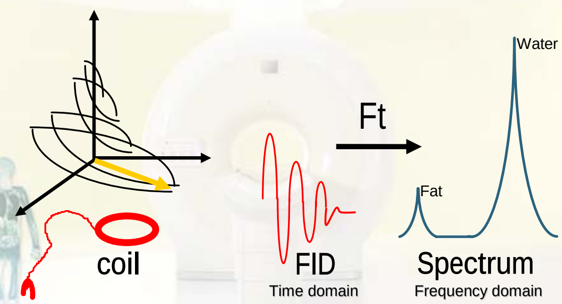
Faraday's Law of Inducation

- Drag a magnet across a conductor,
  a voltage is created (induced) within the conductor

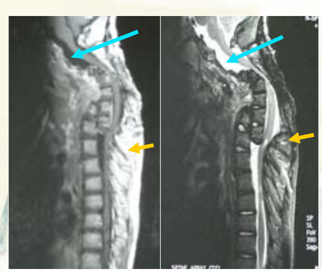


- dB / dt = dV
  Change of magnet divided by time = voltage
- ΔB / Δt = ΔV

Fourier Transformation



Why do fat & water appear differently?

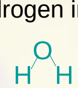


Sagittal Cervical & Thoracic Spine

T1 Image
Fat is bright
Water is dark

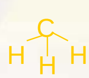
T2 Image
Fat is bright
Water is dark

- Hydrogen in Water



Water Molecule
H_2O

- Hydrogen in Fat

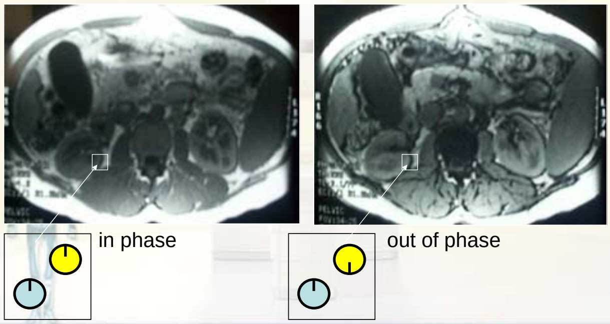


Fat Molecule
CH_3

FOV & Chemical Shift Artifact

frequency | Kidney No CS | frequency | Kidney with cs

Chemical Shift Artifact on Gradient Echoes



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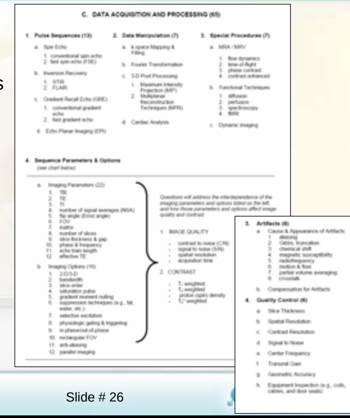
Data Acquisition and Processing

- Data Acquisition & Processing Questions
- What could they ask?
  - Only 65 total questions
  - Review content specs
- Study
  - Pulse sequences
  - Data manipulation
  - Special procedures
  - Imaging parameters
  - Imaging options
  - Artifacts
  - QC
- Study guides
  - Review books



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Timing Diagram

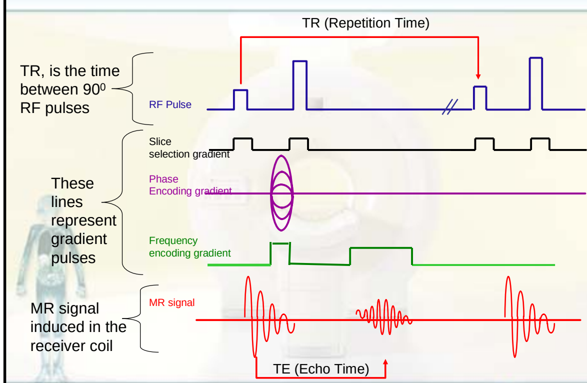

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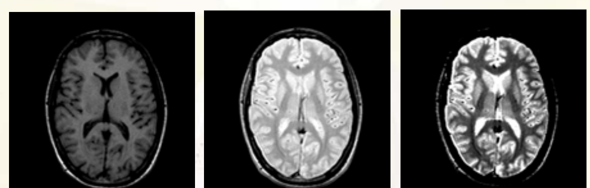
Image Contrast Parameters



T1WI	PDWI	T2WI
Short TR	Long TR	Long TR
Short TE	Short TE	Long TE
Bright fat, short T1 time	Bright fat & water	Bright water, long T2 time

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Pulse Sequences & Scan Time

T1WI	PDWI	T2WI
SE	SE	SE
FSE	FSE	FSE
IR	FLAIR	STIR
Fast IR	Fast FLAIR	*Looks like T2*
GE spoiled	GE	GE
TOF MRA	EPI PD	PCMRA
Enhanced MRA	EPI Flair	EPI
		Perfusion
		Diffusion

Scan time

(SE) = TR * #PE's * NSA
(FSE) = TR * #PE's * NSA / ETL
(GE) = TR * #PE's * NSA
(3DGE) = TR * #PE's * NSA * Nsl
(IR) = TR * #PE's * NSA
(Fast IR) = TR * #PE's * NSA / ETL
(EPI) = TR * SHOTS * NSA

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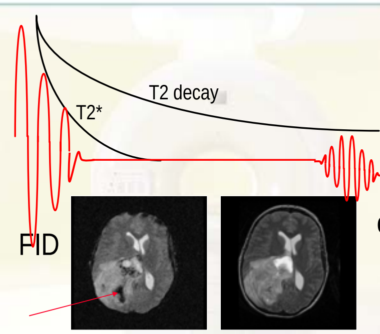
Is a susceptibility artifact always a bad thing??



Axial T2* Brain   Axial T2 Brain

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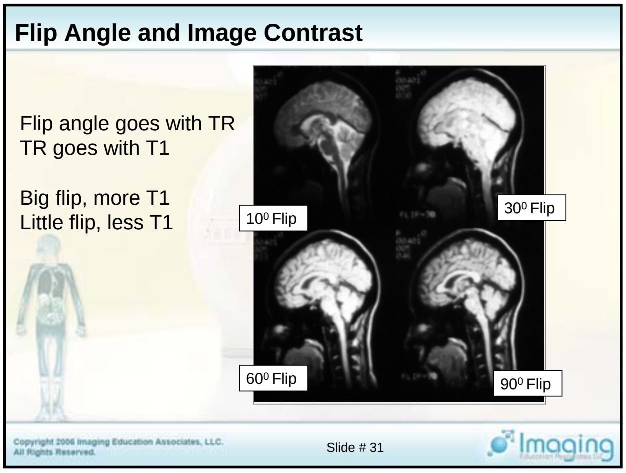
Flip Angle and Image Contrast
Flip angle goes with TR
TR goes with T1
Big flip, more T1
Little flip, less T1
10^0 Flip
30^0 Flip
60^0 Flip
90^0 Flip
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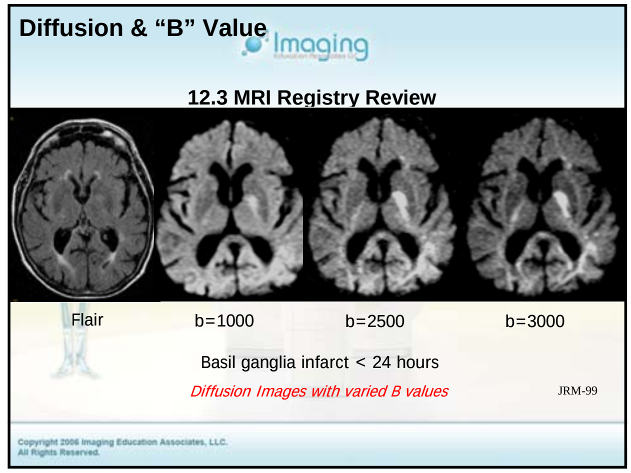
Imaging


Diffusion & "B" Value
Imaging
12.3 MRI Registry Review
Flair
b=1000
b=2500
b=3000
Basil ganglia infarct < 24 hours
Diffusion Images with varied B values
JRM-99
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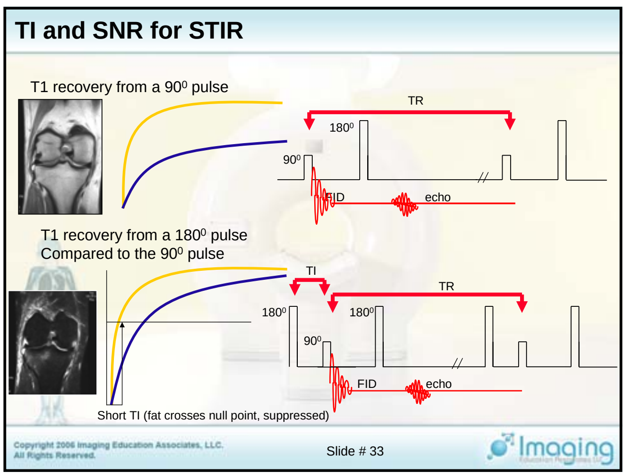
TI and SNR for STIR
T1 recovery from a 90^0 pulse
TR
180^0
90^0
FID
echo
T1 recovery from a 180^0 pulse
Compared to the 90^0 pulse
TI
TR
180^0
180^0
90^0
FID
echo
Short TI (fat crosses null point, suppressed)
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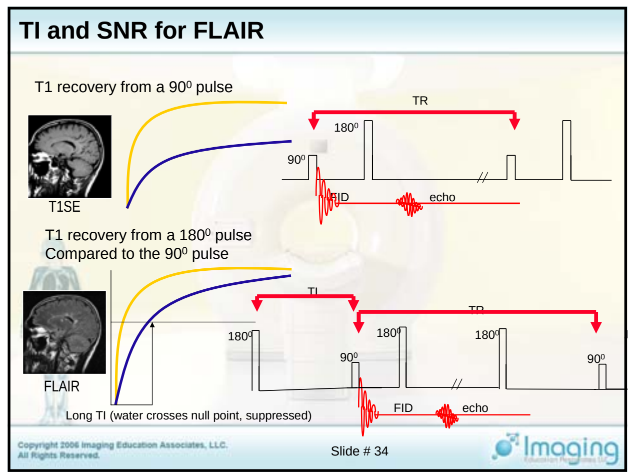
Slide # 33
Imaging


TI and SNR for FLAIR
T1 recovery from a 90^0 pulse
TR
180^0
90^0
FID
echo
T1SE
T1 recovery from a 180^0 pulse
Compared to the 90^0 pulse
TI
TR
180^0
180^0
180^0
90^0
90^0
FLAIR
FID
echo
Long TI (water crosses null point, suppressed)
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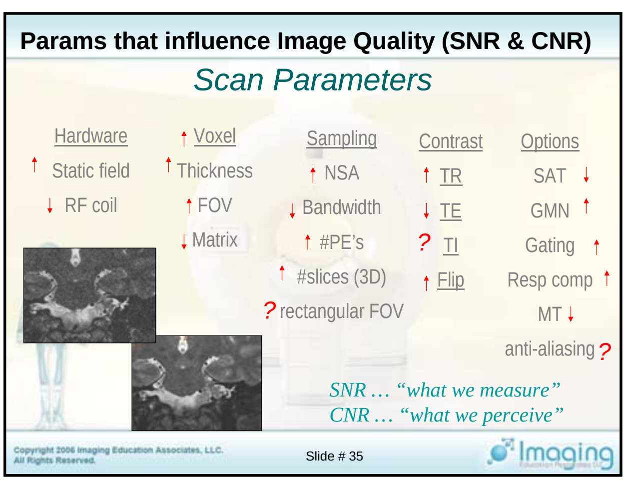
Slide # 34
Imaging


Params that influence Image Quality (SNR & CNR)
Scan Parameters
Hardware
↑ Static field
↓ RF coil
↑ Voxel
↑ Thickness
↑ FOV
↓ Matrix
Sampling
↑ NSA
↓ Bandwidth
↑ #PE's
↑ #slices (3D)
? rectangular FOV
Contrast
↑ TR
↓ TE
? TI
↑ Flip
Options
SAT ↓
GMN ↑
Gating ↑
Resp comp ↑
MT ↓
anti-aliasing ?
SNR … "what we measure"
CNR … "what we perceive"
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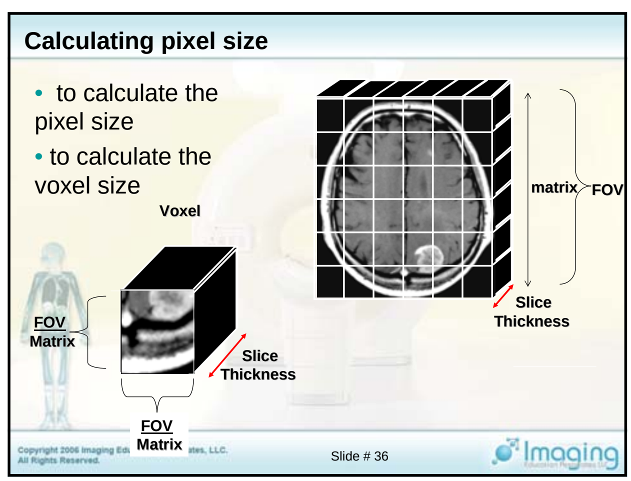
Slide # 35
Imaging


Calculating pixel size
• to calculate the pixel size
• to calculate the voxel size
Voxel
matrix
FOV
Slice Thickness
FOV
Matrix
Slice Thickness
FOV
Matrix
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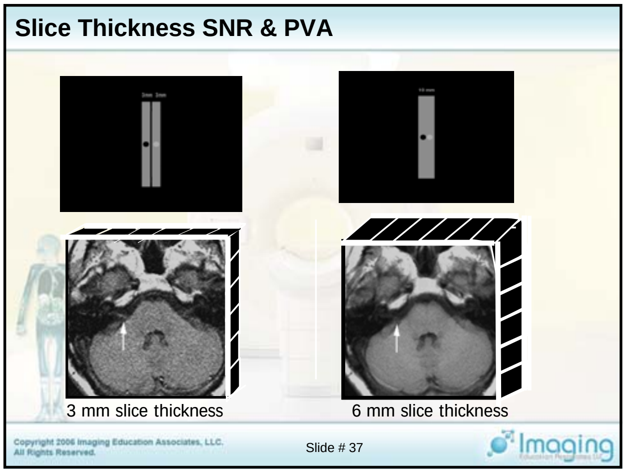
Slide # 36
Imaging


Slice Thickness SNR & PVA
3 mm slice thickness
6 mm slice thickness
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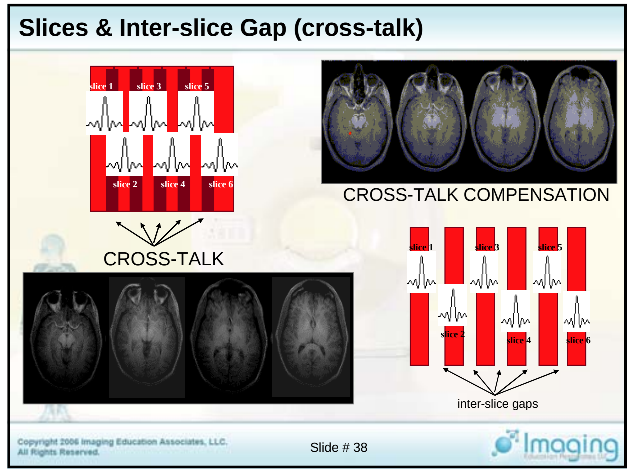
Slide # 37
Imaging


Slices & Inter-slice Gap (cross-talk)
slice 1
slice 3
slice 5
slice 2
slice 4
slice 6
CROSS-TALK
CROSS-TALK COMPENSATION
inter-slice gaps
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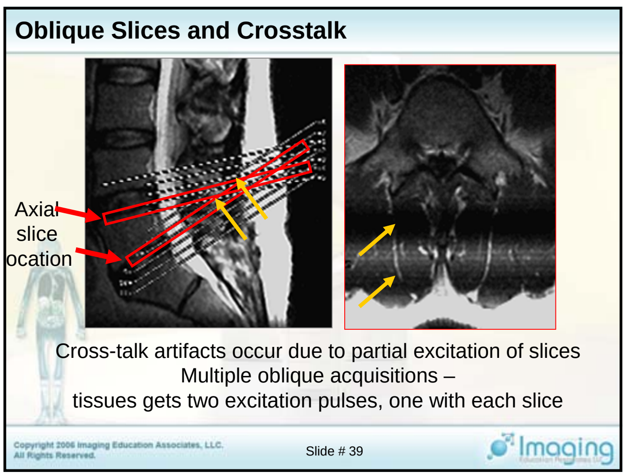
Slide # 38
Imaging


Oblique Slices and Crosstalk
Axial slice location
Cross-talk artifacts occur due to partial excitation of slices
Multiple oblique acquisitions –
tissues gets two excitation pulses, one with each slice
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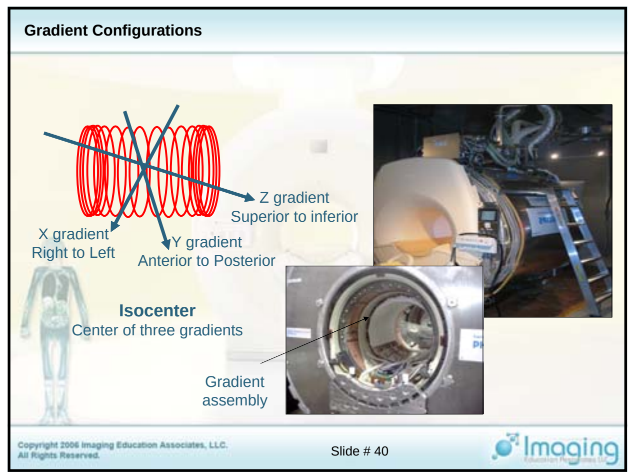
Slide # 39
Imaging


Gradient Configurations
Z gradient
Superior to inferior
X gradient
Right to Left
Y gradient
Anterior to Posterior
Isocenter
Center of three gradients
Gradient assembly
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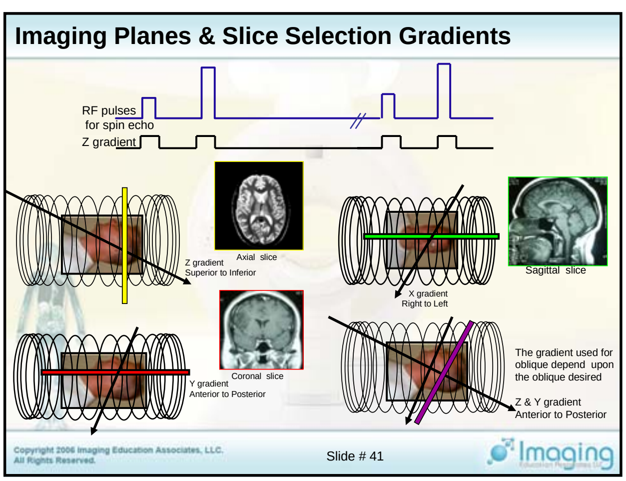
Slide # 40
Imaging


Imaging Planes & Slice Selection Gradients
RF pulses for spin echo
Z gradient
Axial slice
Z gradient Superior to Inferior
Sagittal slice
X gradient Right to Left
Coronal slice
Y gradient Anterior to Posterior
The gradient used for oblique depend upon the oblique desired
Z & Y gradient Anterior to Posterior
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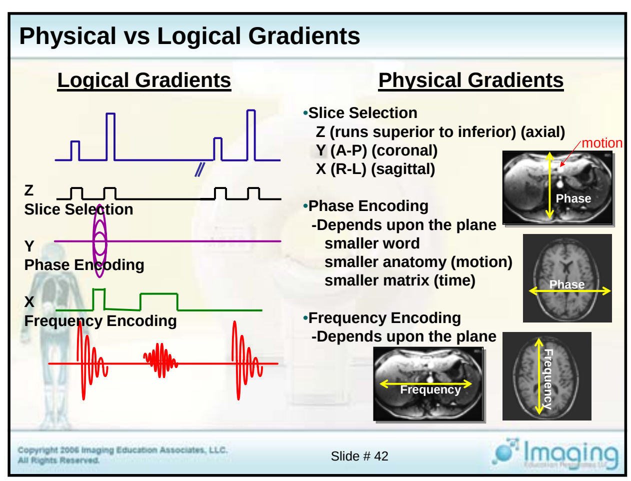
Imaging


Physical vs Logical Gradients
Logical Gradients
Physical Gradients
Z
Slice Selection
Y
Phase Encoding
X
Frequency Encoding
•Slice Selection
Z (runs superior to inferior) (axial)
Y (A-P) (coronal)
X (R-L) (sagittal)
motion
Phase
•Phase Encoding
-Depends upon the plane
smaller word
smaller anatomy (motion)
smaller matrix (time)
Phase
•Frequency Encoding
-Depends upon the plane
Frequency
Frequency
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Slide # 42
Imaging

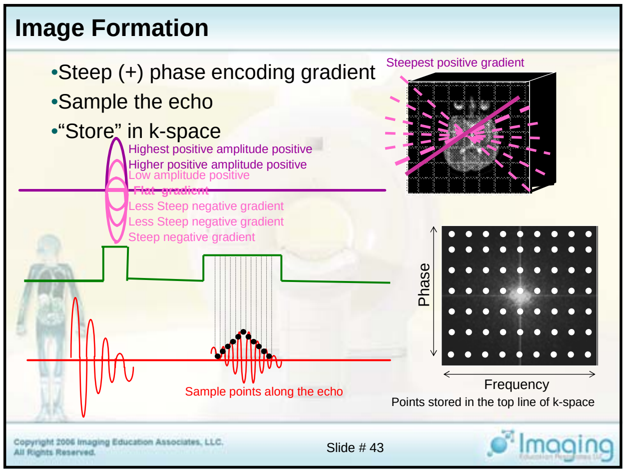
Image Formation
•Steep (+) phase encoding gradient
•Sample the echo
•"Store" in k-space
Steepest positive gradient
Highest positive amplitude positive
Higher positive amplitude positive
Low amplitude positive
Flat gradient
Less Steep negative gradient
Less Steep negative gradient
Steep negative gradient
Phase
Frequency
Sample points along the echo
Points stored in the top line of k-space
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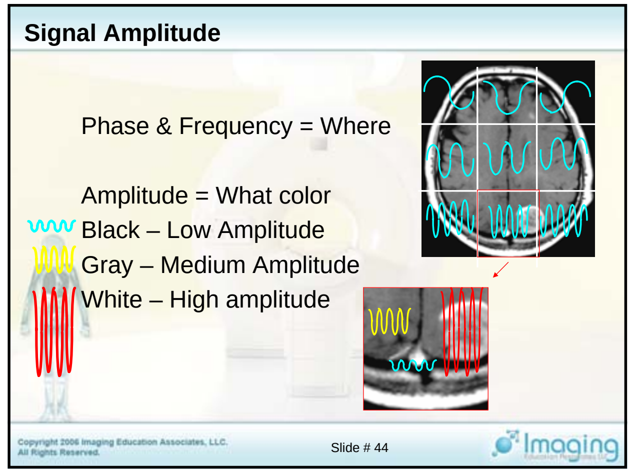
Slide # 43
Imaging


Signal Amplitude
Phase & Frequency = Where
Amplitude = What color
Black – Low Amplitude
Gray – Medium Amplitude
White – High amplitude
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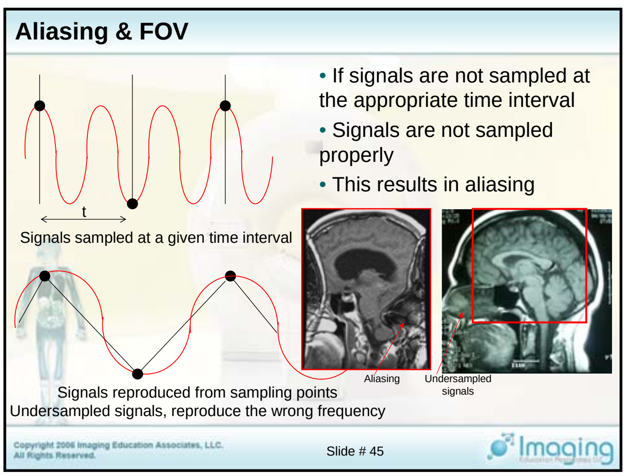
Slide # 44
Imaging


Aliasing & FOV
• If signals are not sampled at the appropriate time interval
• Signals are not sampled properly
• This results in aliasing
t
Signals sampled at a given time interval
Aliasing
Undersampled signals
Signals reproduced from sampling points
Undersampled signals, reproduce the wrong frequency
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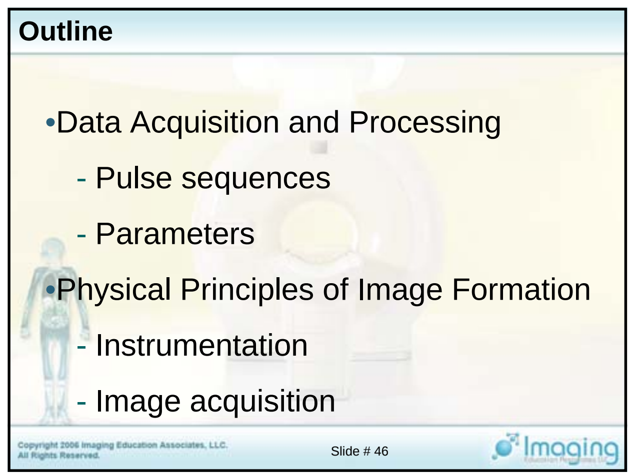
Slide # 45
Imaging


Outline
•Data Acquisition and Processing
- Pulse sequences
- Parameters
•Physical Principles of Image Formation
- Instrumentation
- Image acquisition
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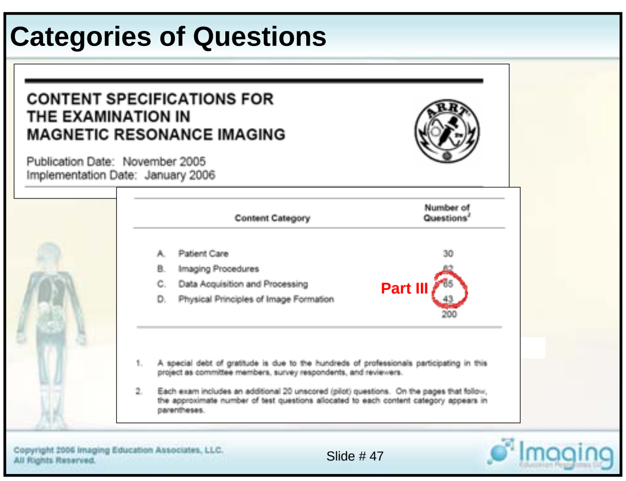
Slide # 46
Imaging


Categories of Questions
CONTENT SPECIFICATIONS FOR
THE EXAMINATION IN
MAGNETIC RESONANCE IMAGING
Publication Date: November 2005
Implementation Date: January 2006
Content Category
Number of Questions
A. Patient Care 30
B. Imaging Procedures
C. Data Acquisition and Processing
D. Physical Principles of Image Formation
200
Part III
1. A special debt of gratitude is due to the hundreds of professionals participating in this project as committee members, survey respondents, and reviewers.
2. Each exam includes an additional 20 unscored (pilot) questions. On the pages that follow, the approximate number of test questions allocated to each content category appears in parentheses.
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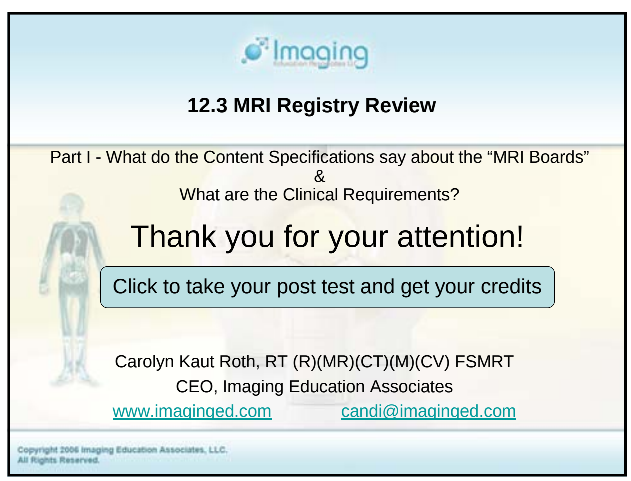
Slide # 47
Imaging


Imaging
12.3 MRI Registry Review
Part I - What do the Content Specifications say about the "MRI Boards"
&
What are the Clinical Requirements?
Thank you for your attention!
Click to take your post test and get your credits
Carolyn Kaut Roth, RT (R)(MR)(CT)(M)(CV) FSMRT
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