Imaging

Parameters & Options for MRI

Params & Options & Artifacts for SNR, CNR, Resolution, Time

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Outline

Parameters and Options for MR Imaging

1. Params for Hardware
2. Params for SNR, CNR, Resolution
   - Voxel size
     FOV, thickness, Matrix
   - Sampling
     Matrix (PE's), NSA, BW, #slices in 3D
3. Params for Image Contrast
   TE, TE, TI, Flip
4. Artifacts & Options

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MR Image Quality Components

- Contrast Resolution
- Spatial Resolution
- Signal-to-Noise
  - Contrast-to-Noise
- Scan Time
  - Temporal Resolution

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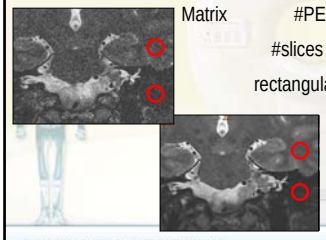
Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

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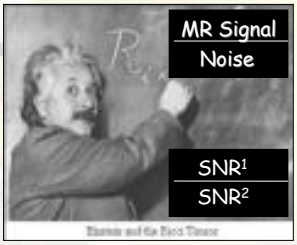
Definitions

Signal-to-Noise Ratio
The ratio of MR signal to Noise

Contrast-to-Noise Ratio
The ratio of SNR^1 to SNR^2



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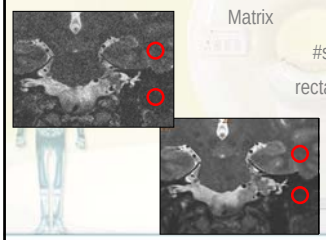
Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field ∝ SNR	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

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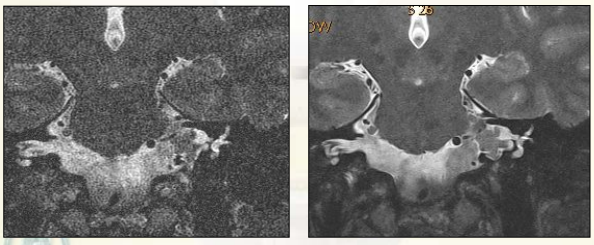
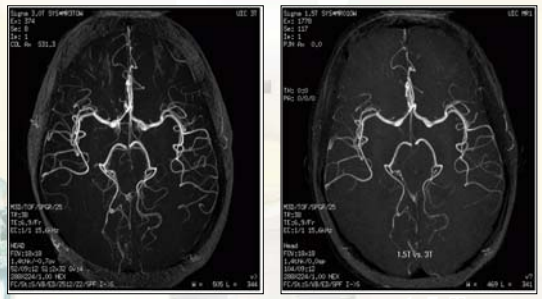
SNR & Field Strength



1.5T 3.0T

Field strength is linearly related to SNR
Double field strength, double SNR

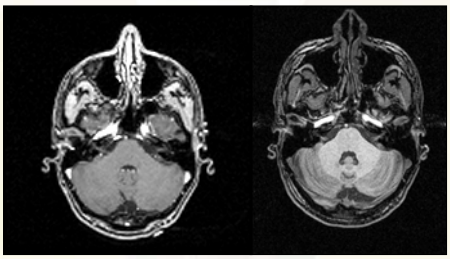
CNR & Field Strength



3.0T 1.5T

Increase field strength, increase CNR

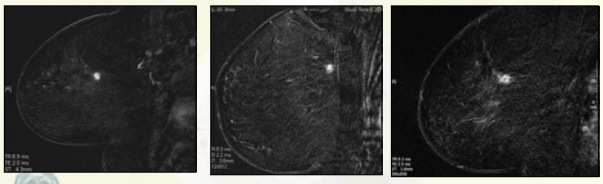
SNR & Field Strength



1.5T 3.0T

Images complements of U of P
Everything is not as it appears…

SNR, CNR & Resolution & Field Strength

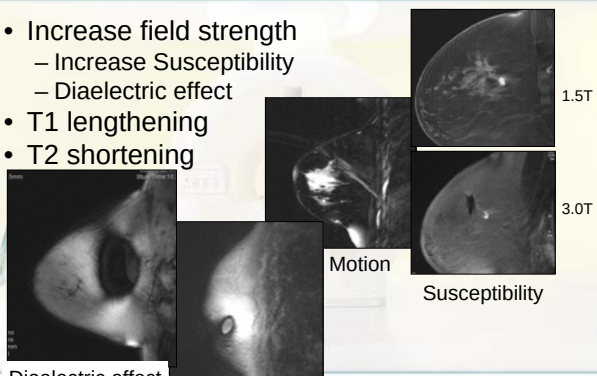


1.5T (512 x 256) 1.5T (512 x 512) 3.0T (896 x 896)

Increase field strength, increase SNR
Trade SNR for resolution

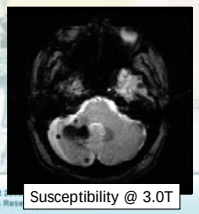
Artifacts & Field Strength

- Increase field strength
  - Increase Susceptibility
  - Diaelectric effect
- T1 lengthening
- T2 shortening

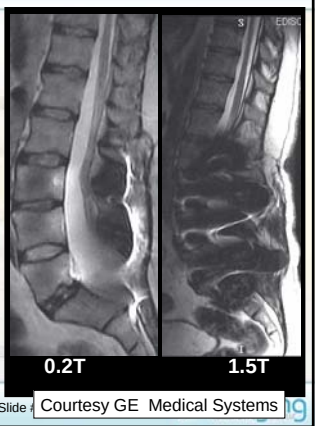


Susceptibility & Field Strength

- Increase Bo
  - Increase Susceptibility
- Susceptibility
  - Field strength
  - Voxel size
  - Scan type
  - Size & Type of metal



Susceptibility @ 3.0T



Courtesy GE Medical Systems

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
The smaller the better-	Matrix	#PE's	TI	Gating
The more the better		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

SNR … "what we measure"
CNR … "what we perceive"

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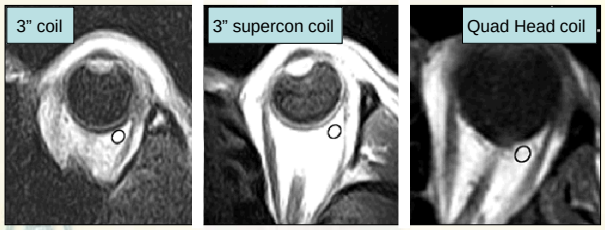
Coils & SNR



Smaller coils , better SNR
Superconducting coils reduce noise, thus increase SNR

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Coils & SNR

MAGNETOM Avanto
The first Tim system

Wrap- around coil made from soft and flexible material provides high patient comfort

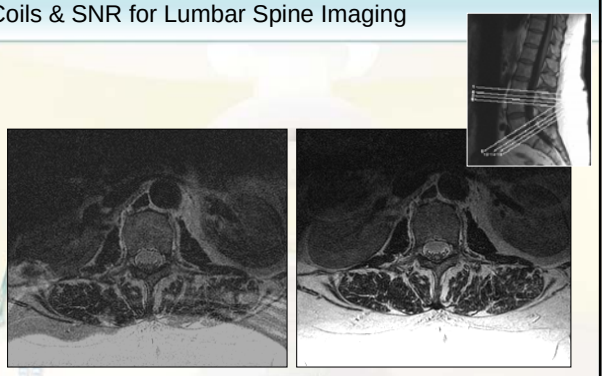
4-element design with 4 integrated preamplifiers, 2 clusters of 2 elements each

12-element design with 12 integrated preamplifiers, two rings of 6 elements each (i.e. 4 clusters of 3 elements each)

6-element design with 6 integrated preamplifiers, with 2 clusters of 3 elements each
Operates in an integrated fashion with the Spine Matrix coils (2 rings of 6 elements each = 12-element design)
Can be combined with further Body Matrix coils for larger coverage

Images courtesy Siemens

Coils & SNR for Lumbar Spine Imaging



Body Coil

Multi Coil Array

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Receive Coils for Low Field

MAGNETOM Concerto

Body Spine Array Coils

CP Head/Neck Array Coil
2 channel array receive coil
2 additional neck coil elements

Multipurpose Coil 4.3 in
Single channel receive coil

Images courtesy Siemens

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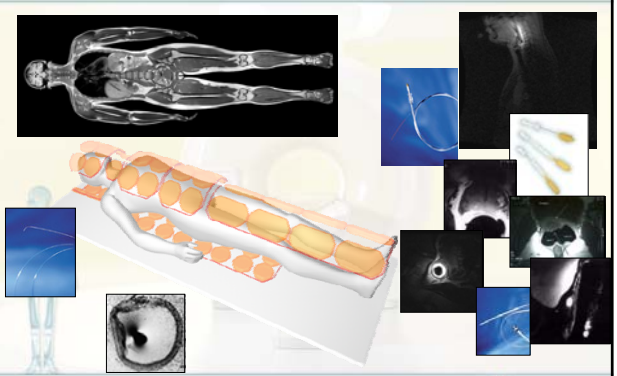
Coils, Coils, Coils



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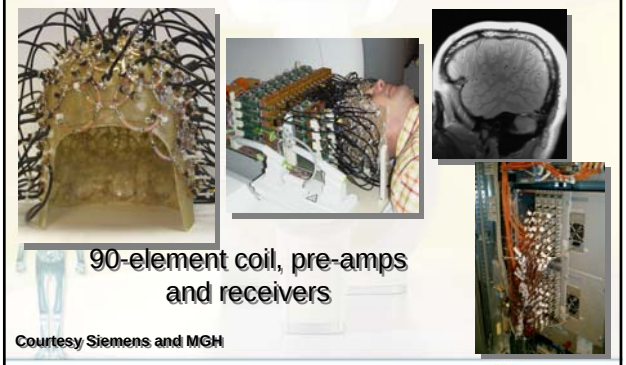
On the Horizon?



90-element coil, pre-amps and receivers

Courtesy Siemens and MGH

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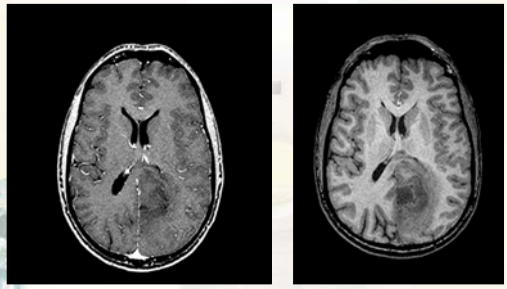
SNR: Field Strength & Coils



T1 3DGE (gadolinium)
1.5 T Standard head coil

T1 3DGE
3.0 T 8 channel head coil

Images complements of U of P

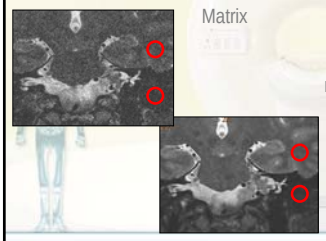
Everything is not as it appears…we changed the coils & field strength

Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	↑ Voxel ∝ SNR	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

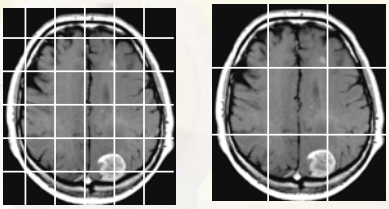


SNR … "what we measure"
CNR … "what we perceive"

Imaging

Imaging Matrix

- Digital images are created with a matrix
- Smallest unit of the digital image is a pixel



6 x 6

3 x 3

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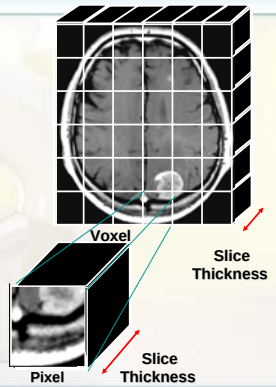
Pixel , Voxel

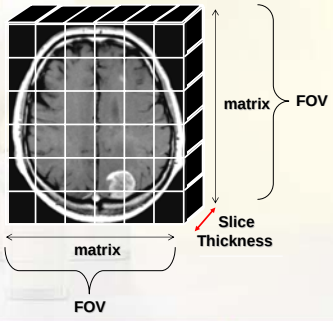
- In MRI slices are acquired
- The voxel is a 3d volume element
- The face of the voxel is the pixel



Imaging

FOV, Matrix, Thickness & Voxels

- The size of the area imaged in MRI is the field of view (FOV)
- The number of pixels (rows x columns) is the matrix
- The depth is the slice thickness



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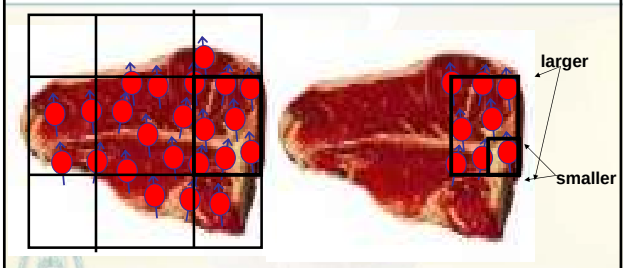
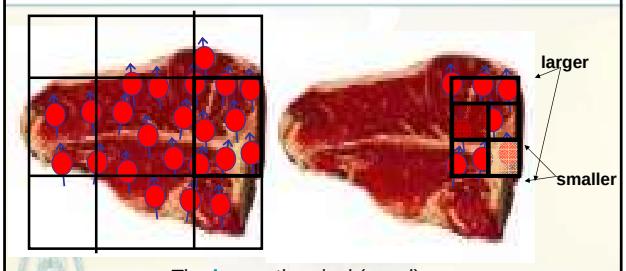
How much “meat” is in the box? vs Signal



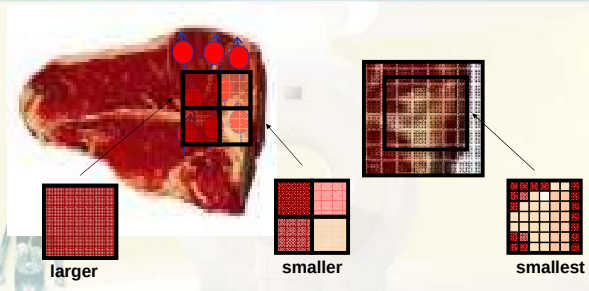
The **larger** the pixel (voxel)
The more “meat” tissues / protons
The **larger** the MR signal
But… since signals get averaged together
The **lower** the spatial resolution

How much “meat” is in the box? vs Resolution



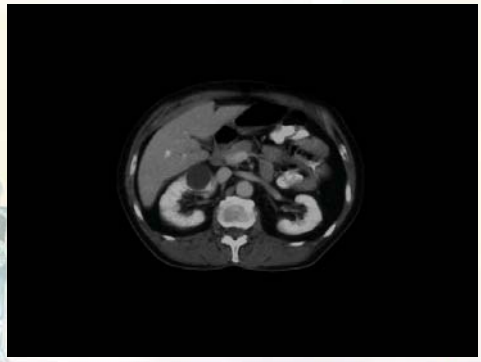
The **larger** the pixel (voxel)
The more “meat” tissues / protons
The **larger** the MR signal
But… since signals get averaged together
The **lower** the spatial resolution

How much “meat” is in the box? vs High Resolution



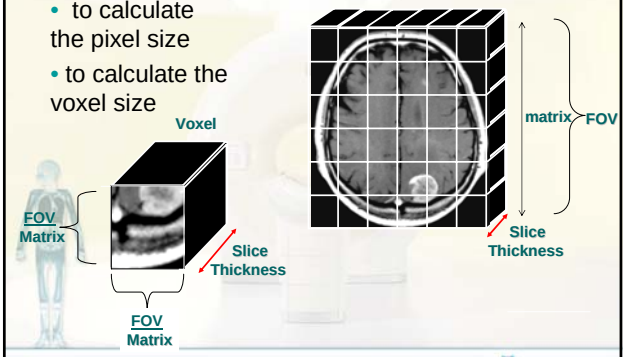
Signals signals get averaged together in large voxels
The **lower** the spatial resolution
Partial Volume Averaging

Calculating Pixel Size



Calculating Pixel Size

- to calculate the pixel size
- to calculate the voxel size



Calculating Pixel & Voxel Size

- Isotropic voxel

$$\frac{FOV}{Matrix} \underset{equals}{=} \frac{FOV}{Matrix} = Thickness$$

- Pixel size

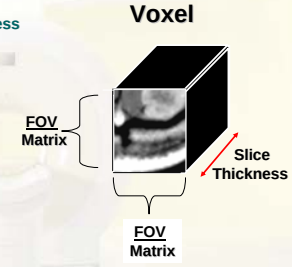
$$\frac{FOV}{Matrix} \underset{by}{\times} \frac{FOV}{Matrix}$$

- Area of the Pixel

$$\frac{FOV}{Matrix} \underset{times}{\times} \frac{FOV}{Matrix} = mm^2$$

- Voxel Volume

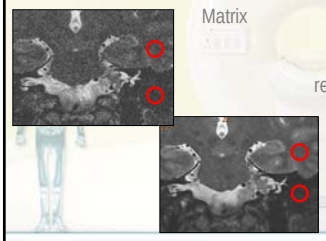
$$\frac{FOV}{Matrix} \underset{times}{\times} \frac{FOV}{Matrix} \underset{times}{\times} Thickness = mm^3$$



Params that influence Image Quality (SNR & CNR)

Scan Parameters

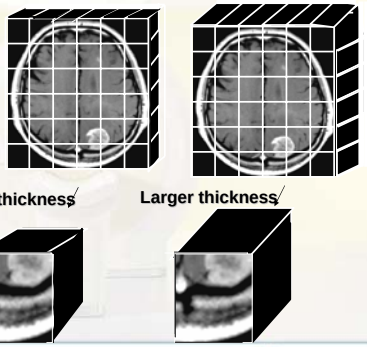
Hardware	Voxel		Sampling	Contrast	Options
Static field	↑ Thickness	SNR	NSA	TR	SAT
RF coil	FOV		Bandwidth	TE	GMN
	Matrix		#PE's	TI	Gating
			#slices (3D)	Flip	Resp comp
			rectangular FOV		MT
					anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

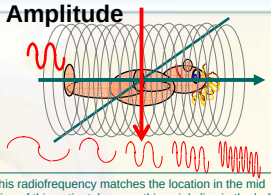
Voxel Size and Slice thickness

- Smaller thickness
- Smaller voxel
- Less tissue in the voxel
- Lower SNR
- Higher resolution



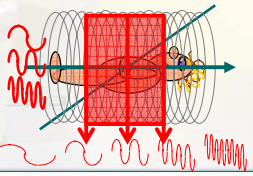
Slice Thickness vs Transmitter BW & Gradient Amplitude

- If only one frequency is "sent in" or transmitted for excitation, we get a slice as thin as tissue paper.



This radiofrequency matches the location in the mid section of this patient, hence a thin axial slice in the belly

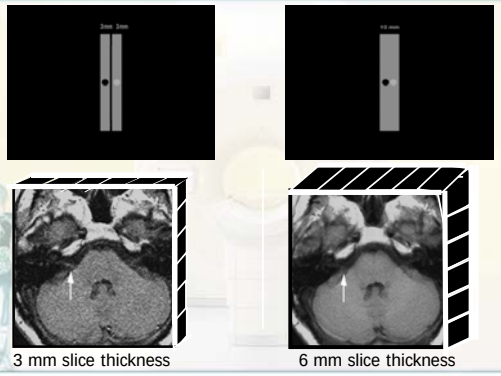
- For a thicker slice a range of frequencies is "transmitted" known as the Transmit Bandwidth



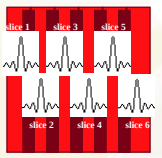
FYI… This is not the bandwidth that we typically "set" during image acquisition. That is the receiver bandwidth. Receive bandwidth will be discussed later in this section

This range of radiofrequencies (or Bandwidth) matches the location in the mid section of this patient, hence a thin axial slice in the belly

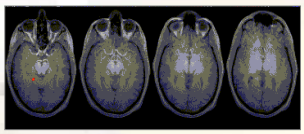
Slice Thickness SNR & PVA



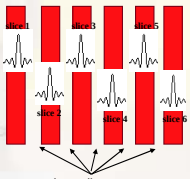
Slices & Inter-slice Gap (cross-talk)



CROSS-TALK

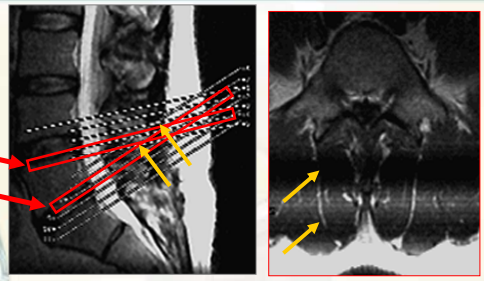


CROSS-TALK COMPENSATION



inter-slice gaps

Oblique Slices and Crosstalk



Cross-talk artifacts occur due to partial excitation of slices
Multiple oblique acquisitions –
tissues gets two excitation pulses, one with each slice

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
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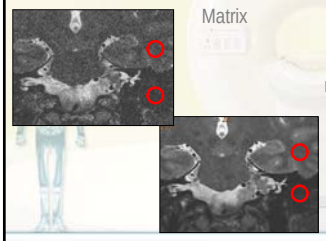
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

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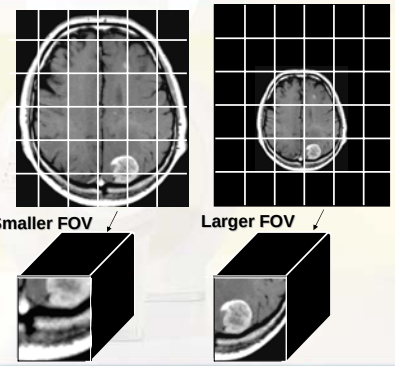
Pixel Size and FOV

- Bigger FOV
- Larger pixel
- More tissue in the pixel
- Higher SNR
- Lower resolution



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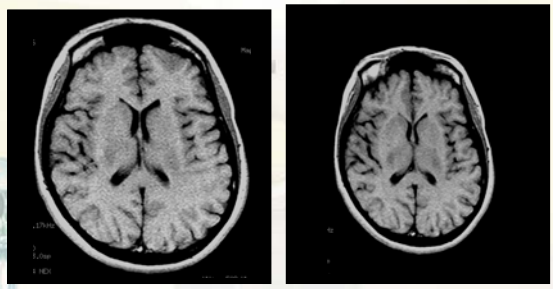
SNR and FOV



20 cm FOV

25 cm FOV

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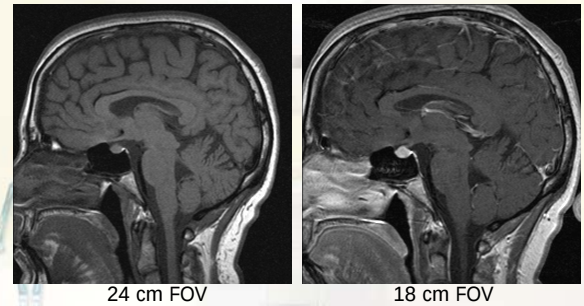
Resolution and FOV



24 cm FOV
T1 without

18 cm FOV
T1 with Gadolinium

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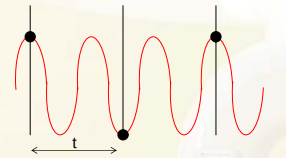
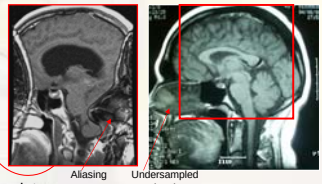
Aliasing & FOV



Signals sampled at a given time interval

- If signals are not sampled at the appropriate time interval
- Signals are not sampled properly
- This results in aliasing

Signals reproduced from sampling points
Undersampled signals, reproduce the wrong frequency



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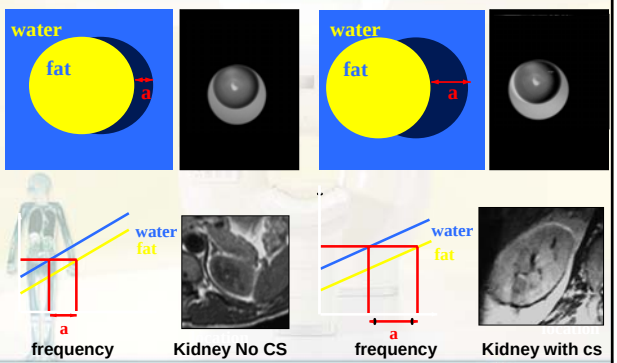
FOV & Chemical Shift Artifact



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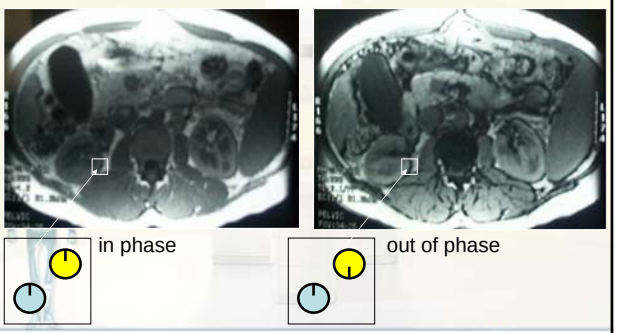
Imaging

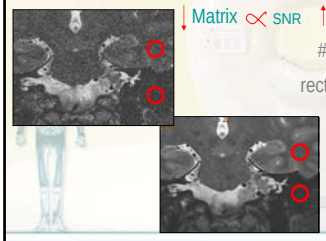
Chemical Shift Artifact on Gradient Echoes



Params that influence Image Quality (SNR & CNR)

Scan Parameters

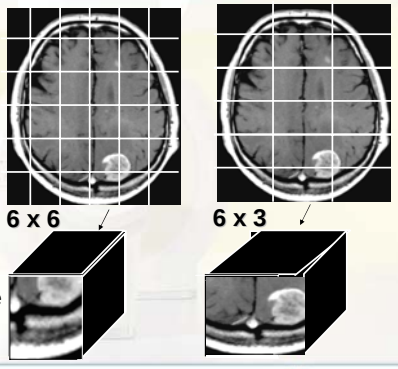
Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix ∝ SNR	#PE's ∝ √PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



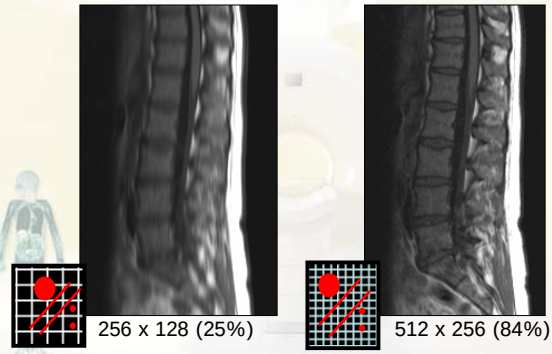
SNR … "what we measure"
CNR … "what we perceive"

Pixel Size and Matrix

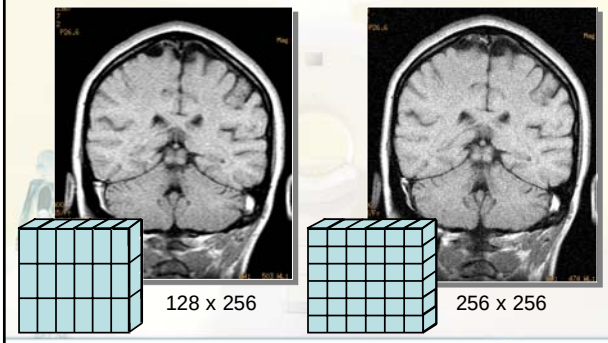
- Lower matrix
- Bigger pixel
- More tissue in the pixel
- Reduce x2 matrix
  - inc x2 snr
- Reduce sampling
  - Reduce √2 SNR
  - Reduce 1.41
- net effect increase .59 SNR



Pixel Size, Matrix & Resolution



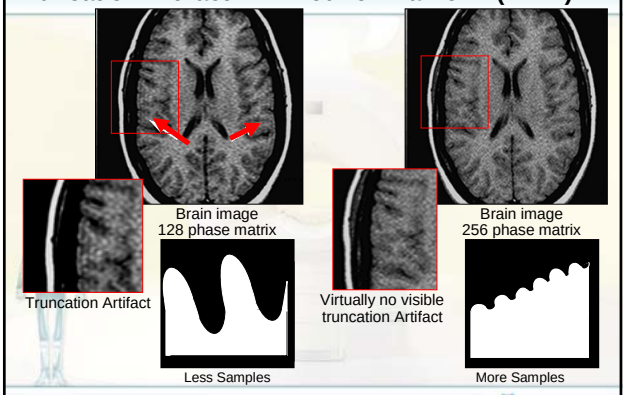
Pixel Size, Matrix, Resolution & Time



High Matrix (Resolution) Imaging for Spine

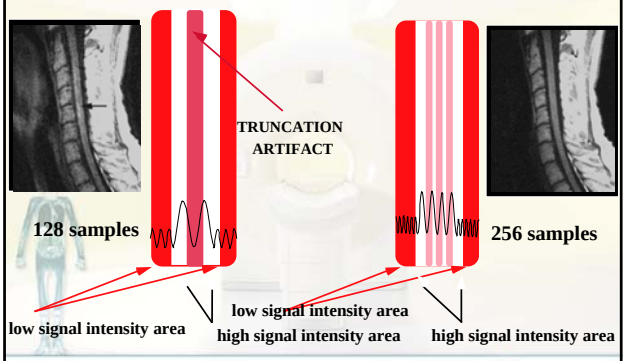
- Increasing phase increases spatial resolution (small pixels)
- Increases scan time
- Reduces SNR (small pixels)

Truncation Artifact – 2D Fourier Tranform (2DFT)



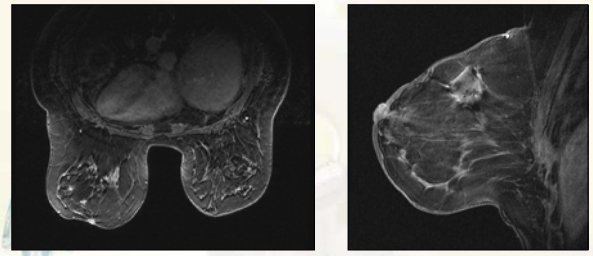
Slide # 49
Imaging

Truncation (Gibbs) Artifact – in the Spine



Slide # 50
Imaging

Resolution & CNR, SNR & Time



40 cm FOV, 192 x 256 matrix
1 minute 40 seconds

20 cm FOV, 512 x 384 matrix
1 minute 40 seconds

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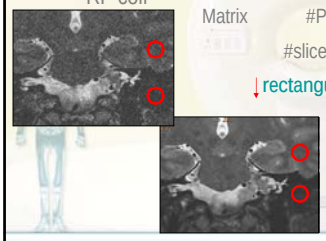
Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

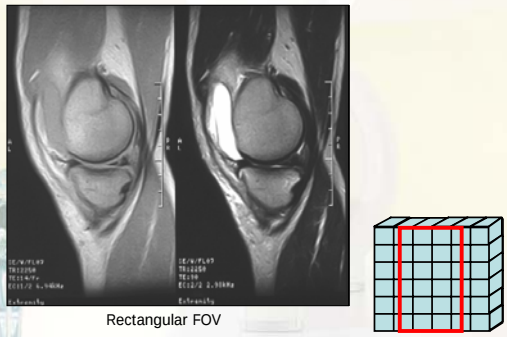
Hardware	Voxel	Sampling	SNR	Contrast	Options
Static field	Thickness	NSA		TR	SAT
RF coil	FOV	Bandwidth		TE	GMN
	Matrix	#PE's		TI	Gating
		#slices (3D)		Flip	Resp comp
		↓rectangular FOV			MT
					anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

Slide # 52
Imaging

Rectangular FOV & Resolution, SNR & Time



Rectangular FOV

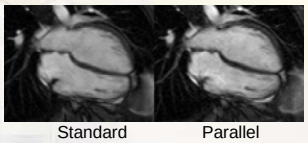
Slide # 53
Imaging

Parallel Imaging: Resolution & Time

"Rectangular FOV on Steroids"

- SENSE / mSENSE
  SENSitivity Encoding Image Data
- SMASH
  SiMultaneous Acquisition of Spatial Harmonics
  Raw Data (k-space)
- GRAPPA
  GeneRalized Autocalibrating Partially Parallel Acquisition

Scan time is reduced by acquiring a reduced number of lines of k-space



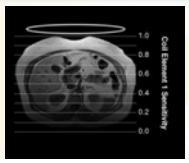
"Physics of Clinical MR Taught Through Images"
V. Runge, Thieme Medical Publishers, 2005

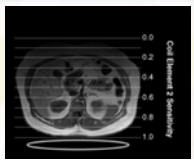
Standard (7 heartbeats)

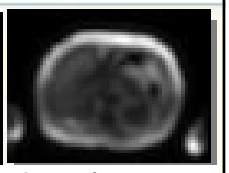
Parallel (4 heartbeats)

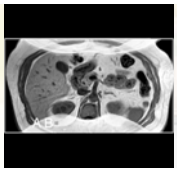
Slide # 54
Imaging

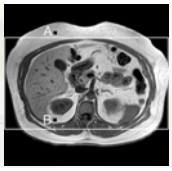
Parallel Imaging: SENSE


Element 1

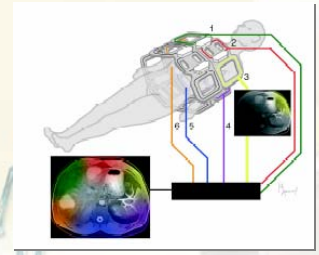

Element 2

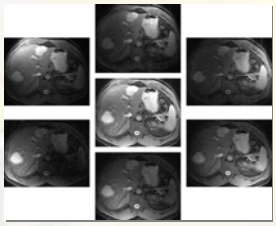

Sense Reference Image


Aliased Rect FOV Image


Rect (parallel) image unwrapped

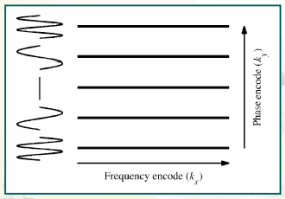
Parallel Imaging: SMASH

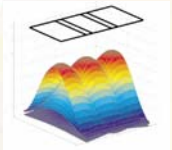




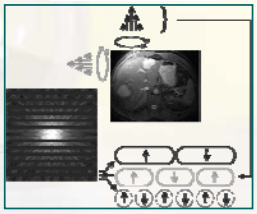
"Physics of Clinical MR Taught Through Images"
V. Runge, Thieme Medical Publishers, 2005

Parallel Imaging: SMASH

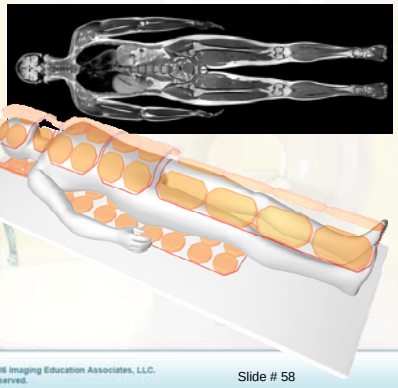




Spatial harmonic profiles are derived by linear combination of coil sensitivities resulting in a k-space "step" that is the same as what would have been produced using a gradient magnetic field



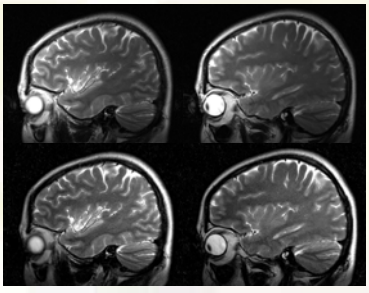
Parallel Imaging: SMASH



Scan Time & Resolution

256 x 248
2:16

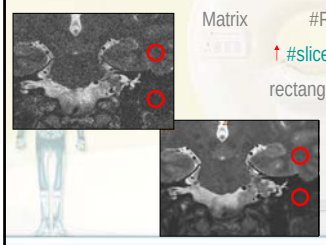
512 x 496
2:16



Params that influence Image Quality (SNR & CNR)

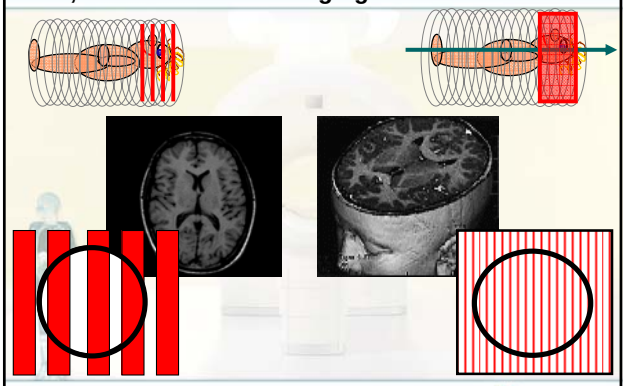
Scan Parameters

Hardware	Voxel	Sampling ($\sqrt{}$ SNR)	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		↑ #slices (3D) ($\sqrt{}$ # slices)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

SNR, Resolution & 3D Imaging



Slide # 61

Imaging

3D Steady State vs 3D Spoiled Gradient Echoes

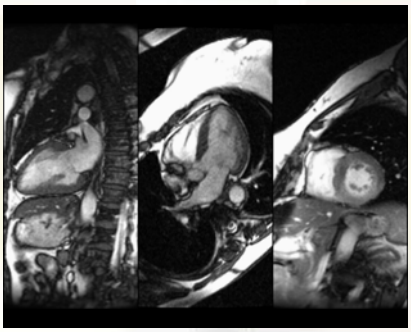
3D Steady State
T2* GrE images

Spoiled Gradient Echoes
T1 GrE images

Slide # 62

Imaging

Temporal Resolution – Cardiac Cine'



Slide # 63

Imaging

Phase Array Coil –Vascular

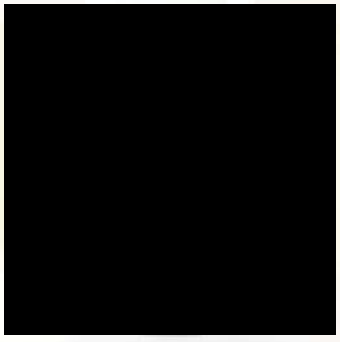
Temporal resolution
Enhanced 4-D MRA

Peripheral Vascular Imaging

Slide # 64

Imaging

Temporal Resolution - 4D MRA

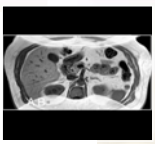


Slide # 65

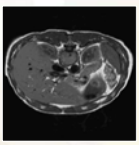
Imaging

Typical Artifacts

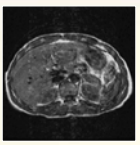
- Metal
- Aliasing
- RF Leak



Aliasing

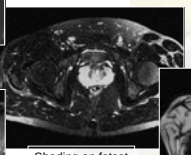


patient prone

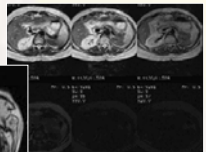


supine w/respiratory motion

Chemical shift artifact
Out of phase image

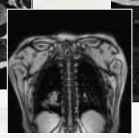


Shading on fatsat



Broken body coil

Chemical shift artifact



Chemical shift artifact

Slide # 66

Imaging

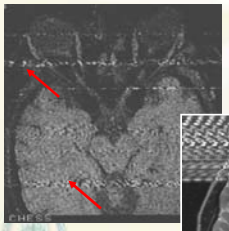
Motion

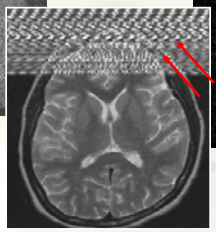
Slide # 67

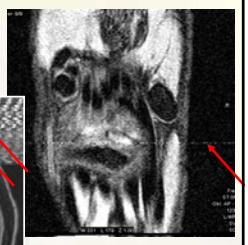
Imaging

RF Noise

Characteristic "Zipper" Artifact







Slide # 68

Imaging

Gradient Malfunction

Spatial Distortion

After Correction

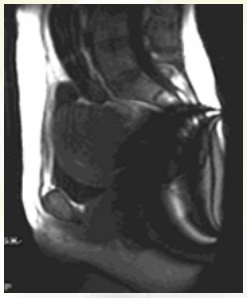
Slide # 69

Imaging

Surface Coil Malfunction

Coil element 1

Coil element 2



Coil element 3

Coil element 4

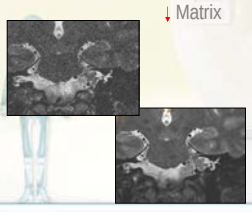
Slide # 70

Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
↑ Static field	↑ Thickness	NSA	TR	SAT
↓ RF coil	↑ FOV	Bandwidth	TE	GMN
	↓ Matrix	↑ #PE's	TI	Gating
		↑ #slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

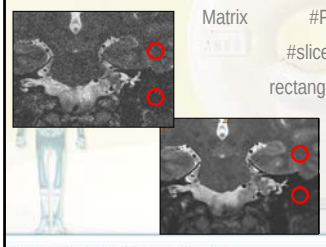
Slide # 71

Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	? Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

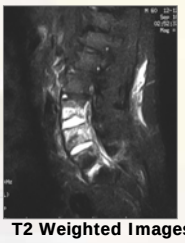
Slide # 72

Imaging

Image Contrast Parameters

- TR *goes with* T1
- TE or Target TE *goes with* T2
- TI *goes with* T1
- flip angle *goes with TR* T1

T1 weighted image
Generally acquired for anatomy

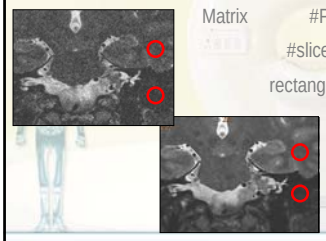


T2 Weighted Images
Generally acquired for pathology

Params that influence Image Quality (SNR & CNR)

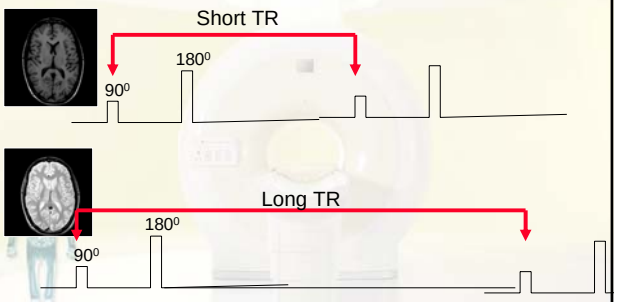
Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	↑ TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

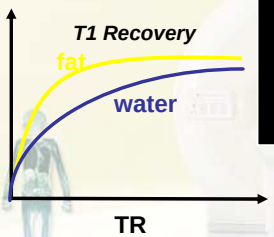


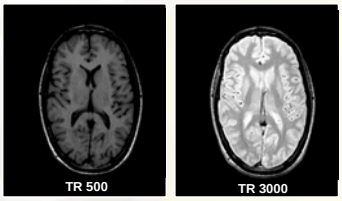
SNR … "what we measure"
CNR … "what we perceive"

Short TR & Long TR Imaging



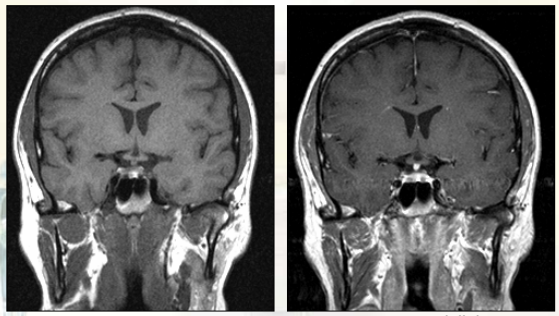
TR & SNR





Increasing TR
- Image Contrast (less T1 effects)
- SNR (increases SNR)
- Scan Time (increases time)
- # Slice Locations (increases #)

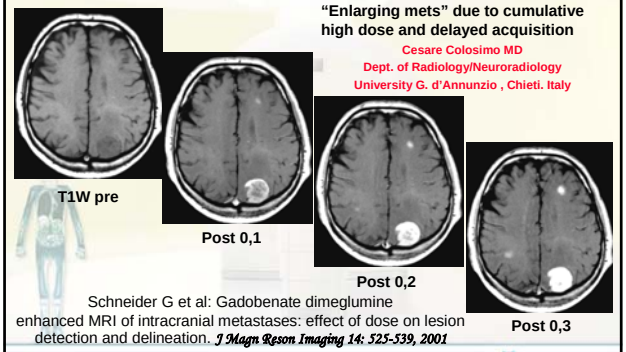
T1 & Gadolinium



T1 pre contrast

T1 post gadolinium

T1 & Gadolinium dose

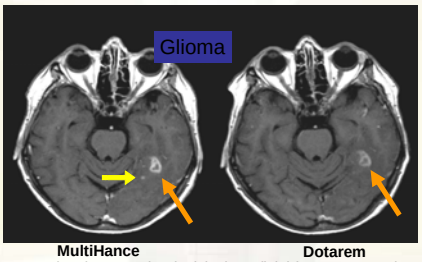


"Enlarging mets" due to cumulative high dose and delayed acquisition

Cesare Colosimo MD
Dept. of Radiology/Neuroradiology
University G. d'Annunzio , Chieti. Italy

Schneider G et al: Gadobenate dimeglumine enhanced MRI of intracranial metastases: effect of dose on lesion detection and delineation. *J Magn Reson Imaging 14: 525-539, 2001*

T1 & Gadolinium "Type"



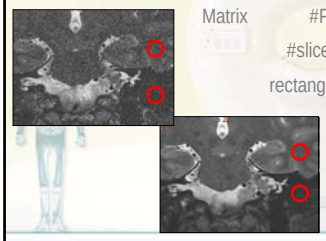
MultiHance Dotarem

Colosimo C et al: Is increased relaxivity beneficial for contrast-enhanced MRI of brain tumors? Blinded intra-individual comparison of Gd-BOPTA and Gd-DOTA. *Neuroradiology In press*

Params that influence Image Quality (SNR & CNR)

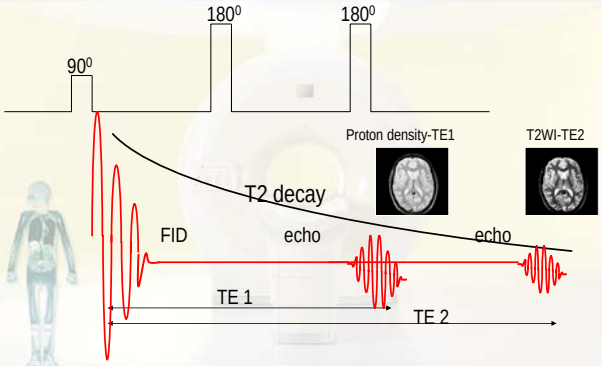
Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	↓ TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

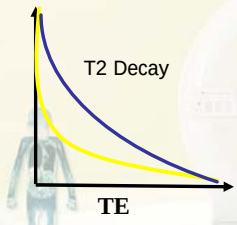


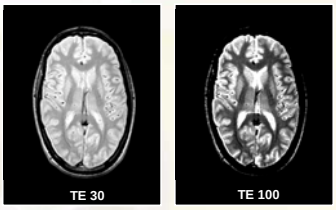
SNR … "what we measure"
CNR … "what we perceive"

Dual Echo Imaging (2 for 1)



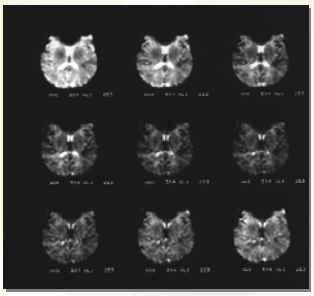
TE & SNR





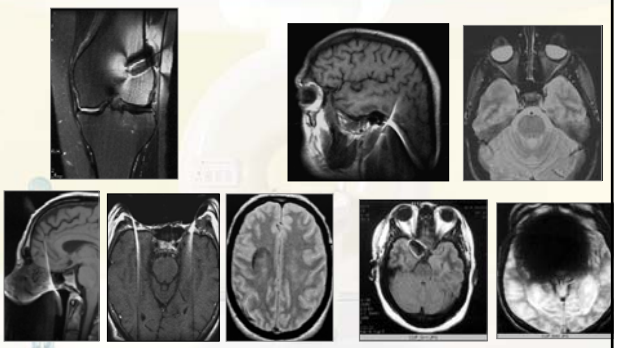
Reducing TE
- Image Contrast (Less T2 effect)
- SNR (Increase SNR)
- # Slice Locations (Increase #)
- Susceptibility (Decrease Effects)

CNR & T2* Imaging with Gd



T2* EPI imaging during dynamic Gd enhancement

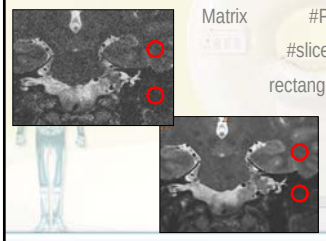
TE & Susceptibility



Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	? TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

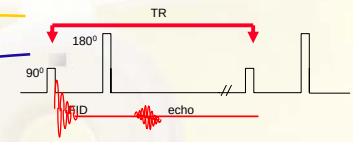


SNR … "what we measure"
CNR … "what we perceive"

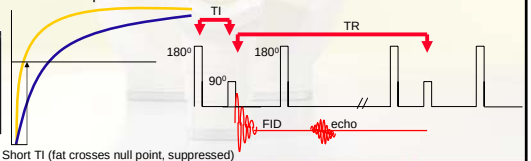
Imaging

TI and SNR for STIR

T1 recovery from a 90⁰ pulse



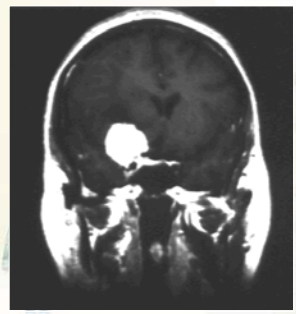
T1 recovery from a 180⁰ pulse
Compared to the 90⁰ pulse

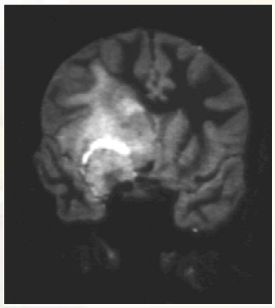


Short TI (fat crosses null point, suppressed)

Imaging

STIR is NOT fatsat





STIR will suppress gadolinium enhancing lesions

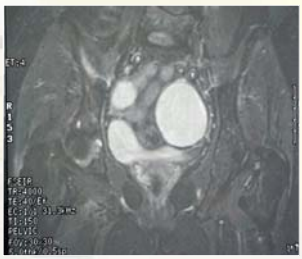
Imaging

FATSAT vs STIR

T1 SE T2 FSE STIR

Imaging

FATSAT FSE vs STIR



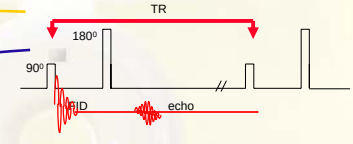
FSE *STIR*

Imaging

TI and SNR for FLAIR

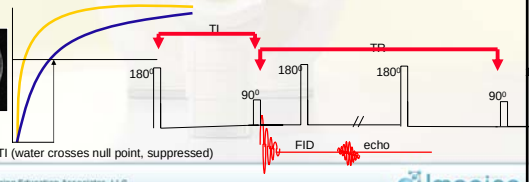
T1 recovery from a 90⁰ pulse


T1SE



T1 recovery from a 180⁰ pulse
Compared to the 90⁰ pulse

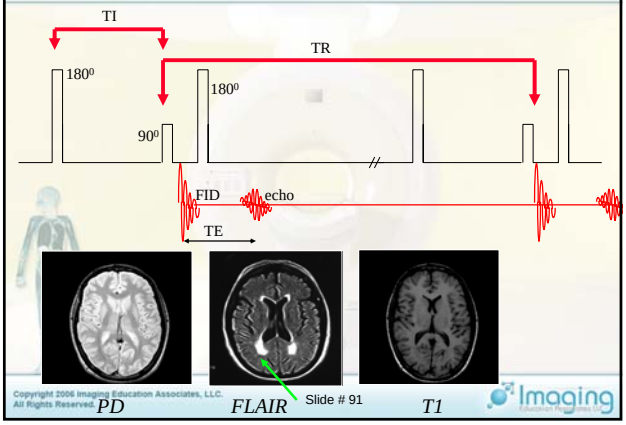

FLAIR



Long TI (water crosses null point, suppressed)

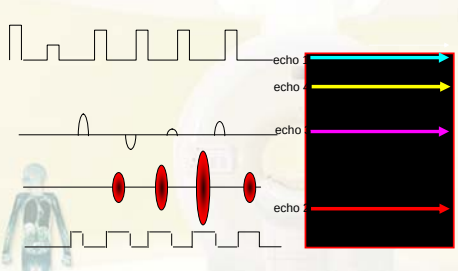
Imaging

FLAIR (Fluid Attenuated Inversion Recovery)

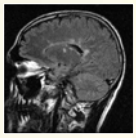


Slide # 91

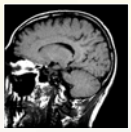
Fast Inversion Recovery – scan time



Lymes disease



FLAIR



T1SE

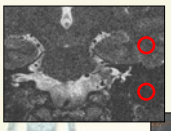
Scan time (FSE-IR) = $\frac{TR * \#PE's * NSA}{ETL}$

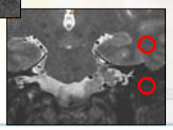
Slide # 92

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	↑ Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing





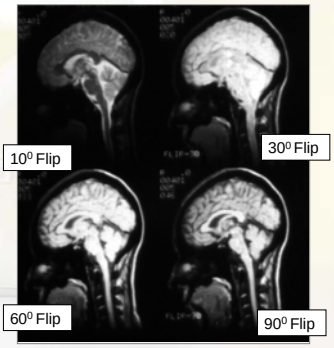
SNR … "what we measure"
CNR … "what we perceive"

Slide # 93

Flip Angle and Image Contrast

Flip angle goes with TR
TR goes with T1

Big flip, more T1
Little flip, less T1

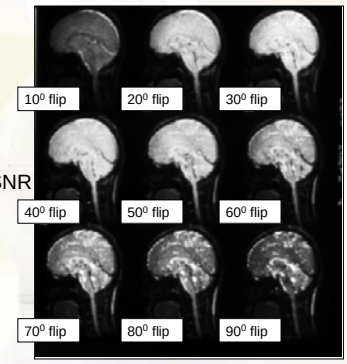


Slide # 94

Flip Angle and Signal Quality (SNR)

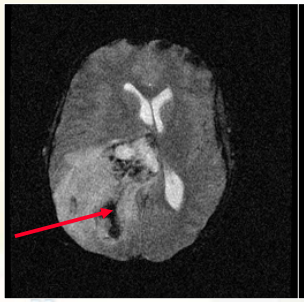
As Flip increases
SNR increases
To a point

Ernst Angle
angle for optimum SNR

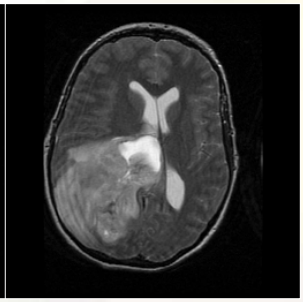


Slide # 95

Susceptibility Artifacts on Gradient Echo



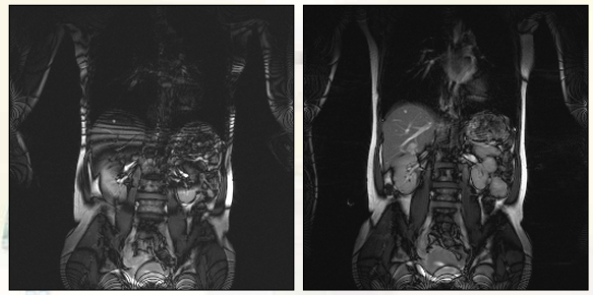
Axial T2* Brain



Axial T2 Brain

Slide # 96

Susceptibility Artifact

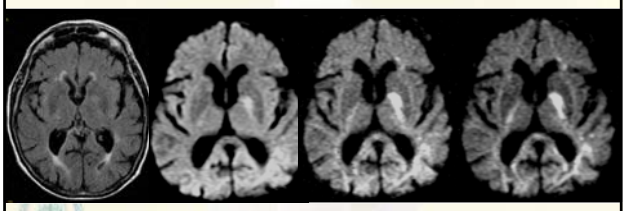


size of the metal artifact vs type of bra... Take it off!

Slide # 97

Imaging

Diffusion & "B" Value



Flair b=1000 b=2500 b=3000

Basil ganglia infarct < 24 hours

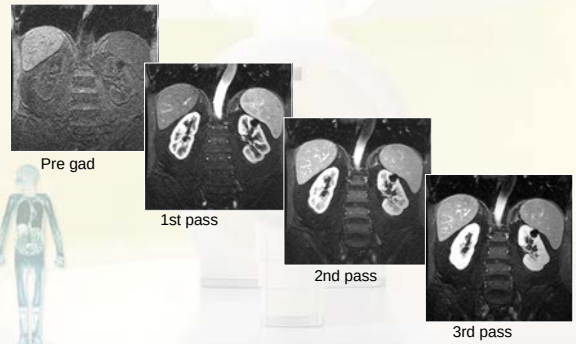
Diffusion Images with varied B values

JRM-99

Slide # 98

Imaging

Dynamic Enhanced (T1) Spoiled Gradient Echoes



Pre gad

1st pass

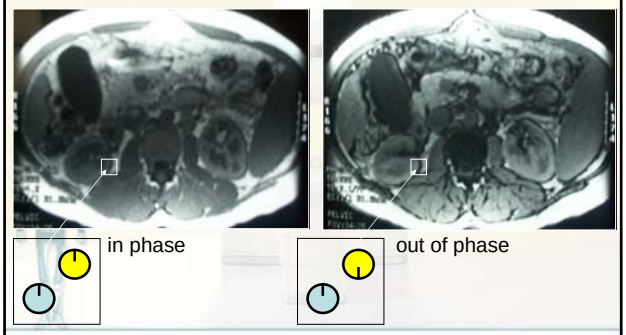
2nd pass

3rd pass

Slide # 99

Imaging

Chemical Shift Artifact on Gradient Echoes



in phase

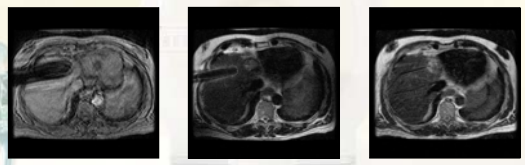
out of phase

Slide # 100

Imaging

Susceptibility Artifact

Size of the metal artifact
vs
Type of metal
&
Type of scan

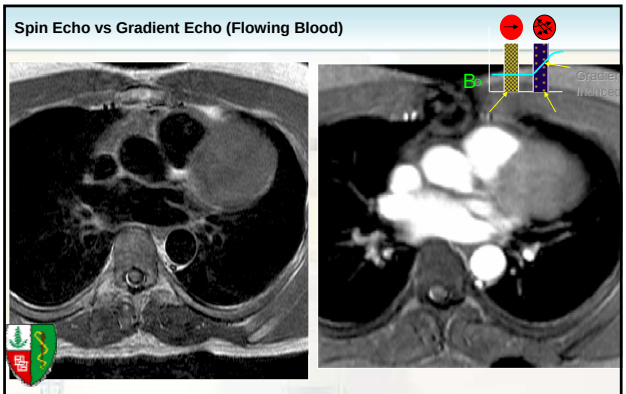


GE (wrong needle) TSE (wrong needle) TSE (right needle)

Slide # 101

Imaging

Spin Echo vs Gradient Echo (Flowing Blood)



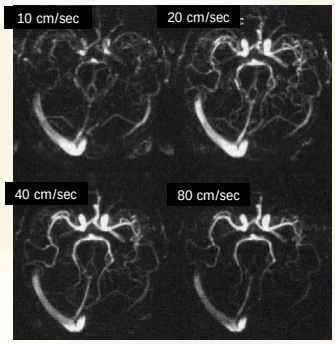
Gated Spin Echo

Gated Gradient Echo

Slide # 102

Imaging

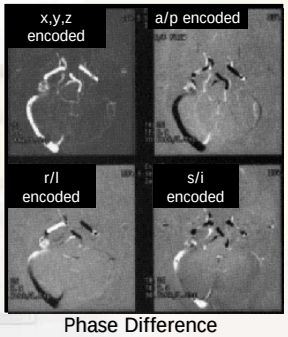
Venc & PC MRA



Slide # 103
Imaging

Direction Encoding on PC MRA


Complex Difference
Flow encoded x,y,z



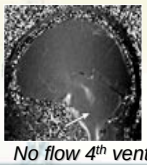
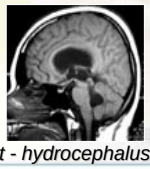
Phase Difference

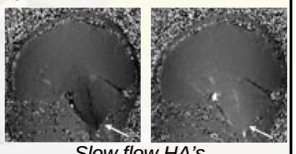
Slide # 104
Imaging

Phase Contrast (PC) MR Angiography (MRA) – CSF Flow


Diastole- dark flow

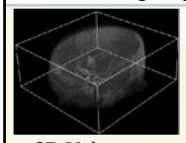

Systole – white flow

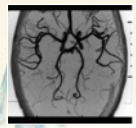


No flow 4th vent - hydrocephalus


Slow flow HA's

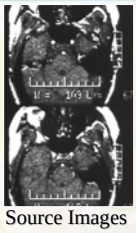
Slide # 105
Imaging

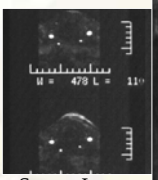
Time of Flight (TOF) MR Angiography (MRA)

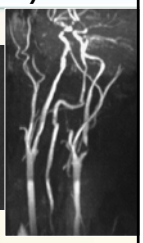

3D Volume

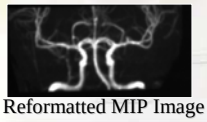

Collapsed Image

3D TOF


Source Images


Source Images

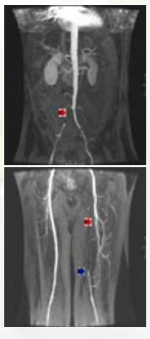

Reformatted MIP Image

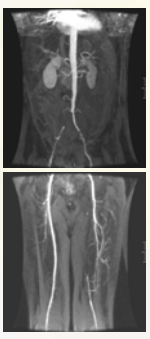

Reformatted MIP Image

2D TOF

Slide # 106
Imaging

Enhanced MRA



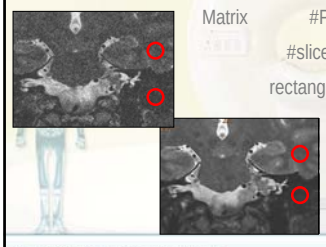


Slide # 107
Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

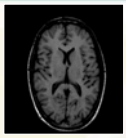
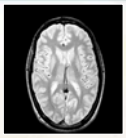
Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing



SNR … "what we measure"
CNR … "what we perceive"

Slide # 108
Imaging

Review Image Contrast & Pulse Sequences


Spin echo family

Longer Scan times Better quality

T1Weighted Image	PD Weighted Image	T2 Weighted Image
SE	SE	SE
(TSE) FSE	(TSE) FSE	FSE
IR	FLAIR	STIR
Fast IR	Fast FLAIR	Fast STIR
	Looks like PD	Looks like T2

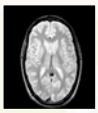
Gradient echo family

Faster Scan times lower quality

(T1 FFE) GrE spoiled	(PD FFE) GrE	T2* Weighted Image
TOF MRA	EPI Flair	(T2* FFE) GrE
Enhanced MRA		PC MRA
		EPI
		Perfusion
		Diffusion

Imaging

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) = $\frac{TR * \#PE's * NSA}{ETL}$

(GE) = TR * #PE's * NSA

(3DGE) = TR * #PE's * NSA * Nsl

(IR) = TR * #PE's * NSA

(Fast IR) = $\frac{TR * \#PE's * NSA}{ETL}$

(EPI) = TR * SHOTS * NSA

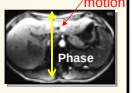
Imaging

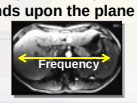
Physical vs Logical Gradients

Logical Gradients

Physical Gradients

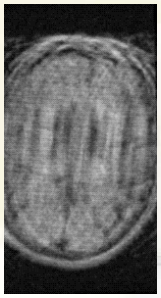
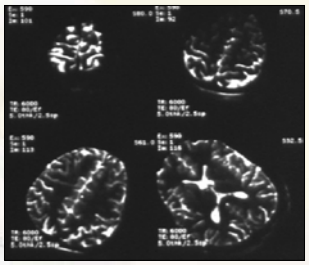
- **Slice Selection**
  - **Z (runs superior to inferior) (axial)**
  - **Y (A-P) (coronal)**
  - **X (R-L) (sagittal)**
- **Phase Encoding**
  - **-Depends upon the plane**
    - **smaller word**
    - **smaller anatomy (motion)**
    - **smaller matrix (time)**
- **Frequency Encoding**
  - **-Depends upon the plane**





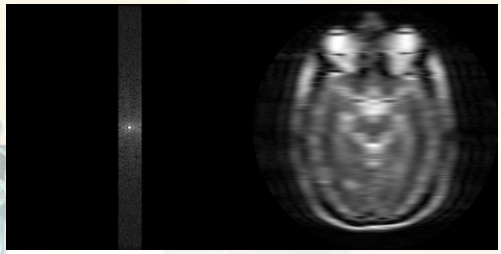
Imaging

Motion Artifact

Imaging

Rapid Imaging Techniques - Propellar Imaging



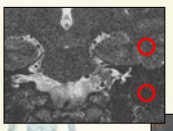
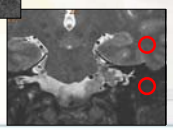
Acquire Blades of data

Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

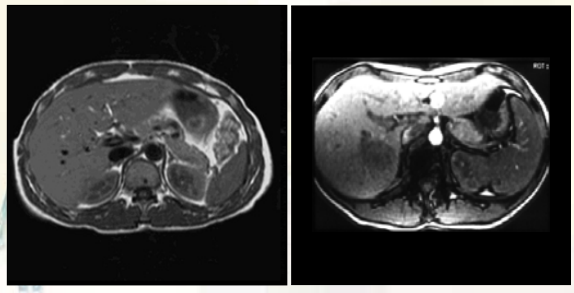
Hardware	Voxel	Sampling	Contrast	Options
Static field	Thickness	NSA	TR	SAT
RF coil	FOV	Bandwidth	TE	GMN
	Matrix	#PE's	TI	Gating
		#slices (3D)	Flip	Resp comp
		rectangular FOV		MT
				anti-aliasing

SNR … "what we measure"
CNR … "what we perceive"

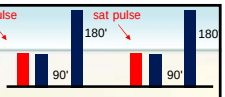
Imaging

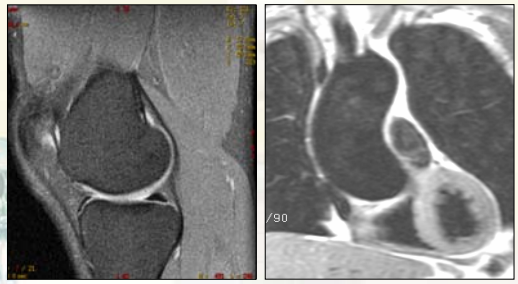
Flow Motion Compensation



Presaturation | Gradient Moment Nulling

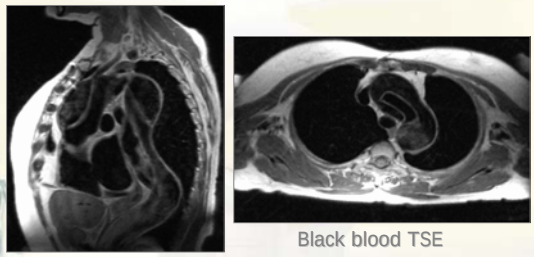
Image Quality & Presaturation





Chemical Shift Selective Suppression FATSAT | Spatial Presaturation SAT

Spatial Presaturation



Black blood TSE

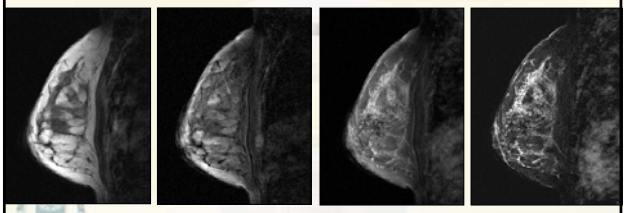
Aortic Dissection

Cambridge University

Fat Suppression (Chemical shift suppression)

T1 SE Pre Gad | T1 Post Gad FAT SAT

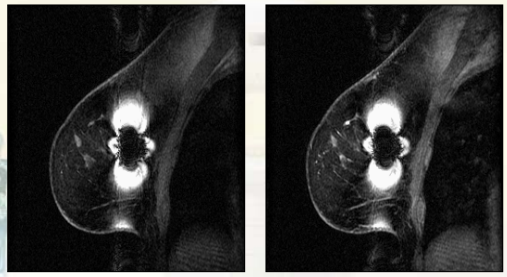
Fat Suppression and Breast Imaging



T1 GE Pre Gad | T1 GE FATSAT Pre Gad | T1 GE FATSAT Post Gad | Subtraction

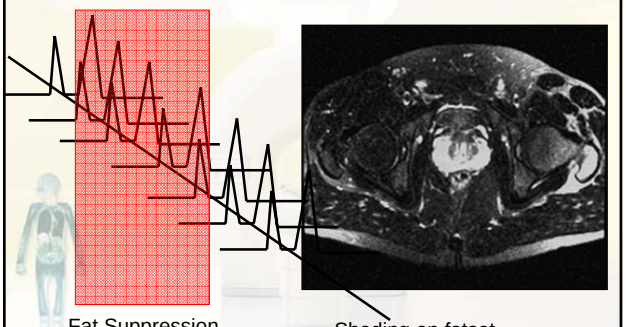
Fat Suppression & Shading

Shading on fatsat



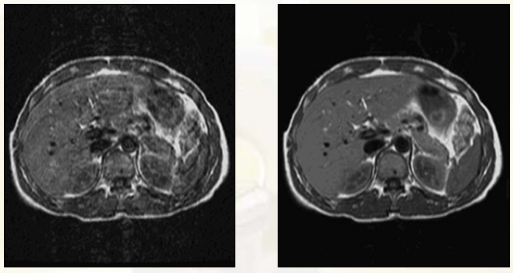
Pre gad | Post gad

Fat Suppression & Shading



Slide # 121
Imaging

Image Quality & Respiratory Compensation



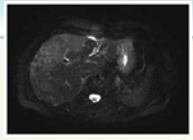
Axial, Spin echo, T1 weighted

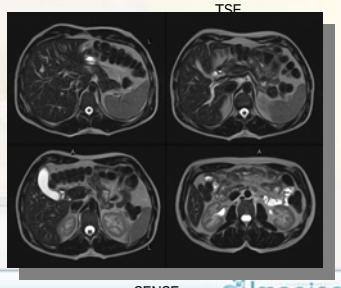
Slide # 122
Imaging

Respiratory Motion

- SENSE
- Free breathing
- Single-shot TSE
- NO half Fourier
- TE 150
- TF 70
- matrix 200 x 256
- no blurring

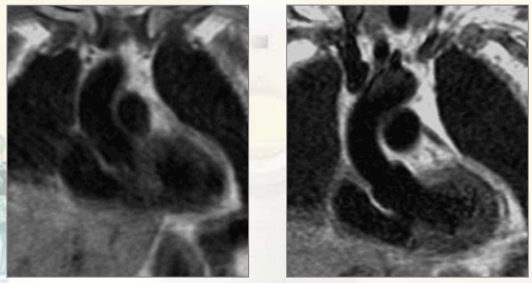
– Shorter Echo Train Length





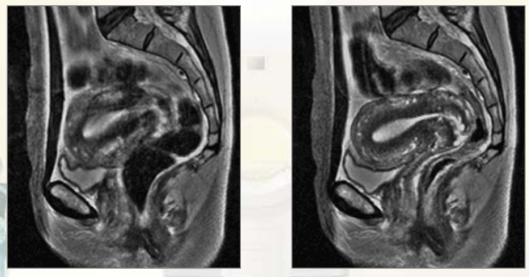
Slide # 123
Imaging

Image Quality & Cardiac Gating
Spin Echo T1 weighted



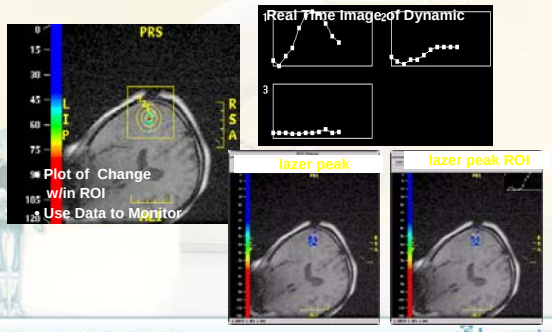
Slide # 124
Imaging

Image Quality & Antismazmodics



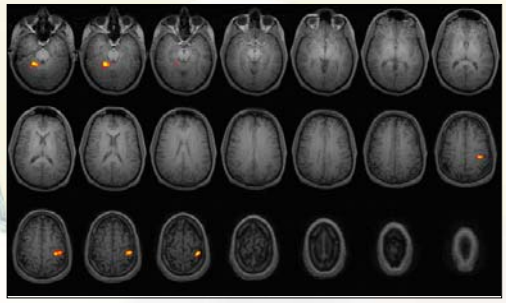
Slide # 125
Imaging

Thermal Imaging – Real Time Image Processing



Slide # 126
Imaging

MOTOR ACTIVATION @ 4.0 T



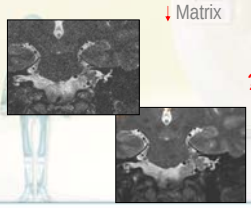
Slide # 127

Imaging

Params that influence Image Quality (SNR & CNR)

Scan Parameters

Hardware	Voxel	Sampling	Contrast	Options
↑ Static field	↑ Thickness	↑ NSA	↑ TR	SAT ↓
↓ RF coil	↑ FOV	↓ Bandwidth	↓ TE	GMN ↑
	↓ Matrix	↑ #PE's	? TI	Gating ↑
		↑ #slices (3D)	↑ Flip	Resp comp ↑
		? rectangular FOV		MT ↓
				anti-aliasing ?



SNR … "what we measure"
CNR … "what we perceive"

Slide # 128

Imaging

Imaging

Parameters & Options for MRI

Params, Options & Artifacts
SNR, CNR, Resolution & Time

Thank you for your attention!

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