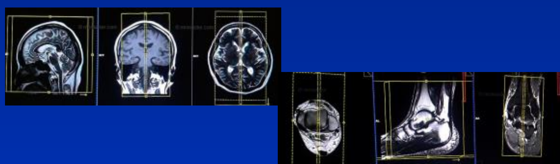
MRI Protocol Basics



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Outline

- MRI protocols in general
- Protocol team: radiologists, physicists and technologists
- Divided into specific anatomic areas: Neuro, Body, MSK and Cardiac
- Pulse sequences - general types:
  - ✓ Gradient-Echo (GRE)
  - ✓ Spin-Echo (SE) and Fast/Turbo Spin-Echo (FSE/TSE)
  - ✓ Inversion-Recovery (IR) types
  - ✓ Diffusion-Weighted Echo-Planar Imaging (DWI EPI)

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Protocol team

- Team for coordinating and updating the MRI protocols
  - ✓ Key radiologists, physicists and technologists
- Meetings for protocol setup and updates
  - ✓ Field strength and vendor specifics
  - ✓ Accommodation for different software versions
  - ✓ Updates and changes due to recent developments in pulse sequences
- Off-line work
  - ✓ Coordinating the changes/updates with the entire team of radiologists of specific subspecialties
  - ✓ Finalizing the protocols and publishing in the Institutional Intranet (share drive)

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Division into Anatomic Areas

- Distribution of the protocols into different subgroups
  - ✓ Neuro
  - ✓ Body
  - ✓ Musculoskeletal
  - ✓ Cardiac
- Screenshots of anatomy specific slice prescriptions from sample MR images
- Constant communication (via e-mail to the groups) with any changes (e. g. adding/eliminating sequences, contrast administration specifics, etc.)

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Pulse Sequences – Basics

- Sufficiently fill k-space to make an image
- Provide necessary tissue contrast/image weighting (T1, T2, T2*, proton-density, etc.)
- Fulfill some other necessary functions, such as navigation, quick localization, bolus timing, etc.

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Pulse Sequences – Basics

- T1-weighted images show anatomy well
- T2-weighted images show the pathologic changes
- Proton-density images show both anatomy and pathology

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Pulse Sequences – Basics

T_2 and T_1 Relaxation Times at 3T and 1.5T Measured at 37°C. Literature data is also shown.

Tissue	T_2—3 T [ms]		T_1—3 T [ms]		T_2—1.5 T [ms]		T_1—1.5 T [ms]	
	This study	Literature	This study	Literature	This study	Literature	This study	Literature
Liver	42 ± 3		812 ± 64		46 ± 6	54 ± 8[35]	576 ± 30	~600[23]
Skeletal muscle	50 ± 4	32 ± 2[25]	1412 ± 13	1420 ± 38[25]	44 ± 6	35 ± 4[25]	1008 ± 20	1060 ± 155[25]
Heart	47 ± 11		1471 ± 31		40 ± 6	44 ± 6[36]	1030 ± 34	
Kidney	56 ± 4		1194 ± 27		55 ± 3	61 ± 11[37]	690 ± 30	709 ± 60[37]
Cartilage 0°	27 ± 3	37 ± 4[25]	1168 ± 18	~1240[25]	30 ± 4	42 ± 7[25]	1024 ± 70	~1060[25]
Cartilage 55°	43 ± 2	45 ± 67[26]	1156 ± 10		44 ± 5		1038 ± 67	
White matter	69 ± 3	56 ± 4[27]	1084 ± 45	1110 ± 45[29]	72 ± 4	79 ± 8[38]	884 ± 50	778 ± 84[38]
Gray matter	99 ± 7	71 ± 10[27]	1820 ± 114	1470 ± 50[29]	95 ± 8	~95[38]	1124 ± 50	1086 ± 228[38]
Optic nerve	78 ± 5		1083 ± 39		77 ± 9		815 ± 30	
Spinal cord	78 ± 2		993 ± 47		74 ± 6		745 ± 37	
Blood	275 ± 50		1932 ± 85	~1550[30]	290 ± 30	327 ± 40[14]	1441 ± 120	~1200[30]

Stanisz GJ et al., Magnetic Resonance in Medicine 54:507–512 (2005)

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Pulse Sequences – Basics

MR Signal Intensities

	T2WI	PD/FLAIR	T1WI
Solid mass	Bright	Bright	Dark
Cyst	Bright	Dark	Dark
Subacute blood	Bright	Bright	Bright
Acute & chronic blood	Dark	Dark	Gray
Fat	Dark	Bright	Bright

John R. Hesselink, MD, FACR http://spinwarp.ucsd.edu

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Gradient Echo

- Simple sequence
- Low transmit RF power
- Main applications: 3D – localizer, timing bolus, MRA, etc.
- Additional more advanced sequences based on GRE: FIESTA, TrueFISP, Steady-State Gradient Echo, etc.
- Sensitive to:
  - ✓ B_0 – inhomogeneities
  - ✓ Magnetic susceptibilities

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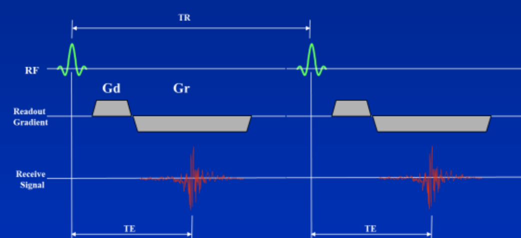
Gradient Echo



Sequence diagram slides are courtesy of Robert Prost, Ph.D.

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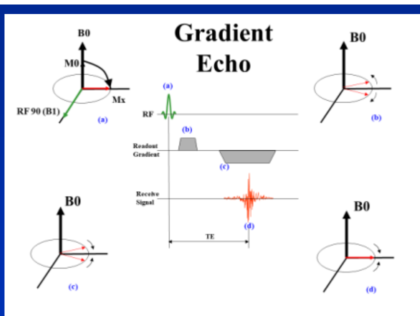

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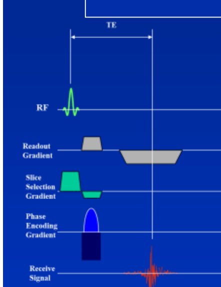
Gradient Echo



Contrast:

- ✓ Combination of T1, T2 and PD
- ✓ Flip angle, TE and TR dependent
- ✓ Combined with RF spoiling to give more T1 contrast (more advanced sequences)

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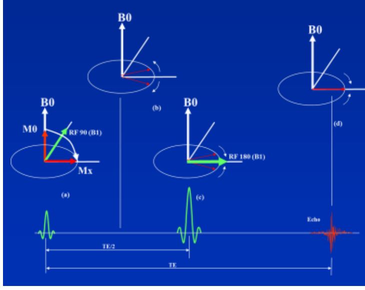
Spin Echo



- 90-degree initial RF pulse
- Follow up 180-degree refocusing RF pulse
- Echo signal

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Spin Echo

- Adds 180-degree RF pulse to the GRE
- Removes magnetic susceptibility artifacts
- Best for refining contrast: T1, T2, PD
- Fills one line of k-space for each TR
- Slow: e. g., for TR = 2000 ms and imaging matrix 256 x 256, sequence time exceeds 8 minutes

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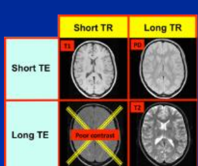
Spin Echo



- Short TR and short TE – T1-weighted
- Long TR and short TE – PD-weighted
- Long TR and long TE – T2-weighted
- Short TR and long TE – not used

http://mriquestions.com/image-contrast-trte.html

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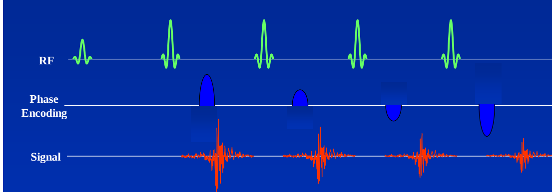
Fast Spin Echo



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Fast Spin Echo

- Fast method of approximating the spin echo contrast
- More efficient k-space filling allows choices
  - ✓ Shorter scan times
  - ✓ Higher SNR

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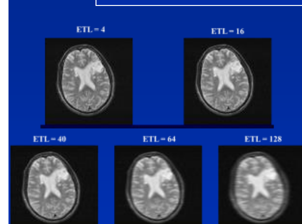
Fast Spin Echo



MR Images are courtesy of Robert Prost, Ph.D.

Pros:
- Acquisition time decreases by a factor of ETL
- More SNR per unit acquisition time

Cons:
- Higher ETL numbers – higher SAR (Specific Absorption Rate)
- Induces tissue T2 dependent blurring
- Fat shows as a hypersignal

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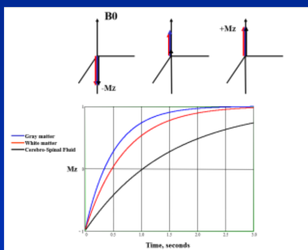
Inversion Recovery



- 180-degree pulse prior to 90-degree in Spin Echo
- Depending on the Time of Inversion (TI) the sequence suppresses the signal from a specific tissue
- Example: STIR (Short Tau Inversion Recovery) –nulls fat

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Echo Planar Imaging (EPI)

- Short imaging time
- Performed with single or multiple excitation pulses
- Increased sensitivity to off-resonance effects
- Gradient echo EPI
  - ✓ fMRI
- Spin echo EPI
  - ✓ Diffusion weighted imaging

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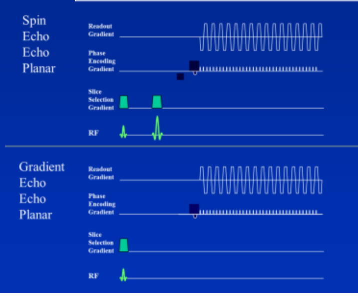
Echo Planar Imaging



- Multiple lines of data acquired after a single RF excitation.
- After 180-degree pulse FEG blips on PEG axis
- GRE EPI shorter TR can be used without large signal loss.

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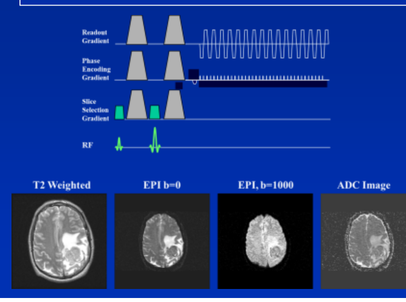
Diffusion Weighted Imaging EPI



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References

- *Bushberg JT, The Essential Physics of Medical Imaging, 3rd Edition, Lippinkot Williams & Wilkins, 2012*
- *Bernstein MA et al, Handbook of MRI Pulse Sequences, Elsevier Academic Press, 2004.*

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Thank you!

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