Fast MRI Technique (FSE, HASTE, EPI)

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Fast Scan

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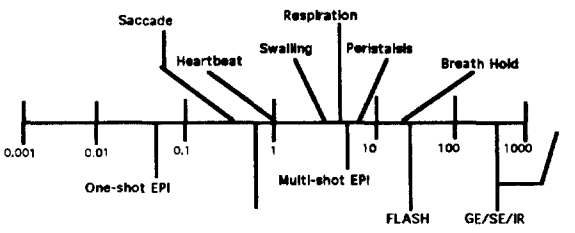
Timing Diagram



Fast Imaging History (I)

- 1977 Echo Planar Imaging proposed by Mansfield
- 1982 2D Multislice/Multiecho Imaging --> minutes
- 1984 EPI venture capital company (Advanced NMR Inc.)
- 1986 FLASH --> 10sec
  Breath holding body imaging
- 1989 EPI and subsecond FLASH --> 0.5sec
  Heart and other organs
  First commercial EPI system at MGH at Boston

Fast Imaging History(II)

- 1992 Improved EPI --> 0.1sec
  suppress noncyclic motion
  (peristaltic, swalling, eye motion, etc.)
- 1993 BURST by Hennig
- 1995 Industry starts to deliver EPI systems
- 1997 prototype of BURST on a comercial MRIs

Idea of Faster Scan

- Reduced TR with Gradient Echoes
  (FLASH, FISP)
- More K-space lines per TR
  (Blip EPI, Spiral EPI)
- RF Trains
  (TurboSE, HASTE, BURST, URGE)

Reduced TR with Gradient Echoes

- Turbo-FLASH
  Pros:
  Low Flip angle
  Angiogram
  Sensitive to susceptibility
  Cons:
  Insensitive to subtle contrast difference
  Low SNR
  No 180° pulses

  Ex TR=5ms, a=6o, Matrix=128x128, Ts=0.5sec

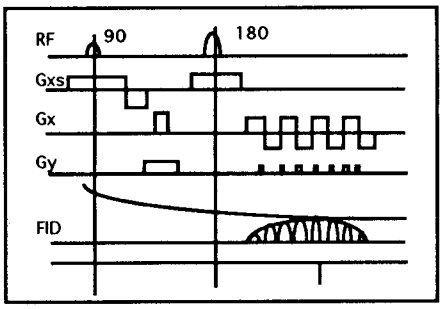
More K space lines per TR

- EPI
  - Pros:
    - 3-4 times Higher SNR than Turbo-FLASH
    - Ultra Fast Scan
  - Cons:
    - Special HW requirement
      - Enhanced Gradients
      - Improved RF and DAS hardware
      - Safety concerns
- Ex. EPI Ts<50ms or 20 images/sec

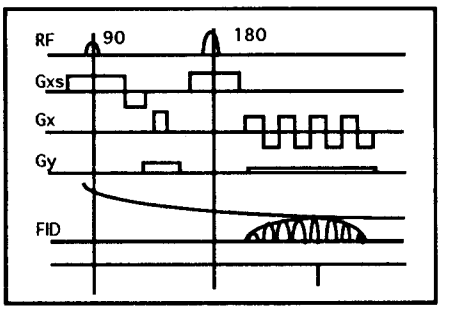
Comparison of Fast Scan Method

	Slices	Matrix	Acq Time
• Seq			
• SE	multi	256	3-12min
• TSE	multi	256	1-4min
• HASTE	single shot	128-256	0.7-1.2s
• GE	multi/3D	256	7s-10min
• TurboFLASH	sequential	64-128	300ms
• EPI	single shot	64-128	50-200ms

EPI Pulse Sequence(Blip EPI)



EPI Pulse Sequence(Zig-zag EPI)



EPI Potentials

- Motion Artifact reduction
  - Thorax, Abdomen, Cranial Studies
- Cardiac Imaging
  - Insensitive to Cardiac Arrhythmias with high intrinsic contrast
- Dynamic Contrast Studies
  - Cerebral Perfusion
- Functional Imaging
  - Brain functional Activities
  - (Finger, Visual, Hearing, Speaking, Memory Tasks)
  - Compete with PET
  - Ex. MGH / U. W 2%-4% signal increases in motor cortex

Pre-requisite Hardware for EPI(I)

- Sufficient Gradient Field Strength
  - Larger capacity gradient coil
    - Increasing current capacity
    - Increasing wire turns
    - Parallel wiring
    - Decreasing the gradient coil diameter
  - High power gradient amplifier
    - Increasing voltage (300V--600V)
    - Increasing current (300Amps--400Amps)

Pre-requisite Hardware for EPI(II)

- Fast DAS capabilities
  - High speed but accurate data acquisition
  - (Over 400 kilosample/sec with 16 bits width)
- Fast data processing capabilities
  - 2D FFT reconstruction less than 100ms for a real time application
- Large data size set
  - Huge size of data set upto 10,000 images per scan
  - over 128MB core memory and 2-3GBytes/day are easily feasible

Drawbacks of EPI

- Sensitive to Off-reonance effects and susceptibilities
- Need excellent homogeneities
  - Geometrical distortion
  - T2* effects
- Chemical shift artifacts

Safety

- Bo and dB/dt
- RF Power Deposition
- dB/dt
  - Peak rate=50-100T/sec
  - Sensations ranging from Tickling to Pain
  - Myocardial current density
    4A/m-2 induced at 250T/sec, dB/dt=80T/sec
- Maximum image acquisition time=100ms
- 256 by 256 at 40cm Field of View
  - If Neural stimulation induced by not dB/dt but B itself

Other considerations

- Acoustic Noise
- Gradient shielding
- RF shield currents
- Mechanical force

Advantage of EPI(Higher Throughput)

- Shorter rise/fall time of gradient Coil
- Shorter Minimum TEs
  - Blood flow artifact reduction
- More slices per TR
  - Breathhold fast spin echo
- Uncooperated patients scan
  - Children or uncooperated patiens
  - No sedation necessary

Advantage of EPI(Body Imaging)

- Breathhold 3D acquisitions
  - thin slice 3D image with isotropic voxels
  - whole body within 10-20secs
- Reduced complex flow artifact, peristaltic motion
  - motion artifact free images
- Lung parenchyma imaging
  - susceptibility (air/soft tissue interface) induced short T2*(~1ms)
  - Fast gradient echo with ultra short TEs.
- Cardiac Imaging
  - Eliminate motion artifact(ungated cardiac imaging)
  - 128 to 256 times faster than standard gated MRI

Advantage of EPI(High Resolution Imaging)

- Strong gradient field
- Thin slice imaging
  1mm for 2D, 0.1mm for 3D
- Smaller Field of View
- Better T2 weighted imaging

Advantage of EPI(Functional Imaging)

- Improved temporal resolution
  3-5sec in conventional MRI
  0.1sec in EPI
- Minimum motion artifact
- Heavily T_2^*-weighted imaging
  Maximum contrast from the task-activated regions

Advantage of EPI(MR Fluoroscopy)

- 15 images per sec up to 20,000 times faster than a conventional MRI
- Real time in-vivo imaging
- Open system for surgery

BURST

- Ultrafast imaging in 10-100ms
- Can be implemented on conventional MRIs
- Does not need a powerful gradient system such as EPI
- Barely audible acoustic noise
- Insensitive to field inhomogeneity, tissue susceptibility
- Long TE and diffusion imaging

Drawbacks of BURST

- Low SNR
- Sensitive to motions
- Low spatial resolution
- Diffusion effect
- Incompatible with multi-slice acquisition

References

- Turner R. Hardware requirements for functional MRI, Proc. IEEE EMBS 11:903-920, 1991
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- Stehling MK, Turner R, Mansfield P. : Echo-planar imaging: Magnetic resonance imaging in a fraction of a second. Science 254: 43-50, 1991
- Hennig J, Hodapp M, MAGMA 1.1:39,1993