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The standard knee protocol: the physics behind it

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Outline

- MRI hardware for knee imaging
- Contrast mechanisms
  - T1 and T2
- Basic sequences
- Fat suppression methods

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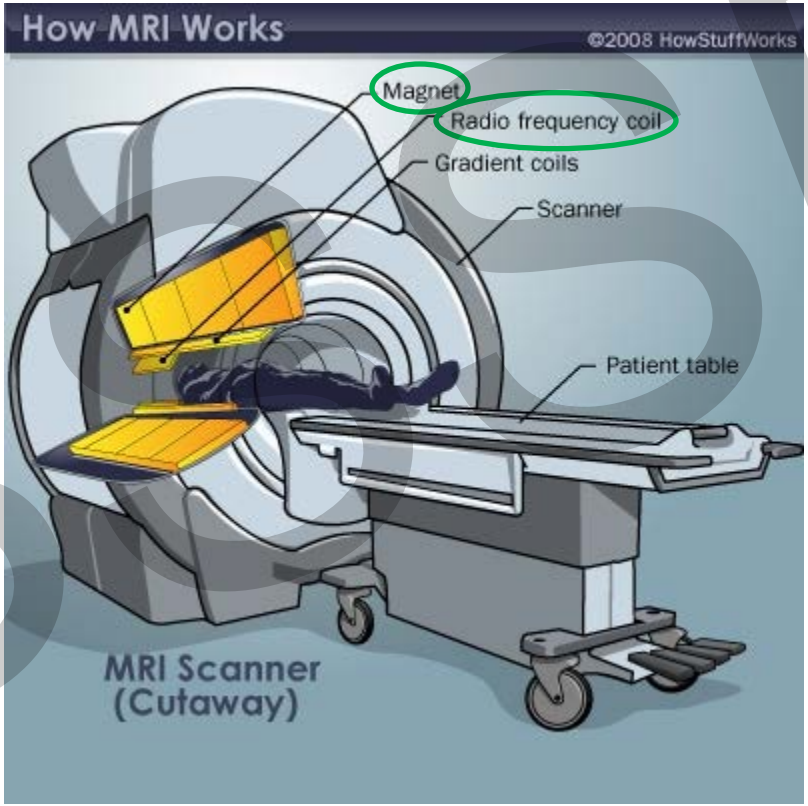
How MRI works

1. Polarization – Magnet
   - Hydrogen atoms
     - Water
     - Fat
2. Excitation – RF Coil
   - Specific frequency
     - Larmor frequency proportional to B0
     - Different for W and F
3. Encoding – Gradients
4. Acquisition – RF Coil

MRI system



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Low field

- 0.2 – 0.5T
  - Low cost
  - Good patient comfort
  - Low resolution and SNR (or long time)
  - Limited protocol choices

Siemens C! 0.35T whole-body

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High field

- 1.5 – 3T
  - Clinical standard
  - Versatility
  - Good resolution and SNR
  - Cost
  - Comfort

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Ultra-high field

- 7T+
  - Excellent resolution and SNR
  - Limited protocol choices
  - Patient comfort
  - Mostly research
  - Cost

MR Image courtesy of X. Deligianni

Coils for knee imaging

- Dedicated TX/RX coil suggested
- High SNR
- Reduced aliasing from contralateral knee

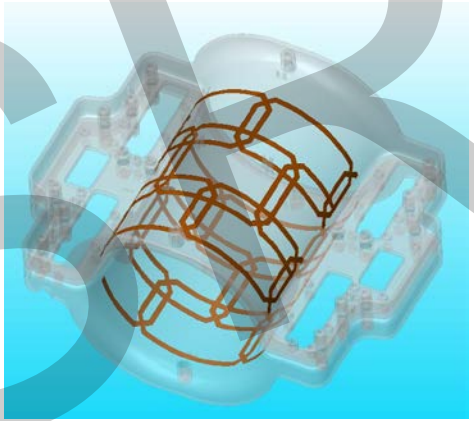

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Image courtesy of Ph. Buckle and F. Del Grande

Basic contrast mechanisms

- Signal is proportional to transverse relaxation.
- Transverse relaxation decays with T2
- Longitudinal relaxation decays with T1

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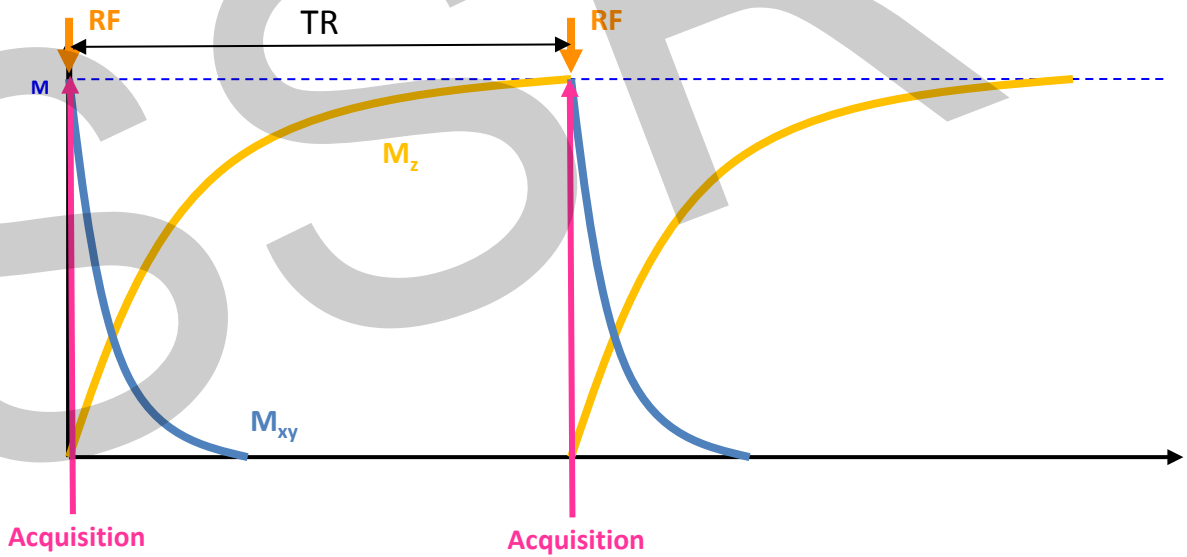
PD-weighting

- TR >> T1
  - TR > 3000ms



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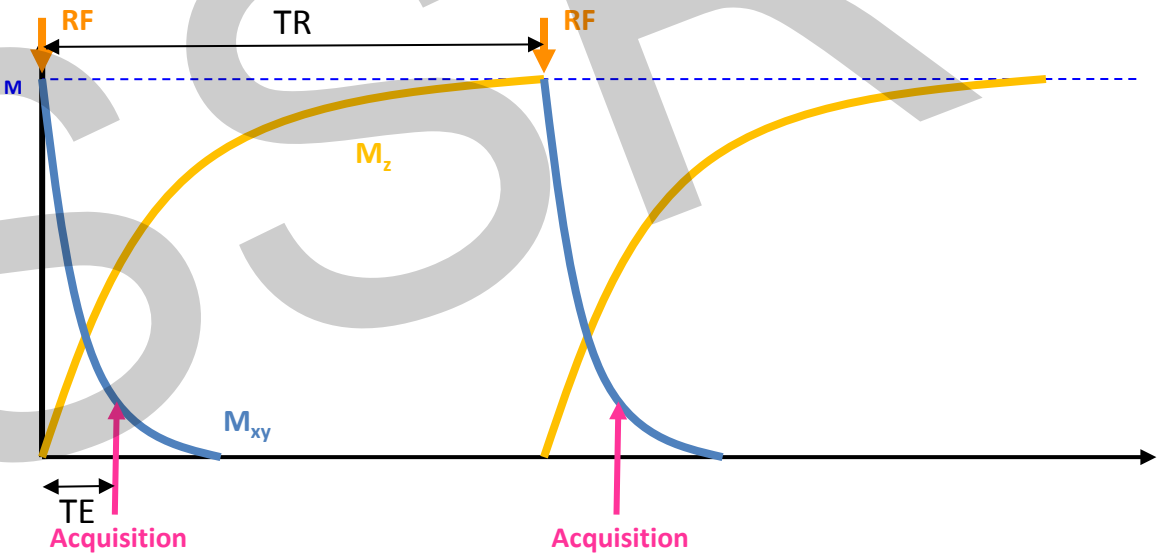
T2-weighting

- TR >> T1
  - TR > 3000ms
- TE ~T2
  - TE ~80



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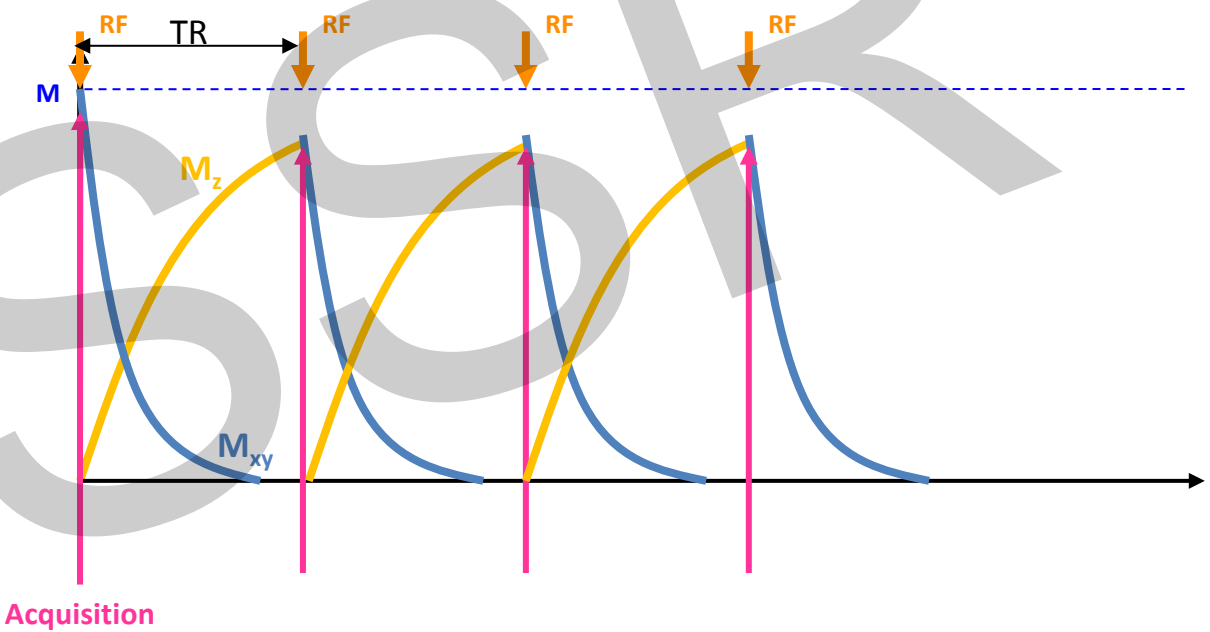
T1-weighting

- TR < T1
  - ~ 900ms
- Contrast is 1/T1
  - Shorter T1 is brighter



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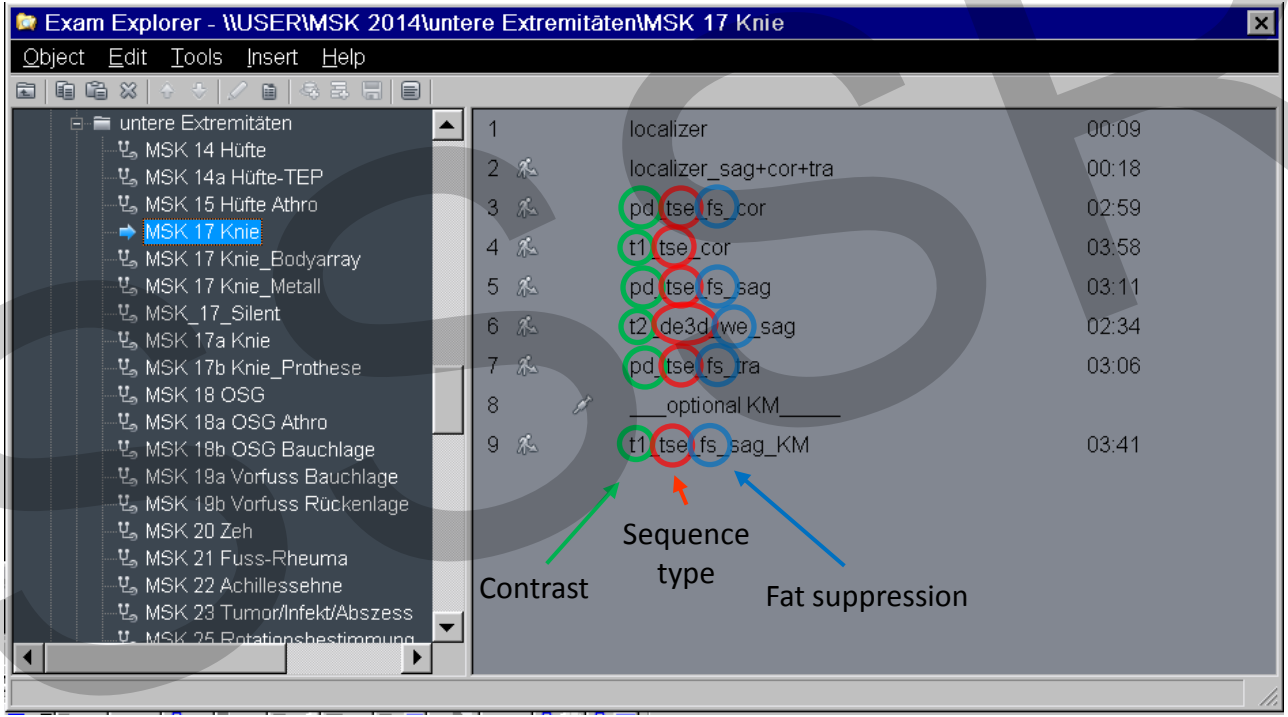
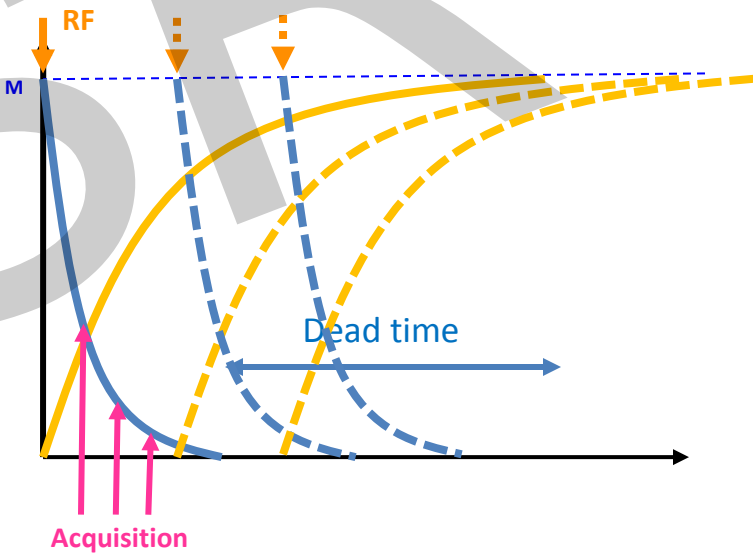
A knee standard protocol



Turbo Spin Echo

- Spin echo: 1 line per TR
- TSE: Multiple lines per TR
  - Contrast is given by effective TE
    - K-space center
  - Indicated in the interface
- Different slices acquired during dead time
  - Slice is thicker than in-plane resolution
- Also called Fast Spin Echo



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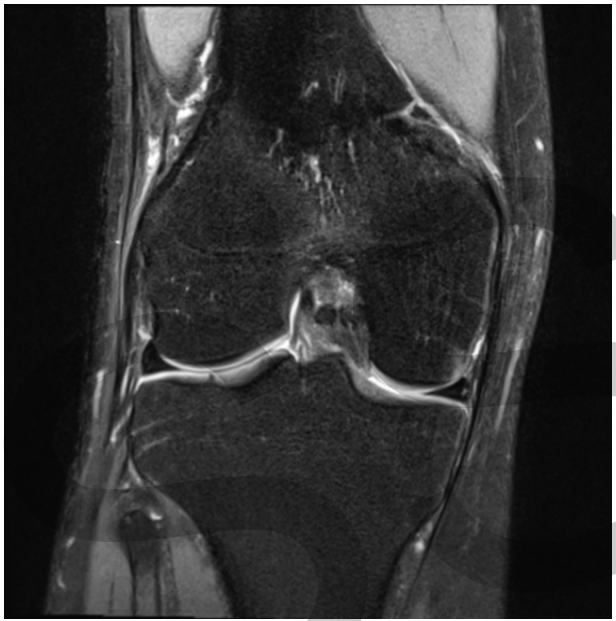
TSE Images



Fat-suppressed coronal PD-weighted TSE

Sagittal T2-weighted TSE

Dual Echo Steady-State

- Different concept
  - Gradient-echo
- T2-like contrast with short TR
- 3D acquisition
  - Not multislice
  - Isotropic resolution

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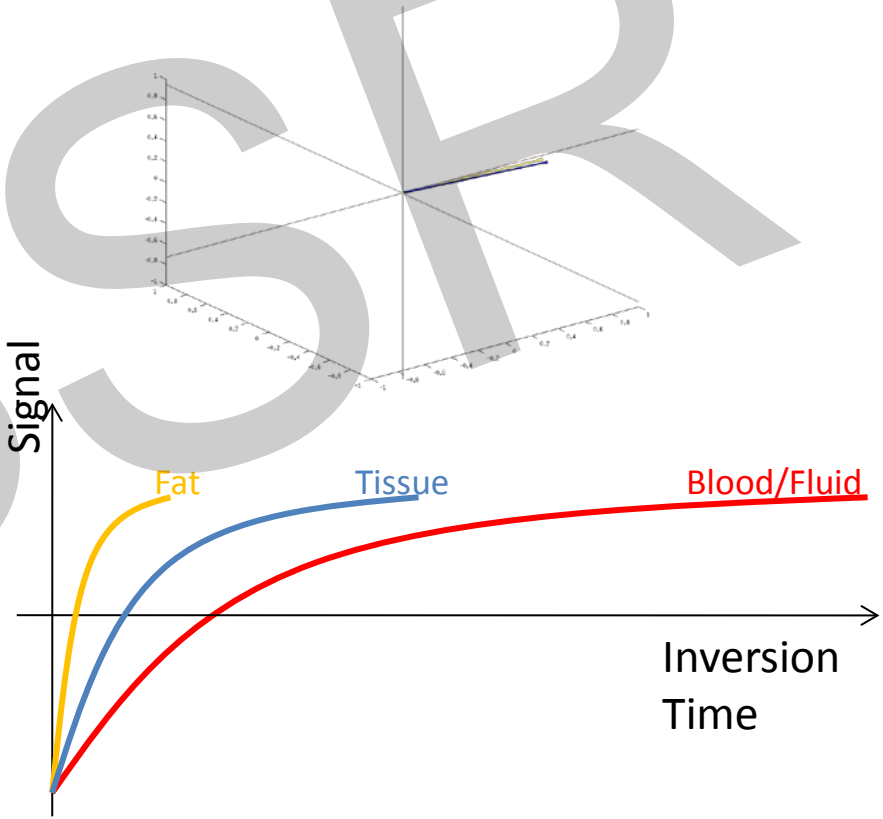
Fat suppression

- Water and fat are the main sources of signal in MRI
- They have different
  - T1 values – good for low field
  - W-F Resonant frequency difference:
    - 7T: 1041 Hz
    - 3T: 446 Hz
    - 1.5T: 223 Hz
    - 0.3T: 44.6 Hz – Too small to be practical



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Pros and cons

Frequency-based methods

- Available at high fields
- Not affecting water signal
- Sensitive to field inhomogenheities
- Not feasible at low fields

T1-based methods

- Suited for low fields
- Insensitive to field inhomogenheities
- Affects water signal

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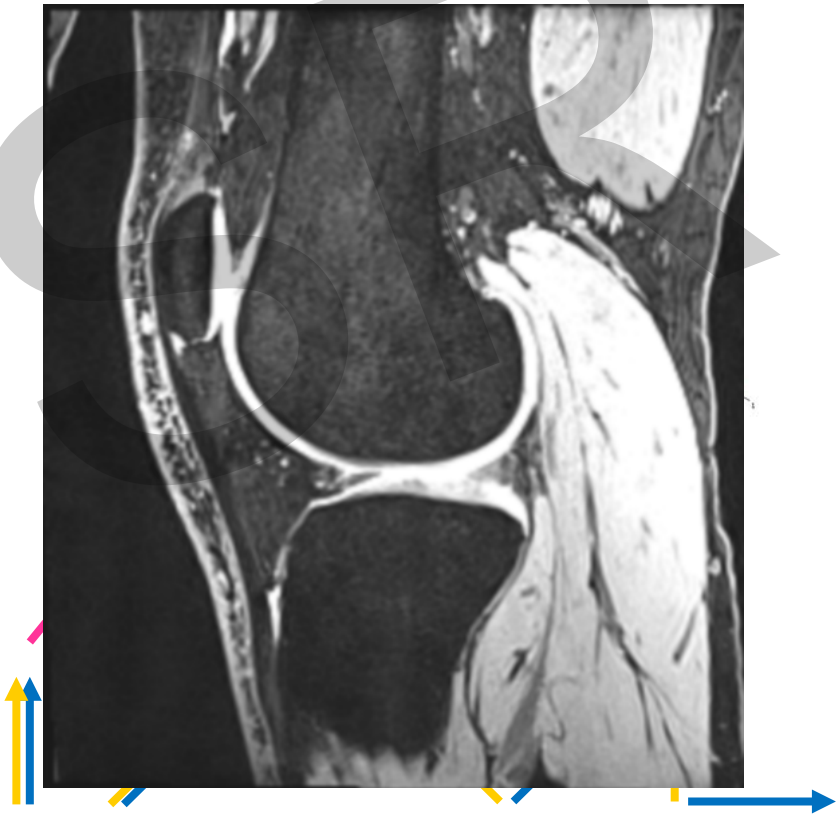
Fat saturation

- Frequency based
- RF pulse with fat
- Fat is excited and

Fat-suppressed coronal PD-weighted TSE

Water excitation

- Frequency based
- Two-part excitation
  - a/2
  - Wait until out of phase
  - a/2



Short-Tau Inversion Recovery (STIR)

- T1
- Sig
- Ac

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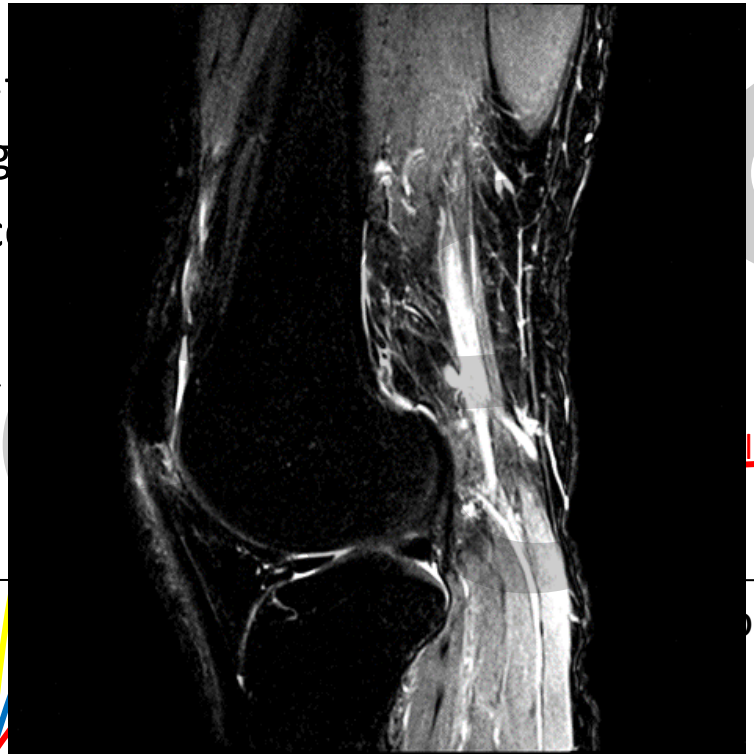
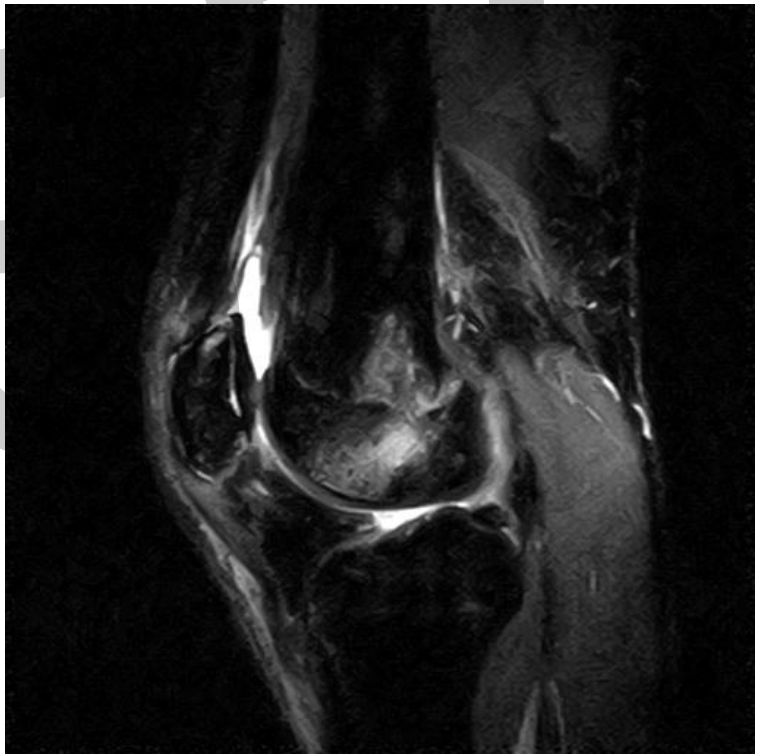
Signal



STIR PD-weighted TSE at 3T



Bone marrow edema STIR TSE at 0.3T

(Hitachi Vento: http://www.hitachi-medical-systems.eu/)

Conclusion

- Knee MRI can be performed on a large number of systems
- T1 and T2 (with and without fat suppression) are the main contrast mechanisms
- Turbo (Fast) Spin Echo is an important general-purpose method
- DESS can give isotropic coverage

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Acknowledgment

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Thank you for your attention