MR Image Quality

莊子肇 副教授
中山大學電機系

To obtain an MRI

- Formation, excitation, and detection of MR signals
- Spatial encoding and image reconstruction
- Multiple contrast: PDWI, T1WI, and T2WI
- How to obtain a good MRI?

What is a GOOD MRI?

- **High spatial resolution**: to resolve fine details
- **High signal-to-noise ratio**: to reduce interference by noise
- **High contrast**: to enhance lesions from surrounding tissues
- Unfortunately, you can’t have them all!

What is a GOOD MRI?

- **High spatial resolution**
- **High signal-to-noise ratio**
- **High contrast**

Matrix size and pixel/voxel

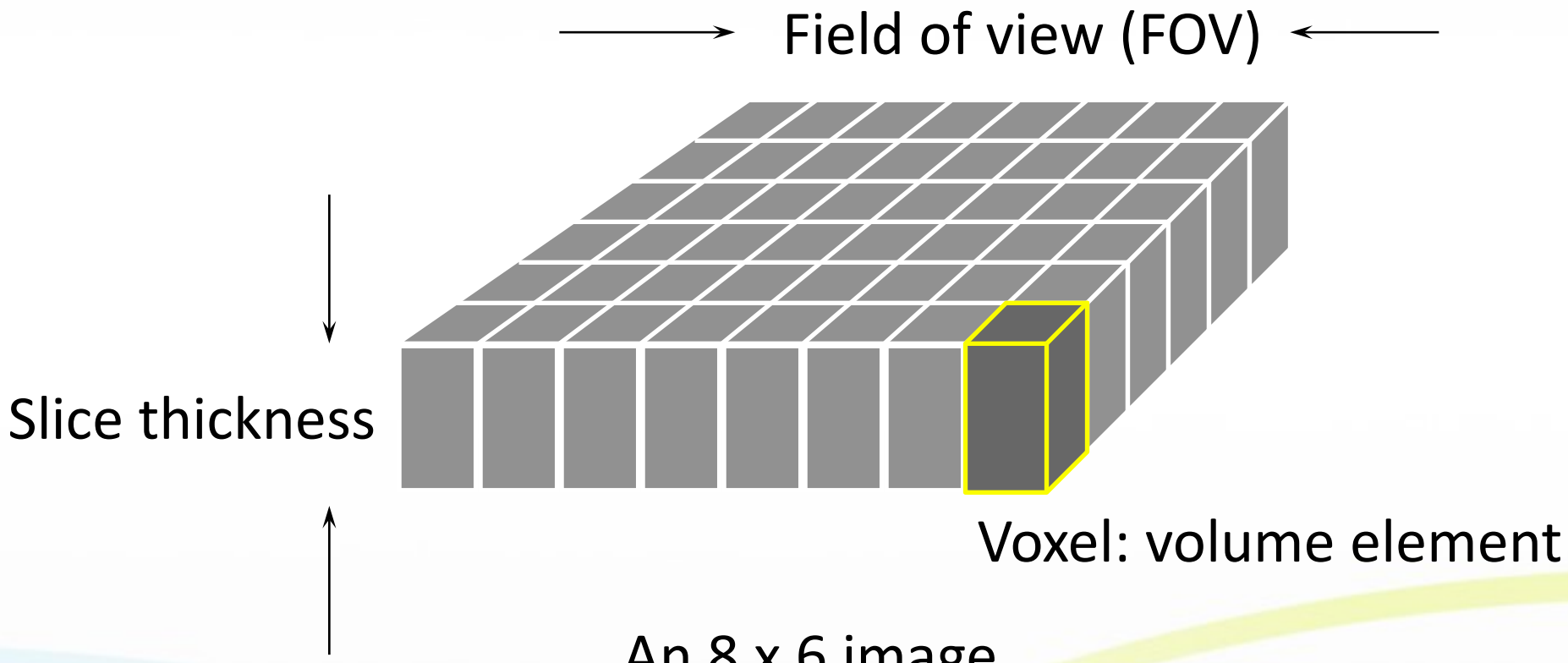


Image resolution

- The smallest size of an object that can be differentiated
- High resolution: larger matrix size or smaller voxel size (nominal)
  - Less partial volume effect
- 256 x 256 → 1024 x 1024?

How about 1024 image?

- A resolution of 0.24 mm with a conventional FOV of 24 cm
- Super strong noise (relative to signal intensity) due to small voxel
- Super long scan time: TR x 1024

What is a GOOD MRI?

- High spatial resolution
- High signal-to-noise ratio
- High contrast
- Short scan time: practical for clinical routine

What is a GOOD MRI?

- High spatial resolution
- **High signal-to-noise ratio**
- High contrast
- Short scan time: be practical for clinical routine

Signal-to-noise ratio

- Defined as the ratio of signal strength to noise level
- Relative intensity of signals (to noise)
- The higher SNR, the better image quality

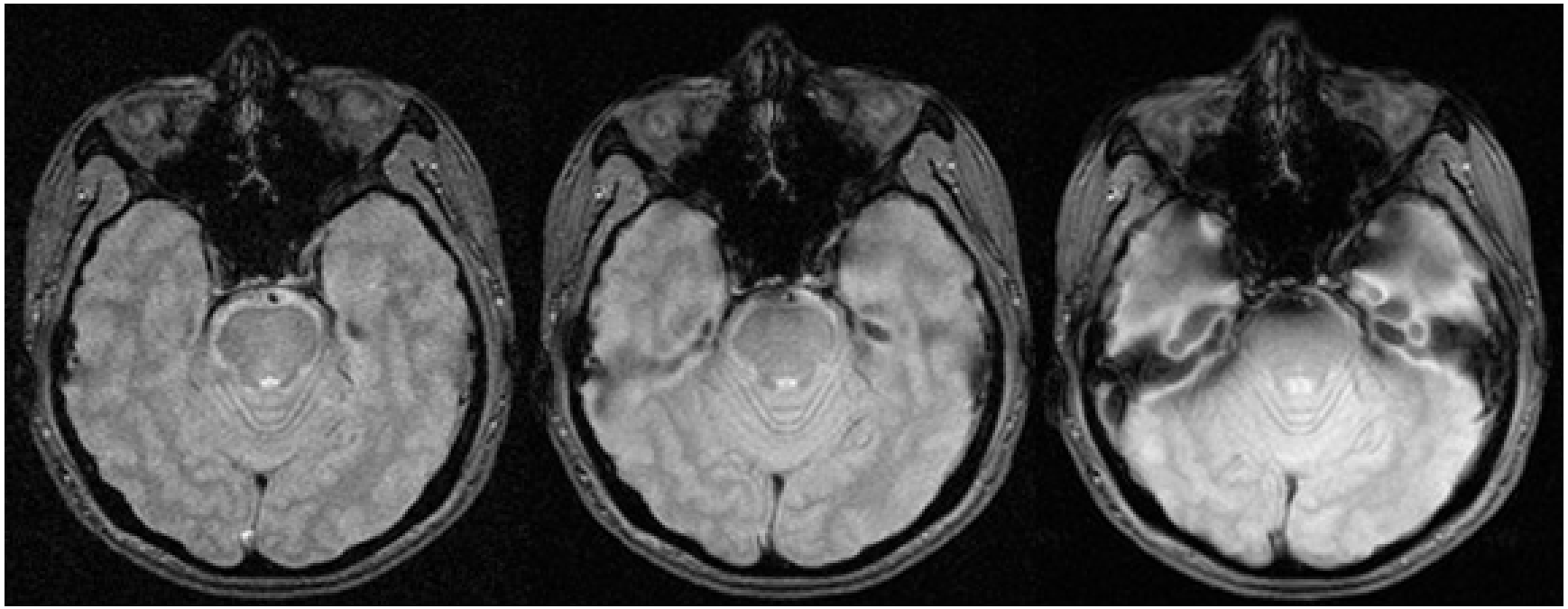
Factors of SNR

- Number of ^{1}H nuclei (~ voxel volume)
- TE and TR (T1/T2 relaxation)
- Number of sampling points
- Number of averages
- RF coil of reception
- Sampling frequency (readout bandwidth)

Number of ^{1}H nuclei (voxel volume)

- Larger volume means…
  - More ^{1}H nuclei
  - Higher SNR
  - Lower image resolution

Comparison of different slice thickness

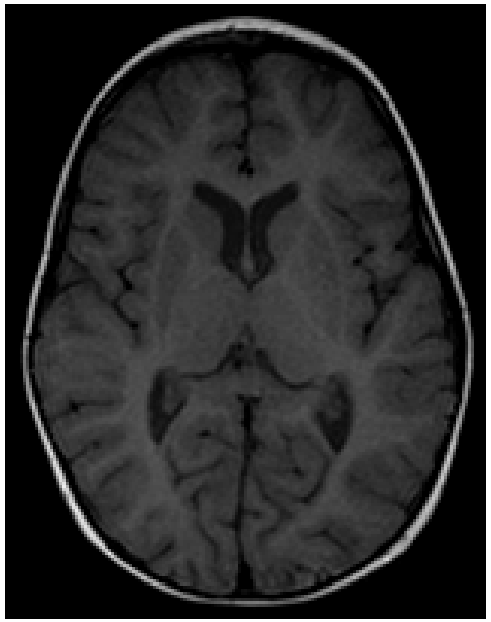


3 mm 5 mm 10 mm

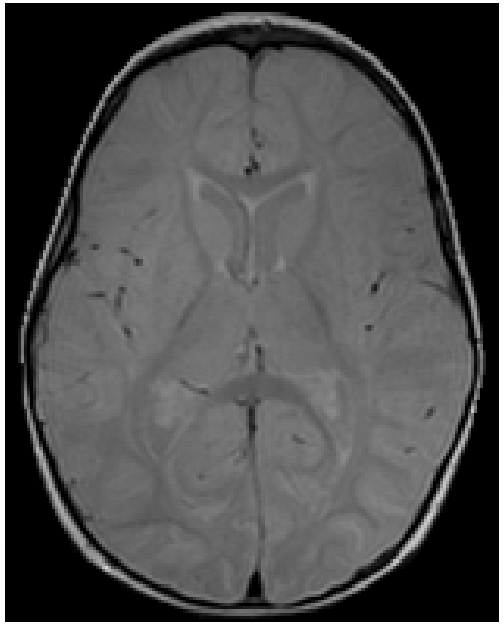
TE and TR

- Longer TR means…
  - More time for T1 recovery and better SNR
  - Less T1 contrast and longer scan time
- Shorter TE means…
  - Less T2/T2* decay and better SNR
  - Less T2 contrast

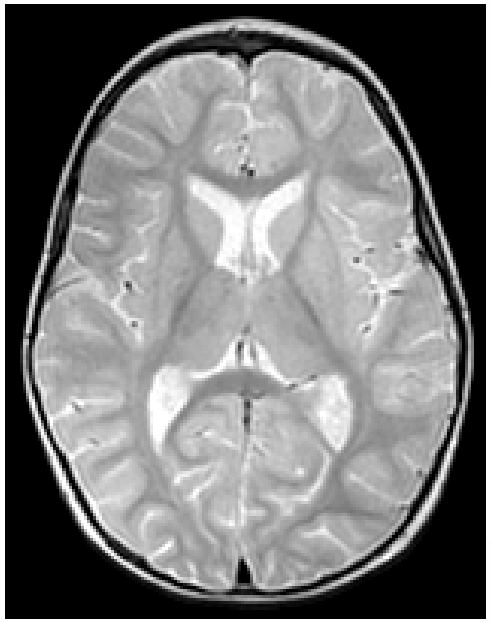
Comparison of TR: SNR and T1 contrast



TR = 600

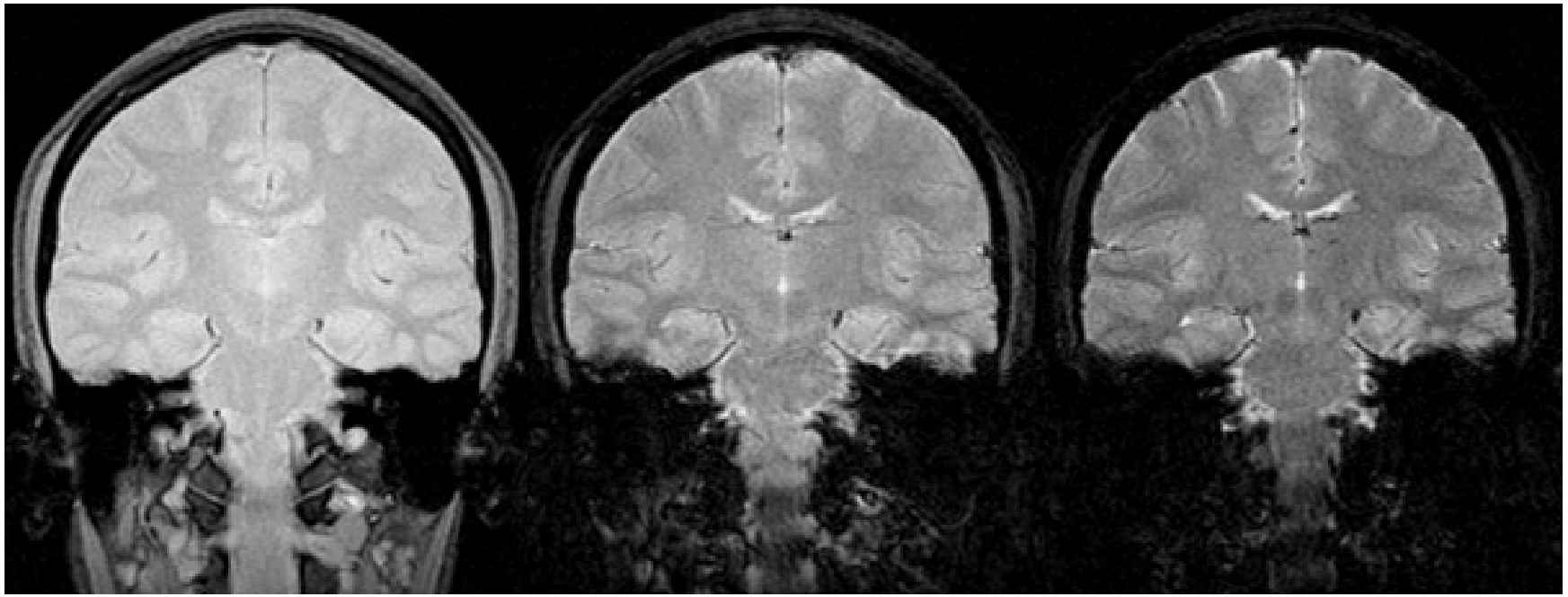


TR = 2400



TR = 4200

Comparison of TE: SNR and T2 contrast



TE = 10 TE = 30 TE = 50

What is a GOOD MRI?

- High spatial resolution
- High signal-to-noise ratio
- High contrast
- Short scan time

Number of sampling points

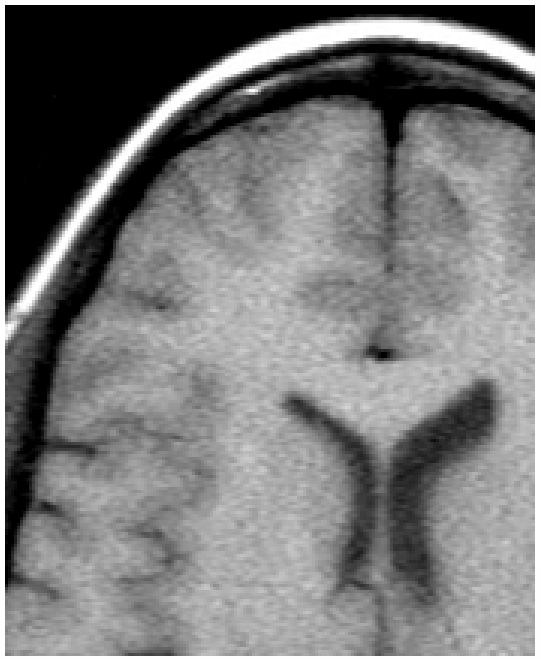
- More sampling points on the same object brings higher SNR.
  - Noise reduced with signal intensity unchanged
- For a fixed FOV, more sampling points also leads to smaller voxel size, which decreases SNR.
- Consideration of both sides

Example: given FOV = 24 cm

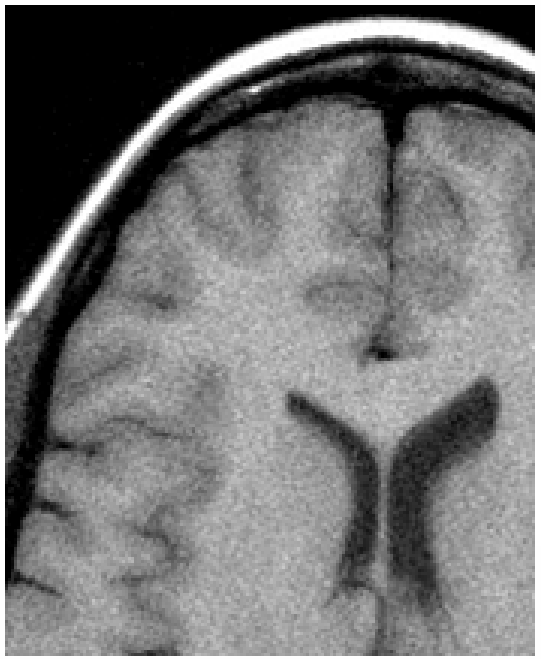
- From 256x128 to 256x256
  - Sampling points doubled → increase SNR by ~40%
  - Voxel size shortened to half → reduce SNR to half
- Overall, SNR is decreased by 30%

Comparison of different sampling points

256x256



512x256



512x512

Number of averages

- Number of signal averages (NSA); number of excitations (NEX)
- More number of averages → higher SNR
- At the cost of longer scan time

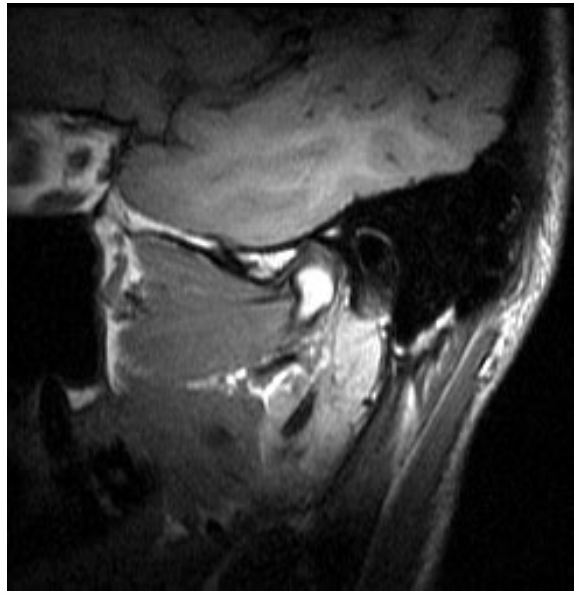
Usage of RF coil (reception)

- A smaller volume coil provides better SNR than a larger one.
- Surface coils usually provide better SNR than volume coils.
- Depending on scanning purpose

Comparison of RF coils

Body coil

Head coil



3” Surface coil

Sampling frequency (readout bandwidth)

- Higher sampling frequency means…
  - Higher noise power from wider bandwidth
  - Shorter minimal TE…
  - Less chemical shift…
- A variable that is seldom adjusted in clinical protocols

Summary:

- SNR is proportional to…
  - Number of ^{1}H nuclei
  - Voxel size (in-plane width and through-plane thickness)
  - $\sqrt{\text{Number of matrix entries}}$
  - $\sqrt{\text{Number of averages}}$
  - $1/\sqrt{\text{Sampling frequency}}$
- Also influenced by tissue properties (T1, T2) and timing parameters (TR and TE)

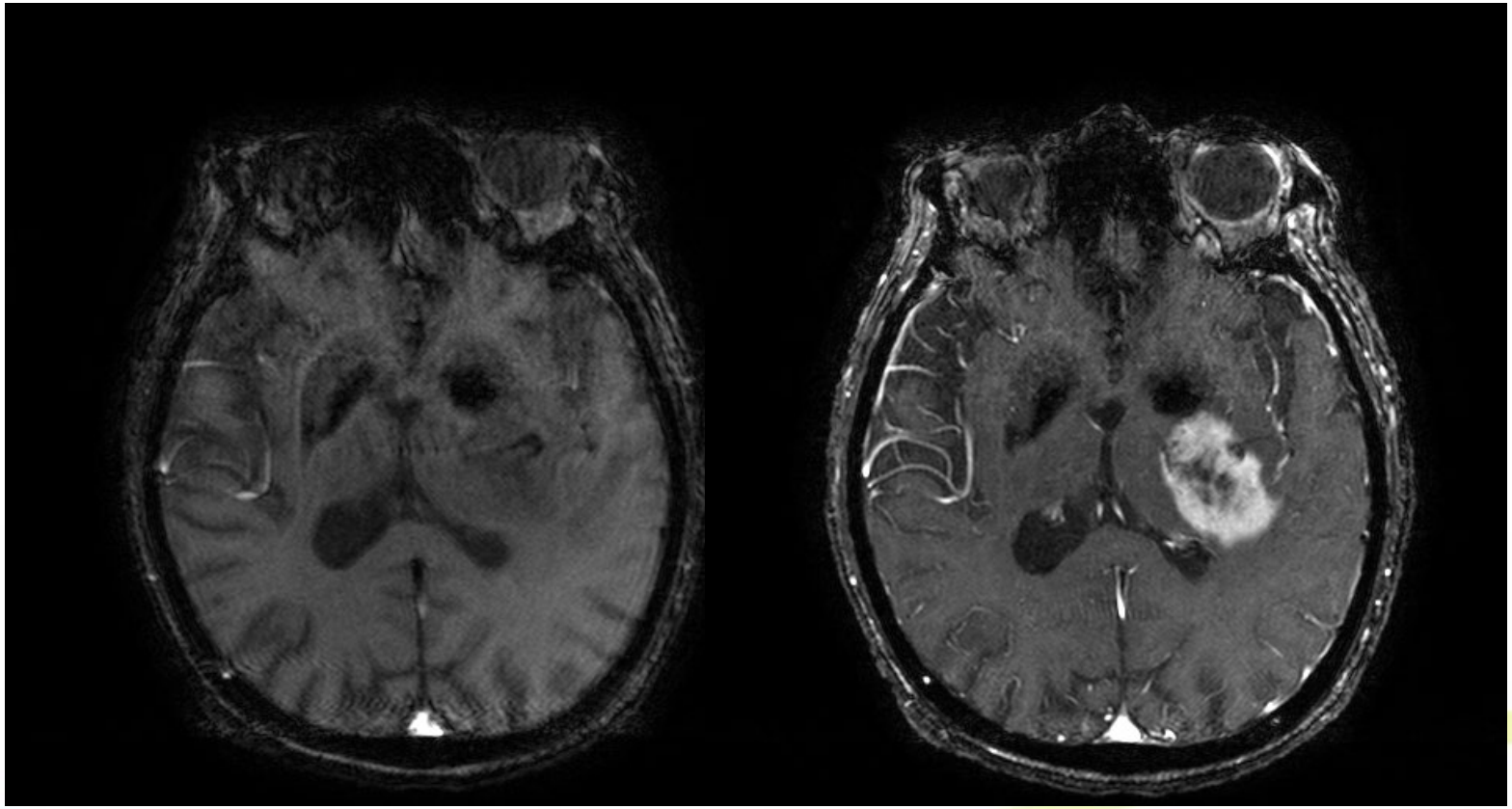
What is a GOOD MRI?

- High spatial resolution
- High signal-to-noise ratio
- **High contrast**
- Short scan time

High tissue contrast

- Optimize TR and TE according to tissue relaxation
- Contrast enhancement by imaging properties of
  - Blood flow
  - Molecular diffusion
  - Contrast agent

MR contrast agent: paramagnetic ions (Gd^{3+})



Pre-contrast Post-contrast

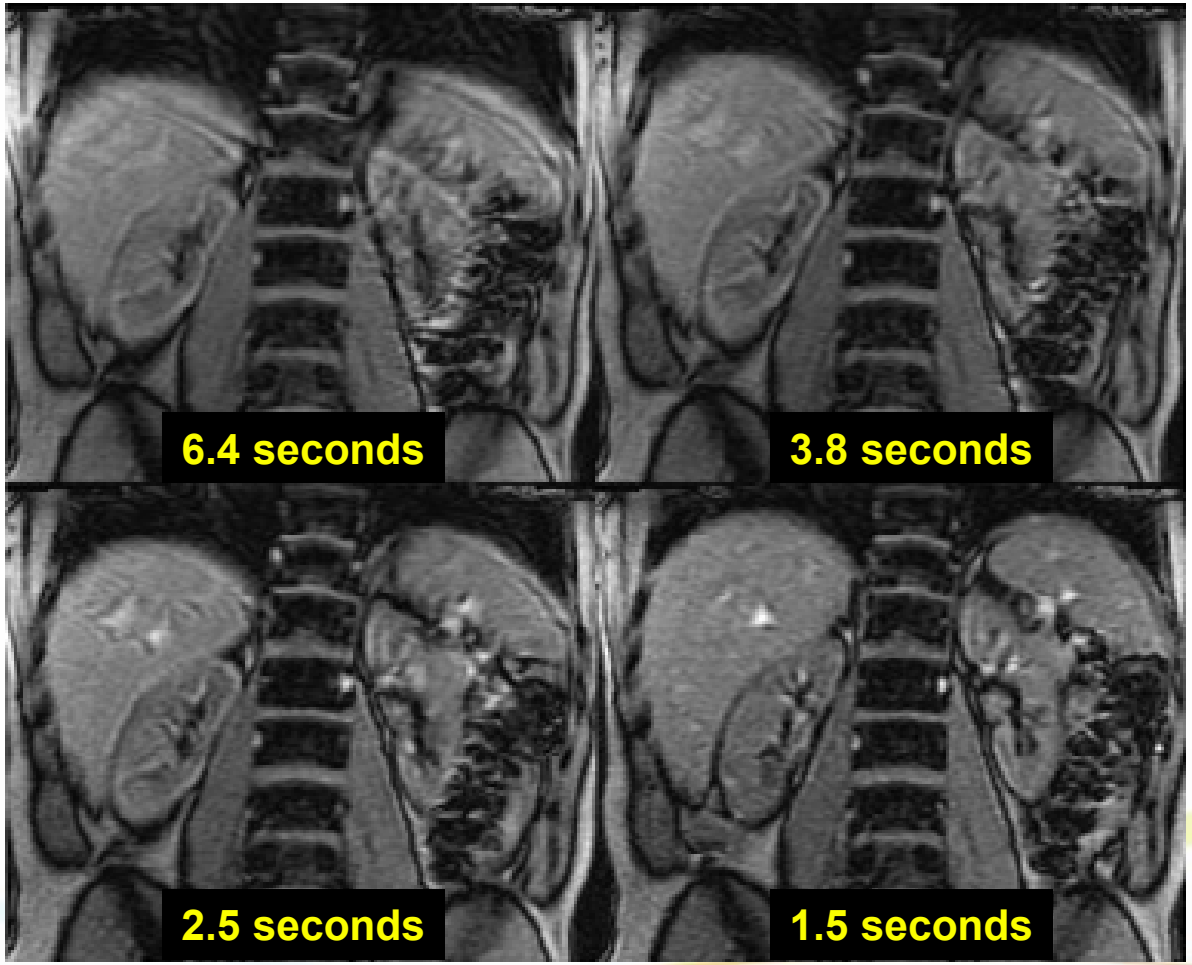
What is a GOOD MRI?

- High spatial resolution
- High signal-to-noise ratio
- High contrast
- **Short scan time**

Scan time = TR x N_{PE} x NEX

- Shorter scan time means…
  - Comfort of patients
  - Lower cost of an MRI scan (more efficient)
  - Lower risk of motion: for both intra-scan and inter-scan

Comparison of scan time: intra-scan artifact



MR Image Quality