

MRI System Quality Control

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'08 KSMRM MR연수강좌

Magnetic resonance imaging

Diagnosis

Qualitative

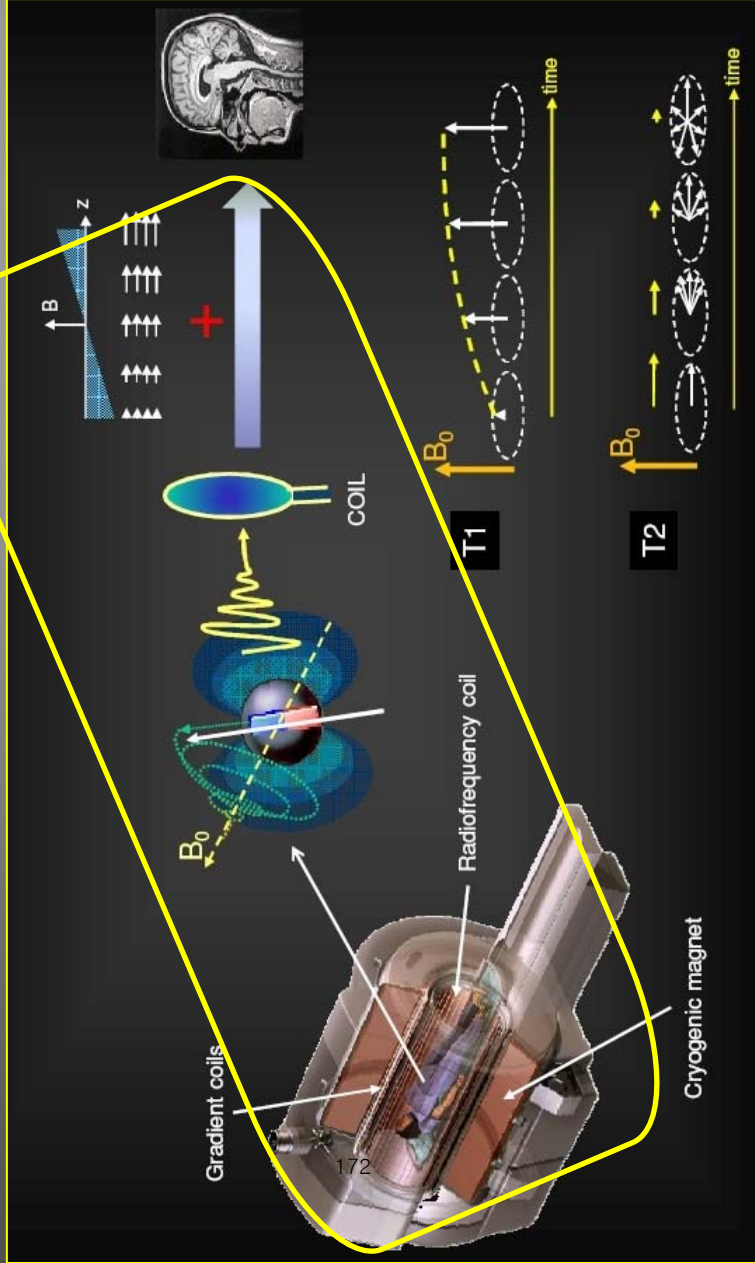
Local variation in signal intensity

T1, T2, PD, flow,...

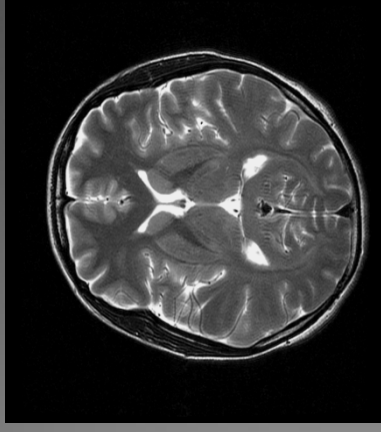
Enhancement (by agent)

Simple, but subjective

Blackbox

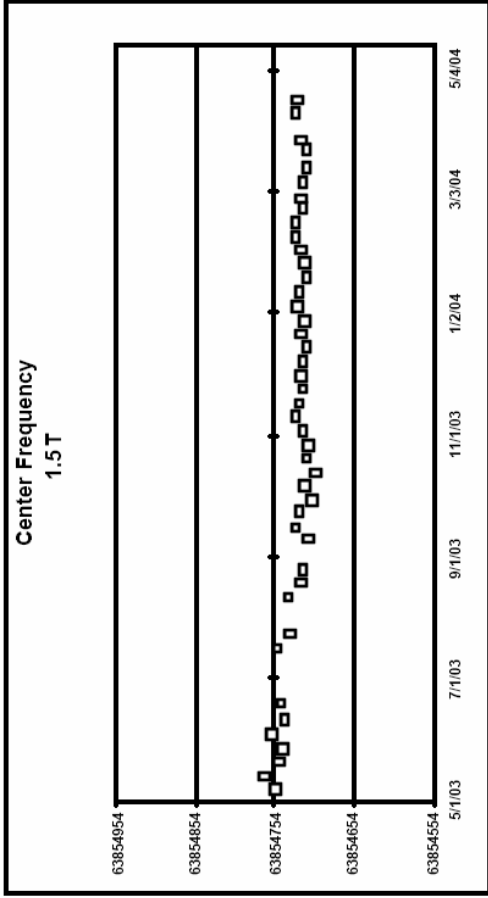


$$S \propto \rho \left(1 - e^{-\frac{TR}{T_1}} \right) e^{-\frac{TE}{T_2}}$$



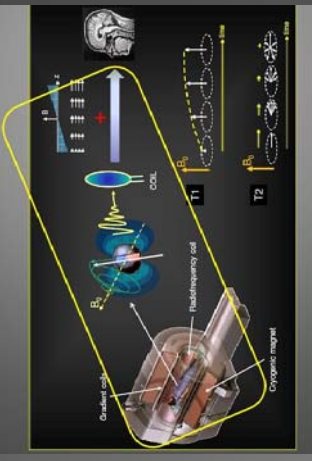
Magnetic field

center frequency – high field

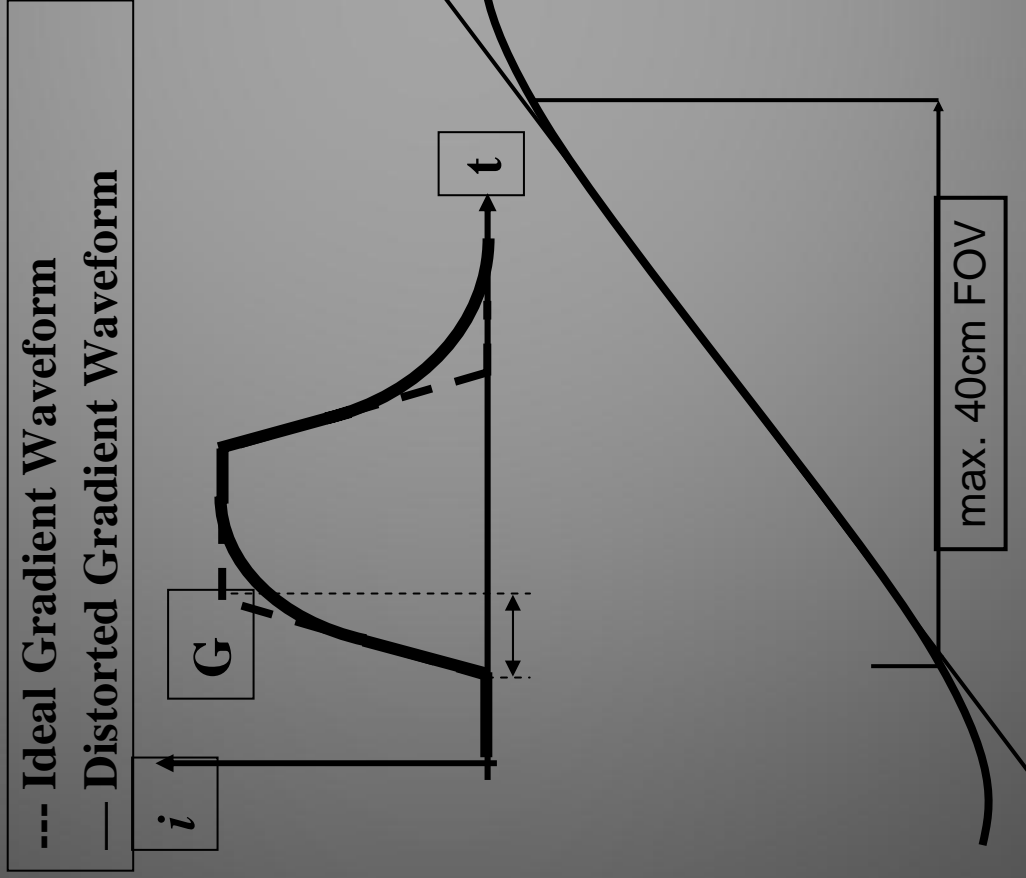


- ◆ Action limits: 63,854,754 +/- 100 Hz
- ◆ horizontal gridlines = 100 Hz

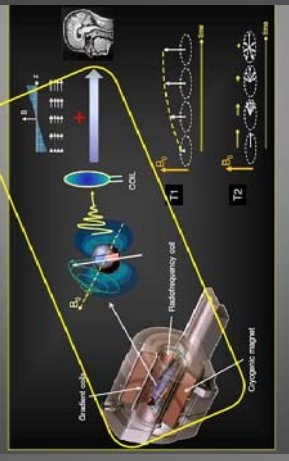
Drift sources
 Natural decay
 Subject
 Tissue susceptibility



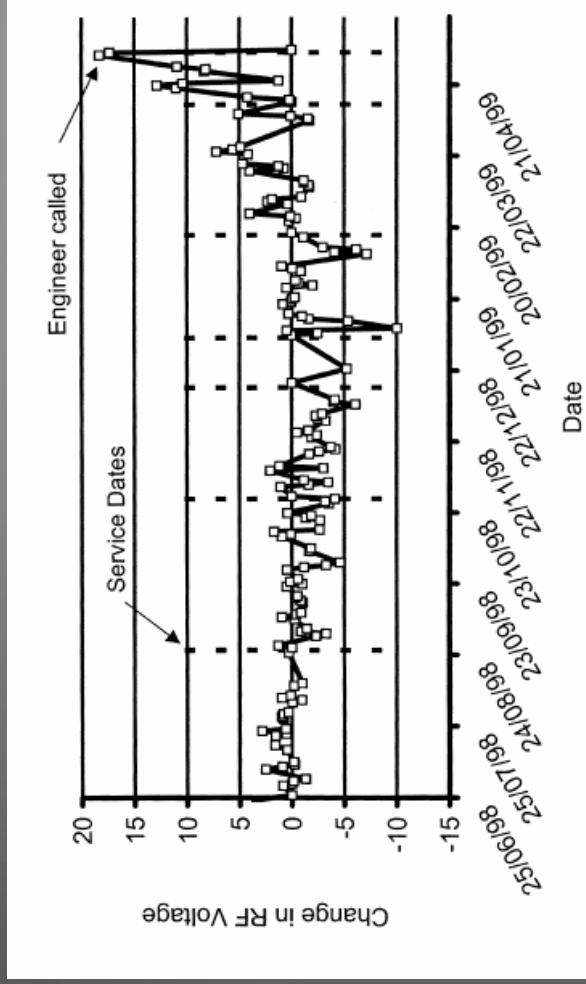
Gradient field



Drift sources
Eddy current
Amplifier error

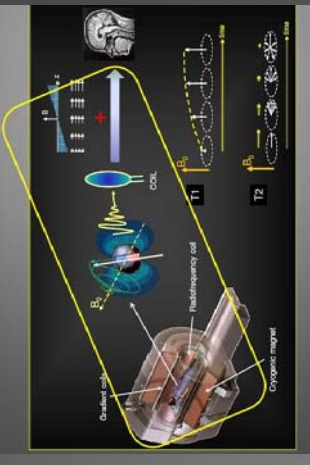


RF field



Transmitter

- Drift sources
- Coil failure
- Loading factor
- Amplifier error

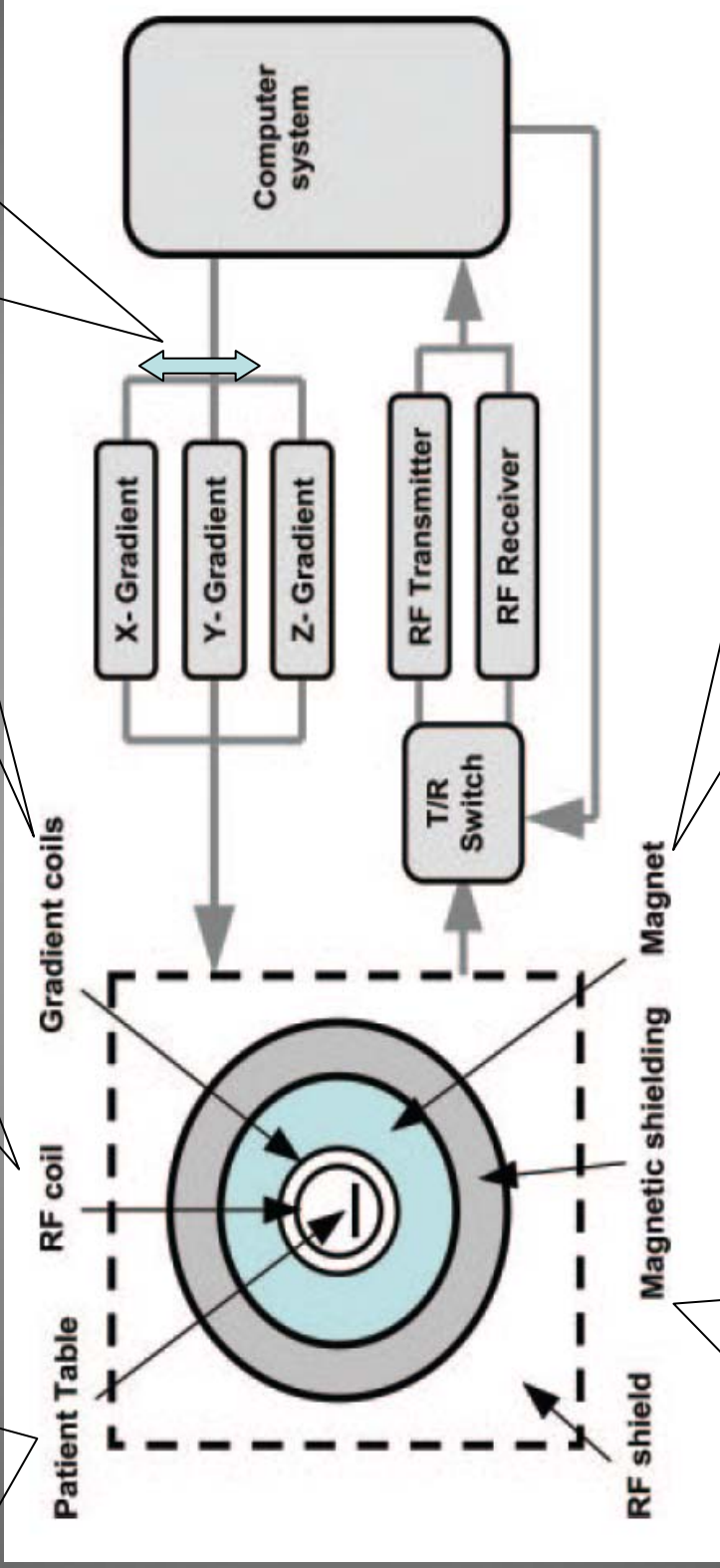


Precise movement

Uniformity

Linearity

Amplifier stability



Block

Homogeneity, Stability

Variation in signal intensity

System performance

Gradient, RF and Coil systems

Causes in variation

- Drift in RF Electronics

RF Coils

RF Transceiver Chain

- Magnetic Field Decay
- Gradient system failures

- Overload of MRI system by a variety of sequences and their measurement parameters

- Introduction of material producing MRI signal
(Foreign ferro- or para- magnetic material)

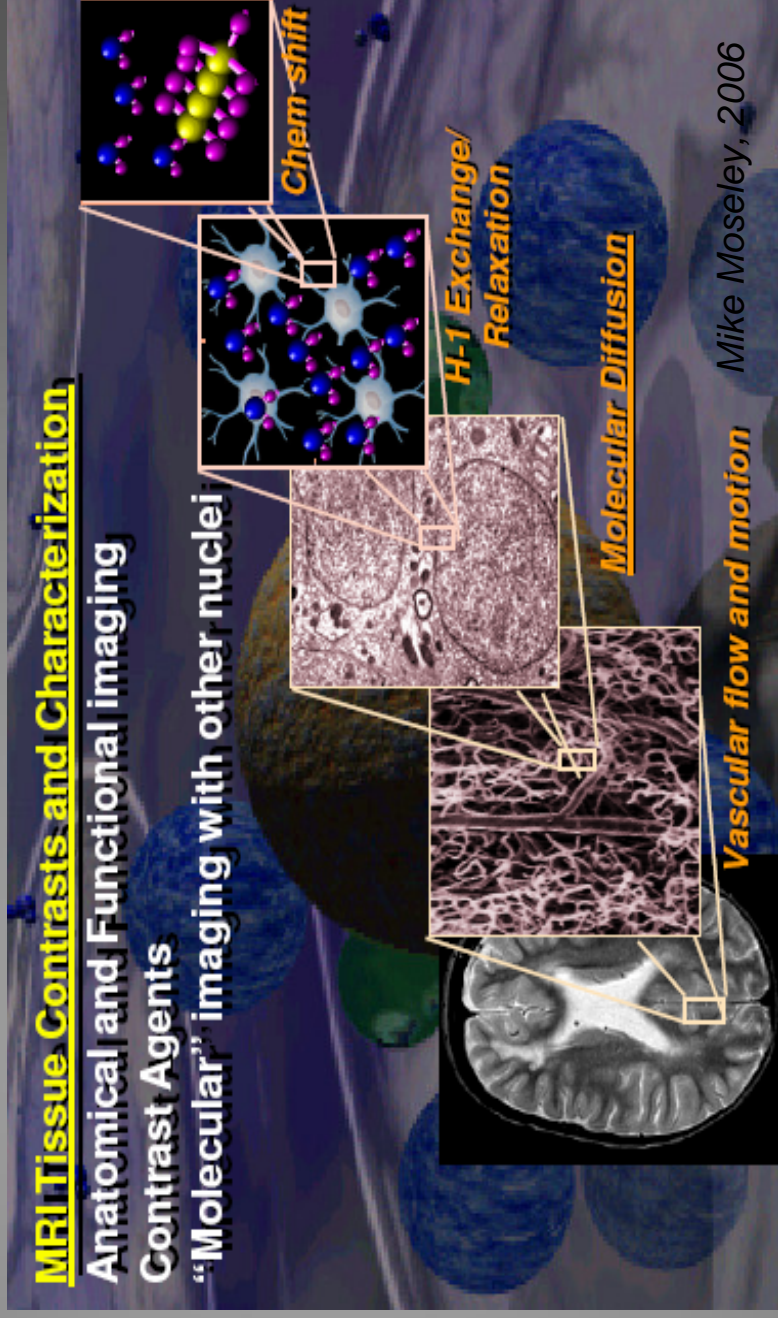
New approaches in MRI

High resolution

Dynamic image

Diffusion MRI

Spectroscopy

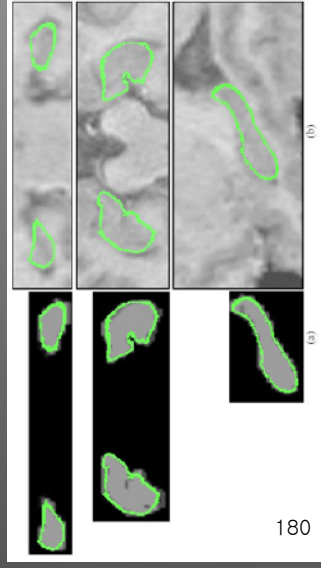


Quantitative MRI

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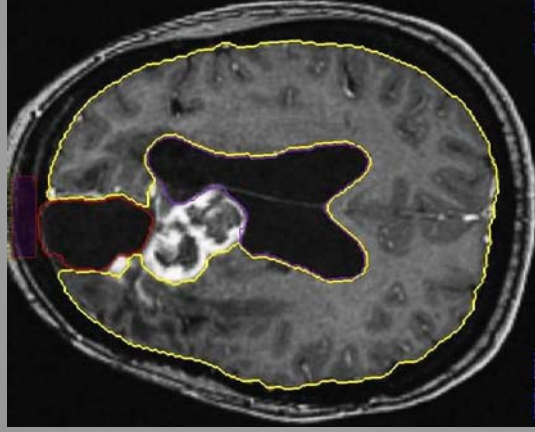
- Quantitative MRI
 - Absolute quantification of physical parameters
 - Volume, Distance, Area
 - Shape
 - Relaxation time
 - MTR, Diffusion, Metabolites' concentration, Flow
 - Kinetic parameters: perfusion, permeability
- Complex, but objective

Hippocampus

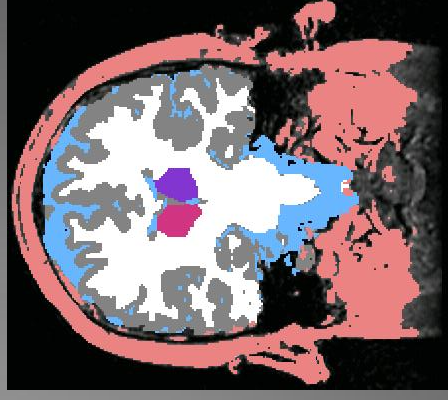
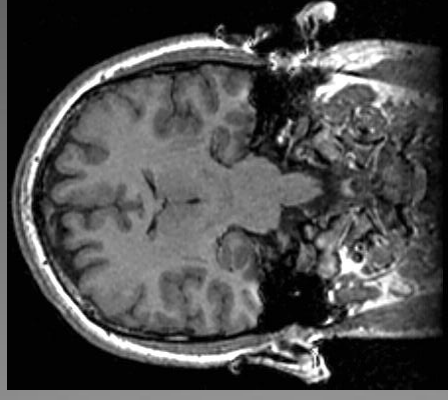


Shape analysis

Tumor



Cortical region



Anatomical image

Volumetric analysis
Segmentation

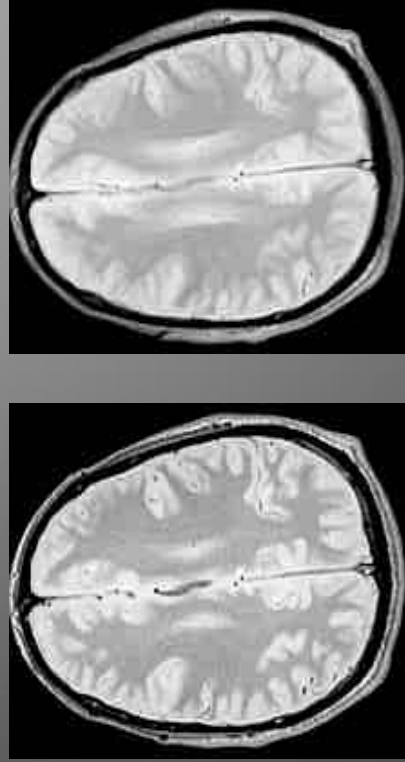
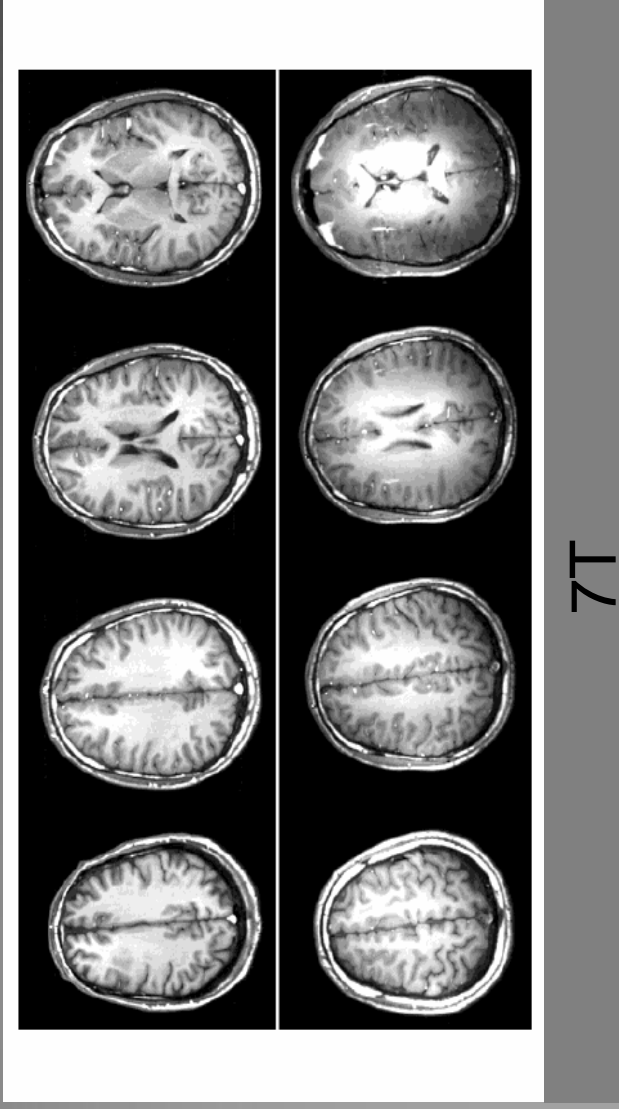
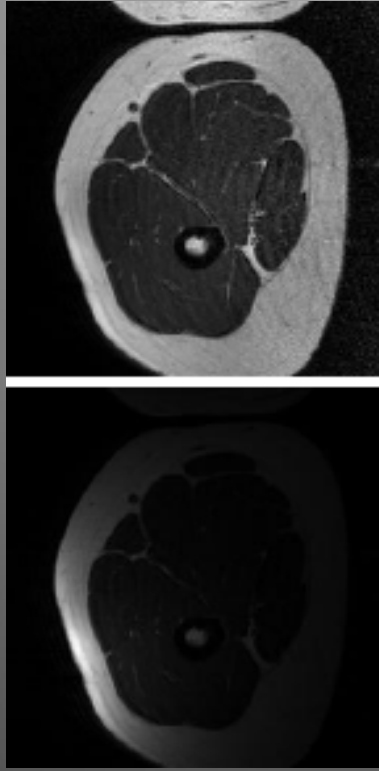
Signal intensity-based

Mutual Information, Expectation -Maximization

perform poorly in structures where there is a
small intensity difference between the inside
and outside of the structure

Pitfalls in segmentation

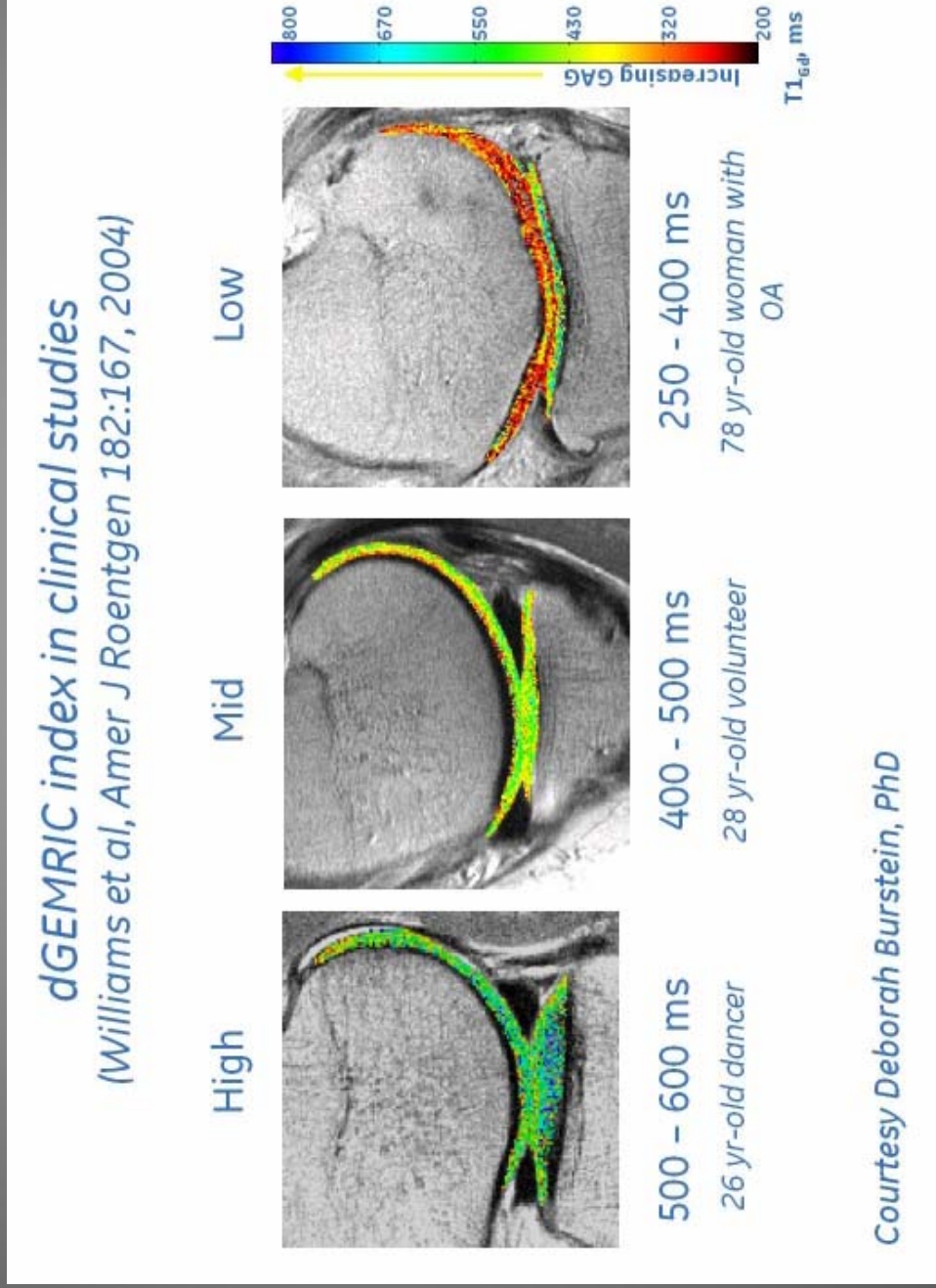
Uniformity



Partial volume(3/10mm)

dGEMRIC technique

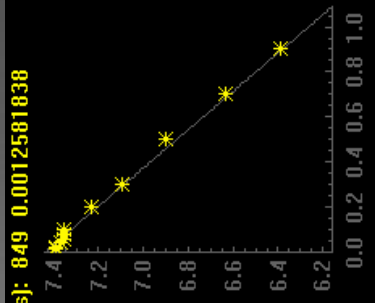
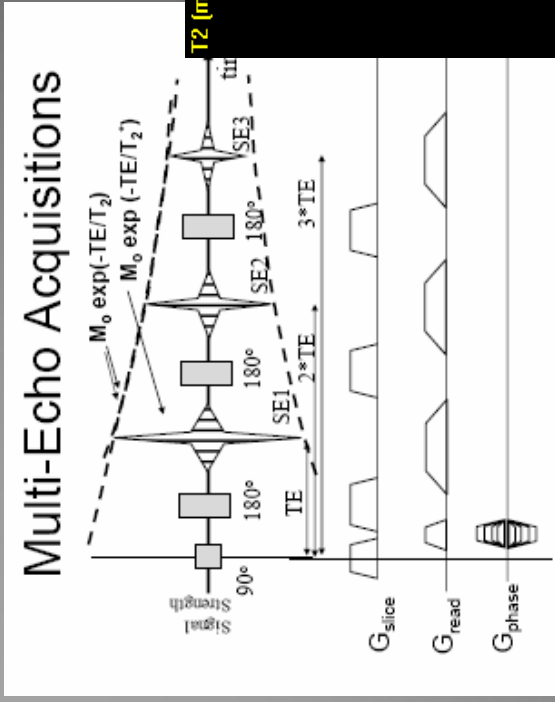
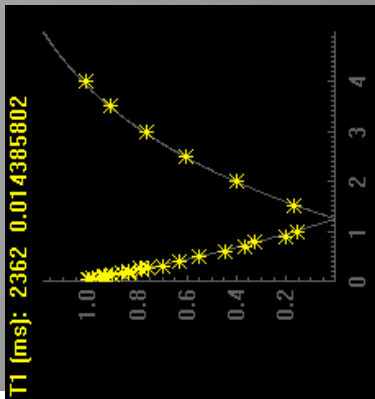
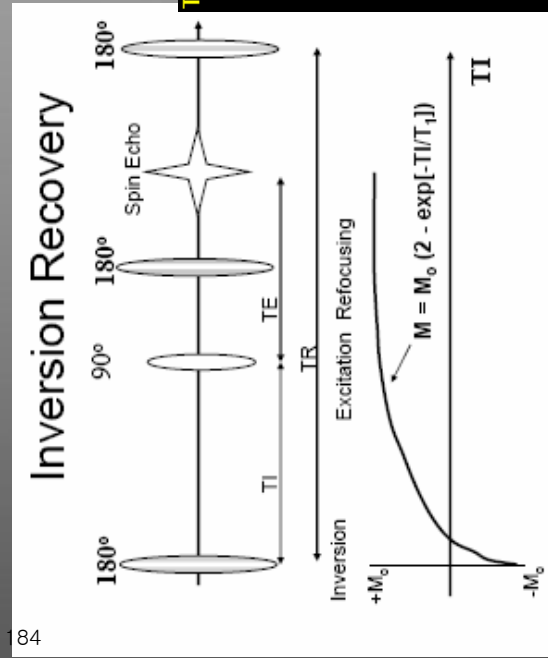
for the noninvasive diagnostics of cartilage-related diseases
Concentration of negatively charged GAGs (glycosaminoglycans)

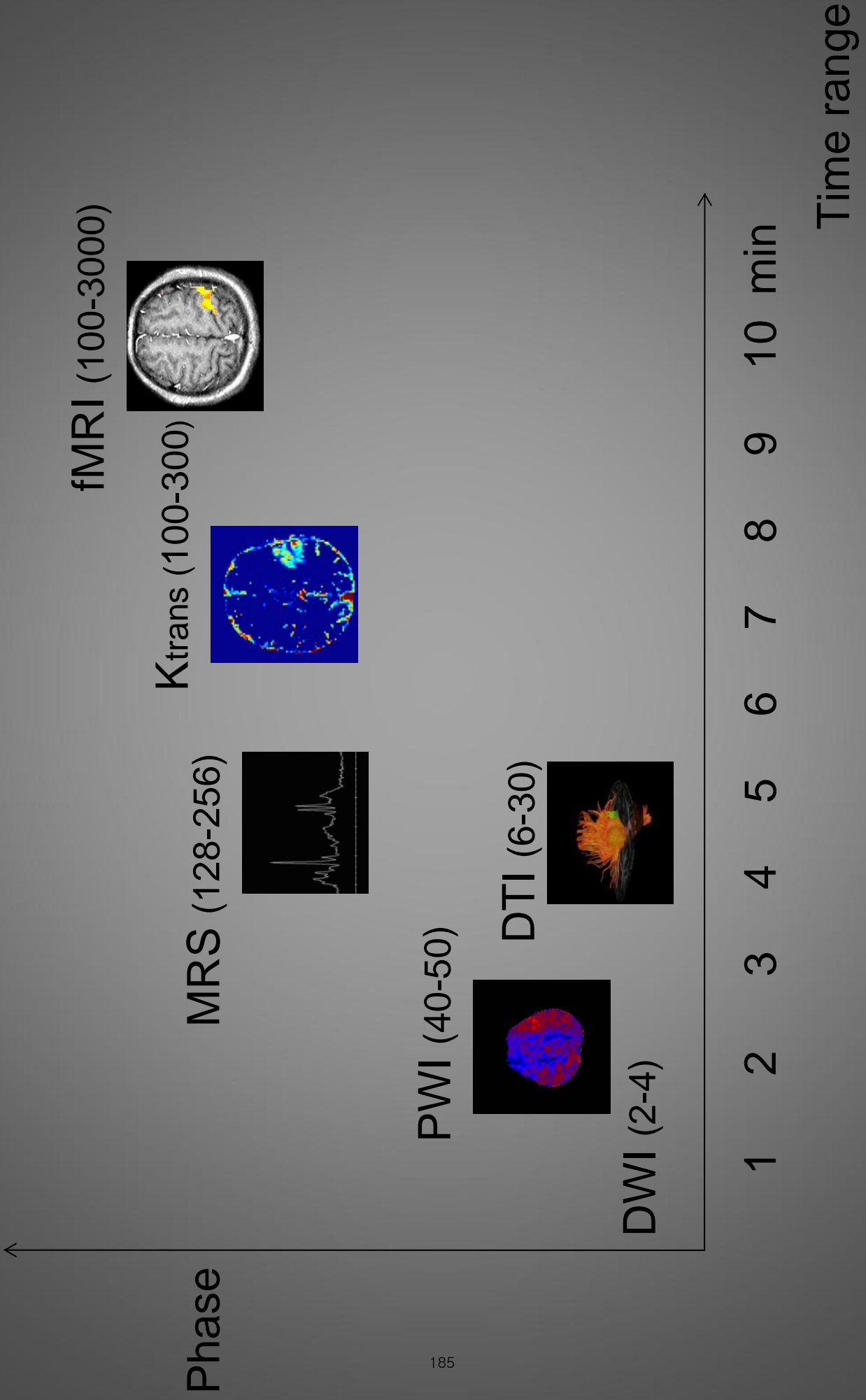


- Measurement of relaxation time
 - Multiple scans

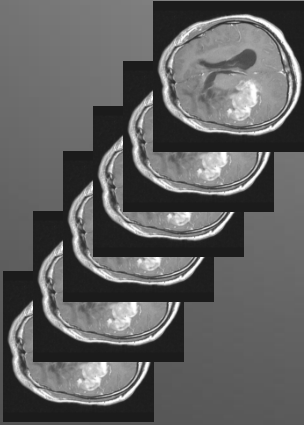
- T2: TES (10,2000ms)
 - CPMG (8-10 min)

- T1: T1S (10,...,3000ms)
 - IR-FSE (30 min)



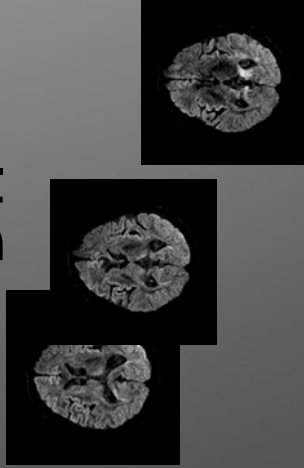


Perfusion



N=40,.. 200

DTI

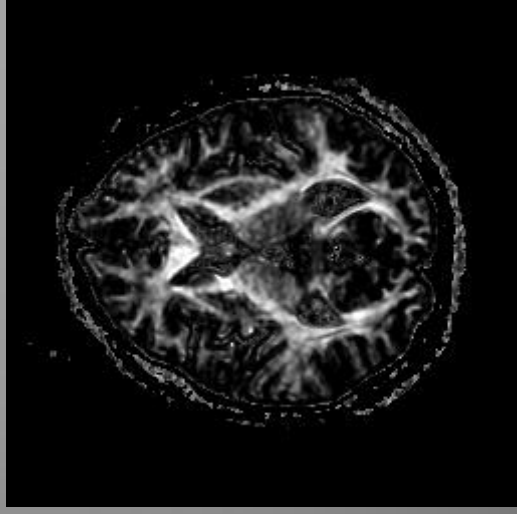
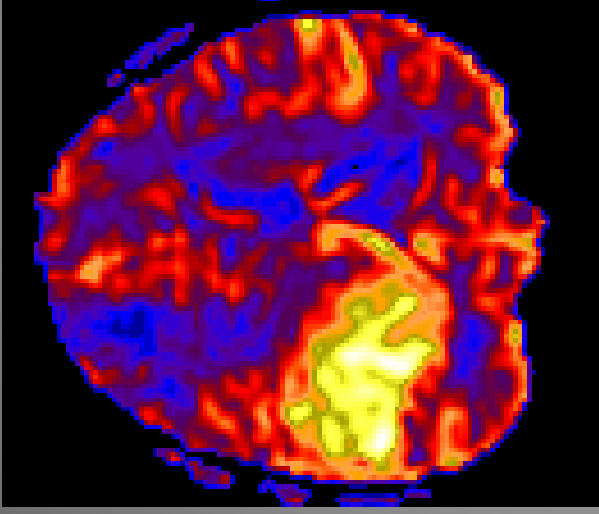


N=7,.. 30

Basic requirements in dynamic study

-Stability of signal intensity in time
sec – min

-The same location of pixels in all images
w/o patient's motion
sequence without distortion



Dynamic or multiphase image

Multiple images

by repeated sequence

by repeated sequence with a little different contrast

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Extraction of parameters by modeling and its fitting procedure

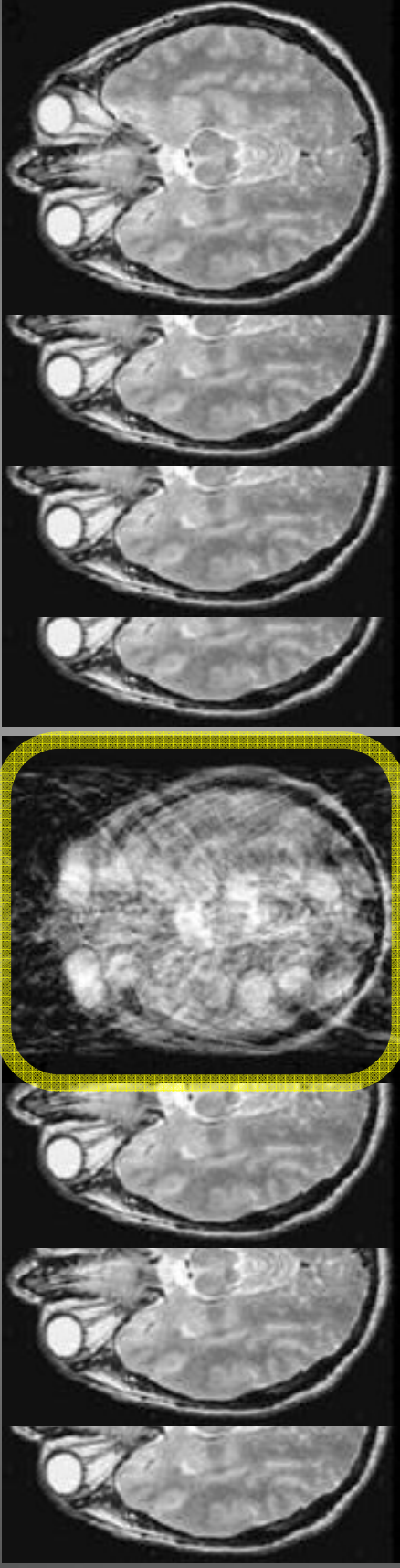
Hemodynamics

Angiogenesis

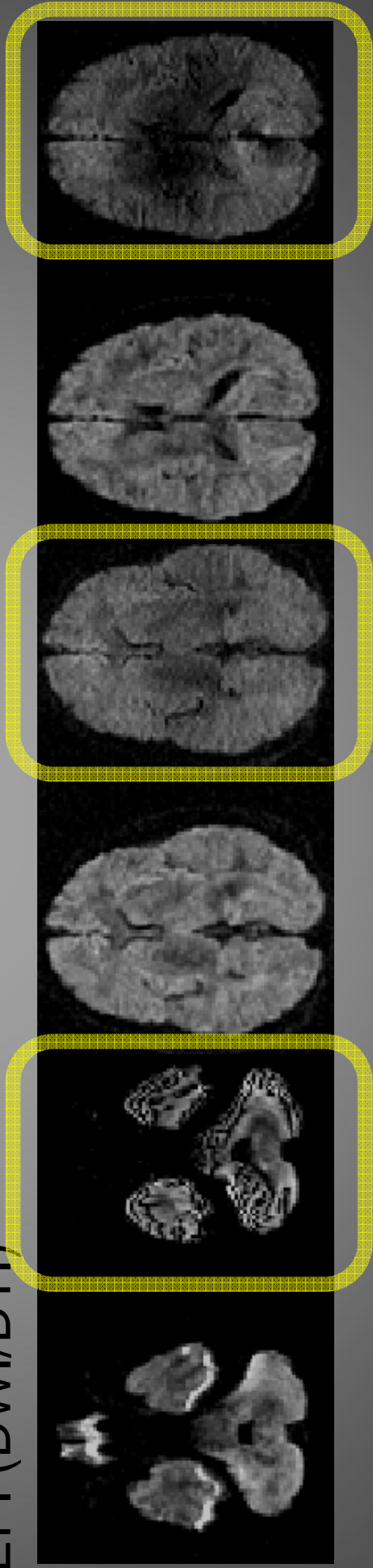
Diffusion, Fractional Anisotropy

Pitfalls in dynamic and multiphase images

Dynamic imaging



EPI (DWI/DTI)



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Requirements in quantitative MRI

High system performance
High SNR
Geometry
Stability

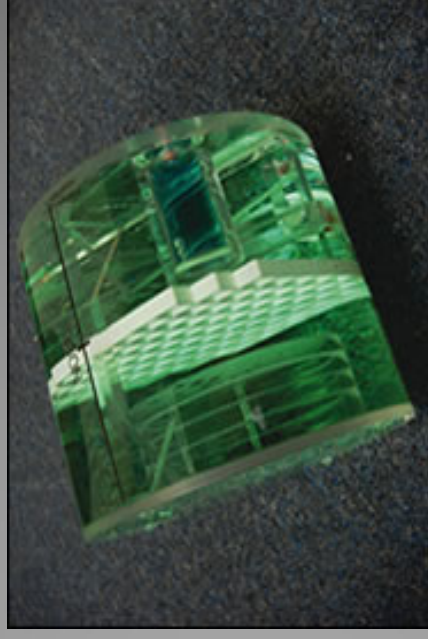
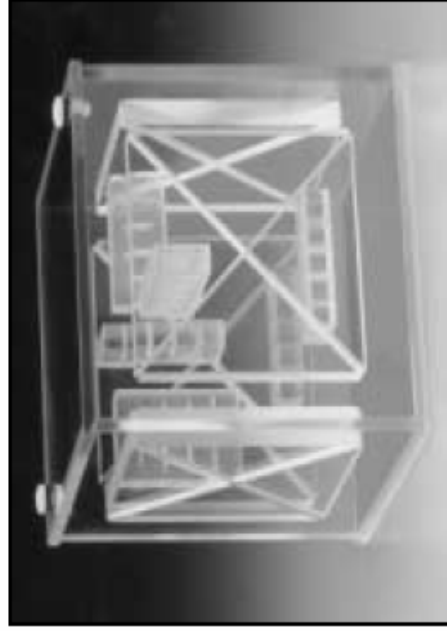
Standardization of
MR protocol and
analysis

Quality control

Cooperation in multi-center

hard to evaluate system performance by clinical images
-> evaluate each evaluation item by phantom

3-D SLICE THICKNESS/HIGH-CONTRAST
RESOLUTION PHANTOM



Several Types of MRI Phantom



Small Spherical Phantom

QC Phantom

KSPM

Quality control by use of a multi-purpose phantom

Geometry information and Contrast

Geometry information

slice thickness

distortion

resolution

Contrast

low contrast

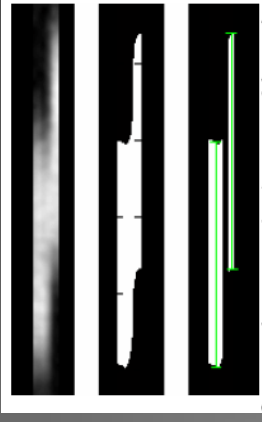
artifact

signal uniformity

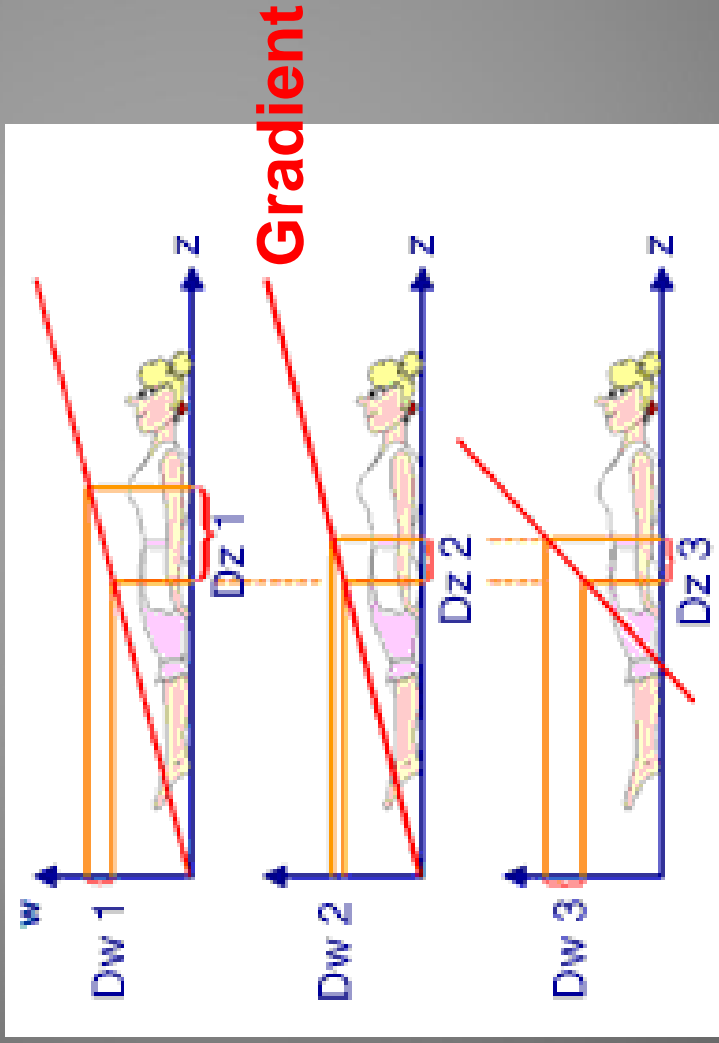
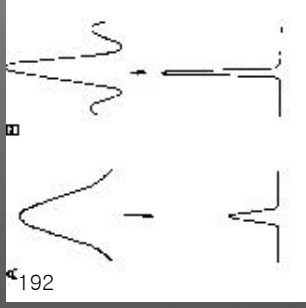
Stability

Temporal variation

Slice profile Wedge method

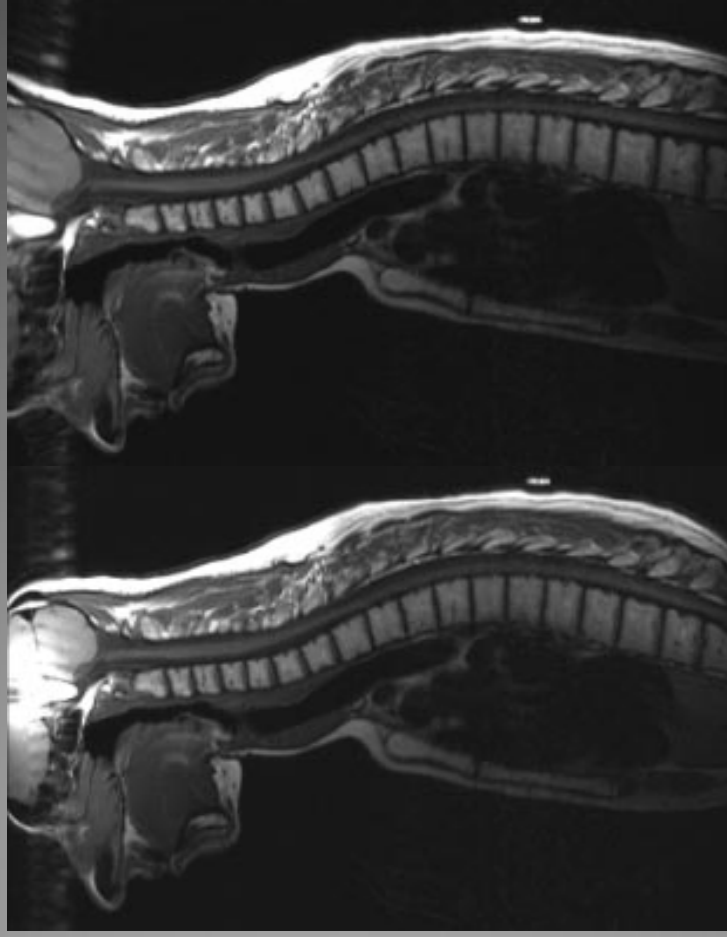
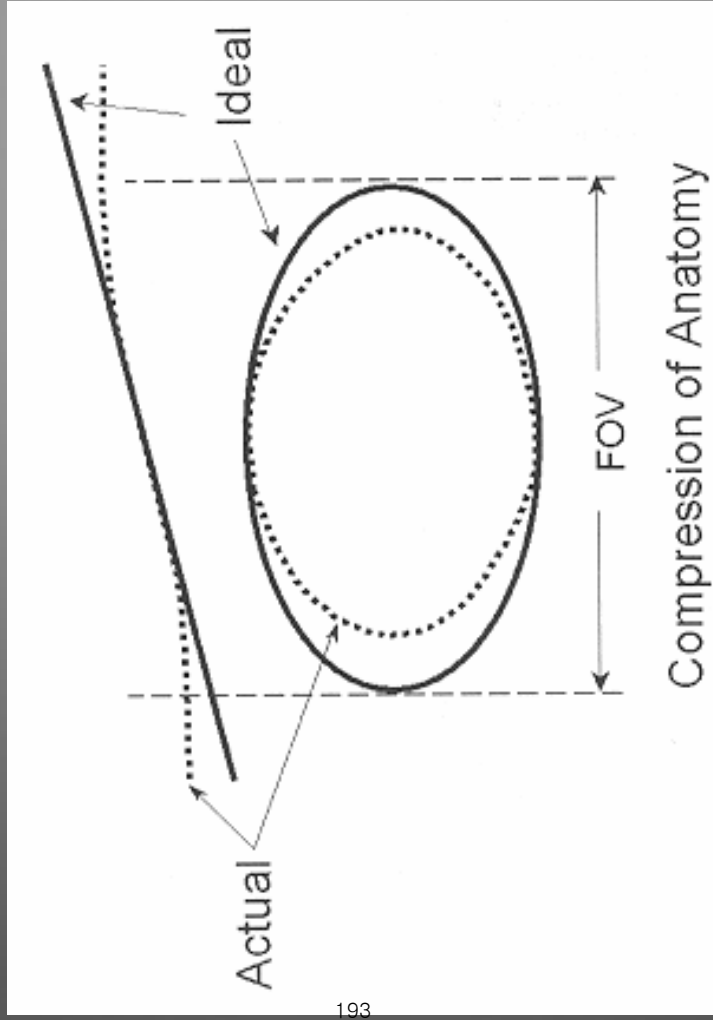
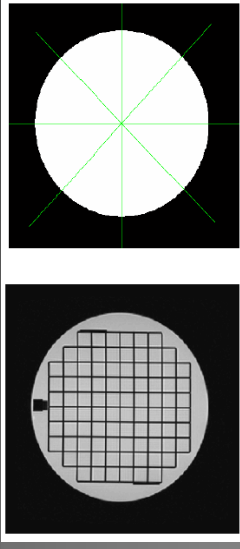


RF



$$\Delta z = \frac{\Delta \omega}{\gamma \cdot G_z}$$

Geometry distortion

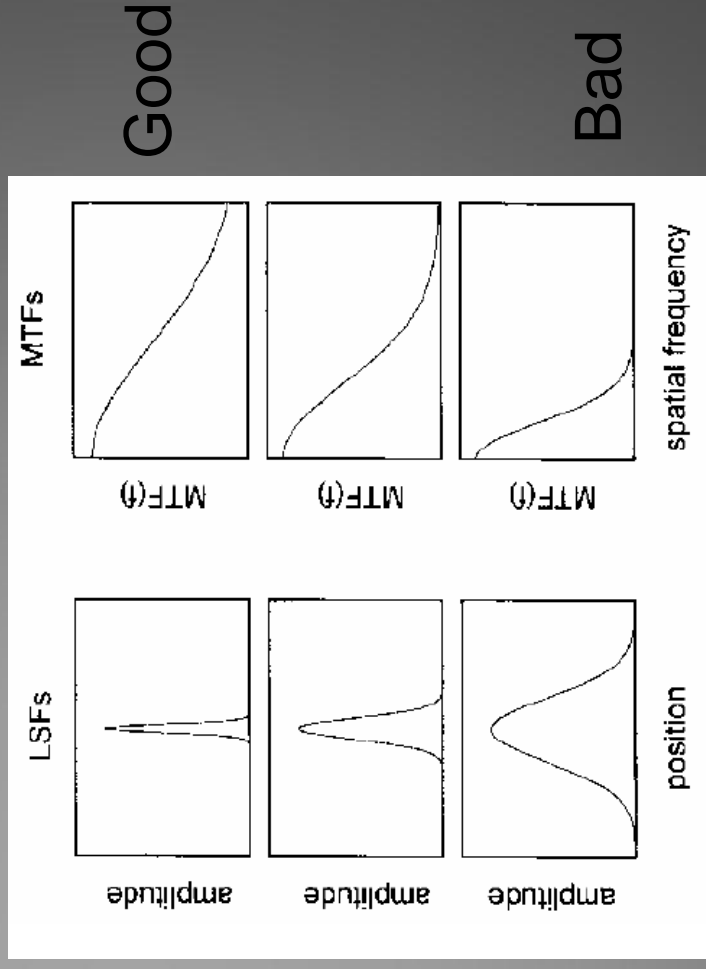
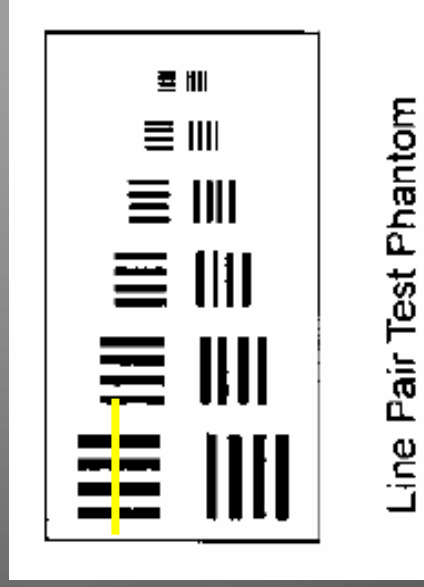
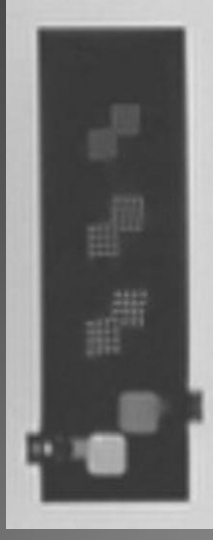


Spatial resolution

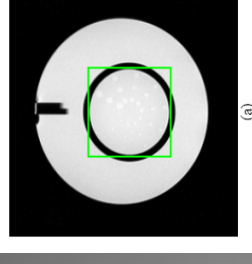
The ability of the MR system to **resolve** high SNR and CNR objects

Point spread function: pixel dimension

Modulation transfer function (MTF)



Low contrast



Contrast

Absolute contrast sensitivity ultimately limited by SNR
and presence of image artifacts

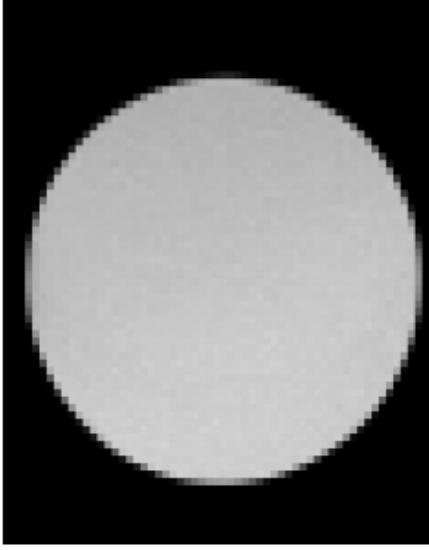
Artifact

Artifacts show up as positive or negative signal intensities that do not accurately represent the imaged anatomy

- Classified into three broad areas – based on the machine, on the patient, and on signal processing

Signal uniformity

Uniformity Narrow vs. Wide Width



Stability test

Repeated scanning
by the same sequence and its measurement parameters

Temporal variation

Signal intensity

Parametric values

MRI Analysis Software

Objective

Reproducible

Easy GUI

Processing time

Standardization
Protocol
Algorithm

Clinical routine tool

Volumetric analysis

- Shape analysis
- Metric analysis

NMR characteristics

- Relaxation time, MT

Physiological imaging

- Perfusion MR imaging
- Diffusion MR imaging
- Functional MR imaging
- Exchange rate MR imaging

Metabolic imaging

- MR spectroscopy

Quality control Standardization

Scan protocol

- High resolution
- Dynamic
- Multiphase

Software

- System-embedded

- Analyzer

- MRlcro

- AFNI

- SPM

- Mrdx

- SAGE

- LCModel

- jMRUI

QMRI for Diagnosis and Treatment monitoring

WHY QUALITY CONTROL ?

Quantitative imaging

Signal deviation =
measurement error
Geometrical distortion =
geometrical / positional error

Diagnostic imaging

Relative comparison of
tissue / structures
(Low spatial frequency
signal changes not
important)

Performance = sequence dependent
Performance = scanner dependent

Multi-center study : Comparable objective characteristics



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