Bioengineering 278
Magnetic Resonance Imaging

Winter 2009
Lecture 6
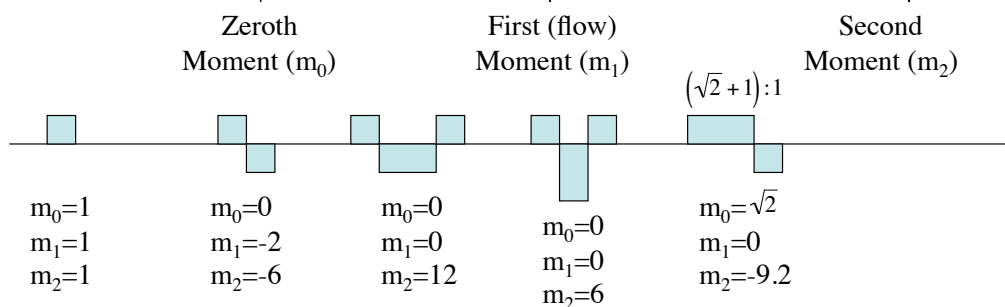
- •Magnetic Resonance Angiography
  - •Phase Contrast
  - •Time of Flight
  - •Contrast Enhanced

Spins flowing through a gradient
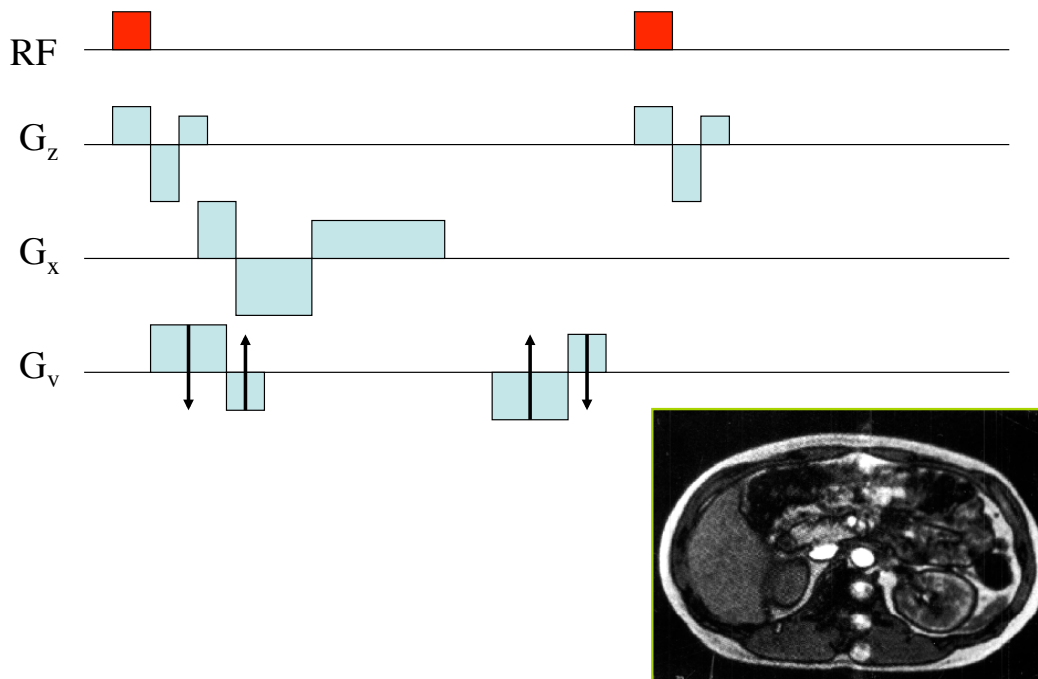
Phase from Motion:

$$\phi(t) = \int \gamma \vec{G}(t) \bullet \vec{r}(t)dt$$

$$= \int \gamma \vec{G}(t)(\vec{r}_0 + \vec{V}t + 1/2\,\vec{A}t^2\,...)dt$$

$$= \vec{r}_0 \bullet \underbrace{\int \gamma \vec{G}(t)dt}_{\substack{\text{Zeroth} \\ \text{Moment } (m_0)}} + \vec{V} \bullet \underbrace{\int \gamma \vec{G}(t)tdt}_{\substack{\text{First (flow)} \\ \text{Moment } (m_1)}} + \vec{A} \bullet \underbrace{\int 1/2\,\gamma \vec{G}(t)t^2dt}_{\substack{\text{Second} \\ \text{Moment } (m_2)}}$$

$(\sqrt{2}+1):1$

$m_0=1$
$m_1=1$
$m_2=1$

$m_0=0$
$m_1=-2$
$m_2=-6$

$m_0=0$
$m_1=0$
$m_2=12$

$m_0=0$
$m_1=0$
$m_2=6$
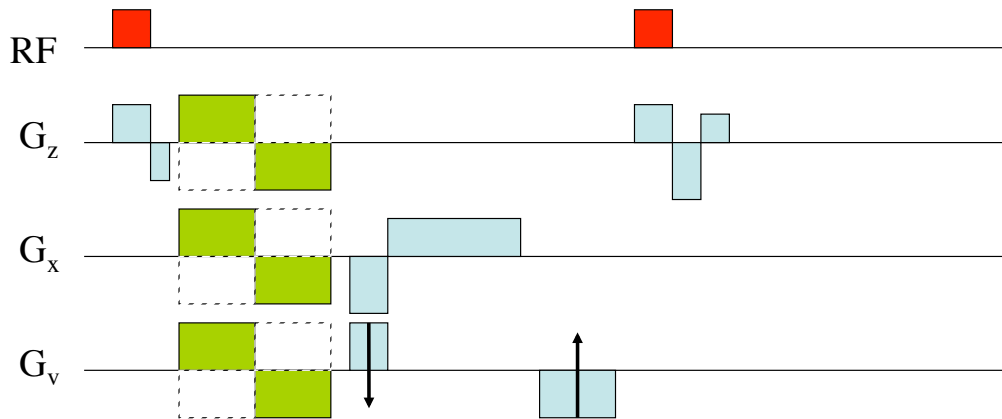
$m_0=\sqrt{2}$
$m_1=0$
$m_2=-9.2$

Flow Compensated Imaging

Flow Sensitive Imaging
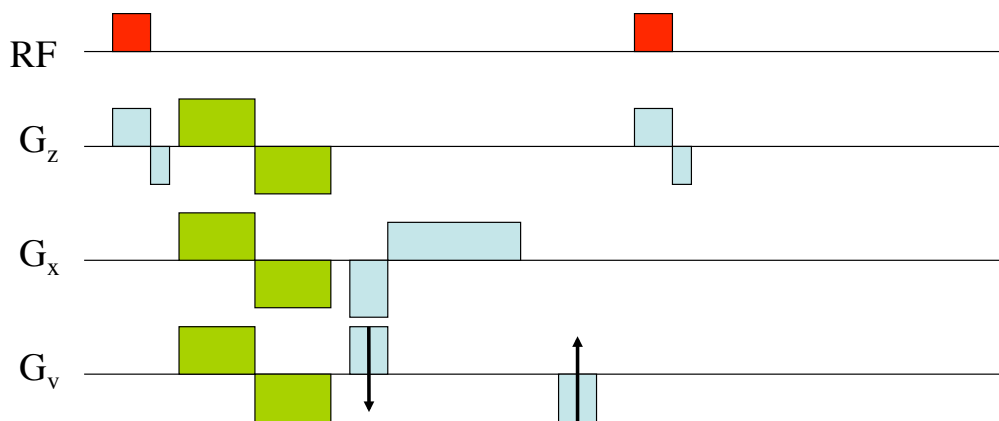
- $m_0 = 0$
- $m_1 = $ big
- Phase shift proportional to $\vec{V} \bullet \vec{m}_1$
- VENC $\equiv$ Velocity that generates phase shift of π
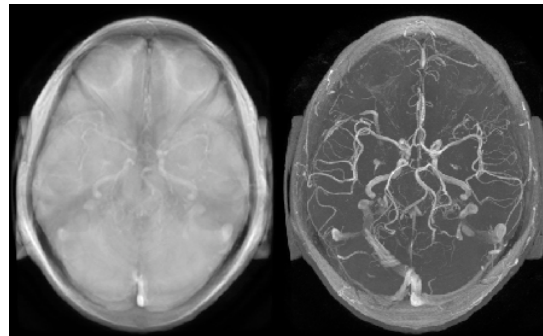
Phase Contrast MRA

RF

G_z

G_x

G_v
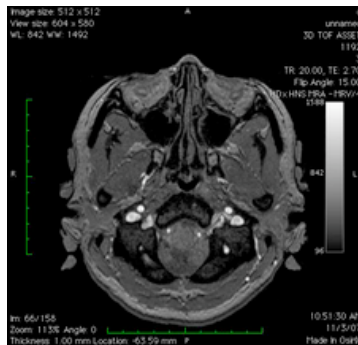
- One image with velocity encoding positive
- One image with velocity encoding negative
- One direction of encoding at a time
- Display phase difference between images
- Phase difference subtracts out off-resonance and other phase effects

# Maximum Intensity Projection

Mean   MIP

- Projection in which the maximum value along a set of parallel rays is projected onto a target plane
- MIP is in contrast to a conventional projection in which the sum or average value along each ray is projected onto the target plane
- In MRA, this results in a projection of vessels onto a plane, ideally without other anatomy obscuring vessels
- Typically, data are projected onto multiple rotated planes

Phase Contrast MRA
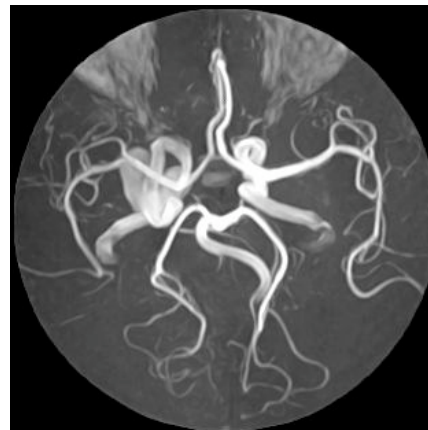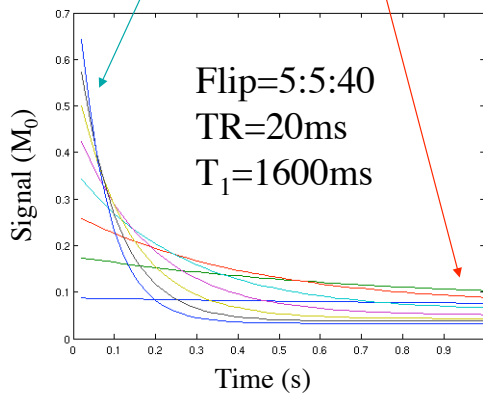
- Phase is proportional to velocity
- Quantitate velocity from phase images and/or:
- Construct angiograms by MIP of velocity maps

MIP
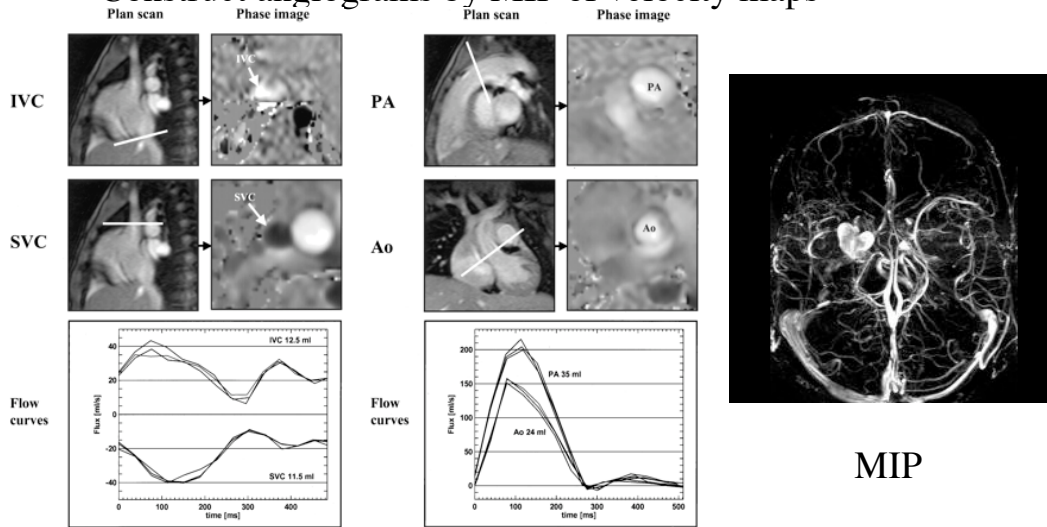
Time of Flight MRA

- Spoiled gradient echo with high flip angle and short TR
- Static magnetization becomes highly saturated
- Relaxed inflowing blood has much higher signal

Flip=5:5:40
TR=20ms
T_1=1600ms

$$M_z(tr) = M_0(1 - ((1 - M_z(tr-1)\cos(\alpha))e^{-TR/T_1}))$$

$$Signal(tr) = M_z(tr)\sin(\alpha)$$

Contrast Enhanced MRA

- MRA acquired during the passage of a bolus of Gd based contrast agent
- T_1 reduced as low as 50ms
- T_1 is so short, no need to rely on TOF effect for contrast
- Allows for very short TR and high flip angle
- Dramatically improves speed and/or SNR
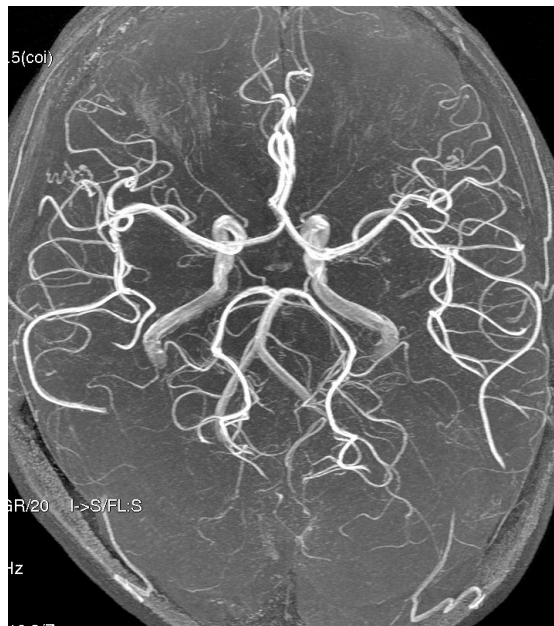- After first pass, Gd leaks into tissues
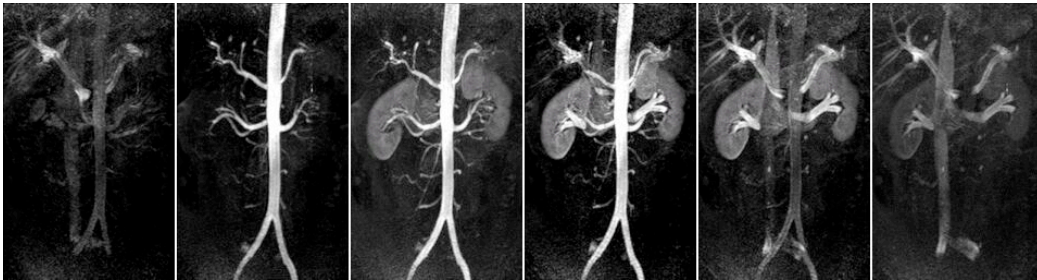
4s per frame

http://www.mr.ethz.ch/sense/sense_application.html

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Contrast Enhanced MRA

GEMS web site

http://www.m.ehime-u.ac.jp/school/radiology/mra/3T-MRA.jpg

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