Bioengineering 208
Magnetic Resonance Imaging

Winter 2007
Lecture 6

- Magnetic Resonance Angiography
  - Phase Contrast
  - Time of Flight
  - Contrast Enhanced

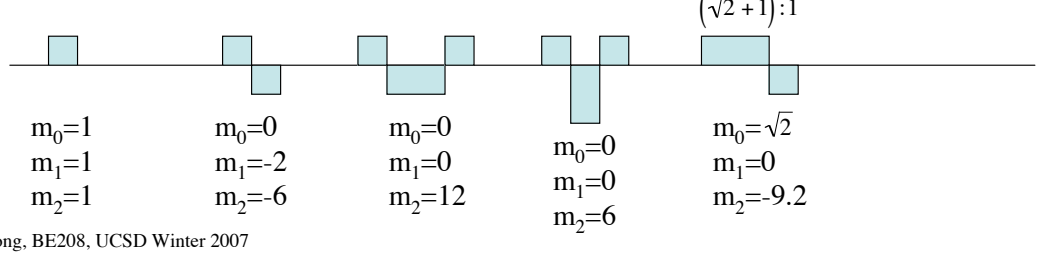
Spins flowing through a gradient

Phase from Motion:

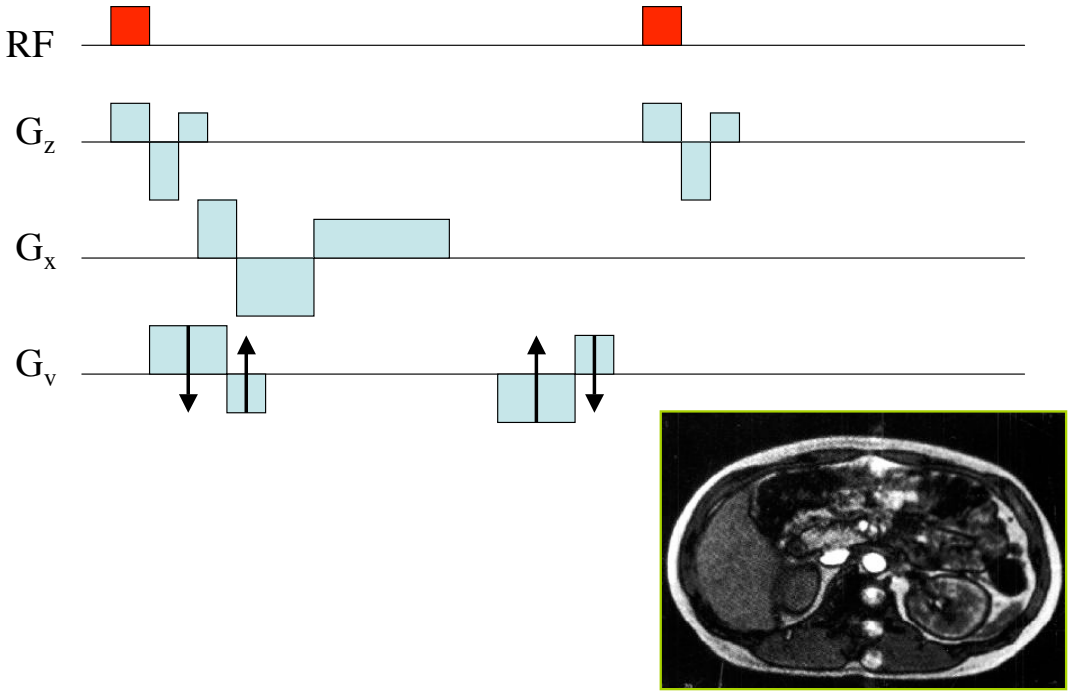
$$\phi(t) = \int \gamma \vec{G}(t) \bullet \vec{r}(t) dt$$

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

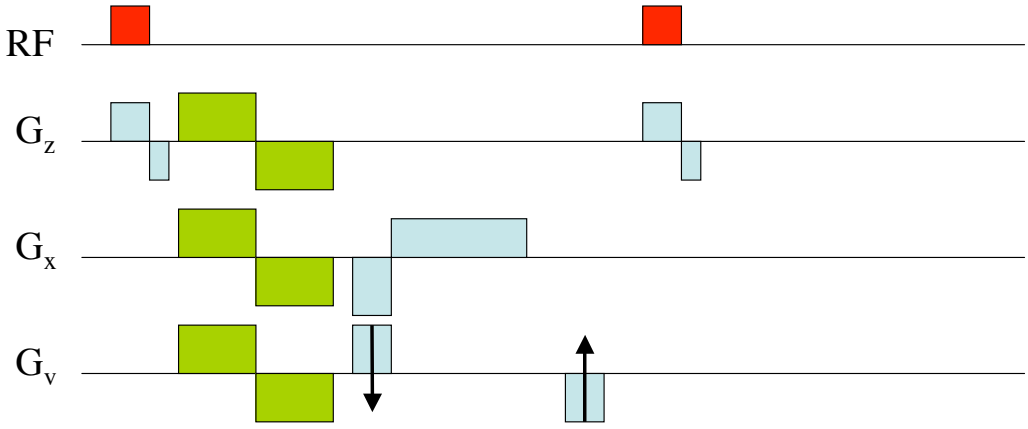
$$= \vec{r}_0 \bullet \underbrace{\int \gamma \vec{G}(t) dt}_{\text{Zeroth Moment } (m_0)} + \vec{V} \bullet \underbrace{\int \gamma \vec{G}(t) t dt}_{\text{First (flow) Moment } (m_1)} + \vec{A} \bullet \underbrace{\int 1/2\,\gamma \vec{G}(t) t^2 dt}_{\text{Second Moment } (m_2)}$$



Flow Compensated Imaging

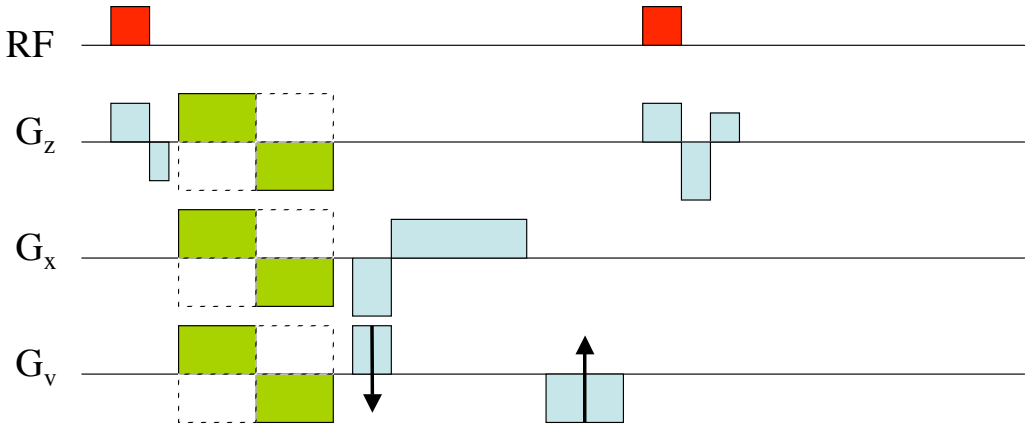


Flow Sensitive Imaging



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

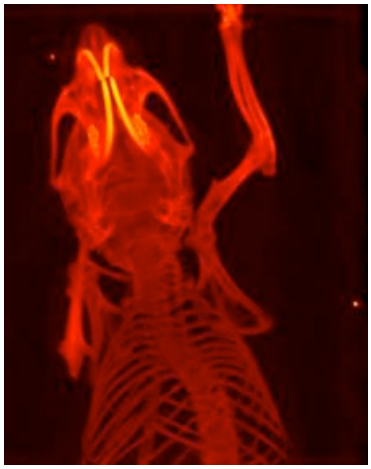
Phase Contrast MRA



- 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

Sidebar: Maximum Intensity Projection

- 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

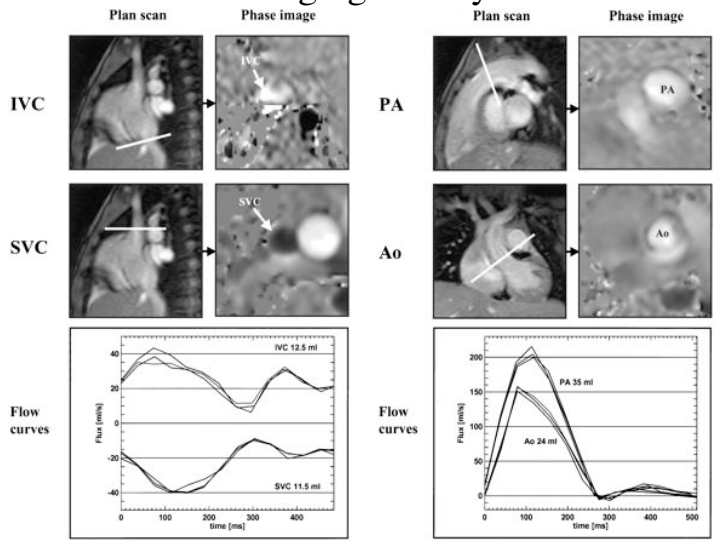


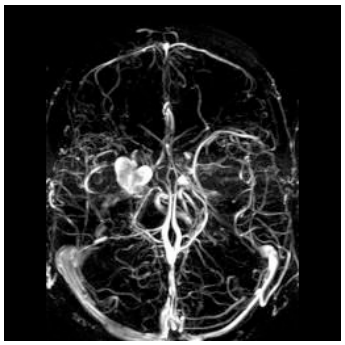
MIP of 3D CT data

http://www.spect-ct.com/site/site.cgi/dispentry.site?id=26

Phase Contrast MRA

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

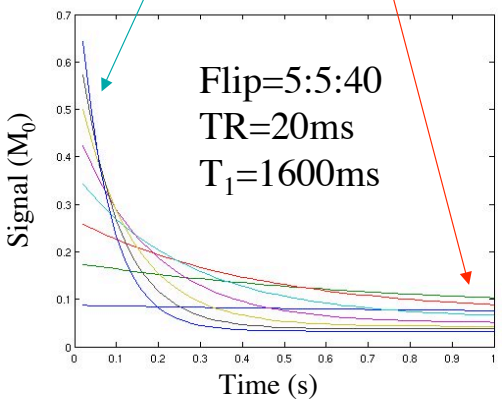


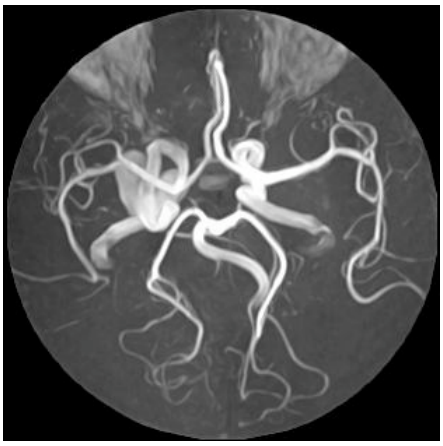


MIP

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





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

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

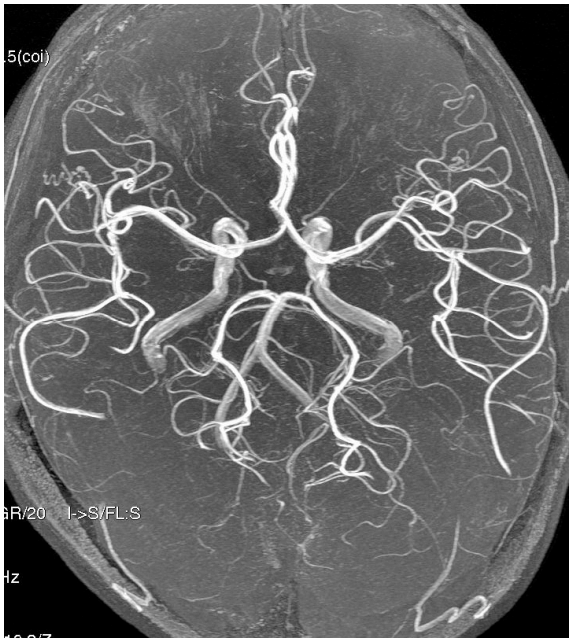
Contrast Enhanced MRA

- 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

Contrast Enhanced MRA



GEMS web site

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