

Bioengineering 208

Magnetic Resonance Imaging

Winter 2007
Lecture 6

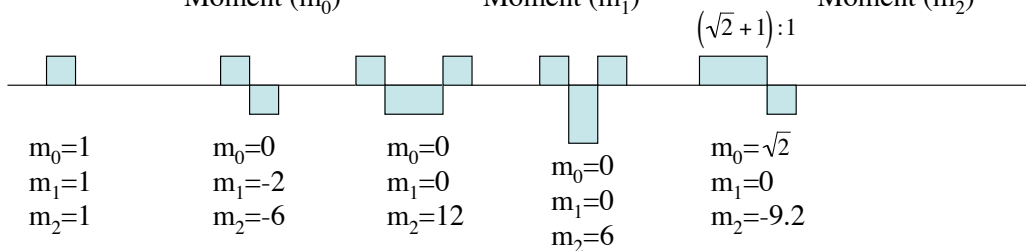
- Magnetic Resonance Angiography
 - Phase Contrast
 - Time of Flight
 - Contrast Enhanced

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Spins flowing through a gradient

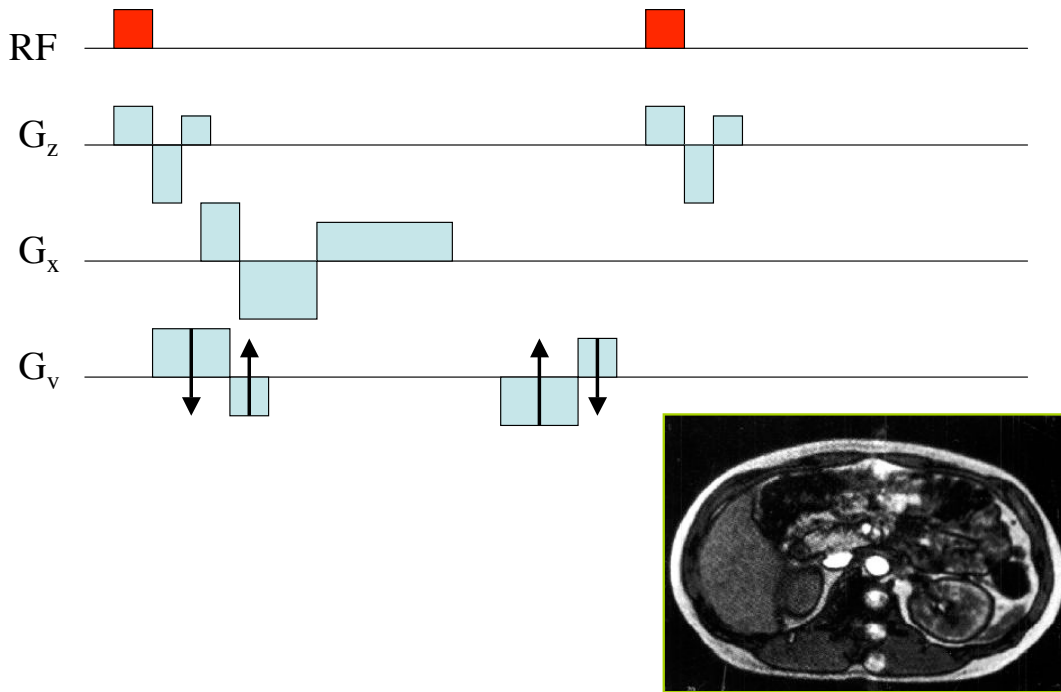
Phase from Motion:

$$\begin{aligned}
 \phi(t) &= \int \gamma \vec{G}(t) \cdot \vec{r}(t) dt \\
 &= \int \gamma \vec{G}(t) (\vec{r}_0 + \vec{V}t + 1/2 \vec{A}t^2 \dots) dt \\
 &= \underbrace{\vec{r}_0 \cdot \int \gamma \vec{G}(t) dt}_{\text{Zeroth Moment (} m_0)} + \underbrace{\vec{V} \cdot \int \gamma \vec{G}(t) t dt}_{\text{First (flow) Moment (} m_1)} + \underbrace{\vec{A} \cdot \int 1/2 \gamma \vec{G}(t) t^2 dt}_{\text{Second Moment (} m_2)}
 \end{aligned}$$



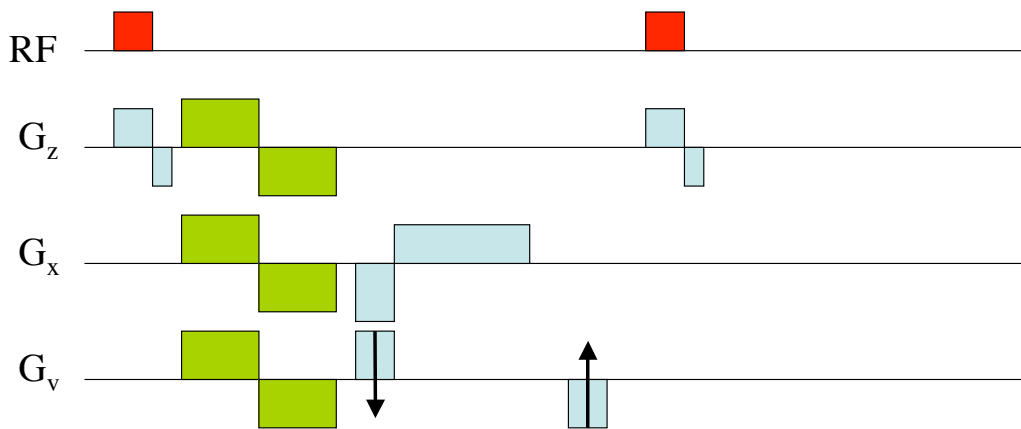
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Flow Compensated Imaging



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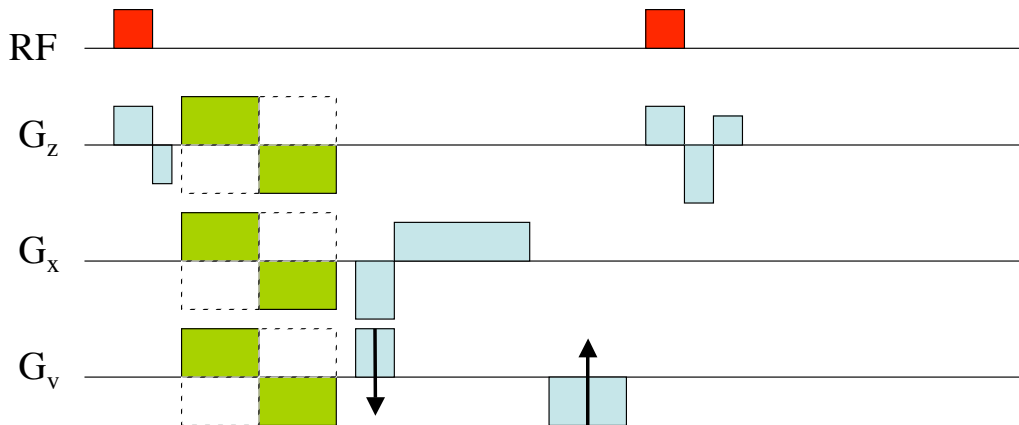
Flow Sensitive Imaging



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

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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

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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



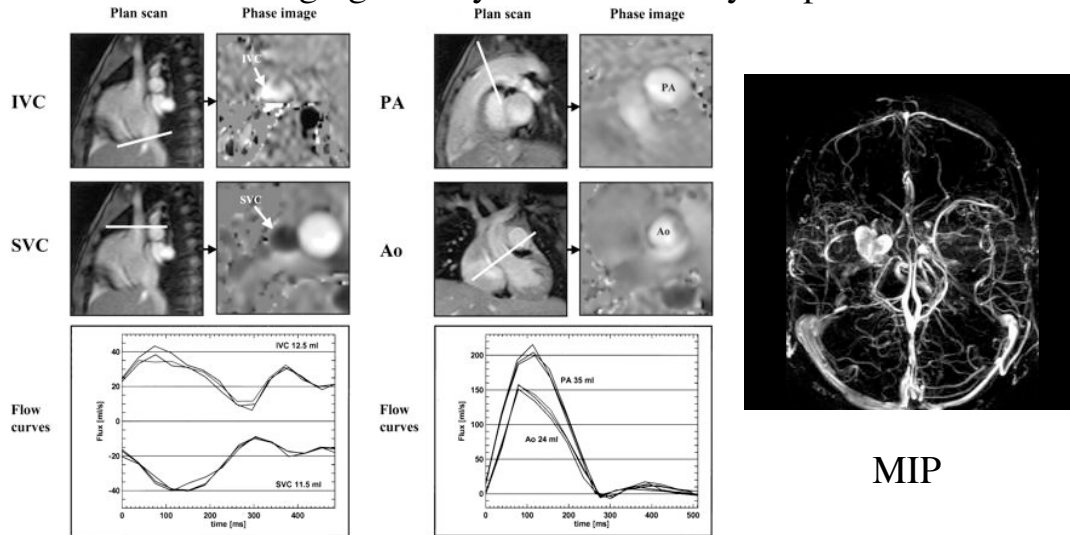
MIP of 3D CT data

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<http://www.spect-ct.com/site/site.cgi/dispenry.site?id=26>

Phase Contrast MRA

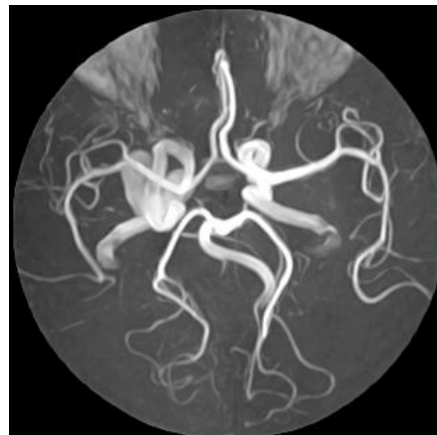
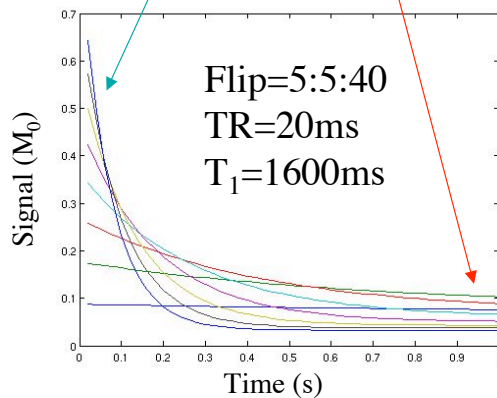
- Phase is proportional to velocity
- Quantitate velocity from phase images and/or:
- Construct angiograms by MIP of velocity maps



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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



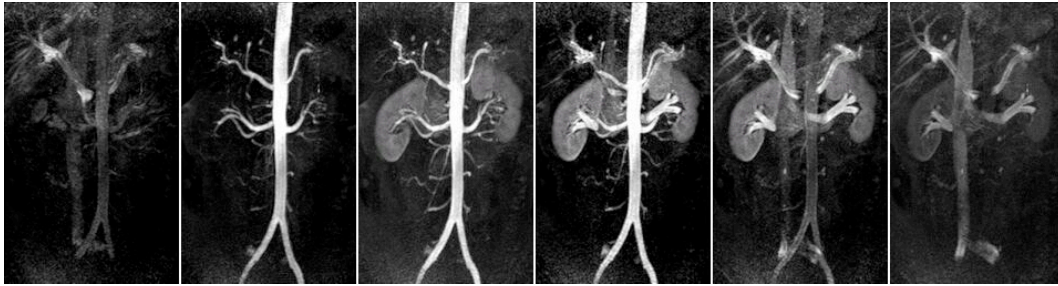
$$M_z(tr) = M_0(1 - ((1 - M_z(tr - 1)\cos(\alpha))e^{-TR/T_1}))$$

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

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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

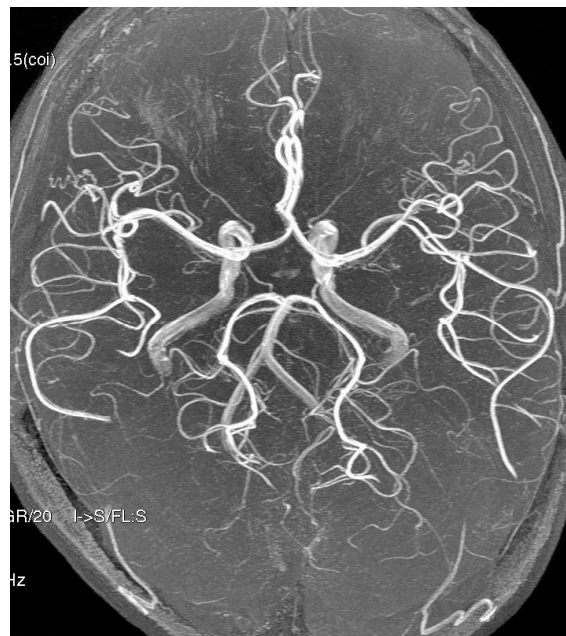
http://www.mr.ethz.ch/sense/sense_application.html

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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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