

INTERNATIONAL SOCIETY FOR  
**ISMIRM**  
MAGNETIC RESONANCE IN MEDICINE




## Declaration of Conflict of Interest or Relationship

Joao Carvalho:

I have no conflicts of interest to disclose with regard to the subject matter of this presentation.

*Toronto!*

## Assessment of stroke volume variability using real-time spiral phase contrast



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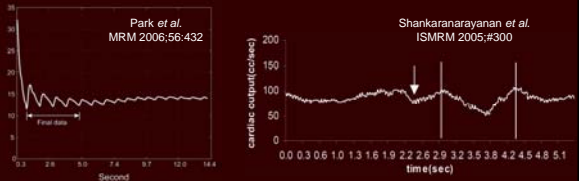
## Stroke volume variability

- Volume ejected by LV beat-by-beat
- Indicator of autonomic response
- Connects heart rate variability (HRV) to blood pressure and venous return variabilities
- Atrial fibrillation, electrophysiology, sudden death
- No non-invasive gold-standard for SV

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## Recent methods in MRI

- Averaged through several heartbeats
- Can measure cardiac output only



- We propose measuring beat-to-beat SV

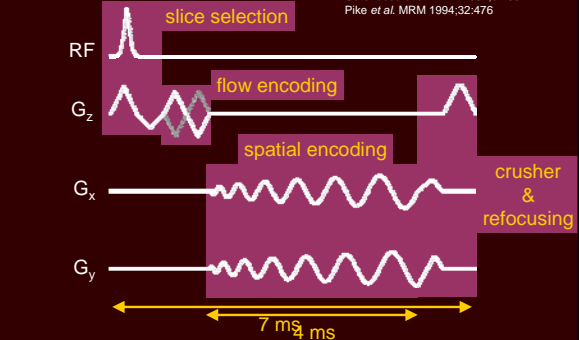
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## Scan parameters

- GE Signa 3T EXCITE HD system
  - 40 mT/m amplitude
  - 150 T/m/s slew rate
- Real-time spiral phase contrast
  - Interleaves: 4
  - Resolution: 3 mm
  - FOV: 25–6 cm
  - Venc: 200 cm/s
  - Temporal resolution: 56 ms

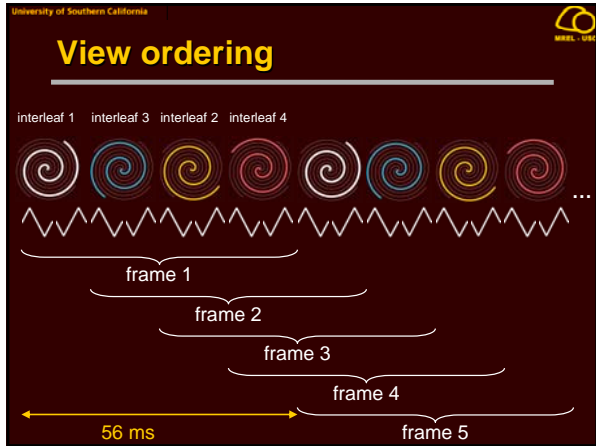
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## Pulse sequence

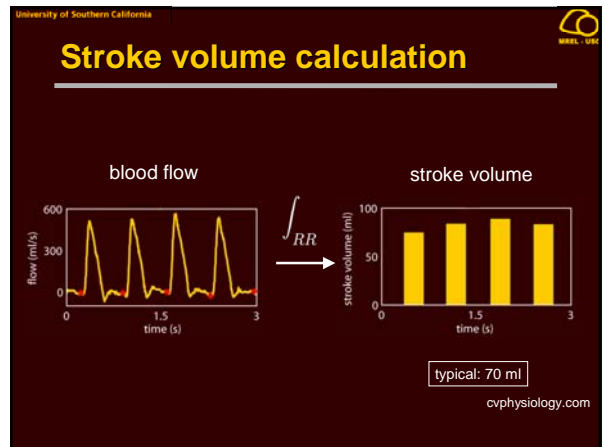
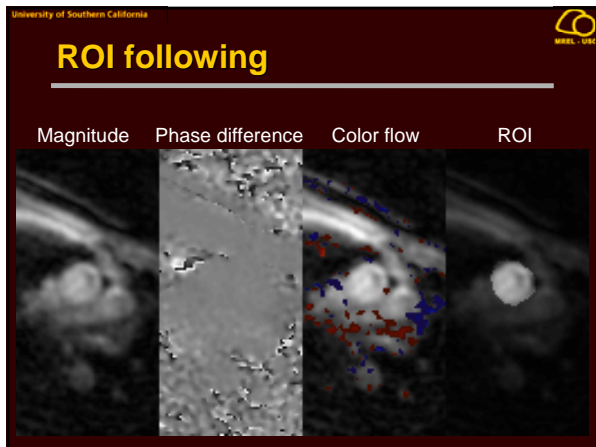
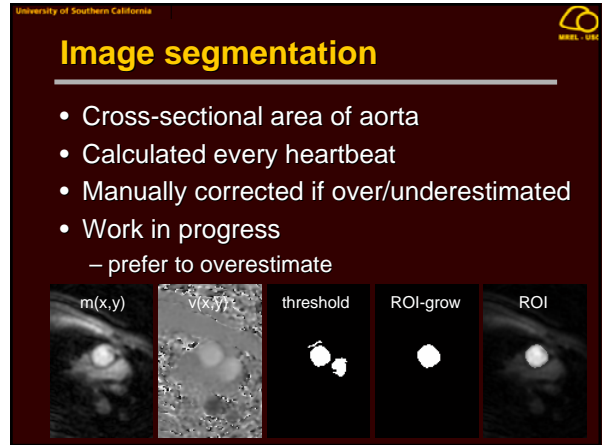
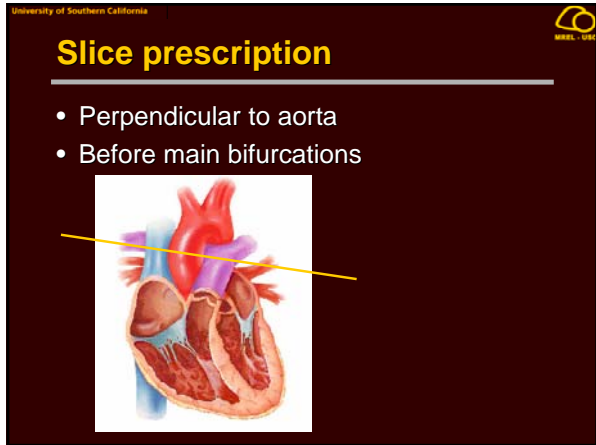


Gatehouse et al. MRM 1994;31:504  
Pike et al. MRM 1994;32:476

7 ms



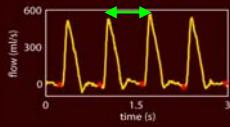
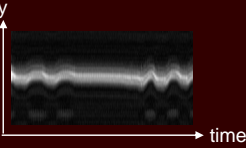
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- ## Assumptions
- Partial volume:
    - PC velocity = average velocity within the voxel
    - Flow in voxel = voxel area x PC velocity
  - Variable density spiral: aliasing artifacts are insignificant within the ROI



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## Heart rate and respiration

- Heart rate obtained from ECG trigger
  - Precision: 7 ms (1 TR)
  - False negatives: corrected based on peak-to-peak intervals on flow waveform
- Respiration:
  - Chest-wall position on MR images
  - Use below if available

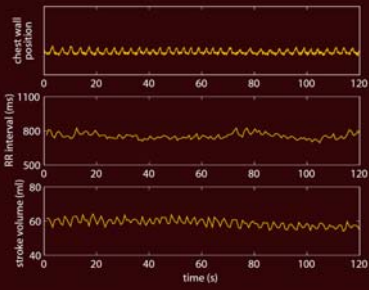
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## Autonomic Stressors

- Free-breathing
- Breath-hold (30 sec)
- Valsalva maneuver (30 sec)
- Handgrip (40% MVC, 2 min)
- Cold compress (2 min)
- Mental stress (2 min)
- Cold pressor (2 min)

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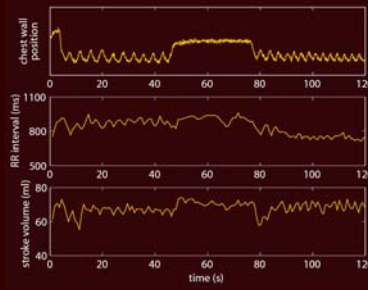
## Results: free breathing



Frequency content of oscillations provides information about the autonomic control

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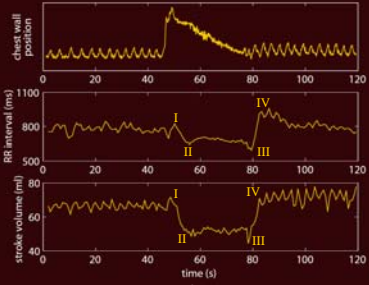
## Results: breath-hold



- Sympathetic response → reduced variability
- Increased venous return → SV increases

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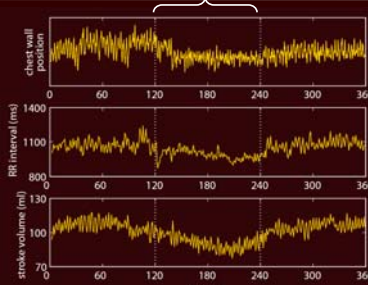
## Results: Valsalva maneuver



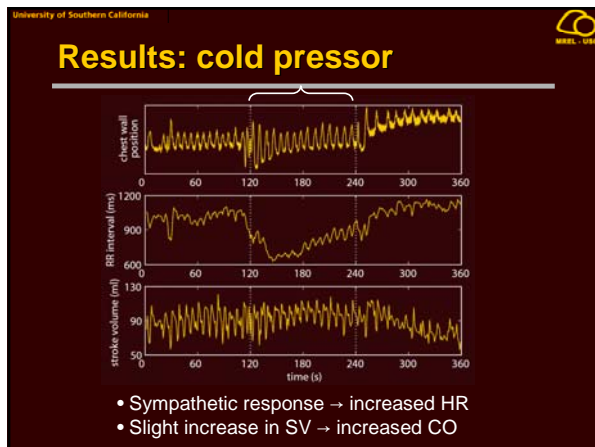
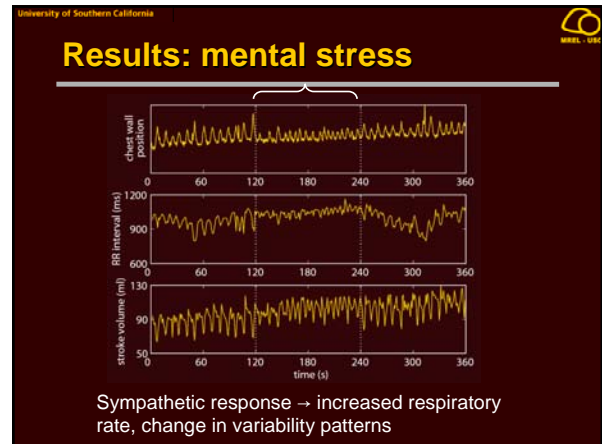
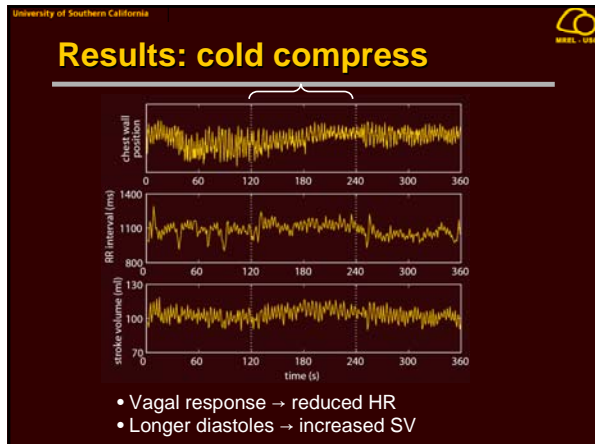
- I: inspiratory pressure → increased SV
- II: sympathetic response → reduced variability, increased HR, reduced SV
- III: expiratory pressure → dip in SV
- IV: vagal response → reduced HR, increased SV, increased variability

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## Results: handgrip (40% MVC)



- Sympathetic response → increased HR, reduced HRV
- Shorter diastoles → reduction in SV



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**Future work**

- Better image segmentation
  - Should follow pulsatility and movement within cardiac-cycle
- Quantitative analysis of SVV x HRV

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**Conclusions**

- Preliminary results suggest that SV may be measured on a beat-to-beat basis using real-time spiral phase contrast at 3T
- Operator interaction is minimal
- Results are in agreement with our expectations based on our current understanding of the physiology

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