Investigating the separate effects of venous outflow and breathing on the cranio-spinal CSF flow dynamics using two types of phase contrast sequences (Conventional and real time)

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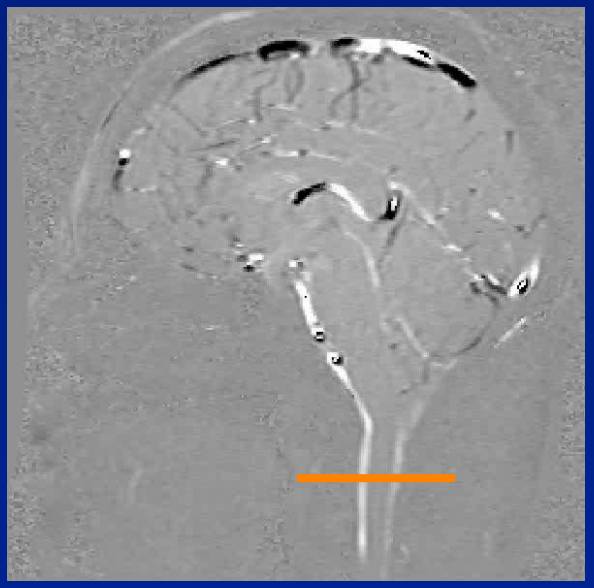
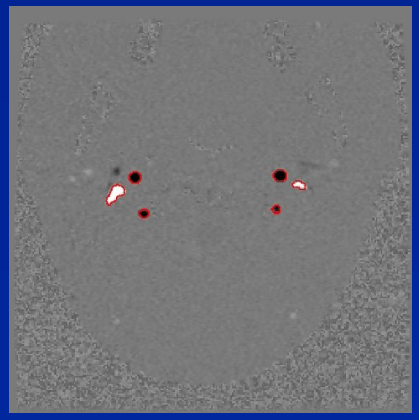
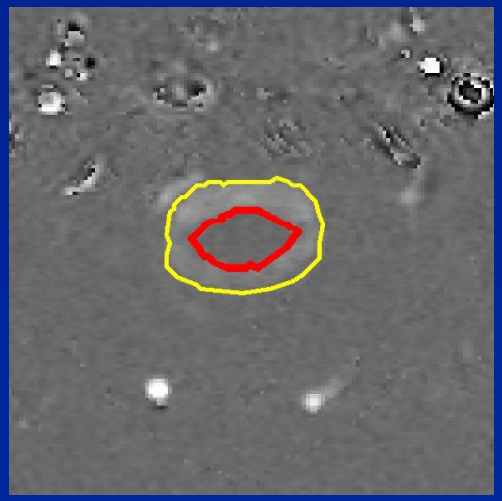
Cine Pulsatile Blood and CSF Flows



Sagittal CSF Flow



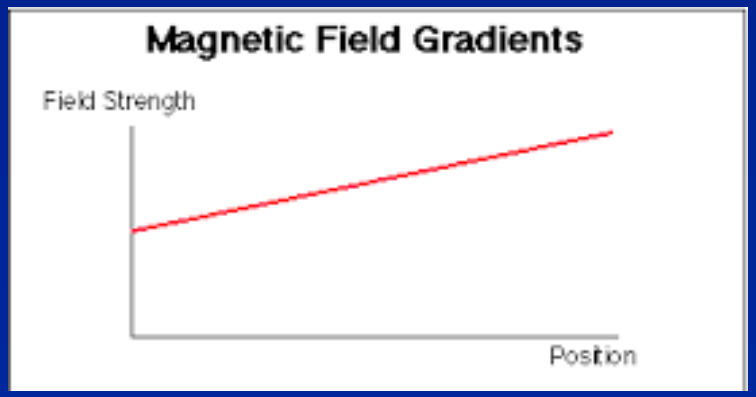


Axial CSF Flow

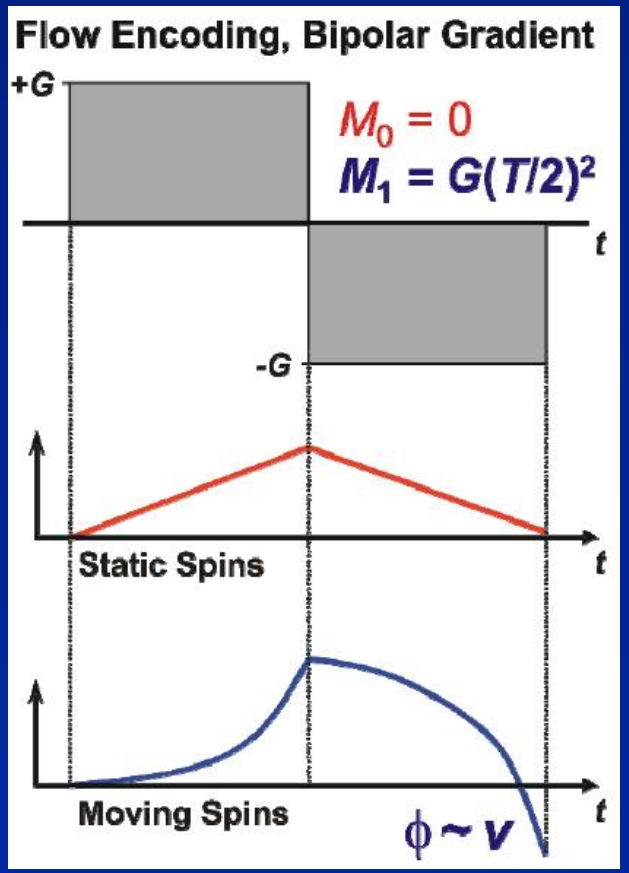
Blood Flow to and From the Brain

Phase Contrast MRI

Spins moving in a magnetic field gradient will change their frequency and therefore their phase will change with respect to static spins



Frequency α Field Strength

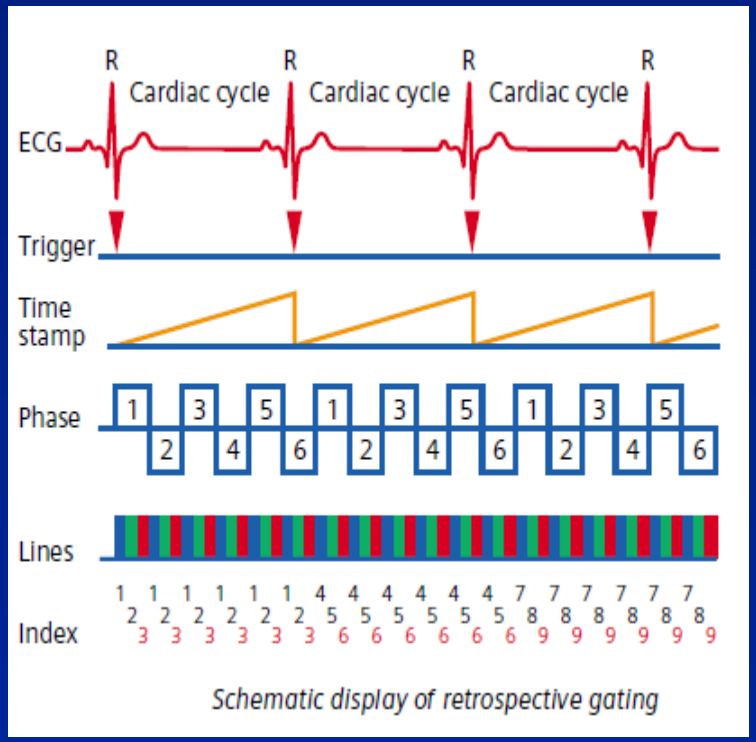


Cine Phase Contrast MRI

Currently, data acquisition use prospective triggering or retrospective gating.

Cine PC does not capture physiologic beat-to-beat variations due to respiration or other manipulations.

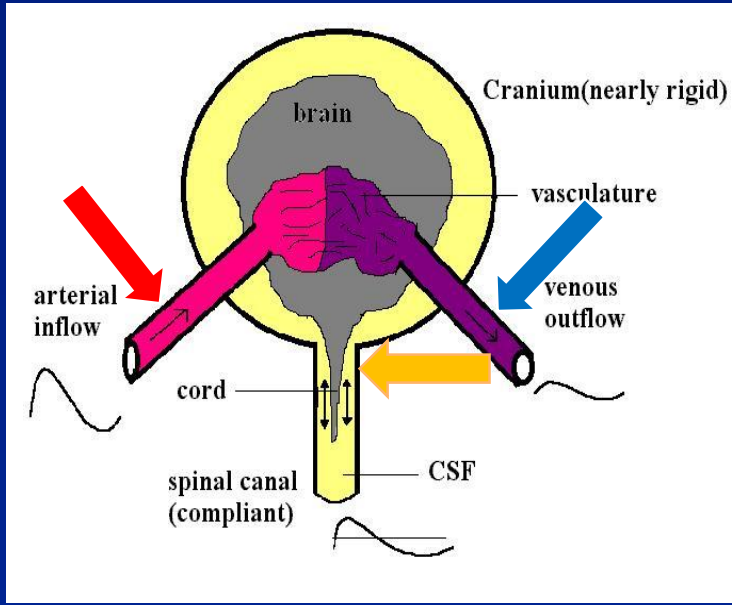
Waveforms obtained using cine PC are an averaged cardiac cycle reconstructed using data acquired over multiple heartbeats.



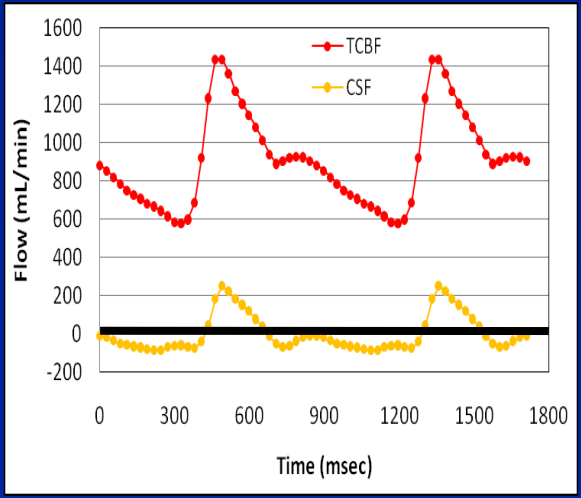
Schematic display of retrospective gating

Cranio-spinal CSF flow

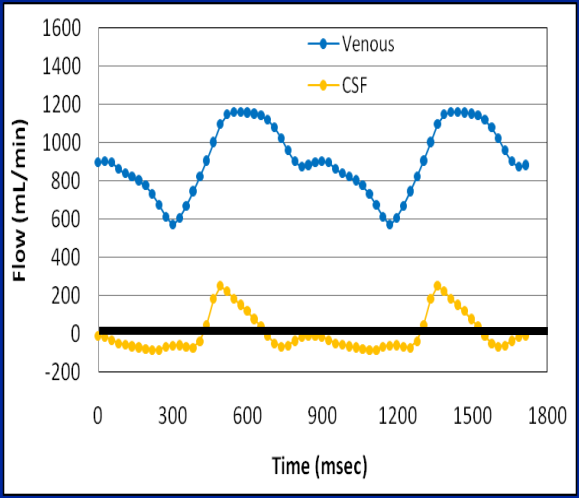
Cranio-spinal CSF flow is driven by the difference between arterial inflow (A) and venous outflow (V)[1]. This coupling is modulated by the intracranial **compliance**, which is inversely related to ICP.



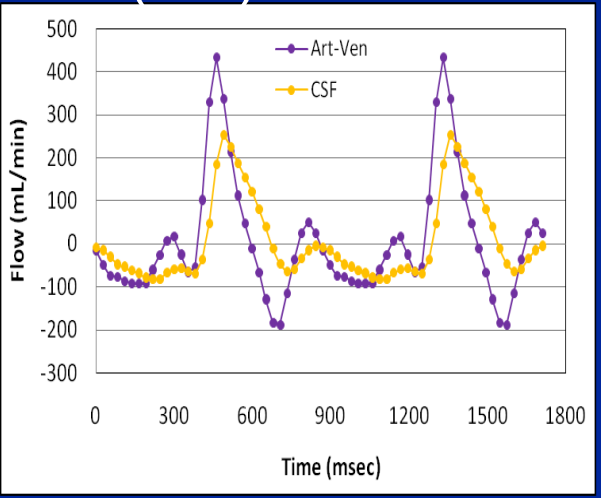
A and CSF



V and CSF

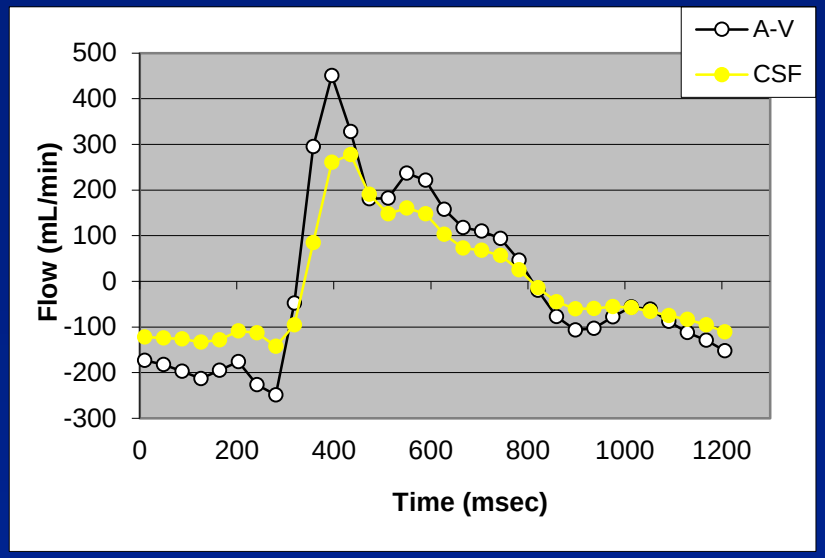


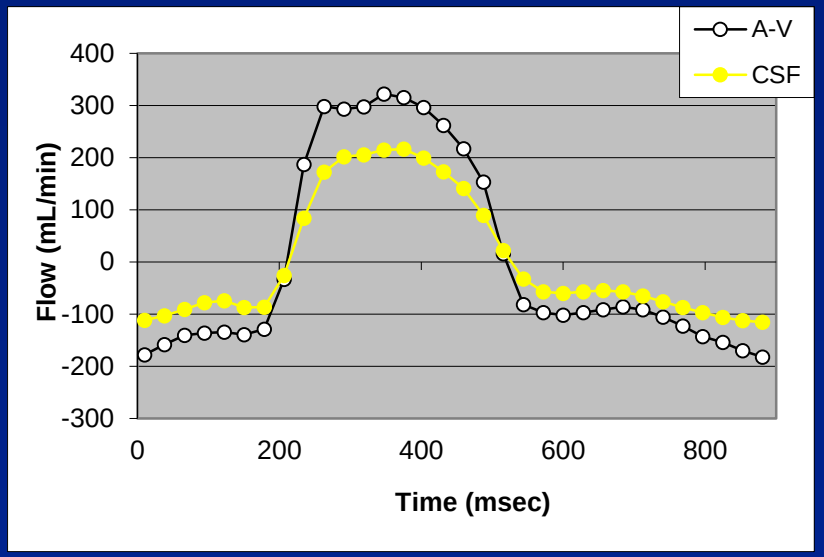
(A-V) and CSF

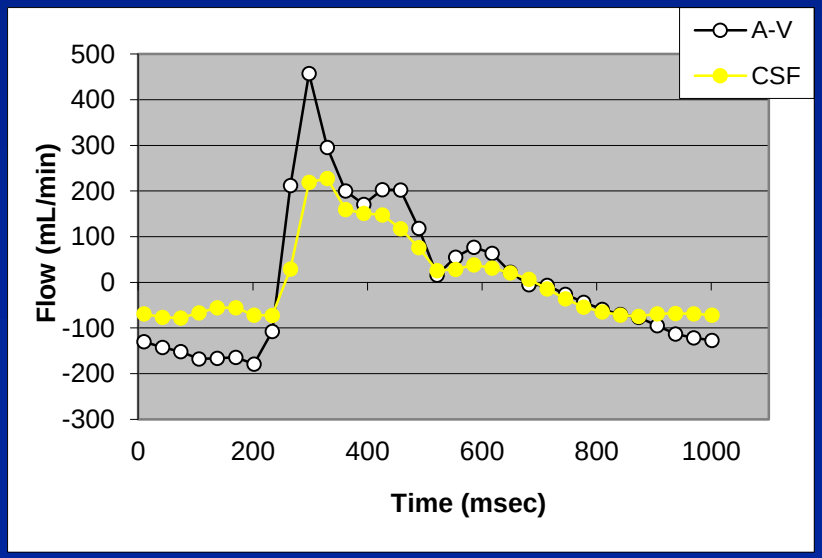


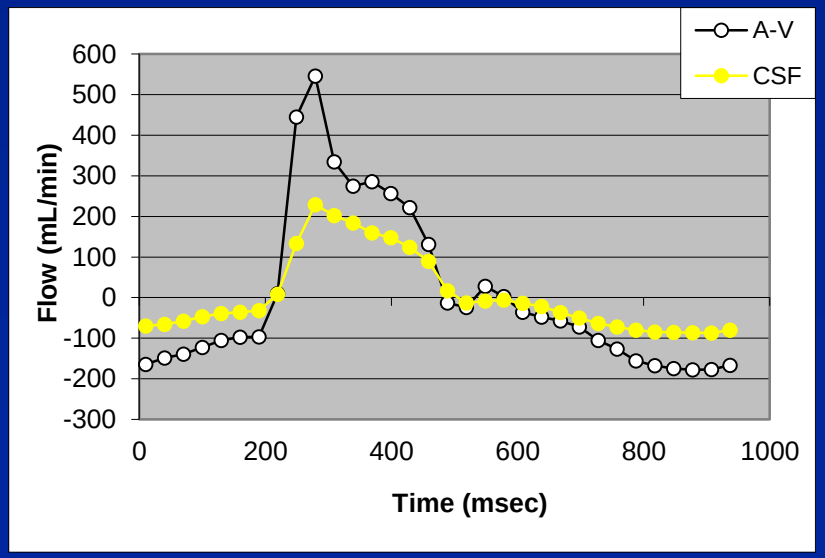
1- Alperin et al. Hemodynamically independent analysis of CSF and brain motion. Magn. Reson. in Med. 35:741–754 (1996)

CS-CSF Vs. Arterial – Venous flow









Real-Time Cine Phase Contrast

Recent advances enable significantly shorter scan time per image by combining several acceleration methods:

1. Echo planar imaging (EPI) readout.
2. Parallel acceleration in the temporal direction (T-PAT).
3. Novel reconstruction - shared velocity encoding (1)

Current efforts focus primarily on cardiac imaging. This work implemented real-time cine PC for measurements of cerebral blood and CSF flows.

[1] Lin H et al. Shared Velocity Encoding:. Magn Reson Med. Dec 2 (2011).

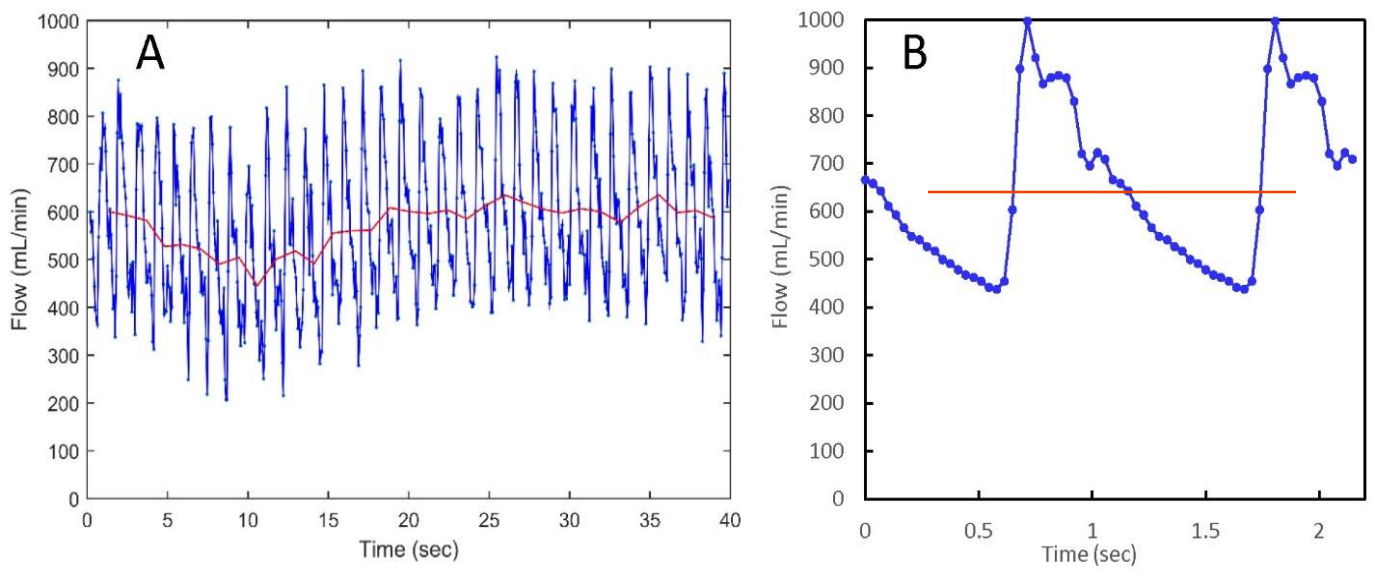
Methods

- Two healthy subjects were scanned with a 3T scanner (Skyra, Siemens Healthcare).
- Total CBF was obtained by summation of volumetric flow rate through the internal carotid and vertebral arteries.
- Both conventional Cine and real-time PC were used to measures arterial inflow, venous outflow and cranio-spinal CSF. Duration for each scan was about 1 min.
- Lumens were automatically delineated using the Pulsatility Based Segmentation (PUBS) method (1) which incorporates temporal information in each voxel to differentiate lumen pixels from background pixels.

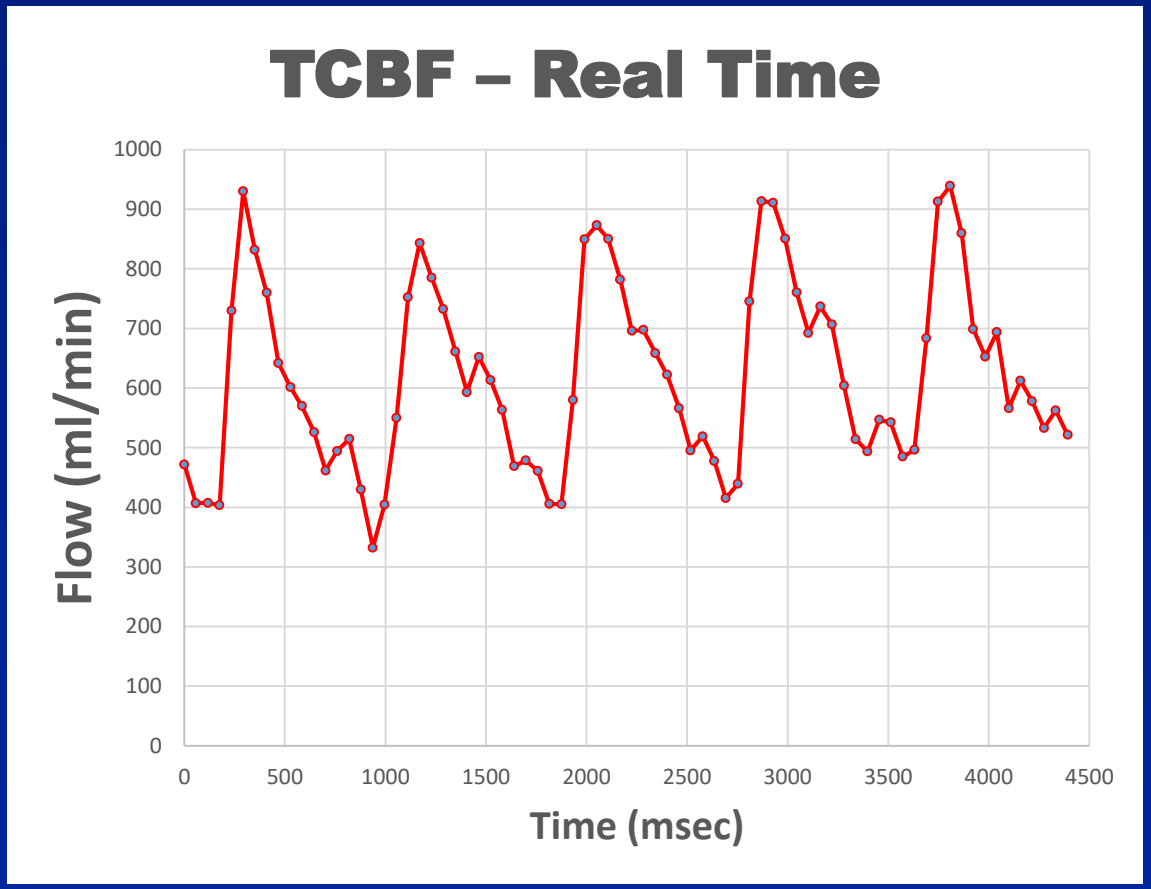
[1]. Alperin N, Lee SH. Magn Reson Med 2003;49:934-944

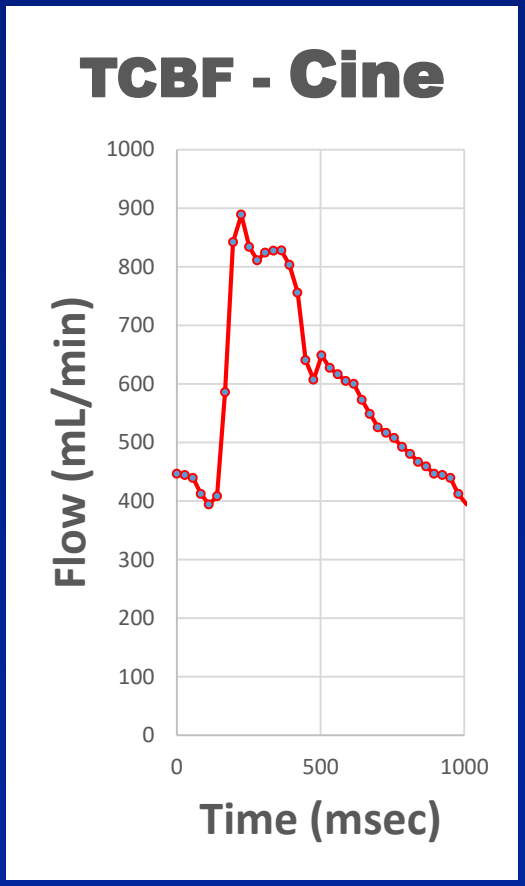
Results

	Real Time PC	Cine PC
Total CBF (mL/min)	572 [47.7]	646
peak-to-peak (mL/min)	499 (51.5)	559
peak-to-peak range	368 to 602	

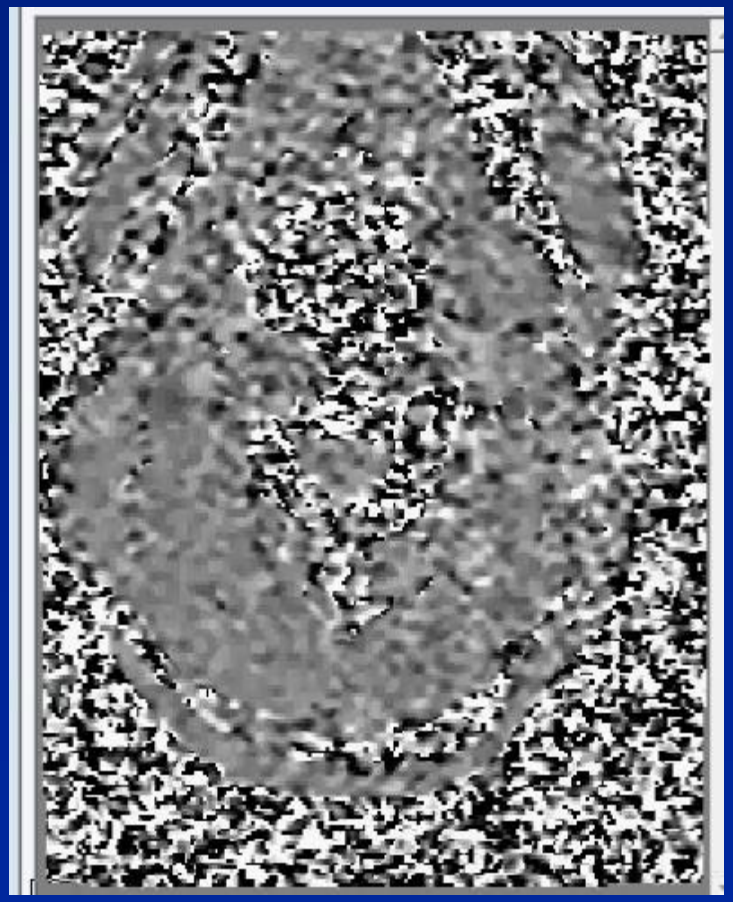


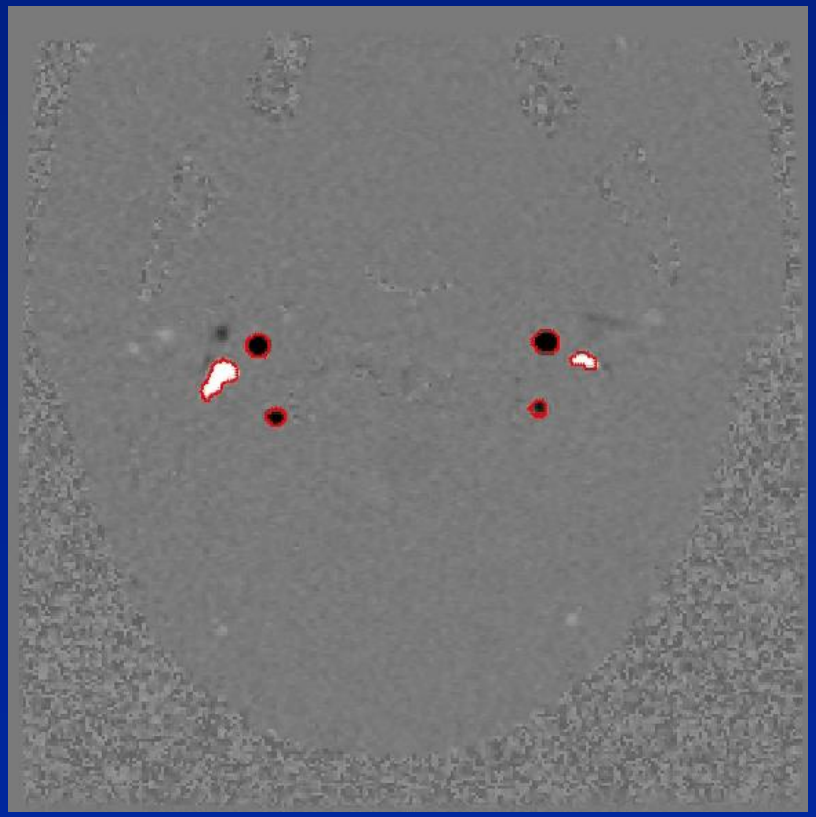
Results


TCBF – Real Time
Flow (ml/min)
1000
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (msec)

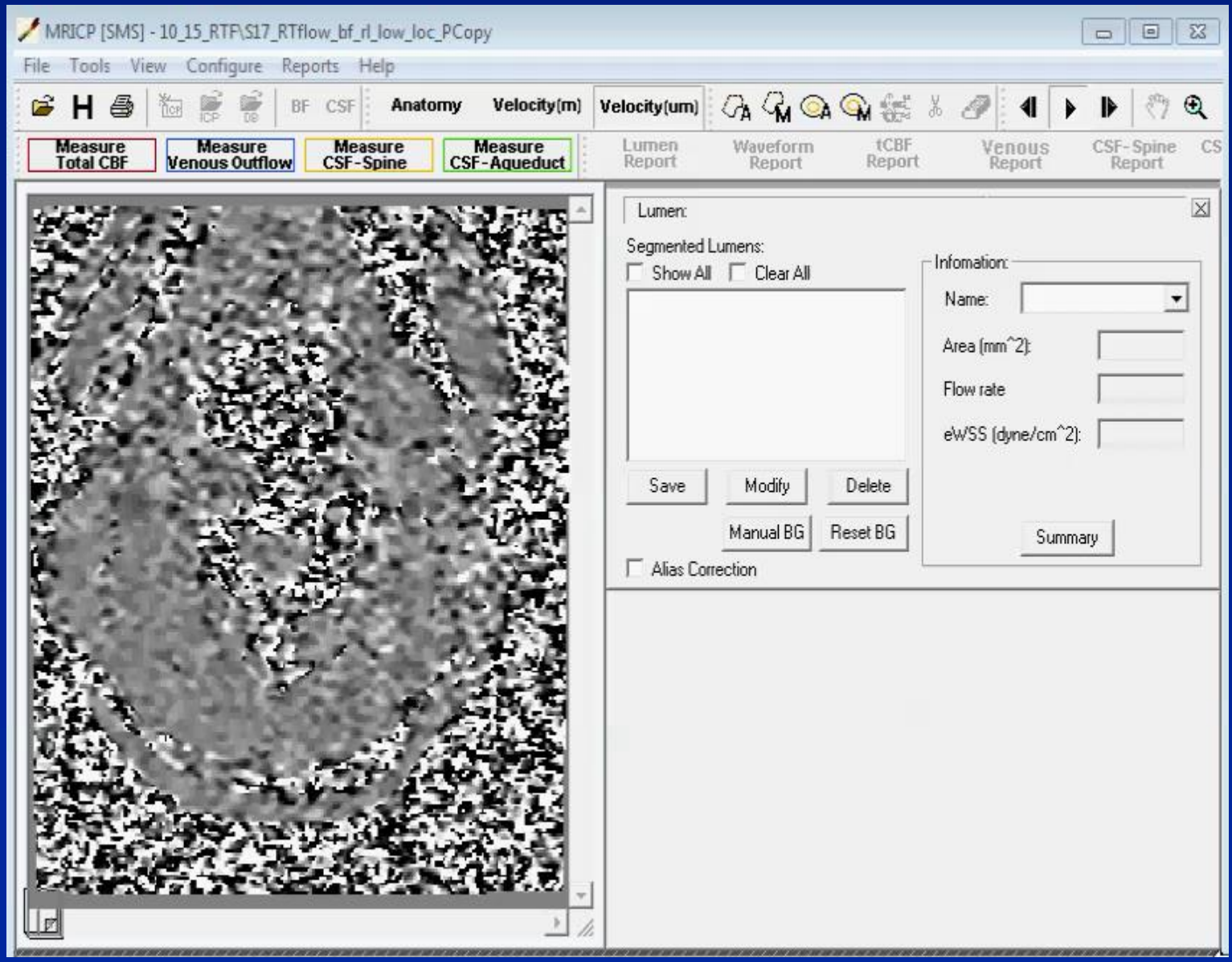

TCBF - Cine
Flow (mL/min)
1000
900
800
700
600
500
400
300
200
100
0
0
500
1000
Time (msec)

Real-Time and Conventional Cine PC



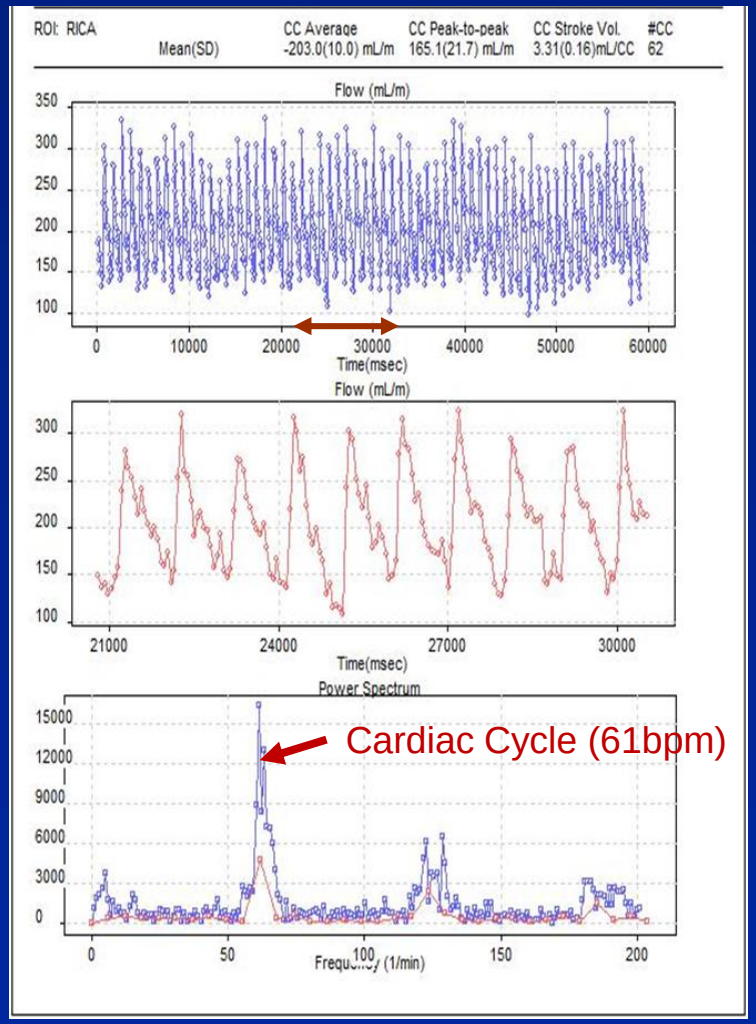


Automated analysis of the RT Vascular Cine Data

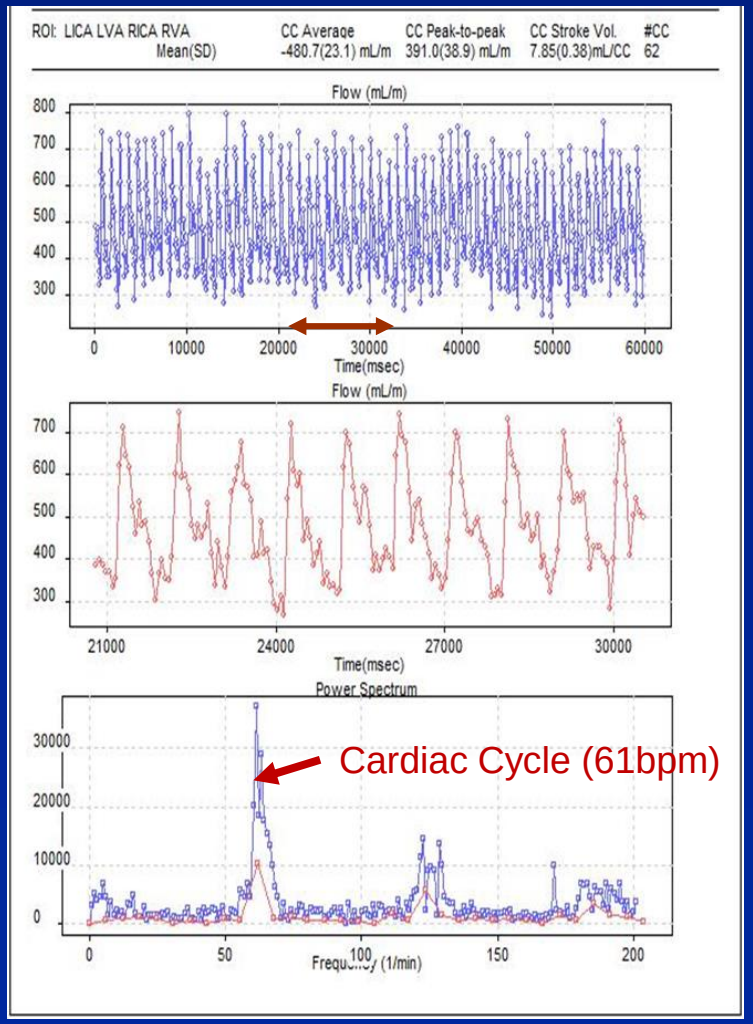


Real-time Arterial Flow

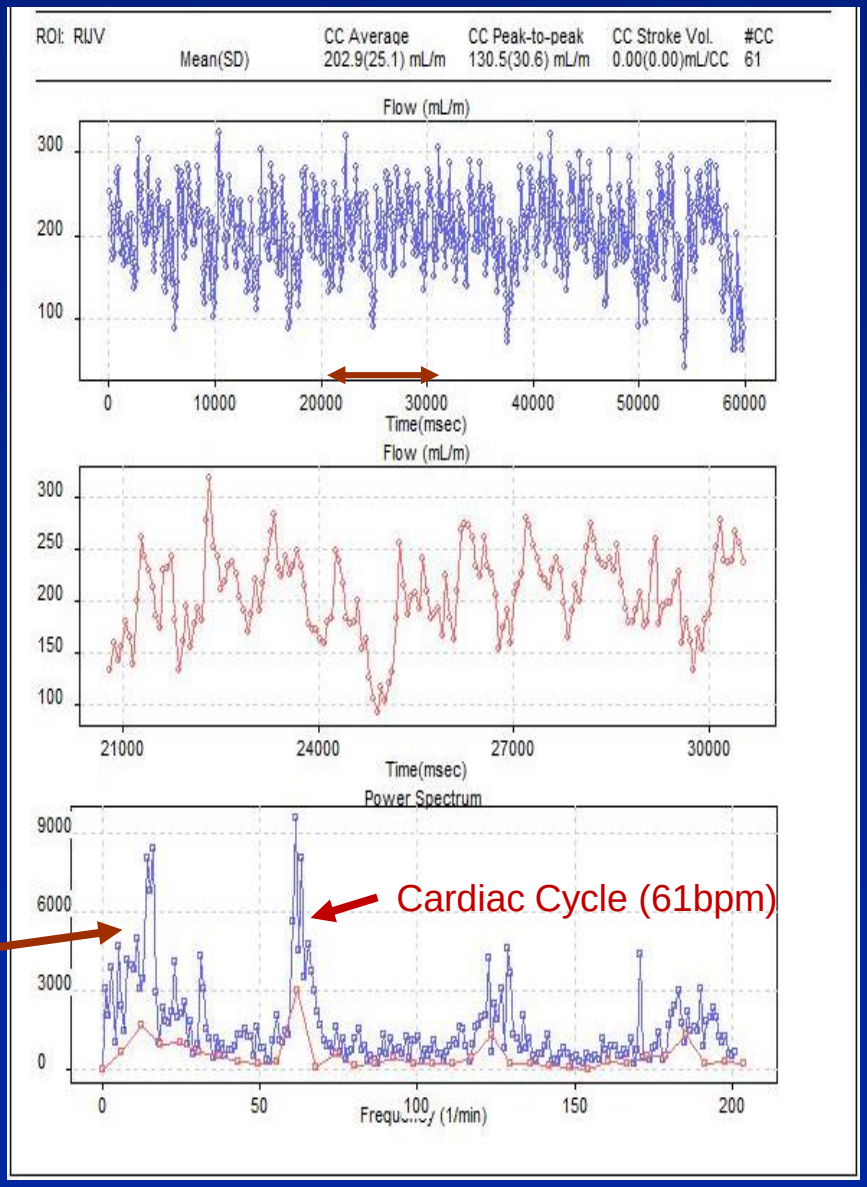
RICA



Total CBF = RICA+LICA+LVA+RVA

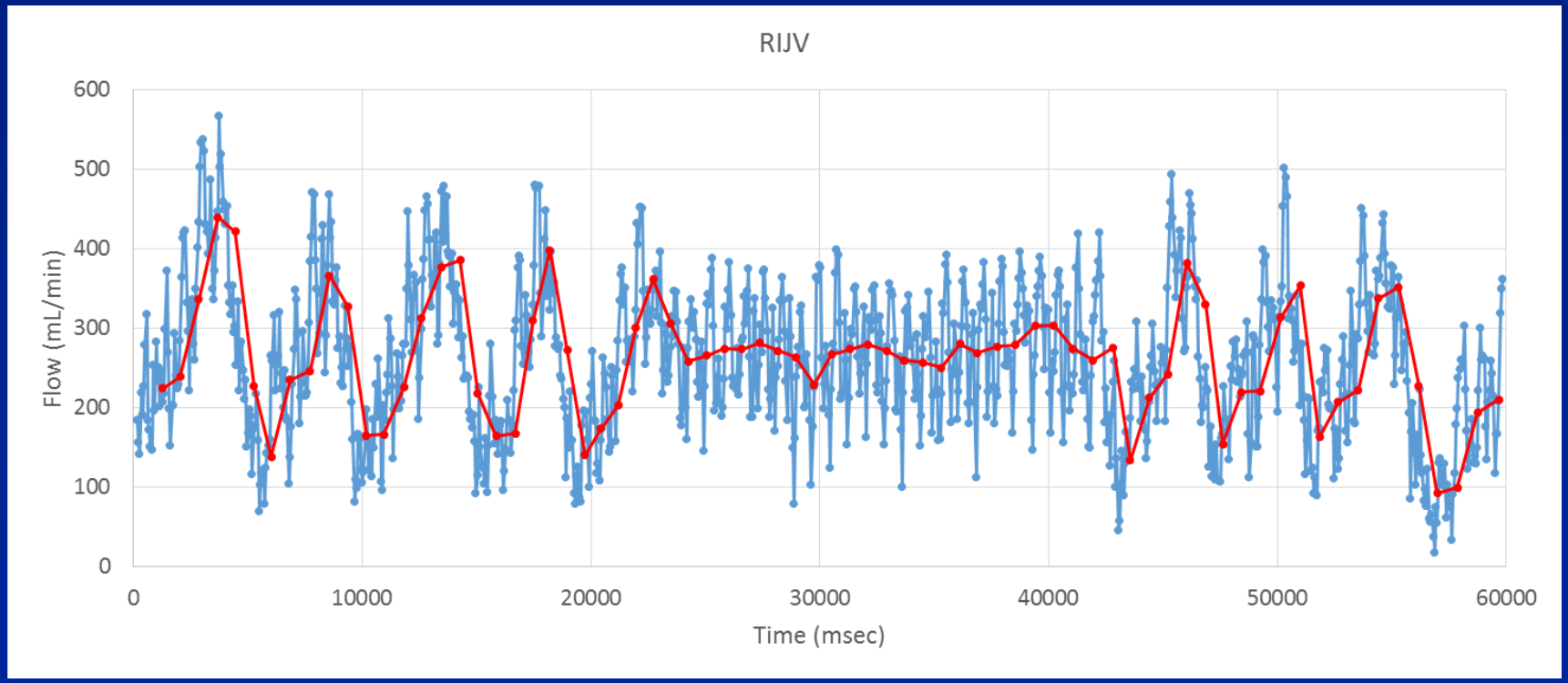


Real-time Venous Outflow



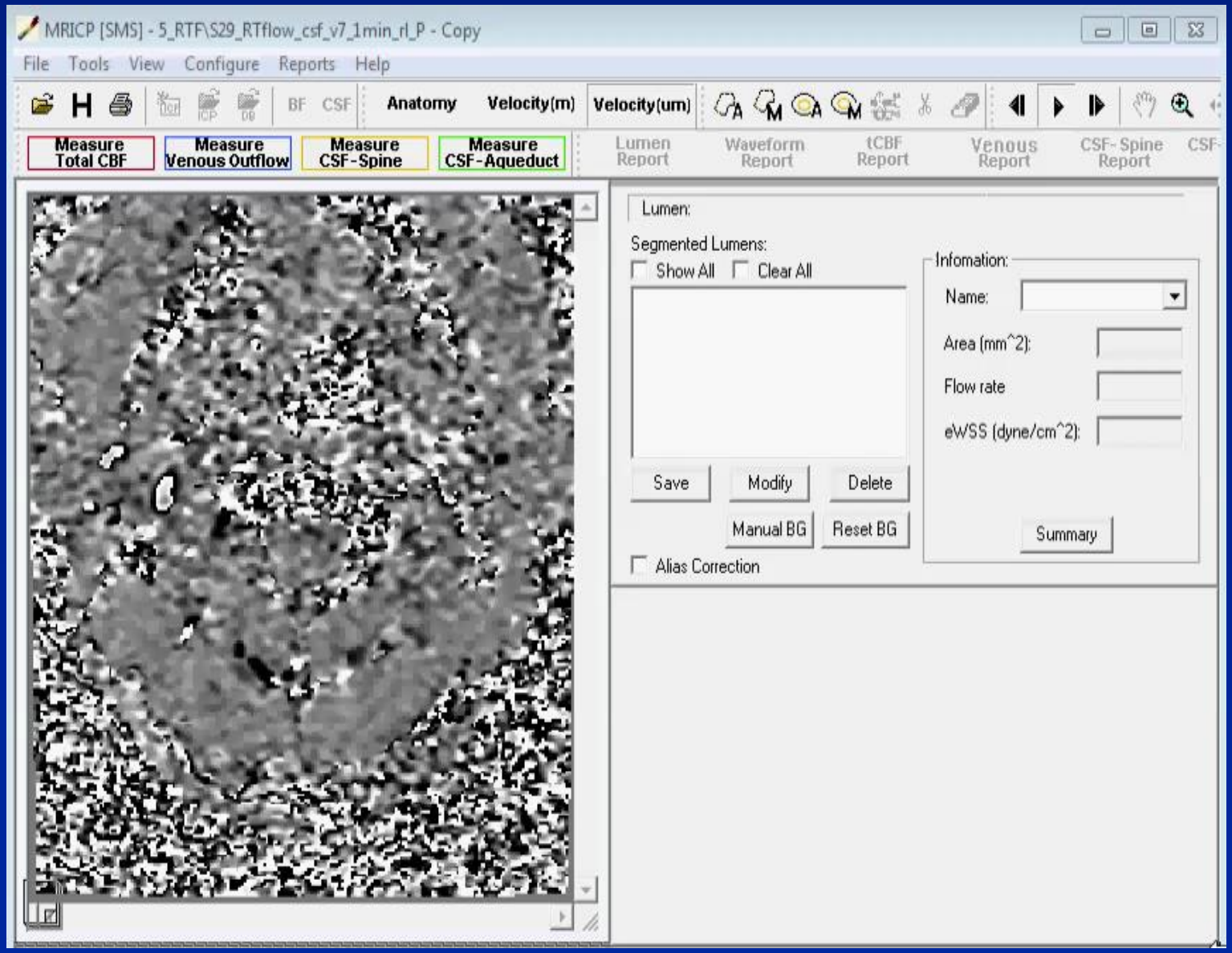
Respiratory Cycle (15cyc/min)

Real-time Venous Flow During Breath-Hold

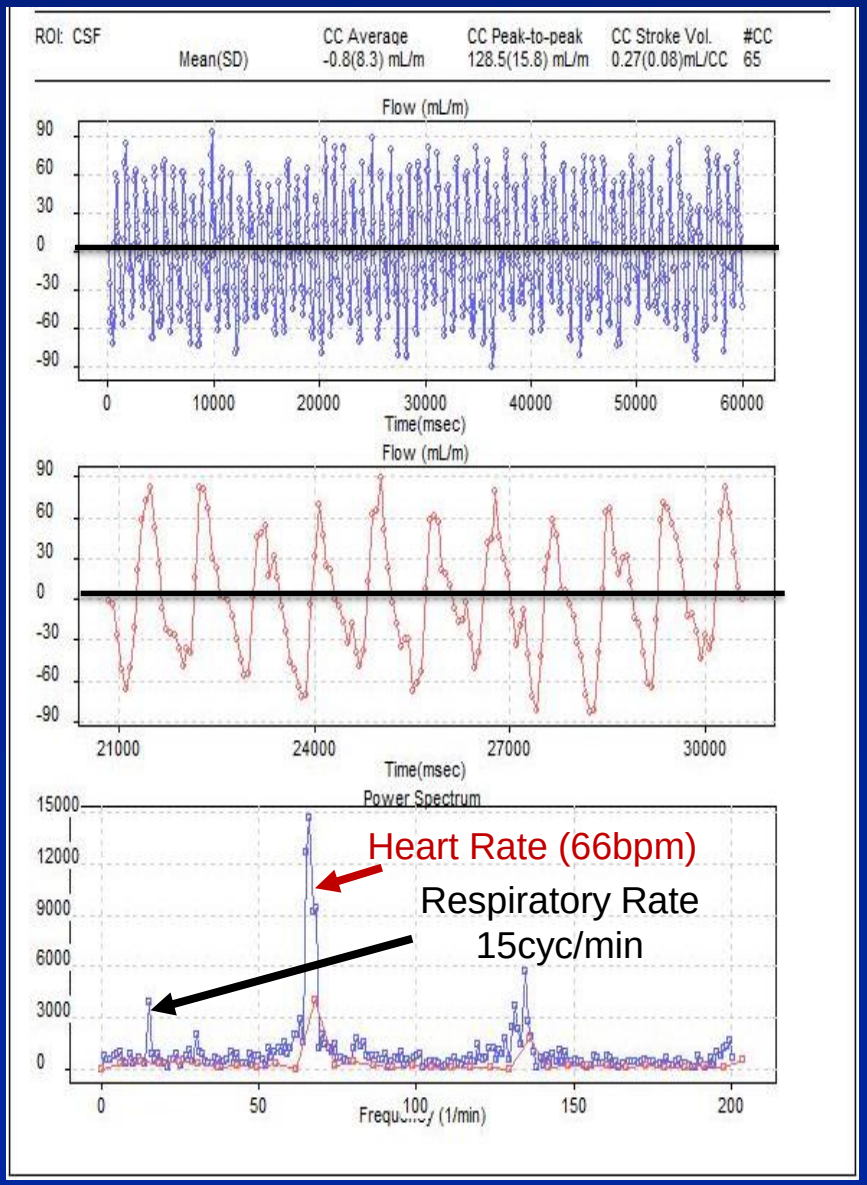


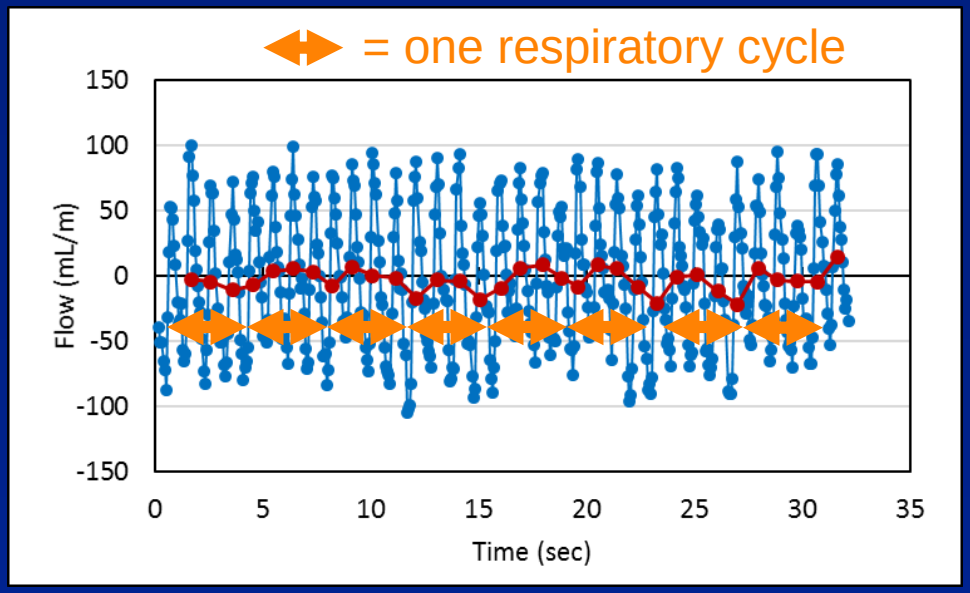
5 deep breathes – breath hold – 3 breathes

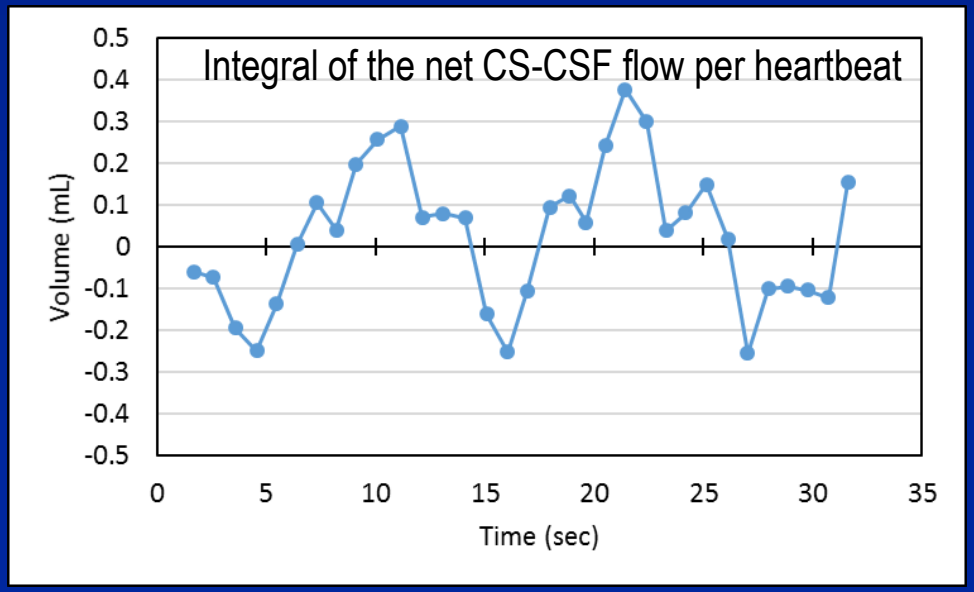
Automated analysis of the RT CSF Cine Data



Real-time Cranio-spinal CSF Flow







Conclusion

- The feasibility of automated real-time measurements of total arterial, venous, and CSF flows has been demonstrated.
- RT measurements have lower SNR and temporal resolution resulting with lower mean flow rates than cine PC but within physiological fluctuations range.
- Cranio-spinal CSF flow is modulated by cardiac (arterial minus venous flow) and breathing (primarily, through modulation of the venous outflow).
- The amount of CSF volume moving between the cranium and spinal canal due to cardiac and normal breathing is on the order of 0.5 and 1 mL, respectively.

Ho imparato così tanto grazie a te