

CSF PCMR Protocol Optimization and Phantom Validation

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List of Contents

- ◆ 1. Previous work
 - NOVA QMRA (Non-invasive Optimal Vessel Analysis)
- ◆ 2. CSF PCMR Protocol Optimization and Validation
- ◆ 3. Problems and Future's work
- ◆ 4. Summary

Traditional MRA:

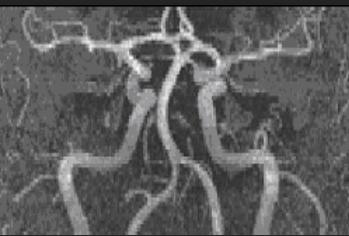


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1. Previous Work on Cerebral Blood Flow Quantification

Traditional MRA:



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- ◆ 1. PCMR technique-NOVA
- ◆ 2. 3D Localizer
- ◆ 3. Validation
 - In vivo
 - In vitro
- ◆ 4. Samples of clinical applications

PCMR Flow Quantification

◆ 2D-PCMR + Time = Sine

- Accuracy
 - Perpendicular to the flow direction
 - Protocol parameters
- Scanning Time (< 1 min)
- Resolution (0.5mm x 0.5 mm)
- Easy to fit into clinical workflow

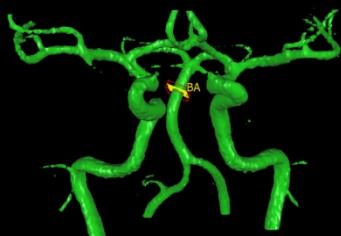
◆ 3D-PCMR + Time = 4D

- Unique VENC for the whole volume
- Scanning Time – Parallel, Spiral, Radial
- Data Intensive

Traditional MRA:



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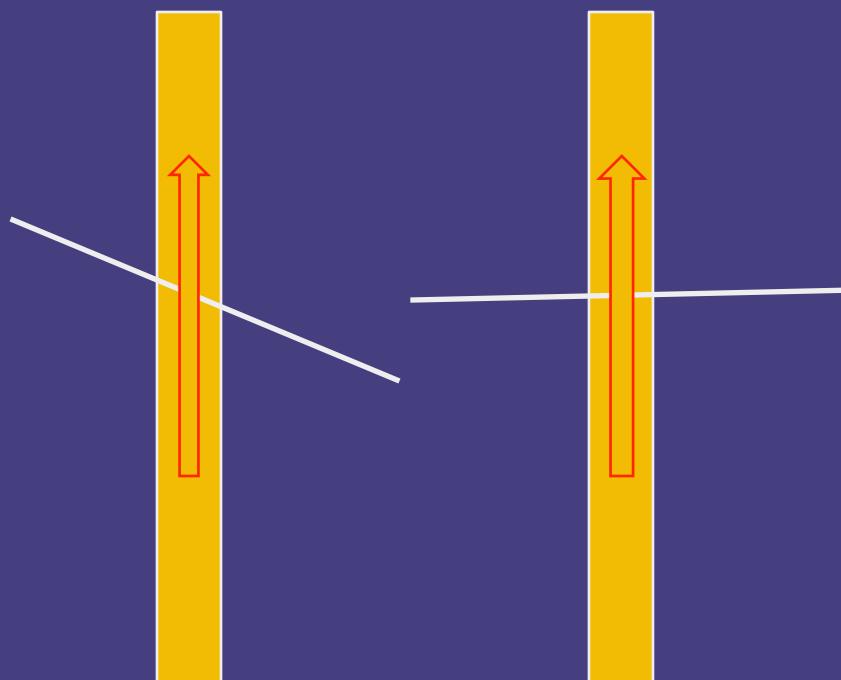


2D PCMR Plane Position?

Traditional MRA:



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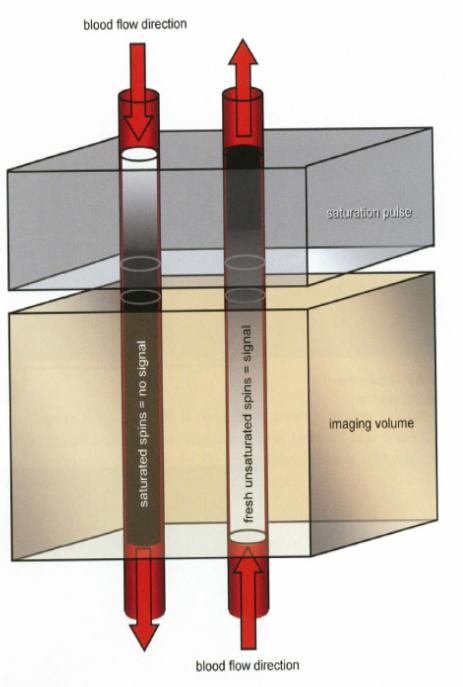


Bad

Good

How?

NOVA 3D Localizer



TOF MRA

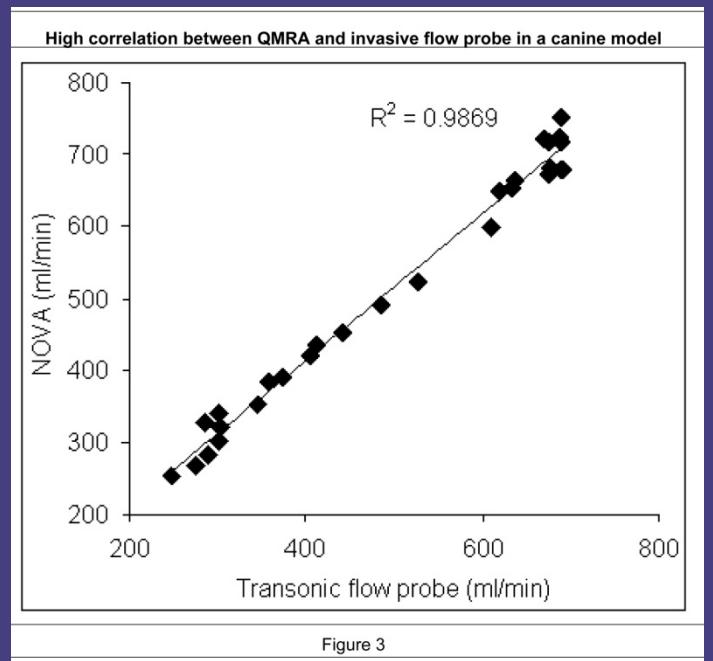
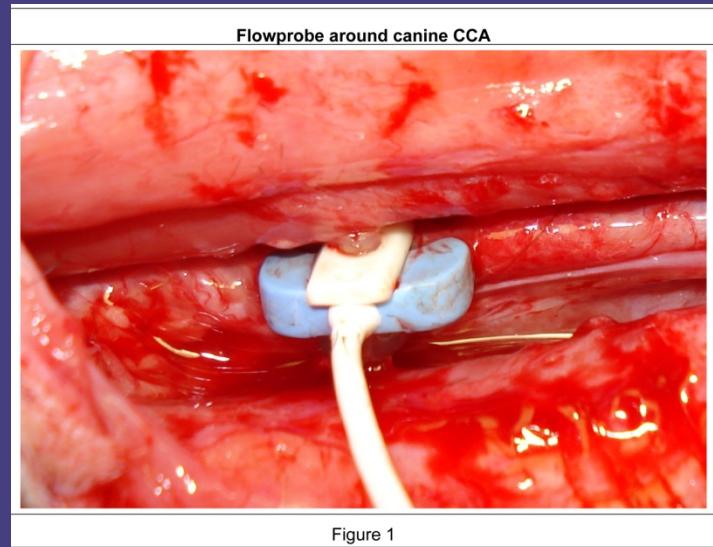


NOVA 3D Localizer



NOVA Validation

- ◆ In Vitro multi- tube phantom
 - ◆ Steady flow different flow rates
 - ◆ Pulsatile flow different flow rates
- ◆ In Vivo dog common carotid artery
 - ◆ Compare Flowprobe with PCMR



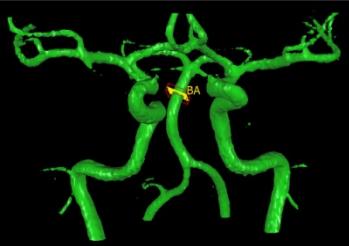
In Vivo Validation of Quantitative Magnetic Resonance Angiography in
Canine Carotid Artery Model
Mateo Calderon – Arnulphi MD

Clinical Applications

Traditional MRA:

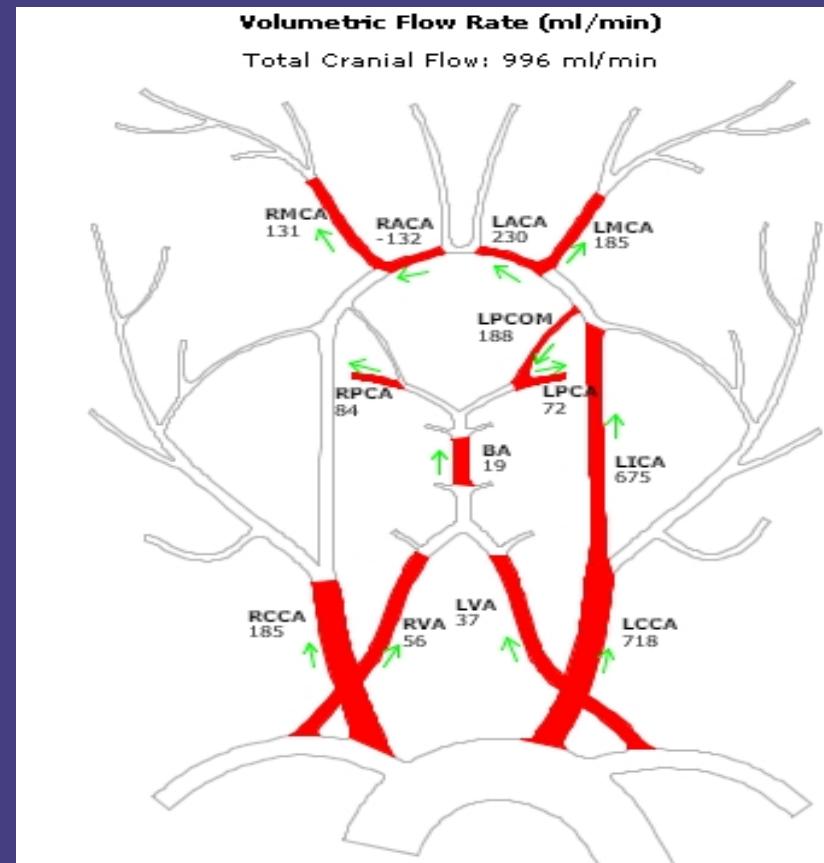


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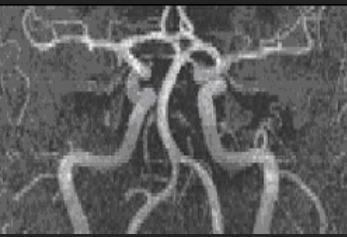
- ◆ Vertebrobasilar Disease
- ◆ Cerebral revascularization
- ◆ Intracranial and extracranial vessel stenosis pre and post stenting
- ◆ Assess collateral volume flow in large vessel disease
- ◆ Evaluate subclavian steal
- ◆ Aneurysm hemodynamics

Basilar Stenosis

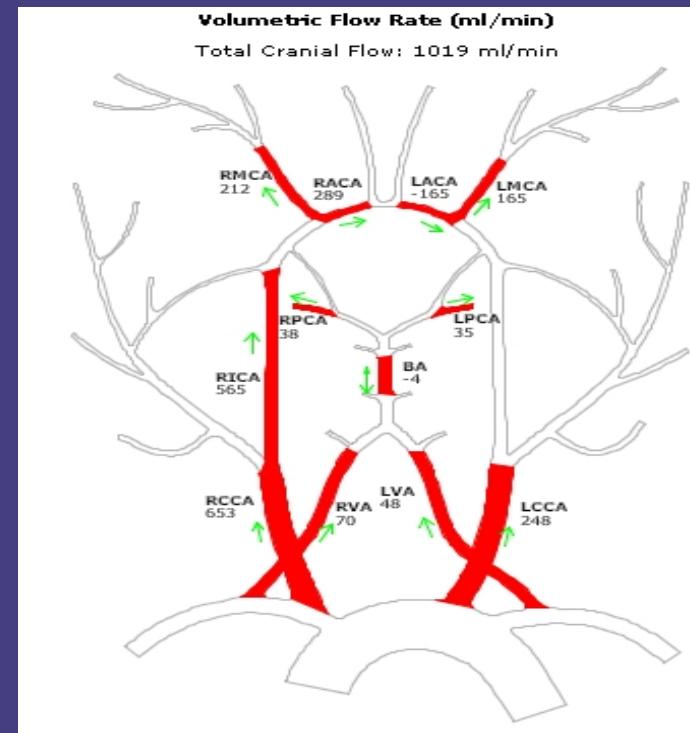
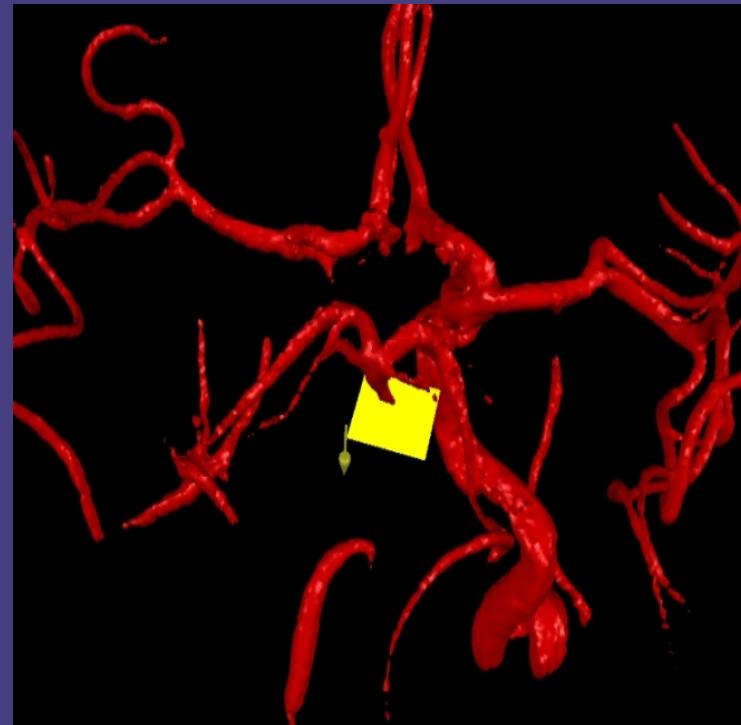
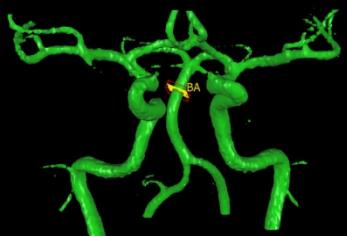


Basilar Occlusion

Traditional MRA:



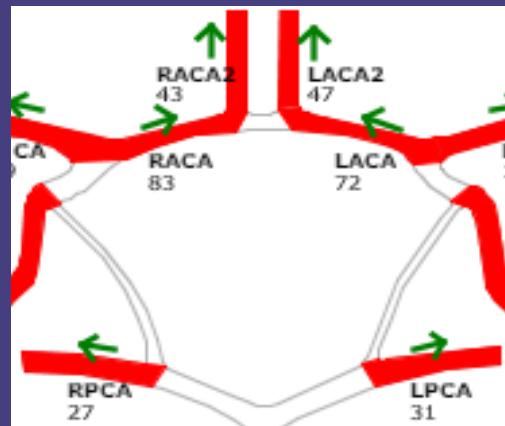
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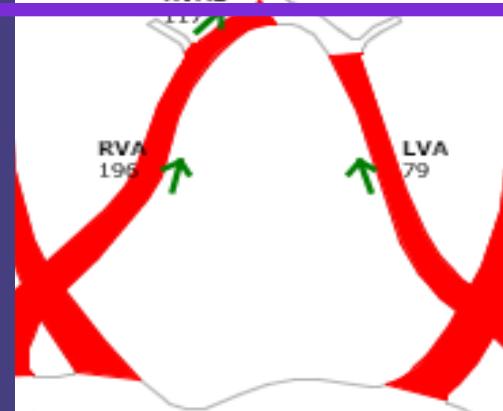
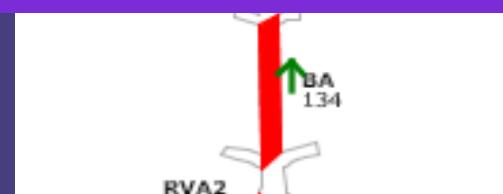
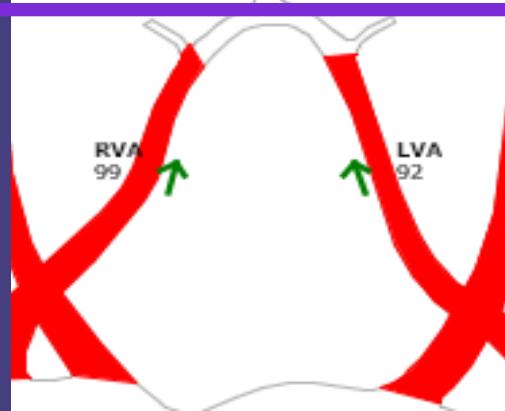
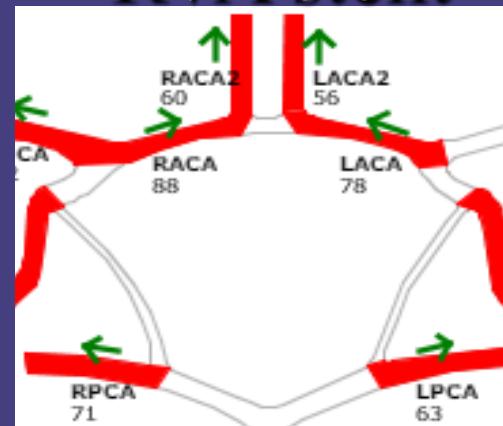
NOVA (QMRA) for Stent Management

Confirmation of improved flow

Baseline

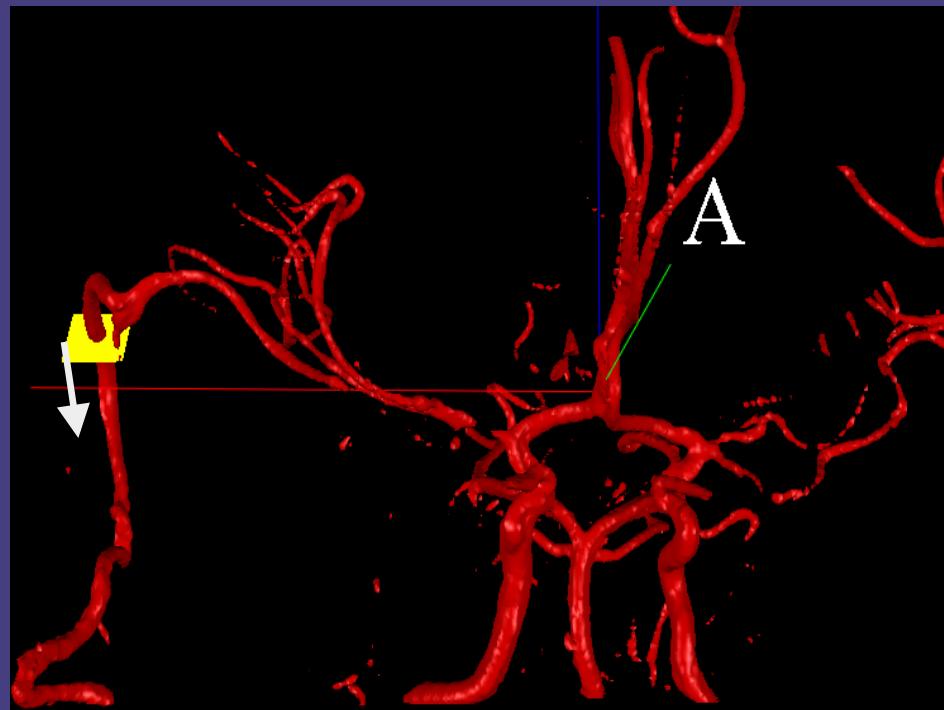


RVA stent



Patent bypass: serial follow-up

-46 months



NOVA Graft flow = 87 ml/min

2. CSF PCMR Protocol Optimization and Validation

- ◆ 1. Apply the same technique to CSF
- ◆ 2. Difference between CSF and Blood Flow
- ◆ 3. Phantom Study
- ◆ 4. Volunteer Study

Traditional MRA:



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Physical Difference Between CSF and Blood Flow

Traditional MRA:



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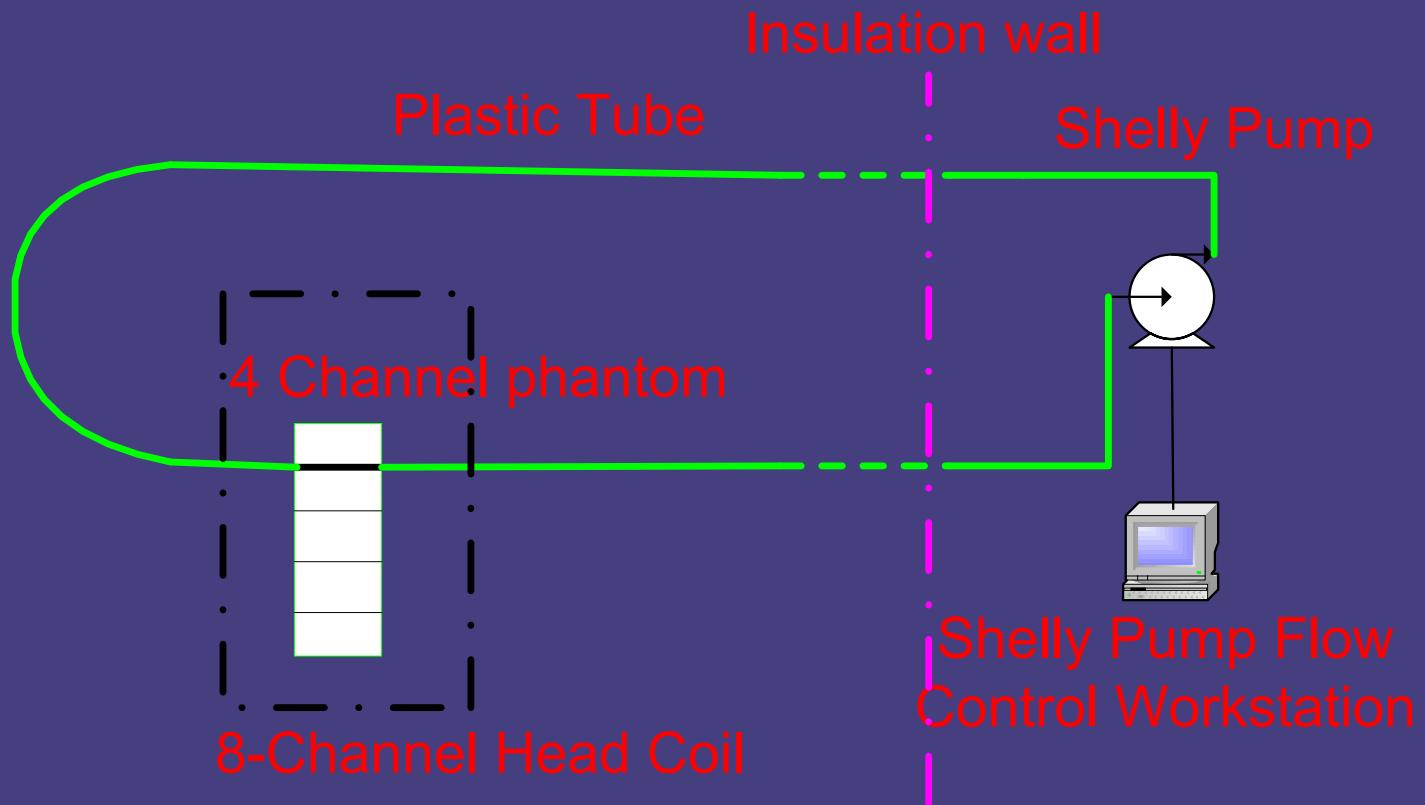
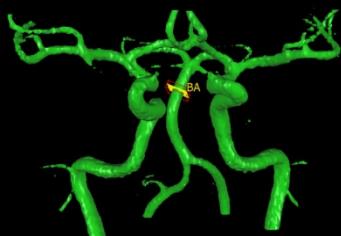
- ◆ Velocity
 - Blood Flow Velocity: ~100 cm/s
 - CSF Flow Velocity: ~ 10 cm/s
- ◆ Flow Pattern
 - Blood Flow: uni-directional
 - CSF Flow: bi-directional, more complex
- ◆ Flow domain
 - Blood Flow: within blood vessels
 - CSF Flow: Ventricles and subarachnoid space

Flow Phantom Diagram

Traditional MRA:

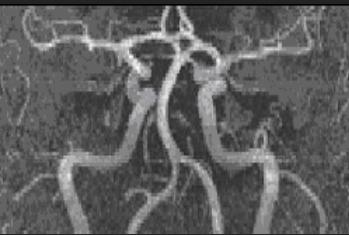


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PCMR Parameters

Traditional MRA:



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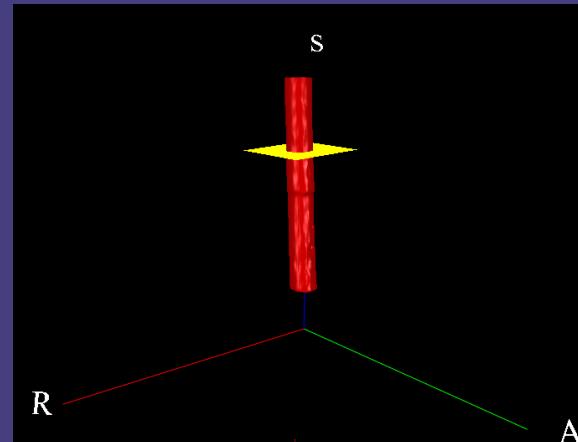
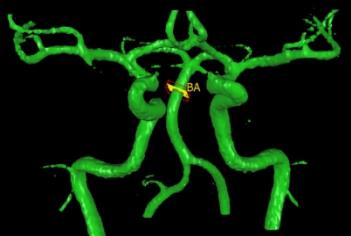
- ◆ Flip Angle 10-15-20
- ◆ VENC 10-20
- ◆ Number of Excitations (NEX) 2-6
- ◆ View Per Segment (VPS) 2-16
- ◆ Number of Phases 12-24
- ◆ Resolutions / FOV

Phantom PCMR Images

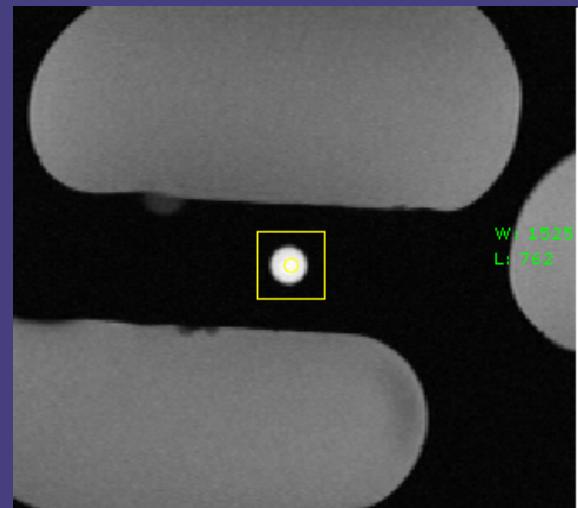
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3D model from
TOF



Magnitude Image



Phase Image

Phantom results

Table 1. Phantom Actual Flow Rate in Comparison with the Flow Rate from PCMR

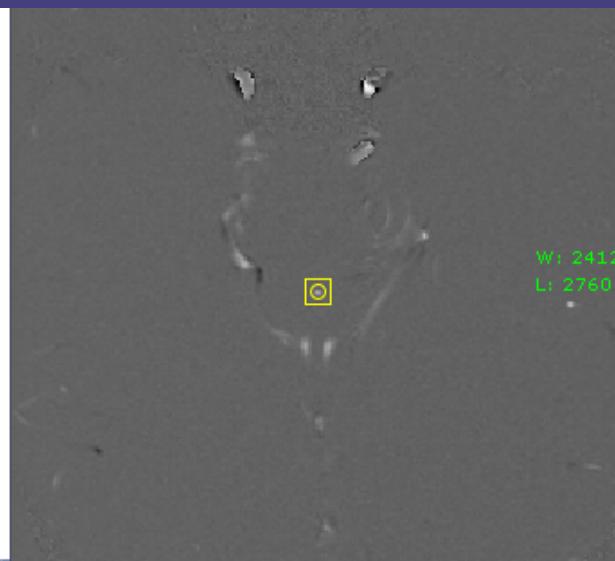
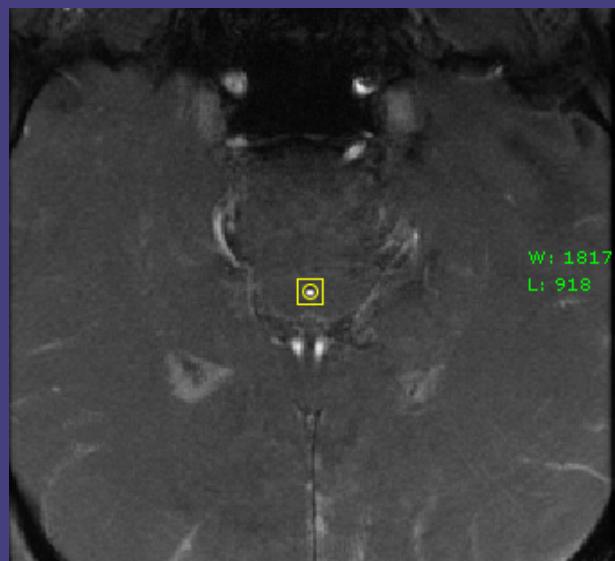
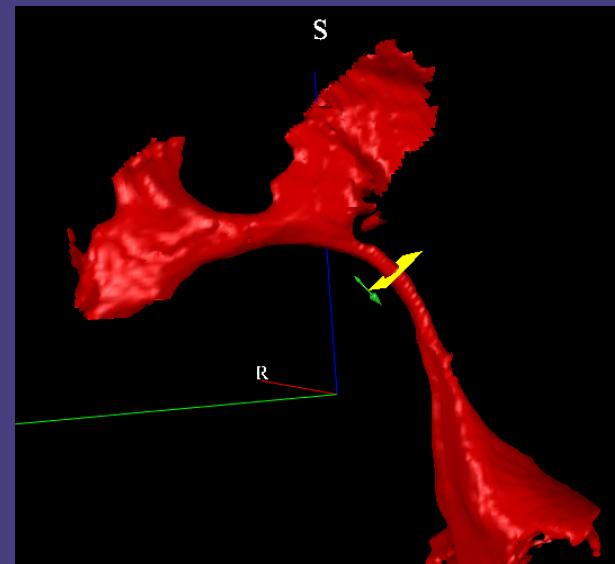
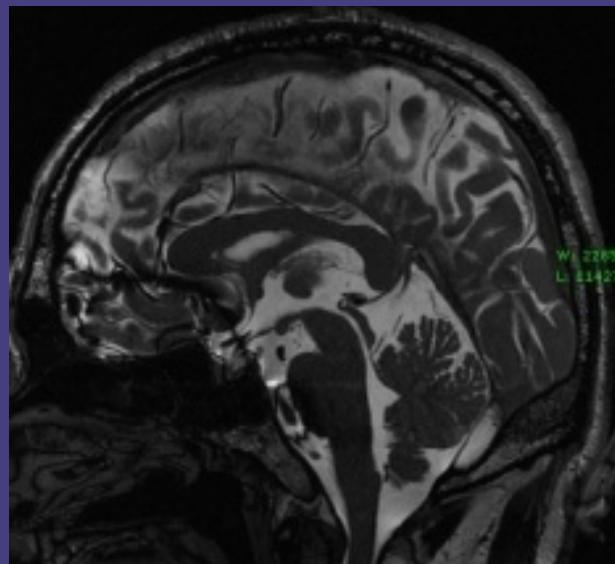
Flow Rate (mL/min)	Avg Velocity (cm/s)	12 Phases (mL/min)				24 Phases (mL/min)			
		Min	Max	Avg	Error (%)	Min	Max	Avg	Error (%)
60	1.99	54.5	57.1	55.58	-7.36	54.7	56.5	55.37	-7.72
120	3.98	113	114	113.5	-5.41	112.1	115.3	113.5	-5.40
180	5.97	173.7	176.3	174.57	-3.01	172.1	175.5	174.0	-3.32
240	7.96	232.2	236.1	233.98	-2.51	218.2	236.8	232.7	-3.04

Volunteer Study

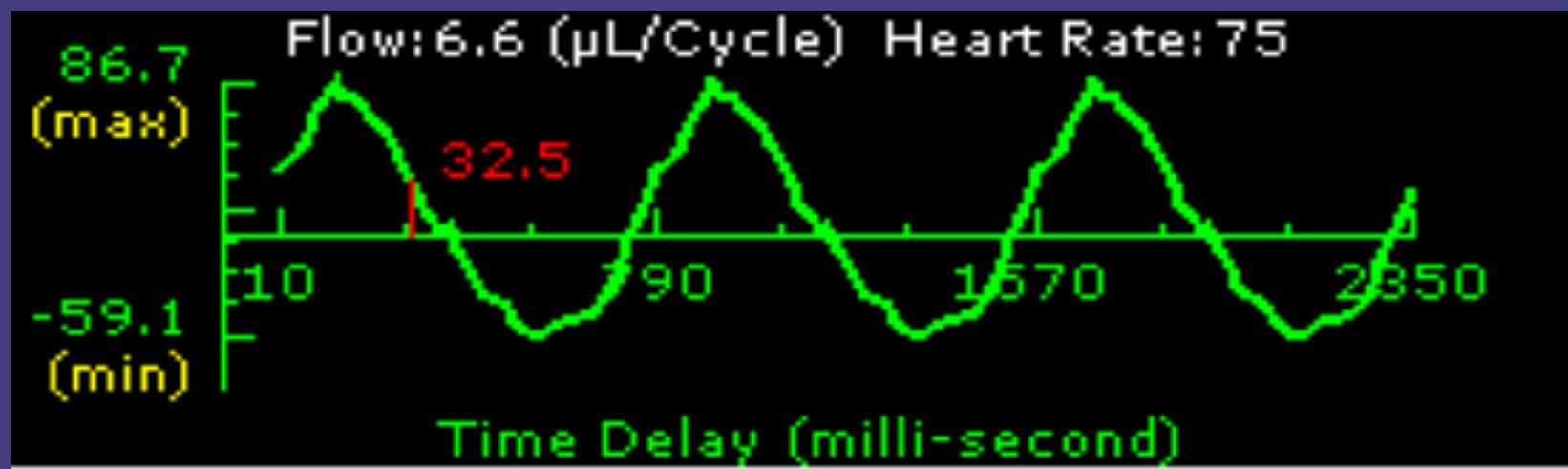
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CSF flow waveform at the Aqueduct



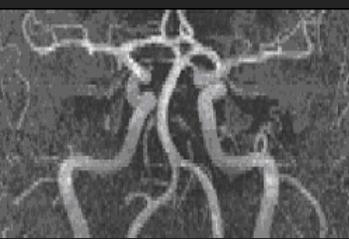
CSF flow waveform at the cerebral aqueduct from a representative human subject.

3. Problems and Future's Work

Problems

- ◆ Inter scanner differences
 - Different magnets, 1.5T, 3T
 - Different sampling methods
 - Different interpolation algorithms
 - Difference can be up to 100%
- ◆ Post processing differences
 - Vessel boundary extraction
 - Background subtraction

Traditional MRA:



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Repeatability –same vendor Same Volunteer

Traditional MRA:



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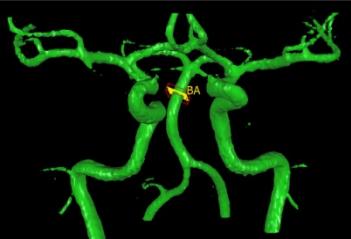
		Stroke Volume (uL/cycle)			
		GE 3T		GE 1.5T	
		VENC = 20	VENC = 30	VENC = 20	VENC = 30
EKG	1	12.6	10.8	21.3	15.0
	2	16.1	16.1	11.8	13.0
	3	19.6	19.5	14.2	9.3
	AVG	16.1	15.4	15.7	12.4
PG	1	17.9	21.8	13.4	18.0
	2	22.2	19.0	17.4	16.3
	3	28.3	22.6	9.1	12.6
	AVG	22.8	21.1	13.3	15.6

Difference between vendor Same Volunteer

Traditional MRA:



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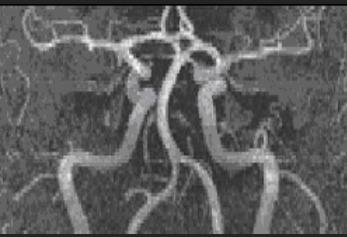


	Stroke Volume ($\mu\text{L}/\text{cycle}$)	Systolic / Diastolic Volume ($\mu\text{L}/\text{cycle}$)	Net Flow ($\mu\text{L}/\text{cycle}$)	Peak Systolic / Diastolic Velocity (mm/s)	Average Peak Systolic/ Diastolic Velocity (mm/s)
Siemens	32.5	32.8/-32.3	0.4	65/-48	37.9/-28.3
GE	42.0	44.3/-39.7	4.5	84/-53	47.3/-20.8
Difference	29%	35%/23%		29%/11%	25%/36%

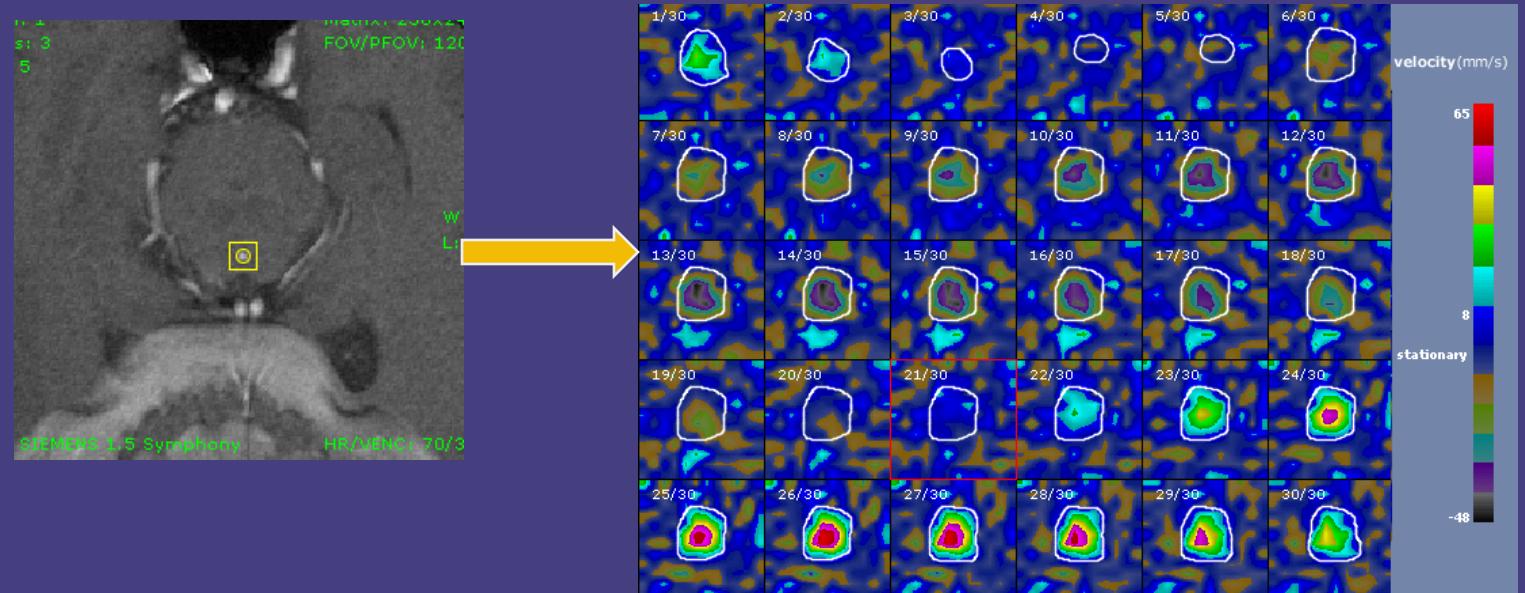
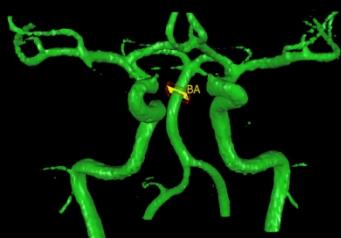
Table 1. Comparing of CSF Flow Results of the same Volunteer on both GE and Siemens scanners

Boundary Inconsistency

Traditional MRA:



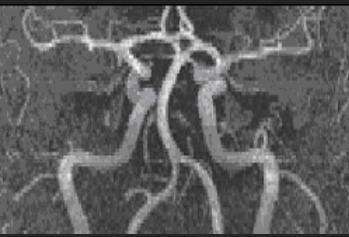
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Further Work

- ◆ Pulstile slow flow phantom
 - Smaller diameters
- ◆ Boundary Extraction Algorithms
 - Robust
 - Accurate
- ◆ Background Noise Suppression
 - Increase SNR
- ◆ Repeatability
 - Same scanner
 - Different scanner
 - Different vendors
 - Different operators

Traditional MRA:



VasSol's Quantitative MRA™

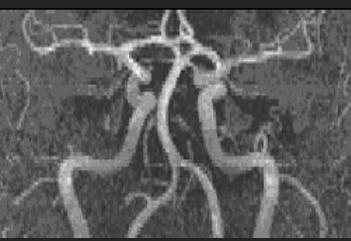


4. Summary - Quantitative Flow Assessment

- ◆ A review of previous work on blood flow quantifications with PCMR
- ◆ CSF PCMR protocols are optimized and validated
 - In vitro with phantom study
 - In vivo with volunteers
- ◆ Problems and future's work.

References

Traditional MRA:



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1. Sepideh Amin-Hanjani, MD; Xinjian Du, MD; Meide Zhao, PhD; Katherine Walsh, NP; Tim Malisch, M; Fady T. Charbel, MD. *Use of Quantitative Magnetic Resonance Angiography to Stratify Stroke Risk in Symptomatic Vertebrobasilar Disease*, *Stroke*. 2005;36:1140..
2. Amin-Hanjani S, Charbel FT. Flow-assisted surgical technique in cerebrovascular surgery. *Surgical Neurology*. July 2007 (68);S1:4-S1:11.
3. Amin-Hanjani S, Shin JH, Zhao M, Du X, Charbel FT. Evaluation of extracranial-intracranial bypass using quantitative magnetic resonance angiography. *J Neurosurg*. Feb 2007;106(2):291-298.
4. Calderon-Arnulphi MA-H, S; Alaraj, AM; Ostergren L; Zhao, M; Du, X; Charbel, FT. In Vivo Validation of Quantitative Magnetic Resonance Angiography in Canine Carotid Artery Model. 2008 International Stroke Conference. New Orleans, LA; 2008.
5. Markus Chwajol, M.D., Alejandro Berenstein, M.D., Chandranath Sen M.D., David J. Langer, M.D. Occipital Artery to Posterior Inferior Cerebellar Artery Bypass for Treatment of Bilateral Vertebral Artery Occlusion: The Role of Quantitative Magnetic Resonance Angiography Non-invasive Optimal Vessel Analysis (NOVA). *Neurosurgery* 64E:779-E781, 2009.

Thanks

Traditional MRA:



VasSol's
Quantitative MRA™



William Bradley, MD

Joe Zhou, Ph.D

Xinjian Du, MD

Lauren Ostergen

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Traditional MRA:



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Thank you!