Per quanto concerne i moderatori, relatori, formatori, tutor, docenti è richiesta dall'Accordo Stato-Regioni vigente apposita dichiarazione esplicita dell'interessato, di trasparenza delle fonti di finanziamento e dei rapporti con soggetti portatori di interessi commerciali relativi agli ultimi due anni dalla data dell'evento. La documentazione deve essere disponibile presso il Provider e conservata per almeno 5 anni.

Dichiarazione sul Conflitto di Interessi

Il sottoscritto CASTELLARO MARCO in qualità di:

relatore

dell'evento "X CONGRESSO AIRMM - RISONANZA MAGNETICA IN MEDICINA 2019: DALLA RICERCA TECNOLOGICA AVANZATA ALLA PRATICA CLINICA"
Milano, 28-29 marzo 2019

da tenersi per conto di **Biomedia srl Provider n. 148,**

ai sensi dell'Accordo Stato-Regione in materia di formazione continua nel settore "Salute" (Formazione ECM) vigente,

Dichiara

che negli ultimi due anni NON ha avuto rapporti anche di finanziamento con soggetti portatori di interessi commerciali in campo sanitario

ISMRM Italian Chapter

Arterial Spin Labelling: thinking out of the brain

Marco Castellaro

Padova Neuroscience Center, University of Padova
Department of Information Engineering, University of Padova

DEPARTMENT OF INFORMATION ENGINEERING
UNIVERSITY OF PADOVA

Milano, 29th March 2019

FAIR
functional and anatomical imaging research

Outline

- **Introduction:**
  - ASL Basic principles

- **ASL in body applications**
  - Literature Review
  - Challenges

- **Case studies**
  - Kidney
  - Placenta
  - Retina
  - Liver

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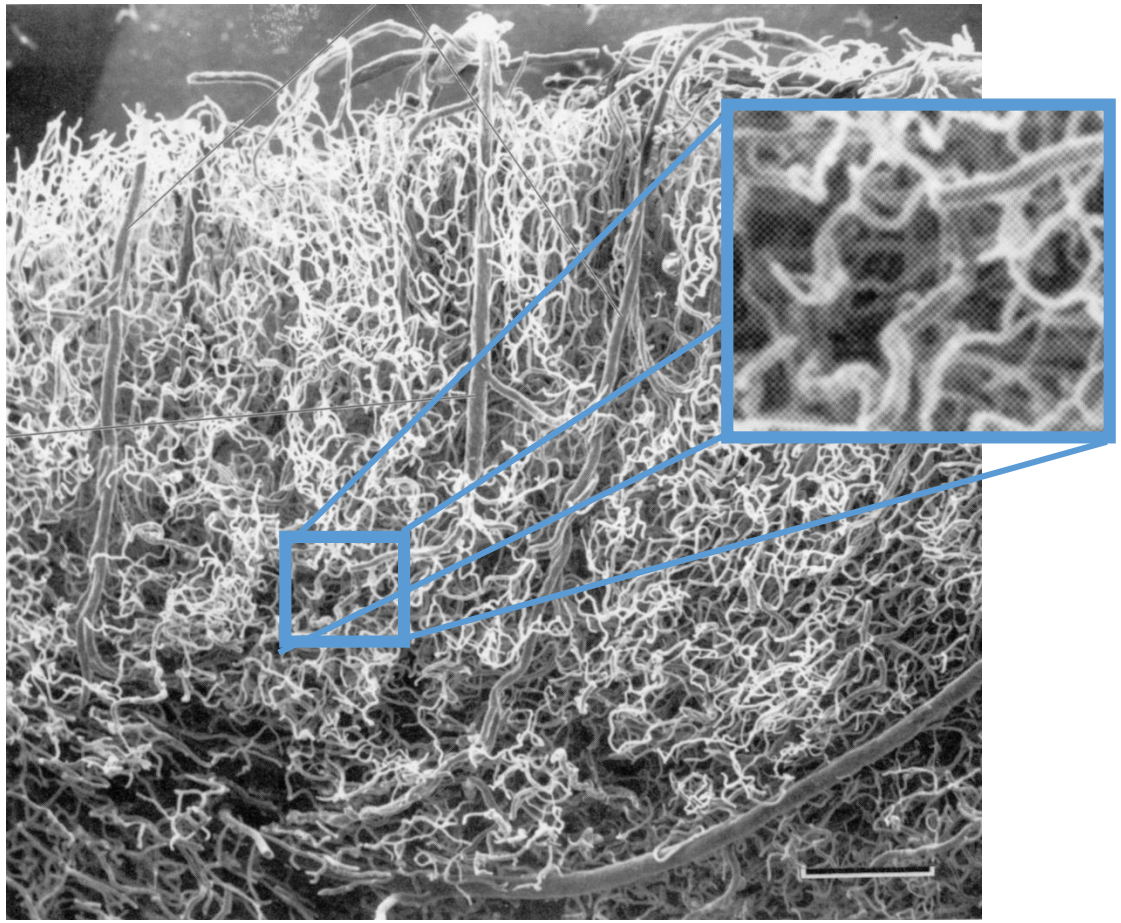
Perfusion: what is it?



Blood flow (BF)

amount of blood that enters the microvasculature per second

ml blood / 100 gr tissue / min

ASL basic principles

- Endogenous tracer
- Based on difference of two images and a calibration
- Absolute quantification with model

Control image − Label image =

Nery et al. Diagnostics 2018, 8, 2; doi:10.3390/diagnostics8010002

ASL implementations

CASL	pASL	BASE	VS-ASL	HE-ASL	Turbo-TILT
FAIR	FAIRER	EPISTAR	ACC-ASL	TF	pTILT
pCASL unbalanced	pCASL ba				Pulsed-CASL
PULSAR	QU	QUIPSS	SASL	DASL	ssDASL
UNFAIR	TILT	DIPLOMA	IDOL	ASSIST	FAIREST

FLEXIBILITY?

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  - Liver
  - Skeletal Muscle

Literature review criteria

Sources: **Pubmed**
asl-network newsletter (established in 2009)

Queries:

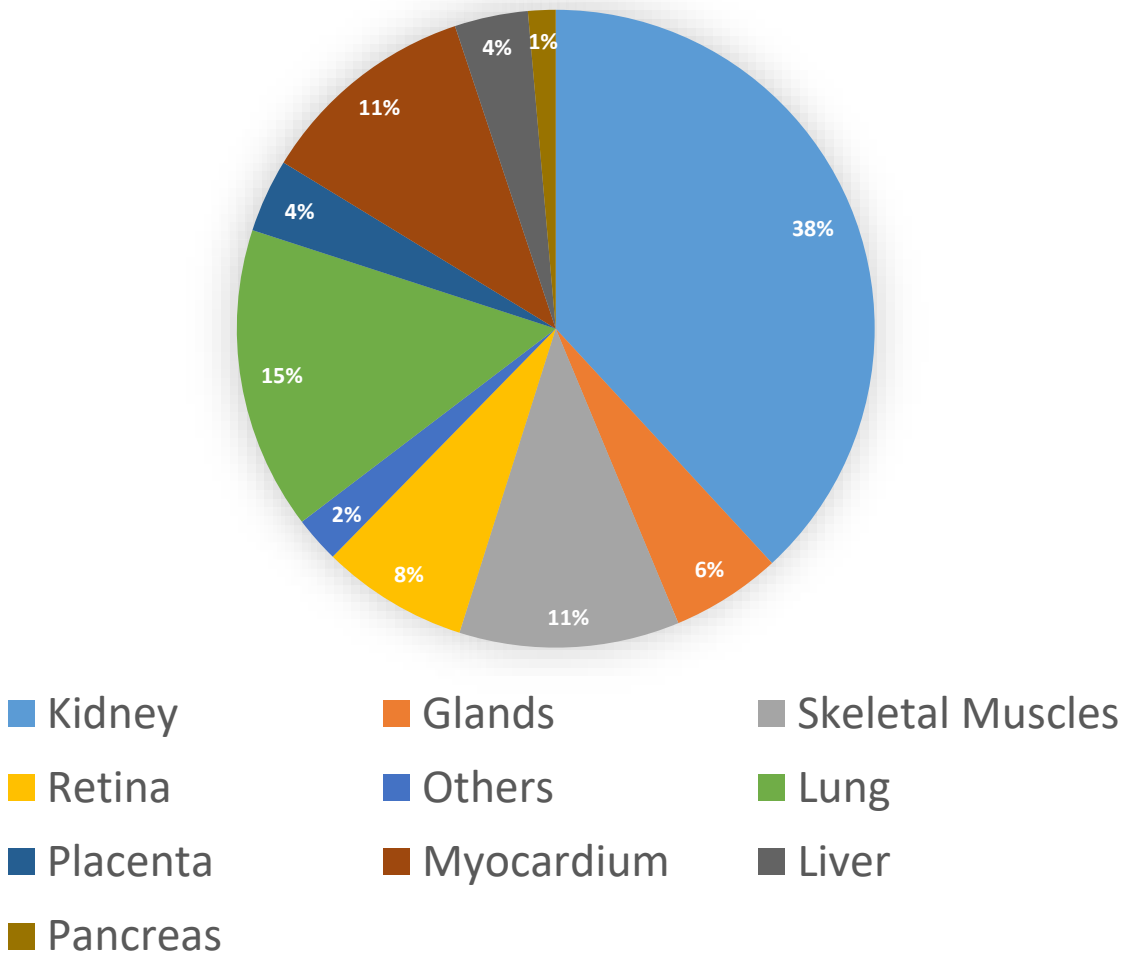
- **"Arterial Spin Labelling" NOT Cerebral Blood Flow NOT Brain**
- **"Arterial Spin Labelling" AND Kidney**
- **"Arterial Spin Labelling" AND Lung**
- **"Arterial Spin Labelling" AND Heart AND Myocardium**
- **"Arterial Spin Labelling" AND "Skeletal Muscle"**
- **"Arterial Spin Labelling" AND "Retina"**
- **"Arterial Spin Labelling" AND "Liver"**
- **"Arterial Spin Labelling" AND "Pancreas"**
- **"Arterial Spin Labelling" AND "Placenta"**

Excluded:
Reviews, Perspectives, Editorial Comments

Literature review summary

District or organ	# papers	Year first paper
Kidney	82	1997
Lung	33	1999
Skeletal Muscles	24	2008
Myocardium	24	2005
Retina	16	2008
Glands	12	2009
Liver	8	2010
Placenta	8	1998
Pancreas	3	2008
Others	5	
TOTAL	215	

Frequency of papers based on district



Challenges

- Motion
  - Respiration
  - Bulk motion
- Complex anatomy
- Find optimal labelling region (or plane) to ensure optimal labelling efficiency

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Case study: Kidney

FULL PAPER

Magnetic Resonance in Medicine

Robust kidney perfusion mapping in pediatric chronic kidney disease using single-shot 3D-GRASE ASL with optimized retrospective motion correction

Fabio Nery[1] | Enrico De Vita[2] | Chris A. Clark[1] | Isky Gordon[1] | David L. Thomas[3,4]

[1]Developmental Imaging and Biophysics Section, University College London Great Ormond Street Institute of Ch

[2]Department of Biomedical Engineering, School of Biomedical Engineering & Imaging Sciences, King's College Thomas' Hospital, London, United Kingdom

[3]Department of Brain Repair and Rehabilitation, University College London Queen Square Institute of Neurology

[4]Leonard Wolfson Experimental Neurology Centre, University College London Queen Square Institute of Neurol Kingdom

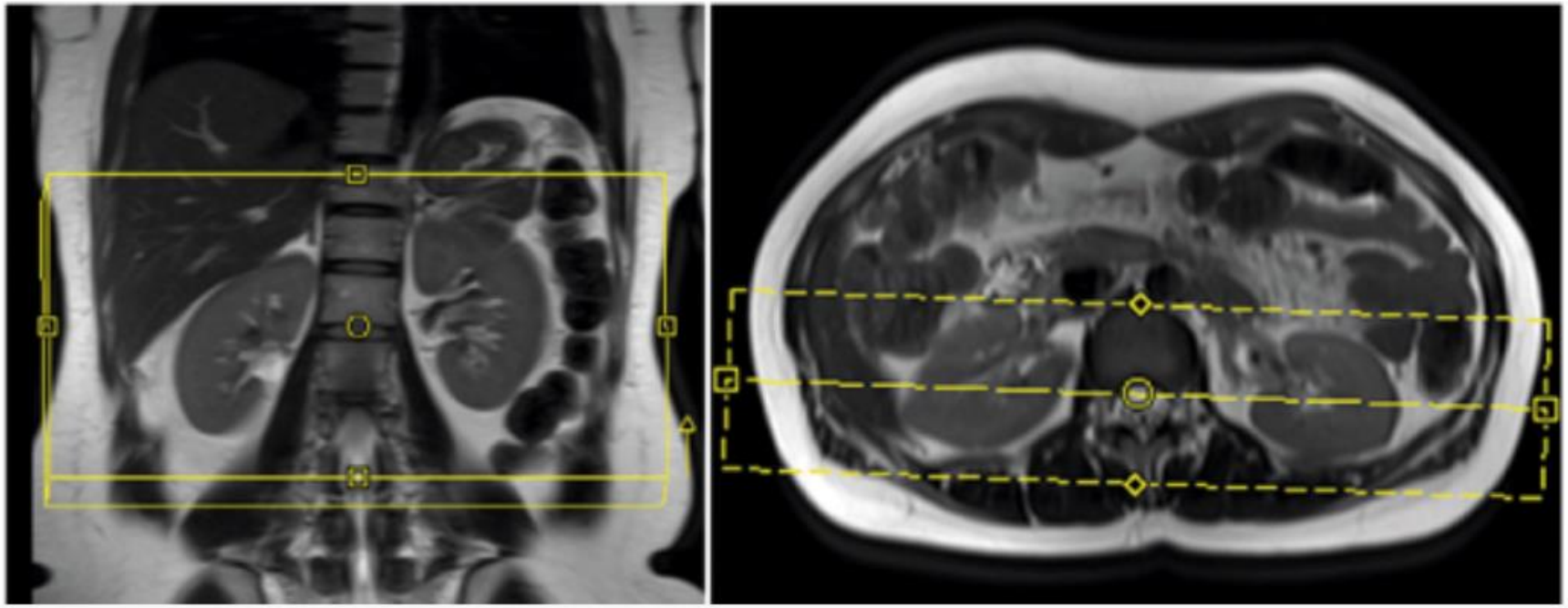
WHY?
Perfusion in the kidney could be useful for disease staging of Cronic Kidney Disease

Contrast agent is controindicated in Renal failure

Nery et al. MRM 2018, doi:10.1002/mrm.27614

Kidney: exam setup

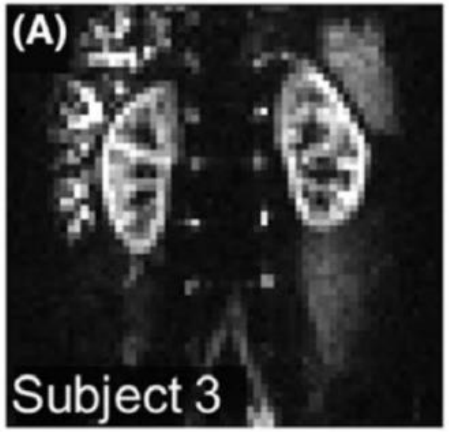
- Labelling: FAIR (PULSED ASL)
- Readout: 3D GRASE
- Acquisition Time: 2:30 min
- Triggered with respiration to the end of expiration phase
- Magnet: 1.5T

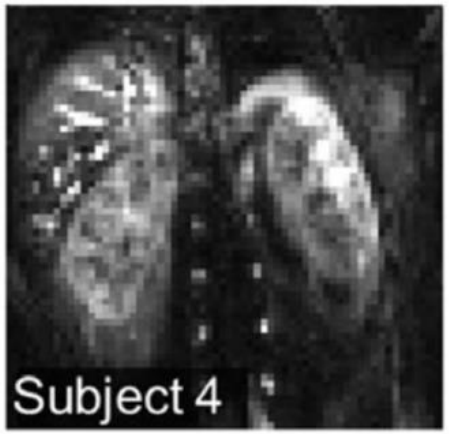


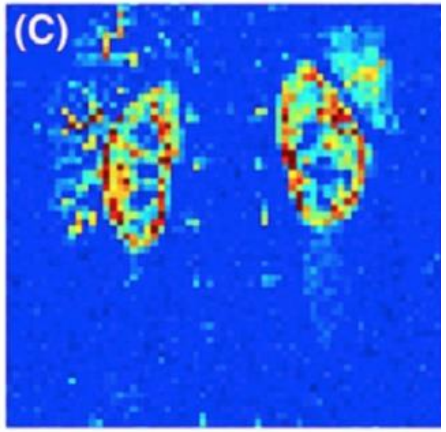
Shirvani et al. European Radiology 2019, doi:10.1007/s00330-018-5628-3

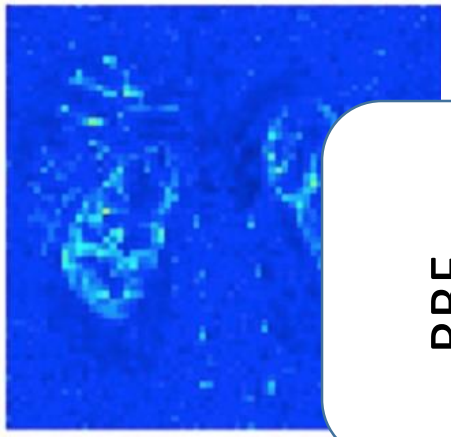
Kidney: motion correction

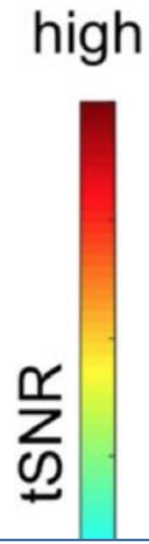
- Prospective motion correction combined with clever weighting based on noise estimation in a single pipeline can help in managing difficult populations











RBF

ICC	Inter session
No Motion correction	0.37
Motion correction	0.84

Nery et al. MRM 2018, doi:10.1002/mrm.27614

Kidney: recommendations

- Still no gold-standard
- Reproducible
  Medulla lower than Cortex
- Single–slice renal perfusion is the most consolidated scheme
- Whole renal perfusion map can be achieved
- Development on motion correction, kinetic modelling and multi-PLD schemes

Table 3. Minimum recommendations for reporting renal ASL studies

Outline patient preparation (e.g. hydration)
Outline subject characteristics
Measure systemic haemodynamics (e.g. blood pressure)
Report current medications (especially those targeting the renin–angio-tensin system)
Outline the labelling scheme
Report the duration of the post-label delay
Outline the readout scheme
Explicitly outline how motion compensation was handled
Explicitly state whether background suppression was applied
Acquire a T1 map to use in the kinetic model
Describe how the region of interest for ASL analysis is selected
Report cortical and medullary values separately
Report within-subject reproducibility for your site preferably both within and between visits
Measure other renal MRI parameters if possible (e.g. BOLD, diffusion)

Odobu et al. Nephrol Dial Transplant 2018, doi:10.1093/ndt/gfy180

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Case study: Placenta

FULL PAPER

Magnetic Resonance in Medicine

Placental perfusion imaging using velocity-selective arterial spin labeling

Zungho Zun PhD[1,2,3,4] | Catherine Limperopoulos PhD

[1] Division of Diagnostic Imaging and Radiology, Children's National Medical Center, Washin

[2] Division of Fetal and Transitional Medicine, Children's National Medical Center, Washingto

[3] Department of Pediatrics, School of Medicine and Health Sciences, George Washington Univ

[4] Department of Radiology, School of Medicine and Health Sciences, George Washington Uni

WHY?

Perfusion could be related to placenta disfuction

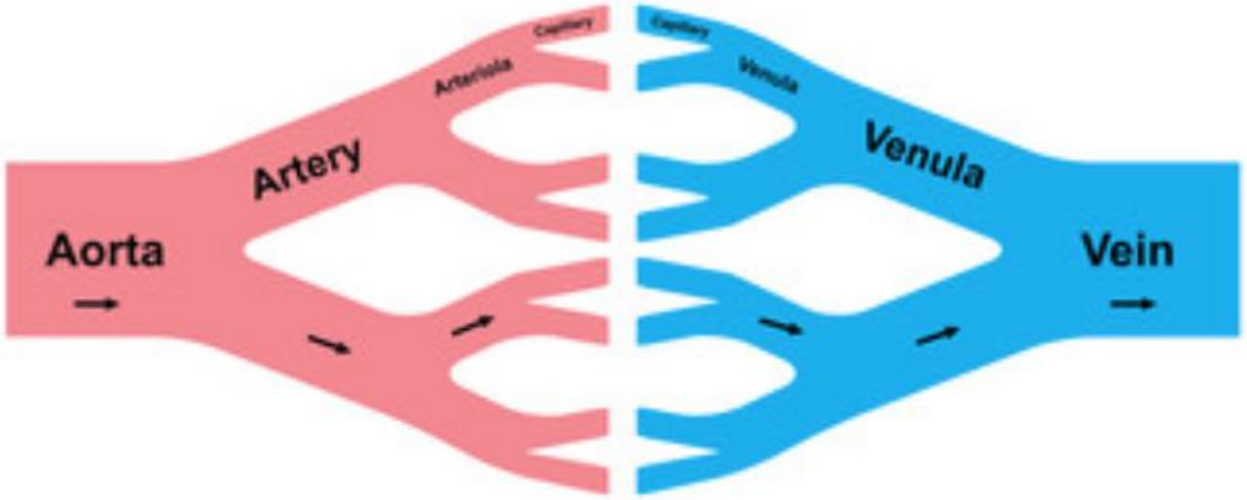
This can provide insight on fetal growth restriction or preeclampsia

Zun et al. MRM 2018, doi:10.1002/mrm.27100

Placenta: Velocity selective ASL

Velocity decreases

Velocity increases

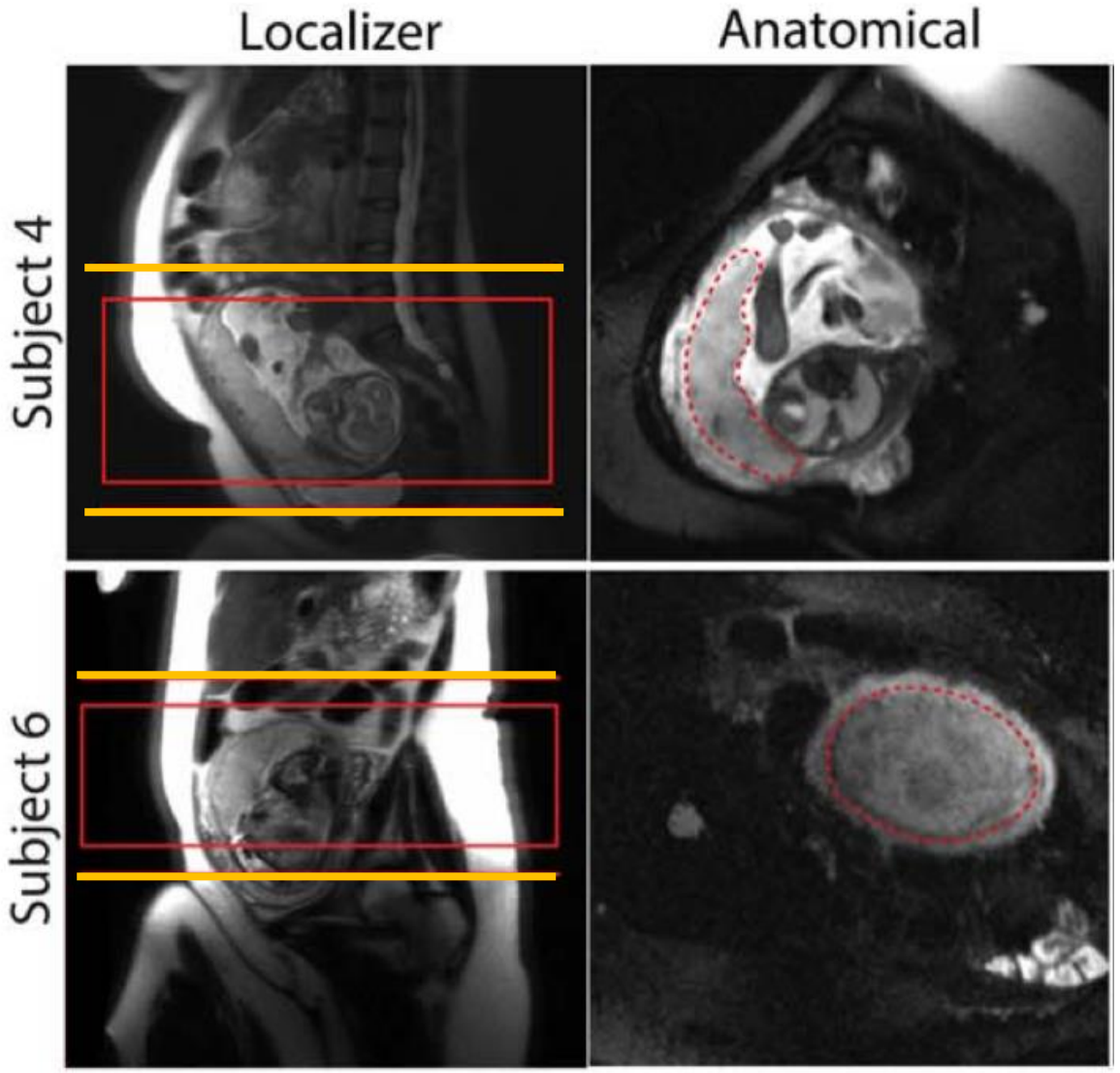


- Similar principle to the diffusion weighted sequence
- Labelling is created based on its velocity regardless position
- Long arterial transit delay artefact can be overcome

- Two velocity selective pulses
- First saturate flow above Vc
- After a PLD a Second Saturate flow above Vc
- Spins decelerating from >Vc and to <Vc are selected

Zun et al. MRM 2018, doi:10.1002/mrm.27100

Placenta: exam setup



pCASL labelling plane

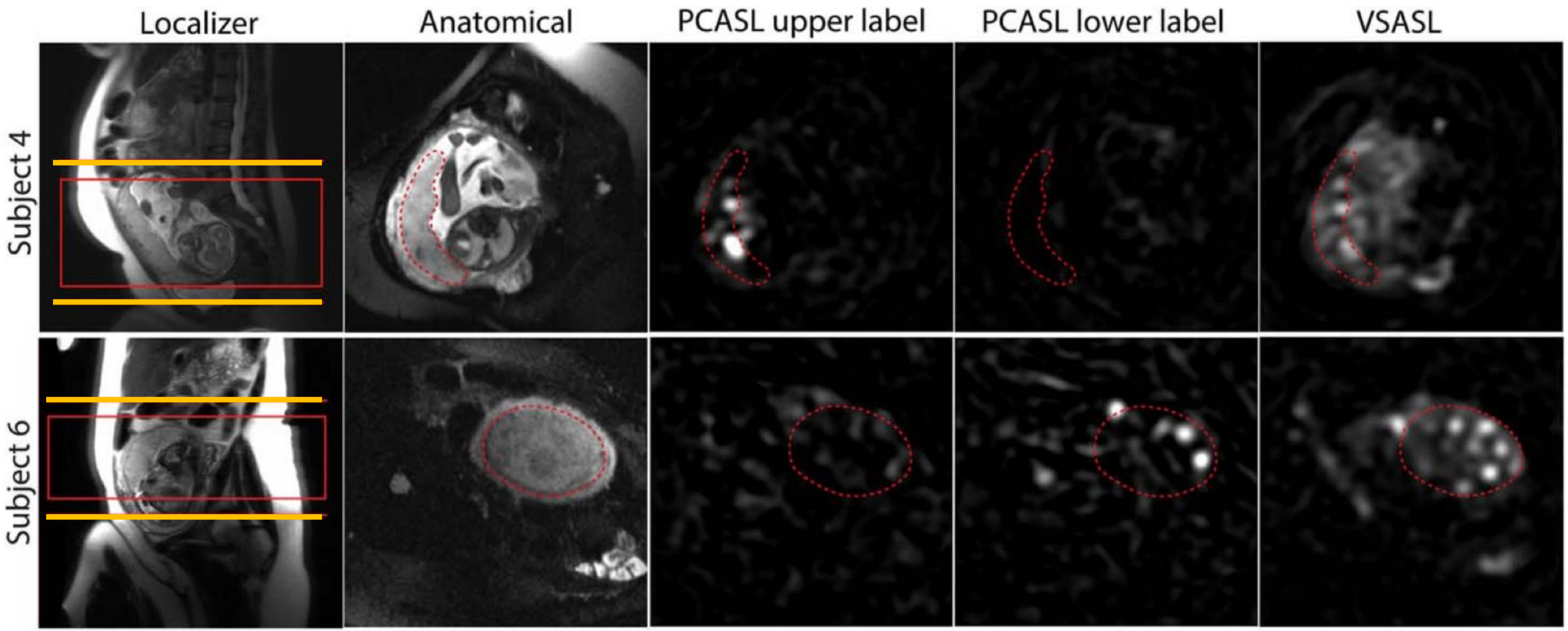
FOV / VS labelling

Upper labelling plane :
Descending aorta

Lower labelling plane:
Utherine artery

Zun et al. MRM 2018, doi:10.1002/mrm.27100

Placenta: pCASL vs VS-ASL



Zun et al. MRM 2018, doi:10.1002/mrm.27100

Placenta: Take home messages

- Still no gold-standard
- Reproducible (ICC = 0.97)
- Feasible at 1.5T
- pCASL vs VS-ASL comparison suggests the use of VS-ASL
- Development is needed to further validate this technique

Zun et al. MRM 2018, doi:10.1002/mrm.27100

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Case study: Retina

Magnetic Resonance in Medicine 65:1768–1775 (2011)

MRI of Blood Flow of the Human Retina

Qi Peng,[1,2] Yi Zhang,[1,2] Oscar San Emeterio Nateras,[2] Matthias J.P. van Osch,[3] and Timothy Q. Duong[1,2,4–6]*

WHY?

MRI can provide unique information with depht resolution

BF regulation investigation to probe the neural tissues they subserve

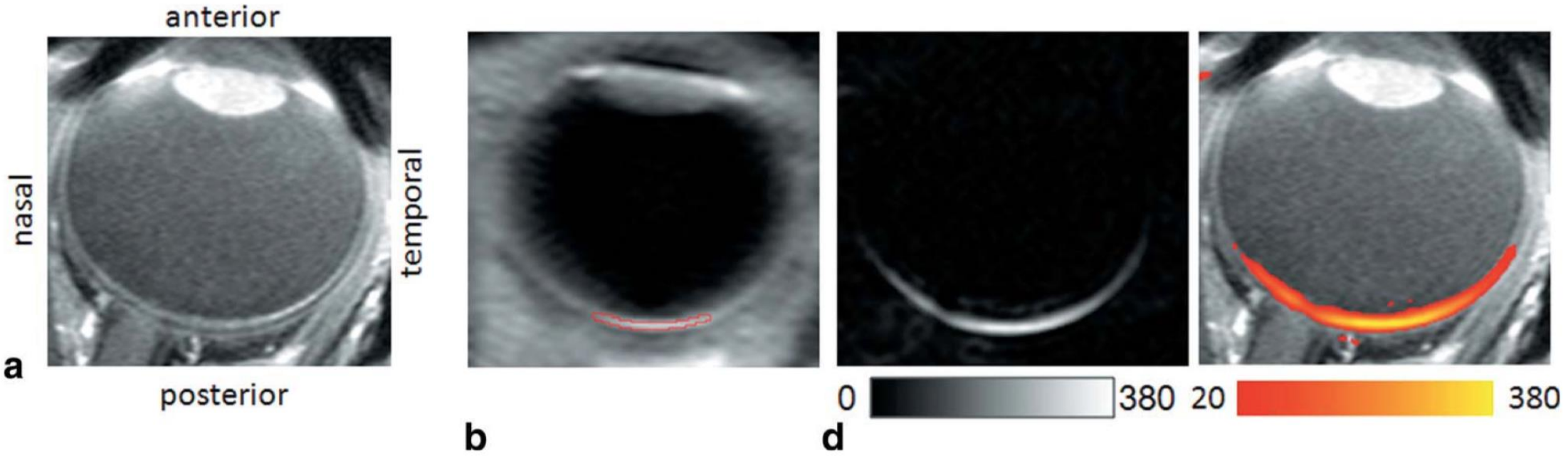
Peng et al. MRM 2011, doi:10.1002/mrm.22763

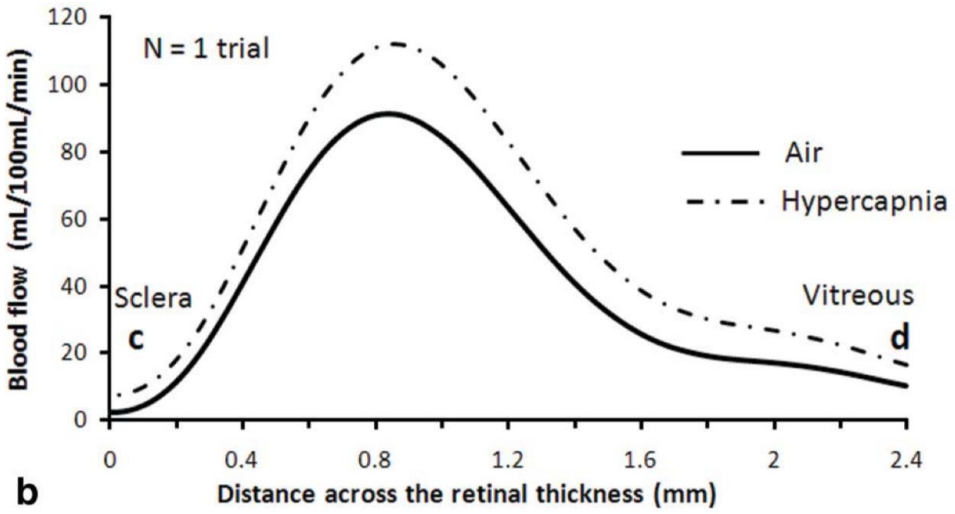
Retina: exam setup

- Custom readout coil
- Labelling pCASL
- Magnet 3T
- Background Suppression
- High Resolution
- Patient un-anaesthetized
- Readout synchronized eye blink movement

Peng et al. MRM 2011, doi:10.1002/mrm.22763

Retina





Keypoint

Feasibility of imaging basal retinal BF and hypercapnia-induced blood-flow changes

Peng et al. MRM 2011, doi:10.1002/mrm.22763

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Case study: Liver

Spatial-temporal perfusion patterns of the human liver assessed by pseudo-continuous arterial spin labeling MRI

Petros Martirosian[1,*], Rolf Pohmann[2], Christina Schraml[3], Martin Schwartz[1,4], Thomas Kuestner[1,4], Nina Franziska Schwenzer[3], Klaus Scheffler[2,5], Konstantin Nikolaou[3]

[1] Section on Experimental Radiology, University Hospital of Tübingen,
[2] Department of High-field Magnetic Resonance, Max Planck Institute f
[3] Department of Diagnostic and Interventional Radiology, University Ho
[4] Institute of Signal Processing and System Theory, University of Stuttg
[5] Department of Biomedical Magnetic Resonance, University Hospital o

Received 16 April 2018; accepted 27 August 2018

WHY?

Focal lesion detection

Diffuse disease evaluation

Martirosian et al. Z Med Phy 2018, doi:10.1016/j.zemedi.2018.08.004

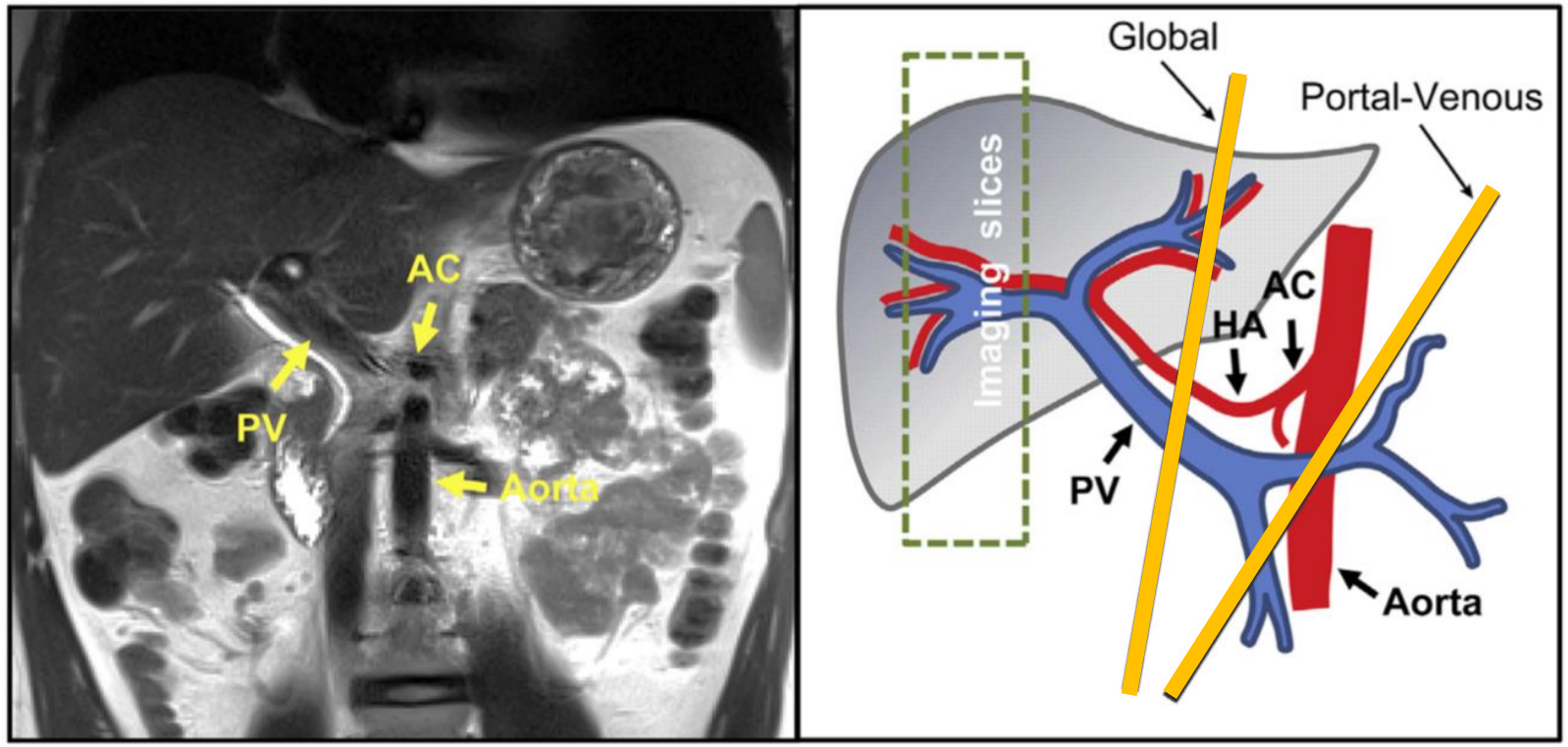
Liver: exam setup

- Labelling: pCASL
- Readout: 2D EPI
- Acquisition Time: 4:57 min for each PLD
- Triggered with respiration to the end of expiration phase
- Magnet 3T

- Two labelling positions

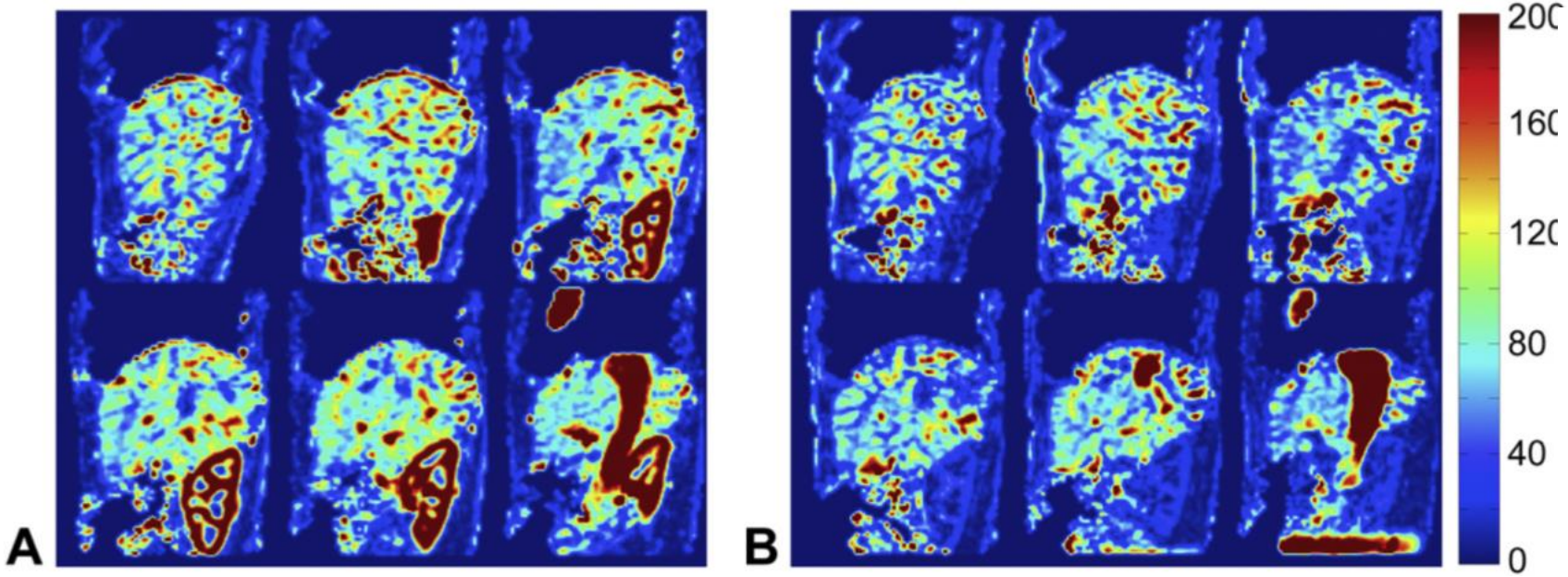
- Global Blood Flow
- Portal Vein

- Difference to obtain arterial portion only



Martirosian et al. Z Med Phy 2018, doi:10.1016/j.zemedi.2018.08.004

Liver: exam setup



Global Blood Flow

Portal Vein Blood Flow

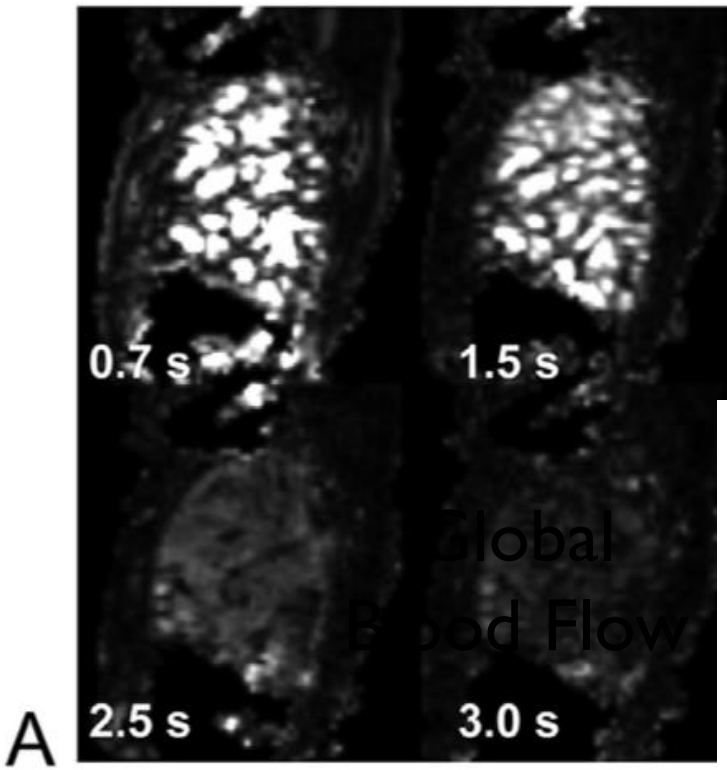
Arterial Blood Flow

Martirosian et al. Z Med Phy 2018, doi:10.1016/j.zemedi.2018.08.004

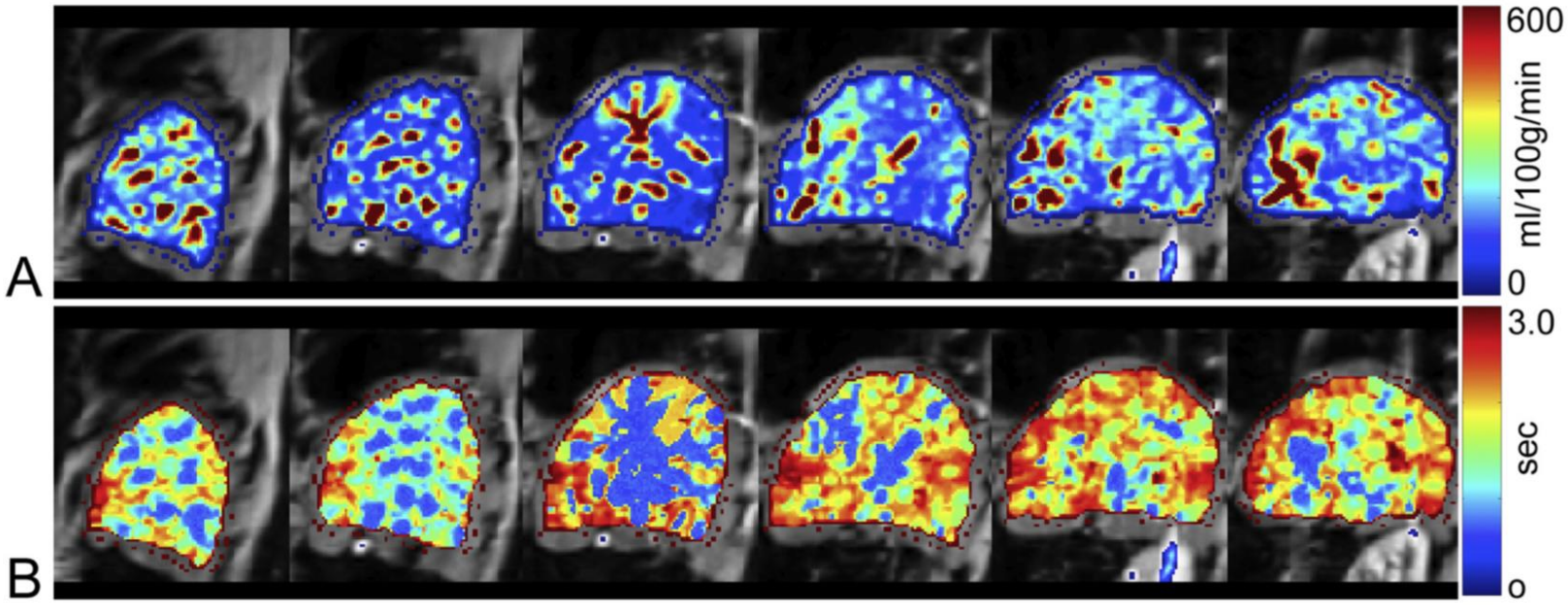
Liver: Multi-PLD

ASL model fitting

Single PLD	Multiple PLD	
Perfusion (ml/100g/min)		Arterial Arrival Time (ms)
82 ± 15	153 ± 15	1938 ± 332



Global Blood Flow



Arterial Arrival Time

Martirosian et al. Z Med Phy 2018, doi:10.1016/j.zemedi.2018.08.004

Liver: take home messages

- Still no gold-standard
- pCASL with multiple PLD provided ATT maps and perfusion maps in agreement with literature values
- Development is needed to further validate this technique

Take home messages

ASL body applications are feasible: ASL is flexible!!

However … ASL body application are still challenging…

Nevertheless, ASL body application are continuously in development for clinical applications

Thank you for the attention!!

Kidney: caveat

- In population with Chronic Kidney Disease (i.e. in this study glomerular filtration of 26 ± 9 mL/min per 1.73 m^2) is necessary to measure T_1 since it has been associated with renal impairment
- Saturation Recovery was collected to estimate T_1 and to modify the quantification model
- Motion Correction was applied also to the saturation recovery to retrieve also the best T_1 and calibration images

Nery et al. MRM 2018, doi:10.1002/mrm.27614