

Clinical MRI: From Physical Principles to Practical Protocols

Vivian S. Lee, Timothy J. Mosher, Organizers

Saturday, 6 May, 08:00 - 17:45

Vascular Protocols

James FM Meaney F.R.C.R.



Acknowledgements

F Korosec

JP Ridgway

S Schoenberg

TL Chenevert

P Wielopolski

R Edelman

KaiYiu Ho

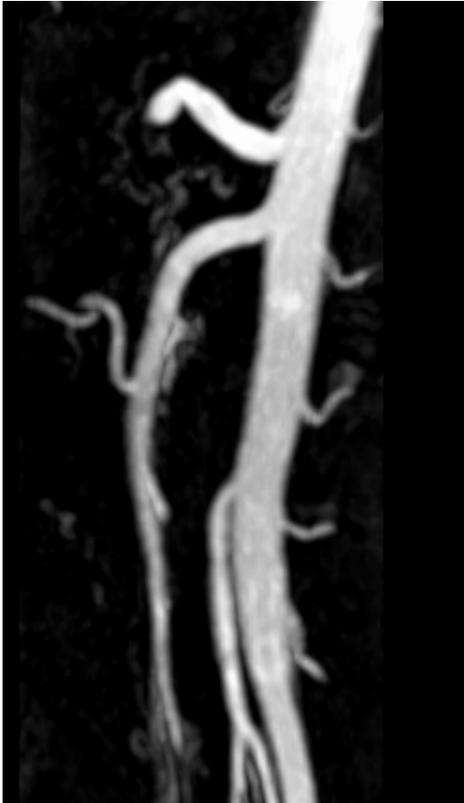
Vince Ho

T Grist

M Knopp

G Boyle

& MR Technologists, Dublin

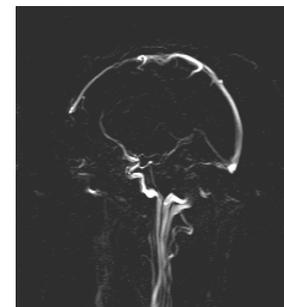
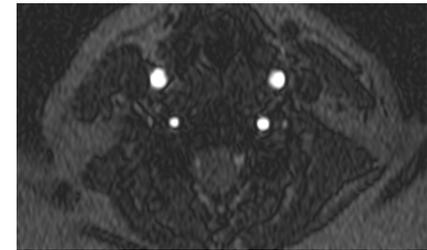
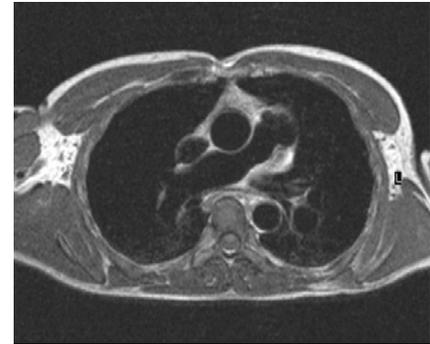


What are the aims?

- Image anatomy (“the lumen”)
(angiogram/venogram)
- Determine function
- Determine parenchymal abnormalities
(renal tumours, etc)
- Image the wall (e.g. unstable plaque)

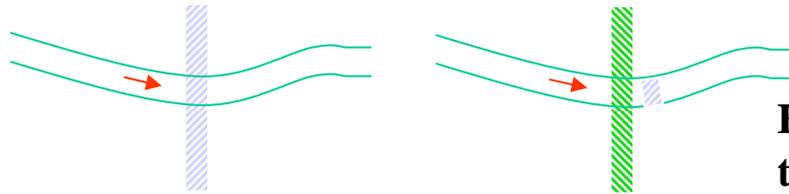
In the last century

- Spin Washout
 - **Black Blood MRA**
- Flow-Related Enhancement
 - **Time of Flight (TOF) MRA**
- Phase-Related Signal Loss
 - **Phase Contrast MRA**



Principle of Black Blood MRA

The Spin Washout effect:



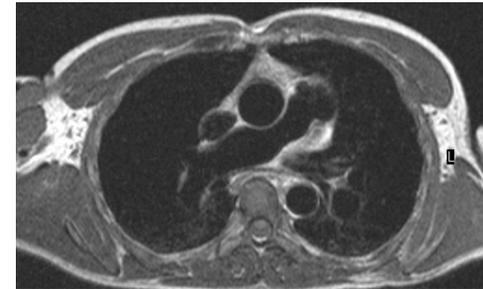
Excited spins wash out of the slice before the 180° pulse is applied

90° RF pulse

180° RF pulse

Spin Echo
Pulse
Sequence

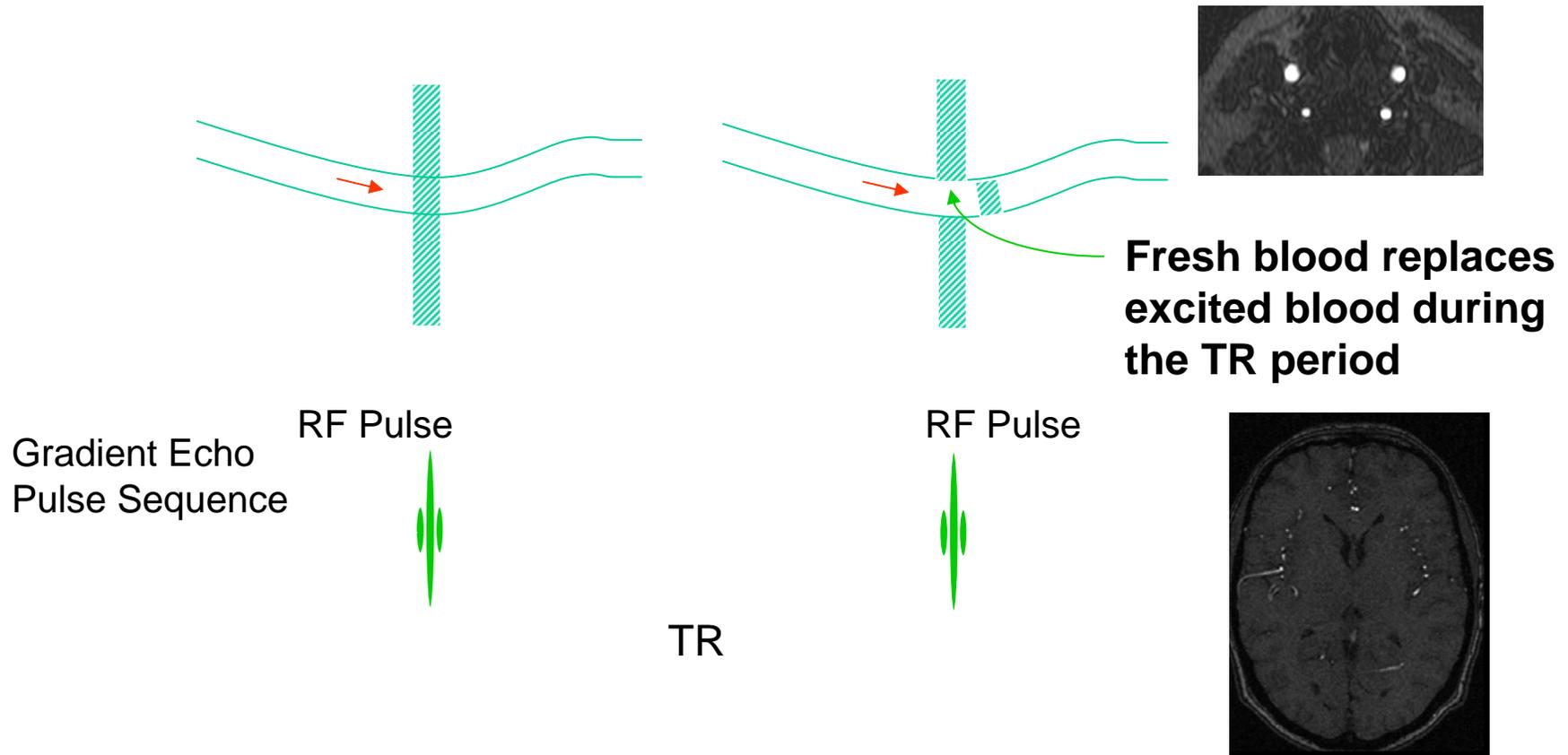
TE/2



“Spin Washout”

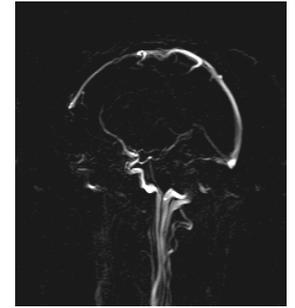
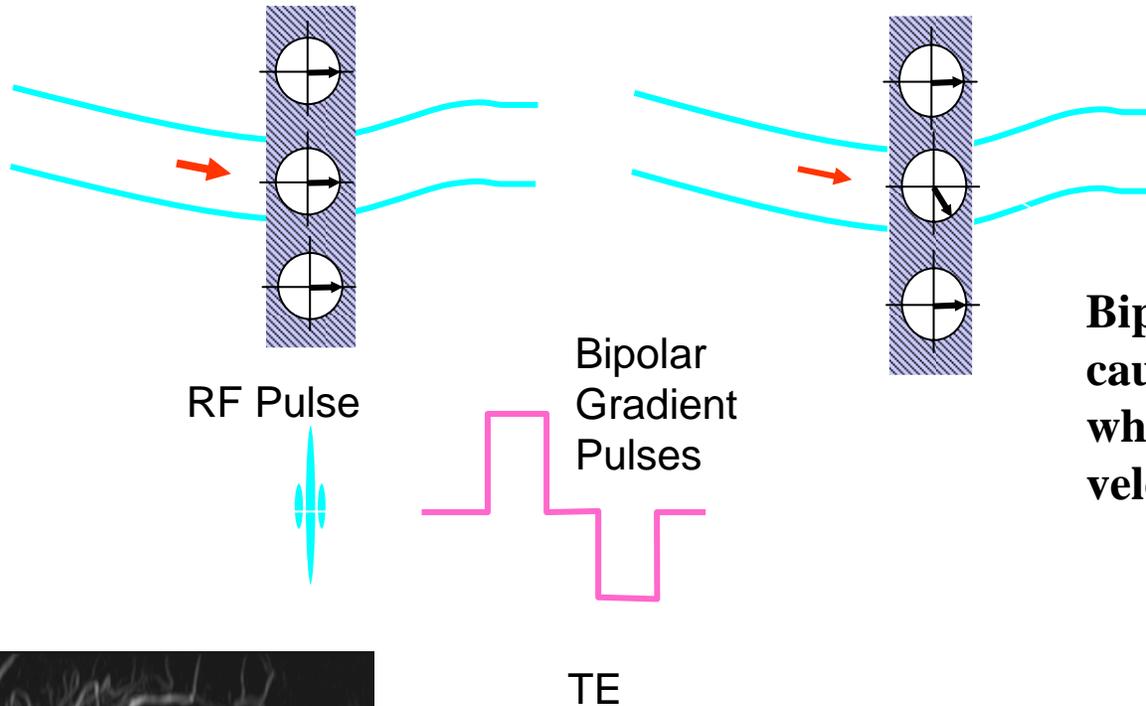


Principle of Time-of-Flight MRA

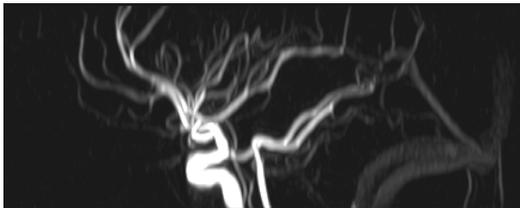


“Flow-related Enhancement”

Principle of Phase-Contrast MRA

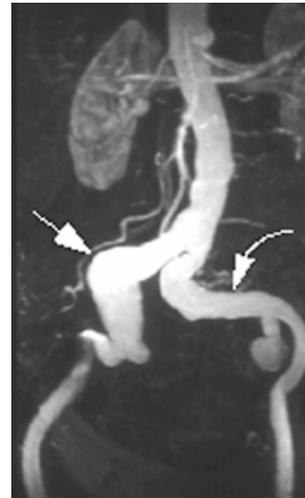
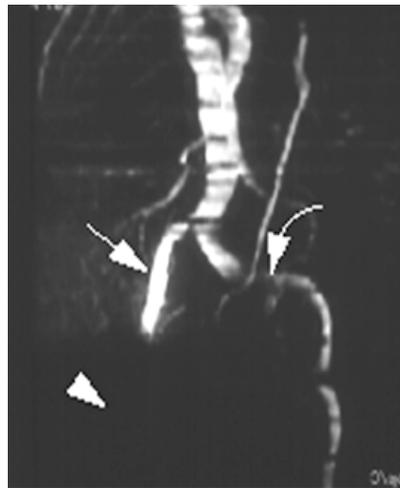
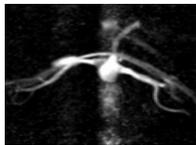
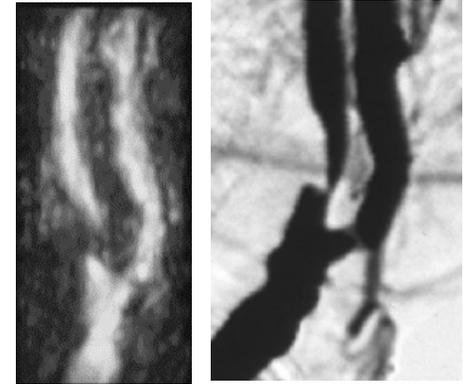


Bipolar gradient pulses cause a change in phase which is proportional to velocity



Limitations of non-contrast MRA

- Inflow considerations (long TR)
- Dephasing == → artefactual stenosis)
- Saturation effects
- *Venc*
- Long scan times
 - Patient movement
 - Coughing
 - Discomfort



Images courtesy of Tom Grist, U of Wisconsin

3D CE-MRA – basically an angiogram!

Intrinsically high SNR

Excellent background suppression

- high flip angles
- short TR's



Slow flow  **excellent!**

Images are predominantly “diastolic” in nature

DSA vs. CE-MRA?

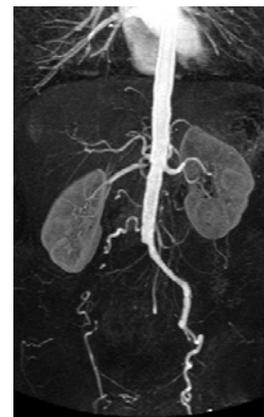
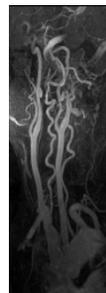
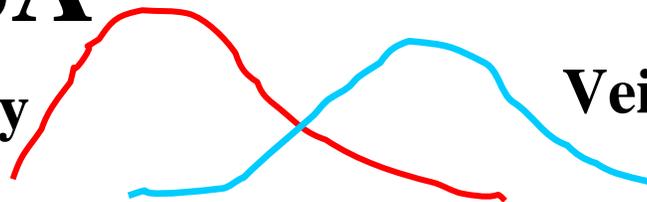
MRA

No catheter!

DSA

Artery

Vein



MRA

Advantages of CE-MRA

- No nephrotoxicity
- Almost negligible anaphylaxis
- No cardio-toxicity
- No ionizing radiation
- Three-dimensional data-set
- Cheap!

Scan time for CE-MRA

No “inflow” limitation

* “fast” gradients



TR x N_p x N_s x NSA

TOF MRA	>20msec	192	100	2-4
CE-MRA	*5msec	192	40	1

>20 fold reduction in scan time!

(<20 secs)

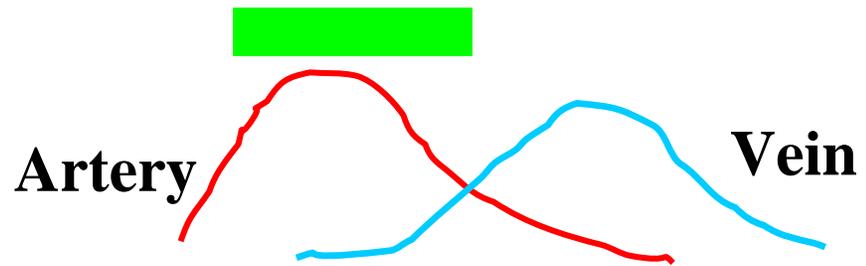
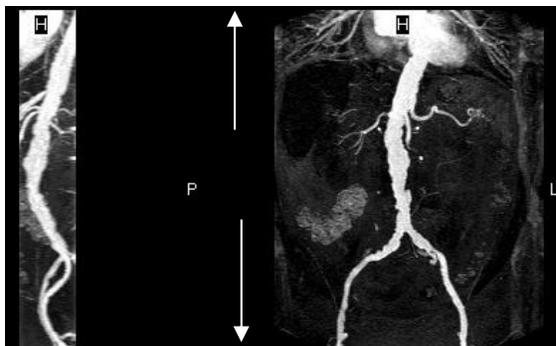
Hardware requirements

- 1.0-1.5Tesla
- **0.5T?**
- Fast gradients
 - Short TR's



2-4mm

32



$$TR \times N_p \times N_s \text{ NSA}$$

CE-MRA

“Imaging the lumen”

CE-MRA

1. Same basic approach for almost all territories
2. Simply alter spatial & temporal resolution & anatomic coverage according to the region-of-interest

CE-MRA - 6 easy steps

- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set

CE-MRA - 6 easy steps

- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set

Which localizer?

Faster is better!

- 1. GRE +/- MIP**
- 2. HASTE**
- 3. “Anatomic” images**



Which localizer

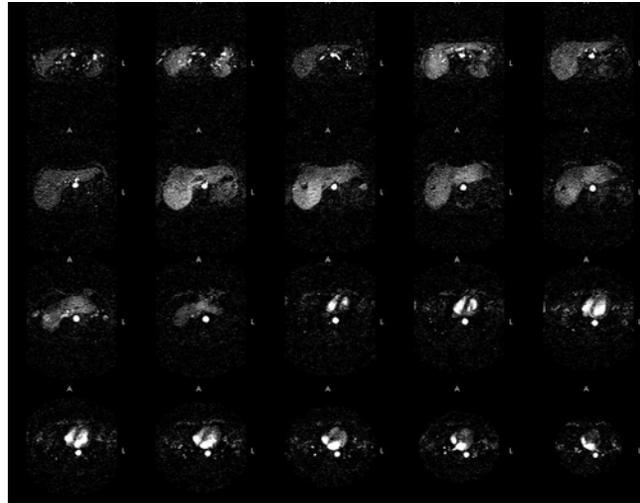
Faster is better!

1. GRE

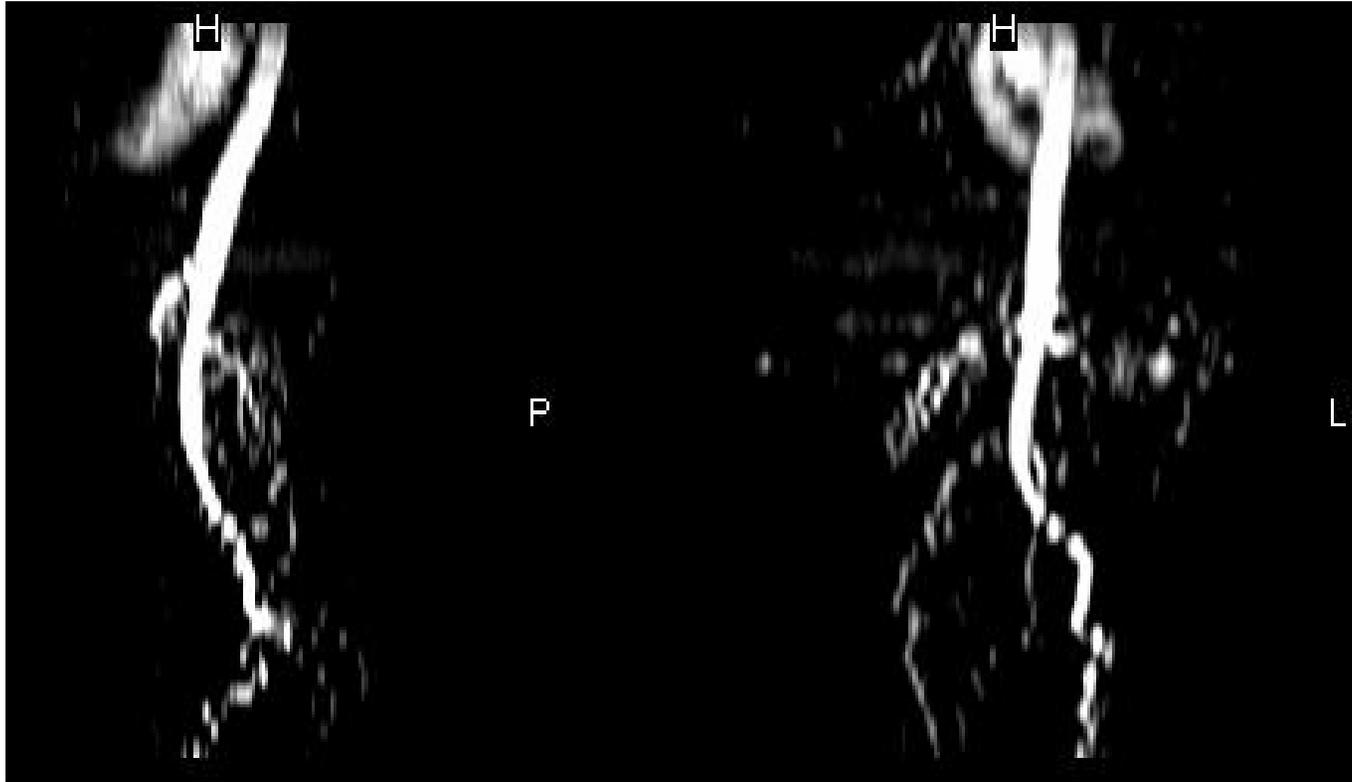
2. +/- MIP

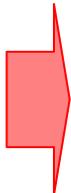
3. HASTE

4. “Anatomic” images



MIP of “localizer” scan



NB  Data is *interpolated* (3mm slices/7mm gap)
“Rough outline” only

CE-MRA - 6 easy steps

- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set



Which sequence?

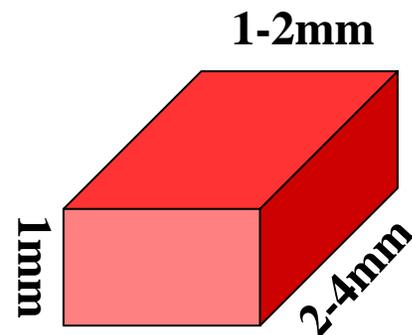
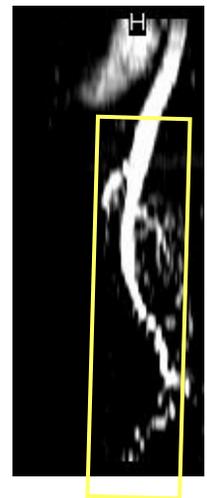
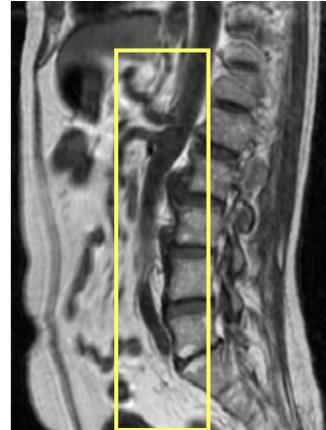
- 3D spoiled-gradient-echo
- TR - < 5msec
- TE – as short as possible
- Flip angle – 30-45deg
- Matrix 512 x 192-512
- No flow-encoding
- No respiratory/ECG triggering
- Breath-holding

Technical details

- 1/1.5Tesla state-of-the-art scanner (SNR proportional to Field Strength)
- Fast 3-D gradient-echo acquisition
- TR/TE/Flip $<5msec/2msec/40$ deg
- Matrix 512x200/FOV 40x32cms

Scan time 20 seconds (40 x 2mm = 8cm)

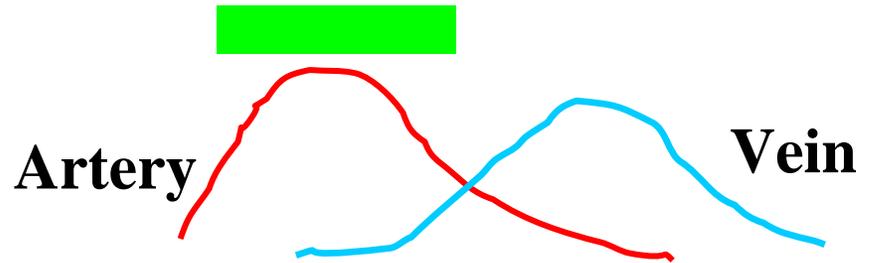
- **Breath-holding**
- **A V window**



Parallel Imaging

- Enables reduction of phase encoding without loss of spatial resolution by utilizing a receiver coil array
- Cartesian sampling of k-space:
 - increased distance of phase encoding lines
 - aliased single coil images
 - un-aliasing using coil sensitivities
- in situ reference scan for determination of sensitivity profiles

Why faster is better

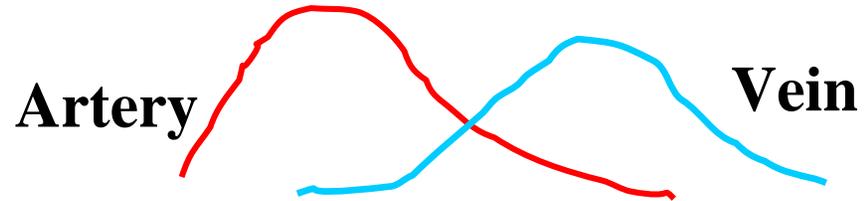


- Short scan times
 - less respiratory motion artefact (breath-hold)
 - Less cardiac motion artefact (fewer heart-beats)
 - less patient movement
 - less peristalsis
- Allows faster injections ↑ signal
- Lower incidence of claustrophobia
- Higher throughput ↓ ↓ *COST*

CE-MRA - 6 easy steps

- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
(Automated injector)
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set

First Pass Concentration



- We would like the T1 of the blood to be reduced to below 50ms
- What does the first pass concentration have to be?

$$c_{\text{first pass}} = 5 \text{ milliMolar (approx.)}$$

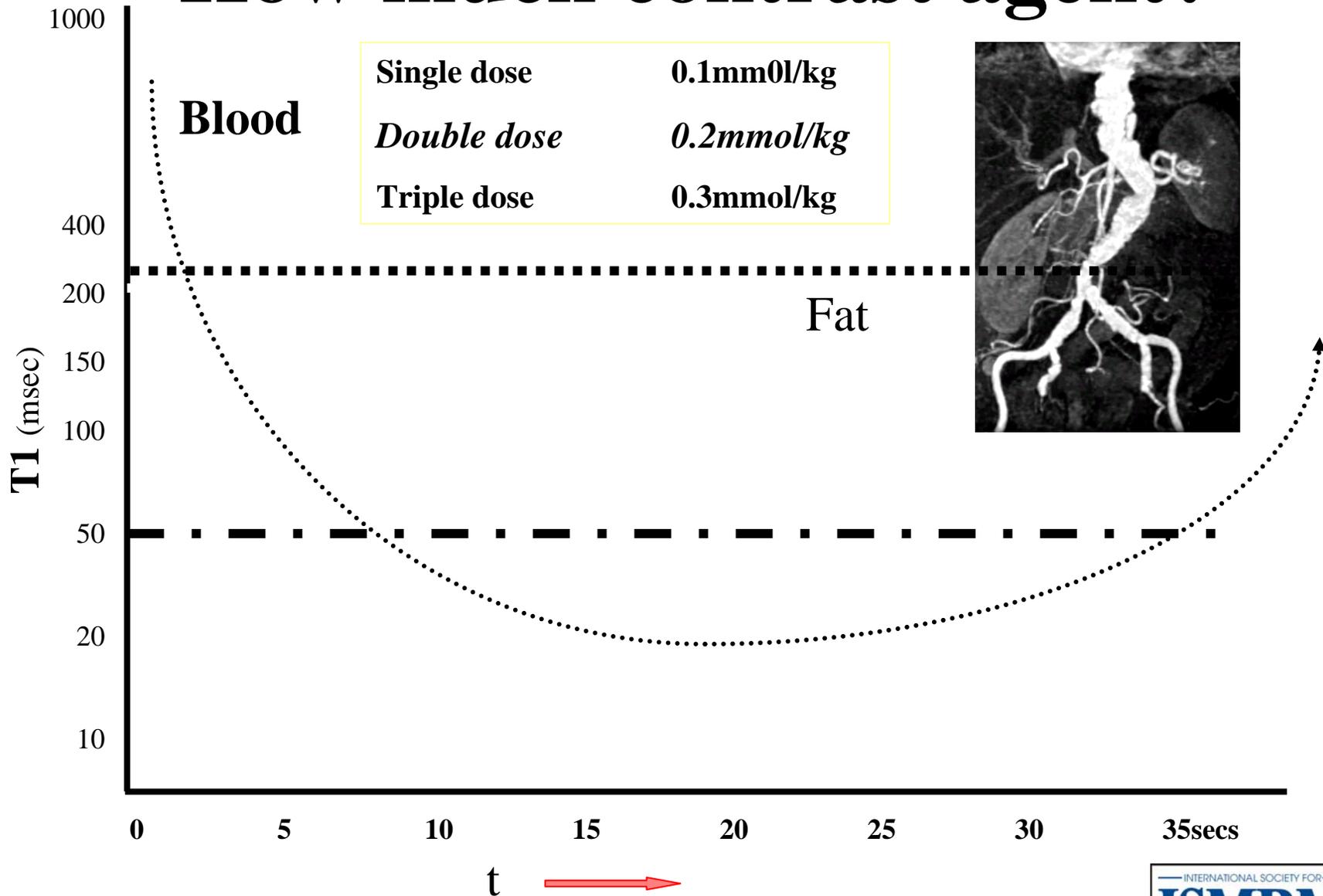
$$1/T1_{\text{observed}} = 1/T1_{\text{blood}} + r_1 \cdot c_{\text{first pass}}$$

r_1 - relaxivity of contrast medium

$T1_{\text{blood}} = 1000\text{-}1200\text{ms}$



How much contrast agent?



How much contrast agent?

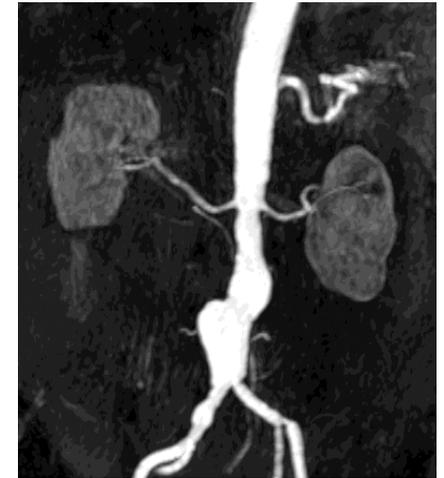
The more the better!

$$\text{SNR} = \frac{\text{TR}}{\text{T1}}$$

Gd: 20ml



Gd: 40ml



But ↑ dose

↑ £\$£\$£\$

↑ Venous enhancement

Compromise → 30cc @ 1-3cc/sec

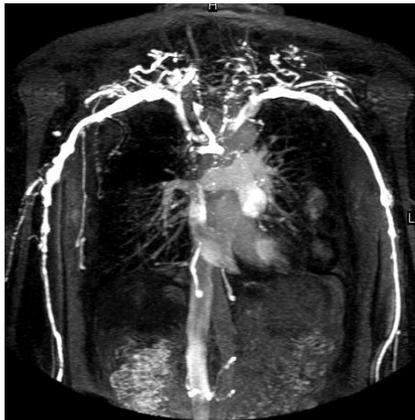
CE-MRA - 6 easy steps

- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set

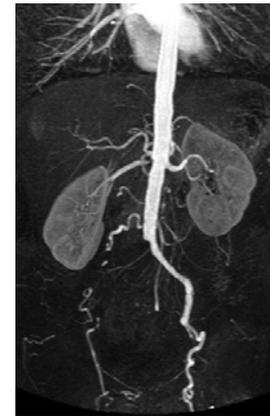
Timing issues: DSA vs.MRA?



DSA



MRA

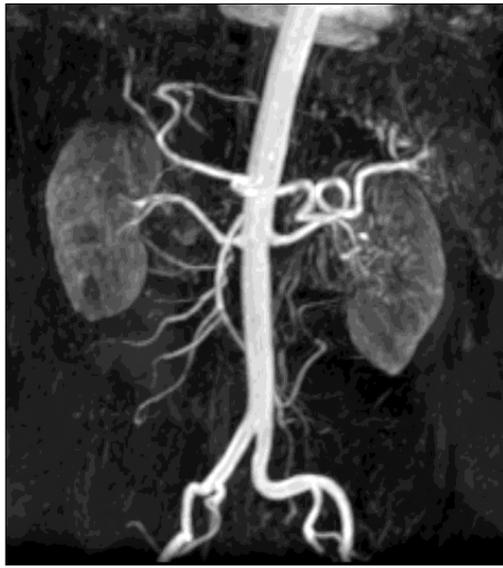


Timing issues?

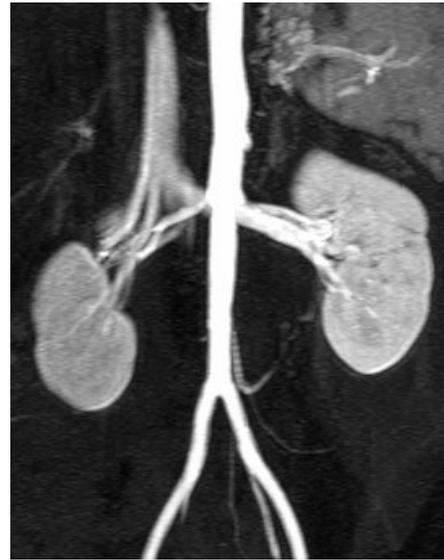
Too early!



Good timing



Could be better!



Too late!



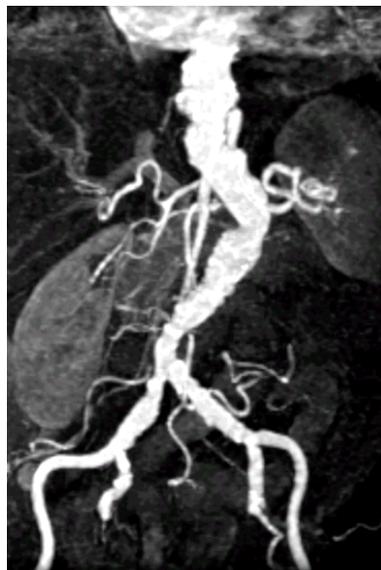
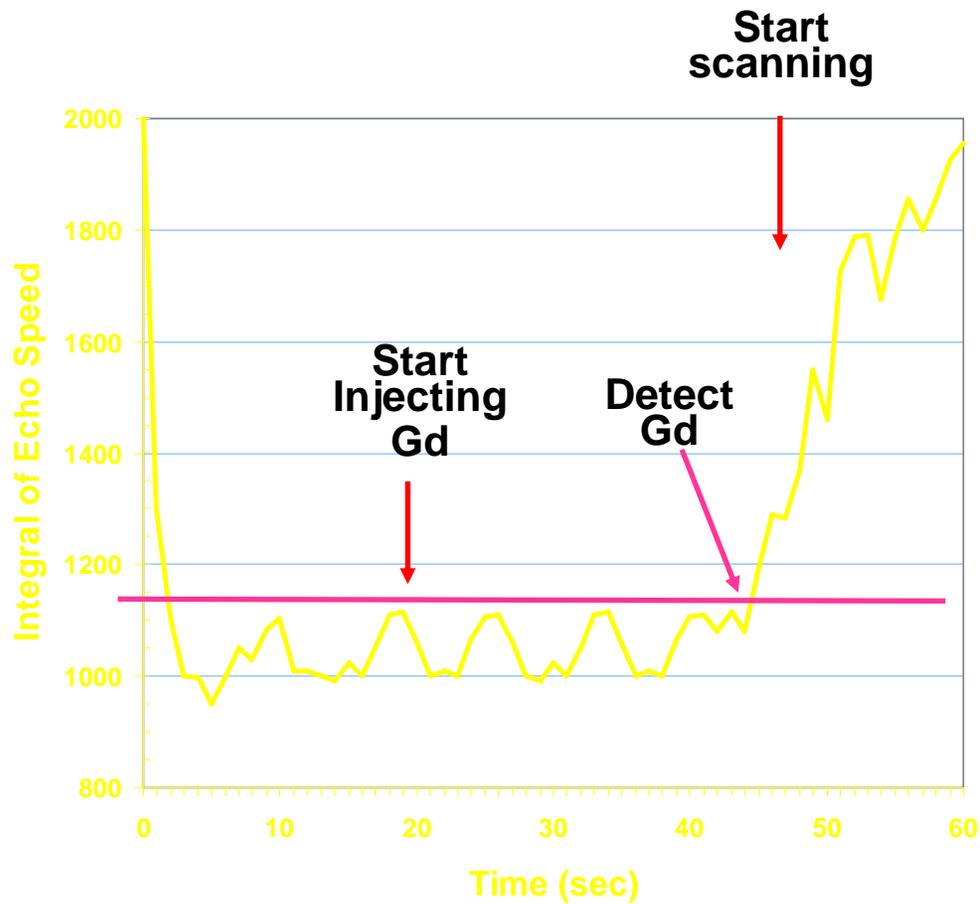
Bolus Timing issues

- “Best guess”
- Timing bolus

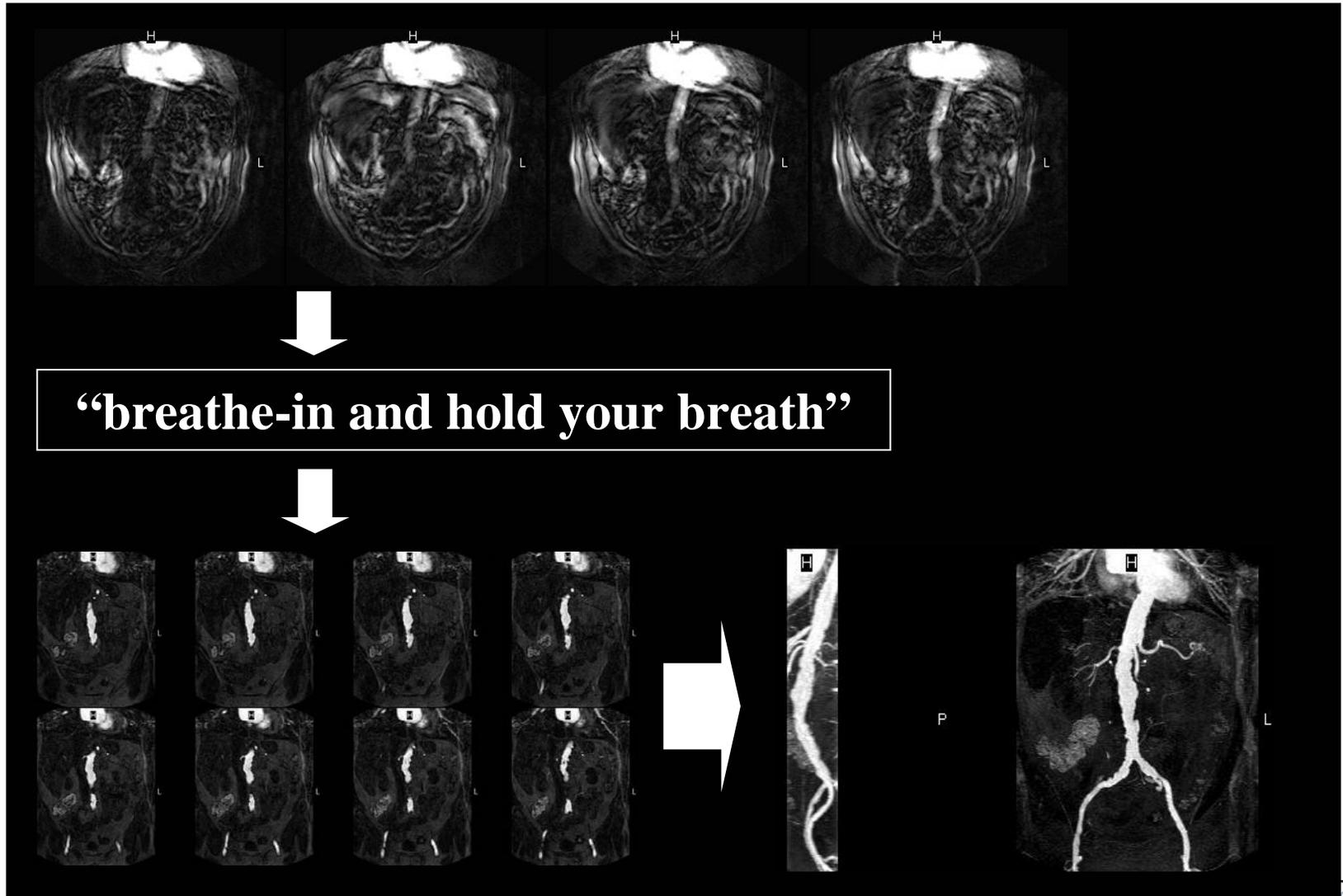
$$\text{Scan delay} = \text{Contrast arrival time} \textit{ plus } \frac{\text{Injection time}}{2} \textit{ minus } \frac{\text{Scan time}}{2}$$

- T.R.I.C.K.S. (c.f. Grist et al)
- Automated “triggering”
 - Black-box (SMARTPREP, GE Medical Systems) (c.f. Prince)
 - 2D Fluoroscopy (c.f. Wilman/Riederer) – BolusTrak/Carebolus

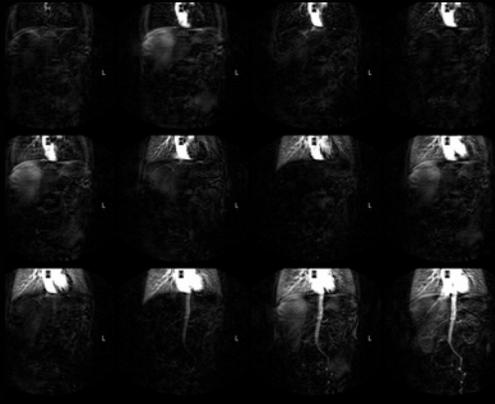
Automatic Gd Detection with MR Smartprep



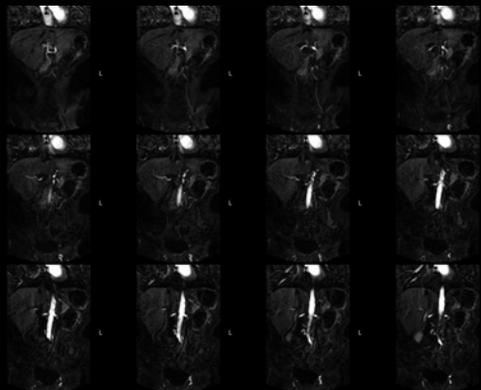
2D fluoroscopic triggering: *BolusTrak/CareBolus*



2D fluoroscopic triggering: BolusTrak/CareBolus



“breathe-in and hold your breath”



Multiphase MRA: functional changes

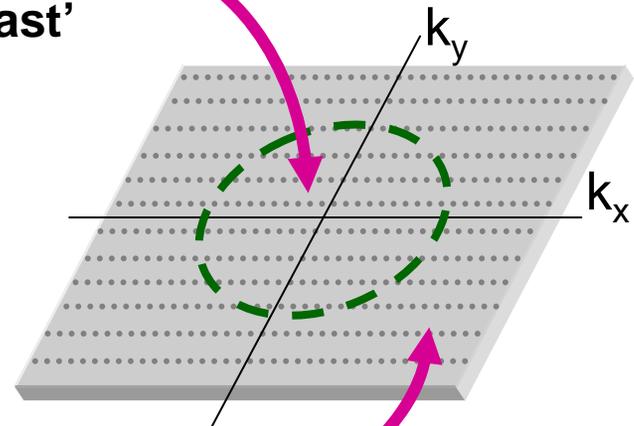


➔ delayed parenchymal enhancement (left)

Resolution & Contrast

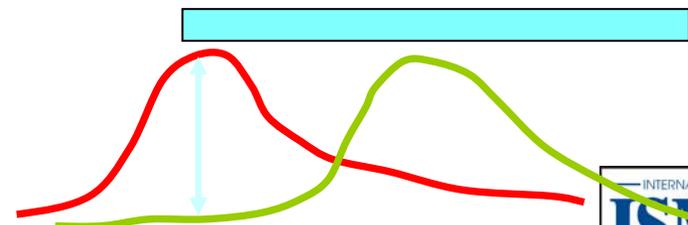
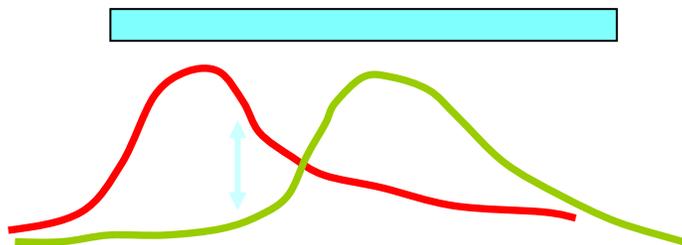
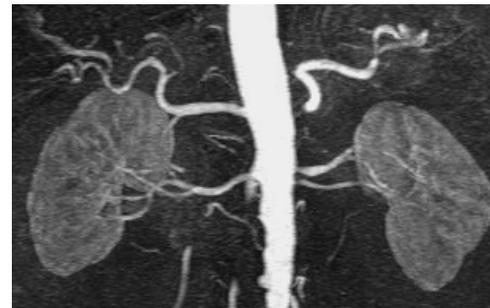
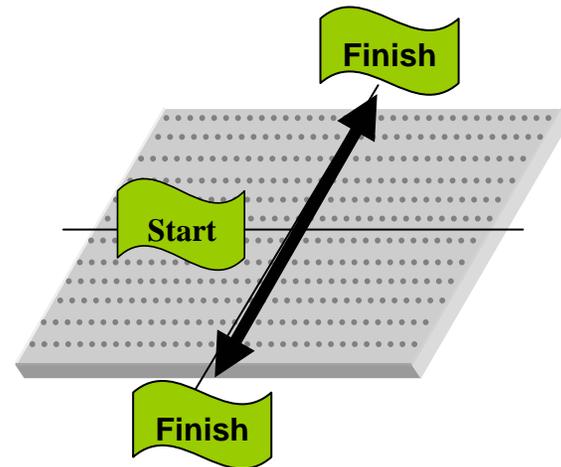
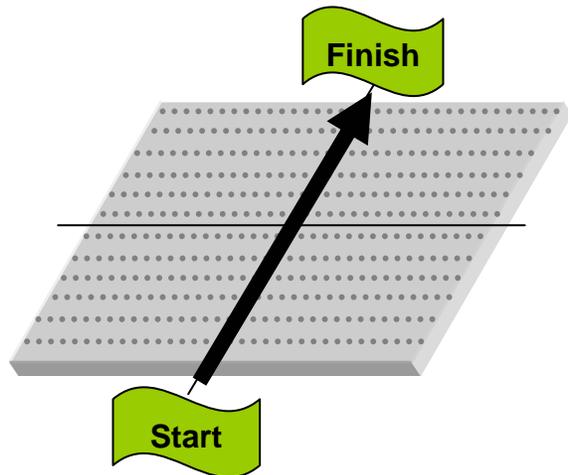
- MR signal data acquired close to the centre of k-space determines **Contrast**
- MR signal data acquired close to the edges of k-space determines **Spatial Resolution**

Low Spatial
Frequencies
'Contrast'



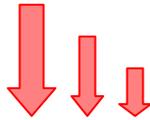
High Spatial
Frequencies
'Resolution'

Low-high (centric) k-space order



Arterial phase imaging

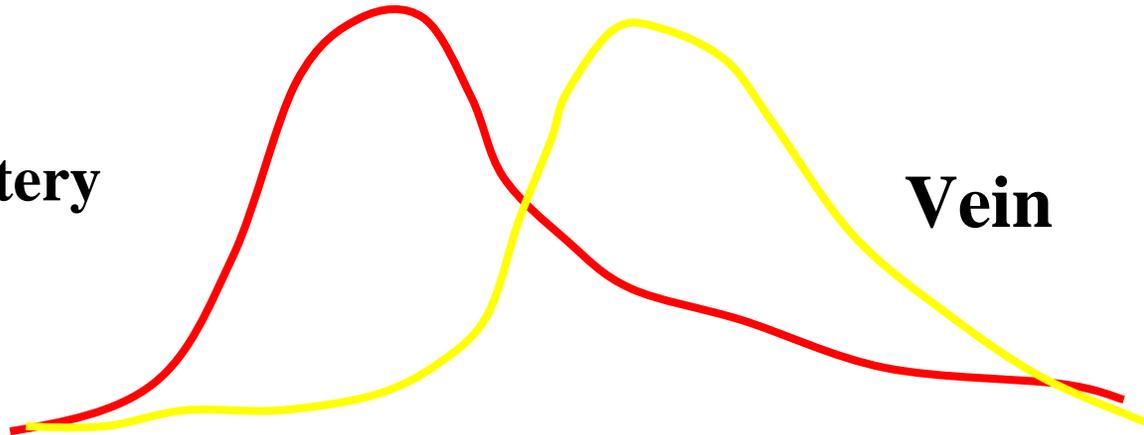
Contrast-defining lines



Detail defining lines



Artery



Vein

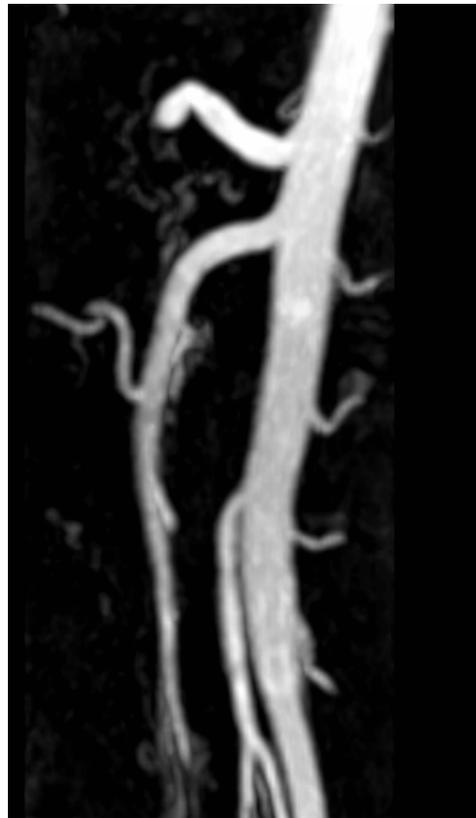
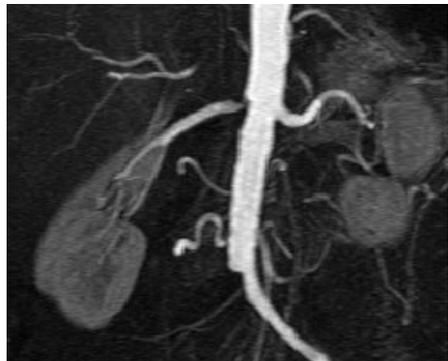
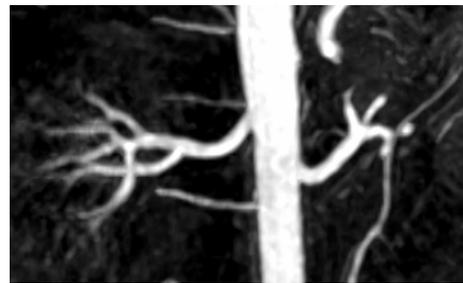
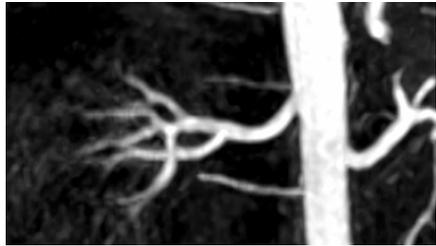


*Allow Scan time $>$ A-V transit time
(We must collect all of the central k-space
data before onset of venous enhancement - “Bolus-detection”)*

CE-MRA - 6 easy steps

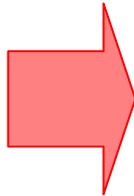
- Acquire a localizer
- Plan a “breath-hold” 3D scan
- Inject a volume of contrast agent
- Wait for contrast to circulate to the region-of-interest
- Acquire a 3D data set
- Post-process data-set

Post-processing - 6 images +



MRA in the clinical context

- Thoracic Aorta
- Great arteries
- Carotid arteries
- Pulmonary arteries
- Coronary arteries
- Abdominal Aorta
- Mesenteric arteries
- Renal arteries
- Peripheral arteries



Aorto-iliac

Femero-popliteal

Infra-popliteal

Current applications

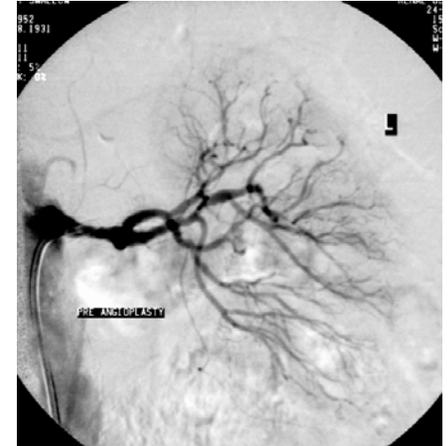
All areas except coronaries!



Types of Renal artery stenosis

Atherosclerotic

- *Osteal/proximal*
 - *Elderly patients*
 - *Variable response to angioplasty/stenting*



Fibromuscular dysplasia

- *Young hypertensive patient*
 - *Female predominance*
 - *More distal lesion*
 - *Much less common overall*
 - *Good response to angioplasty*

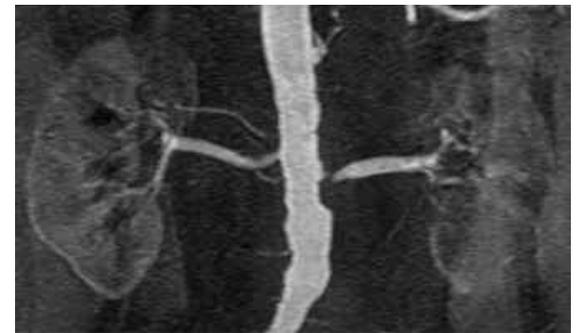
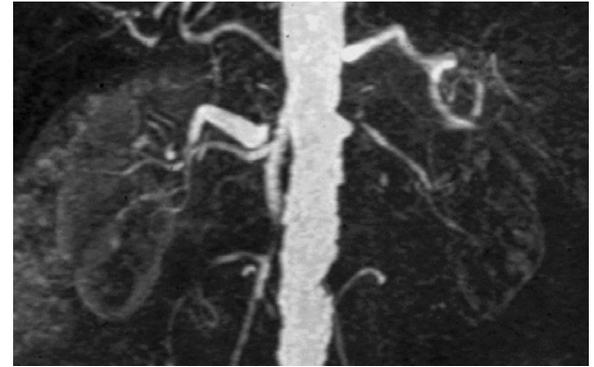


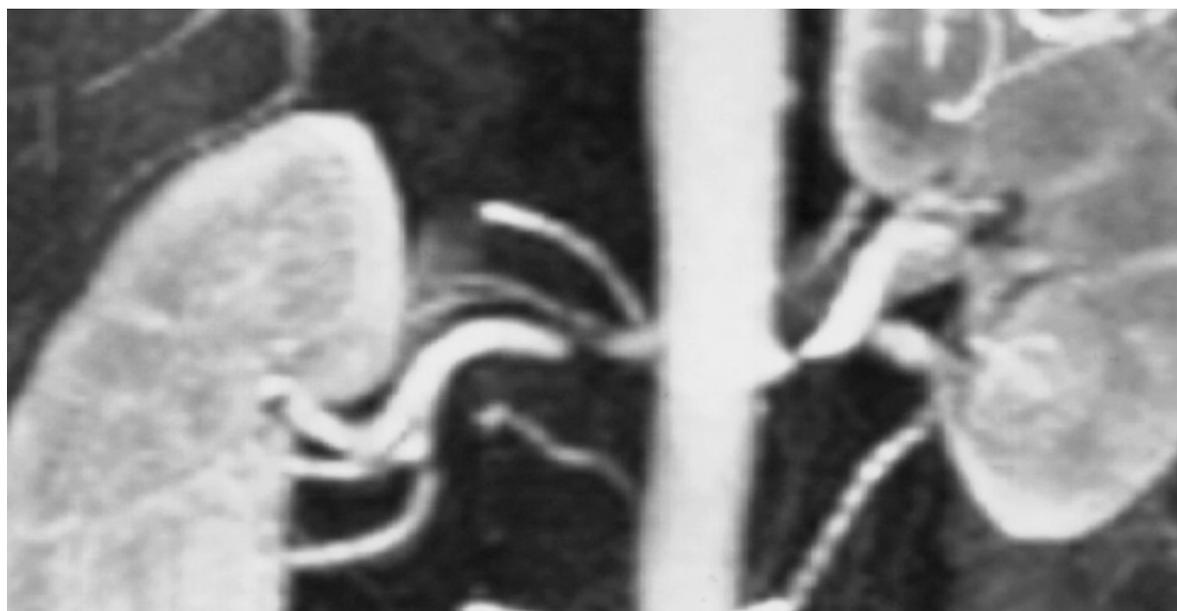
Incidence of Renal artery stenosis

Autopsy studies	4%
Hypertension alone	1%
+ diabetes mellitus	10%
Abdominal aortic aneurysm	10%
Peripheral vascular disease	45%

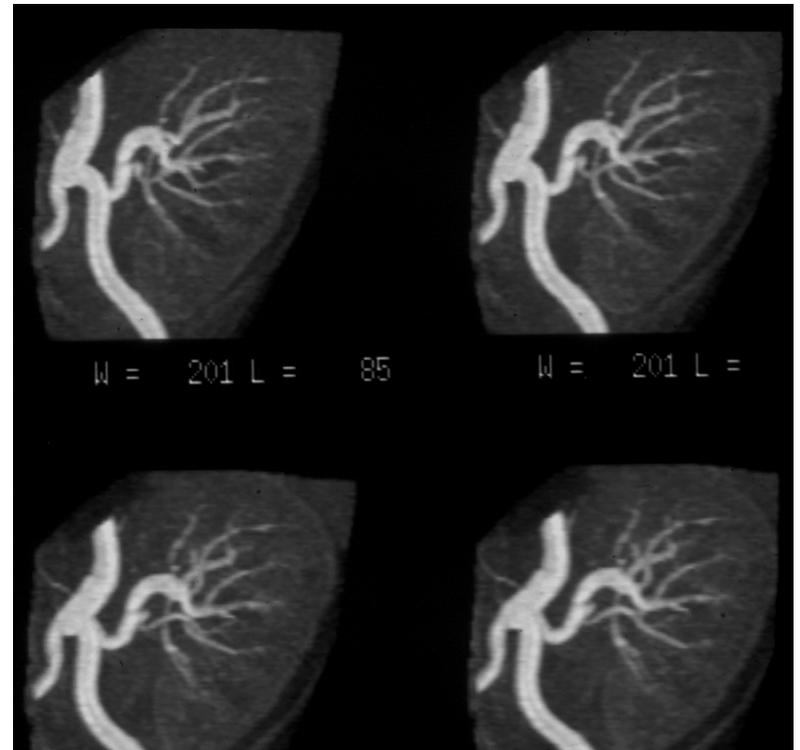
Renal Artery MRA - Questions

- **Is there a stenosis?**
- Is it hemodynamically significant?
- Is the kidney worth saving?
- How best to revascularize?





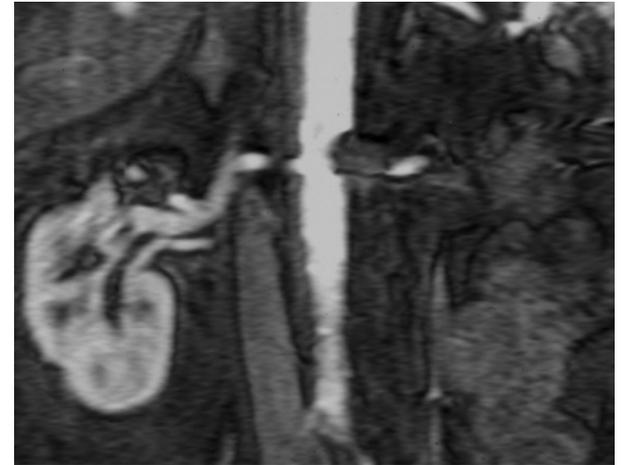
Renal Transplant



Renal MRA - limitations

1. Resolution constraints - 3 areas of difficulty

- **Accessory RA's**
- **Intra-renal arteries**
- **Fibromuscular dysplasia**

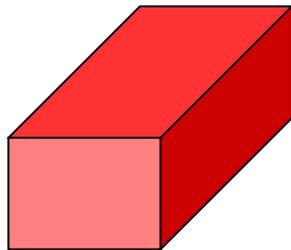
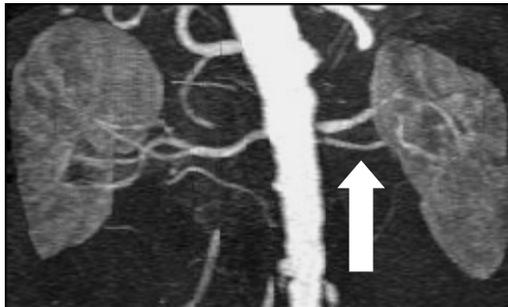


2. Functional significance?

3. Patients with intravascular stents

Depiction of *accessory* arteries

Accessory renal arteries



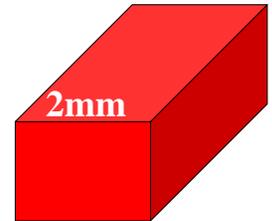
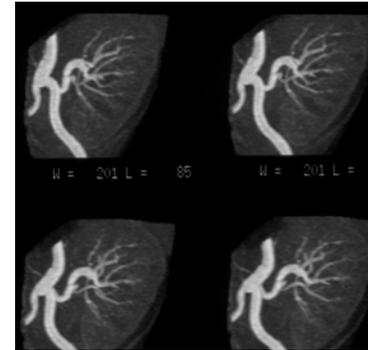
2 x 1 x 2-4mm



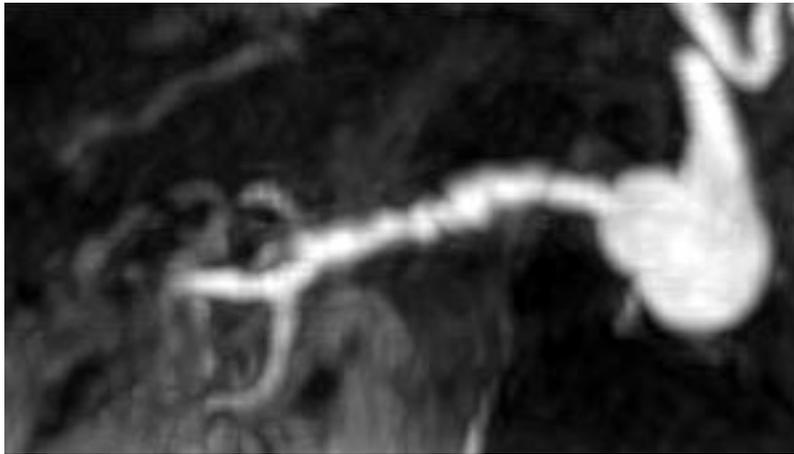
Visualization of distal RA?

Problems

- Resolution
(0.8 x 2 x 2mm)
- Parenchymal enhancement
- Venous overlay
- Timing

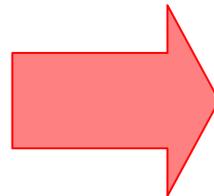


FMD: What's the problem?



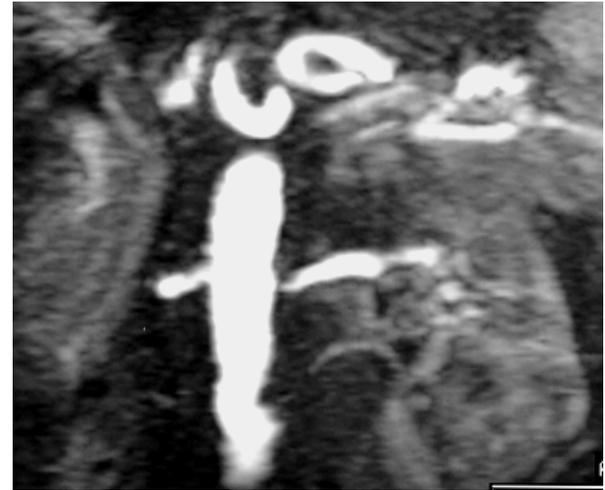
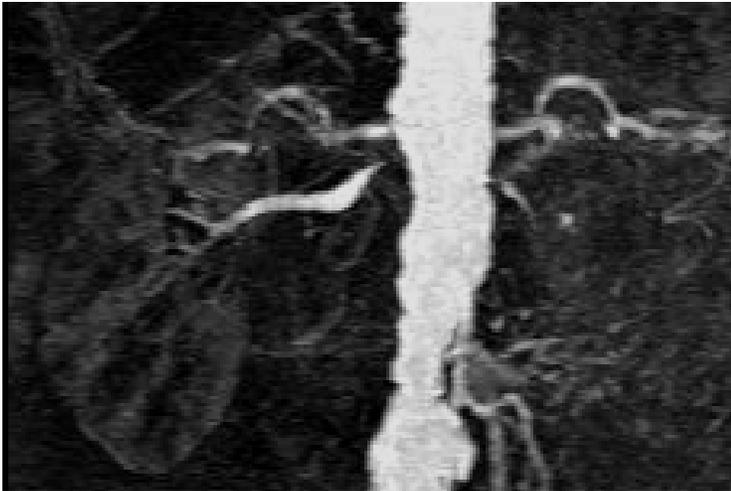
“Corrugations” of FMD

- Small
- More marked distally
- Simulated by normal
- off-axis reformats (2-4mm)



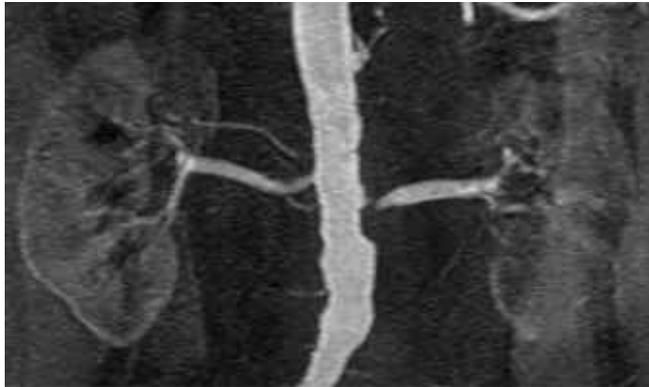
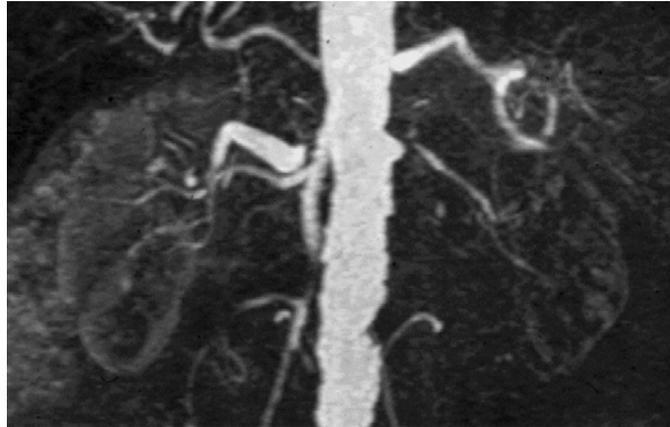
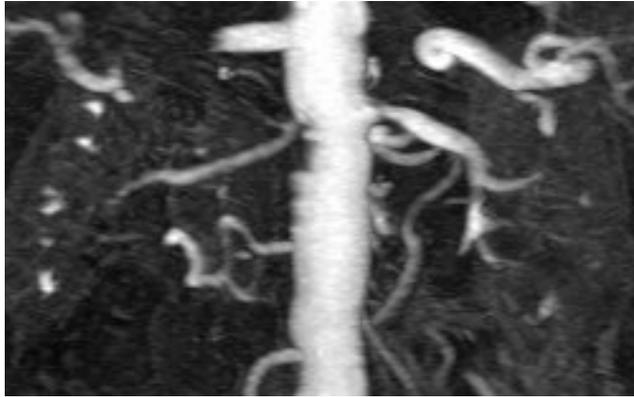
Resolution constraints

Significance of RAS?



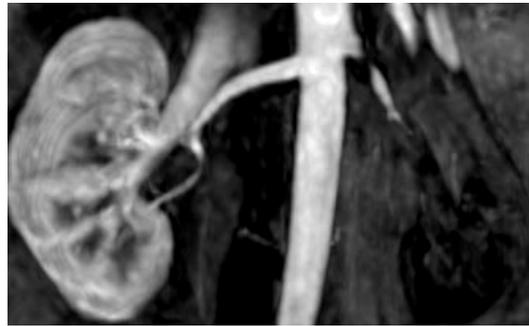
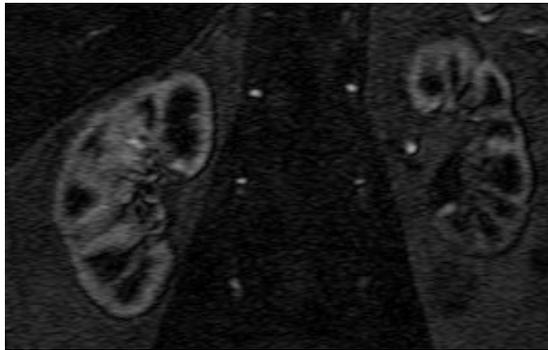
Significance of RAS?

“Eyeball” method (50/75%) stenosis

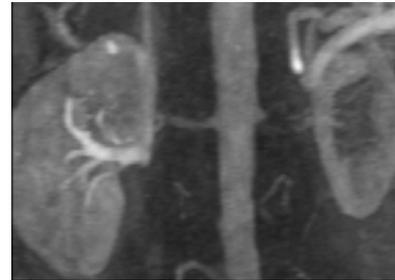
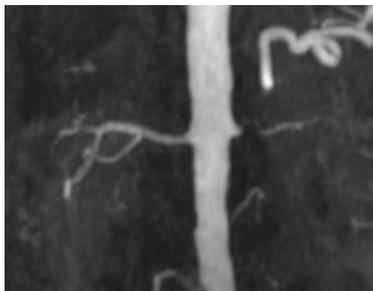


Significance of RAS?

Quality of nephrogram



Multi-phase MRA

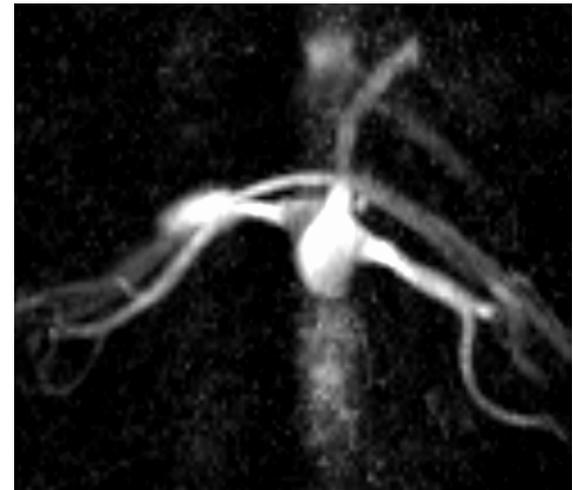


Significance of RAS?

Direct measurement of flow with PCA

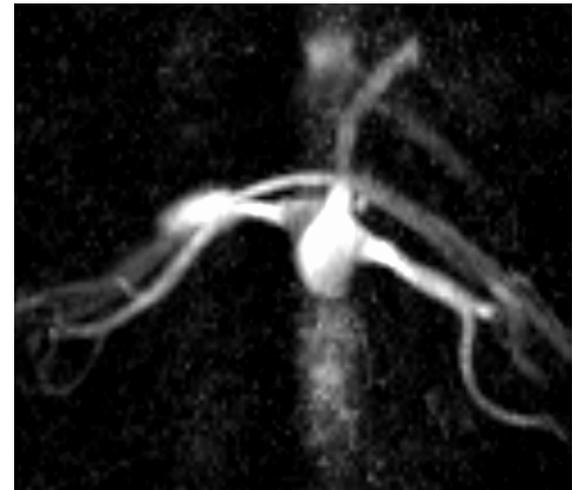
- Signal drop-off on 3D PCA

- TR: 25 msec
- TE: 8 msec
- FOV: 28-32 cm
- Matrix: 256 x 192 x 28
(2.5 mm thick slices)
- **VENC**
 - young: 50-60 cm/sec
 - old: 30 cm/sec
 - CHF, AAA: 30 cm/sec
 - renal failure: 20-30 cm/sec



Axial 3D Phase Contrast (post Gad)

- TR: 25 msec
- TE: 8 msec
- FOV: 28-32 cm
- Matrix: 256 x 192 x 28
(2.5 mm thick slices)
- **VENC**
 - young: 50-60 cm/sec
 - old: 30 cm/sec
 - CHF, AAA: 30 cm/sec
 - renal failure: 20-30 cm/sec



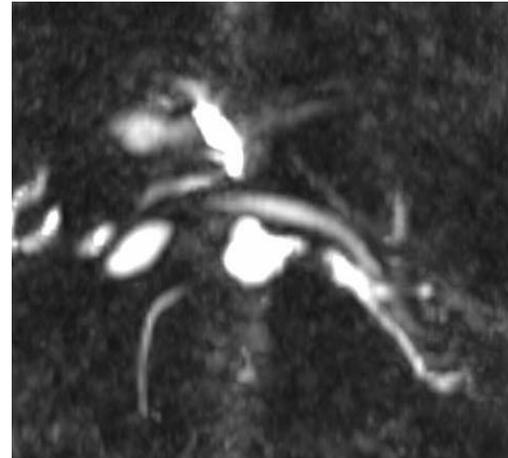
10-15 minute acquisition!

Significant stenosis on CE-MRA?

CE-MRA



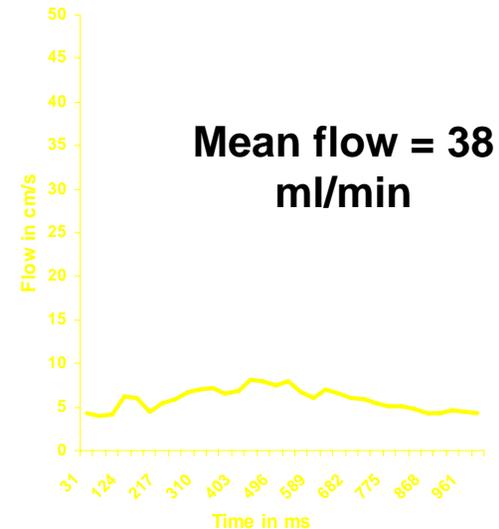
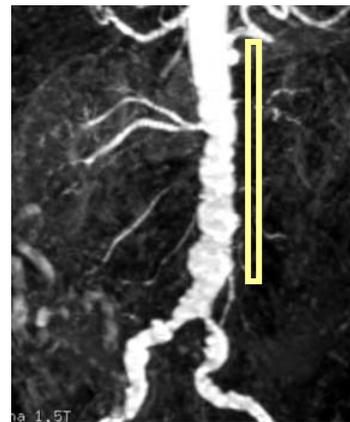
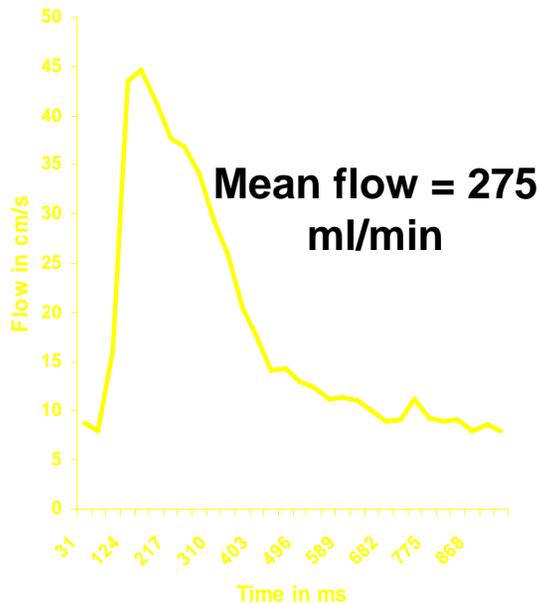
3D PCA



Normal for comparison



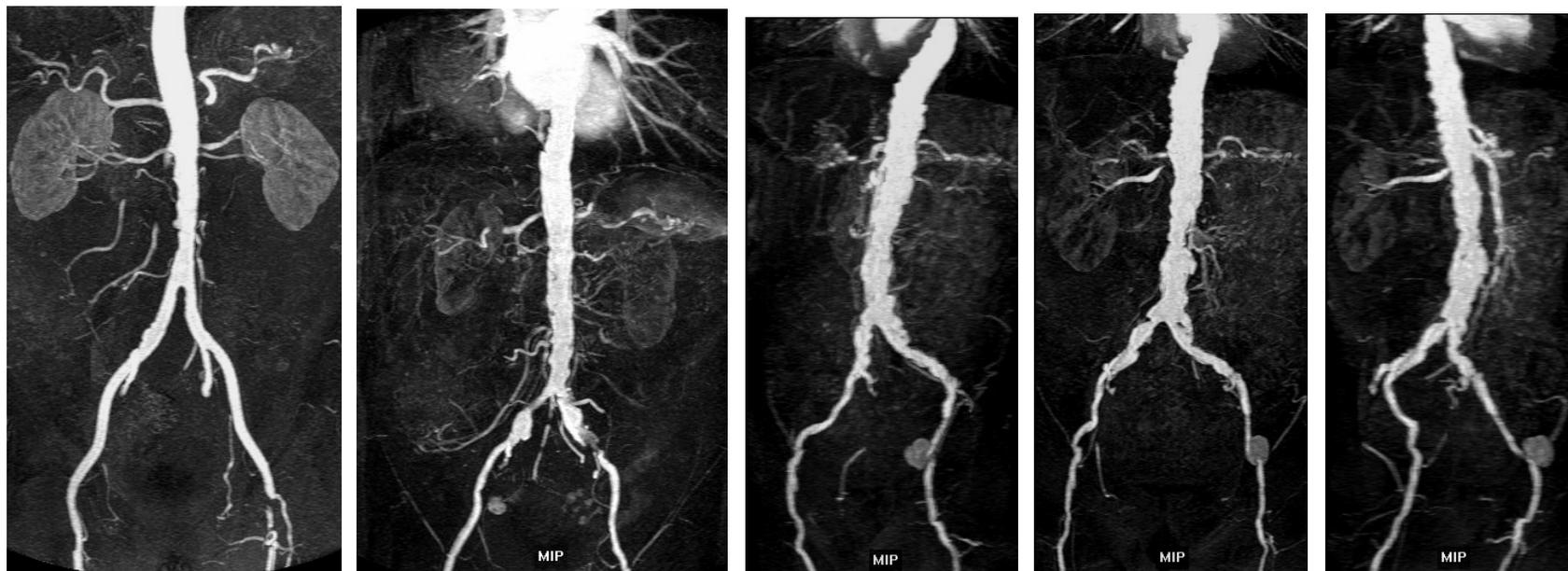
Significance of RAS?



2D PC cardiac gated MRA

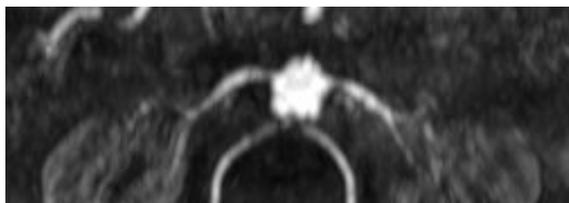
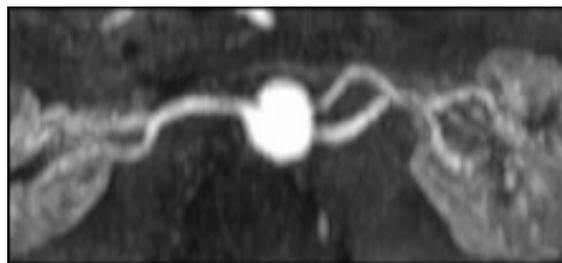
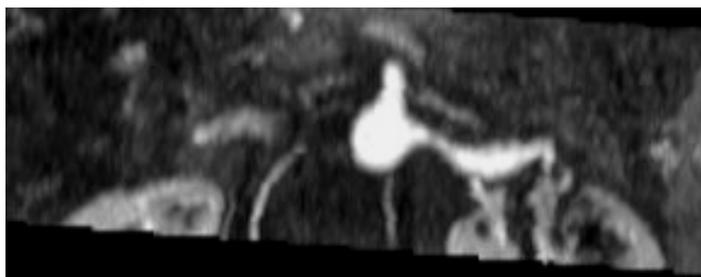
The “Road-map” part 1

Frontal + rotated MIP's for planning of approach

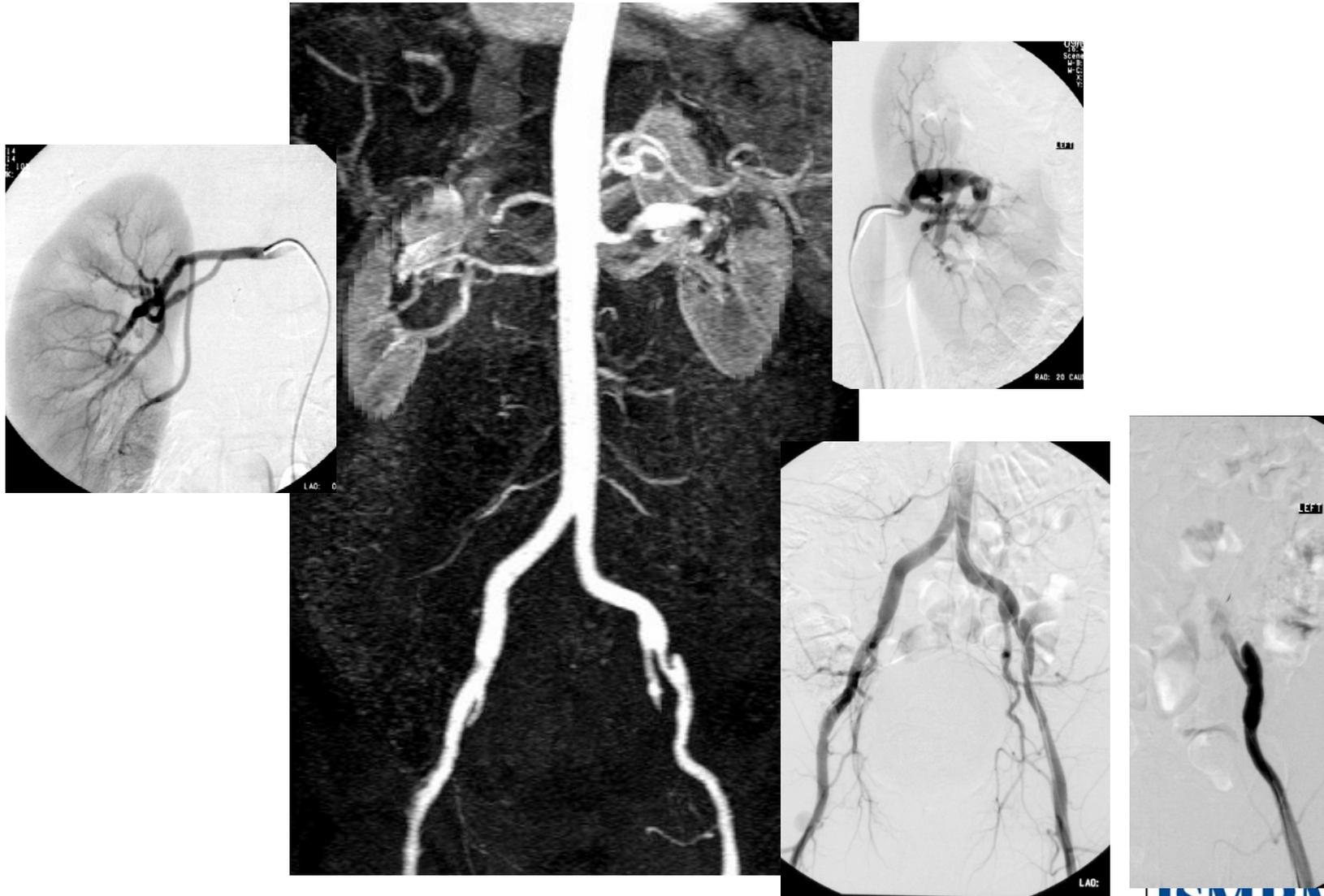


The “Road-map” part 2

**Cranio-caudal view for
catheter tip placement**

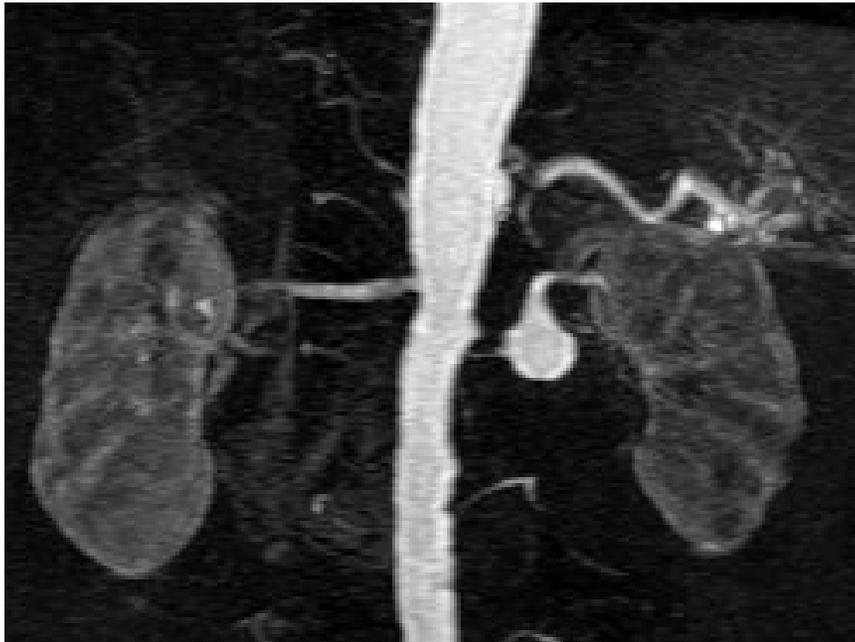


Renal artery aneurysms

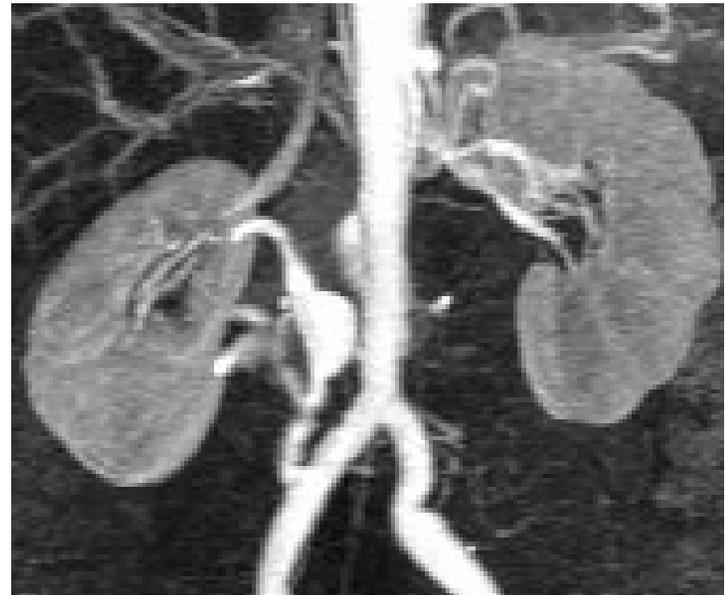


Renal artery aneurysms

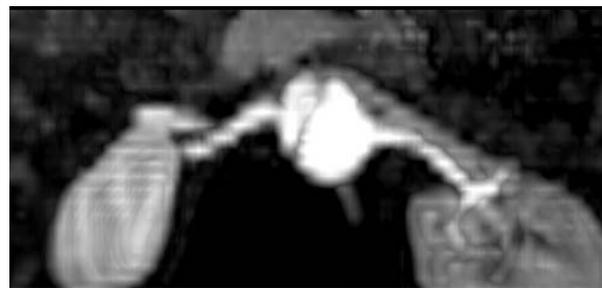
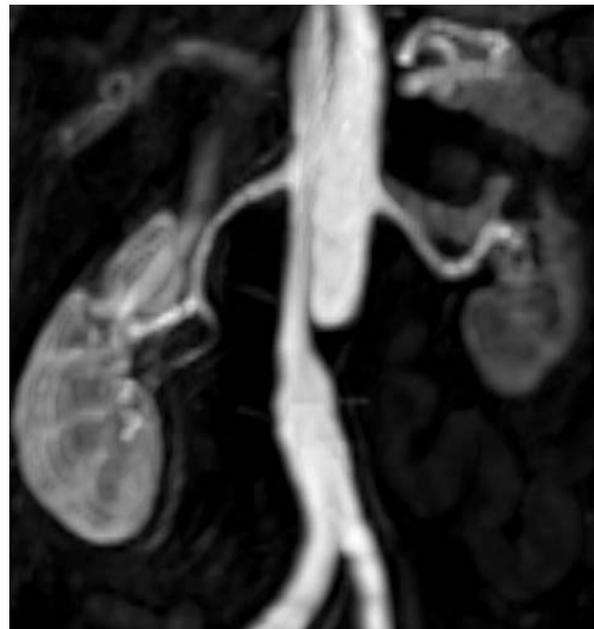
Atherosclerosis



Post-vein grafting



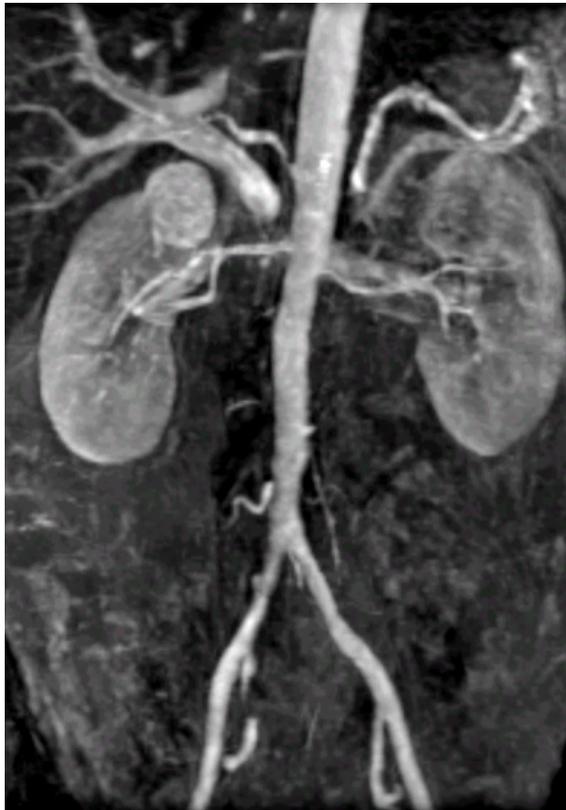
Aortic Dissection



Parenchymal phase

- Hypertension
- Hematuria

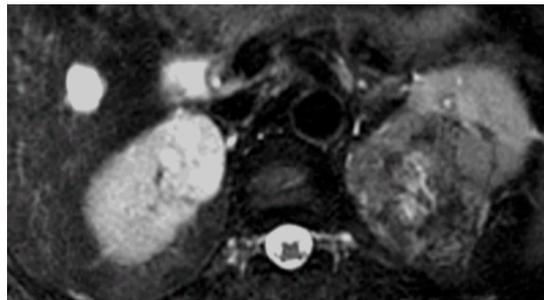
MIP



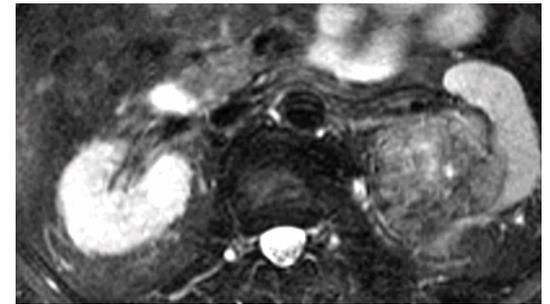
Partition



T2W



T2W



Renal vein thrombosis



- Idiopathic
- Nephrotic syndrome
- SLE
- Hypercoagulable
- Pregnancy

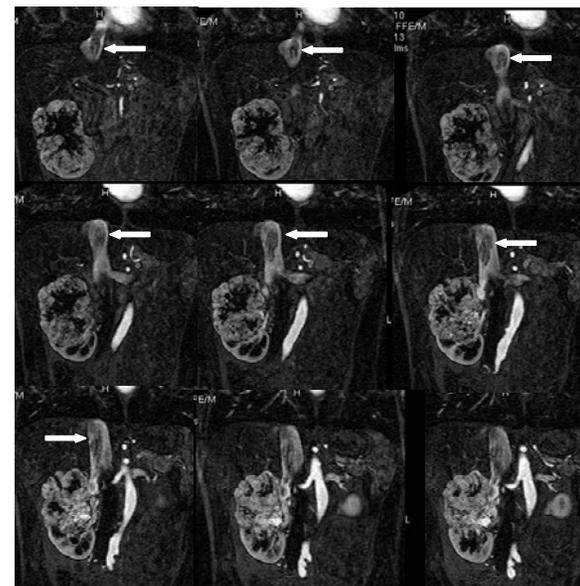
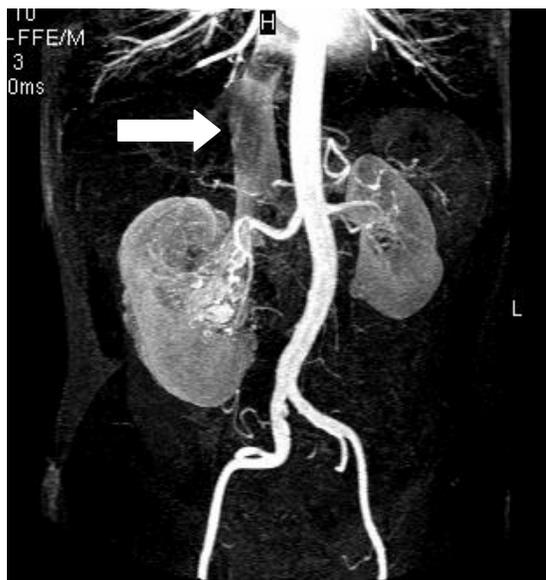


Venous anatomy

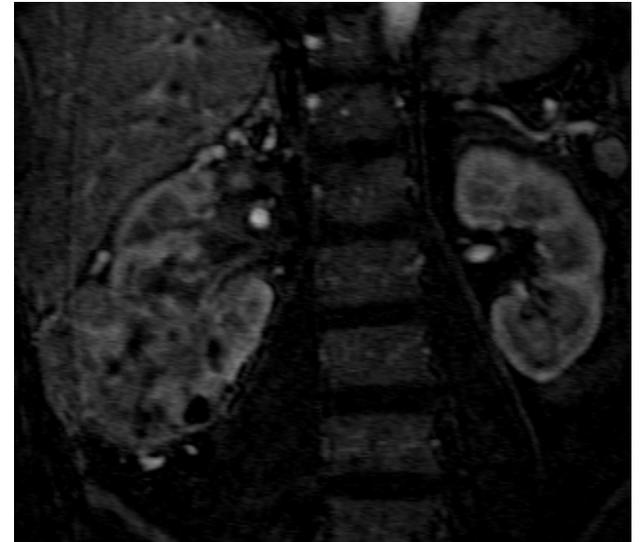
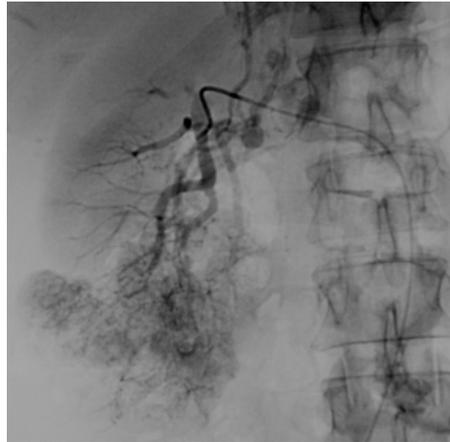
Retro-aortic LRV

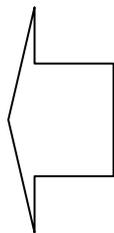
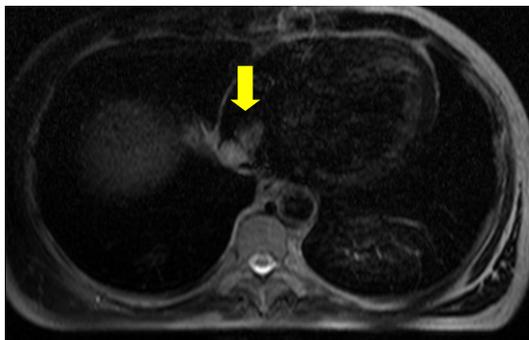


Renal cell carcinoma with IVC invasion

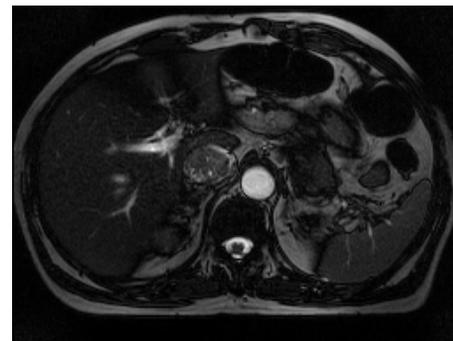
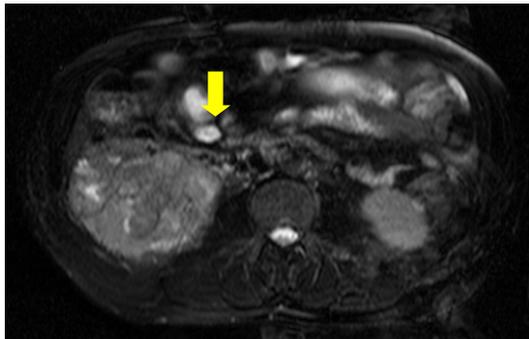
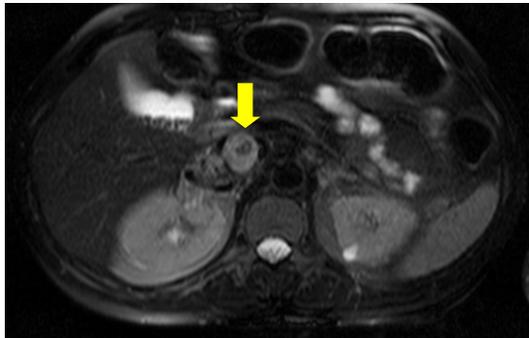
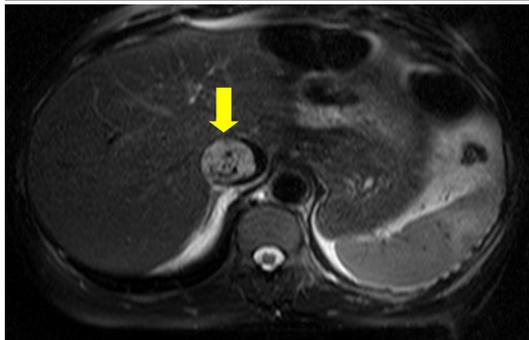


Renal Cell Carcinoma



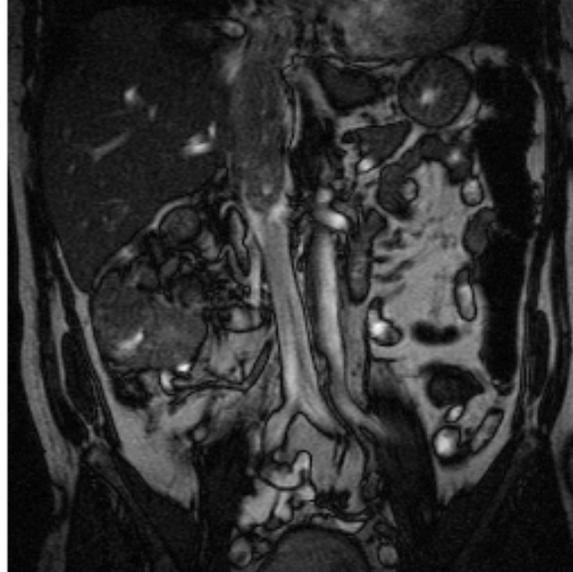


T2 FatSat
4 minutes



TrueFISP
30 seconds

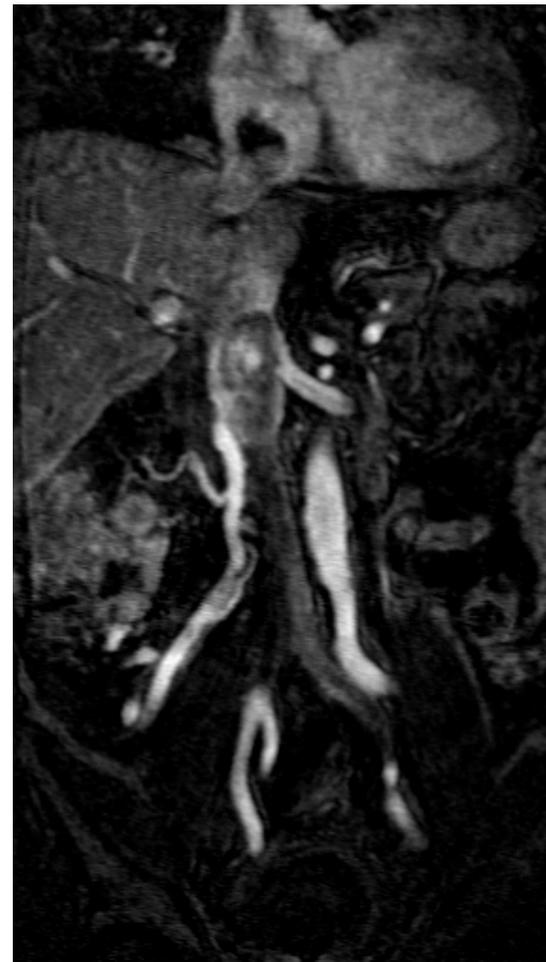
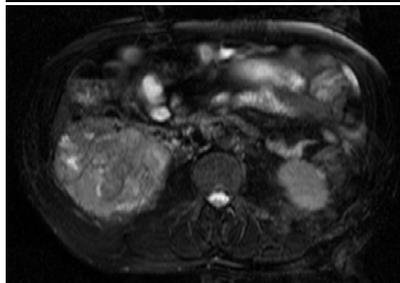
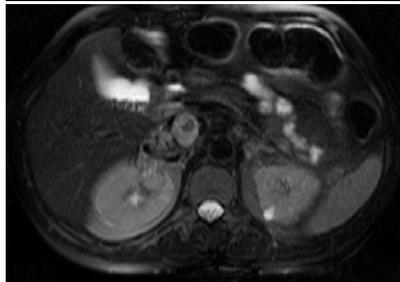
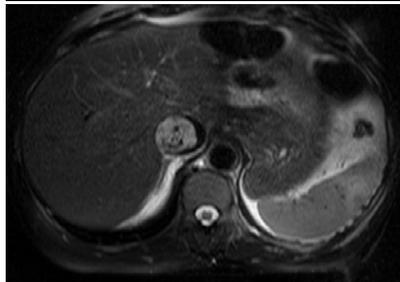
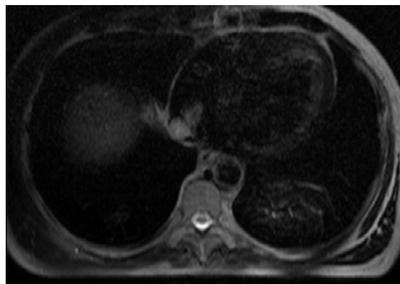
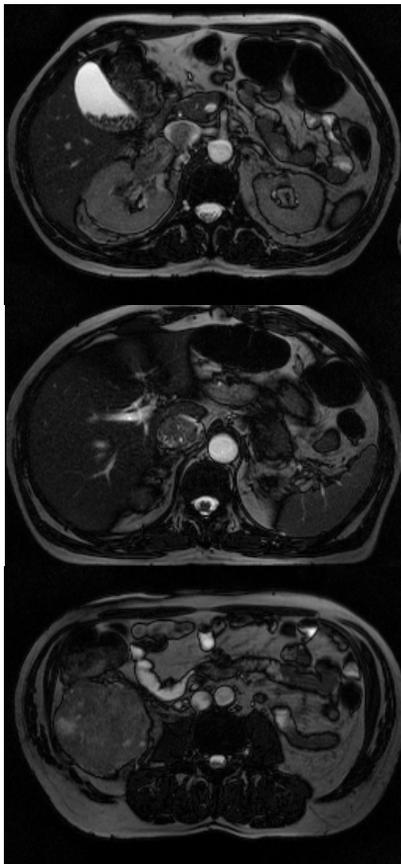
True FISP imaging?



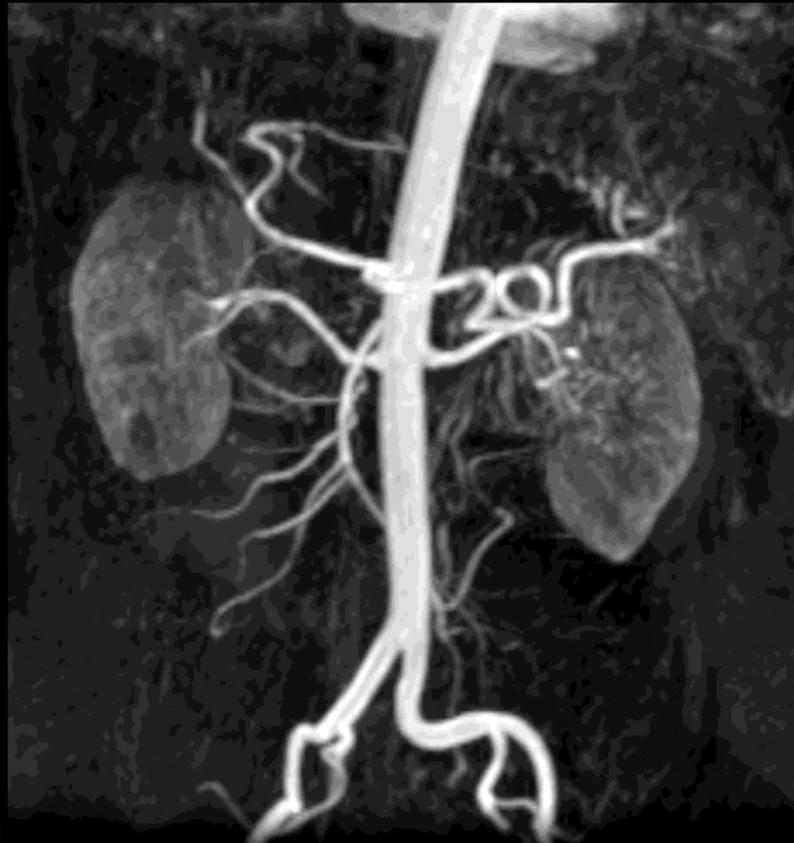
Advantages

- Fast
- Multi-planar
- No post-processing
- Cine-loop
- T2 weighting
- Does not require contrast

Which approach?



Mesenteric MRA



Mesenteric Ischemia

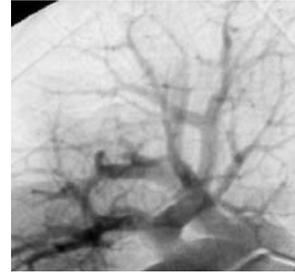
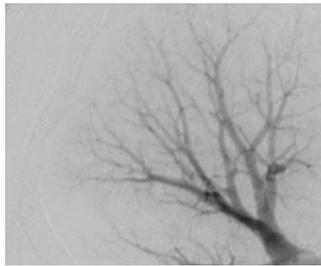
- At least 2 of 3 mesenteric arteries severely narrowed or occluded
- presents with
 - weight loss
 - post prandial abdominal pain
- commonly underdiagnosed



Thoracic vasculature

- Pulmonary arteries
- Thoracic aorta
- Great thoracic veins

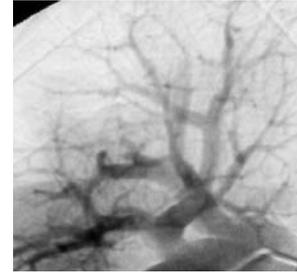
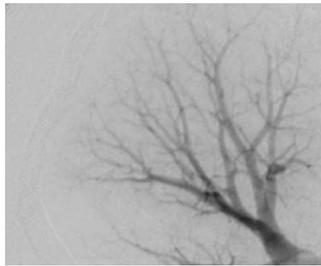
Conventional arteriography?



Advantages

- Unrivalled resolution (?)
- Ability to depict small emboli
- Readily available
- High degree of confidence for clinicians

Conventional arteriography?



Disadvantages

- Invasive (mortality rate 0.1%-1%)
- No through-plane resolution (?)
- High interobserver variation
- Costly

Accuracy of conventional arteriography?



“Gold standard”

BUT

- High interobserver variability especially for small arteries
- Very operator dependent (performance/interpretation)
- Selective views not performed often (?)
- Balloon-occlusion approach not employed

Pulmonary arteries



Big question?

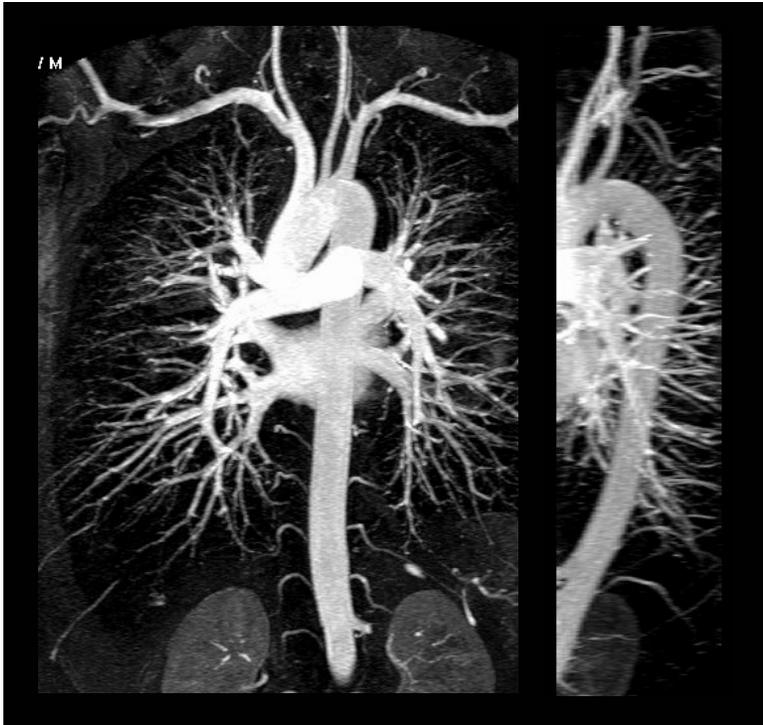
How important is
subsegmental embolism?

Limitations

- Spatial resolution
- Breath-holding

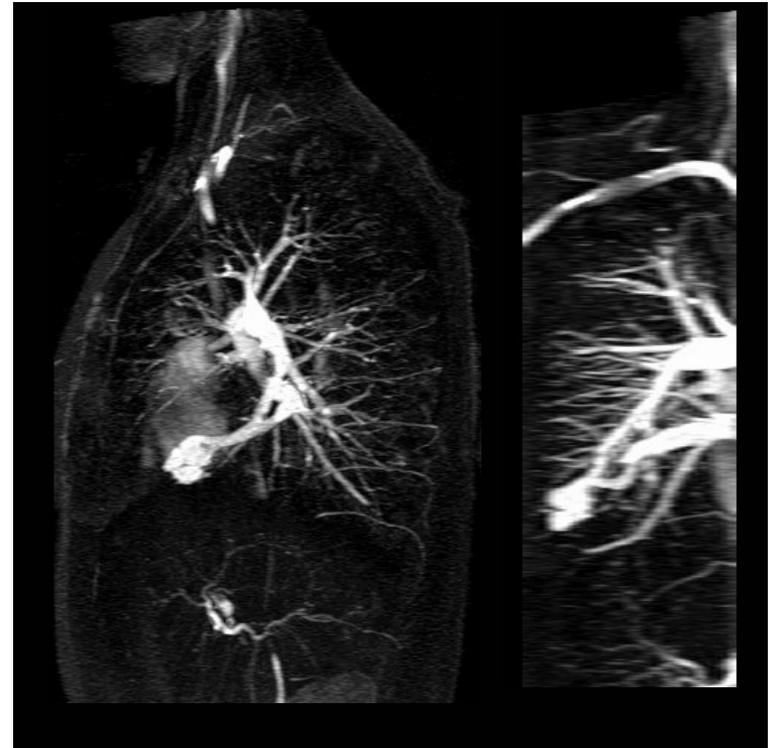
Pulmonary arteries - 3 choices

1. Coronal



- Miss some subsegmental arteries
- Lower resolution

2. Sagittal



Breath-holding

2 injections/2 acquisitions

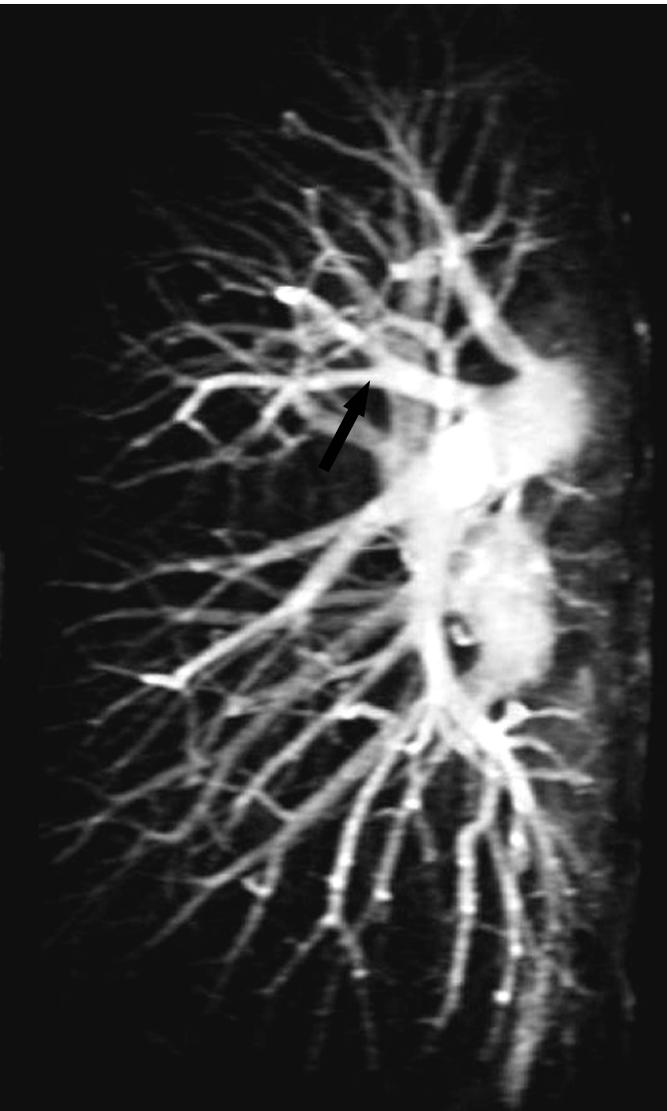
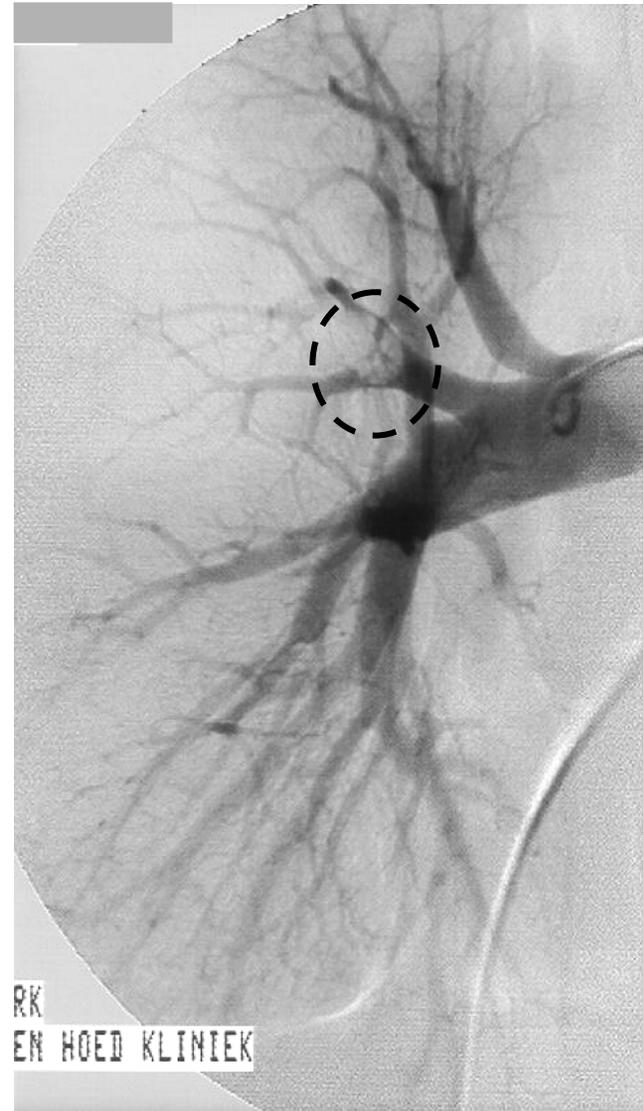
Blood pool agents?

Small PE

CA

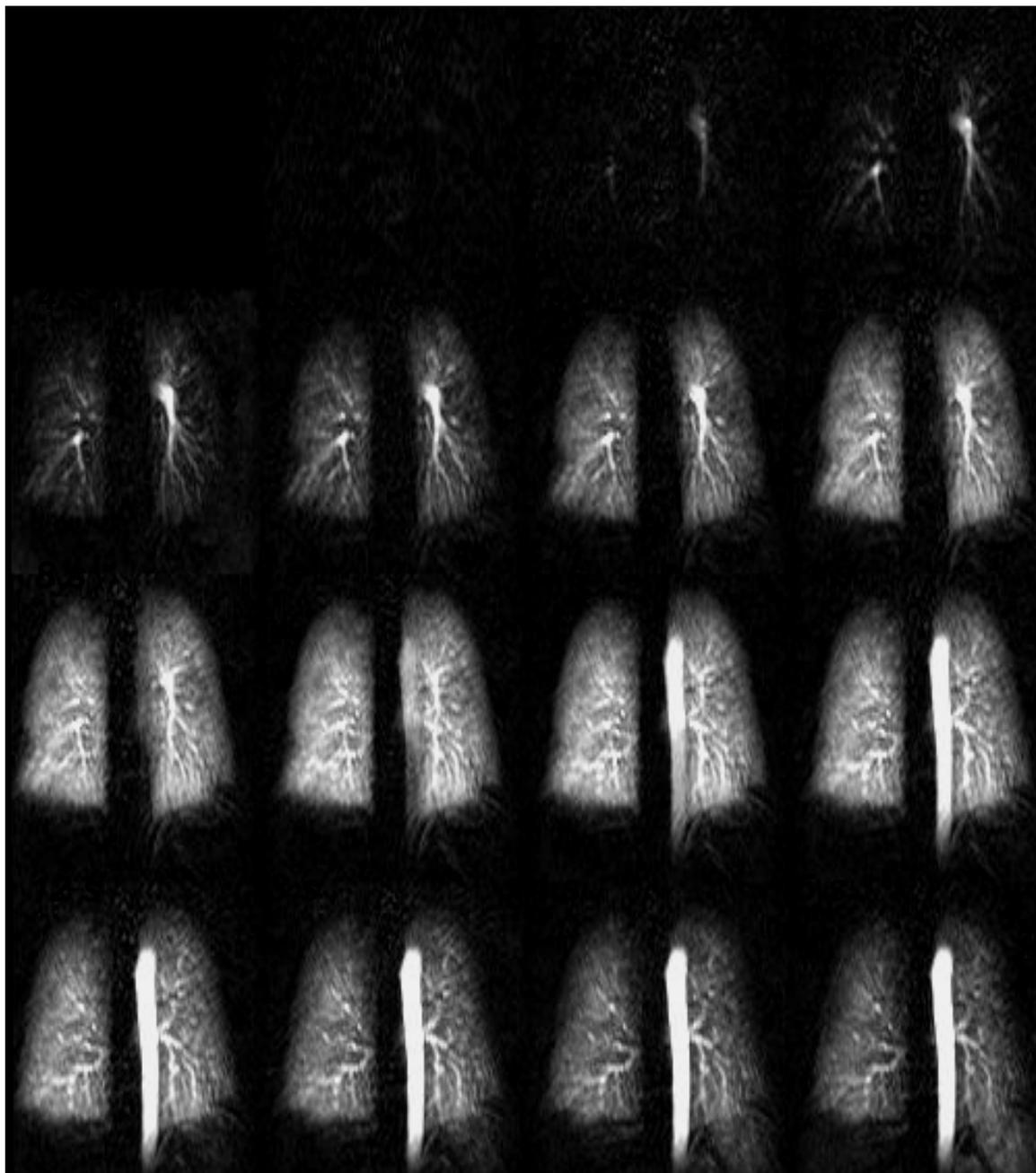
Pre-

Follow up





MRPP

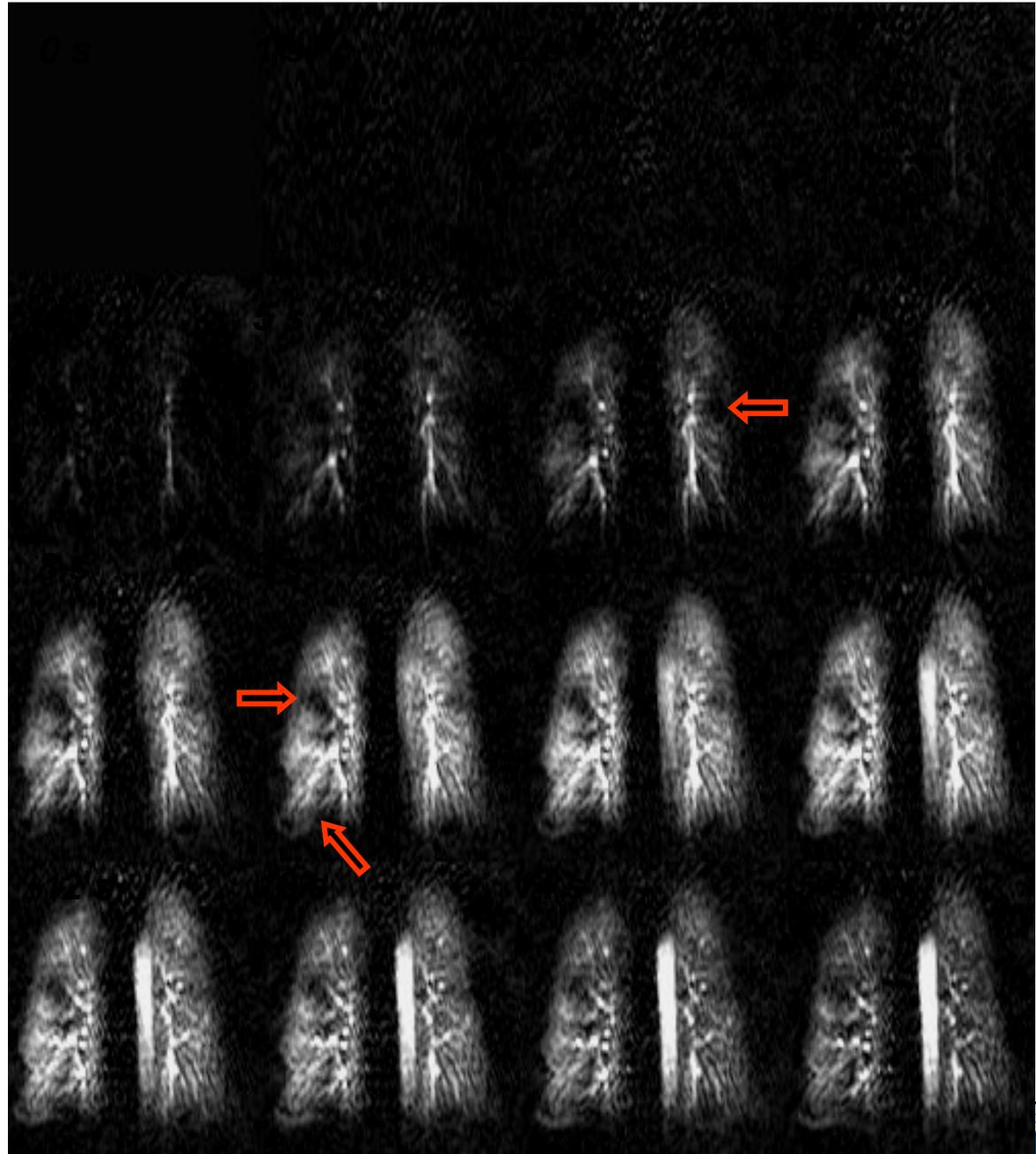


MRPP

 **perfusion defect**

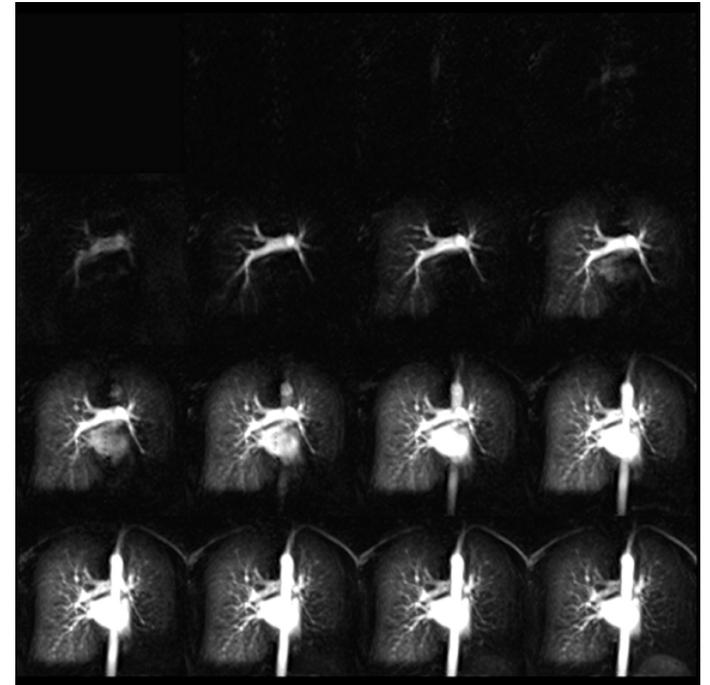
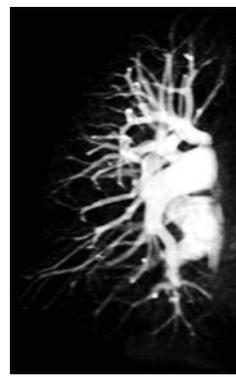
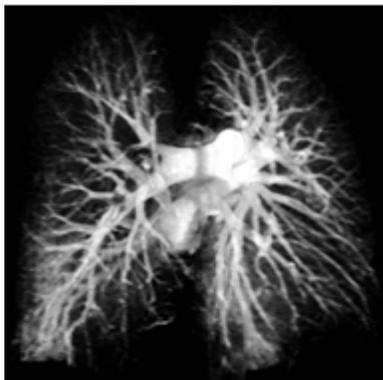
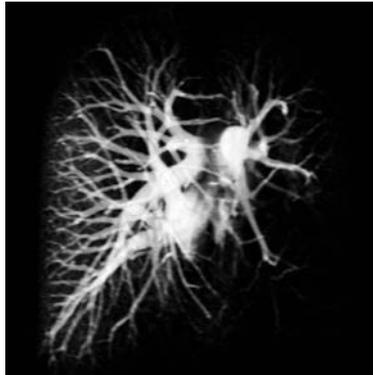
MIP

- posterior-mid section
- 30 mm volume





MRA - The future of PE diagnosis?



Subsegmental emboli

Significance?

- No data
 - PIOPED f/u: 0.6% of patients with negative angiograms developed PE

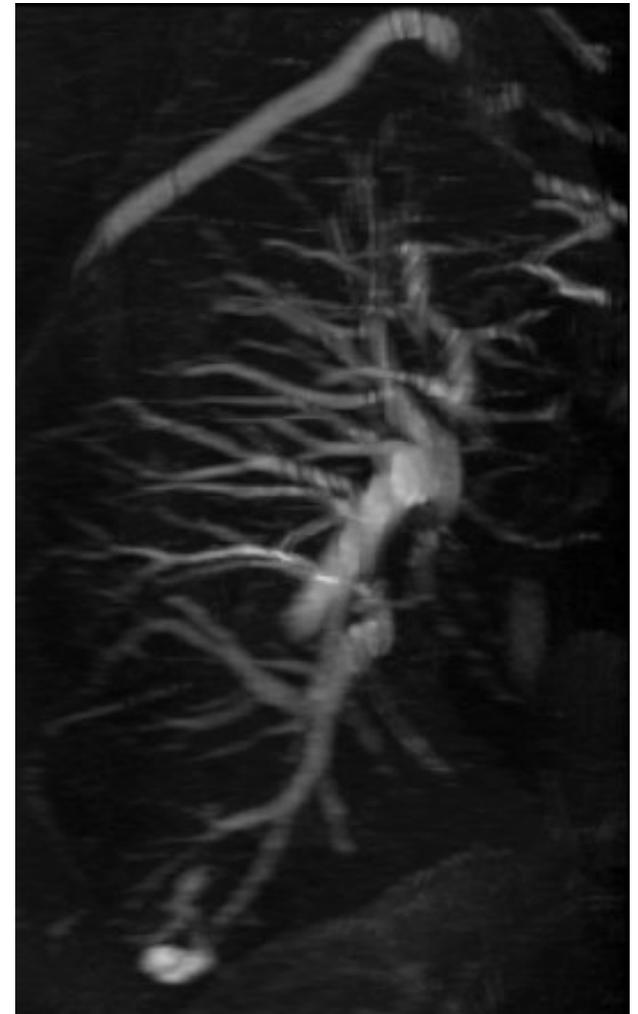
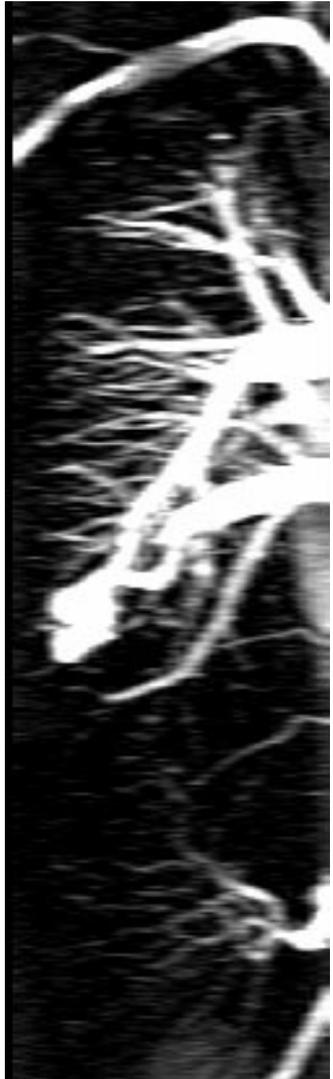
Occurrence?

- PIOPED: 5.6%
- Oser et al 1996: 30%
- Goodman et al 1996: 36%

Blood pool agent imaging?



Arterio-venous malformation?

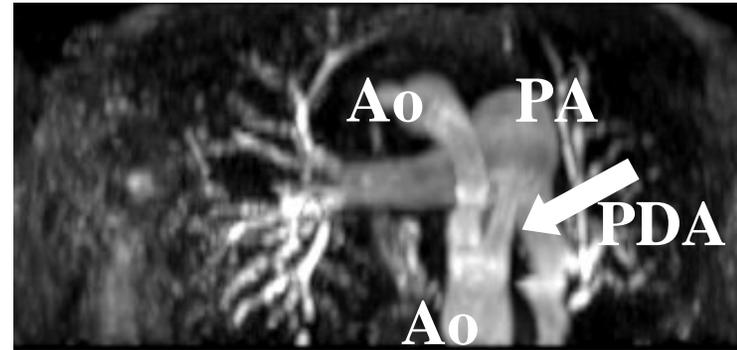
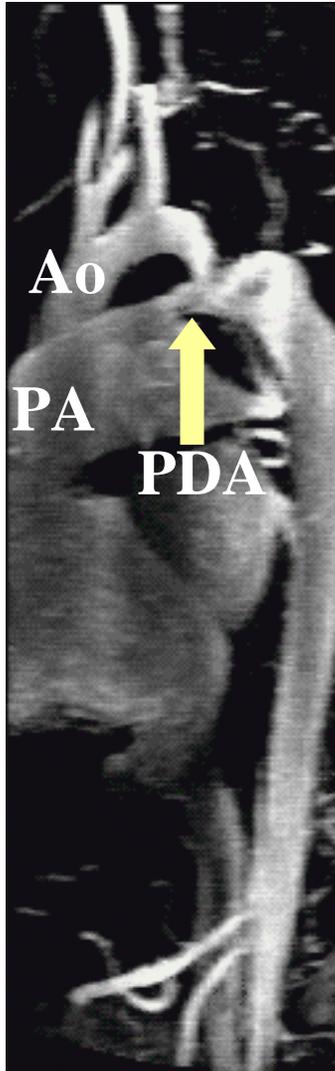


Thoracic aorta



Thoracic aorta





time →



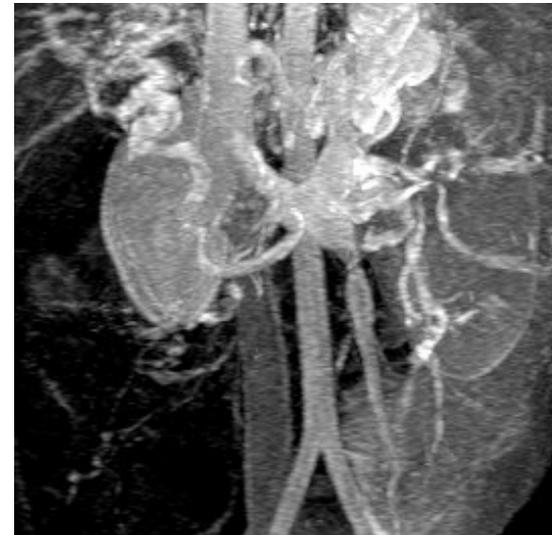
MR Venography

Remember after a peripheral injection

3 (4) phases

- “Venous” first pass
- Arterial
- Parenchymal
- Venous

“Indirect” 3D MRV



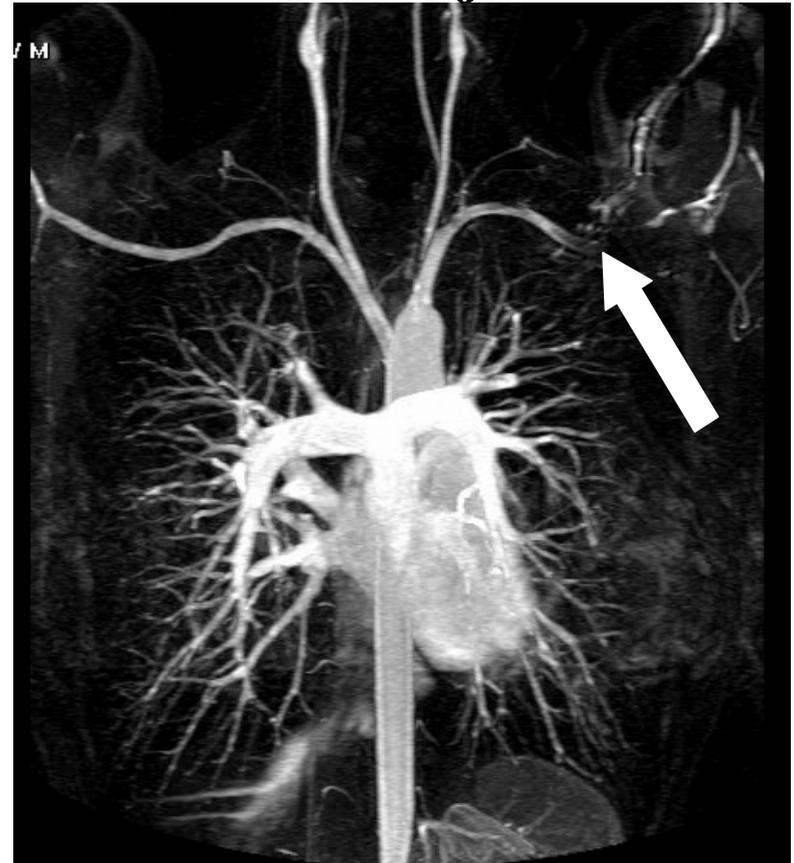
“First venous pass”

Right arm injection



No artefact but no vein!

Left arm injection



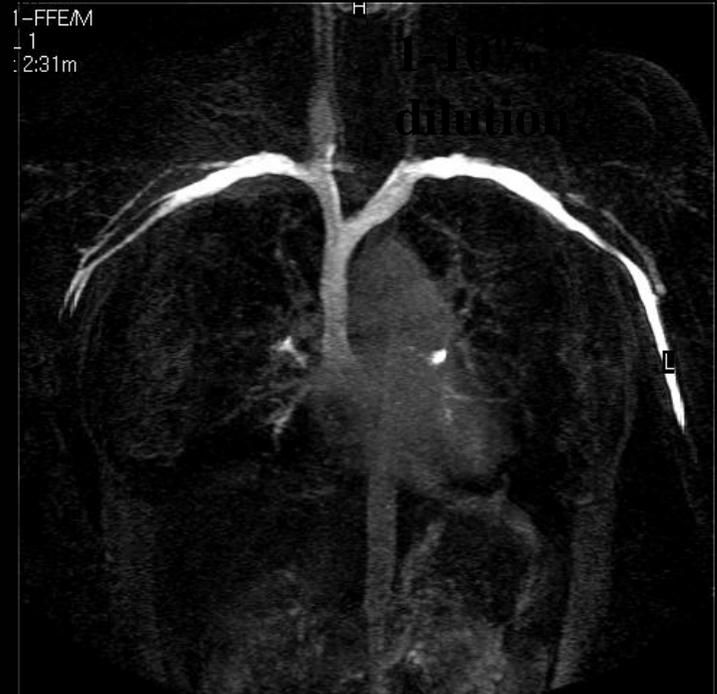
Artefact but no vein!

“Direct” MRV - how much dilution?



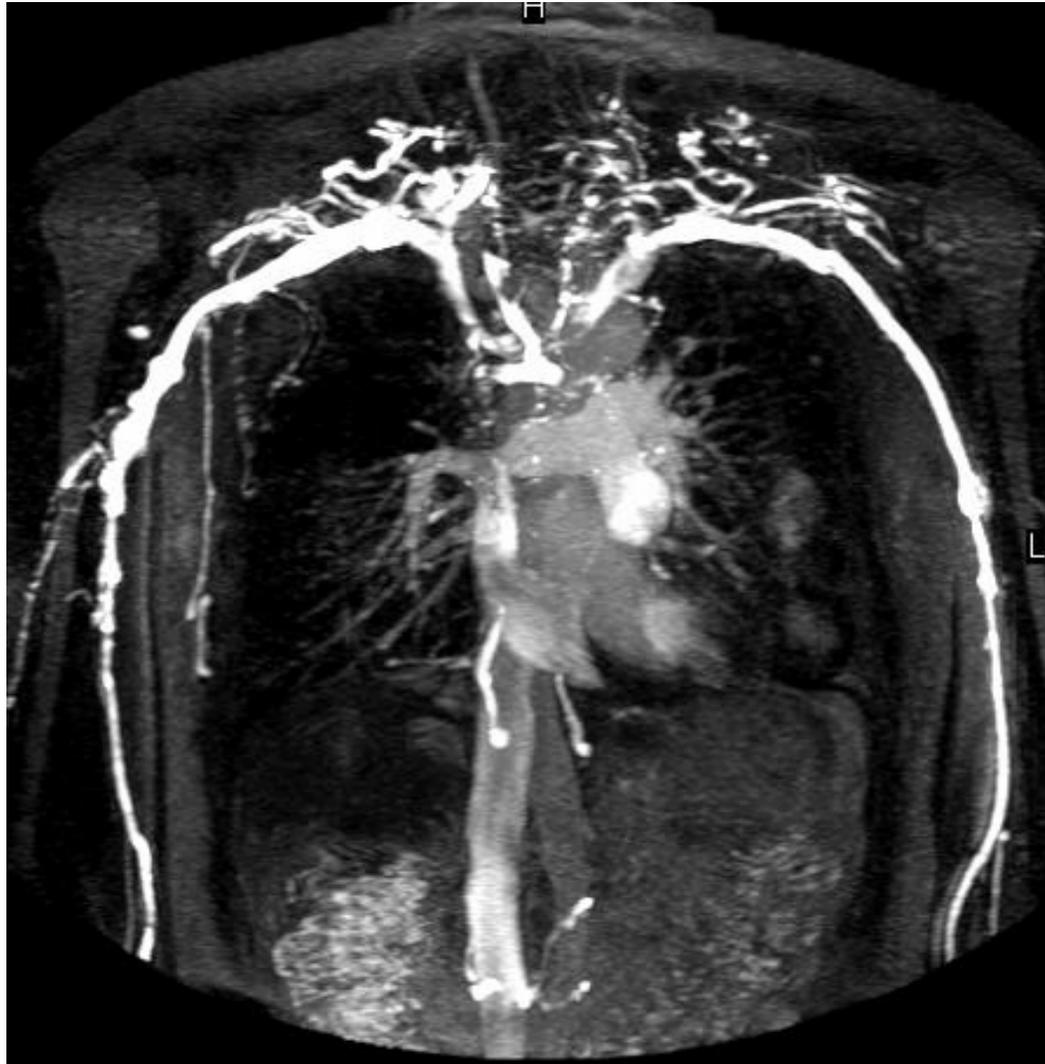
1% 2% 4% 8% 10%

20% 40% 60% 80% 100%



“Direct” 3D MRV

**3cc Gad/
50cc saline**



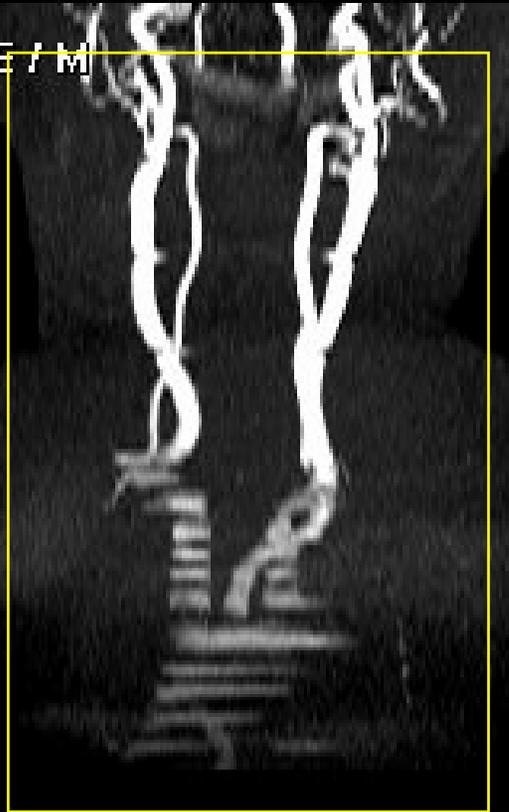
“Indirect” 3D MRV



Carotid arteries

Sc2/3

T1 - FFE / M



Sc2/2

T1 - FFE / M



- localizer
- Plan a 3D scan
- Inject contrast
- Wait
- 3D data set
- Post-process

Aim of imaging?

Very specific!

- Accurately depict stenosis in the carotid bulb at the 70% cutoff
- Depict “tandem” lesions
- Demonstrate vessel origins

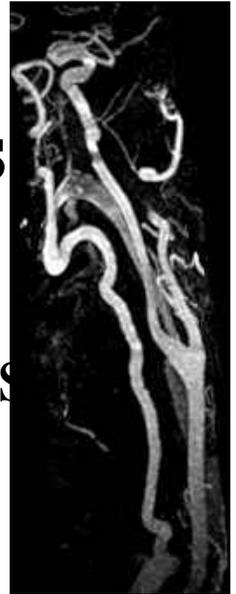
<70% stenosis  Medical therapy

>70% stenosis  Surgical endarterectomy

Carotid arteries - Resolution requirements

“insignificant” vs. “significant” stenosis

70%



Assume ICA is 10mm in diameter

Resolution for “renal” MRA 0.8 x 2 x 2(4)mm

- 60% stenosis → 4mm residual lumen → 1-2 pixels
- **70% stenosis** → **3mm residual lumen** → **1 pixel**
- 80% stenosis → 2mm residual lumen → 1 pixel

Carotid arteries - Resolution requirements



- Build a sequence with sufficient resolution

0.8 x 0.8 x 1mm 36sec acq. time

Assume ICA is 10mm in diameter

- 60% stenosis → 4mm residual lumen → 4-5 pixels
- **70% stenosis → 3mm residual lumen → 4 pixels**
- 80% stenosis → 2mm residual lumen → 2 pixels

Ideally

0.5 x 0.5 x 0.5mm resolution

Carotid arteries

What normally limits us for CE-MRA?

- **Breath-holding capability**  **NOT AN ISSUE!**
- **Arterio-venous transit time**
No extraction of contrast material in brain
(Blood-brain-barrier)

10-12 slices

20-24 slices

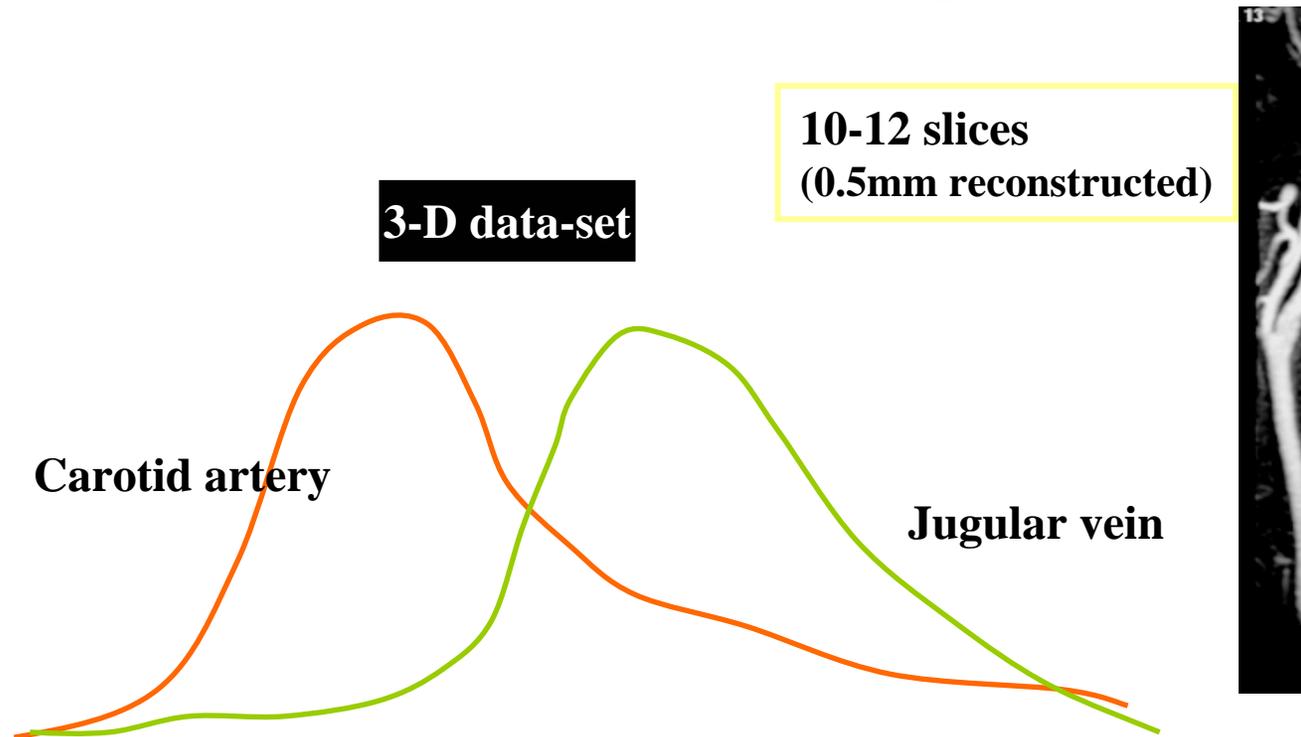
(0.5mm reconstructed)

 **Transit time 8-12 seconds**

vs.

36sec acq. Time

Carotid arteries - Can we achieve arterial phase images?

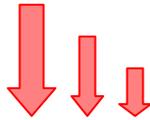


Problems?

- **Timing issues - BolusTrak**
- **Resolution issues - Impossible**

Carotid arteries - solution!

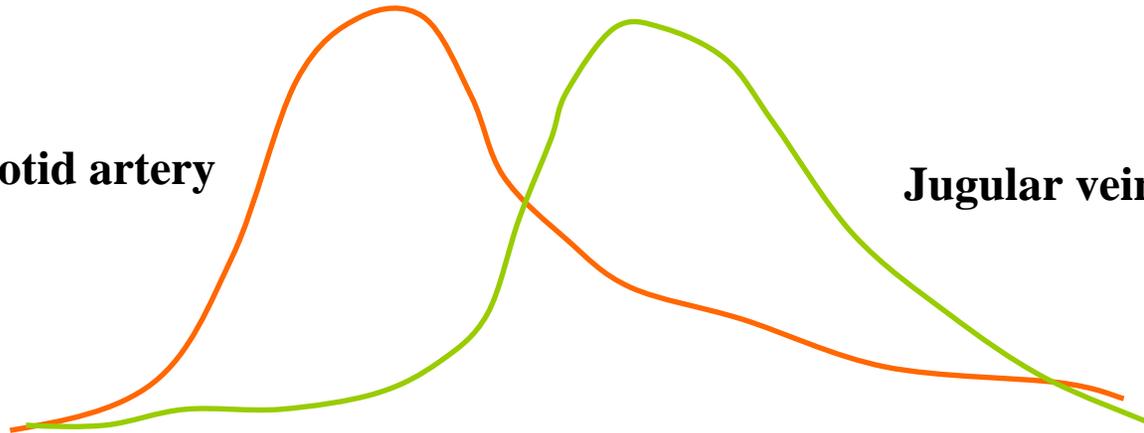
Contrast-defining lines



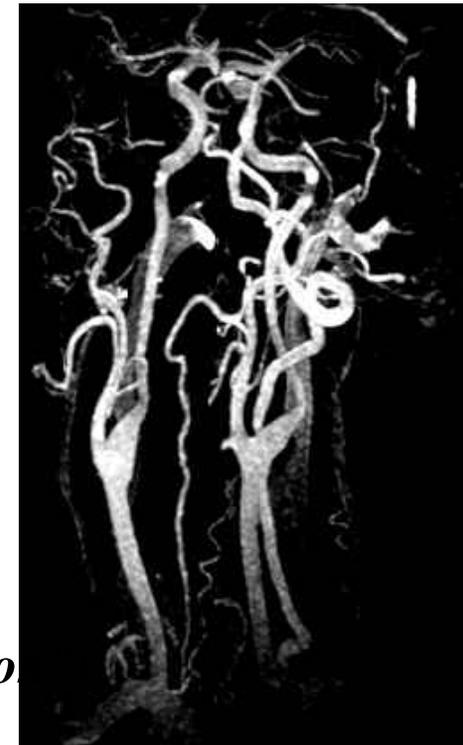
Detail defining lines



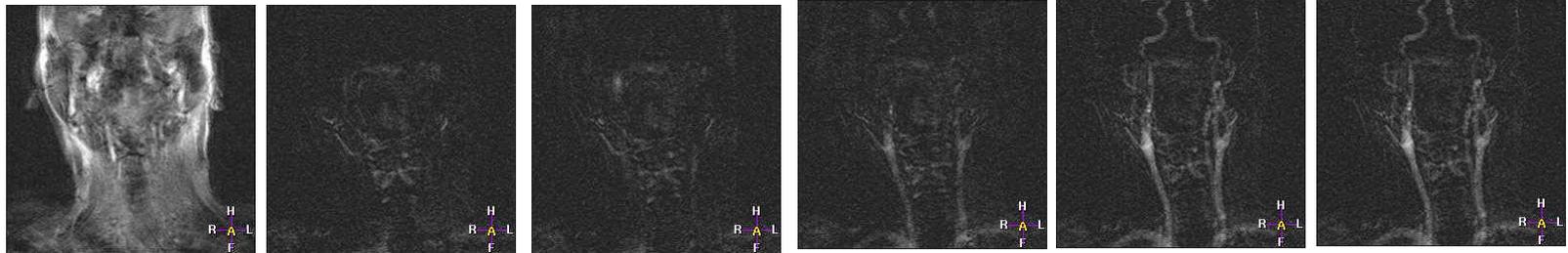
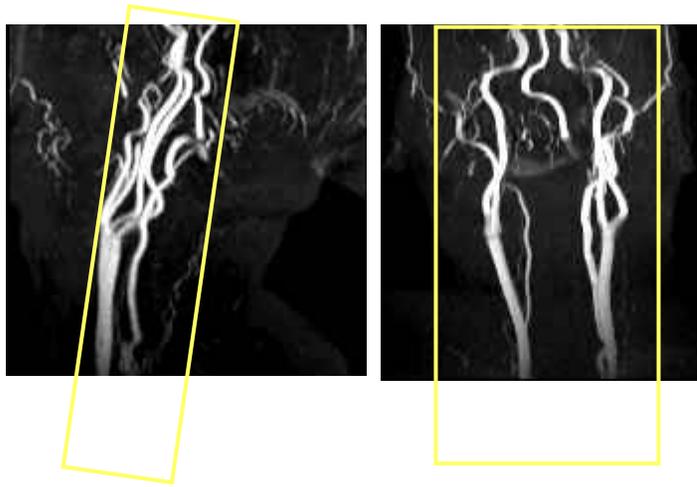
Carotid artery



Jugular vein



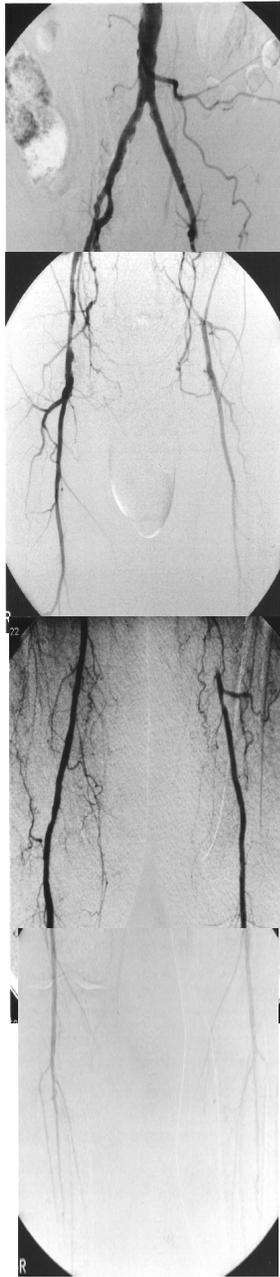
*Allow Scan time > A-V transit time
(We must collect all of the central k-space
data before onset of venous enhancement - "Bolus-detectio*



Carotid artery MRA

- 30cc gad
- 1cc/sec
- (Quadrature) Neck coil
- Triggering (BolusTrak)

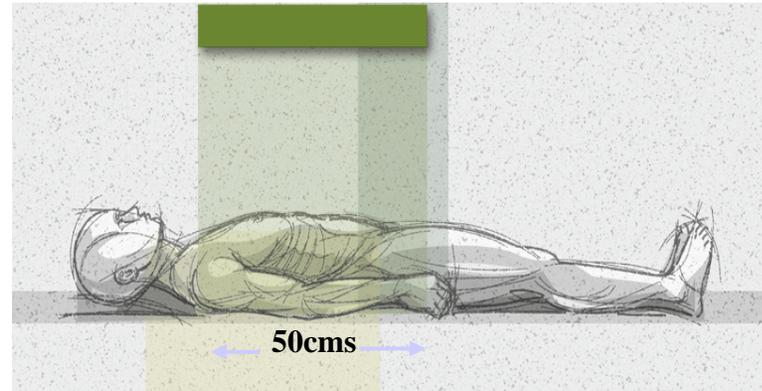
>100cm



Vs.

2 Approaches

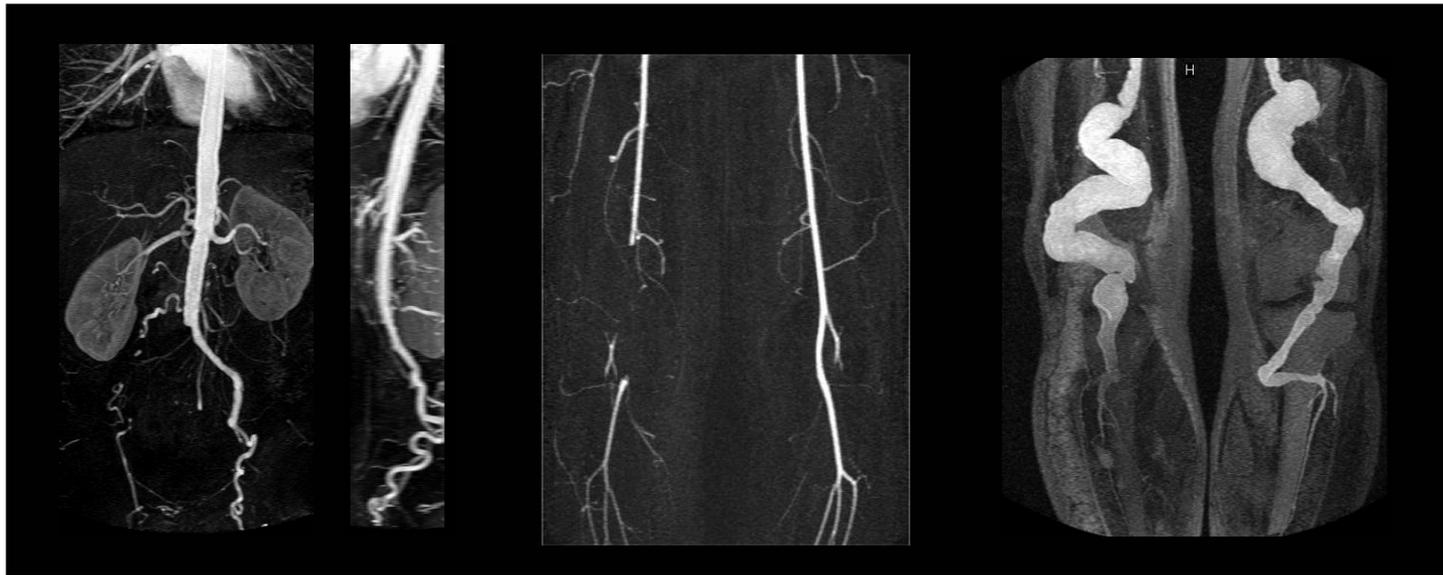
- “Low” resolution screening
- Highly optimized screening



Single-station CE-MRA

Vs. US

- All 3 areas
- Fast
- Cheaper?

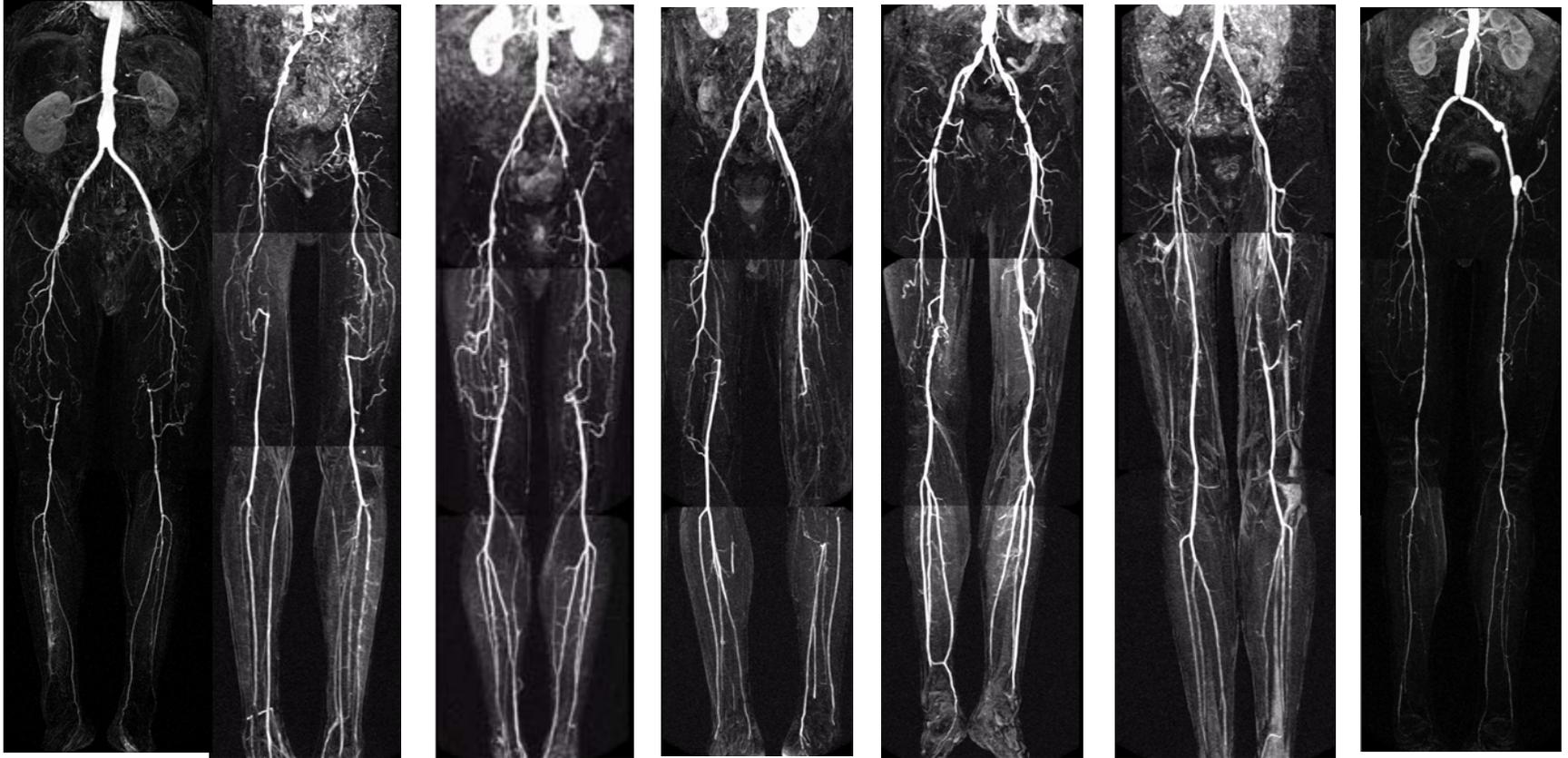


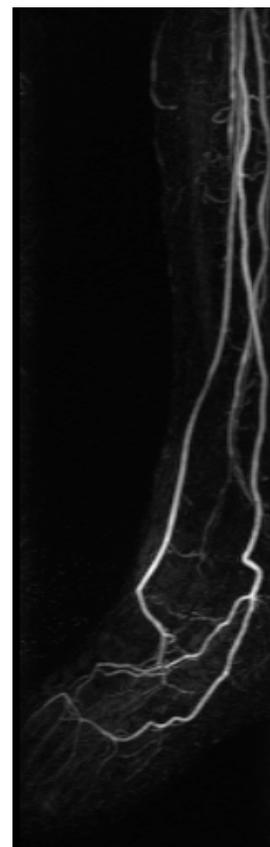
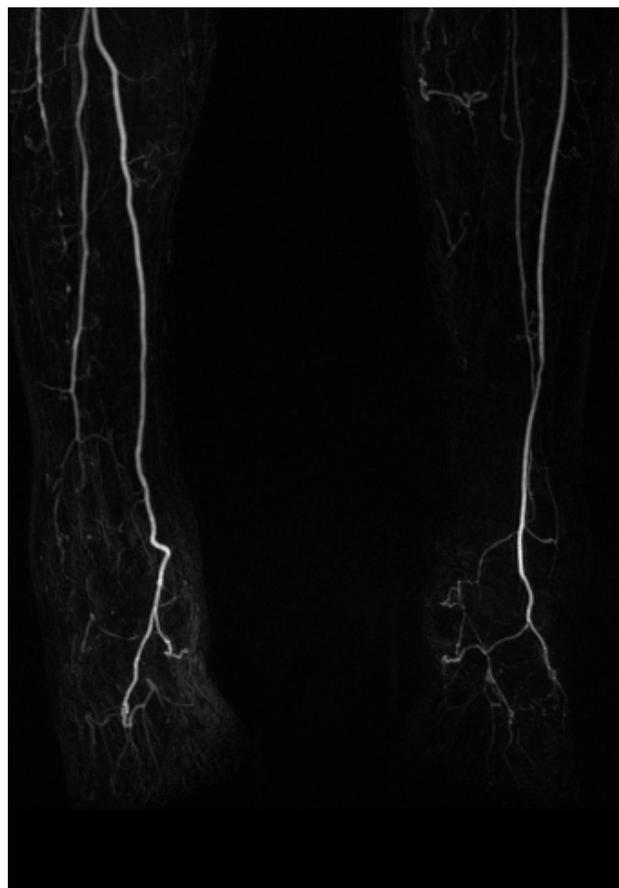
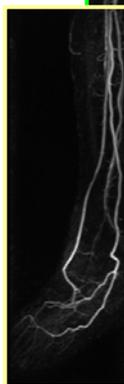
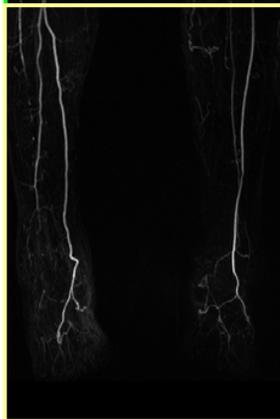
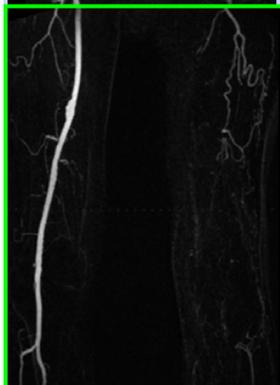
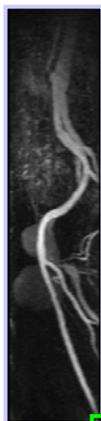
•Anatomy only

Vs. CTA

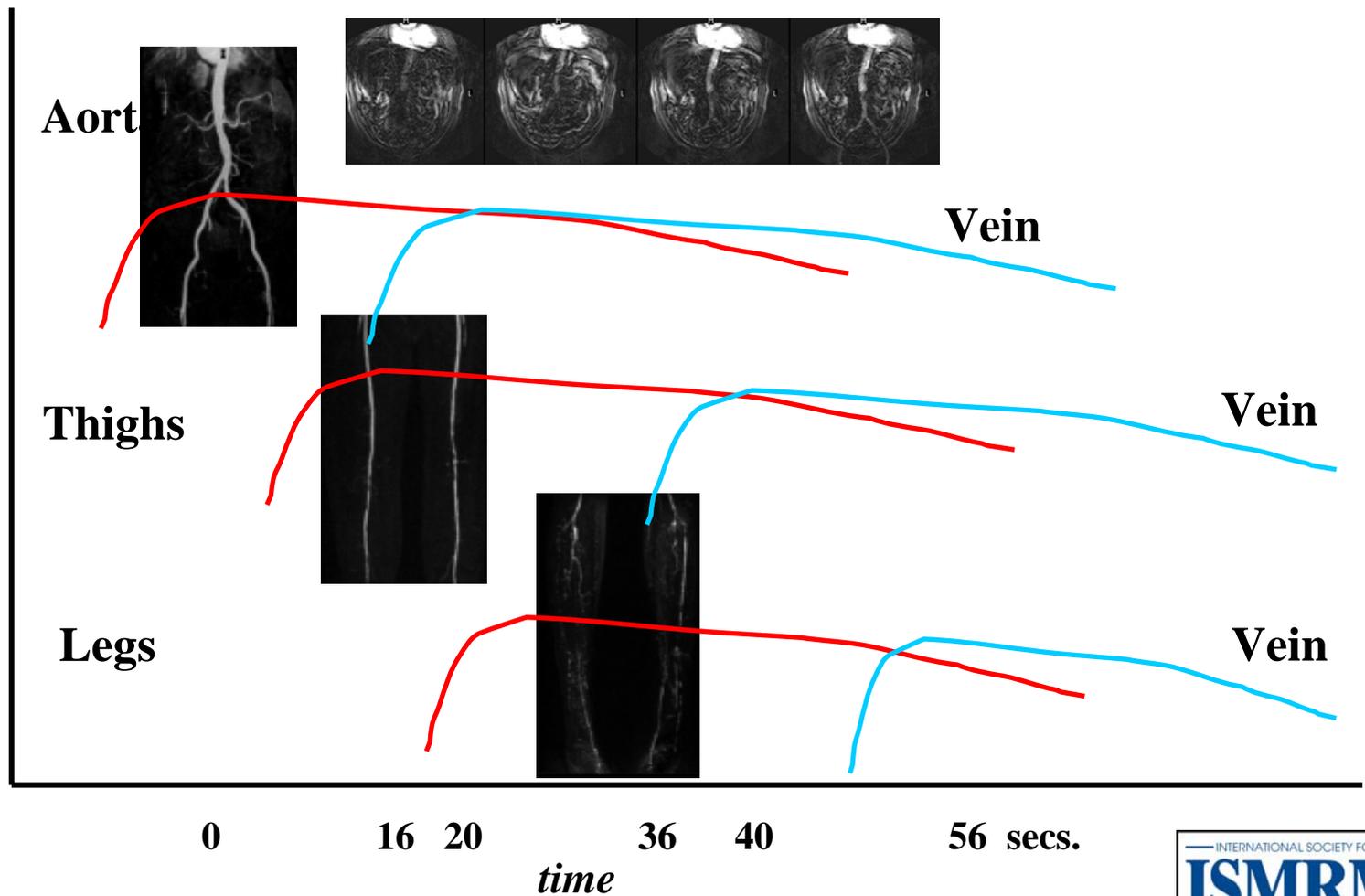
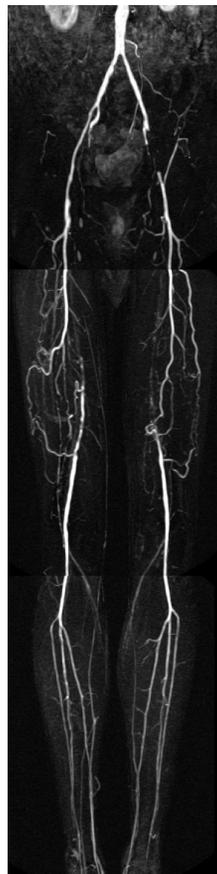
- All 3 areas
- ? Not as fast
- No iodinated contrast material
- No ionizing radiation

Moving-Bed MRA





Bolus outstrips data acquisition!



Faster/Higher Resolution Imaging?

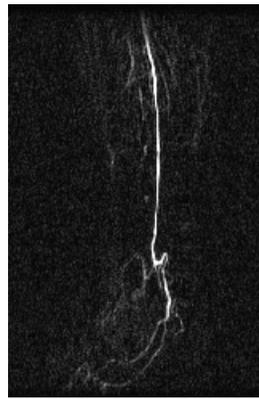
TR x N_p x N_s x NSA x Accel. factor

- 2D/3D hybrids
- K-space manipulation
- Slow down circulation
- Faster scanner x 5
- PAT – x 4

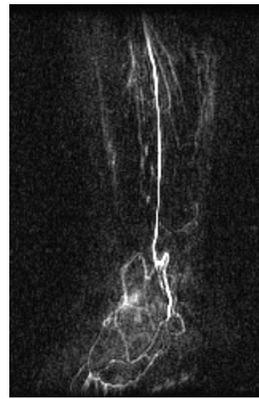
2D Projection MRA



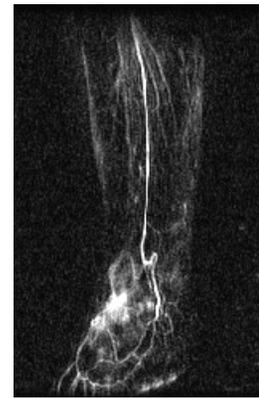
20.3 sec



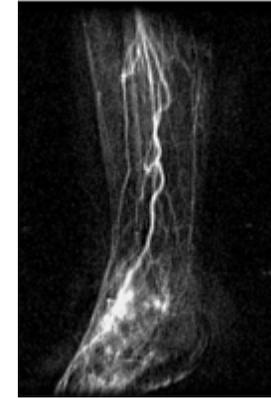
24.4 sec



28.4 sec



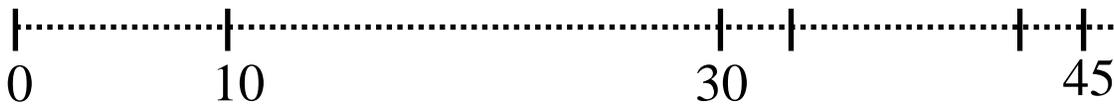
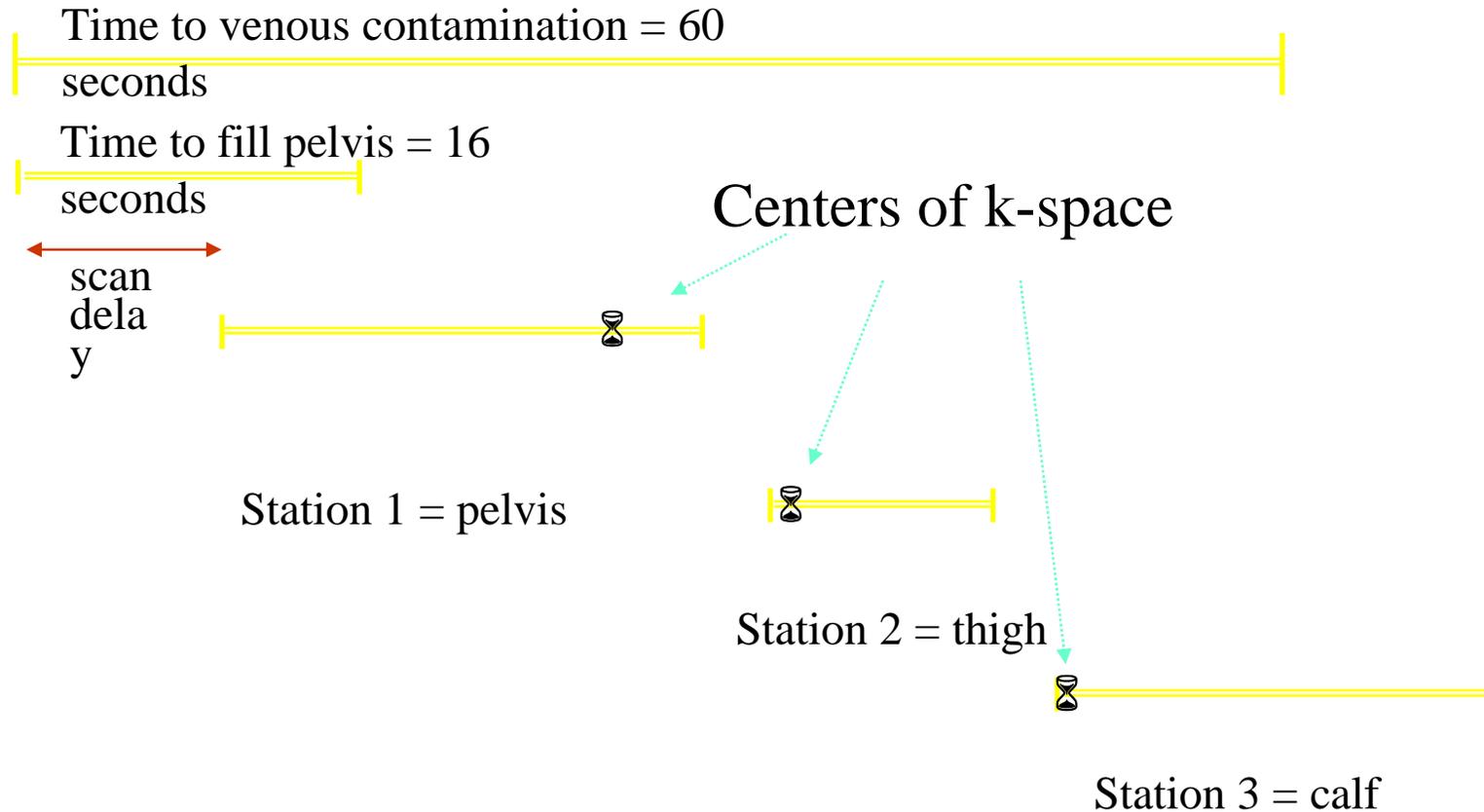
32.5 sec



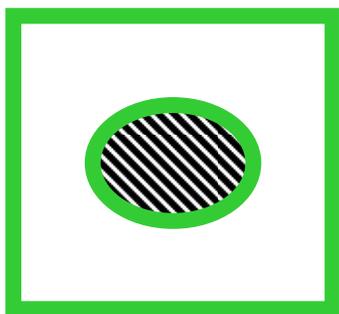
72.7 sec

- Time to fill distal station = 24 seconds
- Time to fill pelvis = $\frac{2}{3}$ (24 sec) = 16 sec
- Time for venous contamination = 60 sec

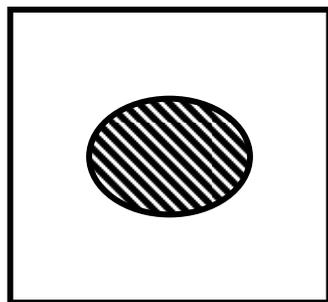
Calculation of Bolus-Chase Injection Timing Parameters



Shoot and Scoot (3D-SNS)

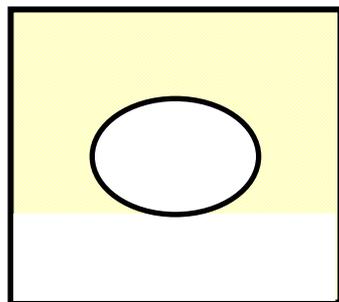


a

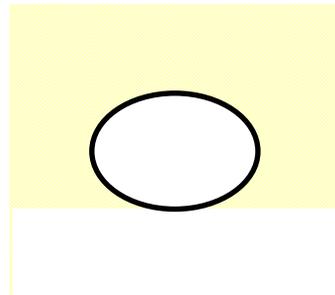


b

K_z

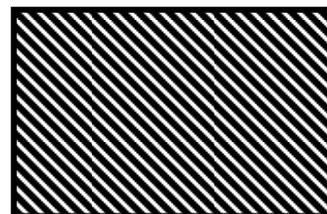


e



d

K_y



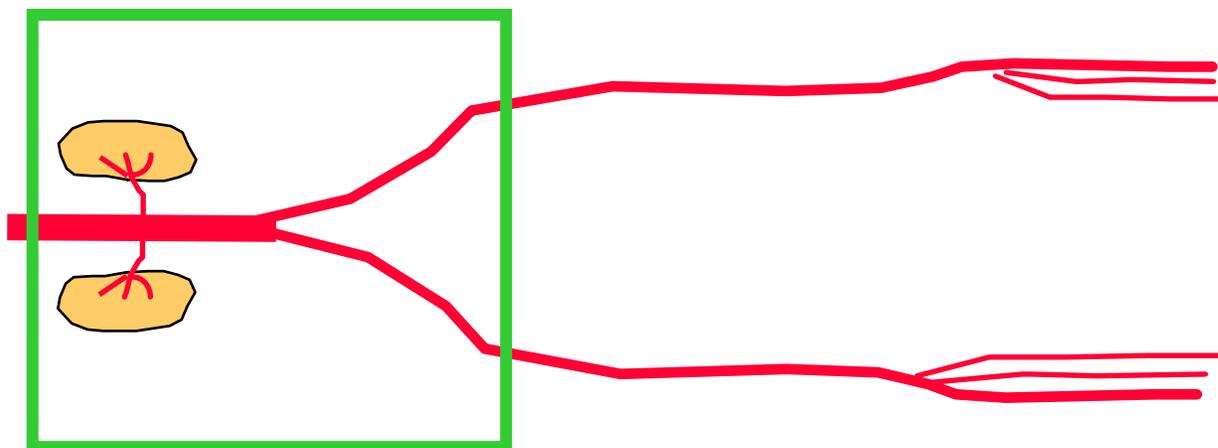
c



Station 1

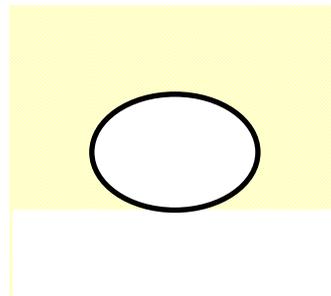
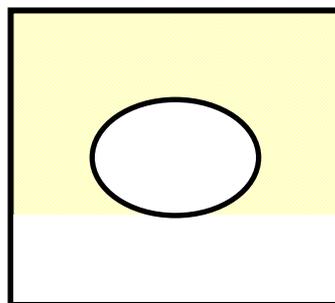
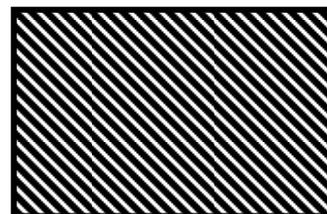
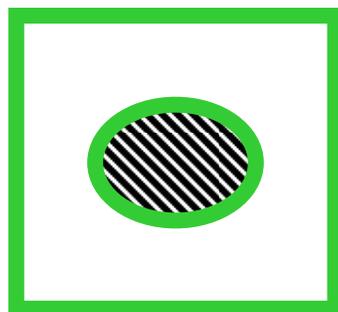
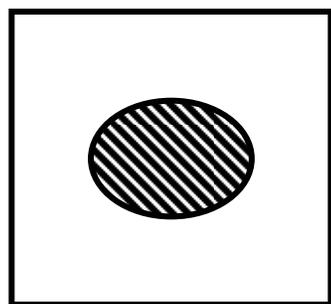
Station 2

Station 3



Courtesy of Vince Ho

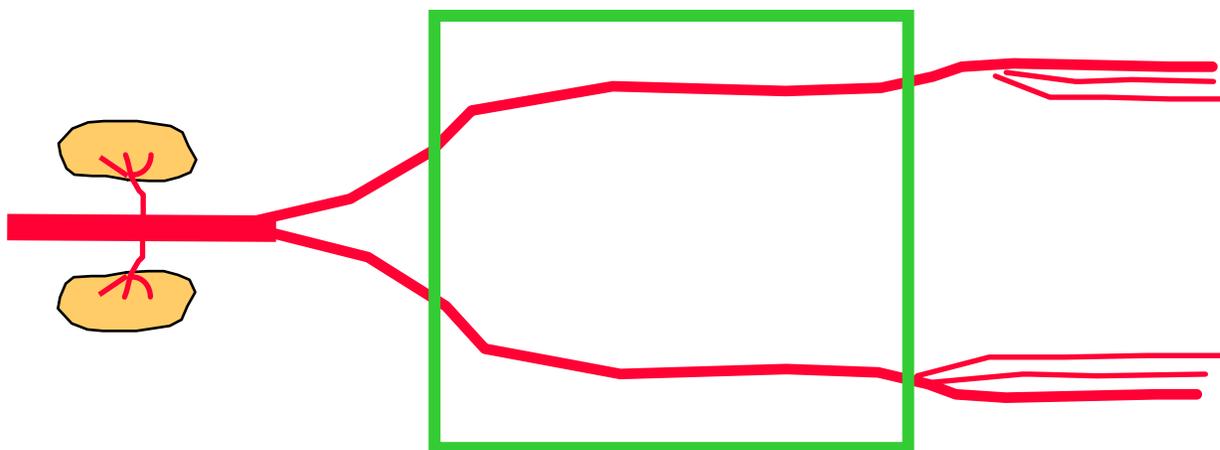
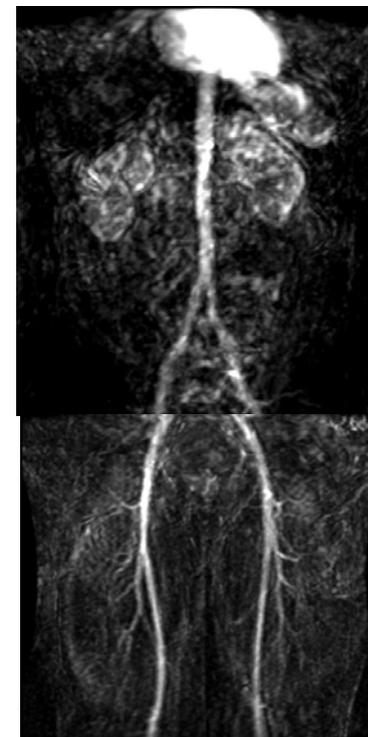
Shoot and Scoot (3D-SNS)



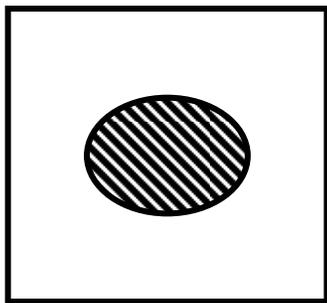
Station 1

Station 2

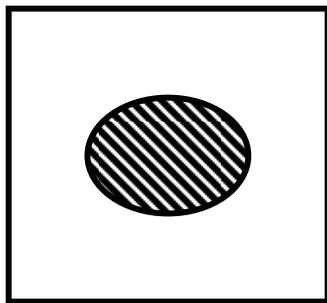
Station 3



Shoot and Scoot (3D-SNS)

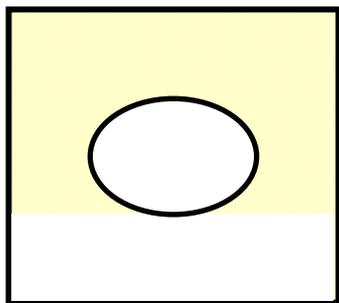


a



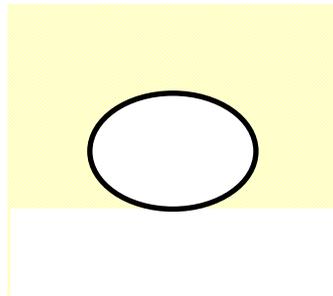
b

K_z



e

Station 1



d

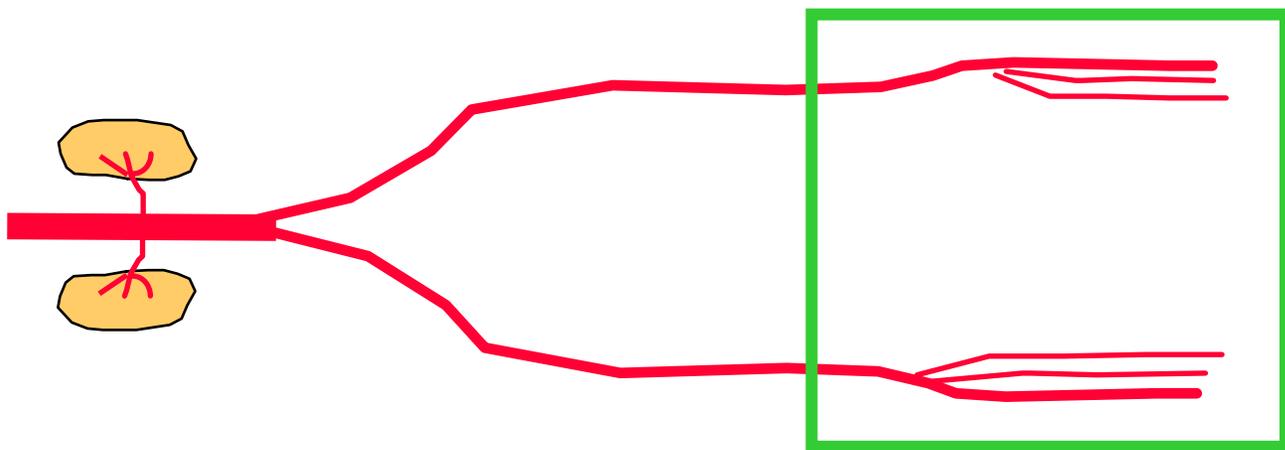
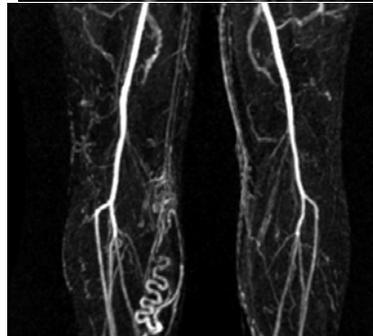
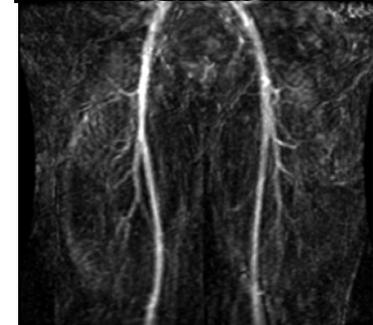
K_y

Station 2

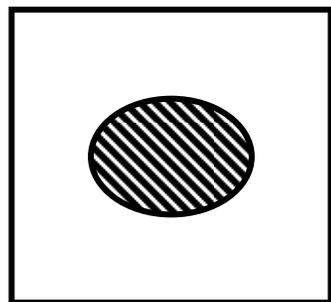


c

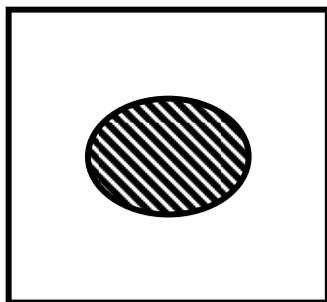
Station 3



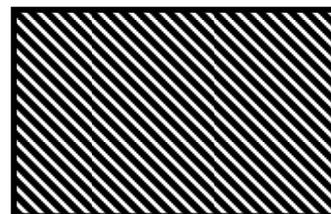
Shoot and Scoot (3D-SNS)



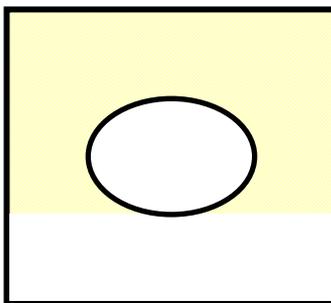
a



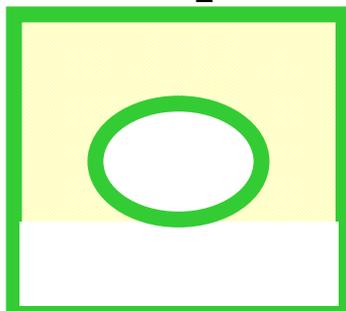
b



c



e



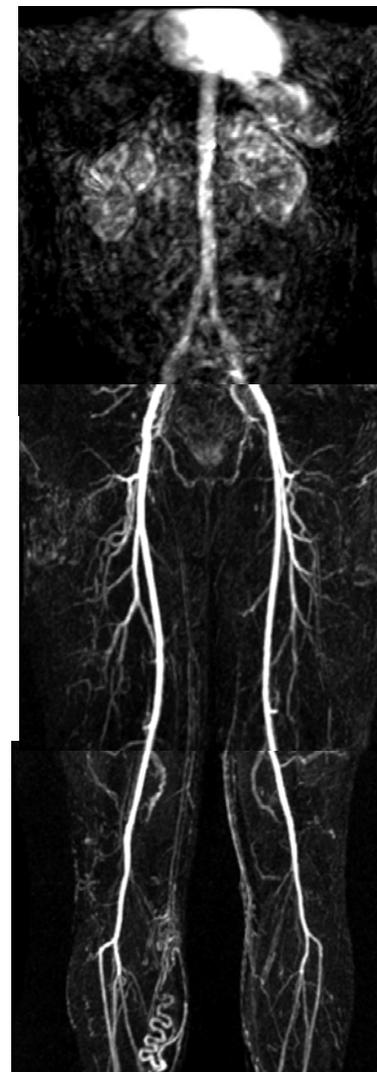
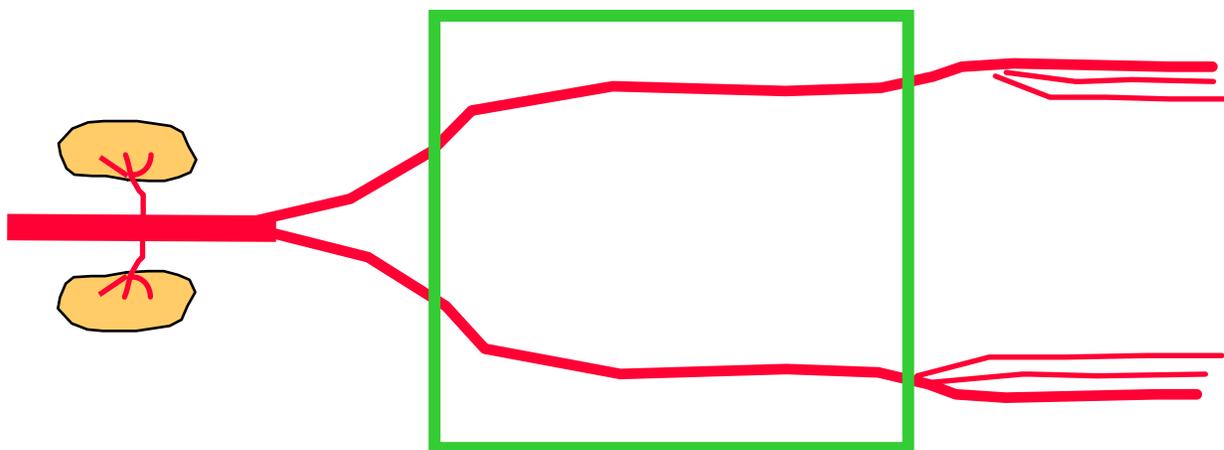
d

K_z
 K_y

Station 1

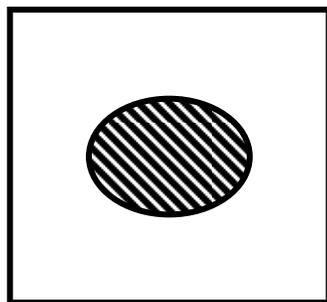
Station 2

Station 3

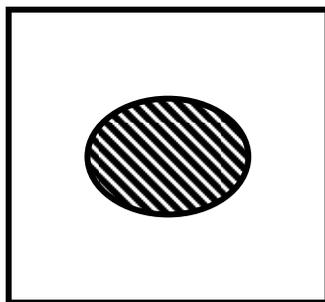


Courtesy of Vince Ho

Shoot and Scoot (3D-SNS)

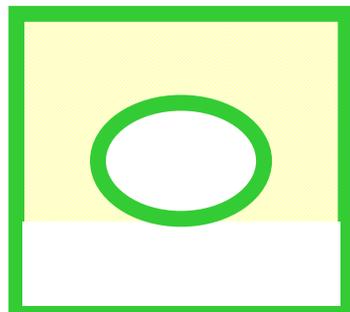


a



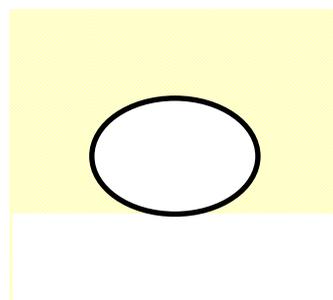
b

K_z



e

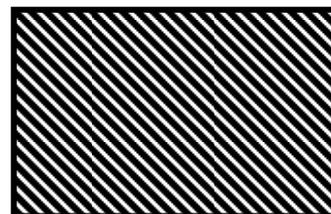
Station 1



d

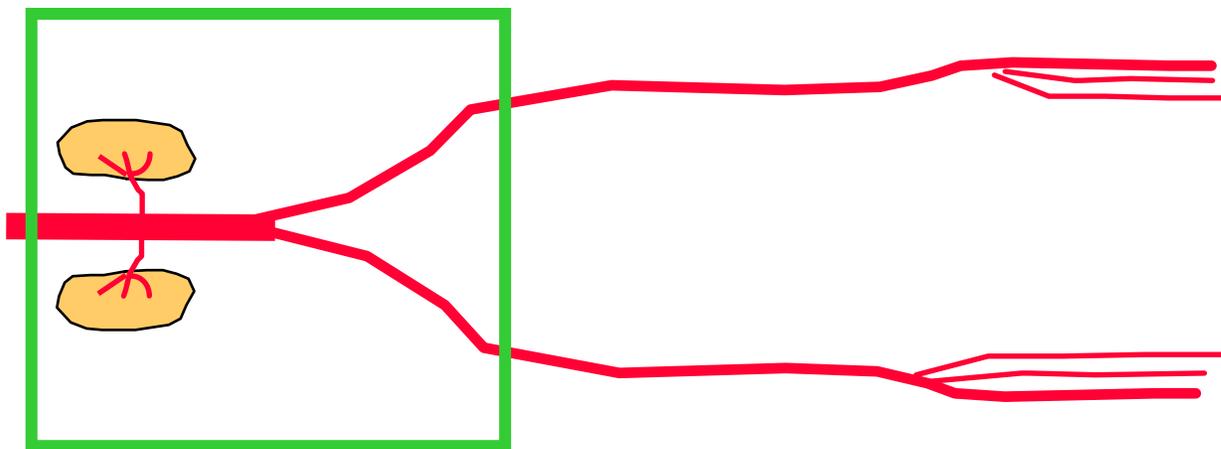
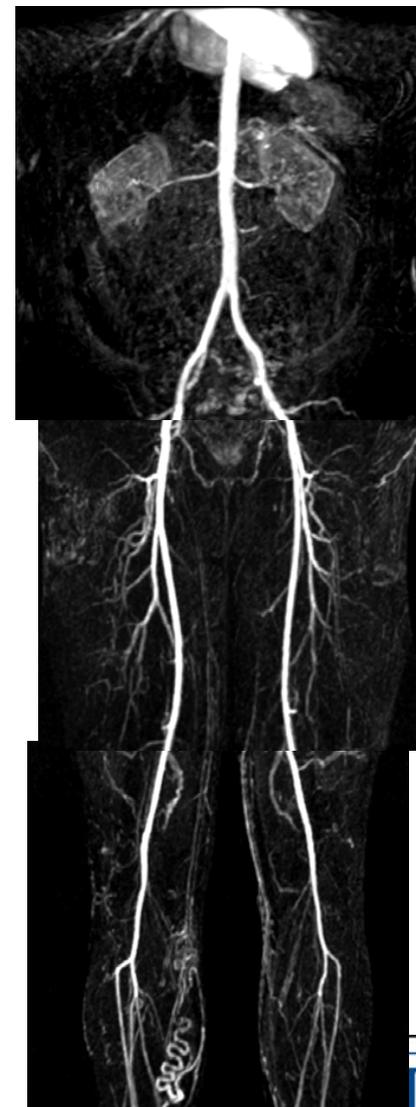
K_y

Station 2



c

Station 3

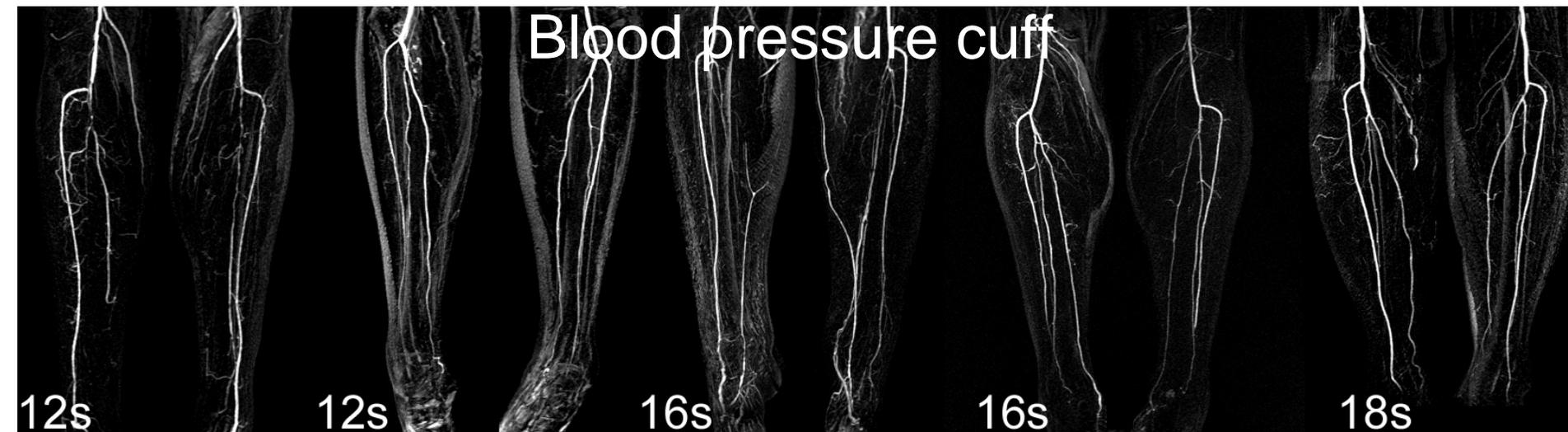


Tourniquets?

No compression



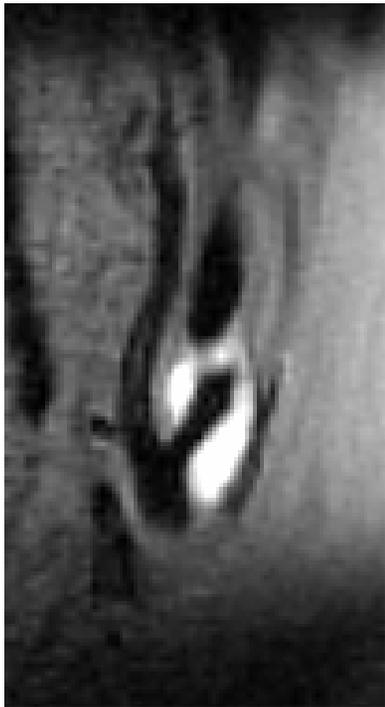
Blood pressure cuff



SENSE: Sensitivity Encoding*

- Enables reduction of phase encoding without loss of spatial resolution by utilizing a receiver coil array
- Cartesian sampling of k-space:
 - increased distance of phase encoding lines
 - aliased single coil images
 - un-aliasing using coil sensitivities
- in situ reference scan for determination of sensitivity profiles

MRI of the wall

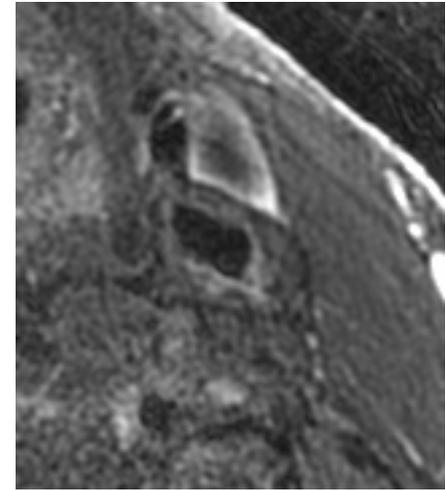


Oblique View

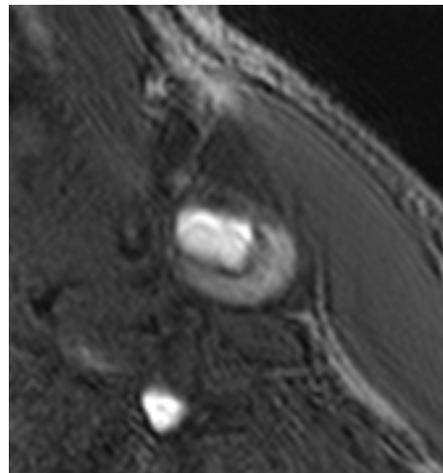
PD,T2: Shared Echo
T1: Double IR



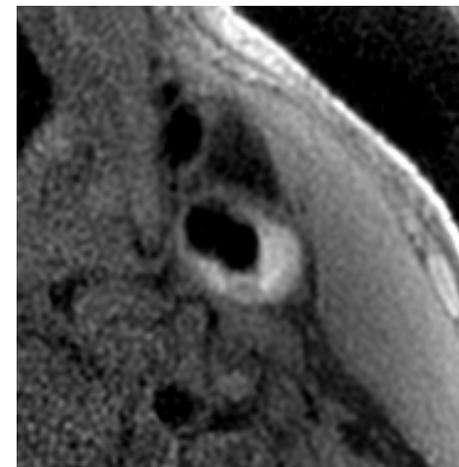
PD



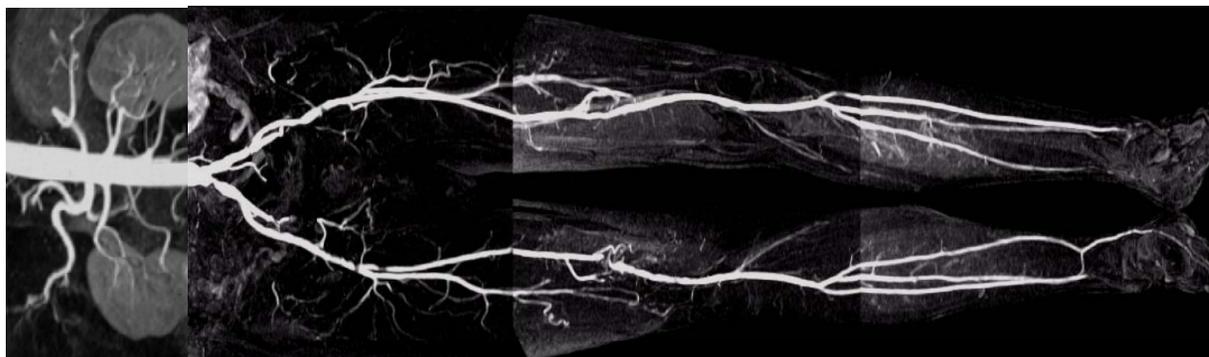
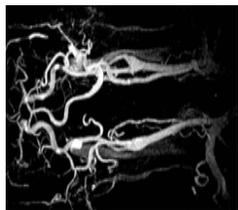
T2



TOF



T1



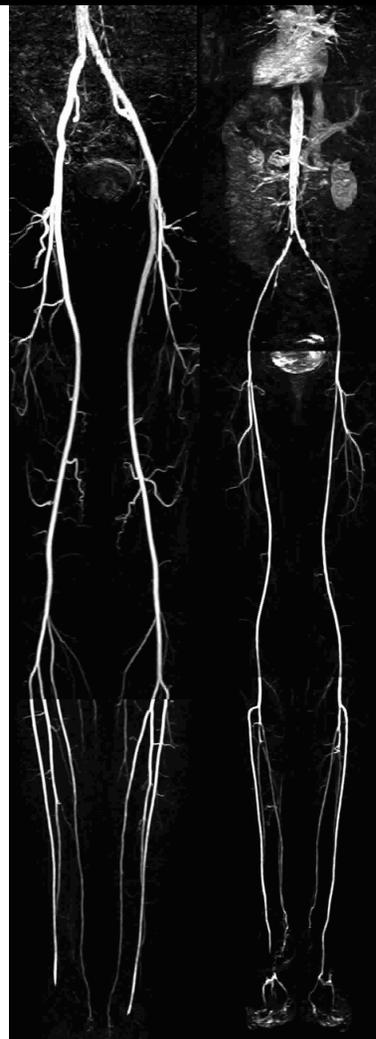
40 secs

20 secs



16 secs

8 secs



16 secs

8 secs

18 secs

8 secs

40 secs

8 secs

What will happen when we image faster?

$$\text{SNR} \propto \frac{\text{TR}}{\text{T1}}$$

$$\text{SNR} \propto \text{Voxel size}$$

What have we done?

TR

Voxel size

Infusion rate (increased T1)

Solution

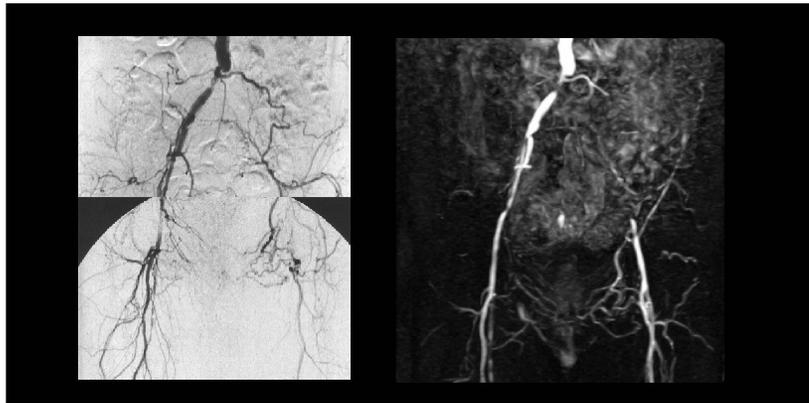
Go faster without shortening TR
(SENSE)

Use more potent contrast agents

Use surface coils

Is there any downside to speed?

MRA

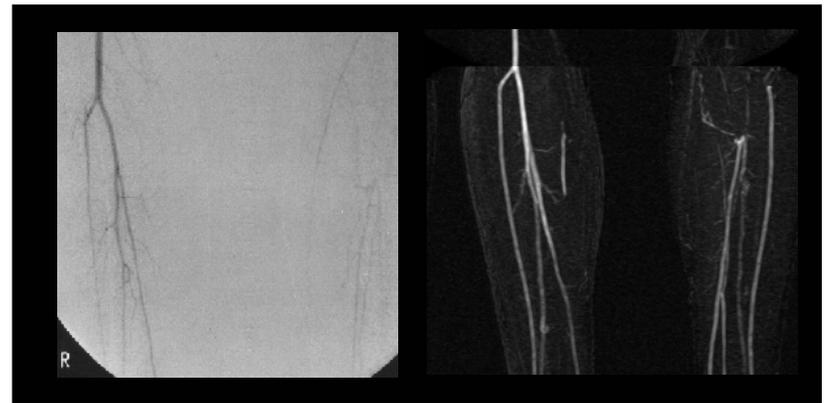


↑
DSA

“FAST”

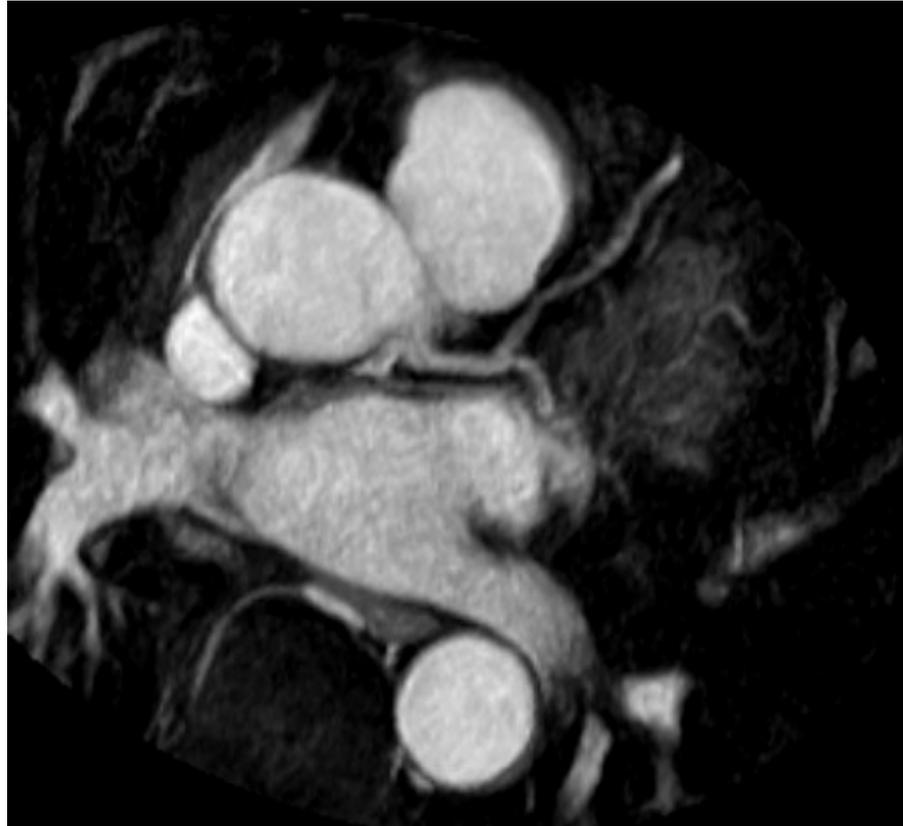
“SLOW”

MRA

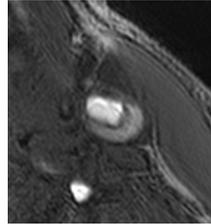
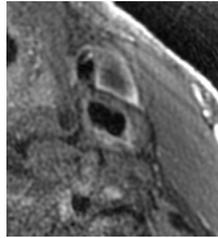
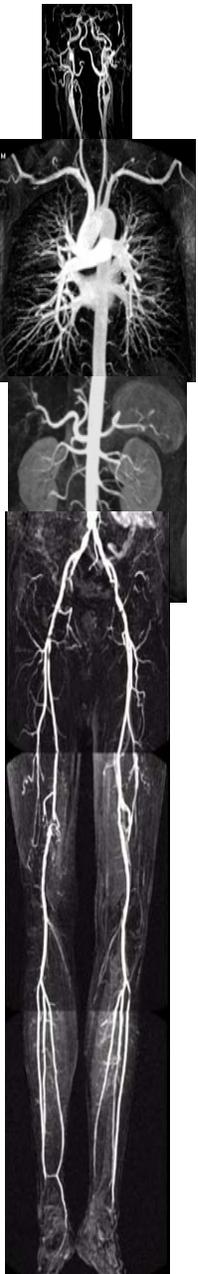


↑
DSA

Coronaries

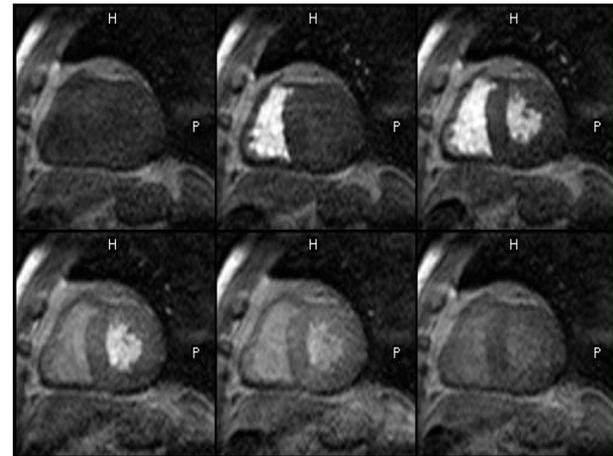
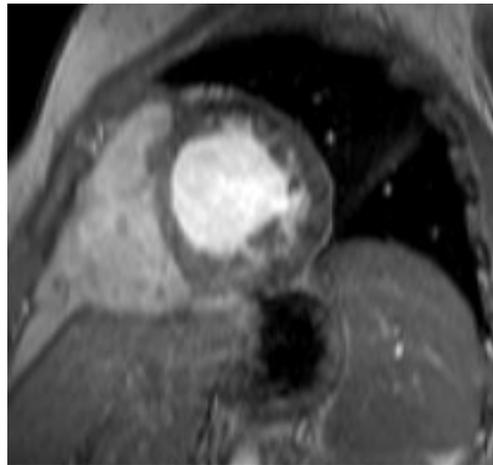


Whole Body MRA + Atherosclerosis Imaging + cardiac assessment



Anatomical *plus*

functional assessment



Conclusion

- CE-MRA is the most widely used technique in clinical practice.
- Non-contrast techniques may stage a “comeback” in the future
- Enormous success to date.
- Basic angiographic principles apply.
- Only currently appreciating the iceberg “tip”.
- No anatomy (apart from coronaries) that cannot be evaluated.

