Université de Paris

Innovations in MRI and their contribution to pediatric imaging diagnosis

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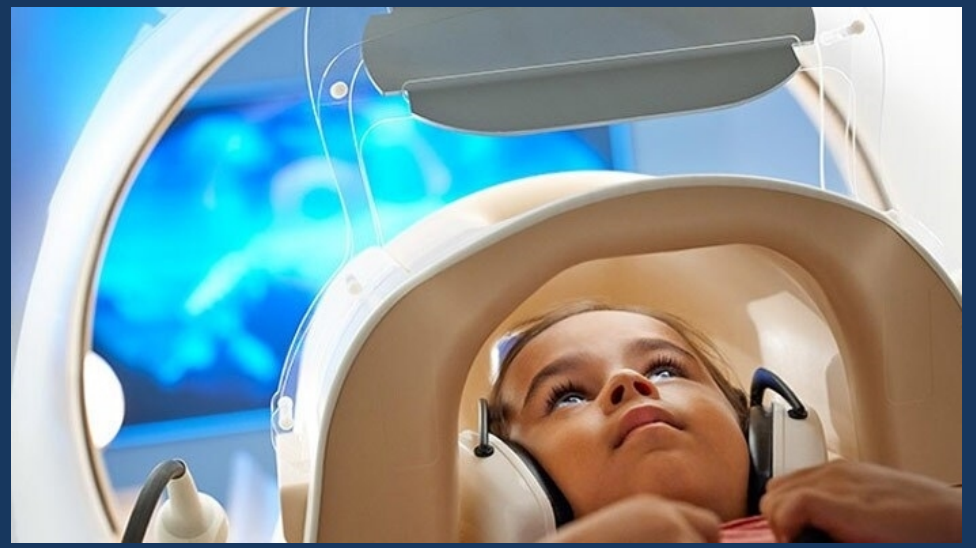
MRI for pediatric patients

- Techniques to avoid sedation
  - Environment
  - Noise reduction
  - Acceleration techniques
  - Motion artefact reduction
- Techniques to avoid contrast injection
- Techniques to avoid X-ray exposure
- Innovative sequences to improve diagnosis

I- Techniques to avoid sedation

1/ Environment

- Friendly environment
- Mock scanner
- Distraction techniques
  (audio visual techniques)

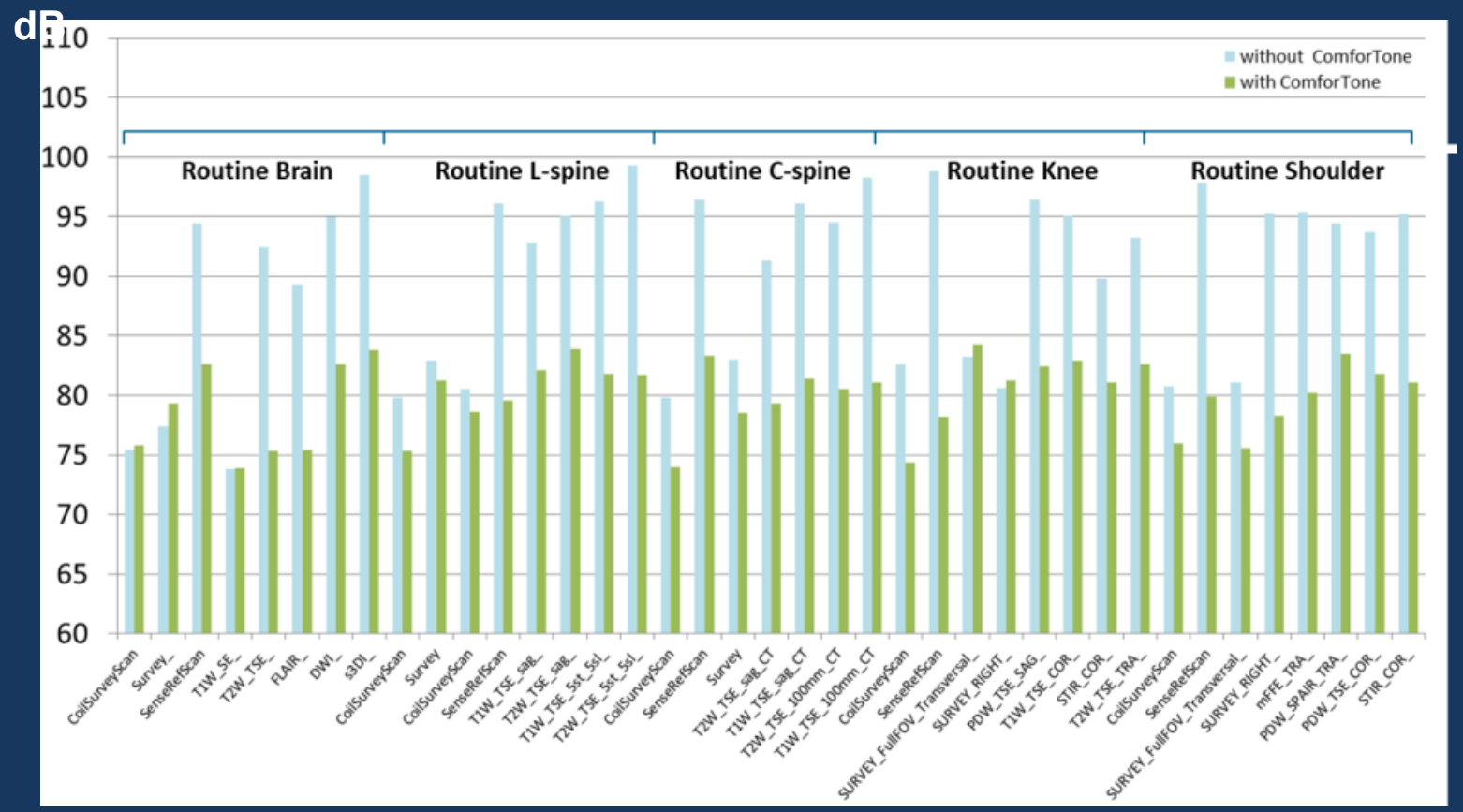


Su-Zhen Dong et al. J Magn Reson Imaging 2019 Oct;50(4):1047-1054. Techniques for minimizing sedation in pediatric MRI

2/ Noise reduction sequences

Confor Tone

- Decrease acoustic noise by modifying pulse sequence
- Gradient optimisation to reach maximal noise level
- Iterative adjustement
- Preservation of the timing of the séquence.

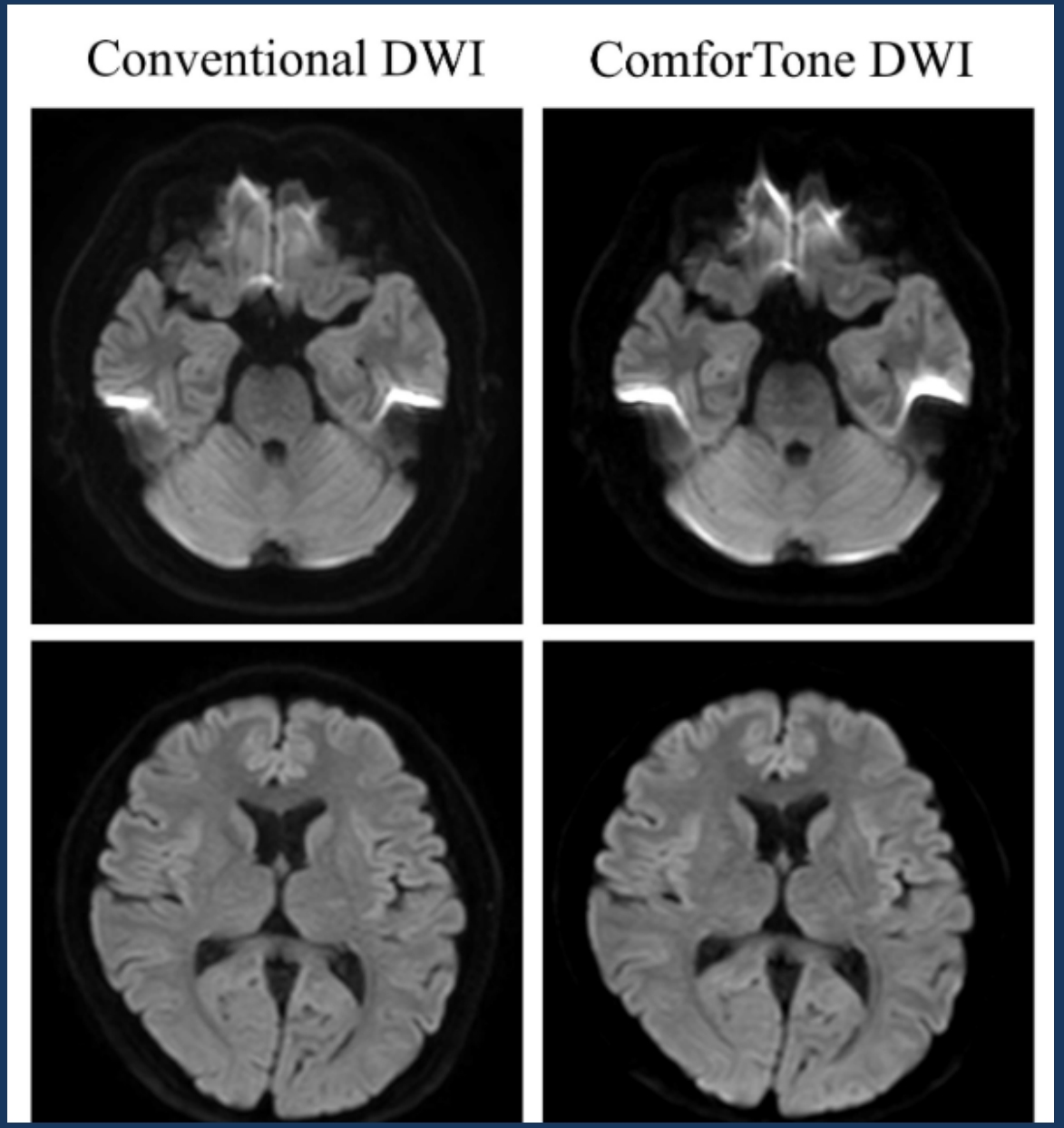


ComforTone

Morphologic sequences

Limitations: TSE/ EPI
- decrease gradient slope
- increasing TR or TE
- decrease Bandwidth

→ Image quality:
distorsion artefacts



Yamashiro el al. Magn Reson Imaging 2019 Nov;63:170-177

3/ Faster acquisition

Table 1 Acceleration techniques and their availability on commercial platforms

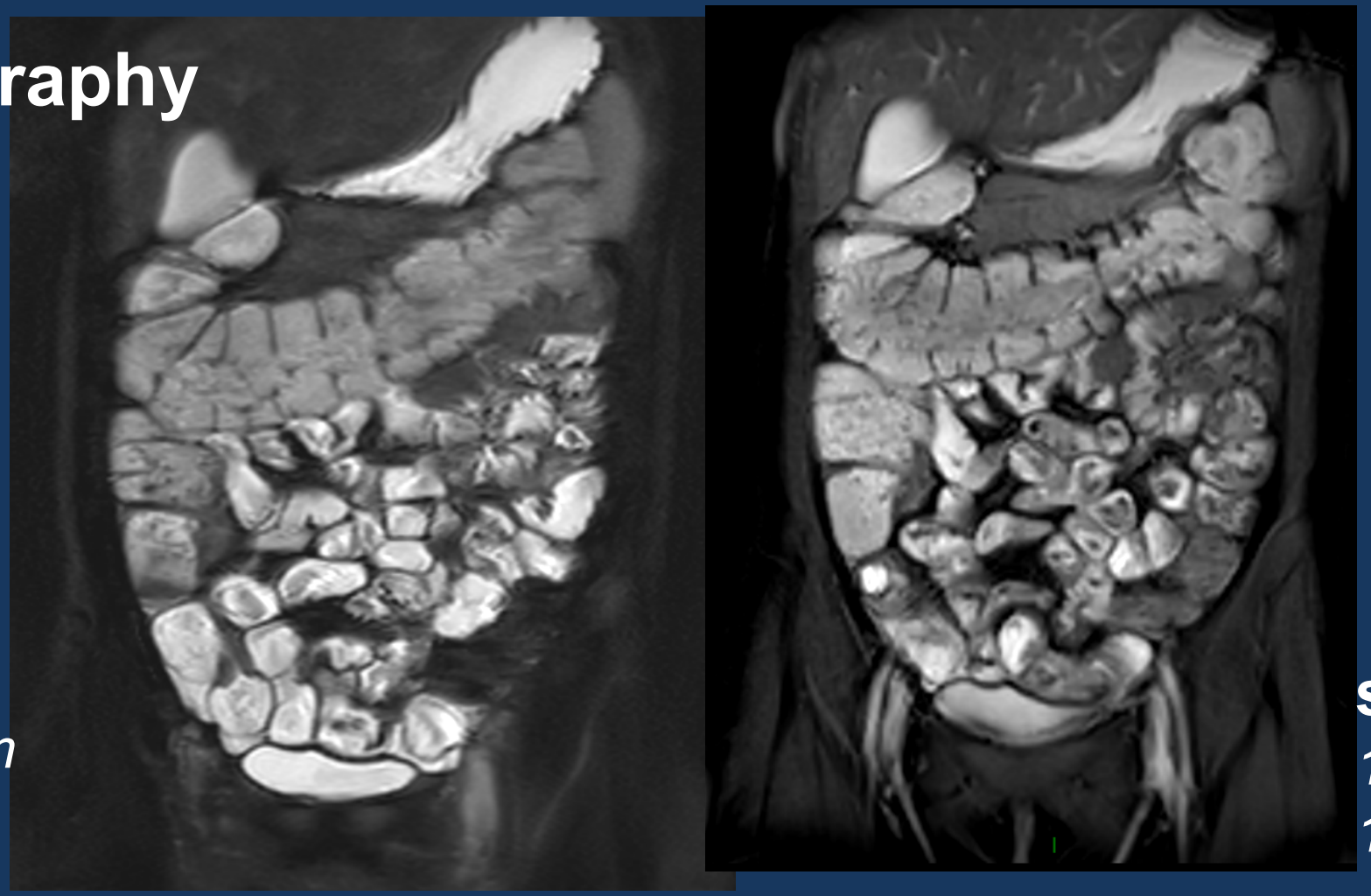
Acceleration technique	Commercial availability	Notes
Parallel MRI	Siemens (GRAPPA, mSENSE), GE (ARC, ASSET), Philips (SENSE), Toshiba (SPEEDER), Hitachi (RAPID)	All major vendors provide SENSE-based, GRAPPA-based, or both reconstruction techniques
k-t SENSE/k-t GRAPPA	Philips (k-t SENSE)	
Keyhole	Siemens (TWIST), GE (TRICKS), Philips (4D–TRAK), Hitachi (TRAQ), and Toshiba (FREEZE FRAME)	Keyhole techniques are commonly used for time-resolved MR angiography
Radial sampling	Siemens (2-D Radial and StarVIBE), Philips	Typically employed in abdominal T1w scans
Spiral sampling	GE	Typically employed in 3D arterial spin labeling and cardiac scans
Compressed sensing	Siemens, GE (HyperSENSE)	
Prospective respiratory gating	All major vendors	
Respiratory compensation	GE (Respiratory Comp), Philips (PEAR), Toshiba (Respiratory Comp), Hitachi (PERRM)	
Respiratory motion-resolved imaging	Not offered	CS-based XD-GRASP is under active development by Siemens
Simultaneous multi-slice imaging	Siemens (CAIPIRINHA, SMS), GE (POMP, HyperBand), Philips (Multi-band), Hitachi (Dual-slice), Toshiba (QuadScan)	Most of these sequences are developed for brain imaging but are being adapted for other applications

Ahmad et al. Pediatr Radiol (2018) 48:37–49.

Faster acquisition

- **T2 Single shot TSE** and **Steady-state free-precession (SSFP):** BFFE/ BTFE (Philips), TrusFISP (Siemens), Fiesta (GE)…

MR enterography



T2 ssh
1.6 x 1.6 x 3mm
39 sec

sB TFE
1.5 x 1.5 x 8mm
1min 36 sec

Faster acquisition

- **T2 Single shot TSE** and **Steady-state free-precession (SSFP):** BFFE/ BTFE (Philips), TrusFISP (Siemens), Fiesta (GE)…

- **T1 2D/3D Gradient Recalled Echo imaging**:

  THRIVE (Philips), VIBE (Siemens), LAVA (GE)…

  high temporal resolution/ used for T1 dynamic sequences/ within a breath hold

Su-Zhen Dong et al et al. J Magn Reson Imaging 2019 Oct;50(4):1047-1054. Techniques for minimizing sedation in pediatric MRI

Faster acquisition: compressed sensing

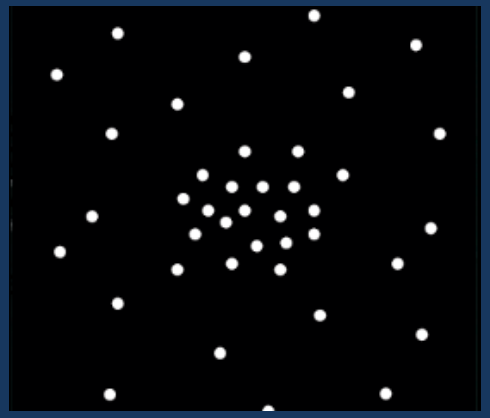
- k-space undersampling in an incoherent manner

in combination with an iterative reconstruction algorithm

to remove incoherent noise artifacts

→ ± combined with parallel imaging (Sense, Grappa)

→ ± used to **improve resolution** with same acquisition time



- Zhang T et al. Clinical performance of contrast enhanced abdominal pediatric MRI with fast combined parallel imaging compressed sensing reconstruction. J Magn Reson Imaging 2014;40:13–25.

- Cheng JY et al. Free breathing pediatric MRI with non rigid motion correction and acceleration. J Magn Reson Imaging 2015;42:407–420.

- Benkert T et al. Free-breathing volumetric fat/- water separation by combining radial sampling, compressed sensing, and parallel imaging. Magn Reson Med 2017;78:565–576

Faster acquisition : compressed SENSE

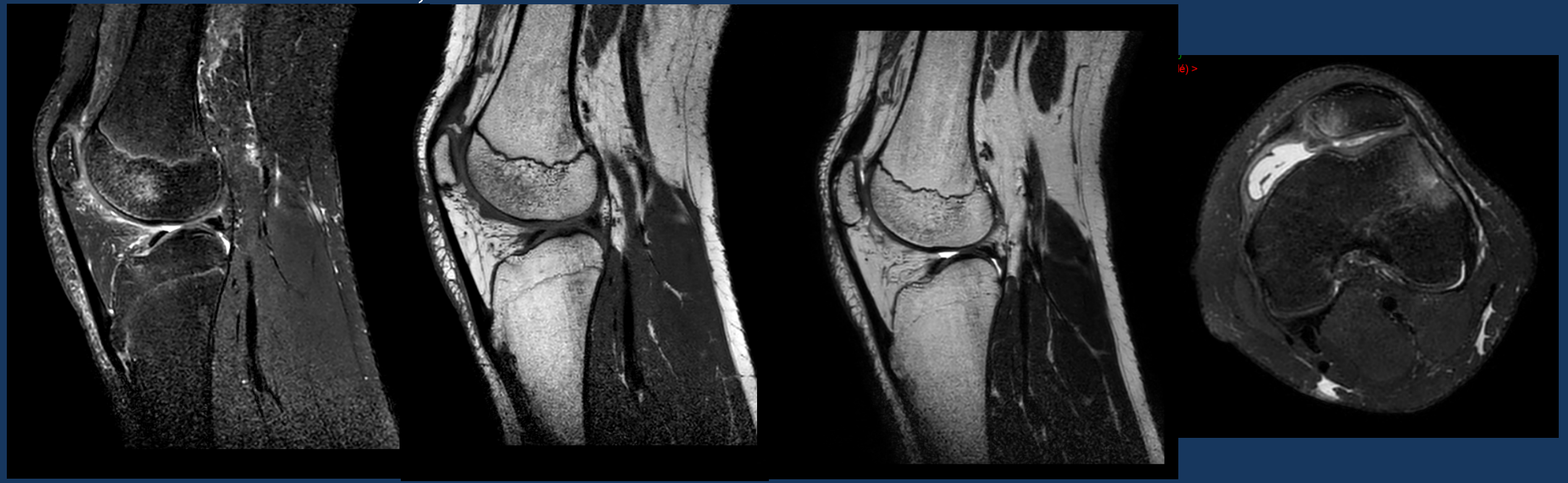
3D HR acquisitions

PD Fat Sat
0,75 mm iso

T1
0,60 mm iso

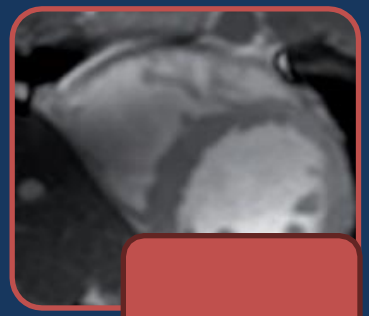
T2
0,68 mm iso

Multiplanar reconstruction

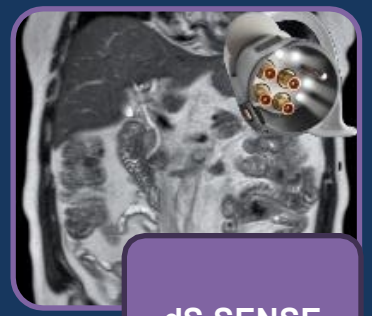


1,5 T: 3 HR volumic sequences = 8 to 12 min protocol

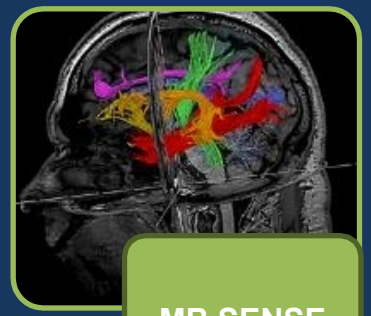
Evolution of acceleration techniques



SENSE (1999)



dS SENSE (2011)

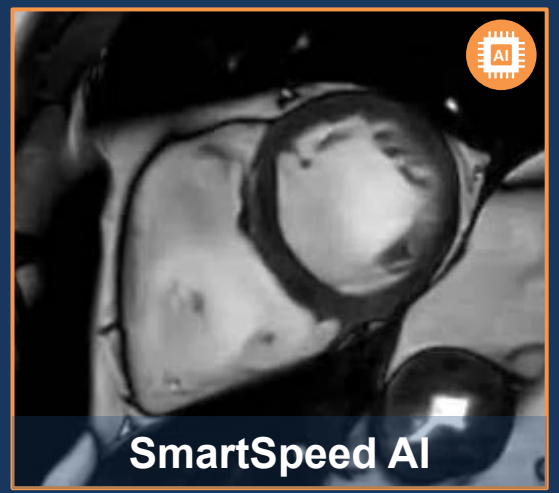


MB SENSE (2016)

C-SENSE (2017)

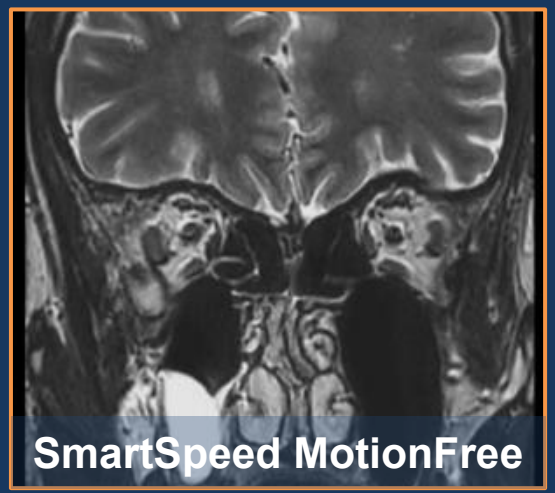
SmartSpeed (2021)

C-SENSE



SmartSpeed AI

C-SENSE



SmartSpeed MotionFree

4/ Motion artefacts reduction

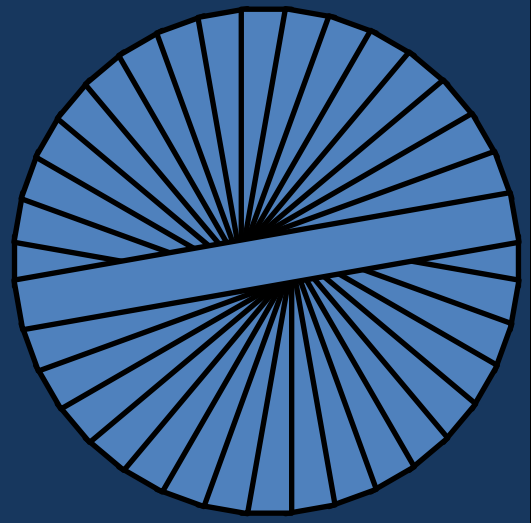
MultiVane XD

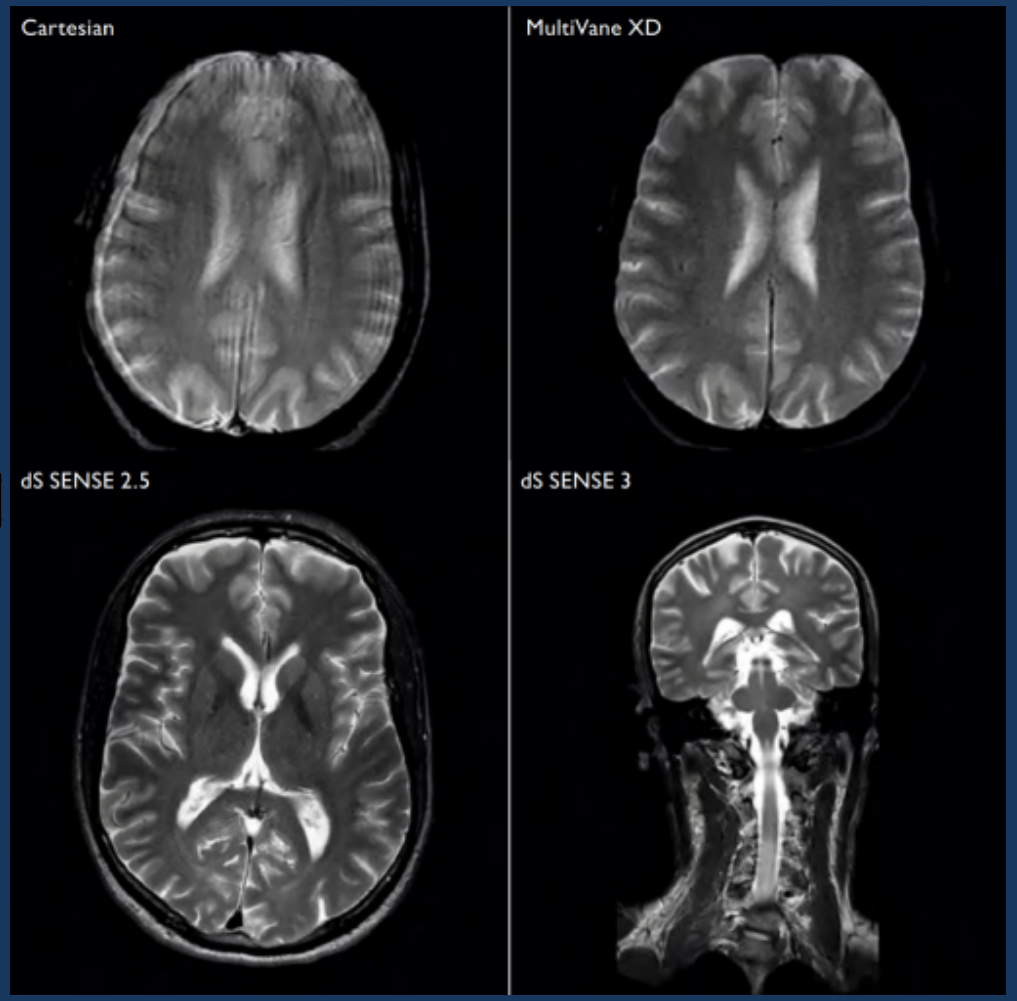
Concentric rectangular blades rotated around the k space origin

Central k space oversampled

Removed translational/ rotational motions

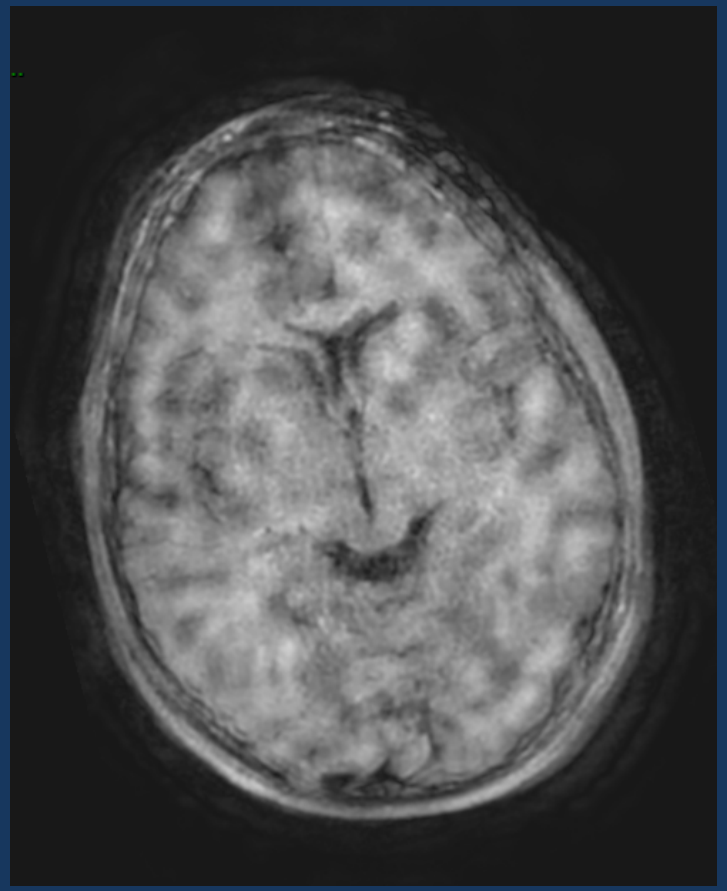
- SENSE compatible
- T2, FLAIR, T1 FLAIR, T2*/ SE
- Any anatomy



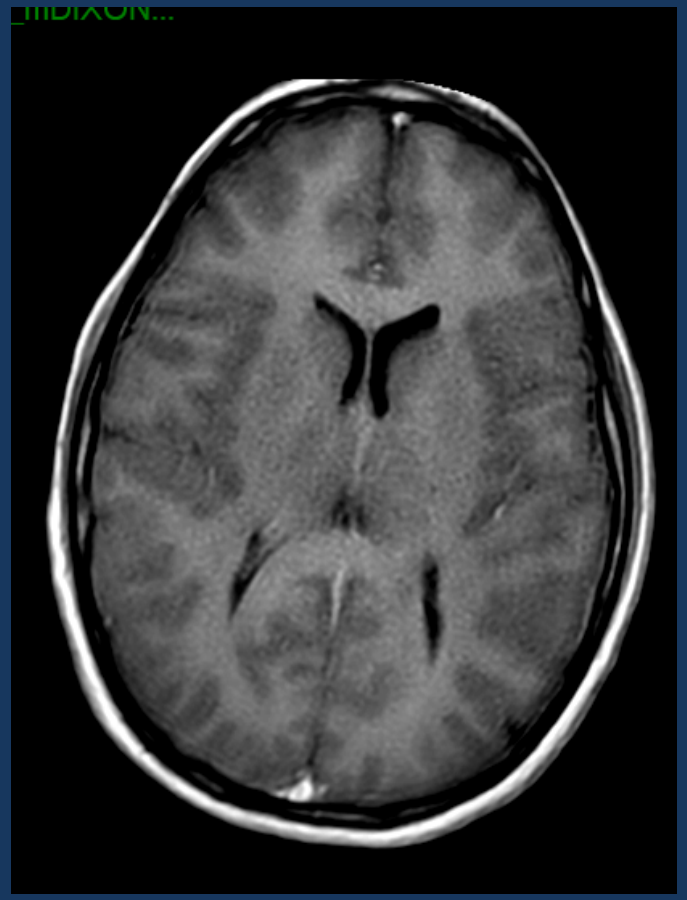


MultiVANE

1,5T



3D T1 TSE
1mm



3D T1 MultiVANE XD
3,5 mm

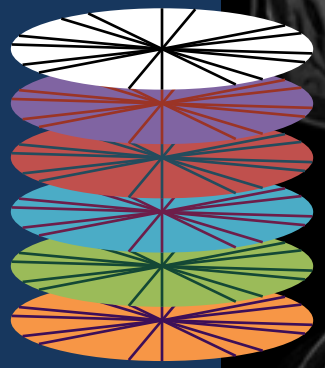
3D VANE XD

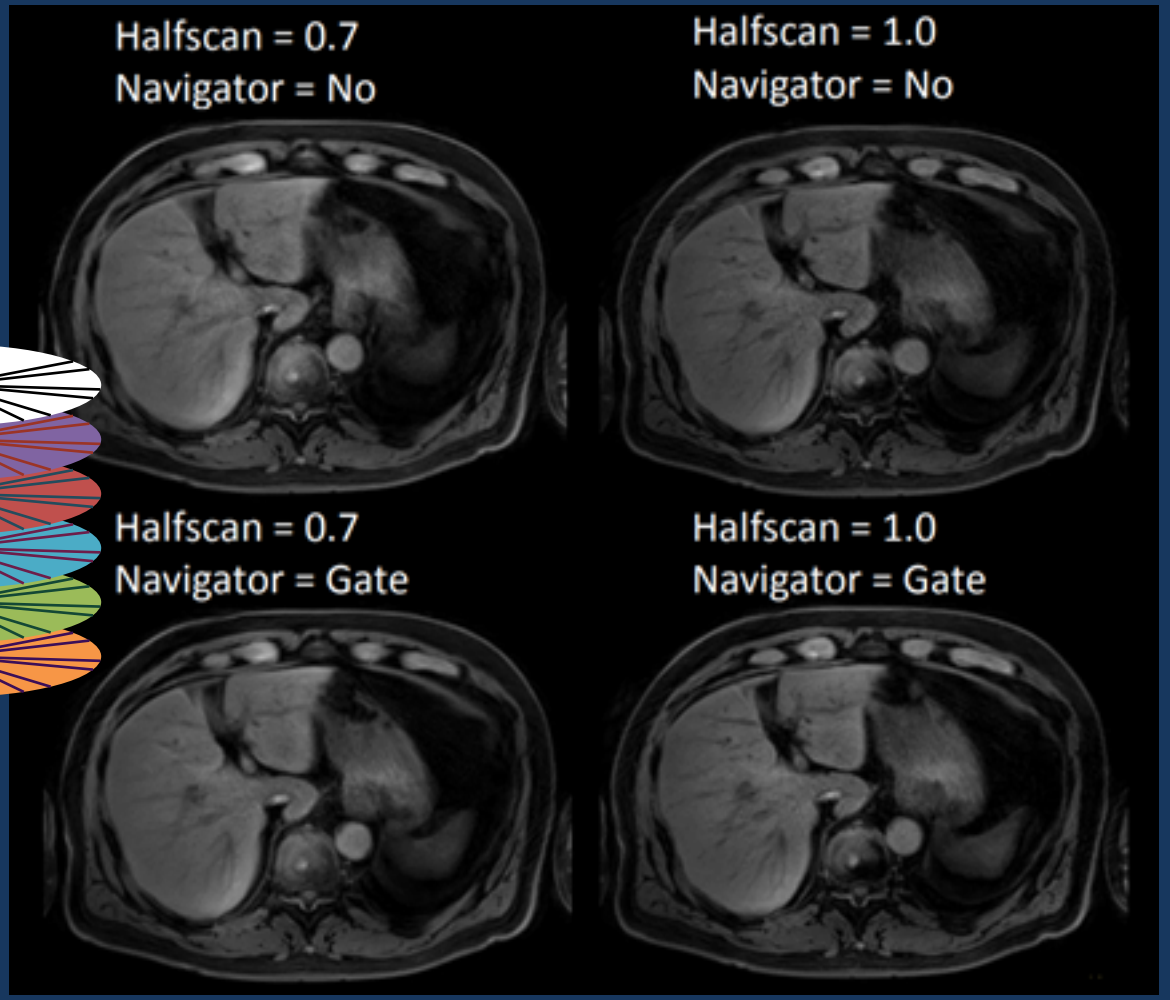
3D Gradient Echo (FFE or TFE)
SPIR *or* mDIXON

- Radial acquisition
- Golden angle radial sampling

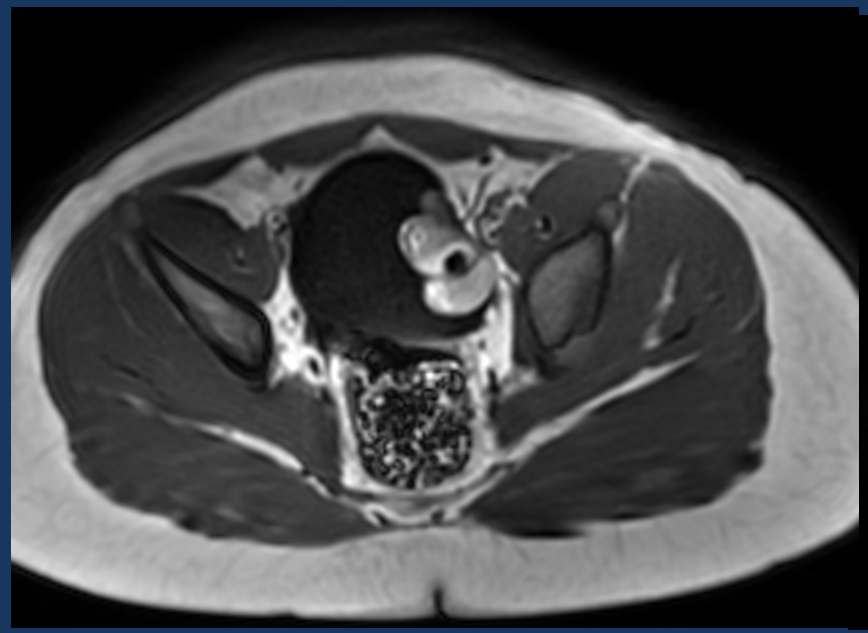
→ Reduce motion artefact (abdomen +++)

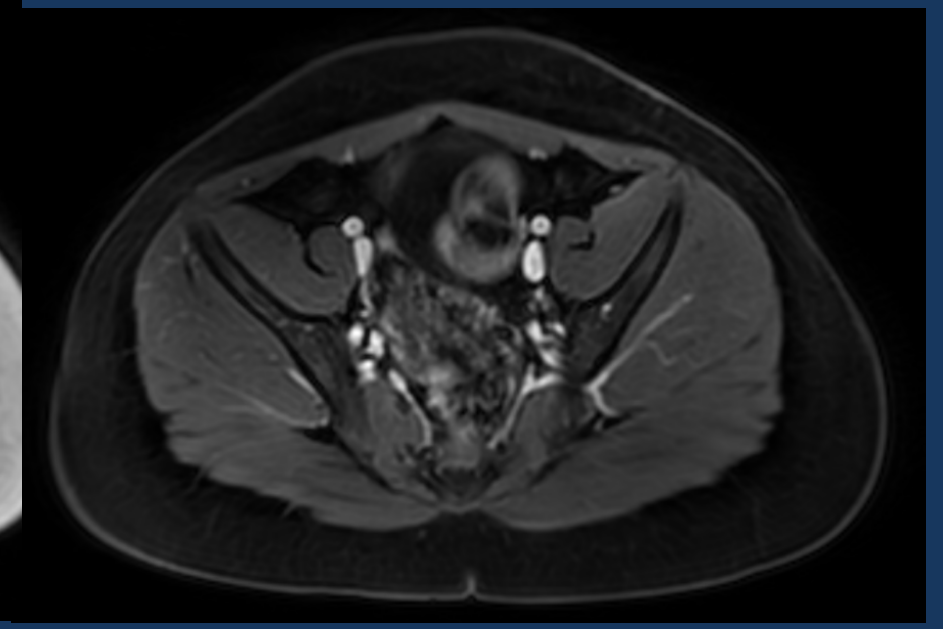
→ Free breathing





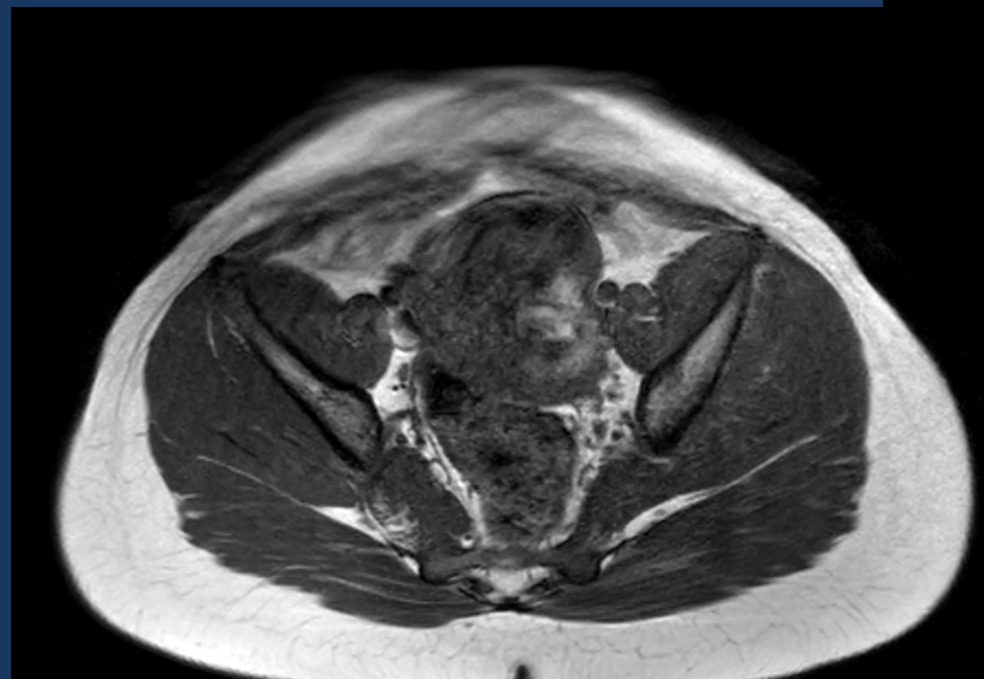
6 yo, ovarian dermoid cyst

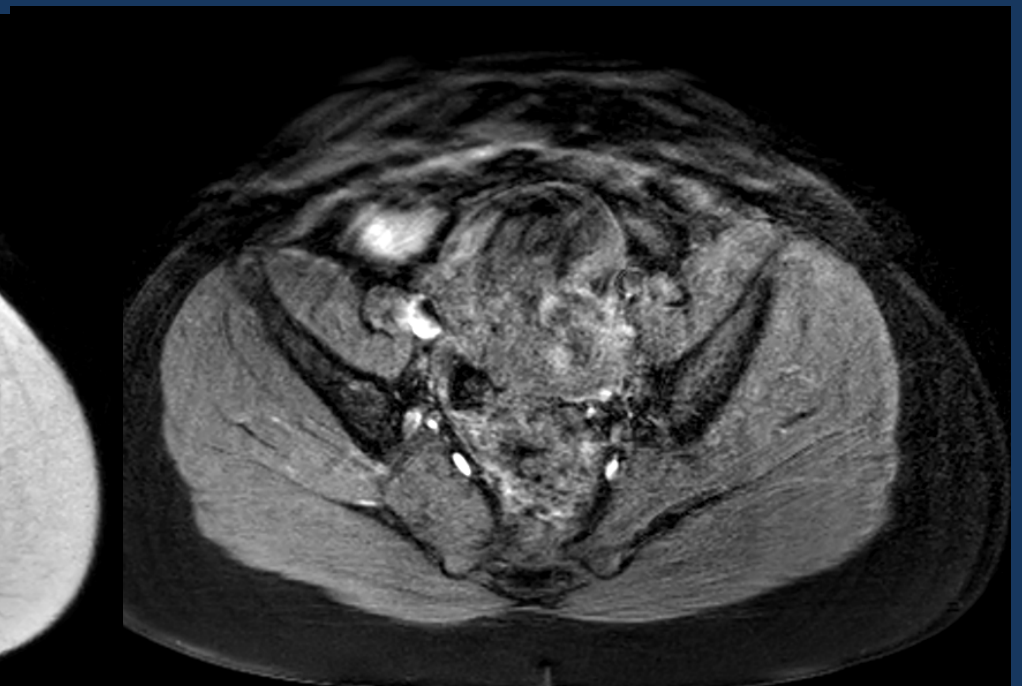




3D VANE XD mDIXON
(1.5 x 1.5 X 3/4mm)
100 slices, 3 min 15

Less respiratory motion artefacts





versus T1 DIXON *(4mm)*

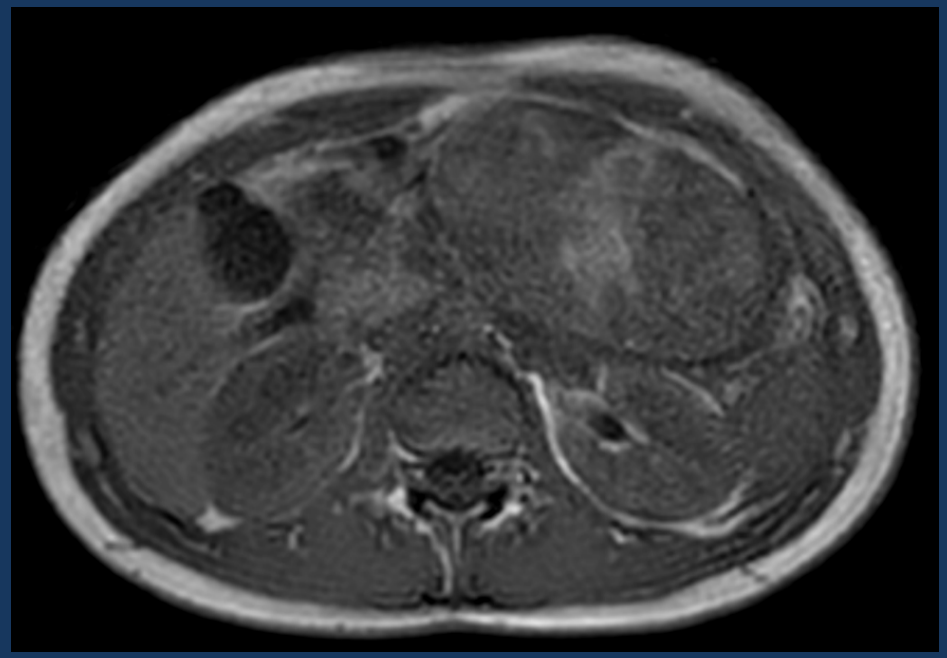
Adolescent, pancreatic tumor, discovered post trauma

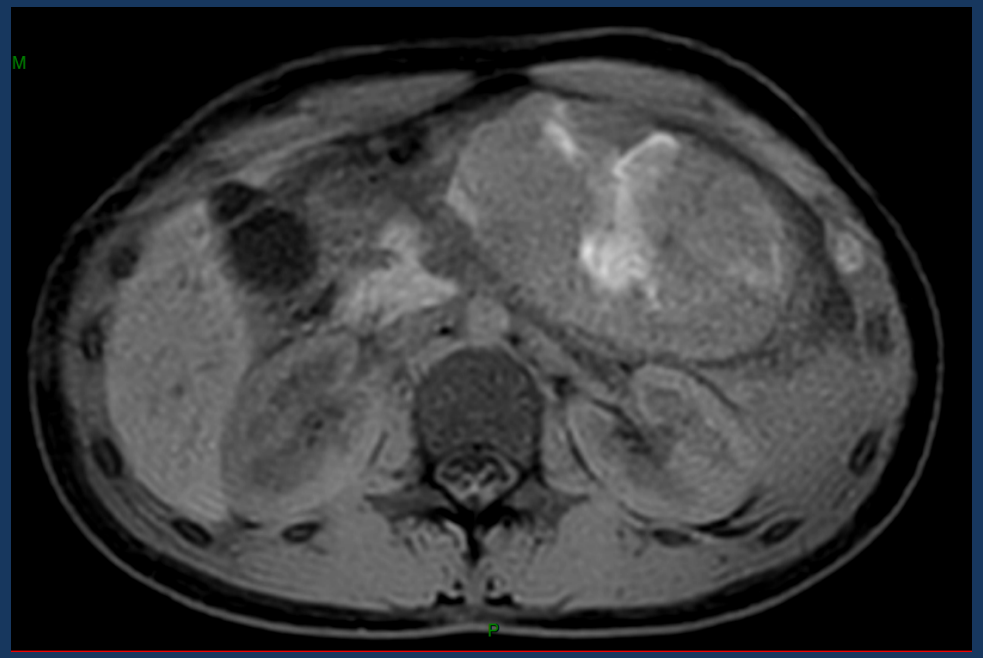
T2 TSE SPIR MultiVane XD

1.6 x 1.6 x 3mm/ 36 slices/ 3 min

3D T1 VANE DIXON

1.5 x 1.5 X 3/4mm)
100 slices,
3 min 15





II- Techniques to avoid contrast injection

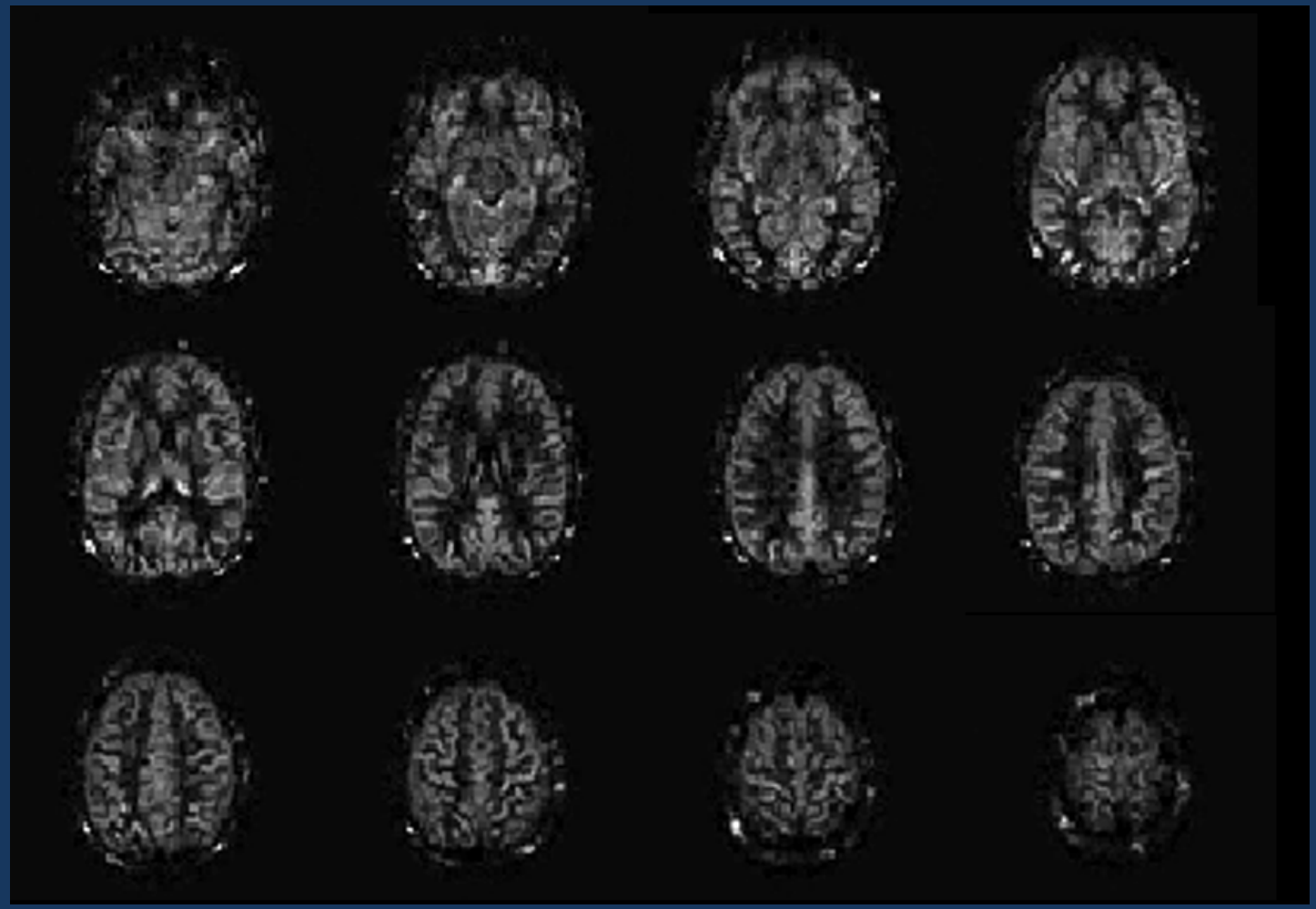
Blow flow: 3D ASL

Tissue blow flow quantification

Labeled arterial blood water (endogeneous tracer)

Recommandations ISMRM Perfusion Study Group

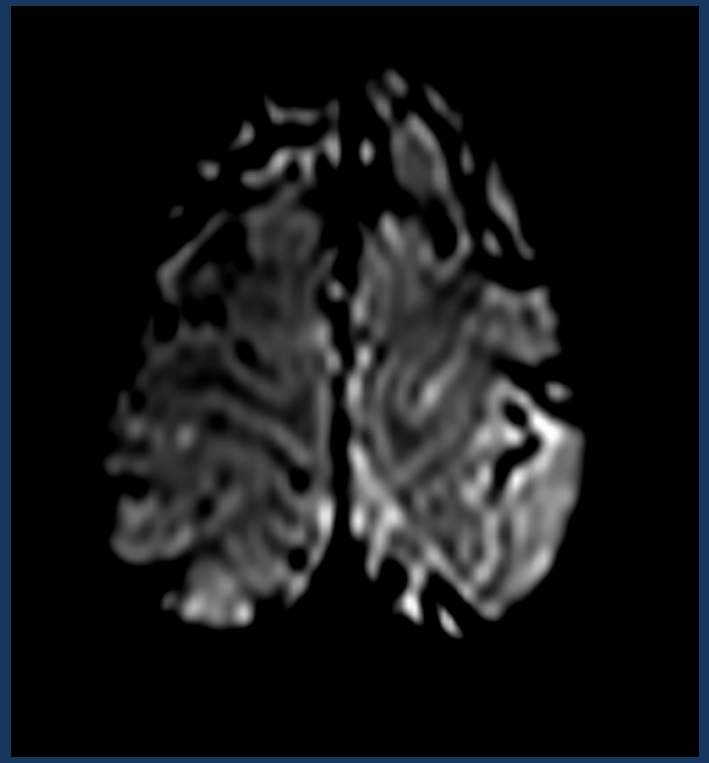
- Presaturation brain
- pCASL tagging
- BackGround Suppression (4 inversions)
- Acquisition (GRASE)



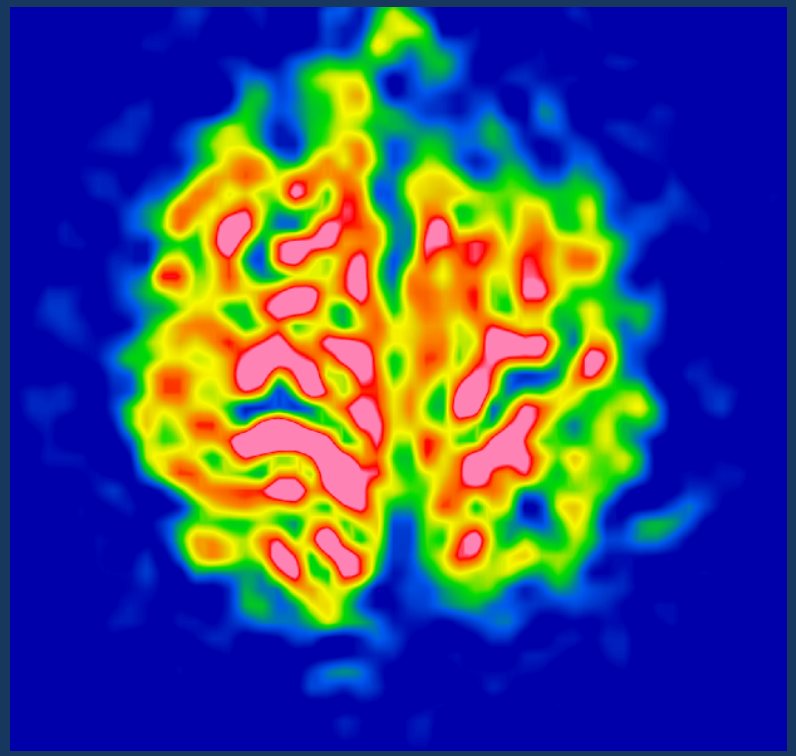
Alsop DC, et al. Magn. Reson. Med. 2015;73:102-116.

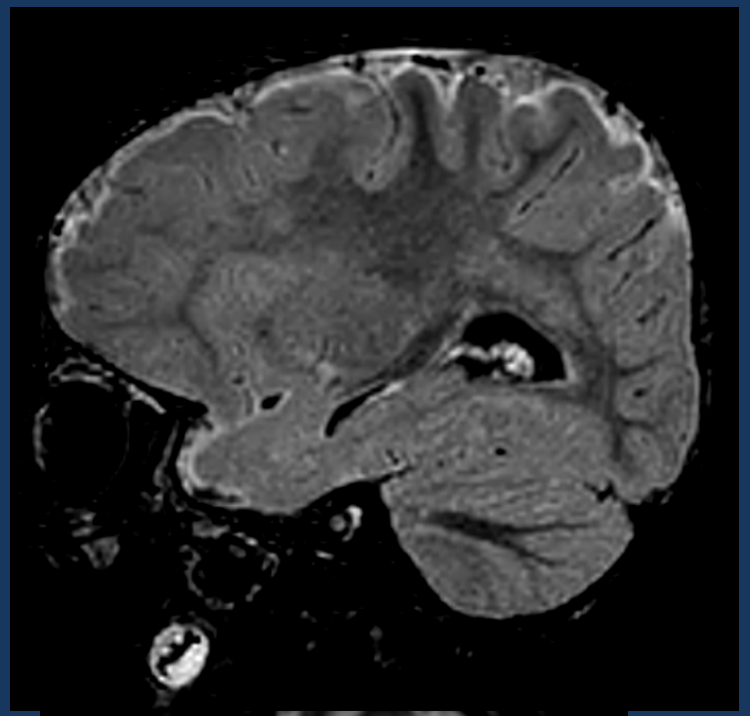
10 months, meningitis
leptomeningeal enhancement,
Restricted diffusion + decreased perfusion

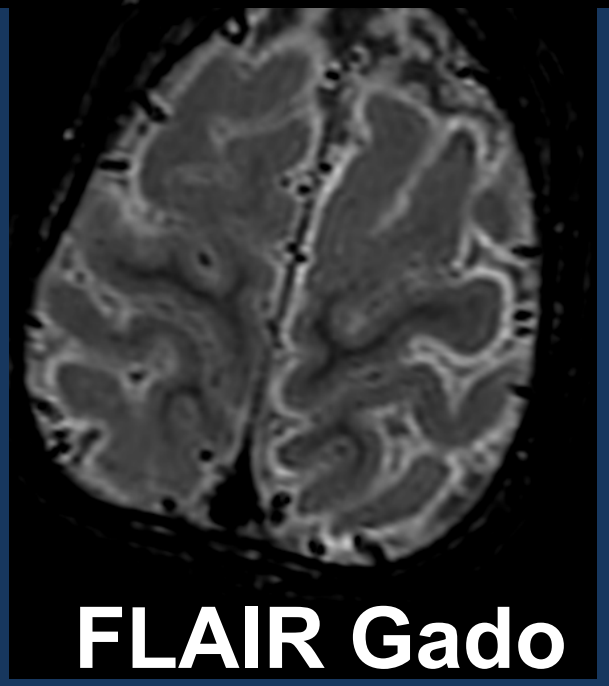
DWI



pCASL 1500

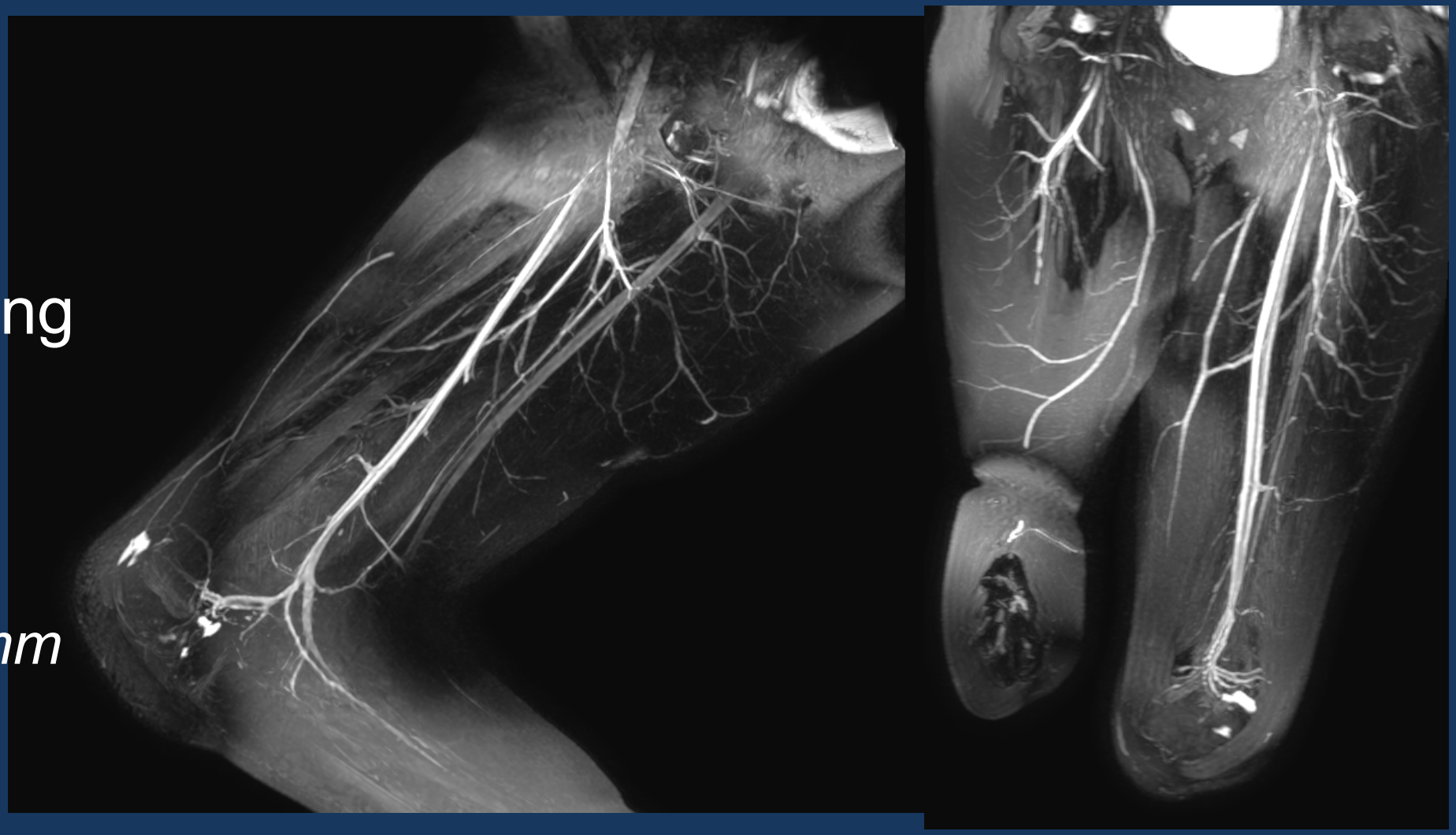






Angiography without contrast
3D SPIR STIR

10 yo,
arthrogryposis
preoperative
vascular imaging



3D IR
1.04 x 1.04 x 1.2mm
133 coupes
4 min 34

Relaxation-Enhanced MR Angiography without Contrast and Triggering (REACT)

3D TFE Sequence

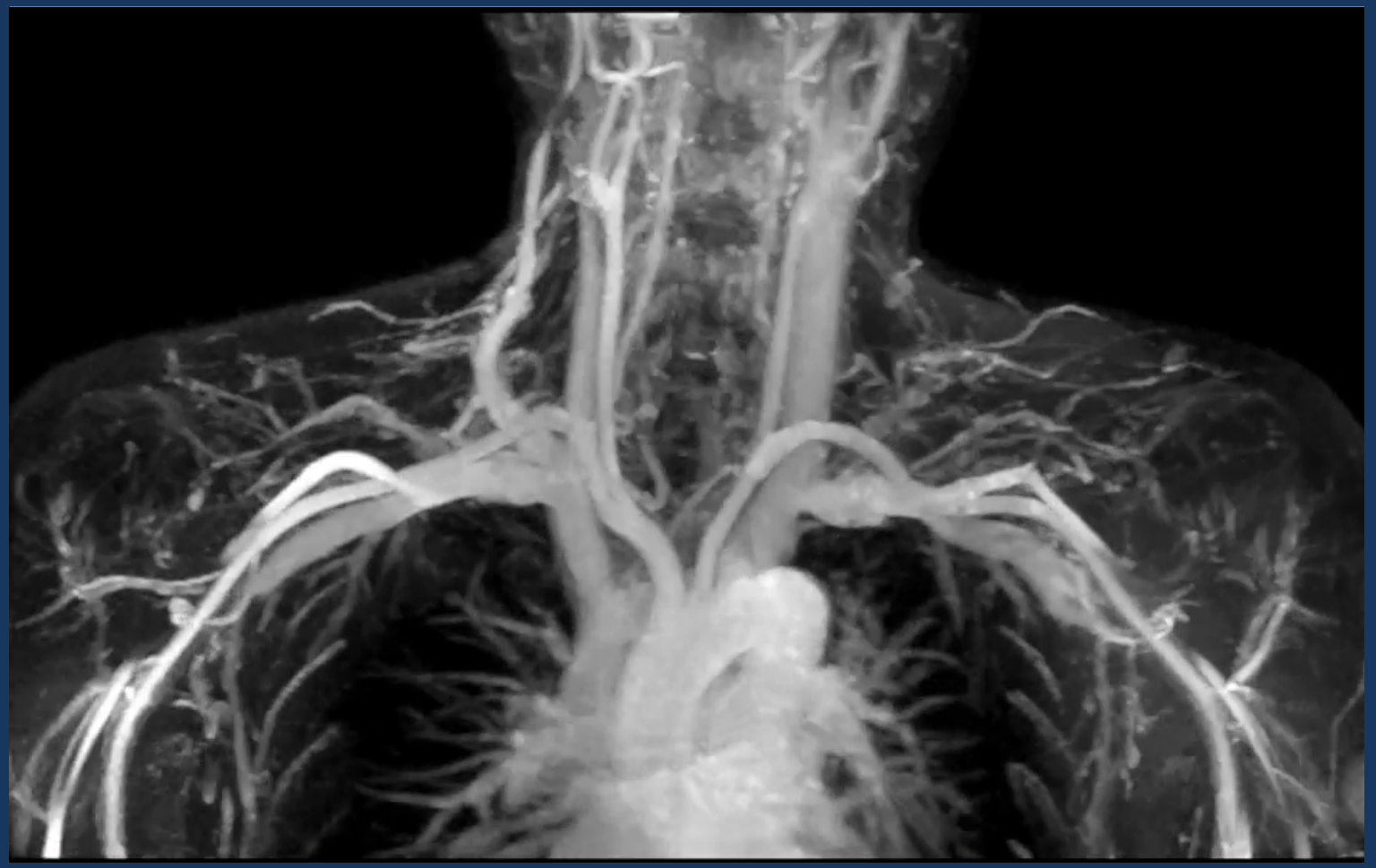
- T2*-weighted (blood)

Background suppression

- T2-prep
- IR prepulse

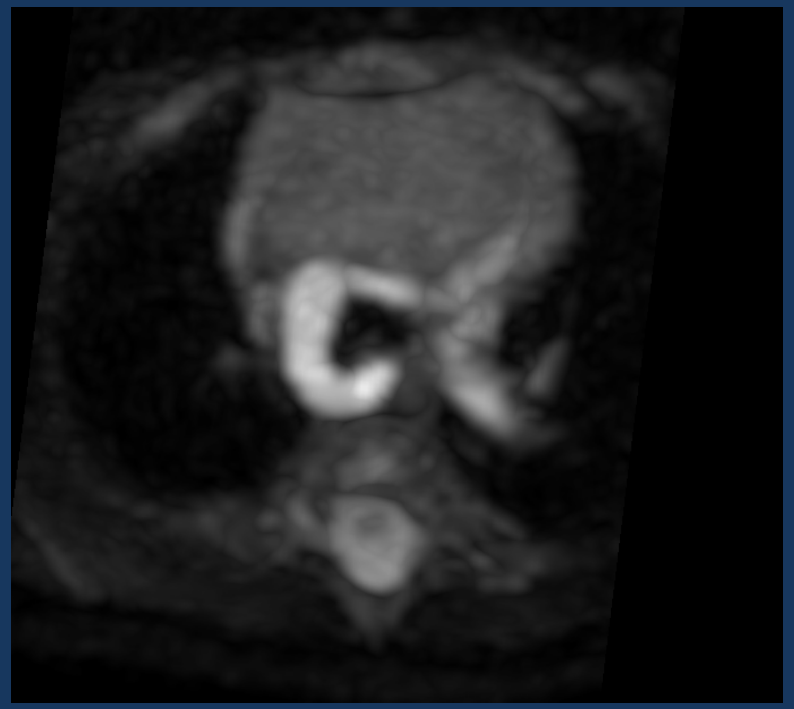
Fat suppression

- mDIXON



Relaxation-Enhanced MR Angiography without Contrast and Triggering (REACT)

3 months, aortic arch: right aorta,
kommerel diverticulum



3D TFE, 1 x 1 X 1.5 mm
4 min/ **No gating, free beathing**

Balanced TRANCE (B-TRANCE)

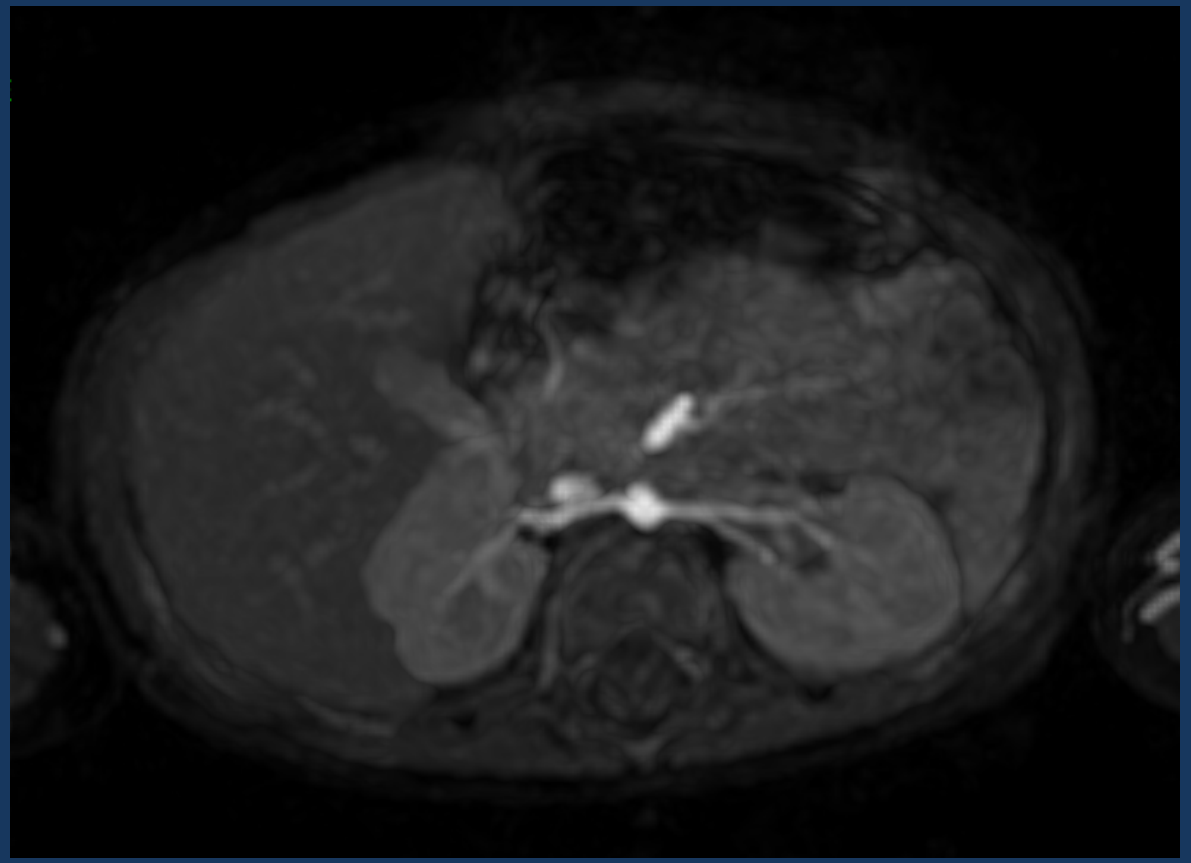
Inversion pulse preparation

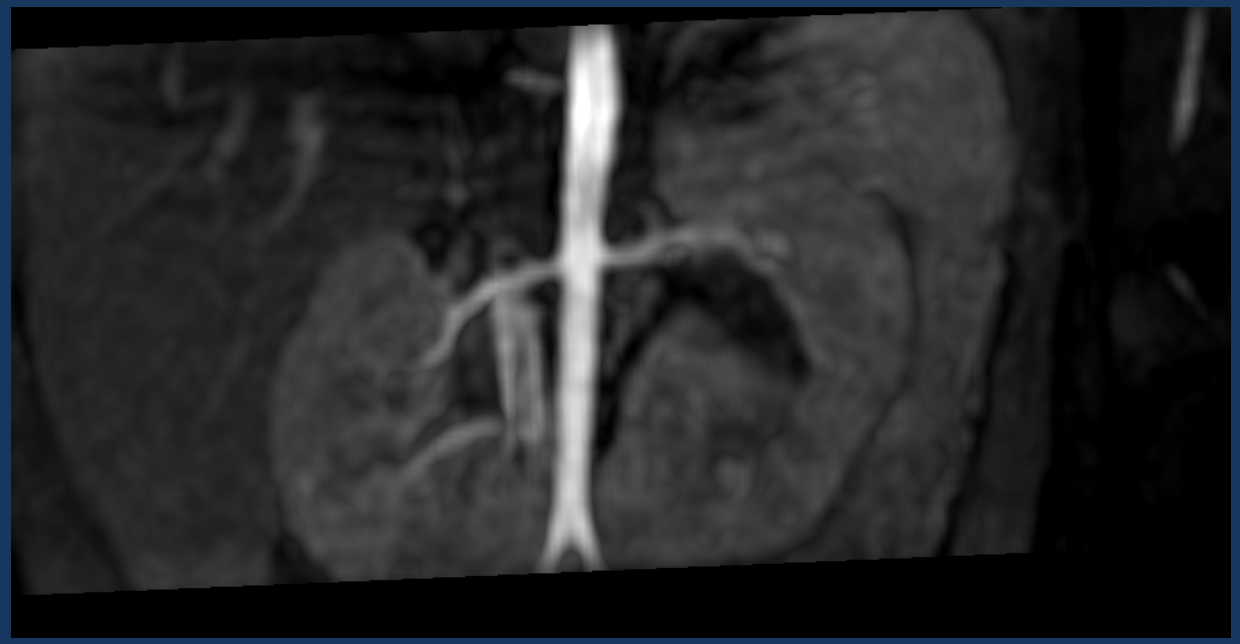
- Suppress static tissue signal
- 3D bTFE lecture
- Blow flow bright

→ For renal arteries

B- TRANCE

1 yo, HTA, horseshoe kidney

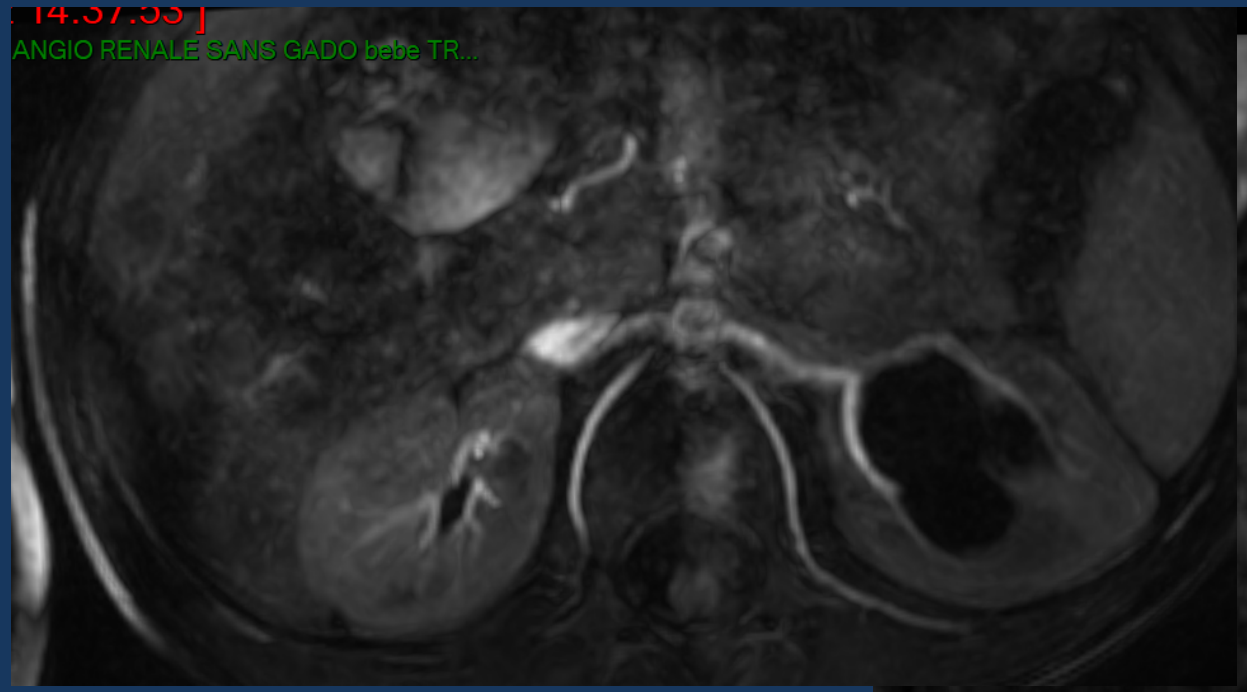


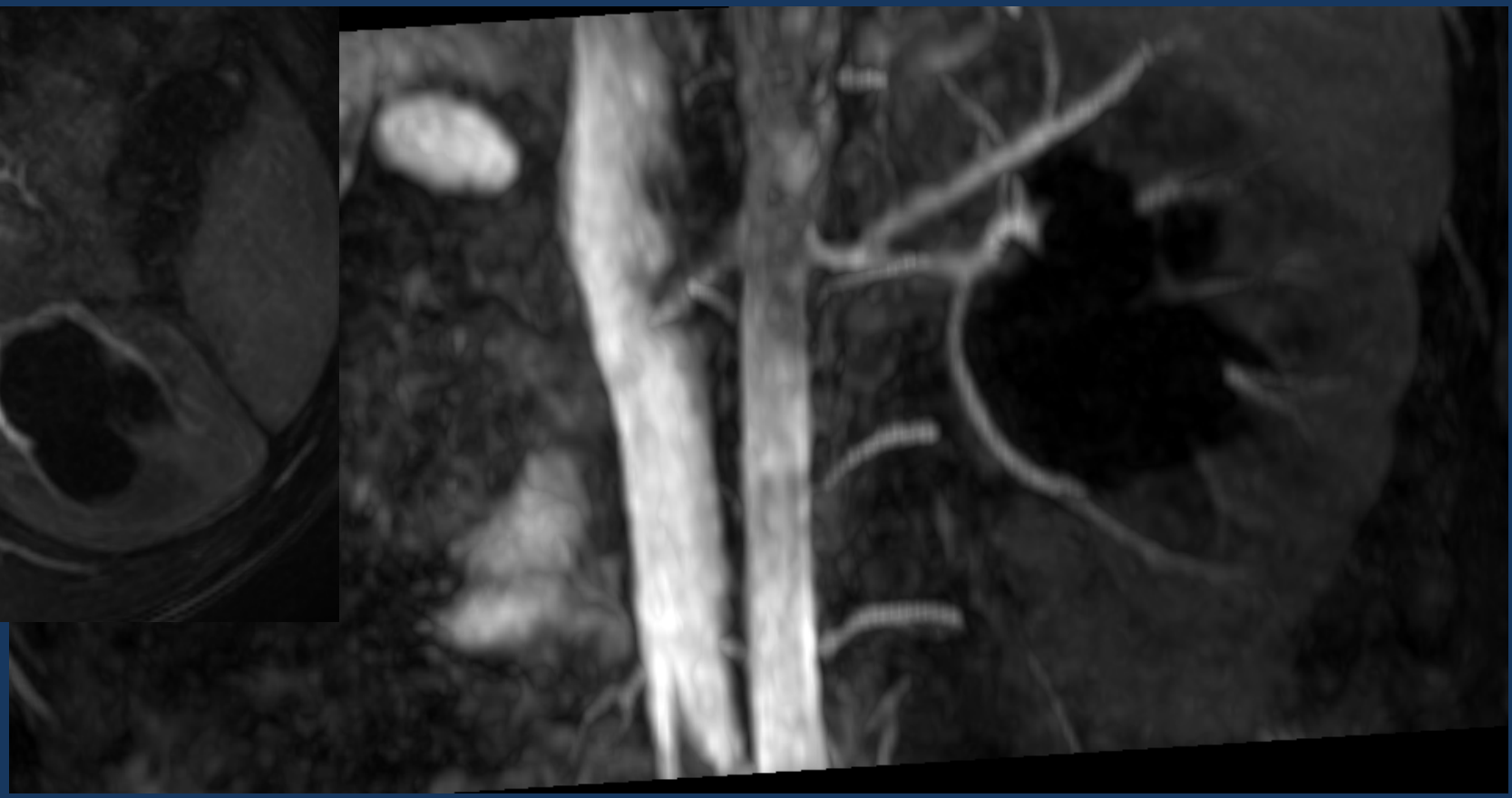


1.5 T/ Free breathing, 1.7 x 1.9 x 2mm/ 7 cm coverage/ 3min 33 sec

B TRANCE

4 yo, polar artery



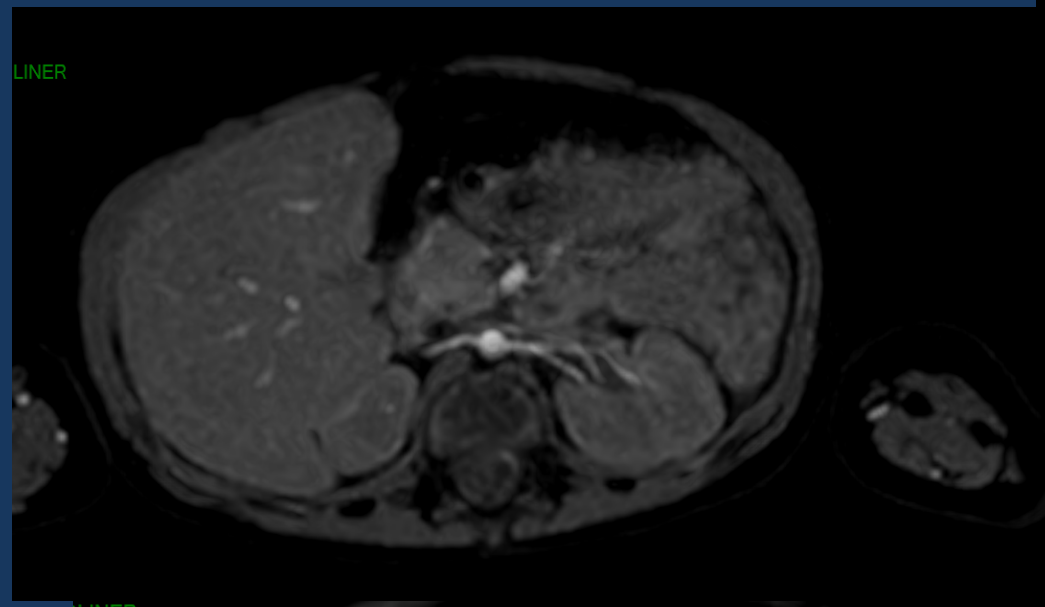


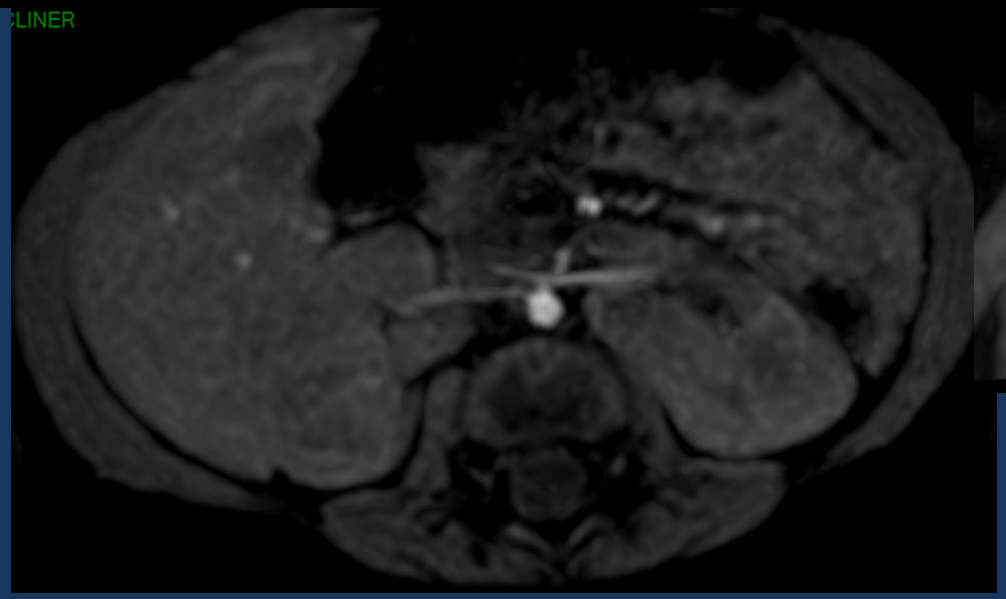
3T trigger

Time of flight – arterial or venous flow

1,5T
Several stacks
Larger coverage
20 cm
1.3 x 1.3 x 3mm
2 min 58

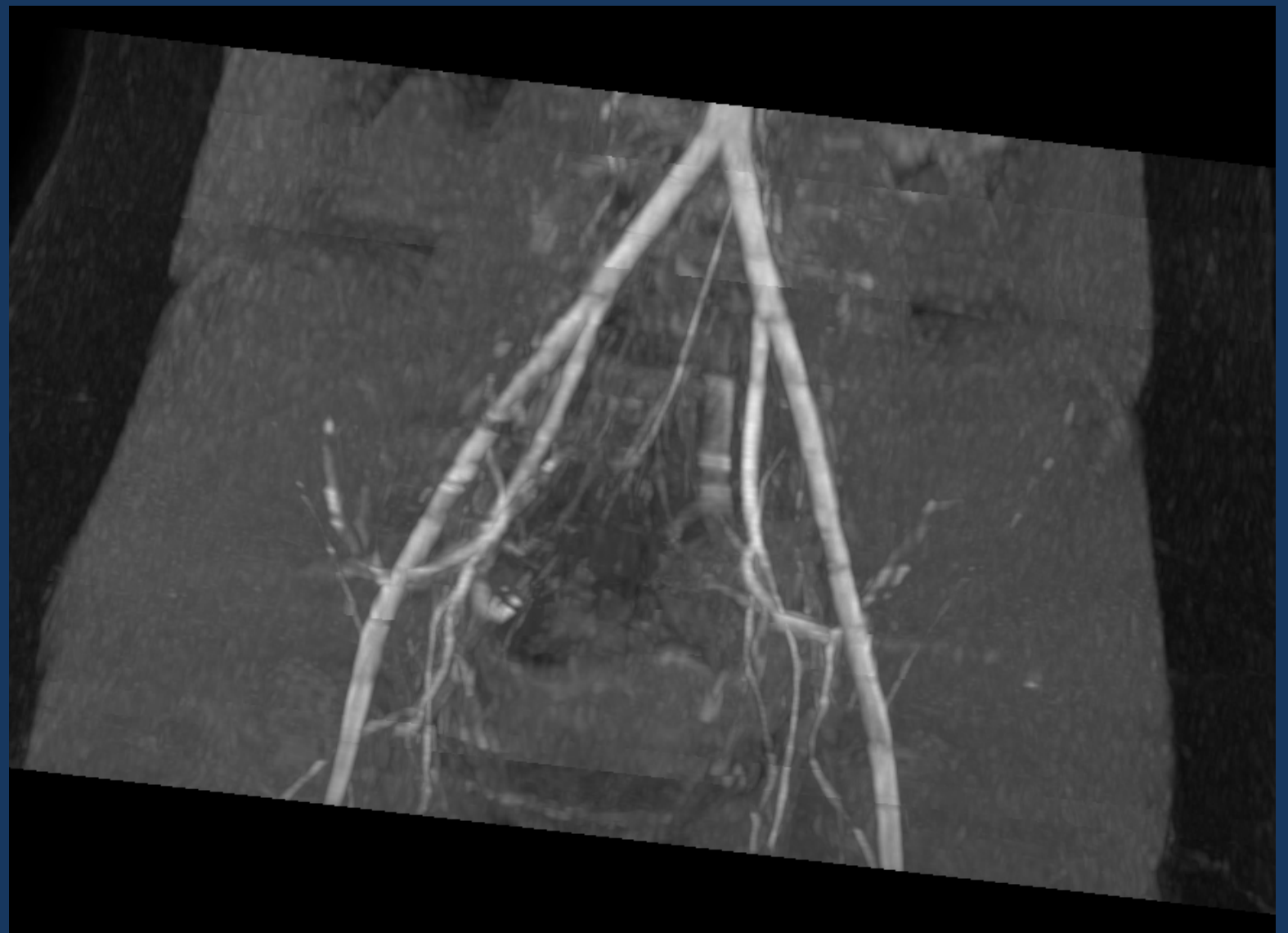
→ Whole abdomen
→ Inferior limbs





TOF: Inferior limb

1,5T



III- Techniques to avoid X ray exposure

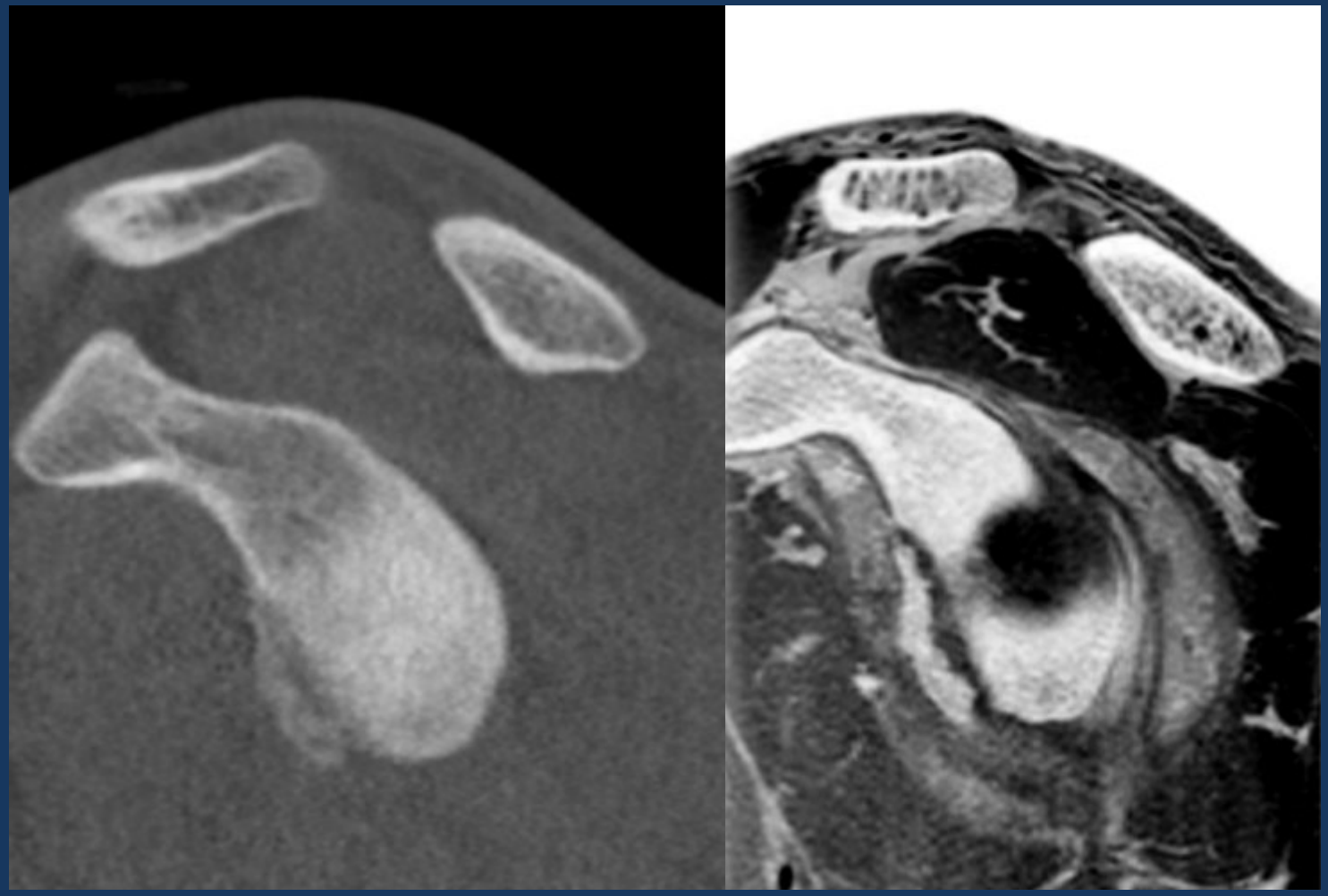
1/ Bone imaging : FFE Resembling A CT Using Restricted Echo-spacing (FRACTURE)

3D FFE with echoes in phase

- Multi écho ↗ T2*effect
- Σ [OtherTE] - [Last TE]
- Suppress long T2 tissue

→ Imaging of short T2 tissue: bone, tendon

→ Future: T2* weighted map

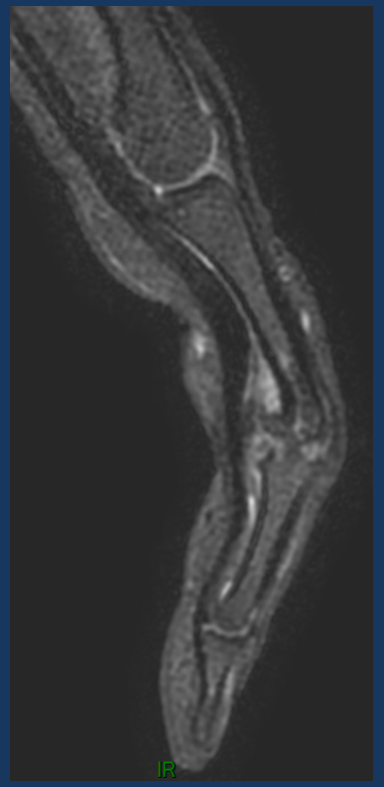


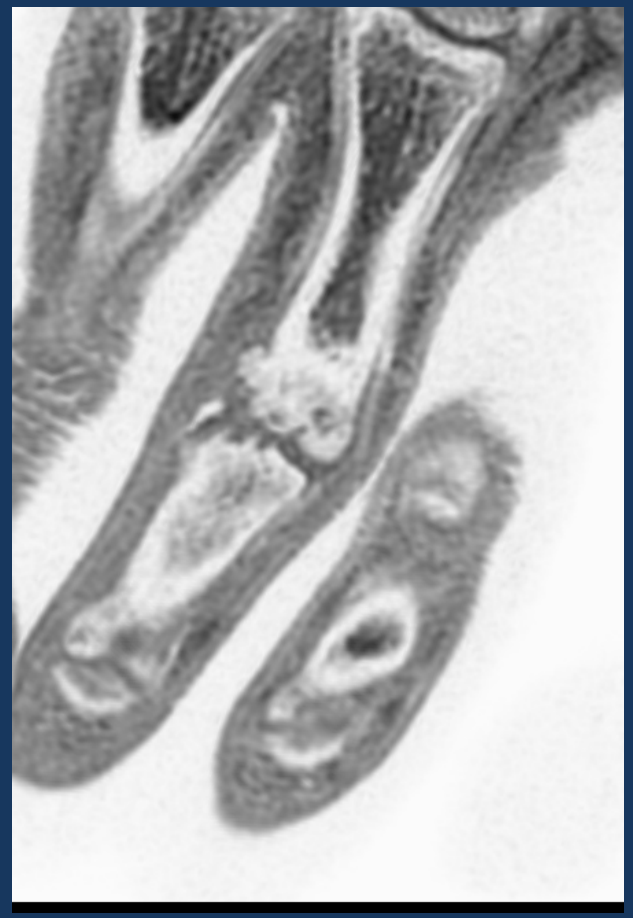
Johnson B, et al. Skeletal Radiol. 2021;50:1705-1713.

7 yo, proximal phalange fracture

0.6mm iso, 3 min 41

14 yo, previous trauma with residual stiffness and deformation

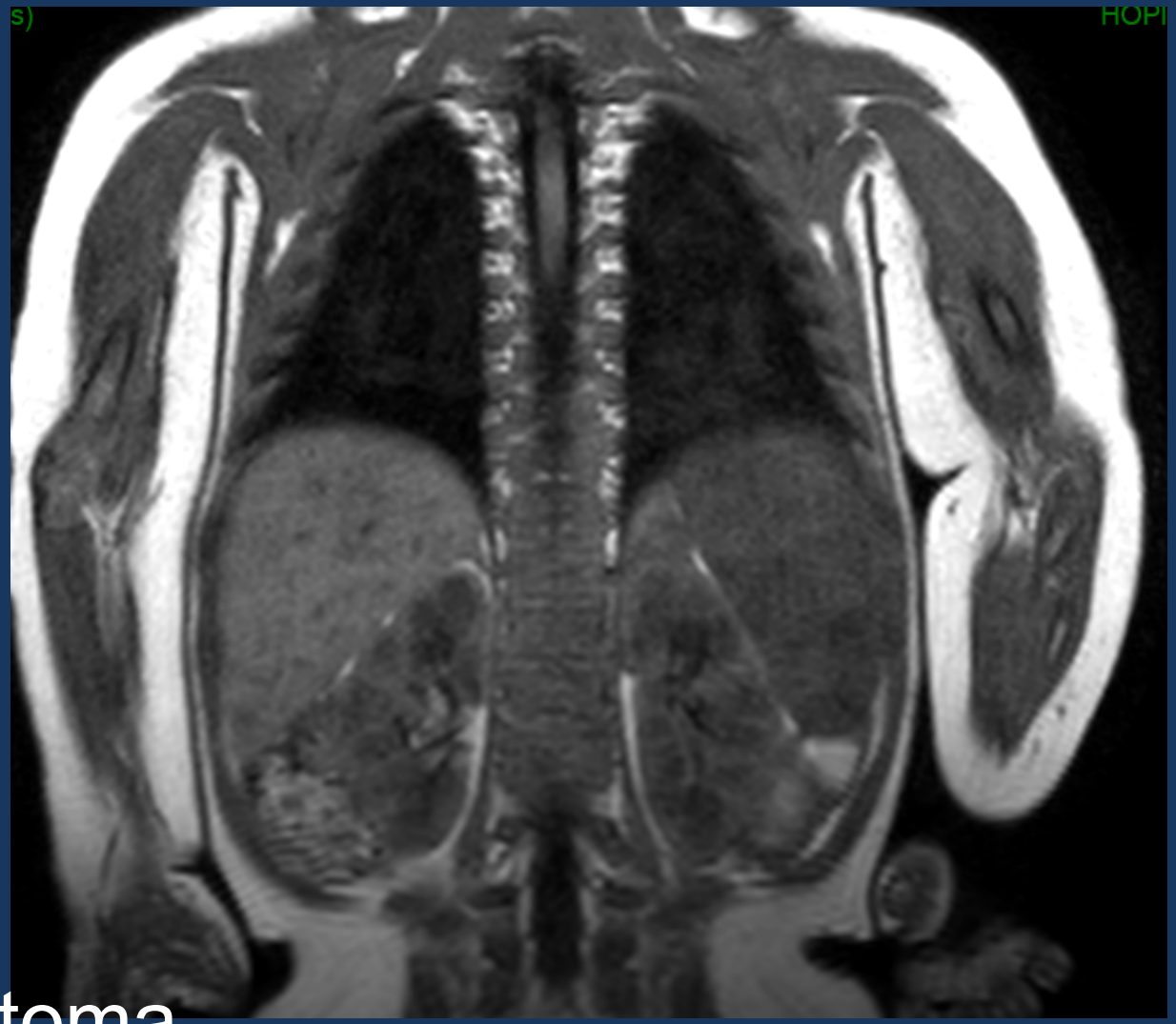




2/ Whole body 3D acquisitions

1.5 T

3D T1
1.1mm
isotropic
2min 28sec

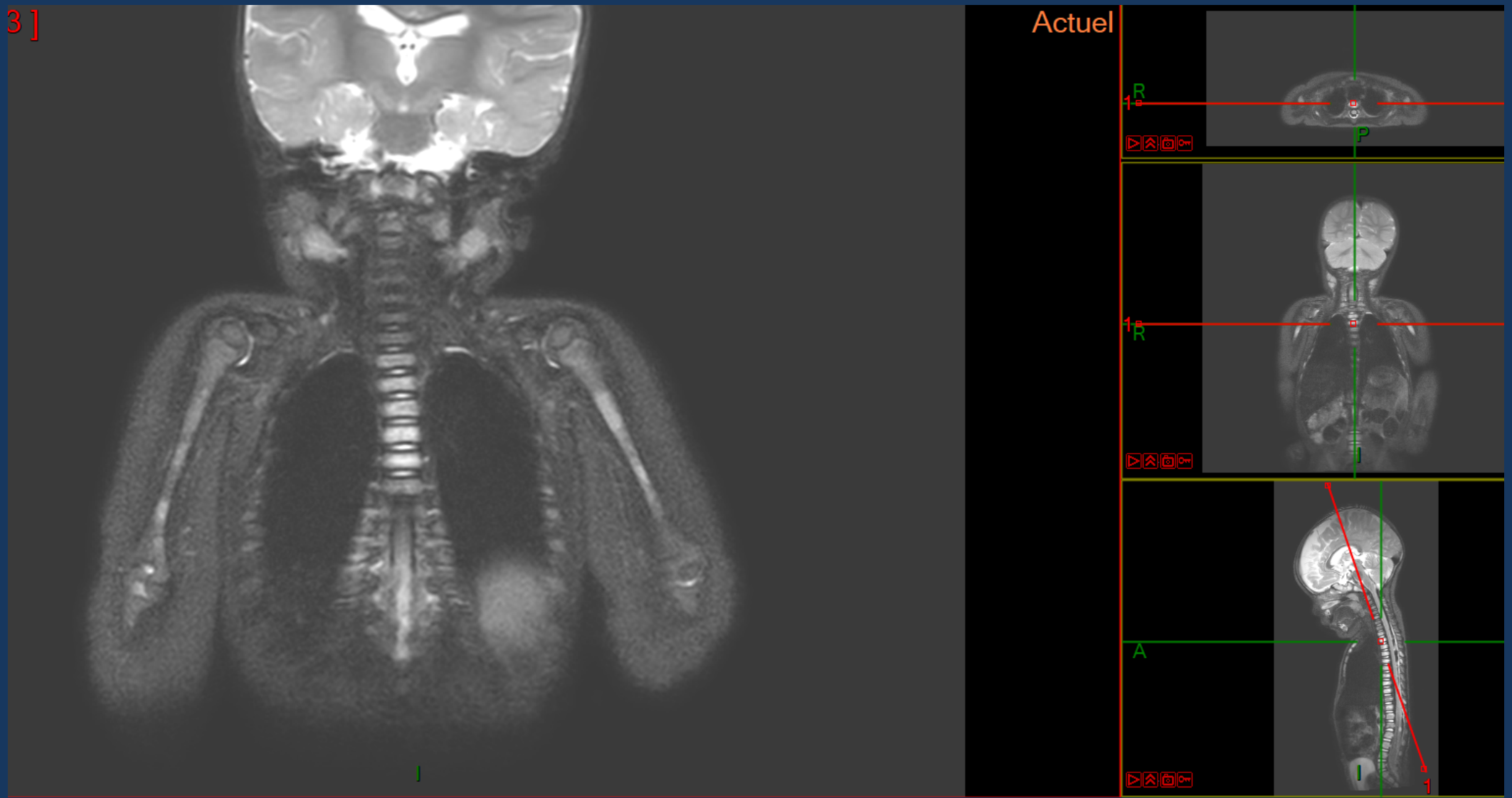


Bone lesions from neuroblastoma

3D STIR

1.1 x 1.1 x 2mm
3min 18 sec

3D acquisition → multiplanar reconstruction
MPR to increase slice thickness (5-6mm) to decrease noise



IV- Innovative sequences to improve diagnosis

Neuro imaging

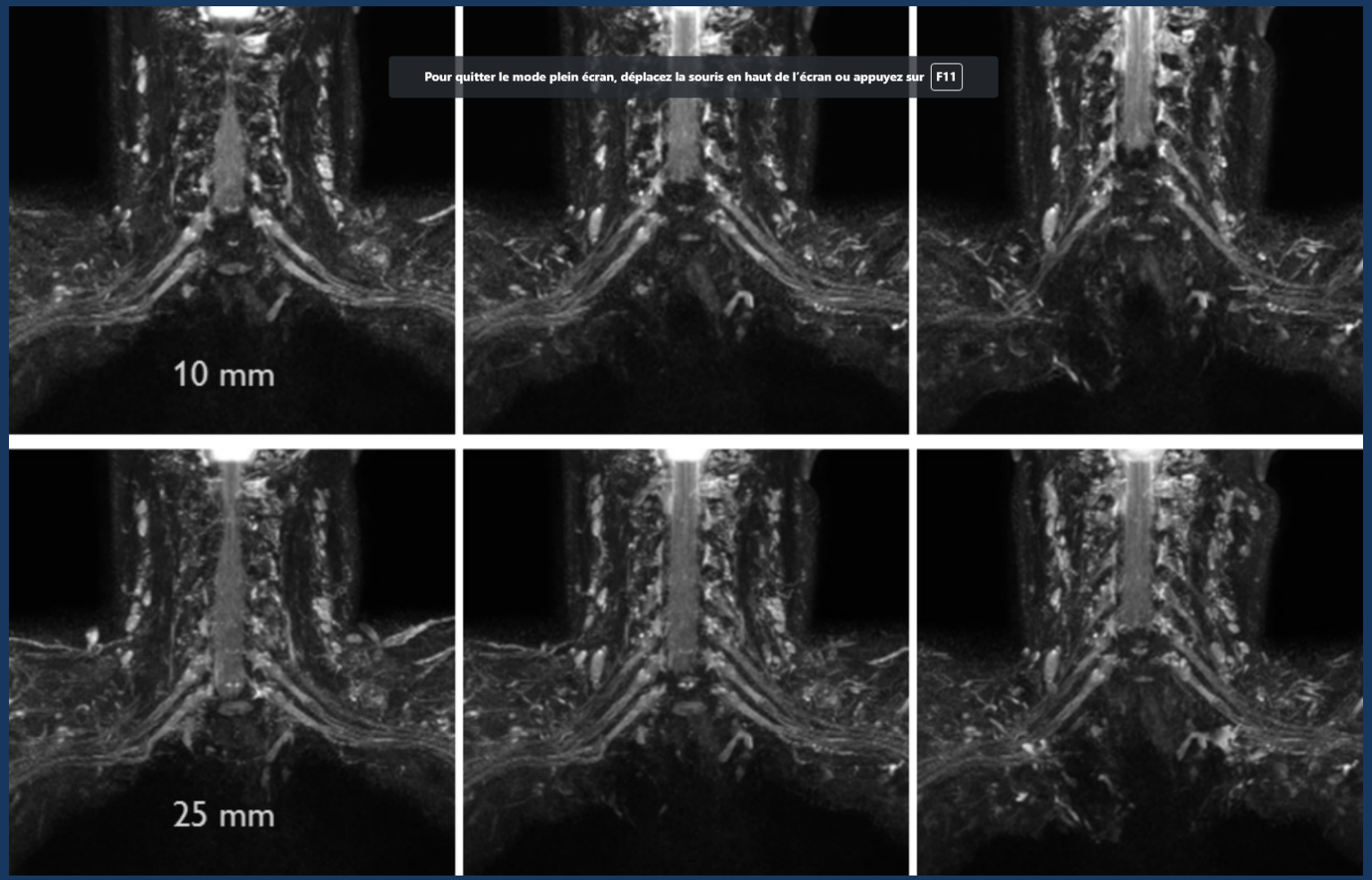
1/ 3D NerveView

Séquence 3D TSE

Refocalisation angle for each tissue

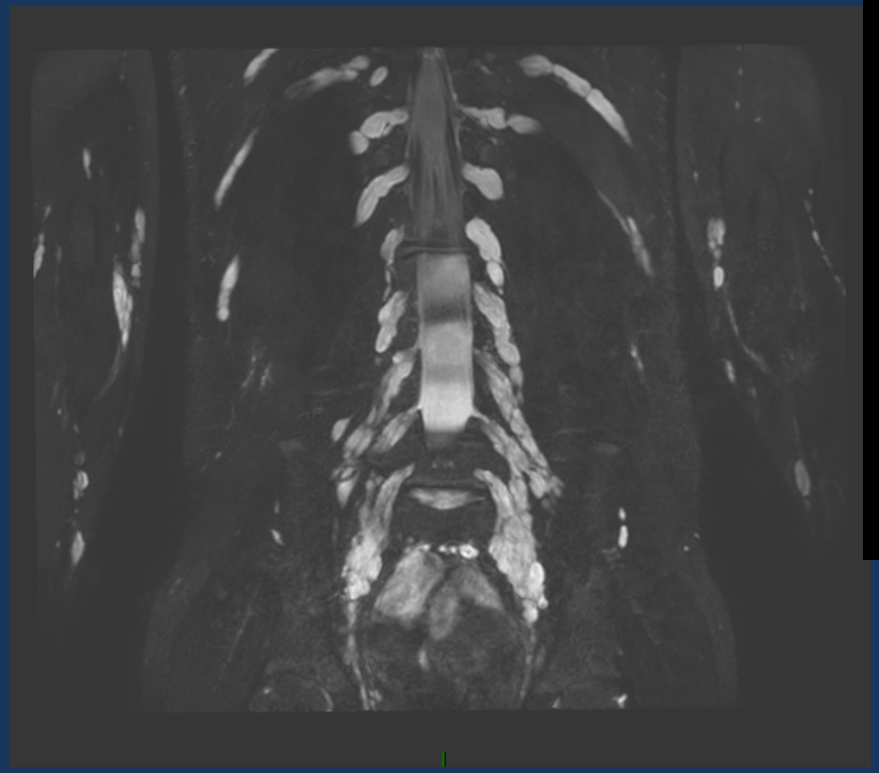
T2 weigted sequence

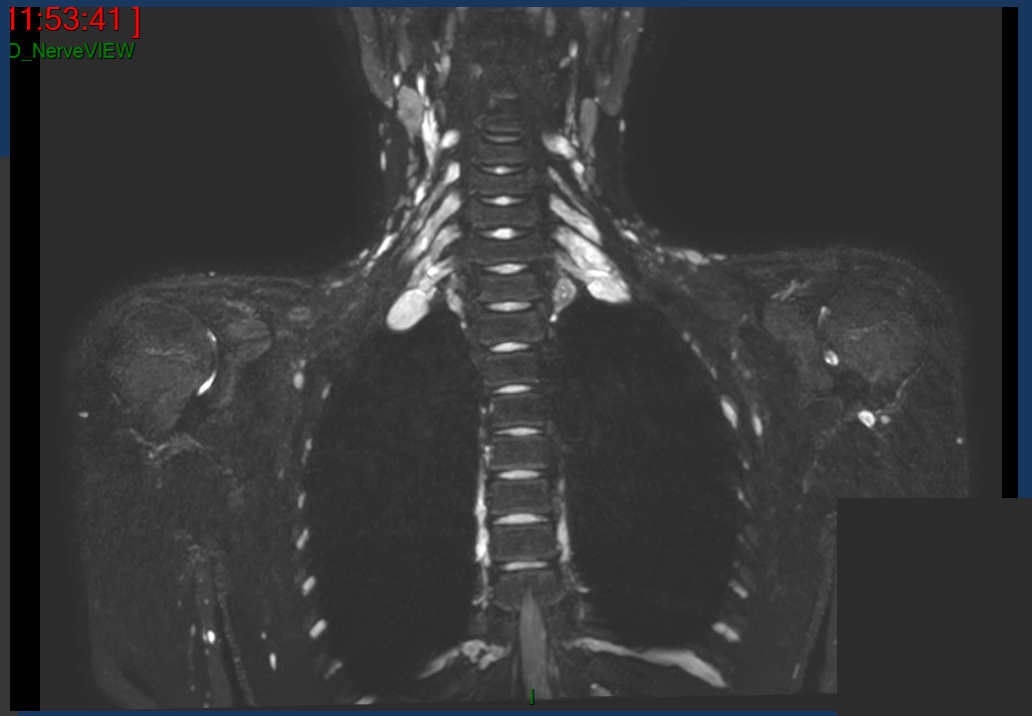
- BlackBlood to decreased venous blood signal

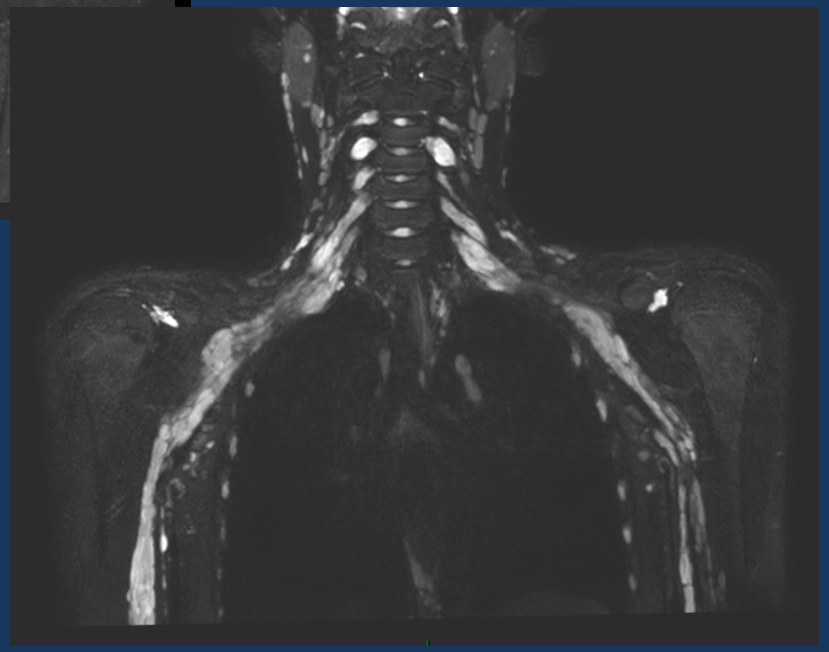


NERVE View

3D IR TSE







1.5 mm isotropic 4 min 28 sec

2/ 3D BrainView

Séquence 3D TSE

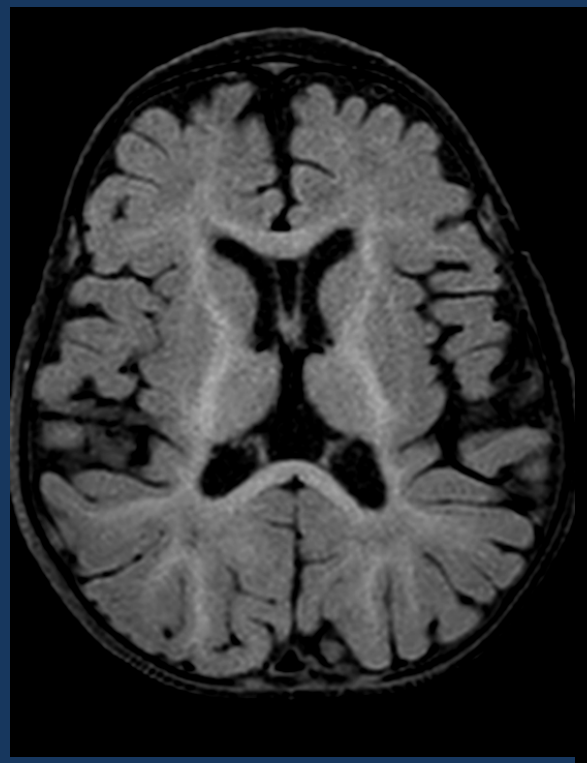
Refocalisation angle for each tissue

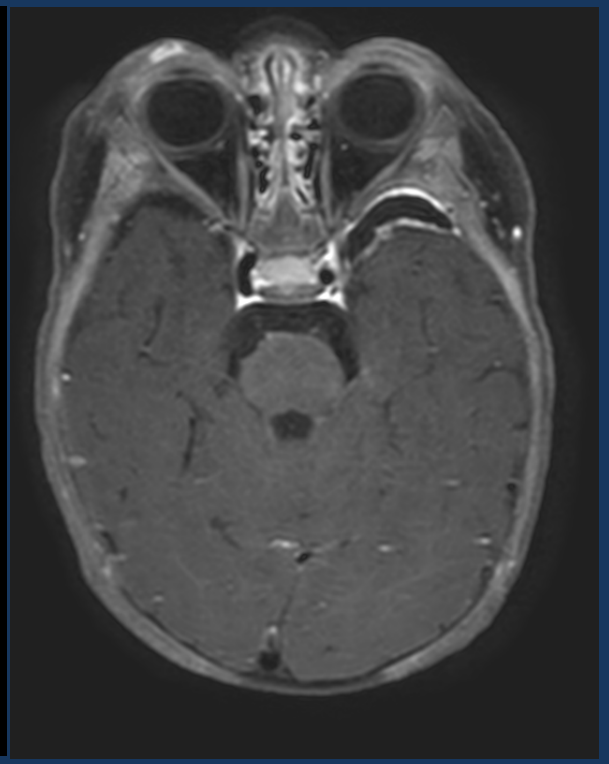
- ↘ Partial volume effect
- ↘ CSF effect
- FLAIR or DIR possible

Low refocalisation angle allows prolonged T2 relaxation

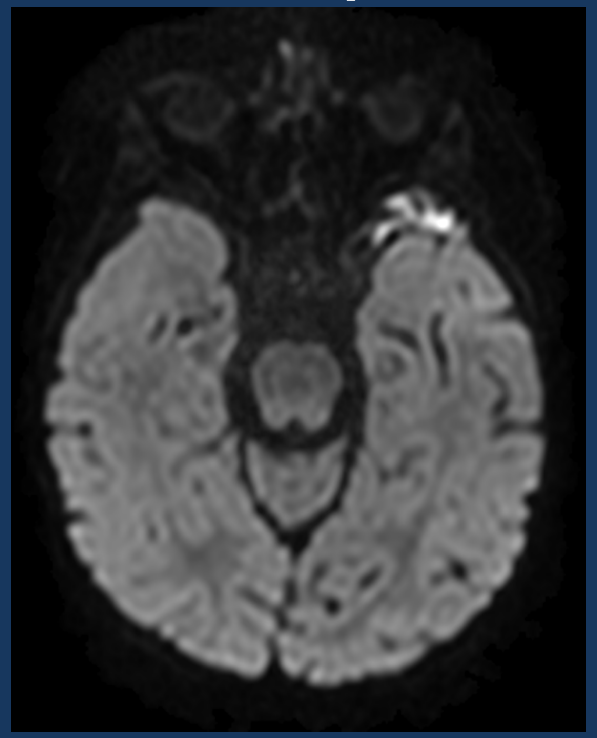
T1 3D TSE brain view – Infant < 6 months

3T 3D T1 TSE brain view 1mm, SPIR, pre and post contrast

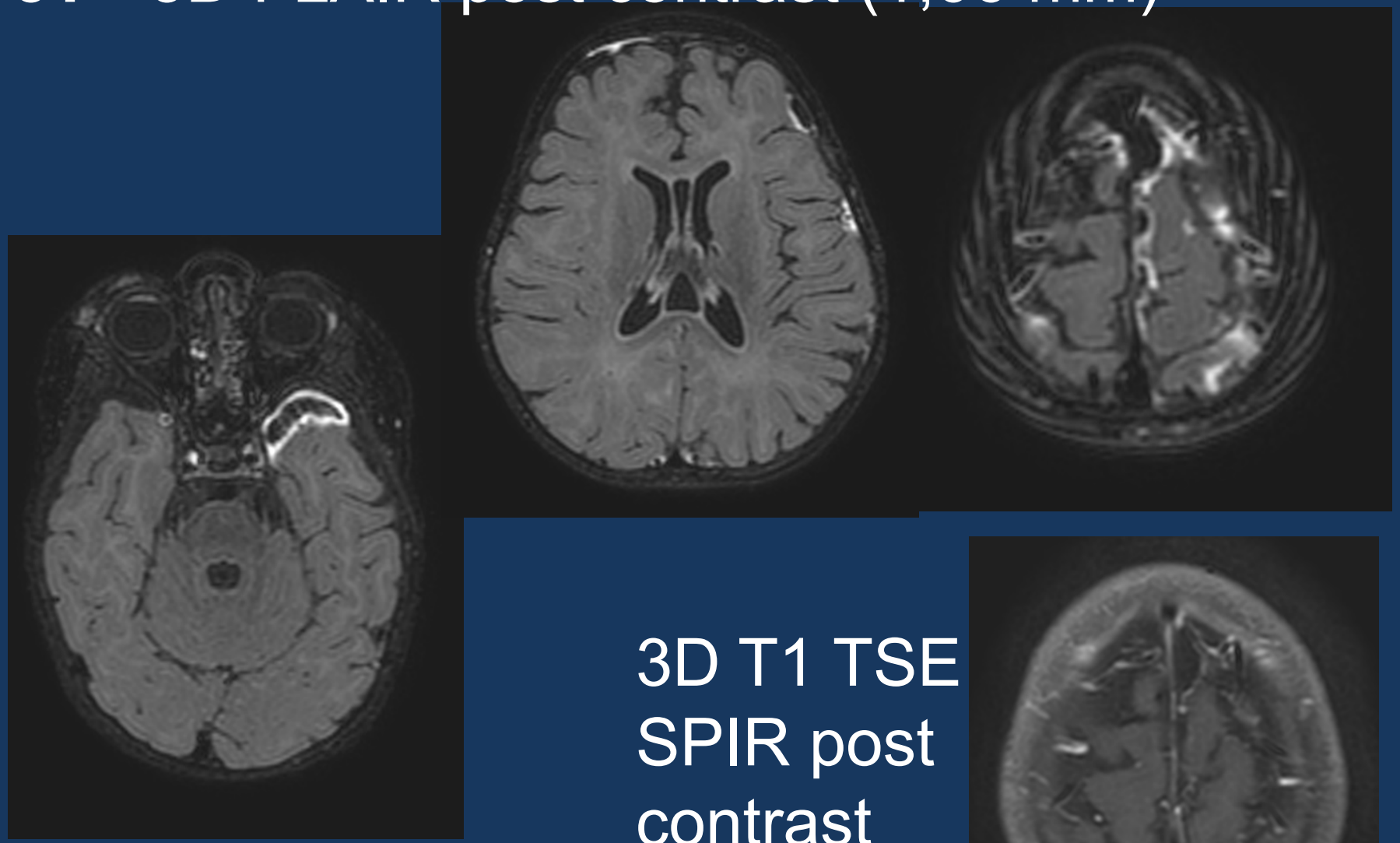




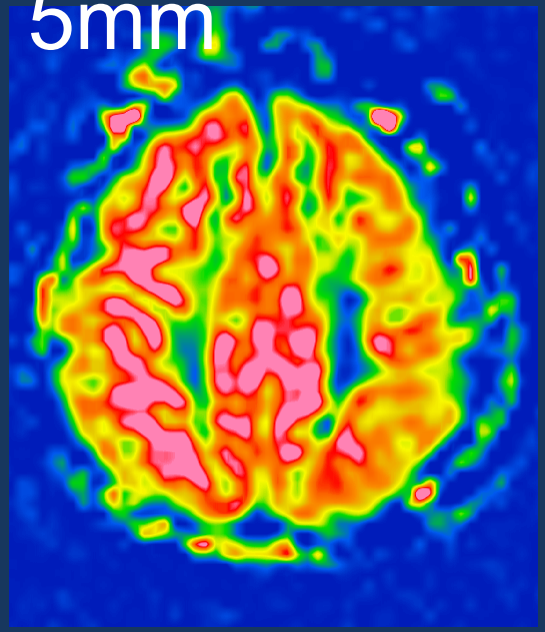
DWI 2mm, 6D, 2b (1000)



3T - 3D FLAIR post contrast (1,06 mm)

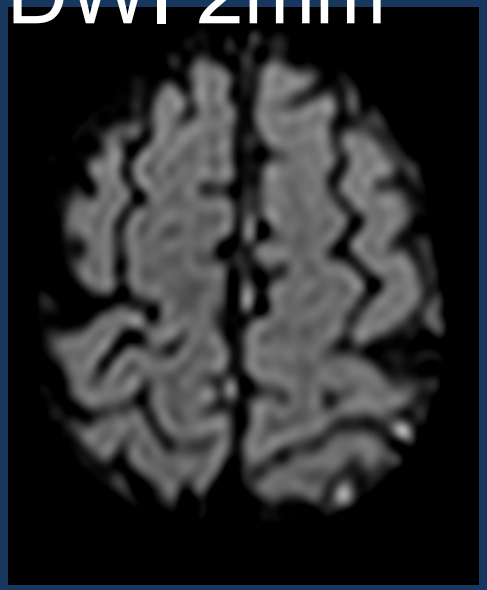


3D pcASL 5mm



3D T1 TSE SPIR post contrast (1mm)

DWI 2mm



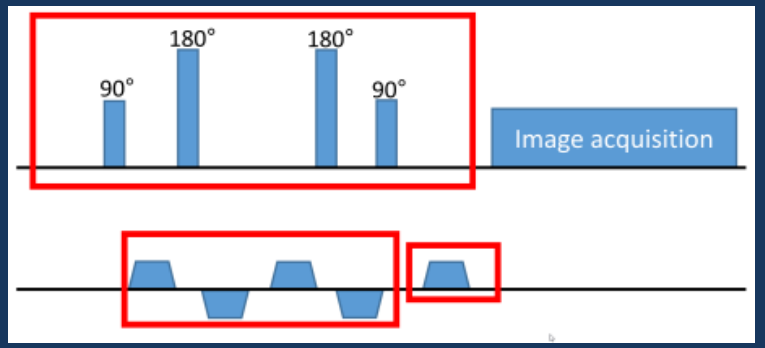
3/ Black blood imaging

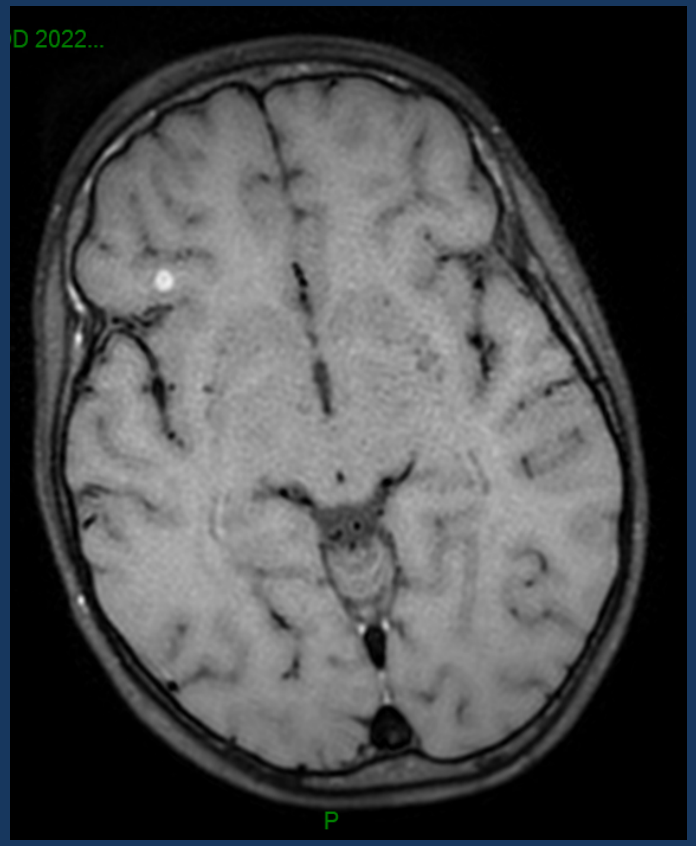
TSE BrainView sequence

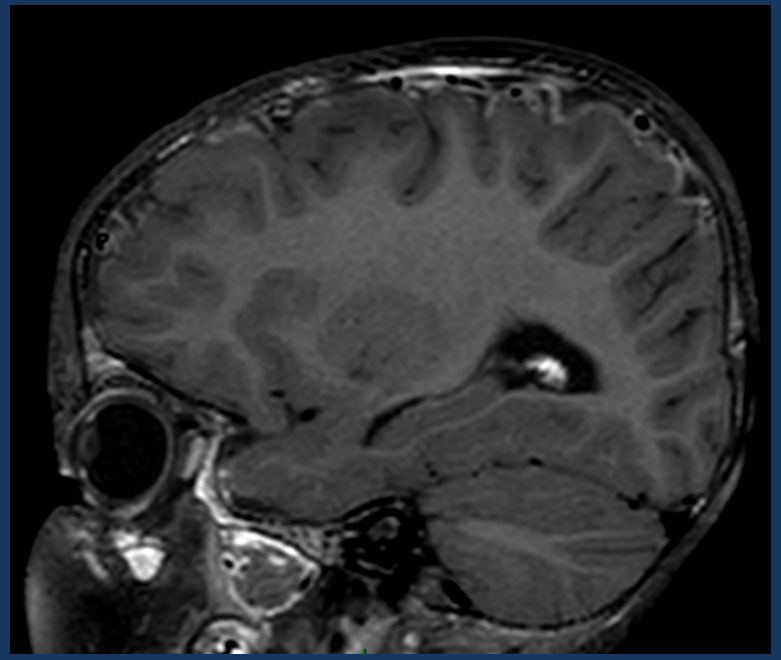
- Rapid blood flow dephasing (low refocalisation angles)

Enhanced black blood effect

- MSDE (Motion-Sensitizing Driven Equilibrium)
- Anti-DRIVE pulse (suppr. CSF) at the end of train length





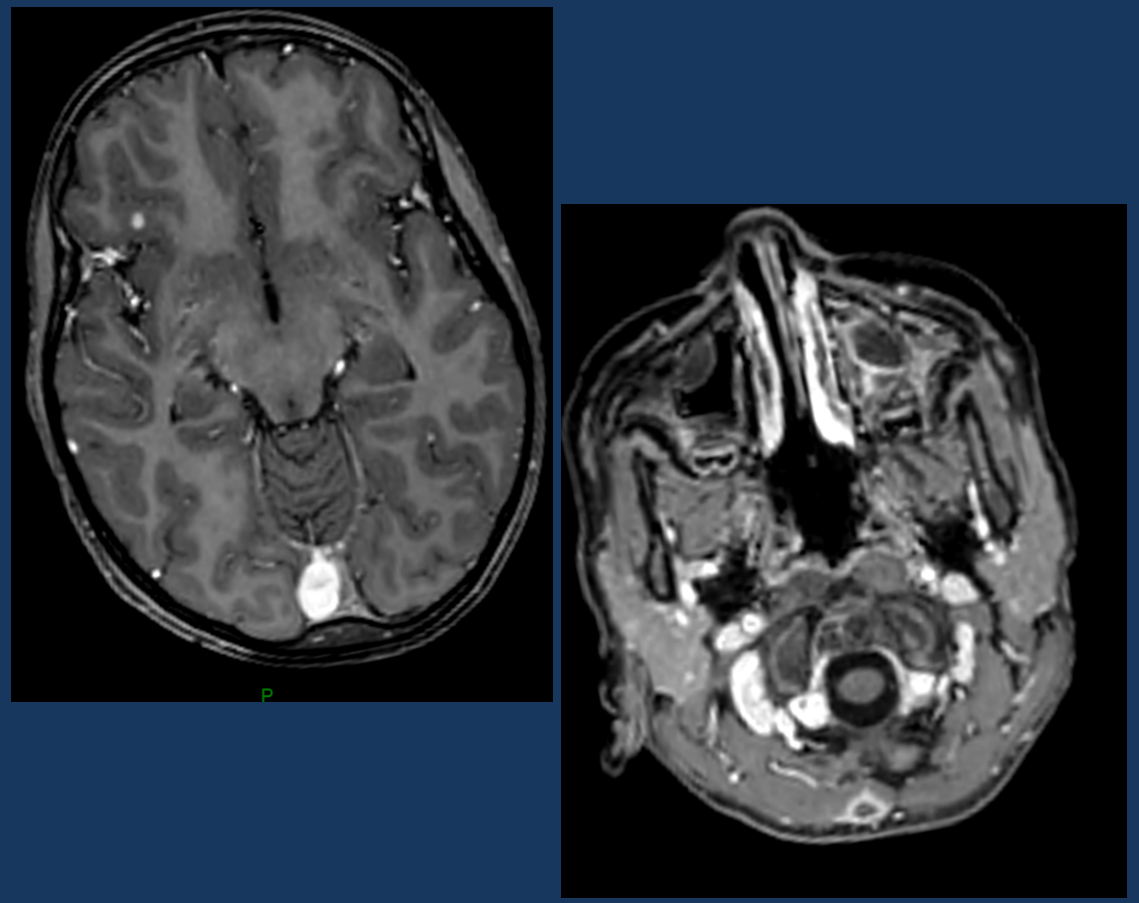


Source : ULB Erasme Hospital, Bruxelles, Belgique.
Source : Ludwig Maximilains Universität, Munich, Allemagne.

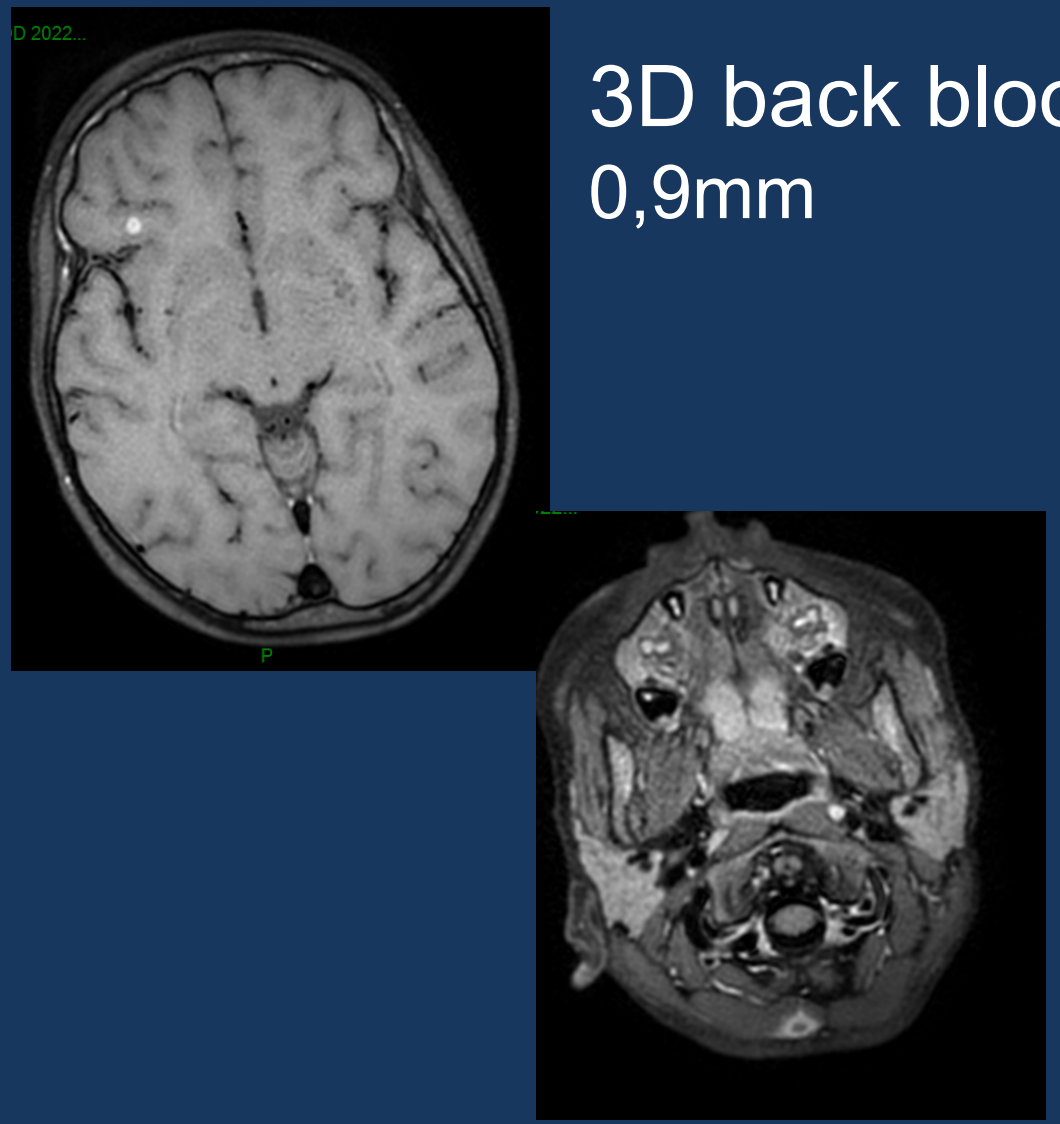
Black blood imaging post contrast

8 yo, tuberculoma

3D T1 TFE 1mm



3D back blood
0,9mm

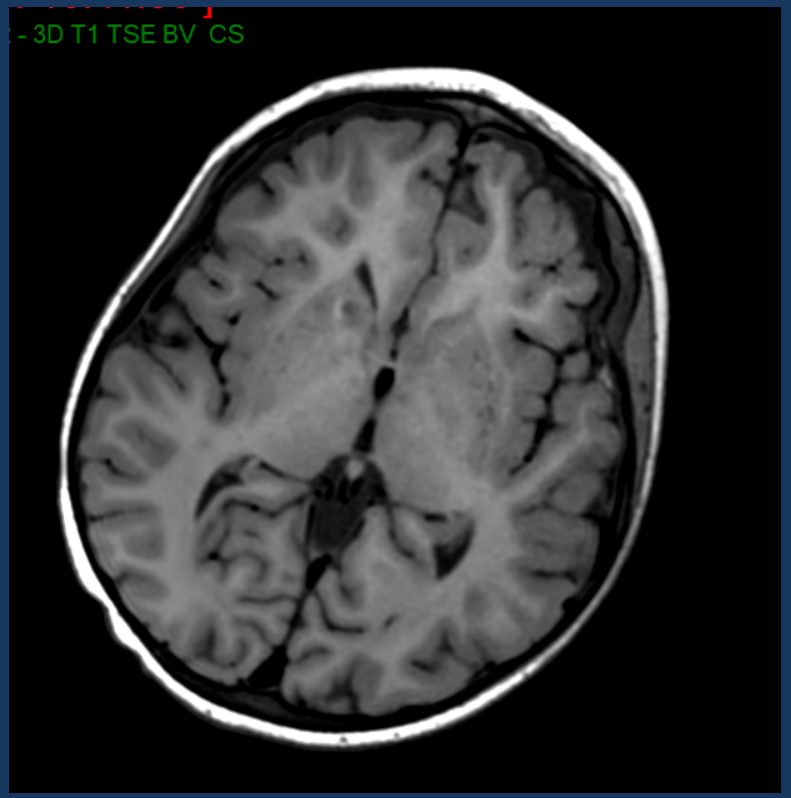


Black blood imaging post contrast

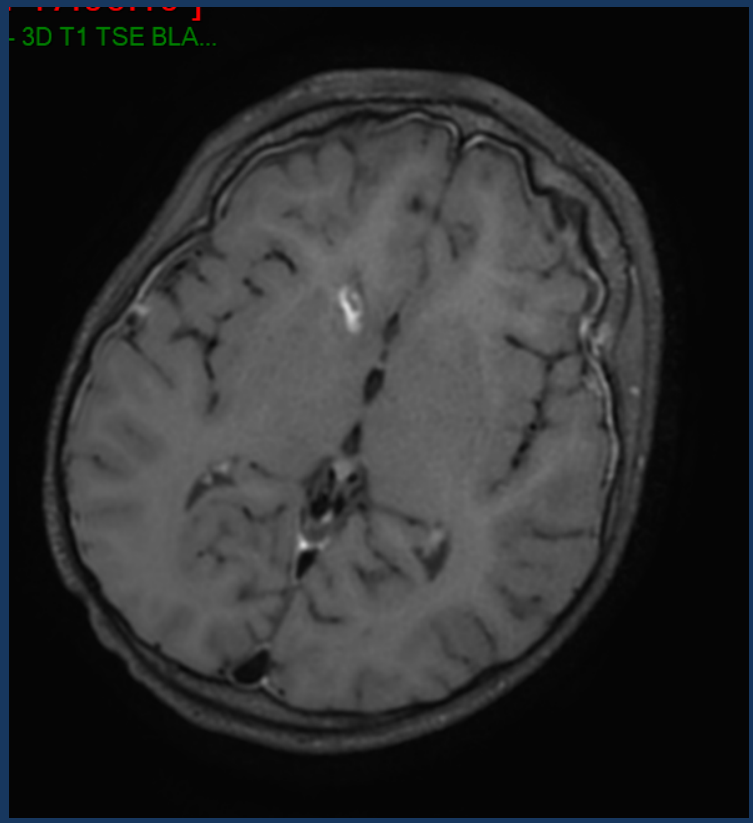
3 yo –pneumococcal meningitis

3T

3D T1 TSE – 0,9mm

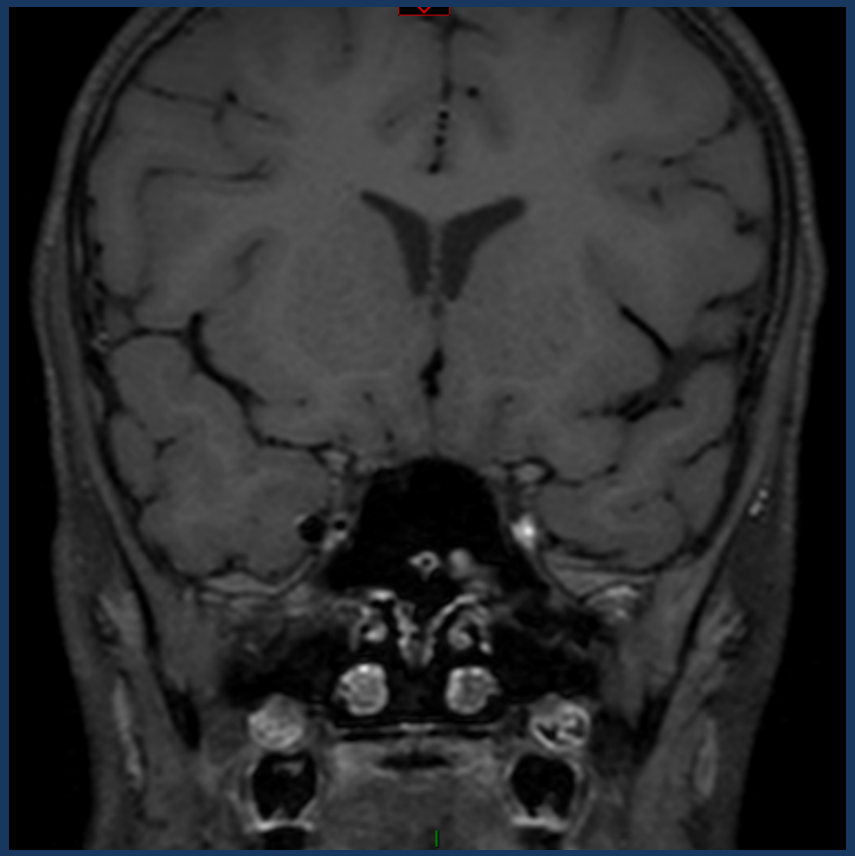


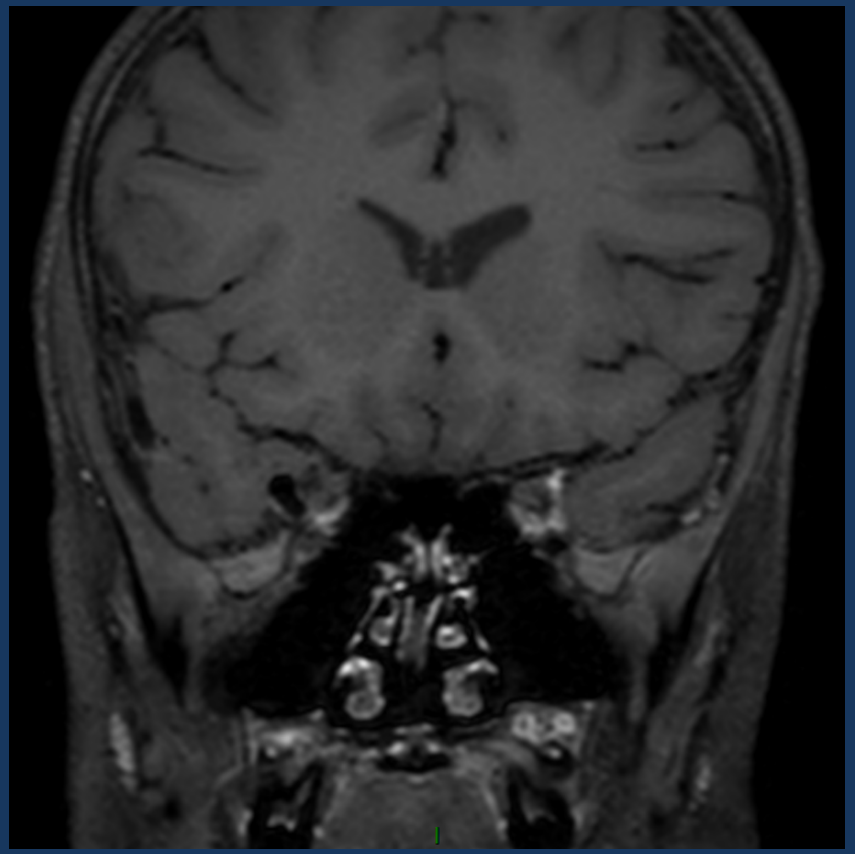
3D T1 TSE Black blood -0,9 mm Post contrast

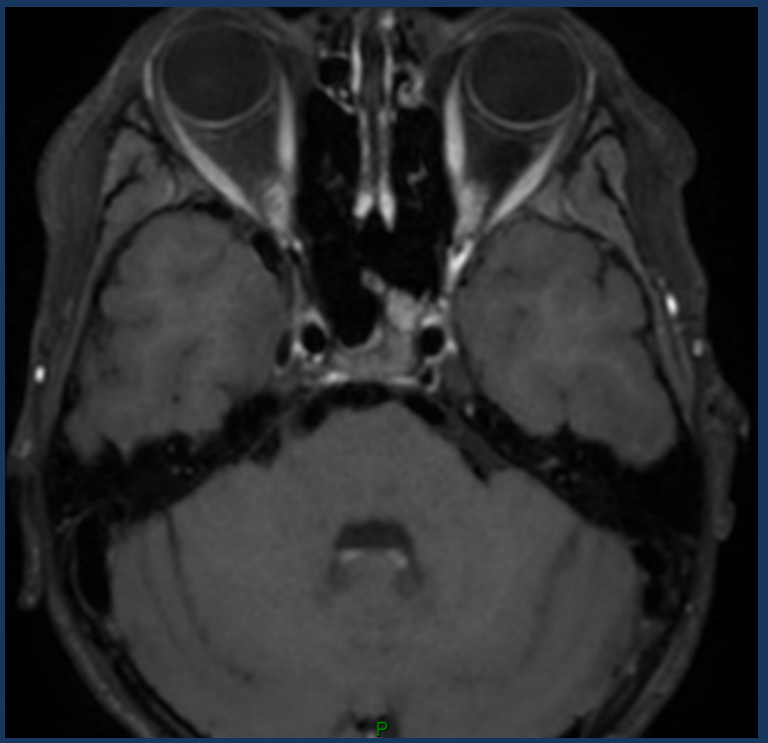


Black blood imaging post contrast

11 yo, Myeloid Acute Leukemia, sensitive left frontal deficit (V1)

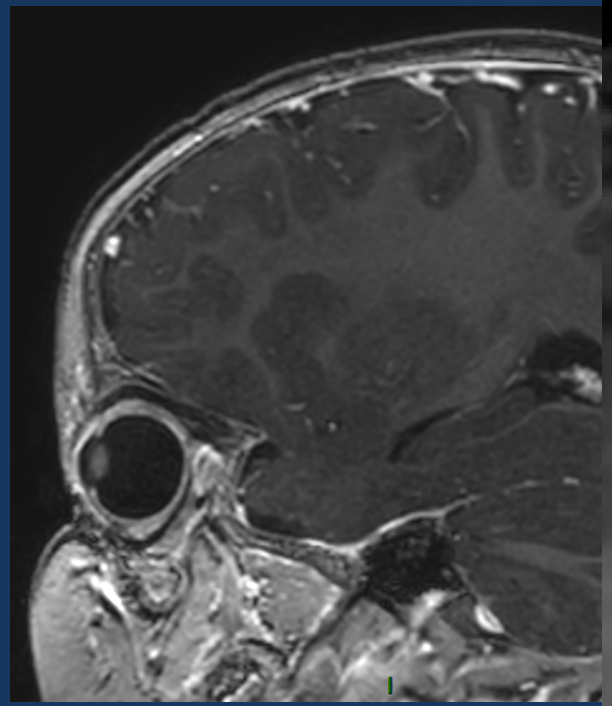




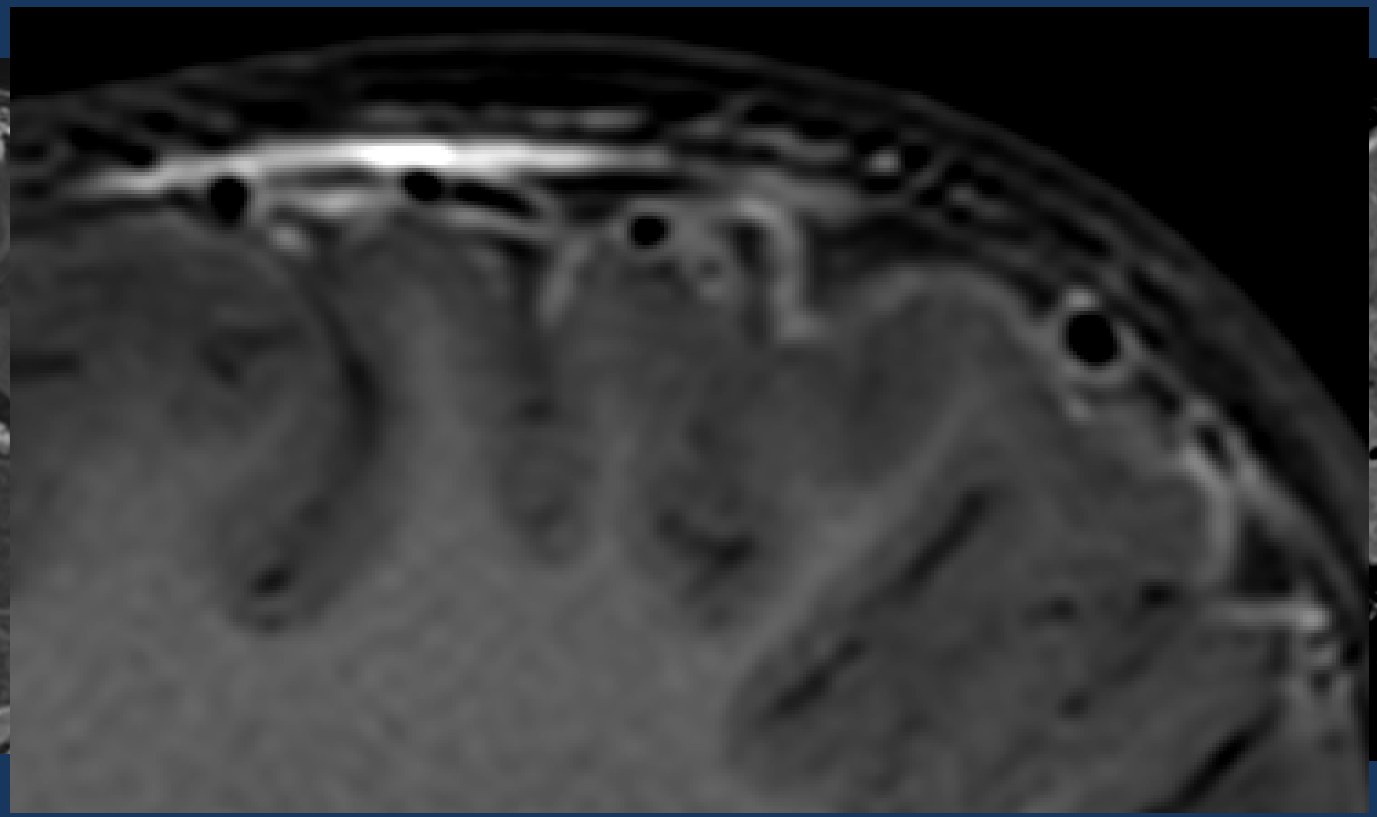


10 months, meningitis
leptomeningeal enhancement, venous wall enhancement

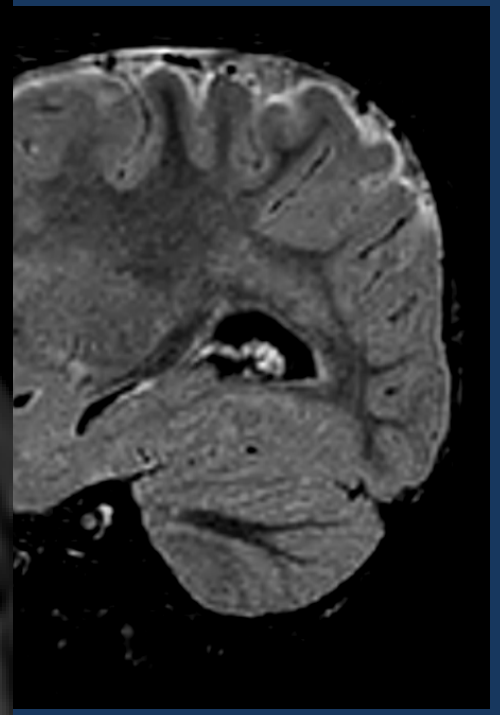
3D T1 TFE post contrast



3D T1 TSE black blood post contrast



3D FLAIR post contrast



Abdominal imaging

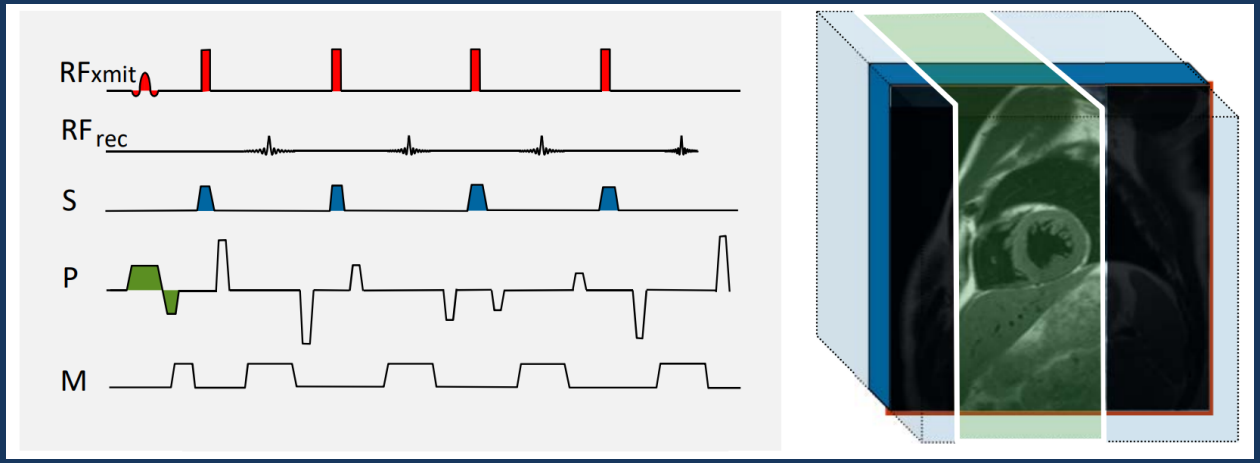
ZOOM and ZOOM DWI

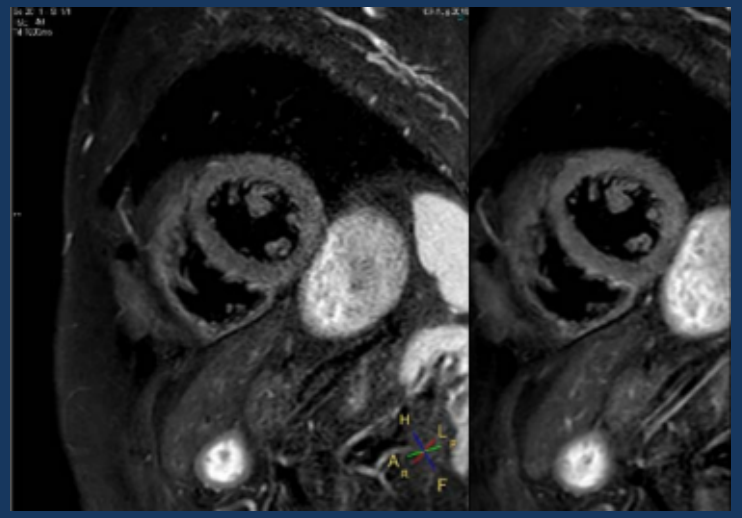
Small FOV

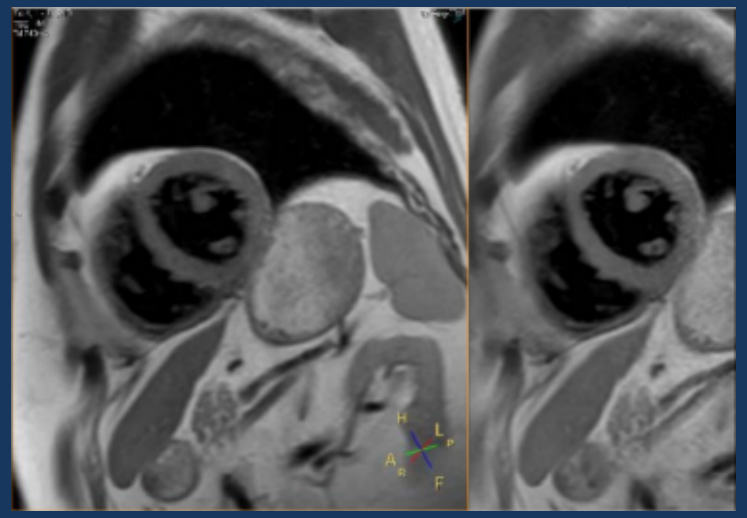
No aliasing

Cross excitation

RF excitation pulse spatially selective (slice and phase encoding direction)

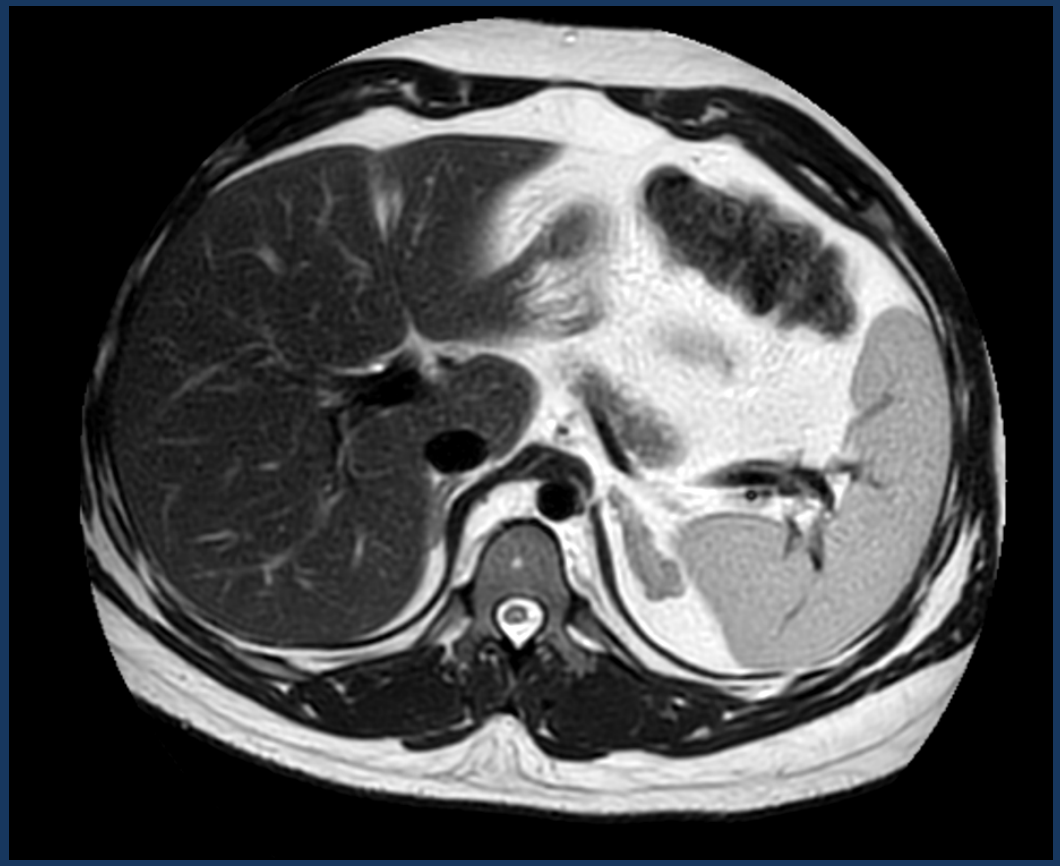






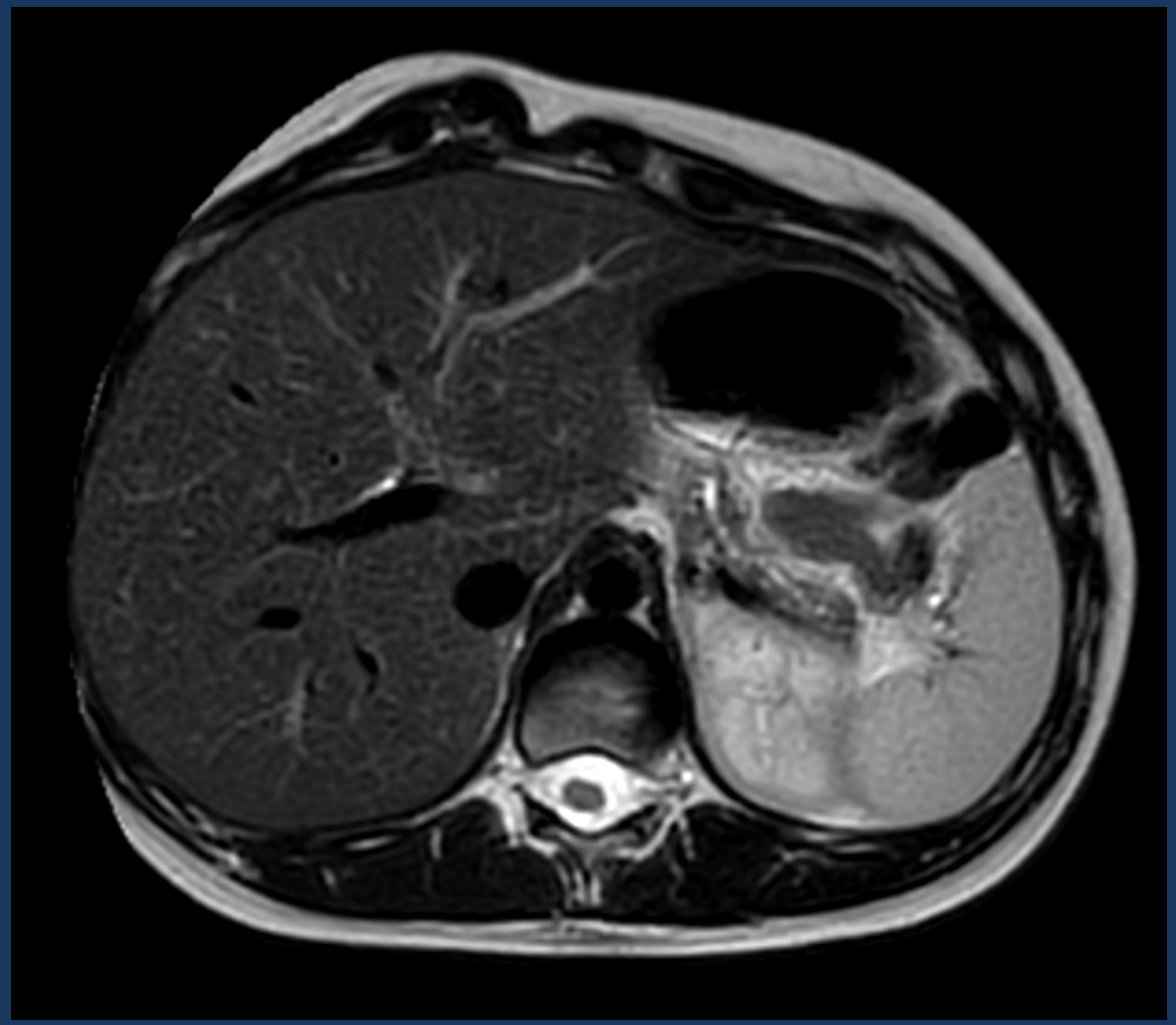
ZOOM T2 TSE

16yo, congenital adrenal hyperplasia



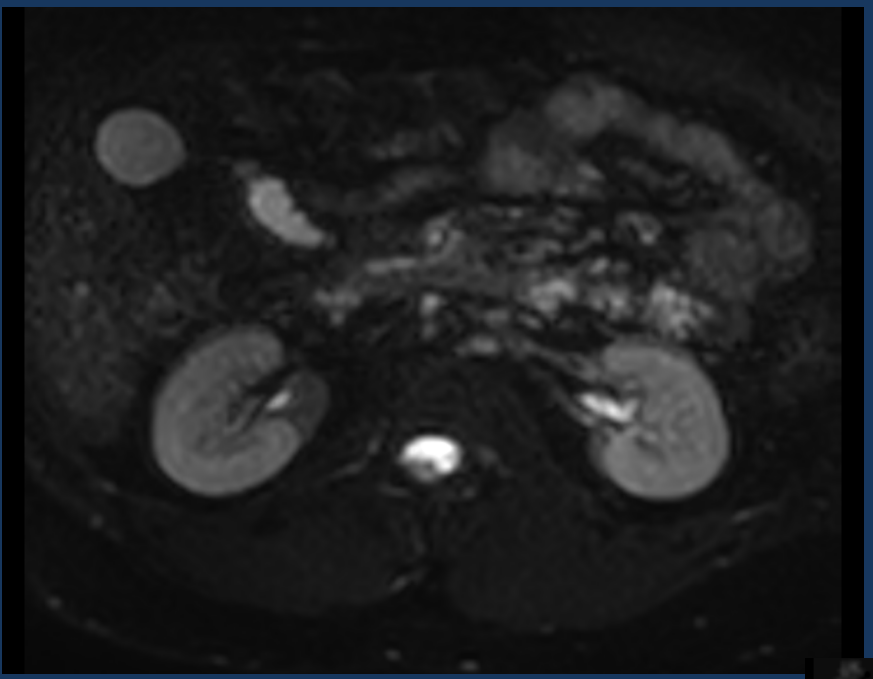
T2 TSE Zoom, 1.5 x 1.5 x 3.5 mm / 2 min 08/ 55 slices

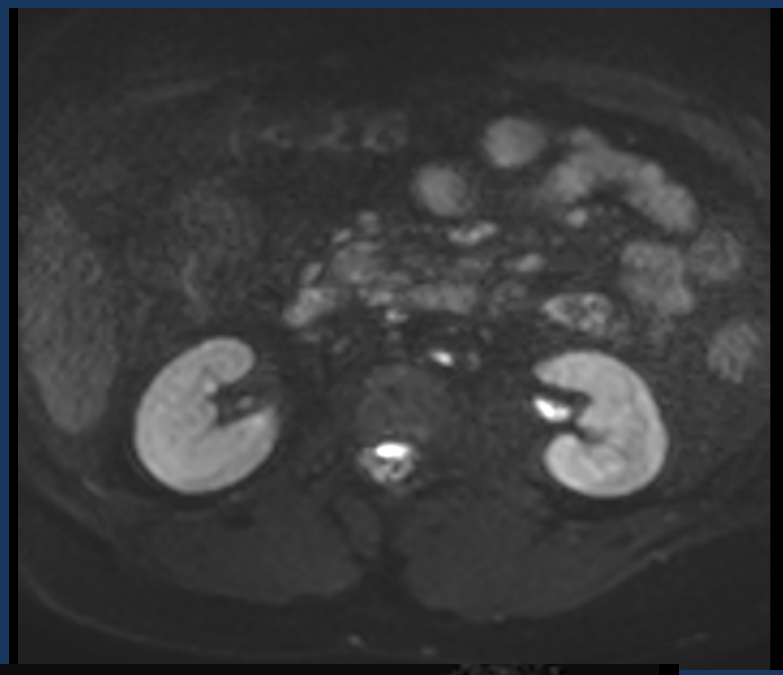
10 yo, chronic pancreatitis, dilated wirsung

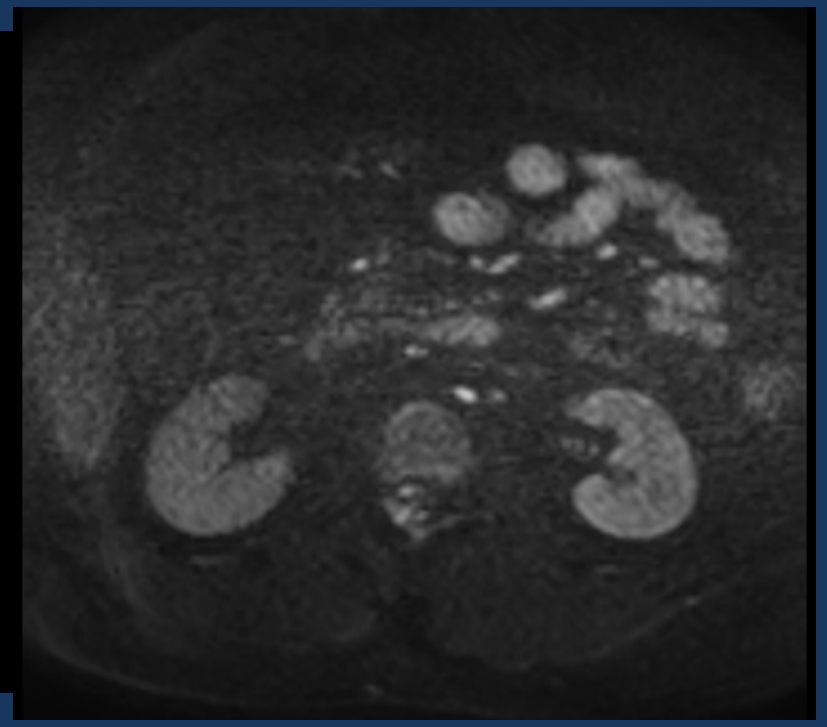


T2 TSE Zoom, 1.5 x 1.5 x 3.5 mm / 2 min 08/ 55 slices

ZOOM DIFFUSION

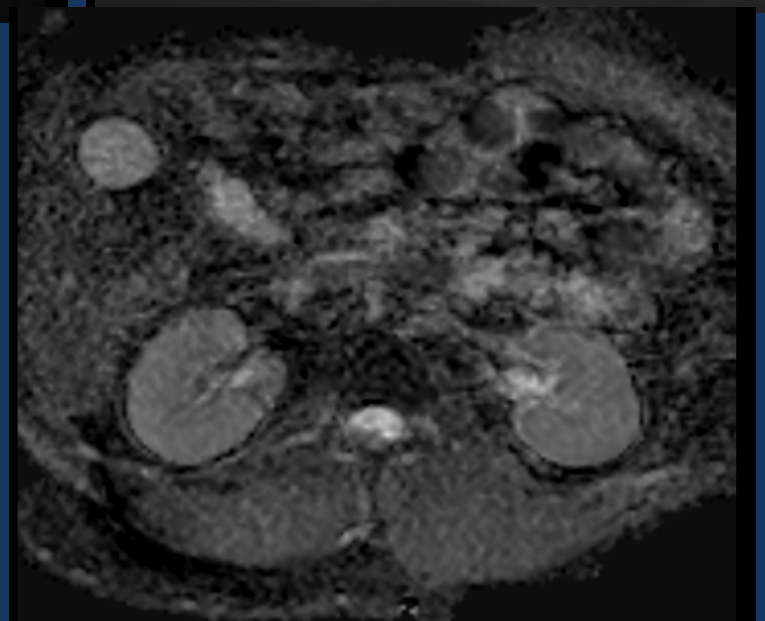






b0, 100, 600, ADC

EPI 1.7 x 1.7 x 4mm
2 min 58
16 slices

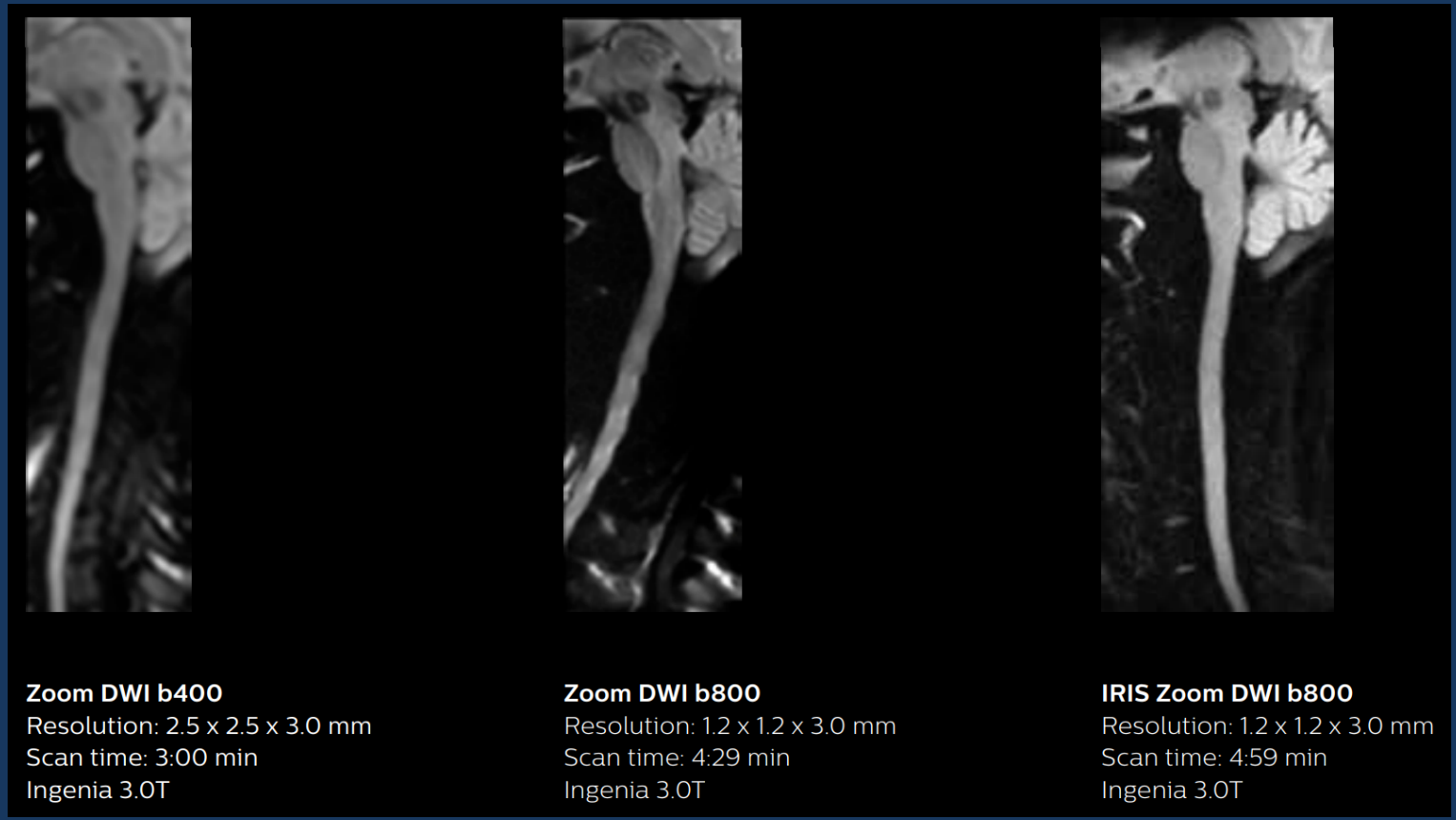


IRIS ZOOM

ZOOM = reduced FOV

IRIS = segmented EPI

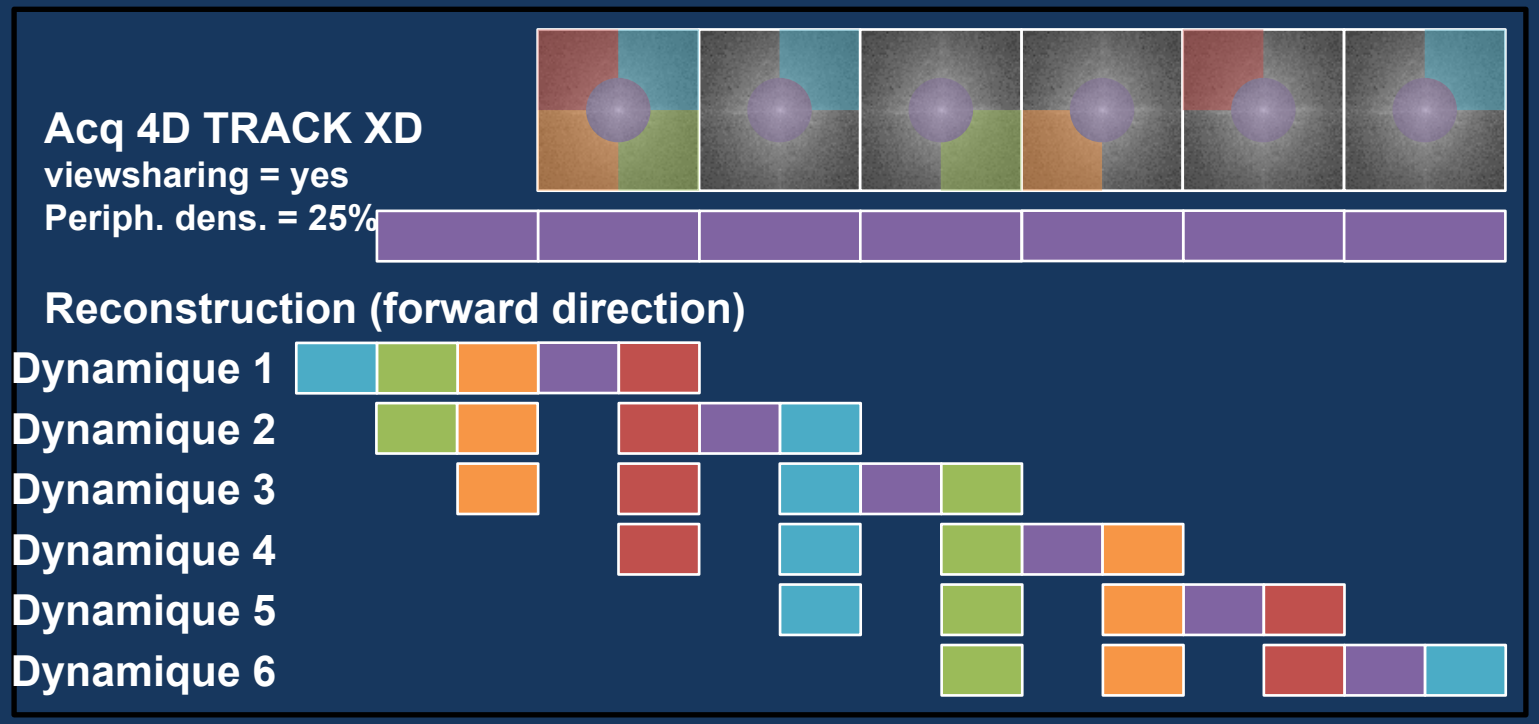
- Higher resolution
- Reduced distorsion
- Improved fat suppression



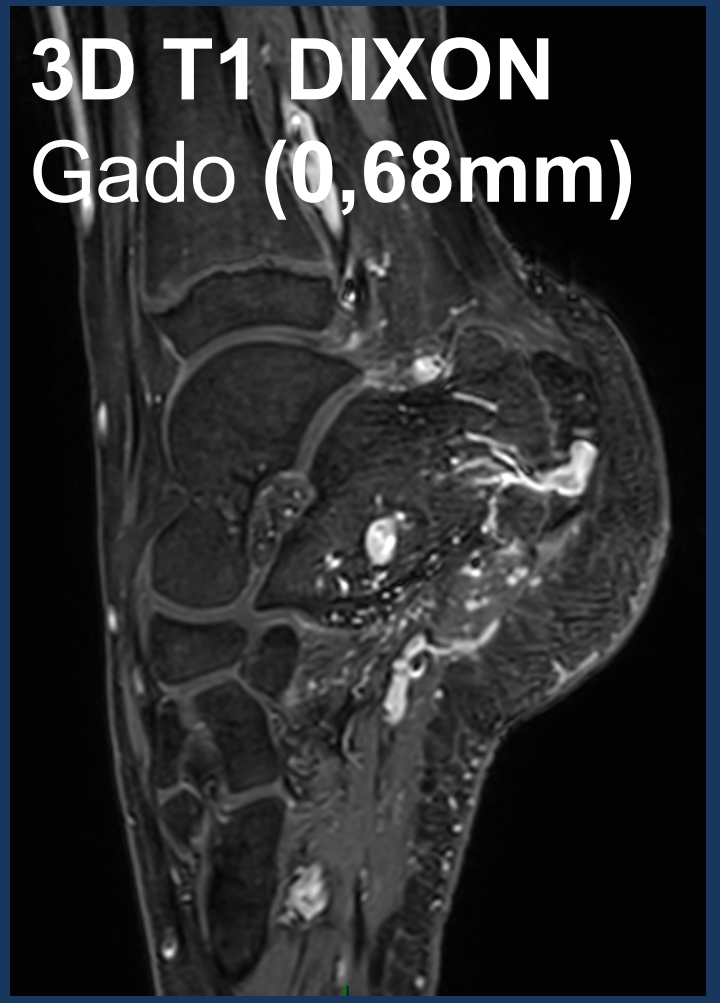
Vascular imaging with contrast

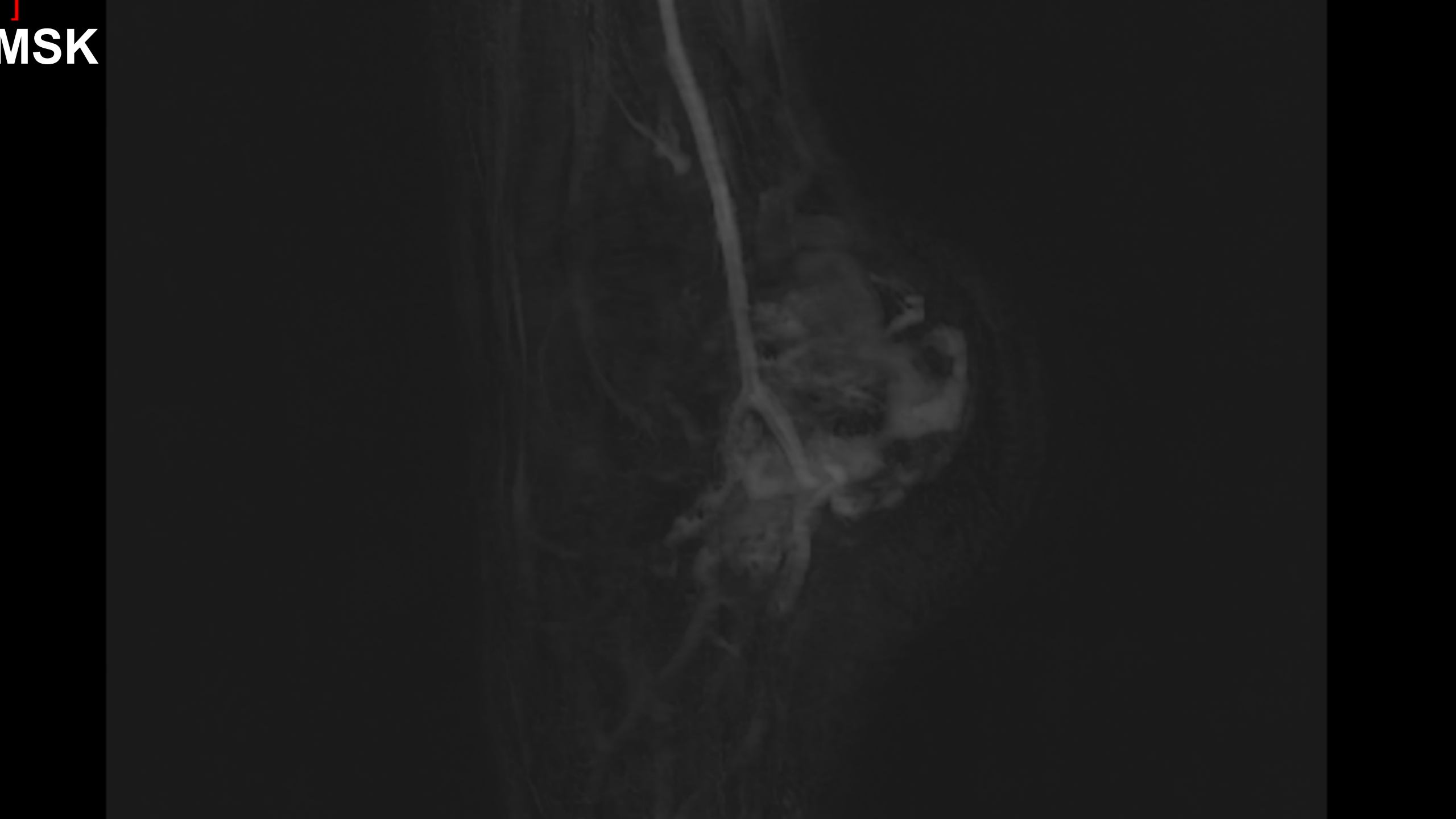
4D TRACK XD

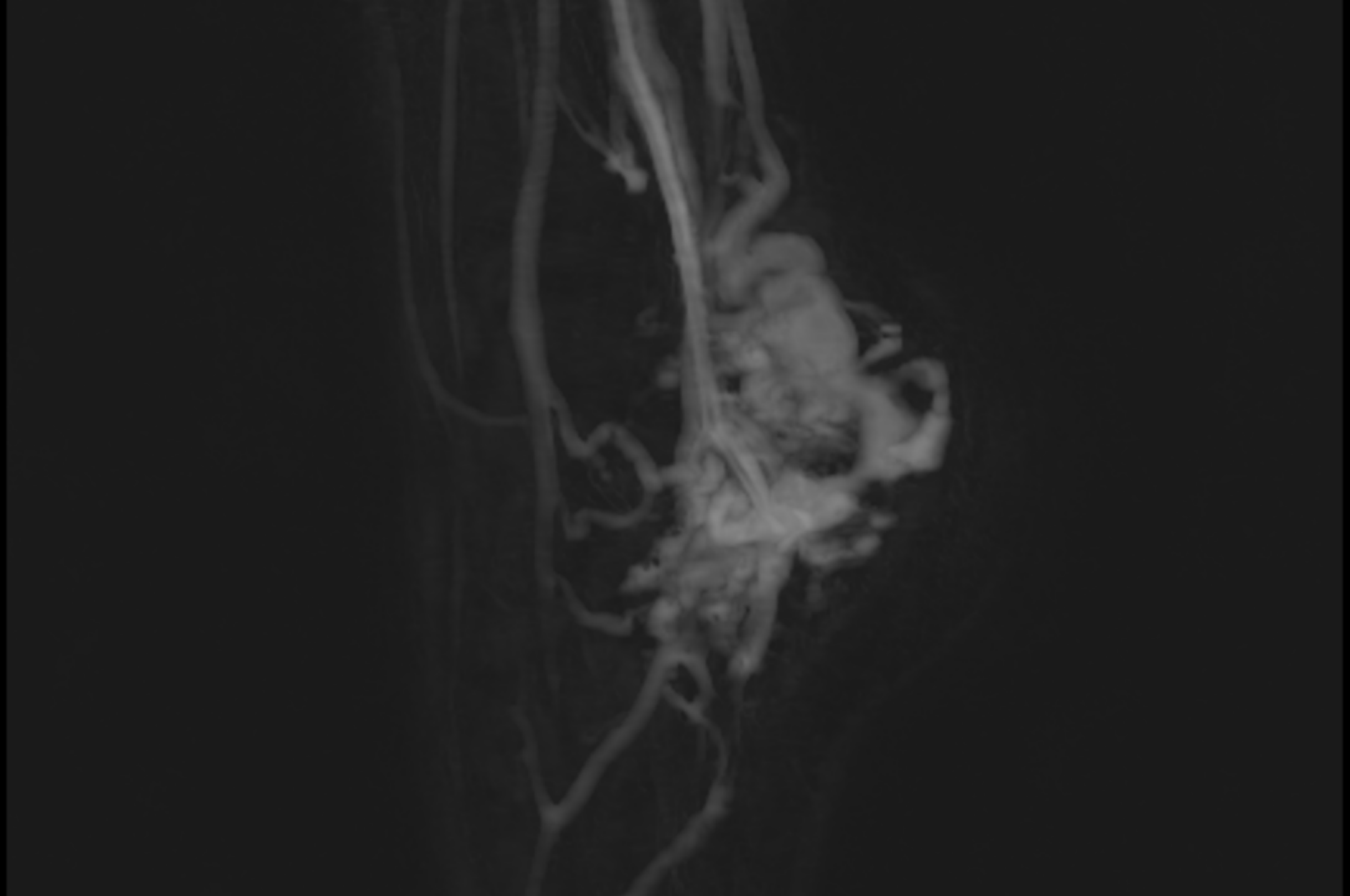
- 3D T1 FFE compatible with SENSE, Keyhole, CENTRA, ViewSharing.
- Temporal Resolution. More flexible (1.2 à 2 sec).

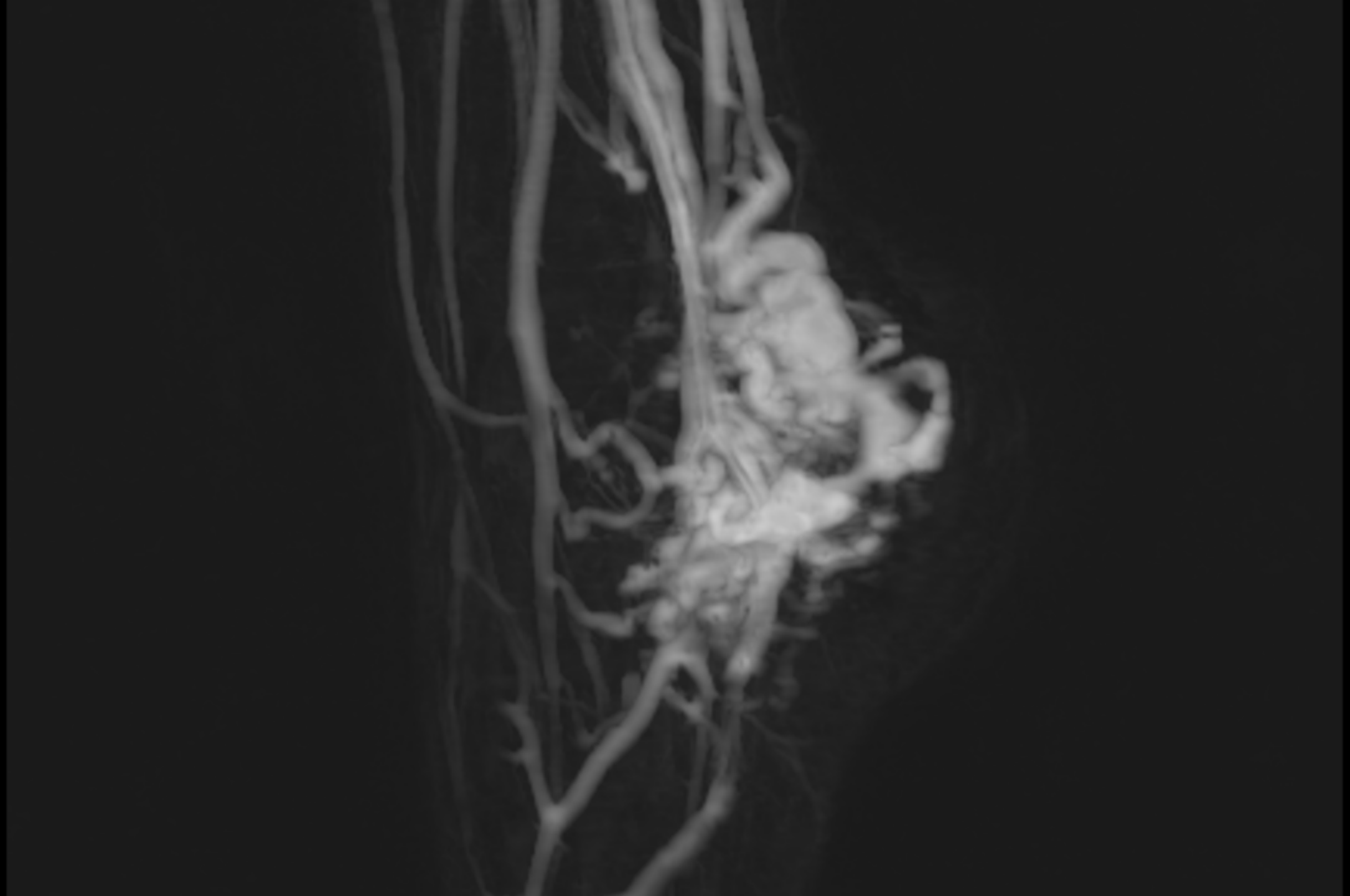


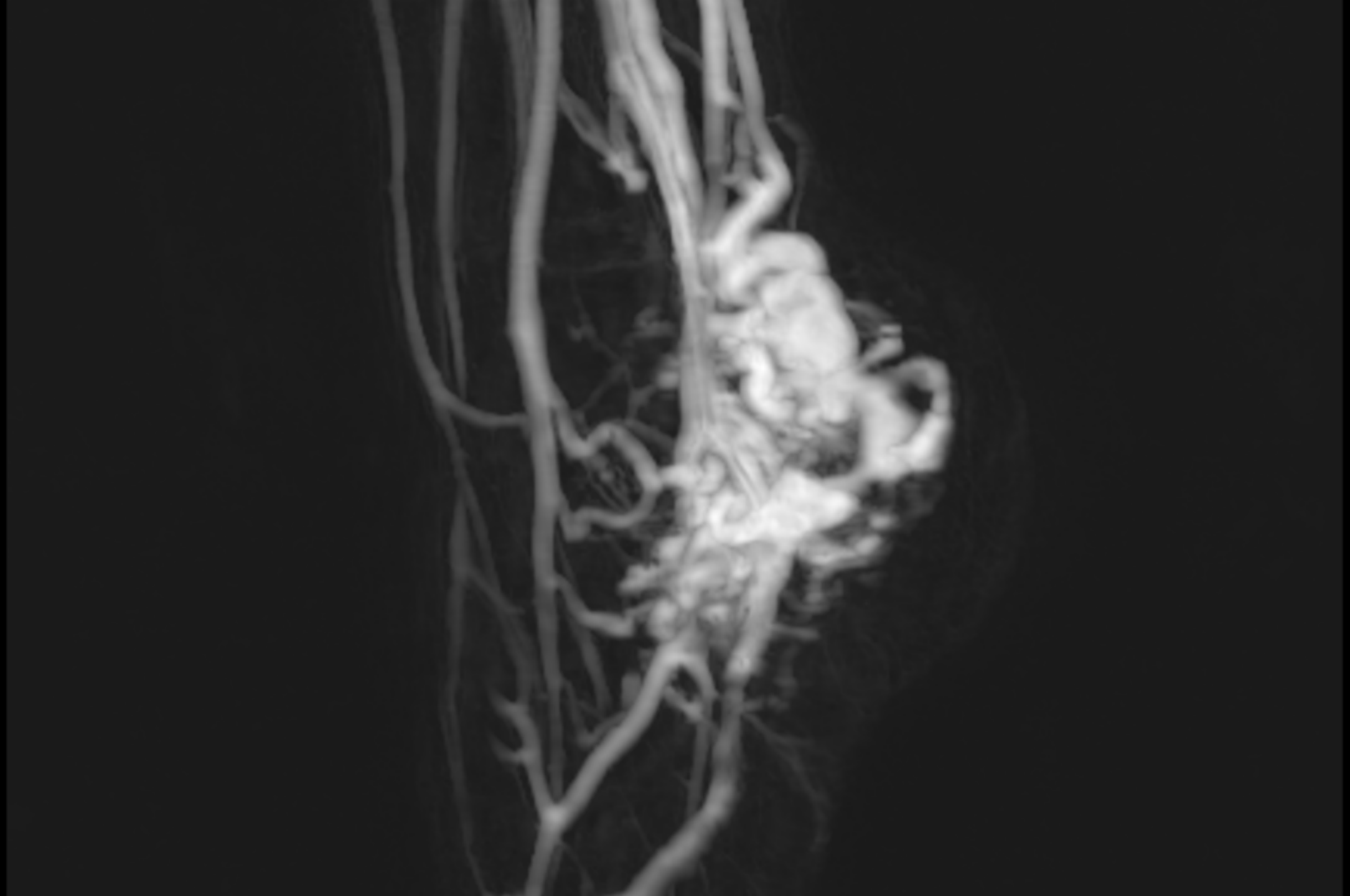

3D T2
(0,56mm)

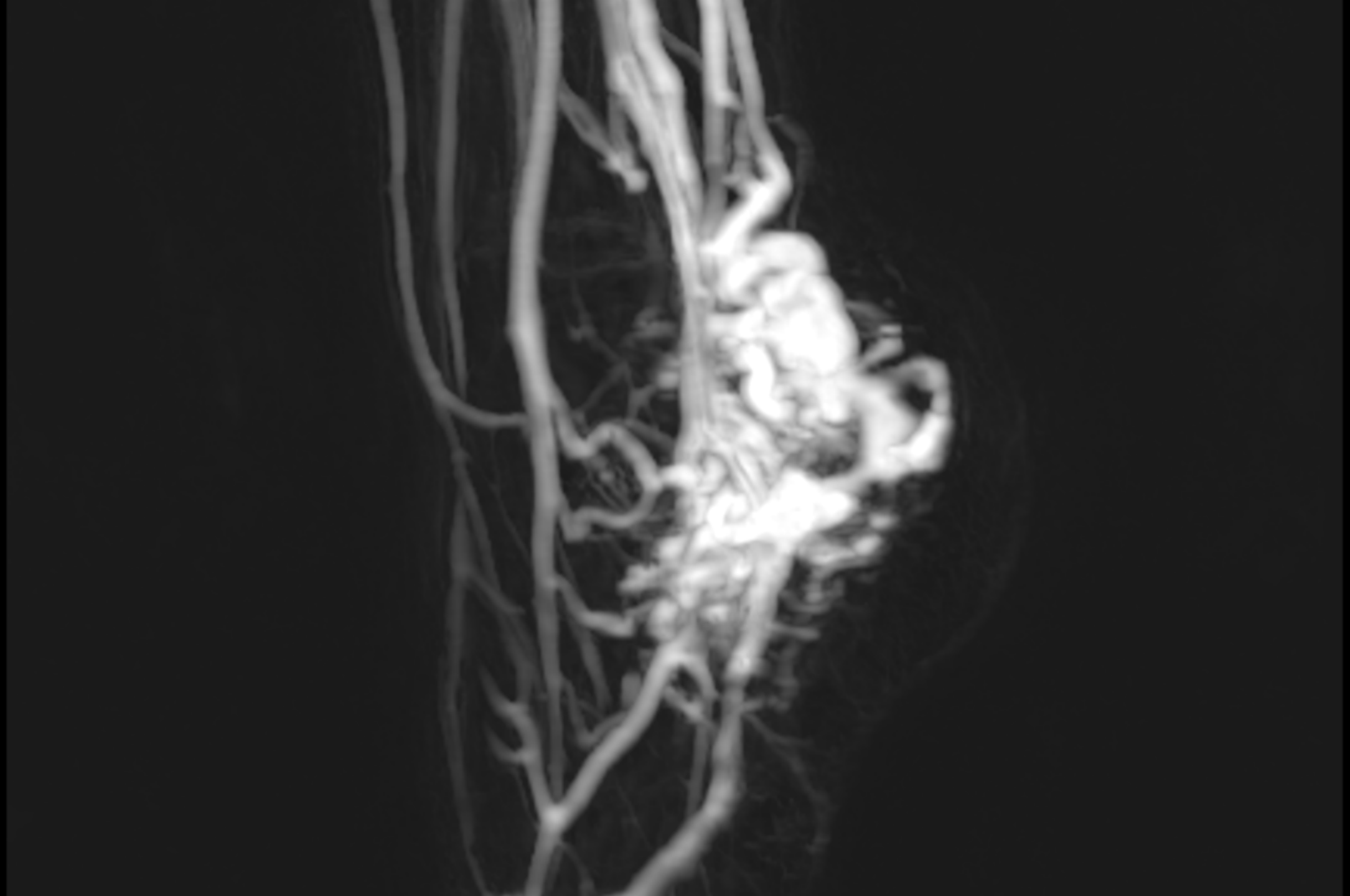

3D T1 DIXON
Gado **(0,68mm)**

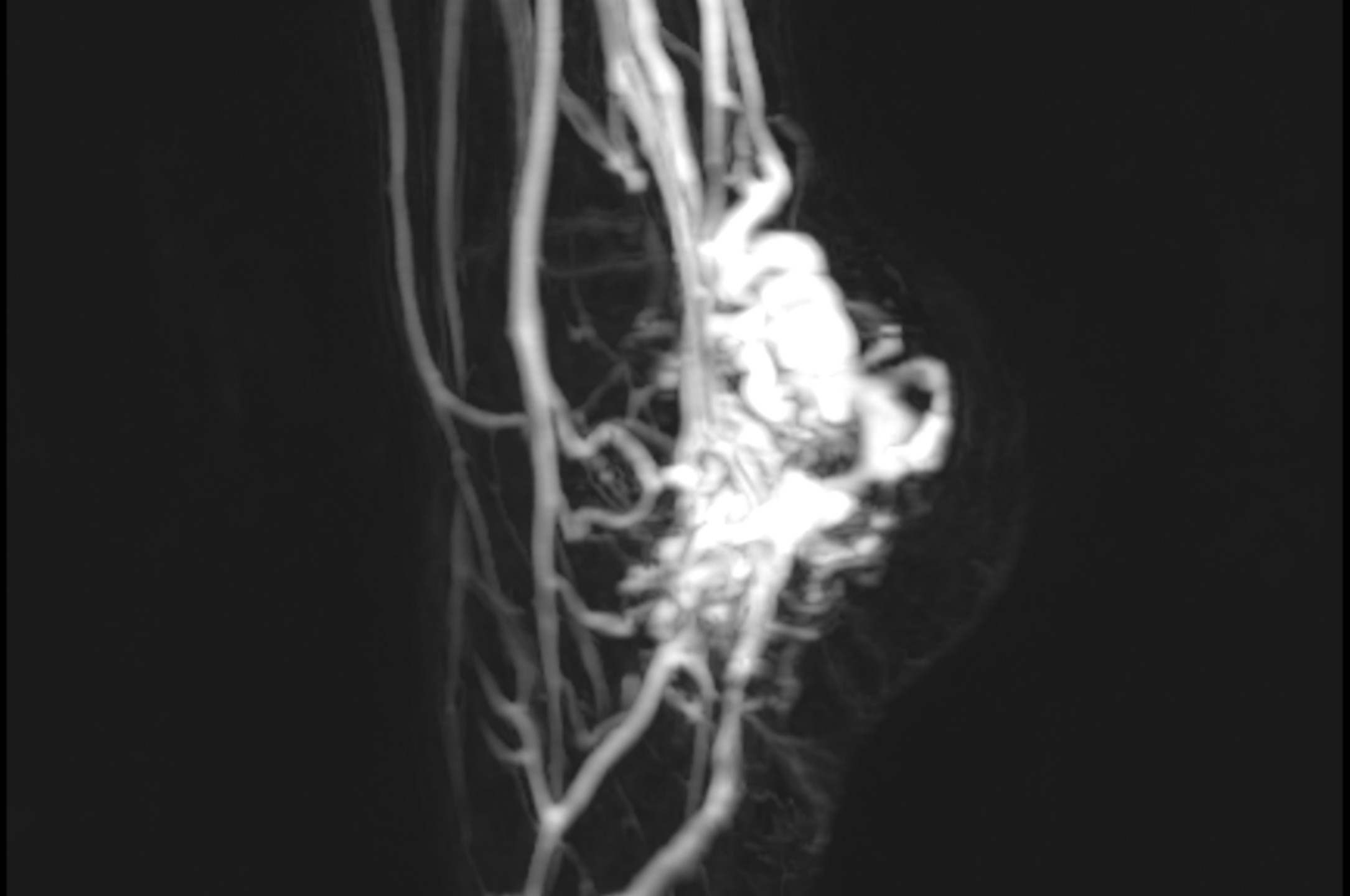

MSK

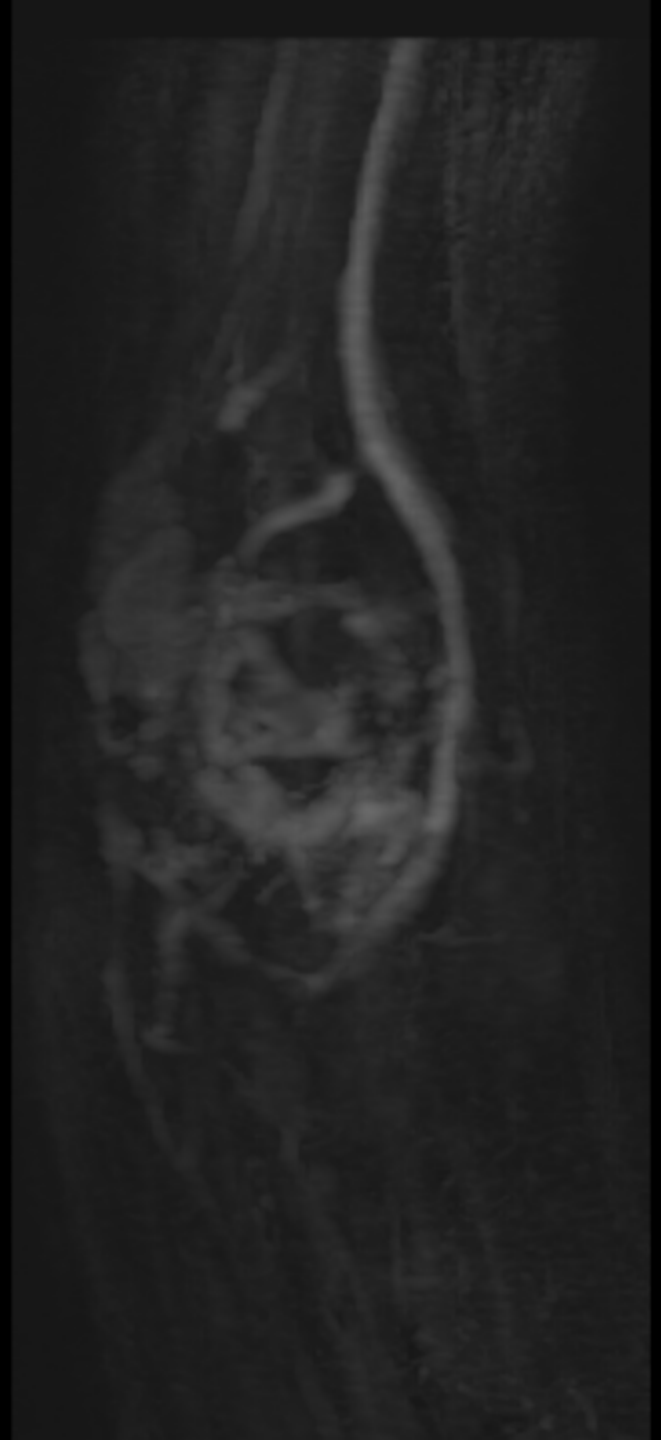


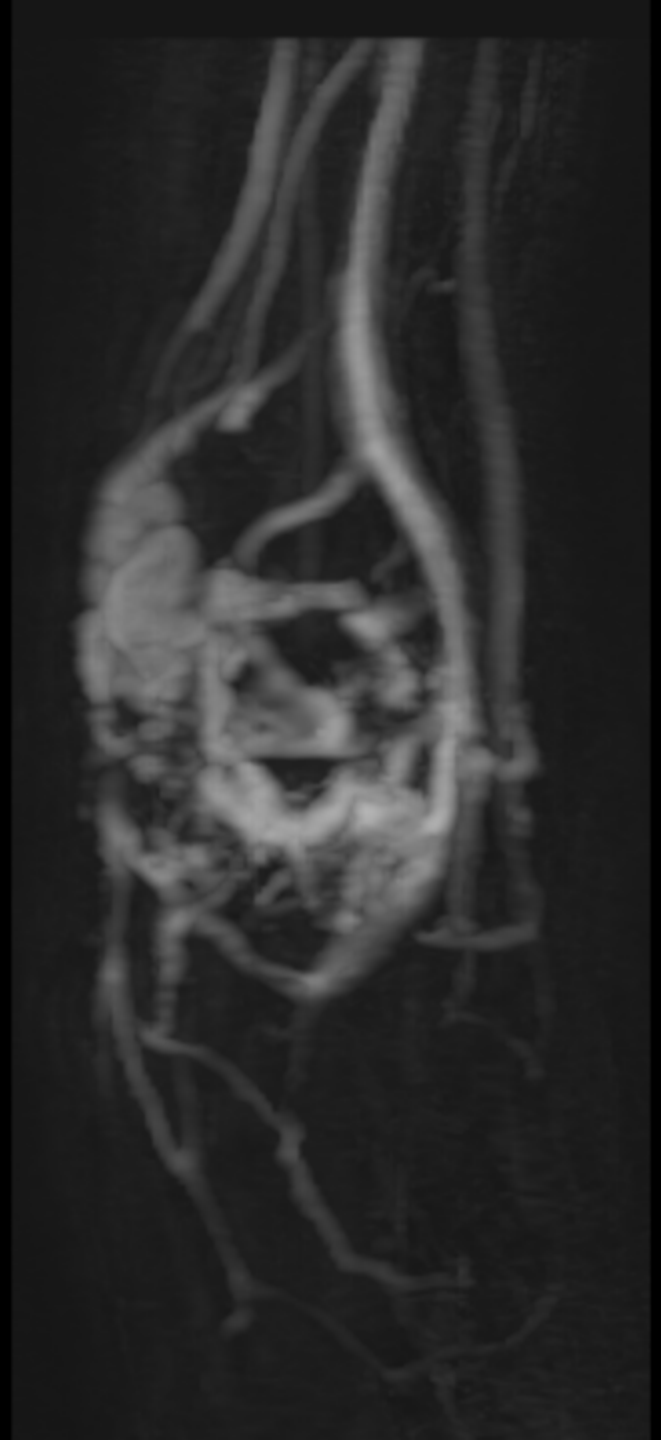


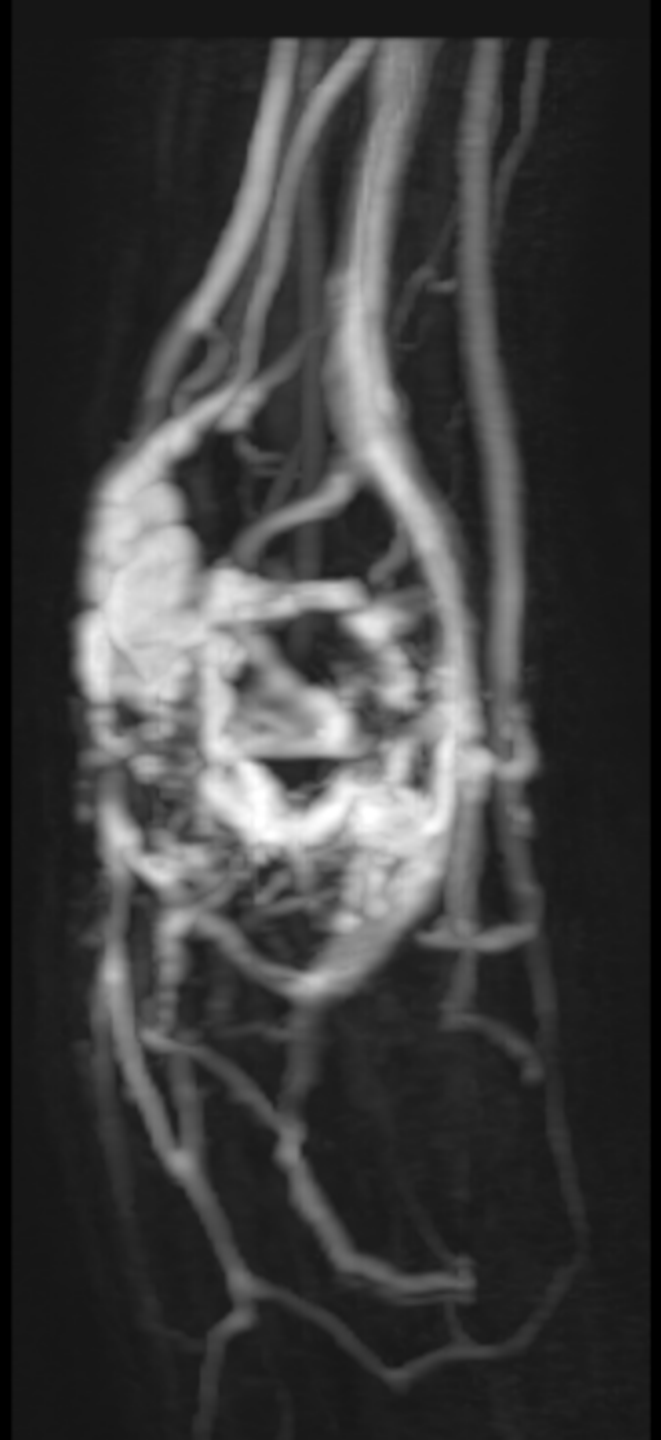


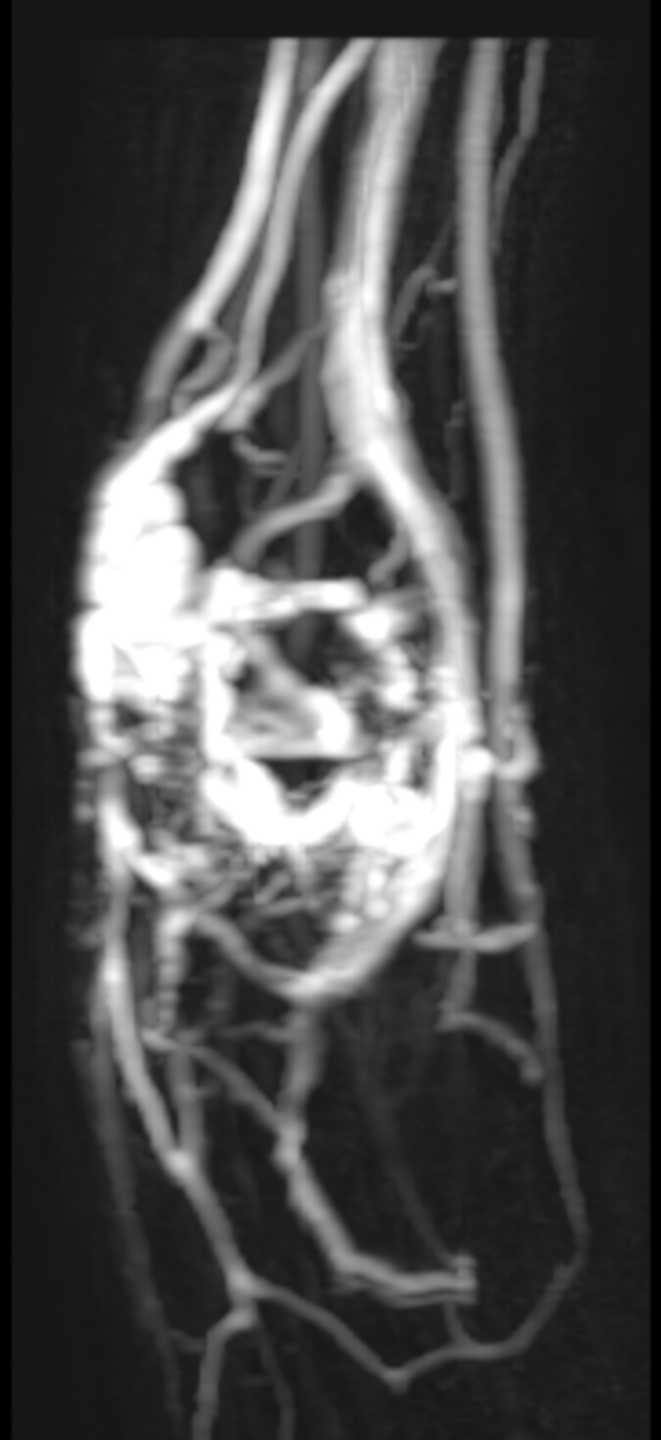


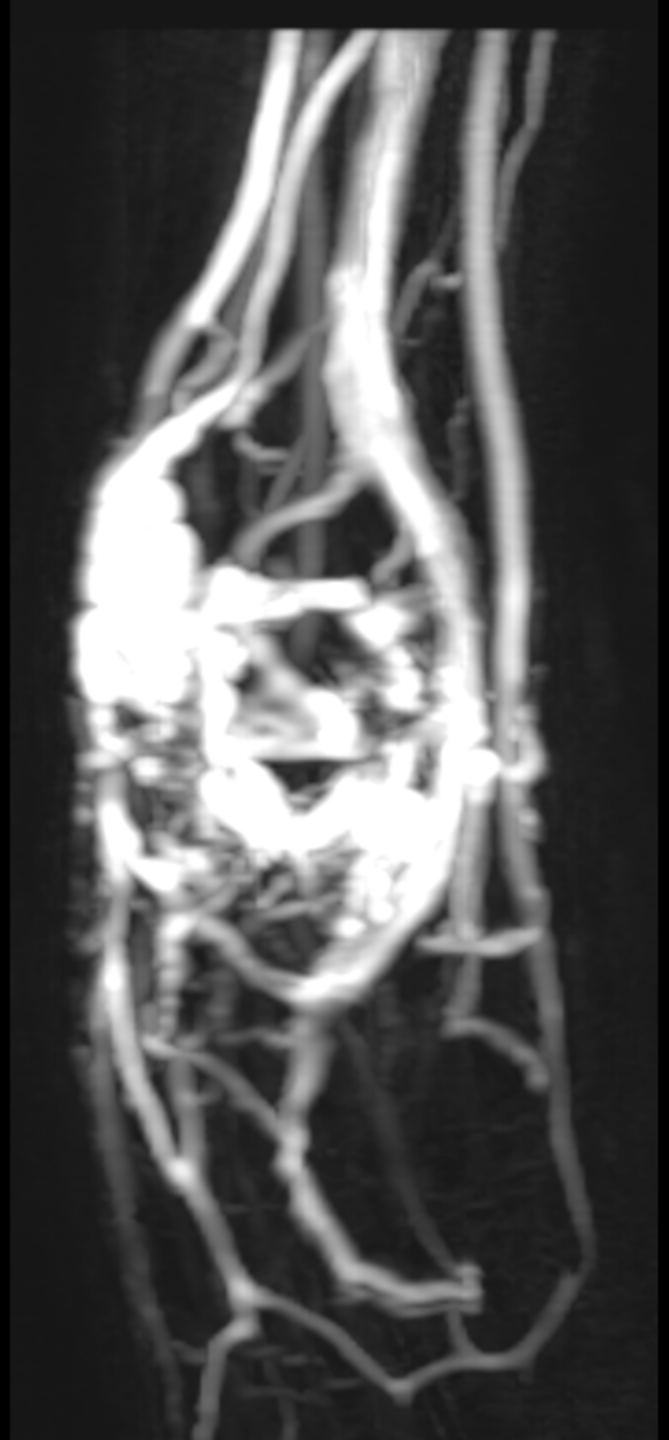


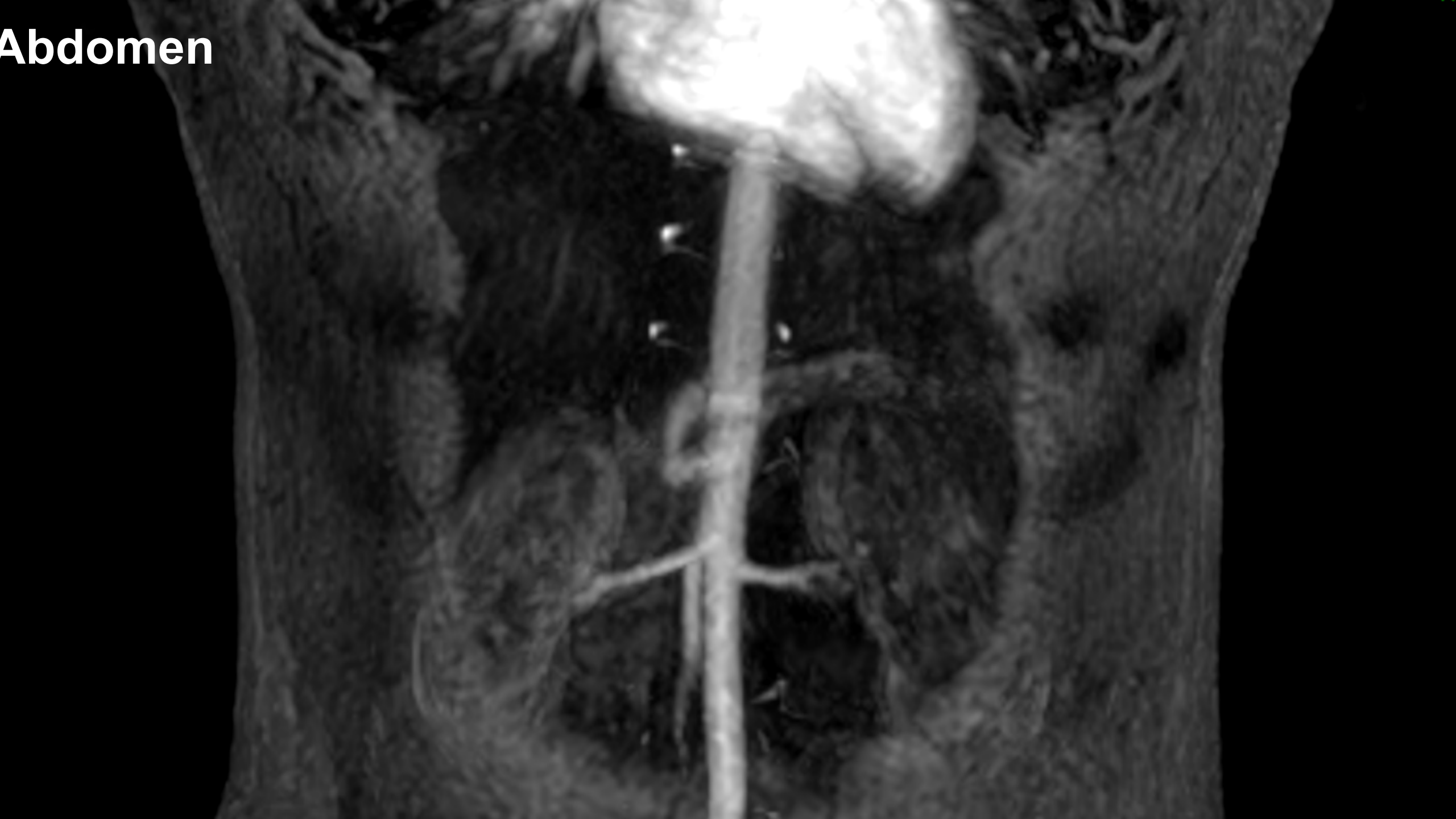











Abdomen

What the pediatric radiologist needs !

- Adapted environment / distraction techniques
- Noise reduction techniques
- Acceleration techniques
- Movement correction techniques
- Non invasive techniques : sequences without contrast
- Whole body imaging replacing X-rays techniques
- Dedicated coils…

- Thank you for you attention !