Cardiovascular CT & MR imaging

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Imaging in cardiovascular diagnosis

- Catheter or direct puncture angiography
  - » Classic invazive approach
- Ultrasound – Doppler methods
- CT – MR based methods

} Non-invazive approach

Advanced CT és MRI techniques in cardiovascular imaging

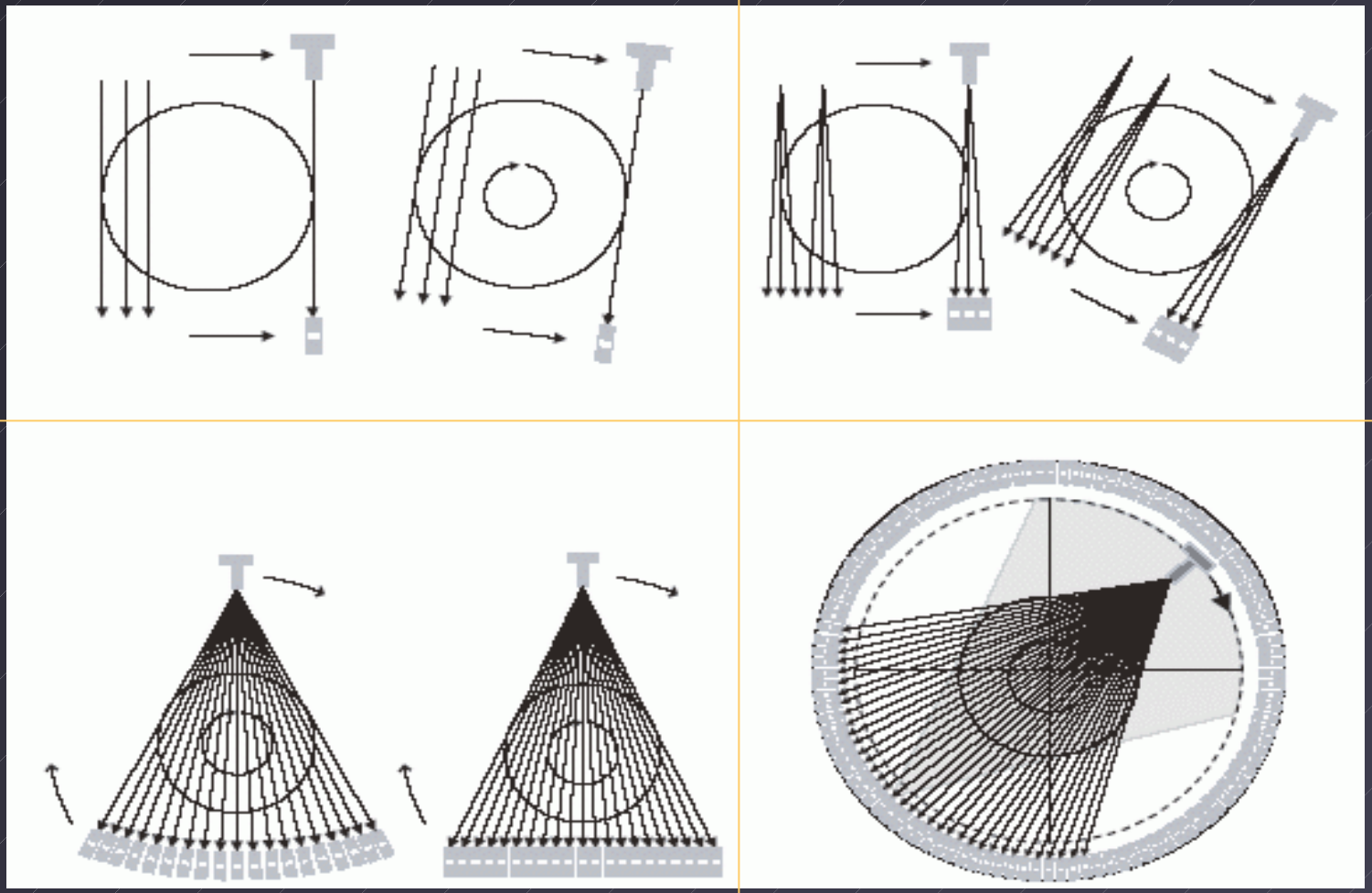
- Spiral CT-angiography
- ECG-gated cardio-CT
- MR-angiography
- ECG-triggered cardio-MR

CT

- Digital tomography using X-ray
- Based on differences of X-ray absorbtion in a given plane
- Conventional (outdated) technique
  - One slice – 2 - 4 sec
  - Whole study: 5 - 15 min
- Spiral (helical) CT
  - One slice– 1 - 1.5 sec
  - Whole study : 30 - 60 sec (+ preparation)
- Multidetector-row spiral CT (4-64 detector-row)
  - One slice– 0.4 - 1 sec
  - Whole study : 5 - 15 sec

CT generations

1.

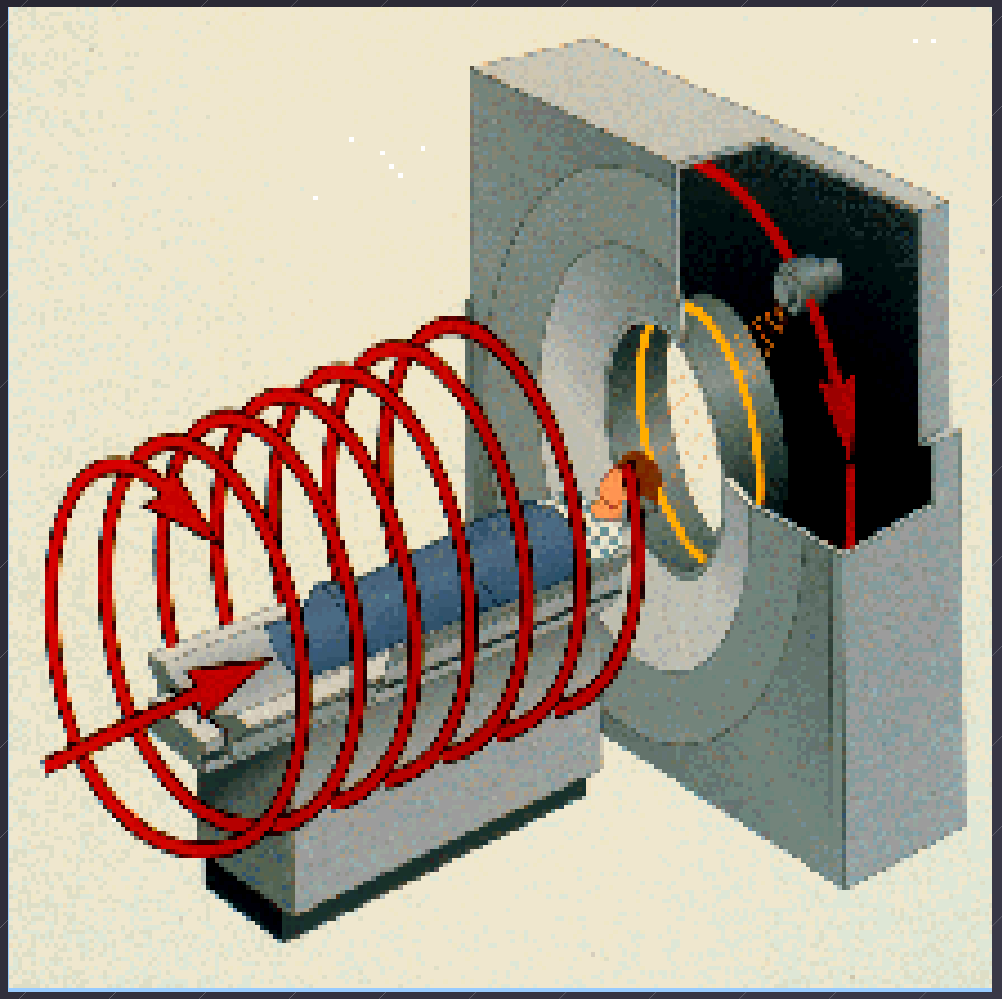


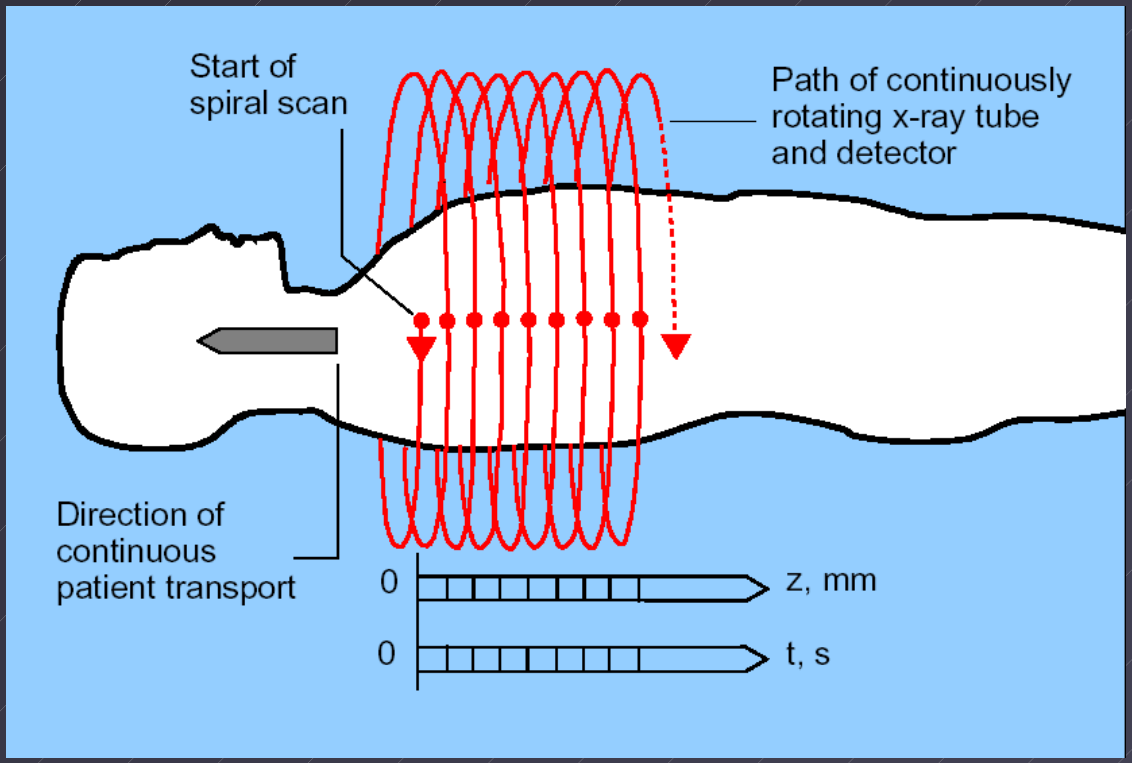
2.

3.

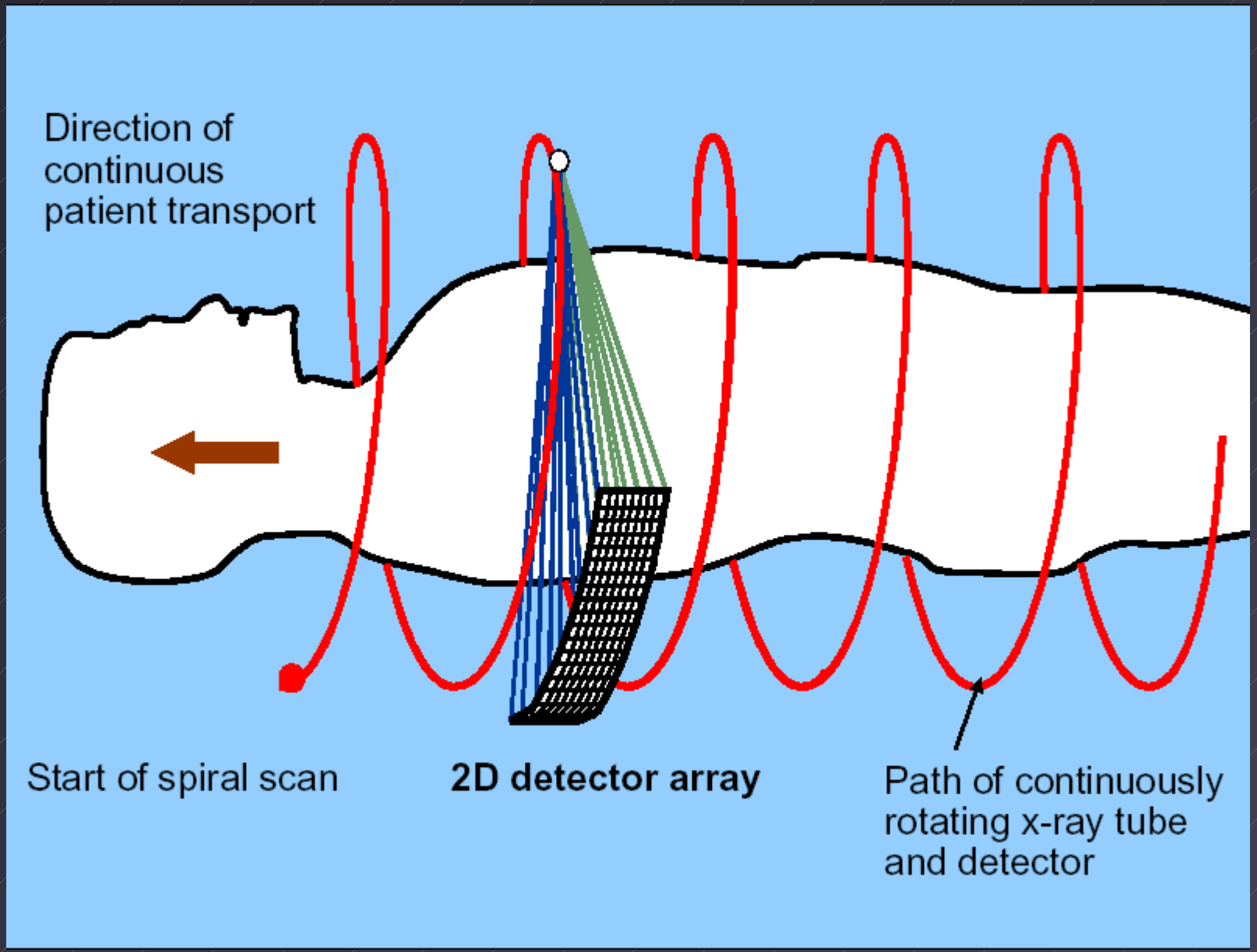
4.

Spiral (helical) CT





Multidetector-row spiral CT



Vascular imaging by CT

- Non-contrast CT (??) - pathologic mural calcification
- Contrast-enhanced CT
  - ”conventional” technique - aorta ($d \geq 1$ cm)
- Spiral CT-angiography
  - Single detector row spiral CT - branches of the aorta ($d \geq 2$-3 mm)
  - Multidetector row spiral CT - peripheral vessels ($d \geq 1$ mm)

Helical (spiral) - CT angiography

- *Dynamic administration of intravenous contrast material*
- *Scan-delay optimized for the selected circulation phase*
- *Helical scanning with thin collimation*
- *Post-processing of primary scan data*
  - *Multiplanar and 3D reformatted images resembling DSA*

CT (X-ray) contrast medium

- Water soluble macromolecule containing Iodine, mely akkumulációjának helyén megnöveli a röntgensugár elnyelést, ezáltal denzitás emelkedést okoz
  - Ionic – outdated (preferably not used since the early 90-s)
  - Non-ionic (monomer, or dimer low-osmolality)
- Excreted by the kidneys by glomerular filtration (nephrotropic)
- Applications: X-rax based imaging modalities
  - Excretory urography
  - Catheter angiography
  - CT
- Other iodinated cantast media
  - GI tract „absorbable” water soluble CM
  - Lipid based, lymphographic CM, currently used for selectiv chemoembolisation in tumor ablation
  - Biliary CM for i.v. cholangiography – not used any longer

Scanning parameters

- Collimation („slice thickness”)
  - Single slice CT: 3 - 5 mm
  - MDCT: 0.625 – 2.5 mm
- Pitch (collimation / table feed)
  - Single slice CT: 1 - 2
  - MDCT: 0.5 -1.3
- Scan delay according to the circulation time of the vascular territory in focus
  - Bolus detection
- Multi-phase study if necessary

Contrast administration

- Dose
  - Single slice CT: 2 – 2.5 cc/kgBW
  - MDCT: 1.5 – 2 cc/kgBW
- Automatic injection
  - 2.5 – 5 cc/sec
- Bolus detection
  - Test bolus
  - Automatic detection
  - Visual control

MRI

- Digital tomography using strong magnetic field and radiofrequency excitations
- Image formation is influenced by numerous physical and physiological parameters, eg.: water/fat/protein content, magnetic characteristics, solid/fluid state, temperature …etc.
- Different examination parameters result in image stacks of different character (sequences), e.g.: T1, T2 weighted, fat supressed, flow sensitive …etc.
- „Rutine" examination
  - 3-4 sequences, 1-8 minutes each
  - Examination time: 15-30 minutes (+ preparation)
- Complex examination (+ contrast medium, MRA …)
  - 6-8 sequences, 1-10 minutes each
  - Examination time : 30-60 minutes (+ preparation)

MR angiography 1.: Without contrast material

2D / 3D sequences based on the magnetic characteristics of flowing blood

3. *"time of flight " or TOF*

short repetition time results in the saturation of stationary tissues; signal is generated only by the unsaturated spins in the blood entering the examination plane (inflow effect)

e.g..: high spatial resolution 3D imaging ofz intracranial arteries

- *"phase contrast" or PC*

flow (depending on its direction and velocity) changes the phase of precessing spins - *flow direction* - *flow velocity* } *can be determined*

MR angiography 2.: With contrast material

Contrast-enhanced MRA (CE-MRA) :

sequences based on the marked T1 shortening effect of paramagnetic Gadolinium

- *Dynamic administration of intravenous contrast material (Gd)*
- *Scan-delay optimized for the selected circulation phase*
- *3D acquisition by special rapid sequences (spoiled gradient echo)*
- *Post-processing of primary scan data: Multiplanar and 3D reformatted images resembling DSA*

MR contrast medium

- Chelate containing paramagnetic Gadolinium: imaging effect is based on T1 and T2 relaxation time shortening
- Distribution in tissues and excretion is analogous with Iodine containing X-ray contrast materials
- Not nephrotoxic !
- Allergyform or vegetative side effects are extremely rare

- „Blood pool" contrast material – under clinical introduction

Post-processing

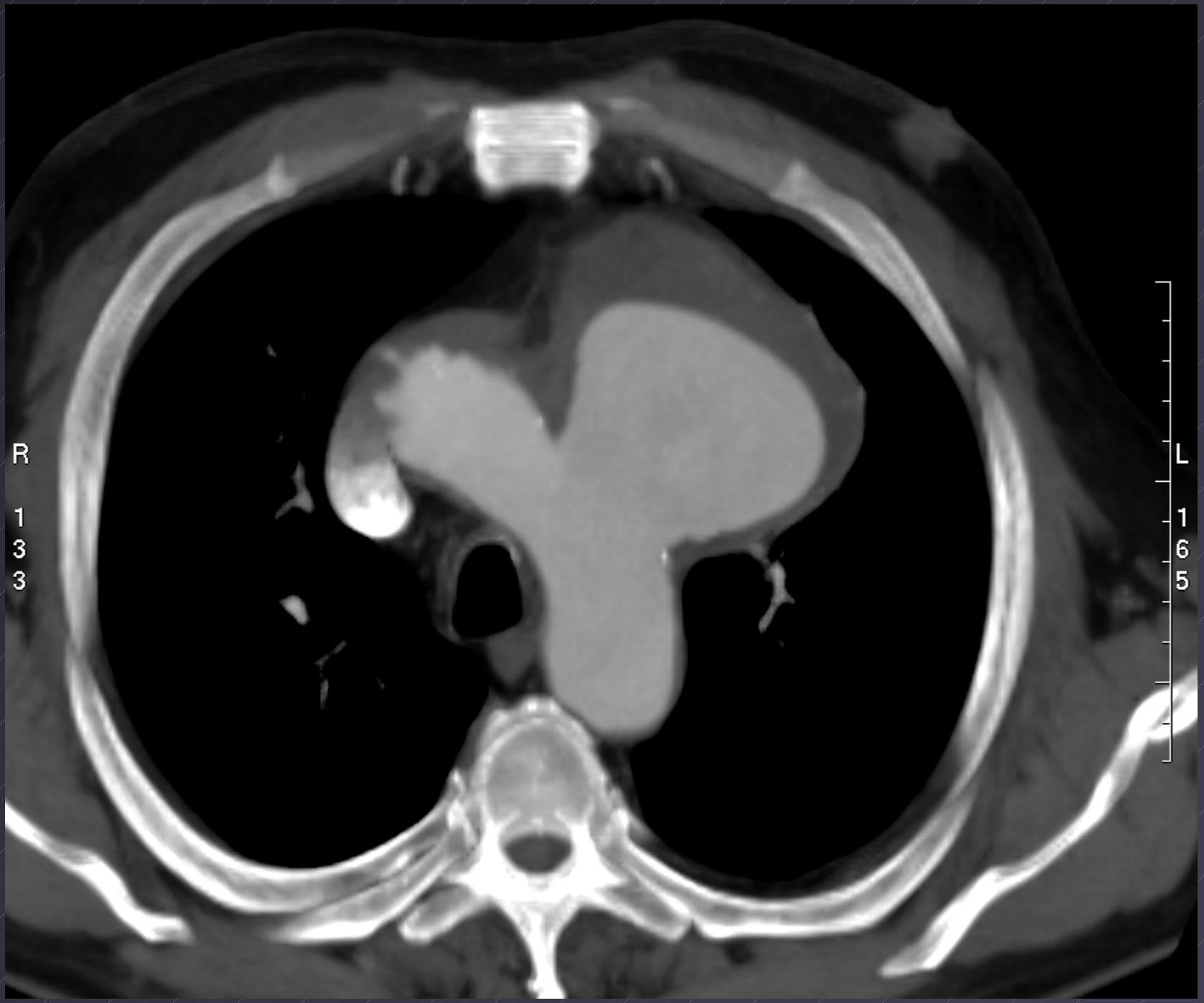
- Retrospective reconstruction of overlapping slices from helical raw data (if necessary)
- 2D reformatted images
  - multiplanar (MPR)
  - curved (along the course of vessels)
- 3D reformatted images
  - maximum intensity projection (MIP)
  - volume rendering (VR)
  - shaded surface display (SSD)
- Semi-automatic analysis program
  - stenosis quantification based on diameter and/or cross-sectional area reduction mesurement

Evaluation

- Primary (overlapping) slices
- MIP
  - » DSA-like demonstration of global vascular anatomy
  - » „slab MIP” - célzott ábrázolás, stenosis analysis
- MPR, CR
  - » stenosis / plaque analysis
- Volume Rendering (VR)
  - » complex anatomy
  - » vessels / bones / parenchymal organs
- 3D SSD
  - » Vessels + bones

Indications of CTA – MRA

- Thoraco-abdominal aortic aneurysm
  - Primary assessment (diameters, lenghth, neck, origin of branches, thrombus, signs of imminent rupture, vessel wall thickness…)
  - Follow-up – growth ?
  - Postoperative follow-up
- Aortic dissection
  - Acute: type A or B típusú?, side branches ?
  - Follow-up after operative / conservative treatment
- Stent-graft implantation
  - Before: sizing
  - After: endoleak ?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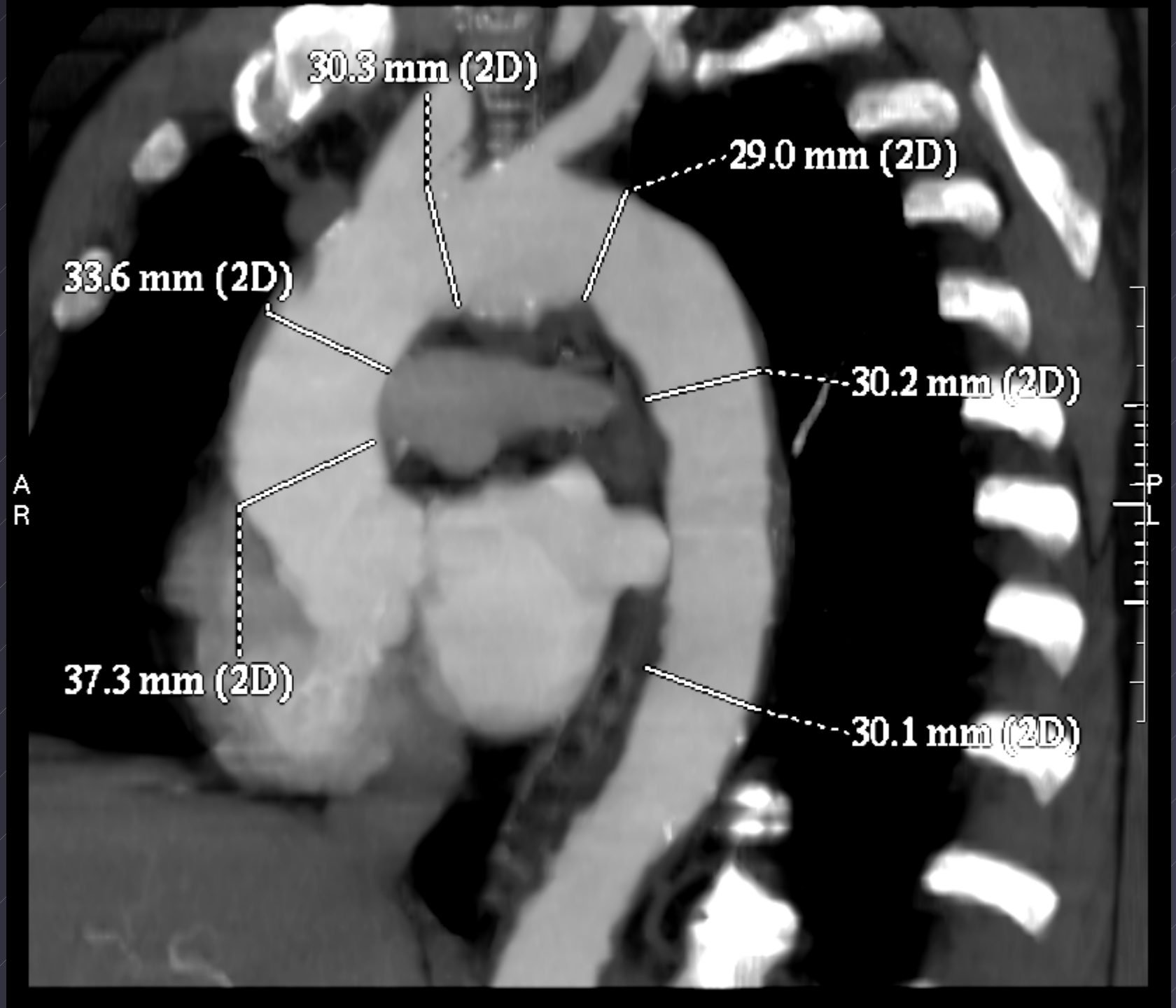
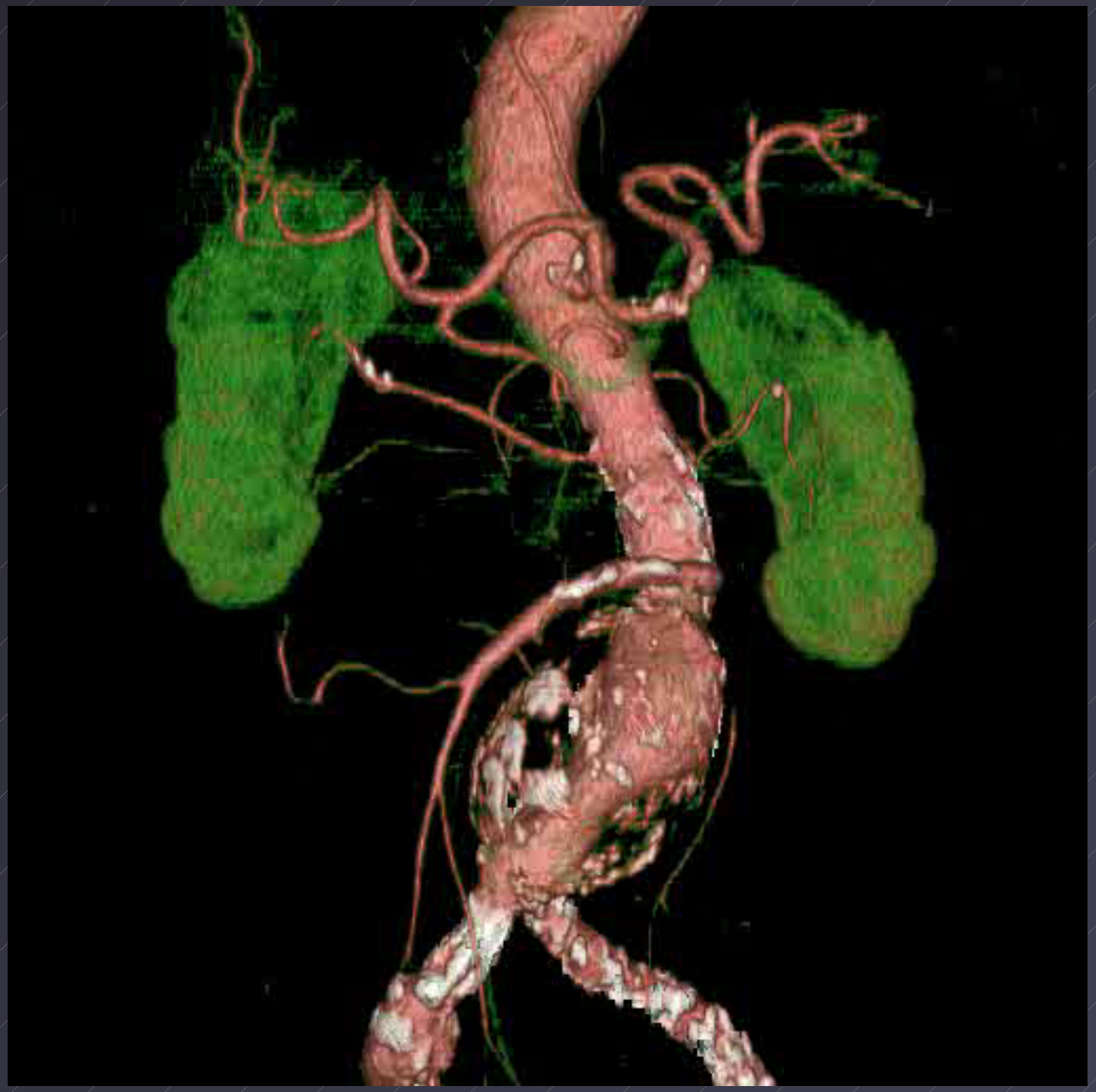
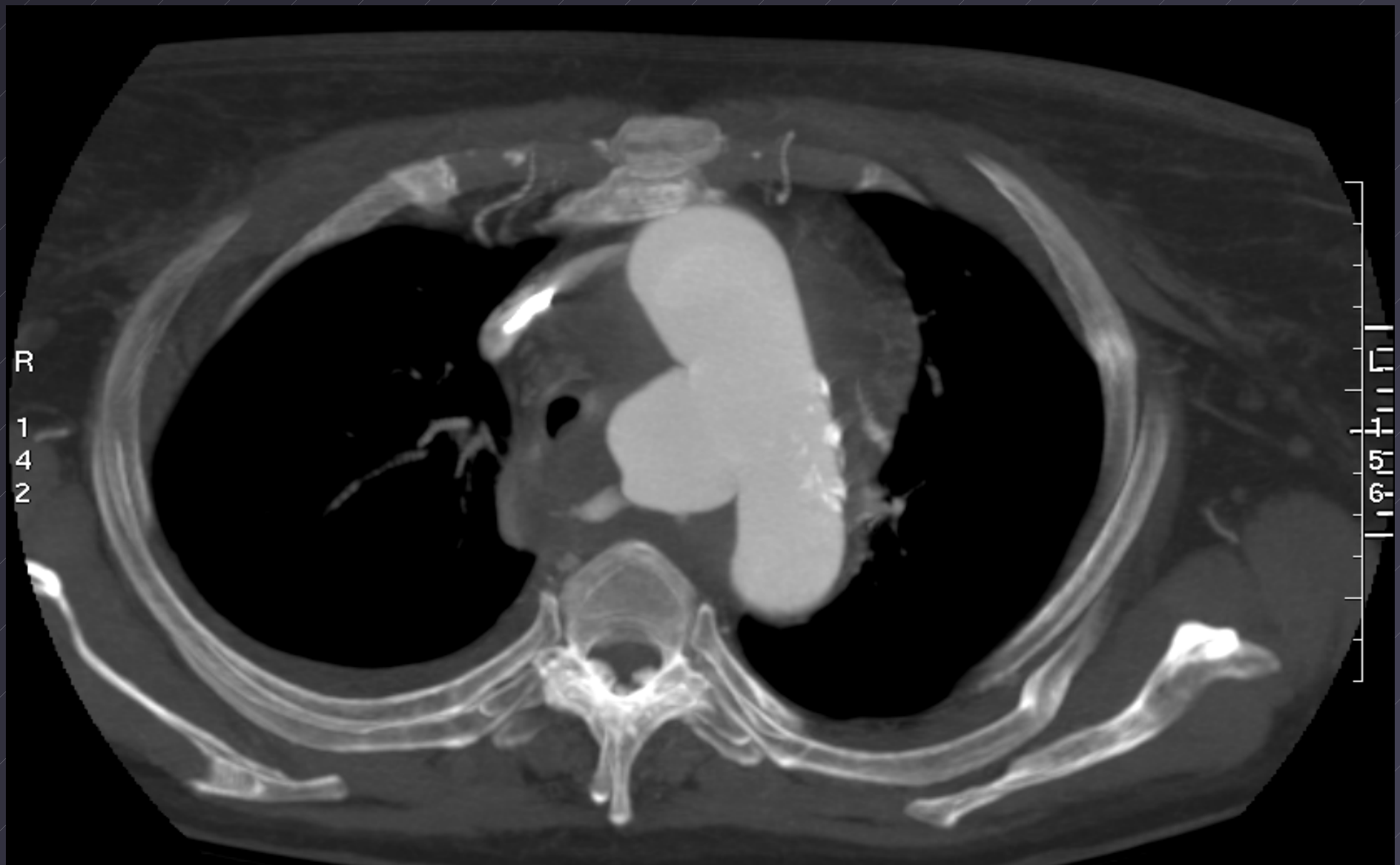
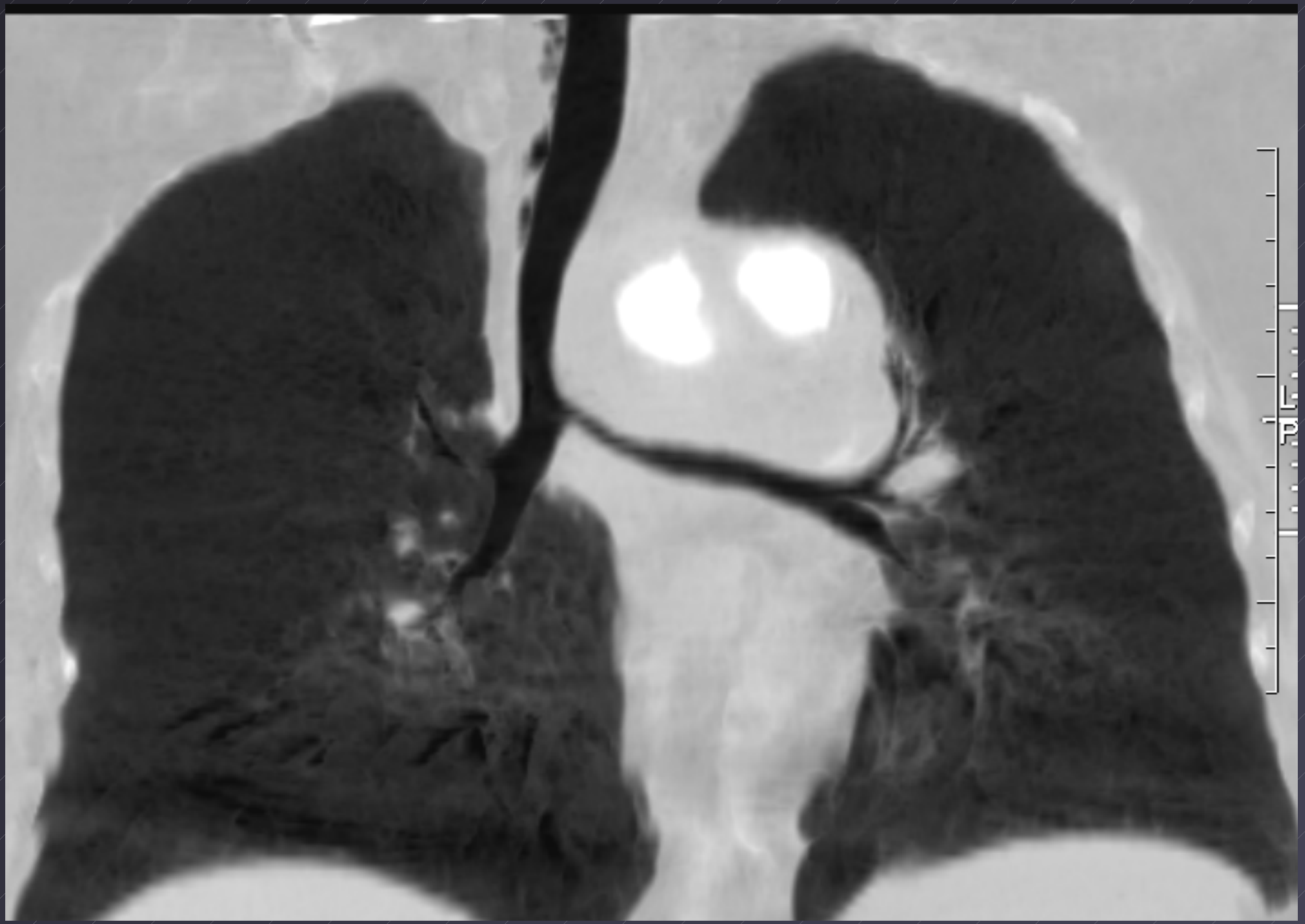

30.3 mm (2D)
29.0 mm (2D)
33.6 mm (2D)
30.2 mm (2D)
A
R
P
L
37.3 mm (2D)
30.1 mm (2D)

Subrenal AAA – CTA volume rendering

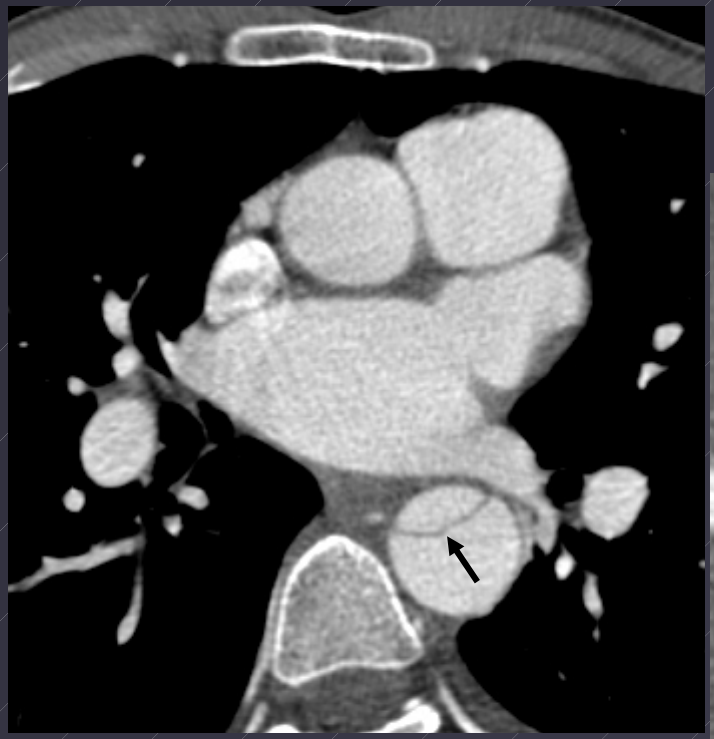


Aortic arch aneurysm rupture + aorto-oesophageal fistula

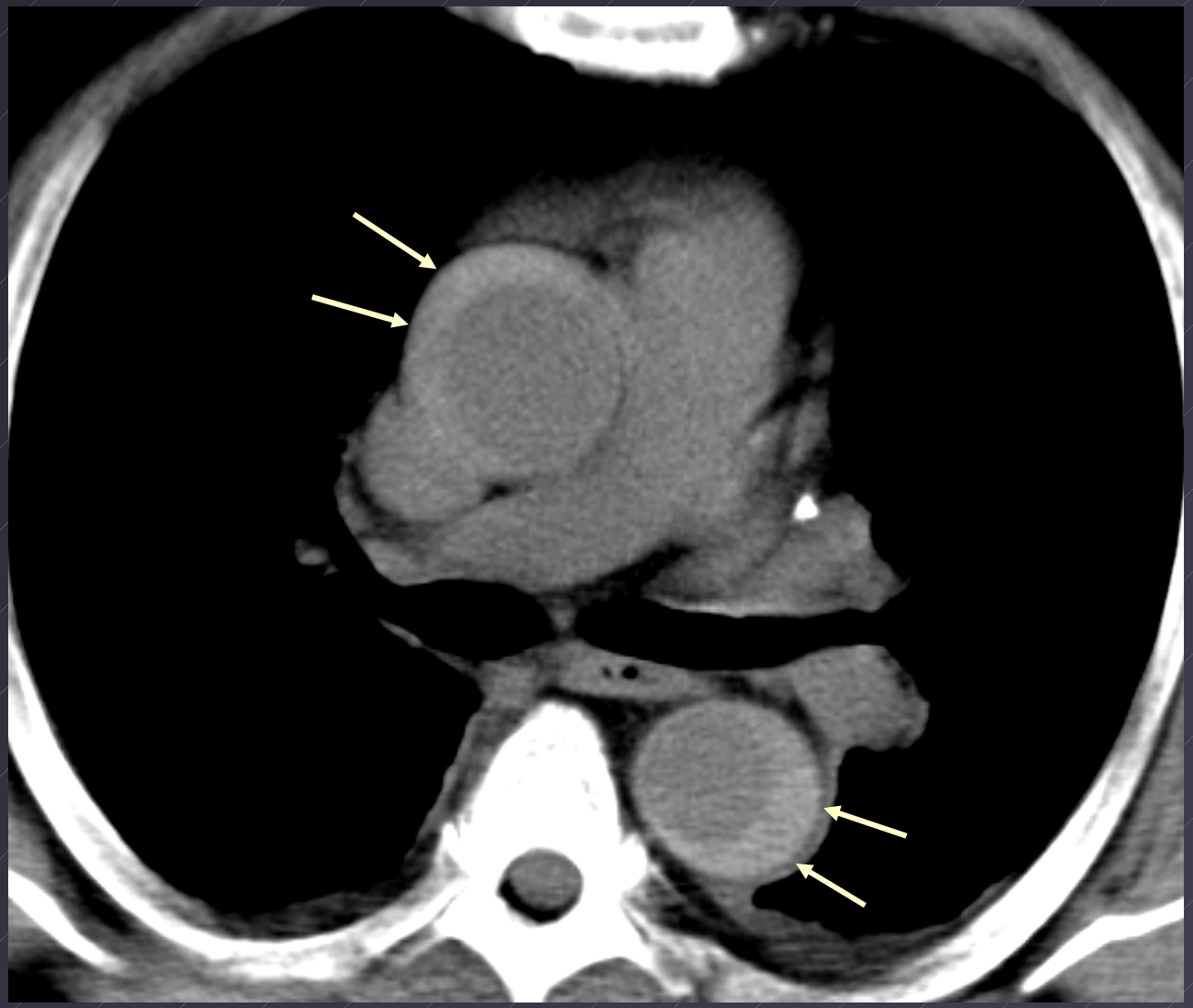




Aortic dissection type B

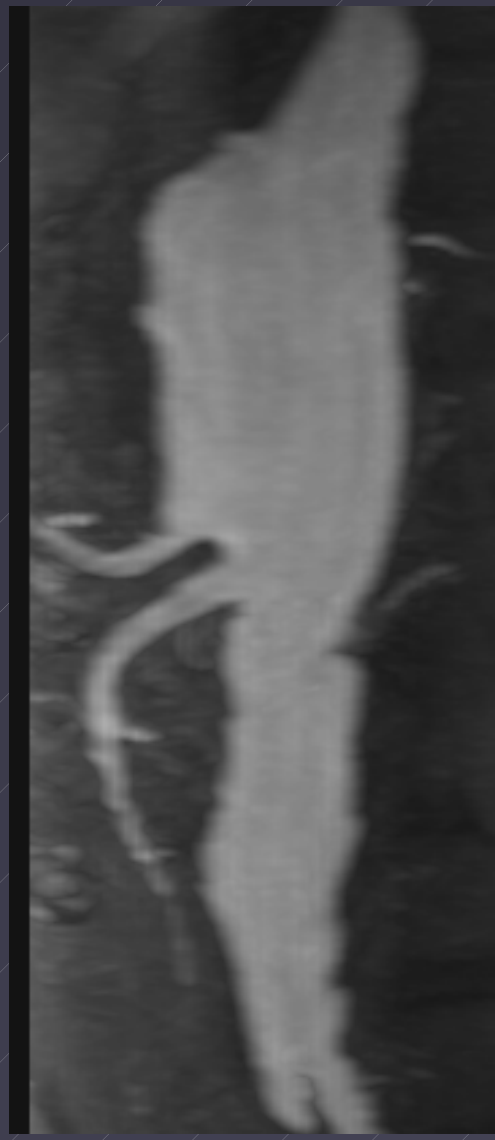


Intramural hematoma – non-contrast CT

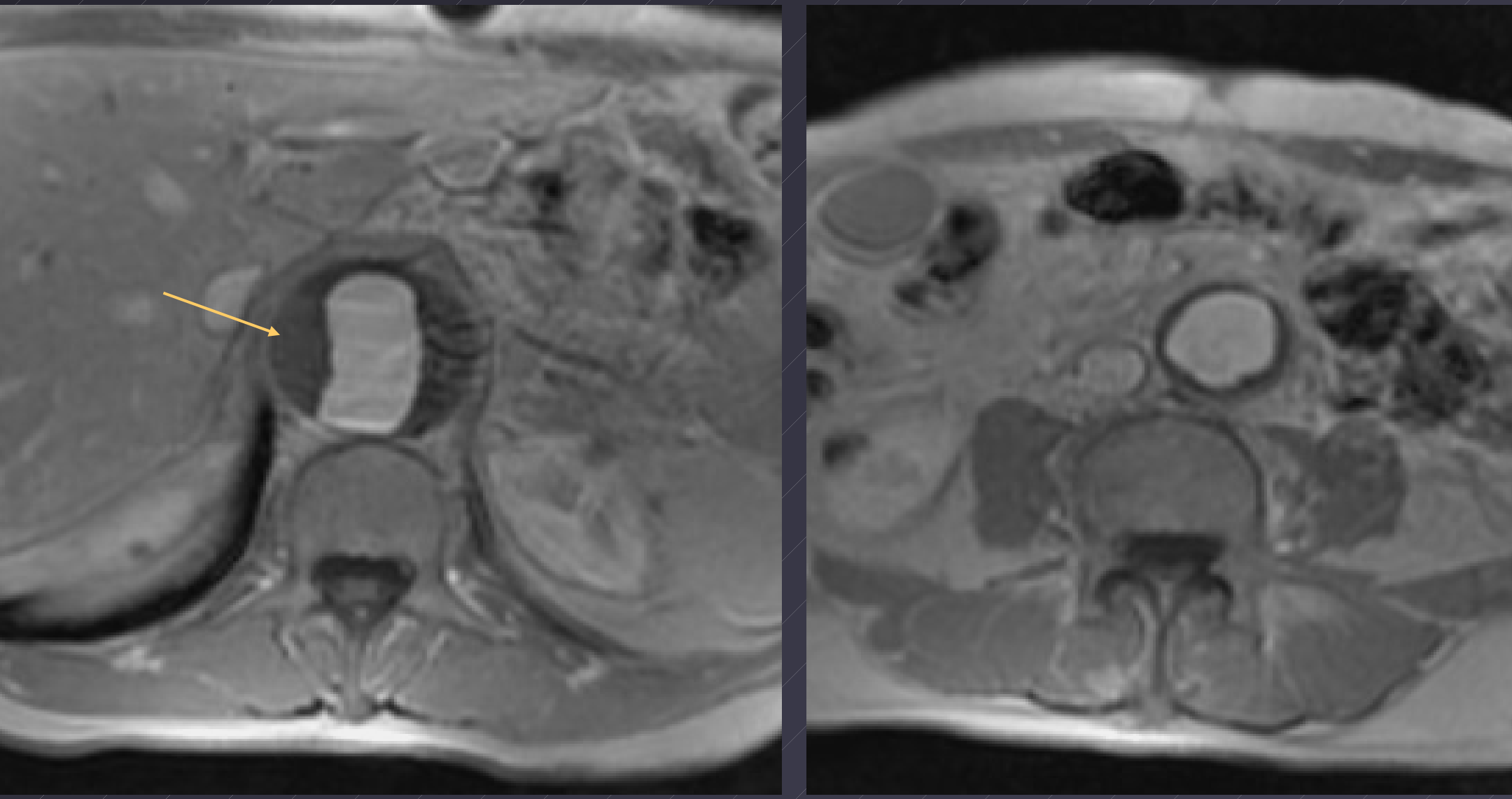


Intramurali hematoma – contrast-enhanced CT

Thoraco-abdominal aortic aneurysm – contrast-enhanced MRA

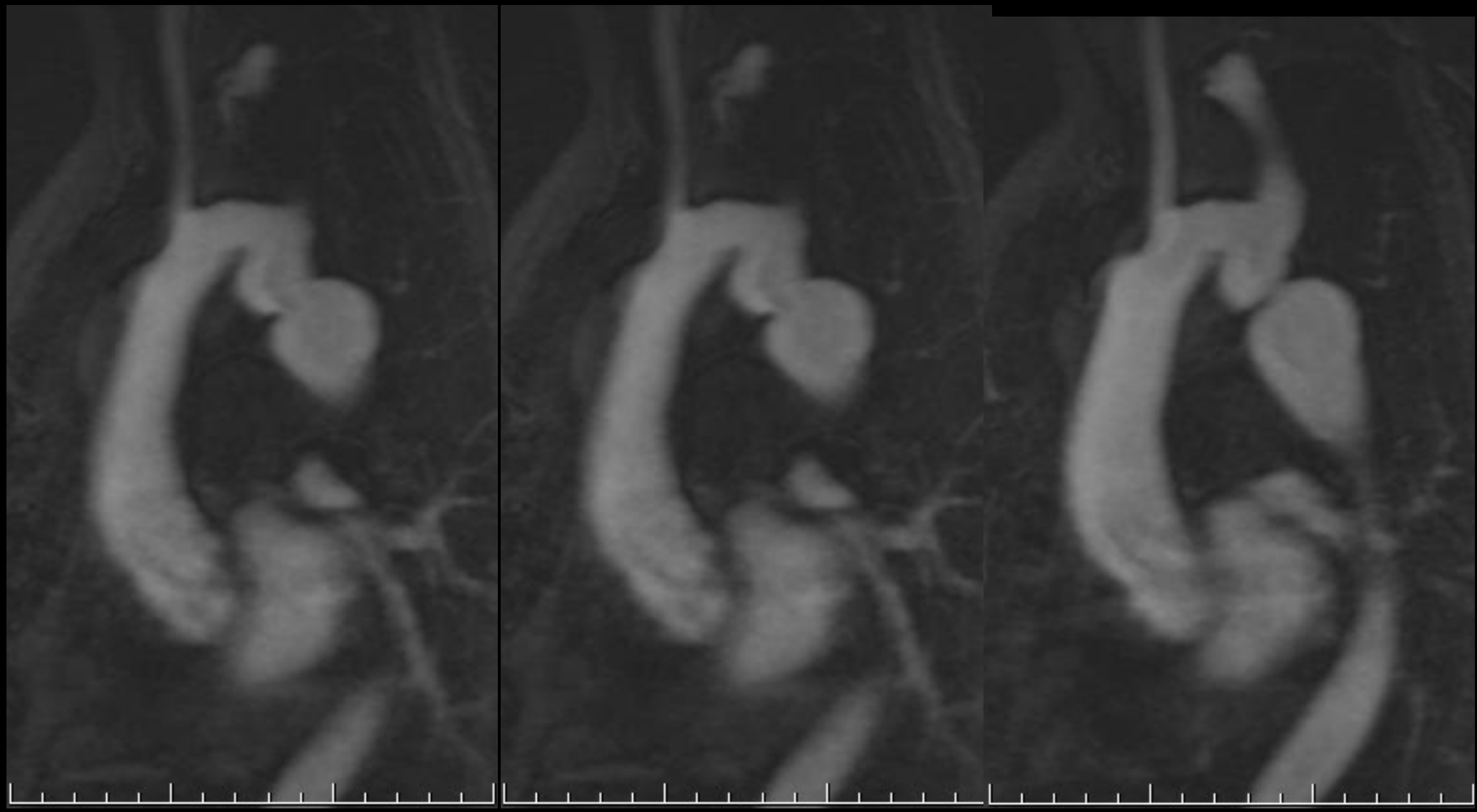


Axial post-Gd T1 – intraluminal thrombus

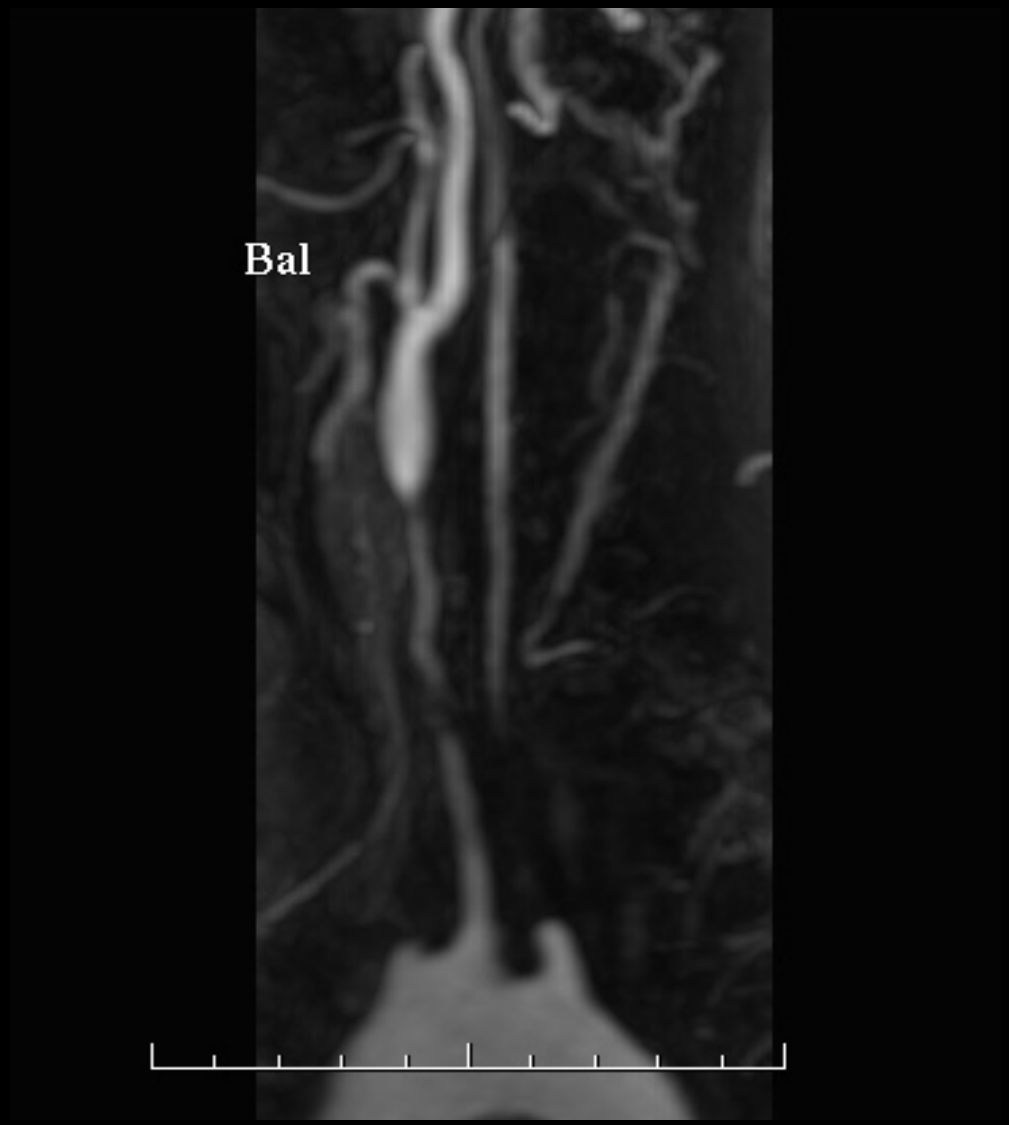


Aortic coarctation - postoperative state

CE-MRA parasagittal MPR series



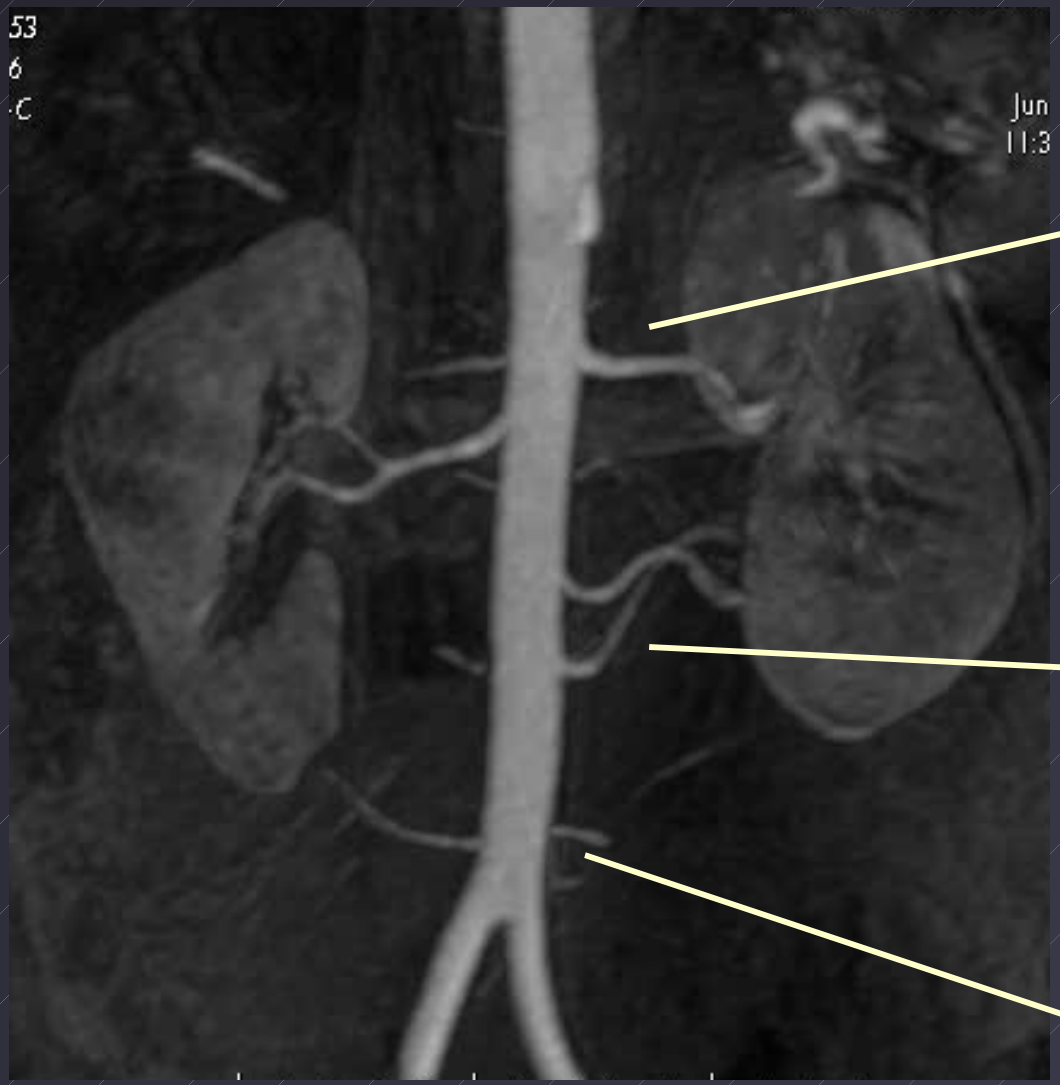
Takayasu arteritis: aortic arch CE-MRA



Indications of CTA – MRA

- Renal arteries – renovascular hypertension ?
  - » Clinical suspicion of RAS with equivocal examination results (clinical data / US / nuclear medicine)
  - » After catheter angiography: complex anatomy
  - » AAA +/- RAS ?
  - » post-operative / stent follow-up

Bilateral multiple renal arteries

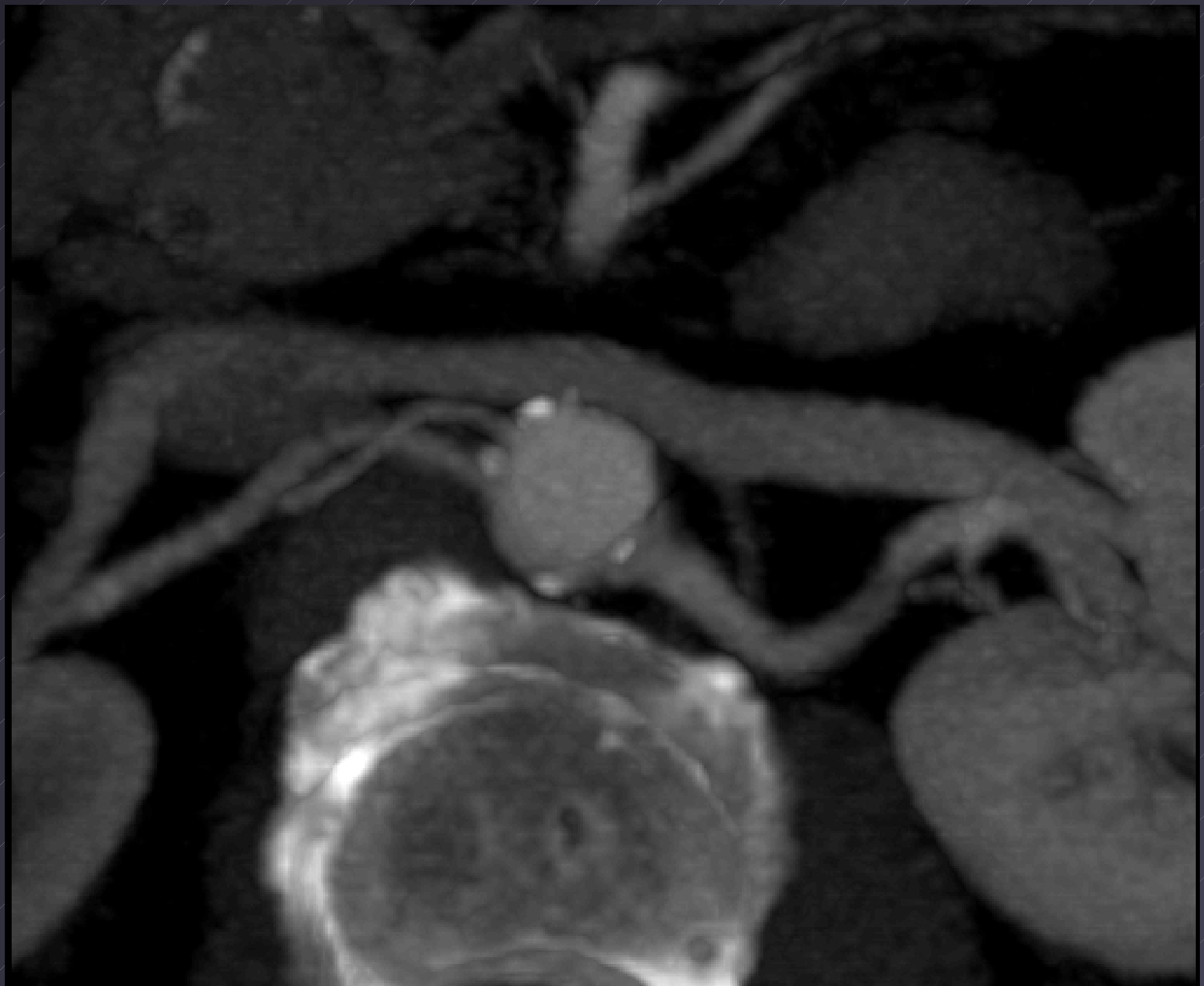


Renal artery stenosis

CE-MRA

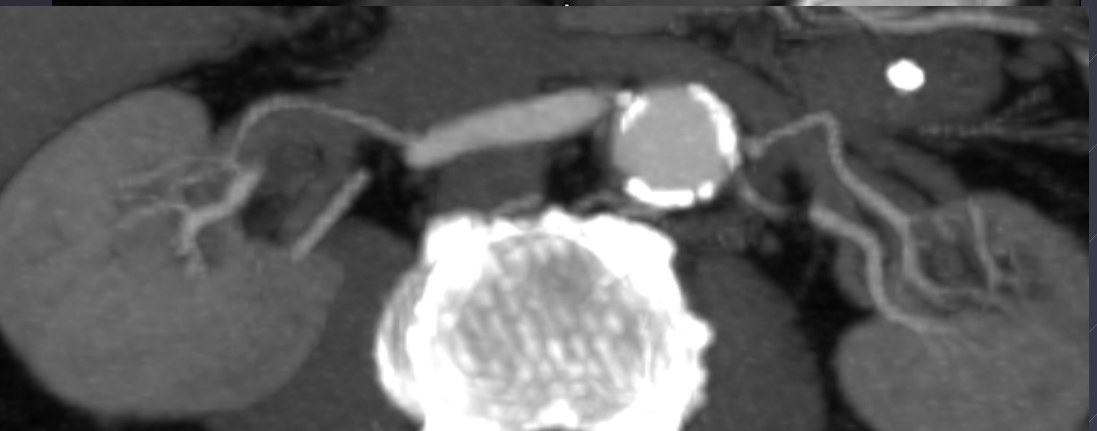
Multiple renal arteries

CTA by single detector-row spiral CT



RAS

CTA by 8 detector-row spiral CT

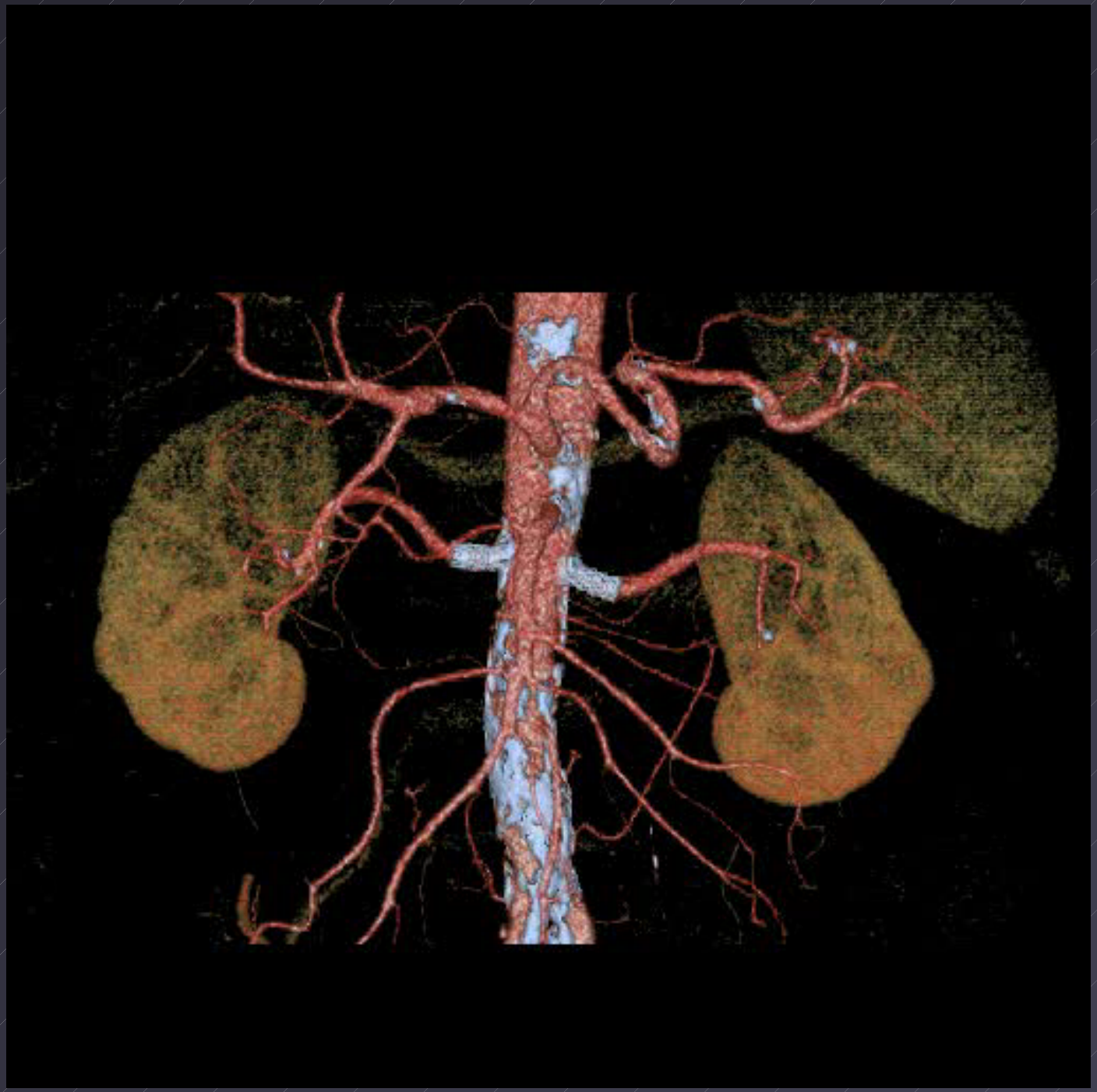


Renal artery aneurysm

CTA by 8 detector-row spiral CT


3D
SPR
Volume Rendering No cut
DFOV 13.0 cm
R
A
S
L
P
I
No VOI
W = 1330 L = 420
IAL

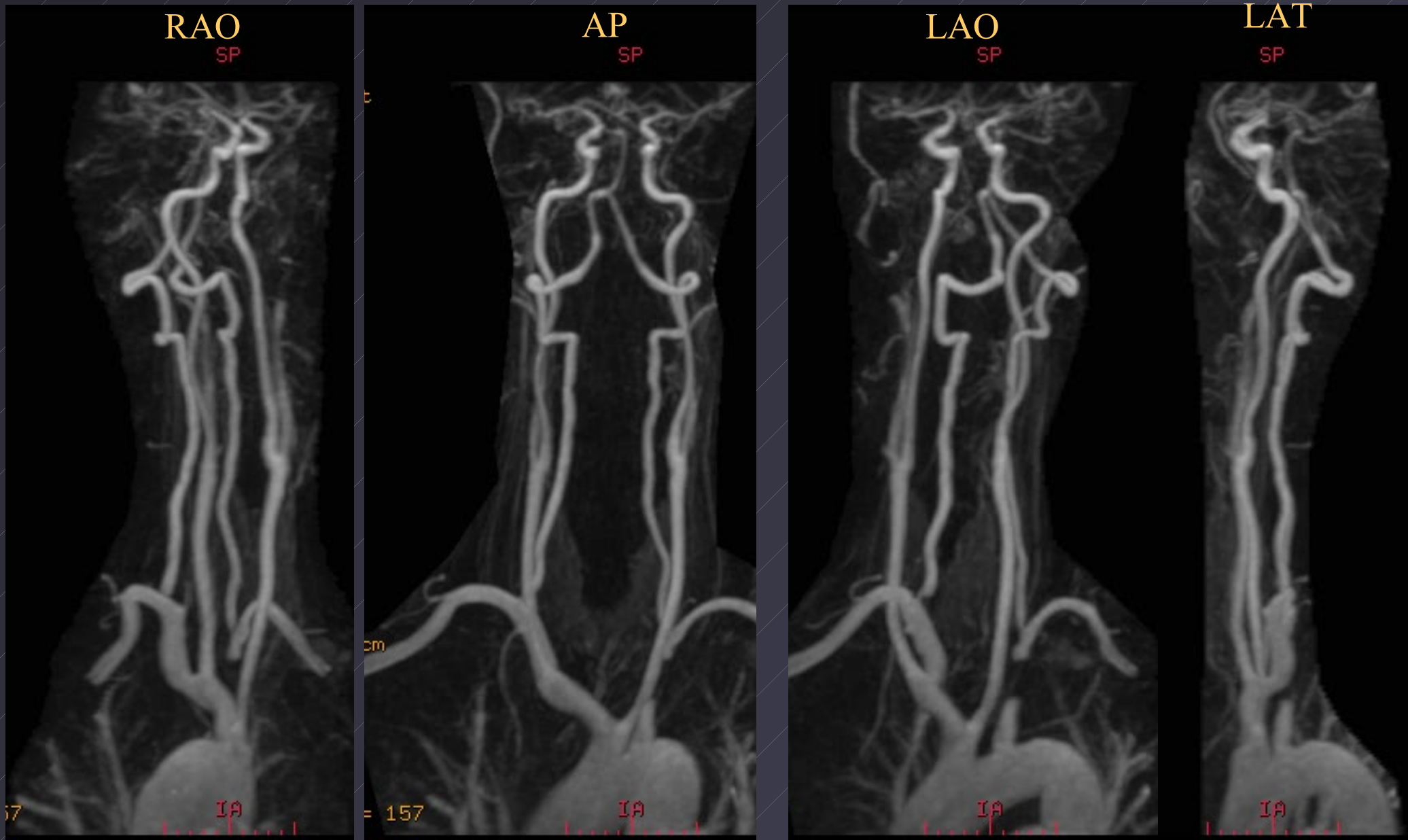
Bilateral renal artery stent: CTA „curved” reformation



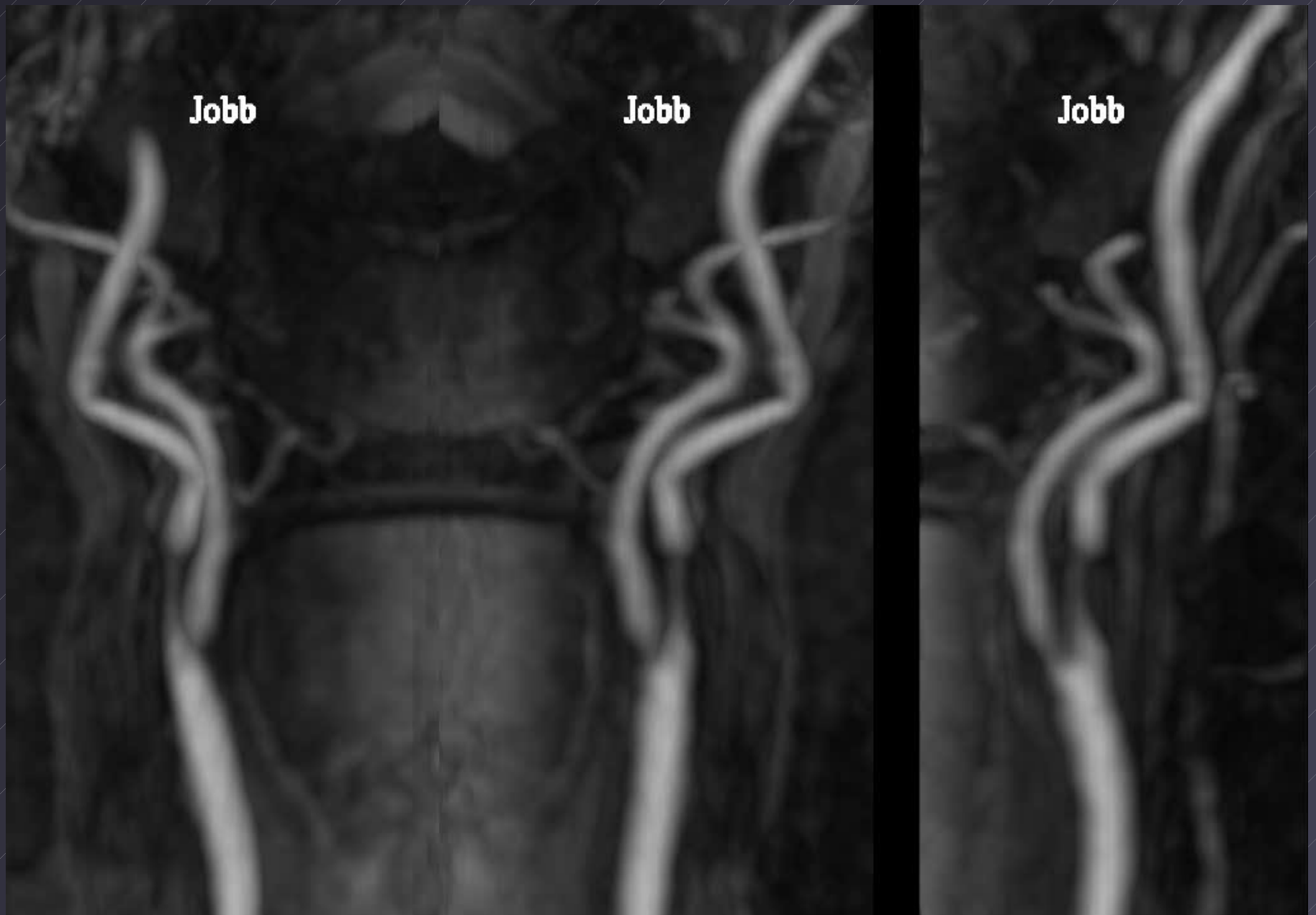
Indications of CTA – MRA

- Cerebrovascular system – carotid stenosis ?
  - » Based on duplex ultrasound result, for preoperative evaluation (as an alternative of DSA)
  - » If duplex US is of limited value
    - tortuos carotid system
    - contralateral occlusion
    - postoperative (endarterectomy) condition

CE-MRA study of the supraaortic arteries:
Multiangle MIP renderings



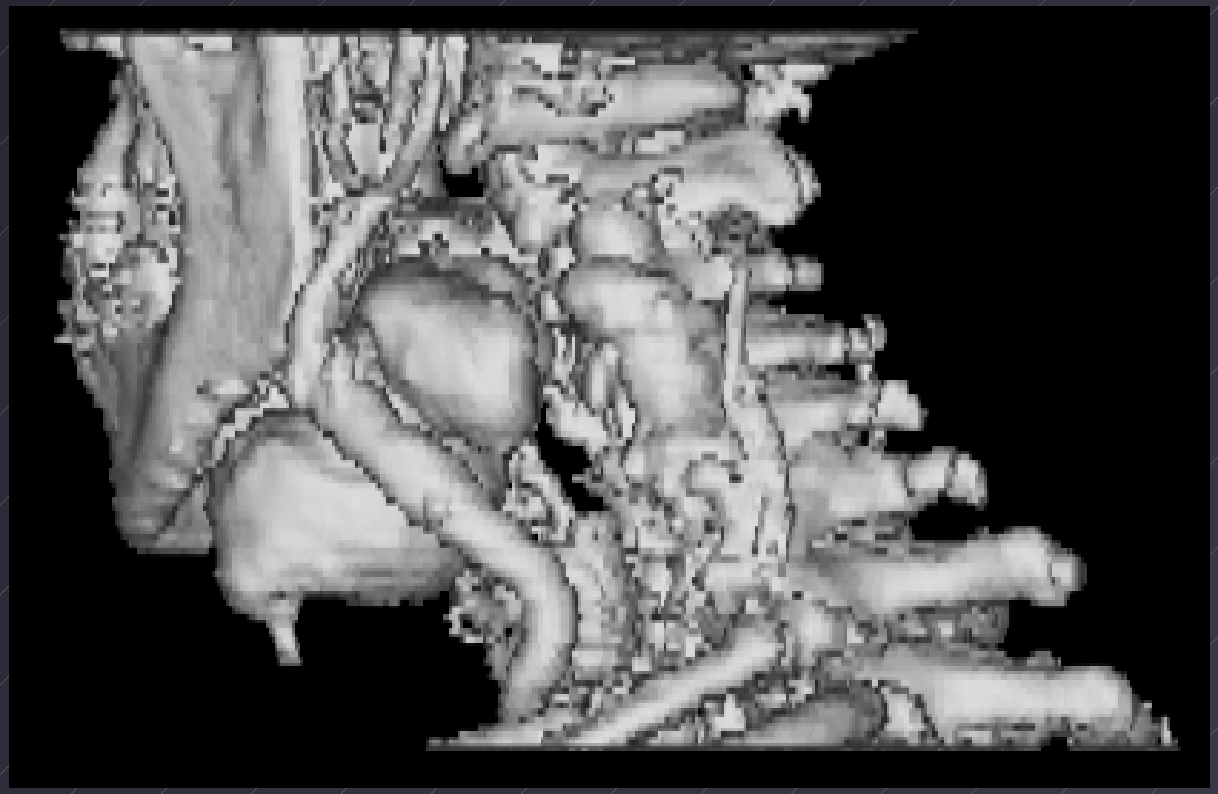
ICA stenosis:
Thick slab (20 mm) MIP

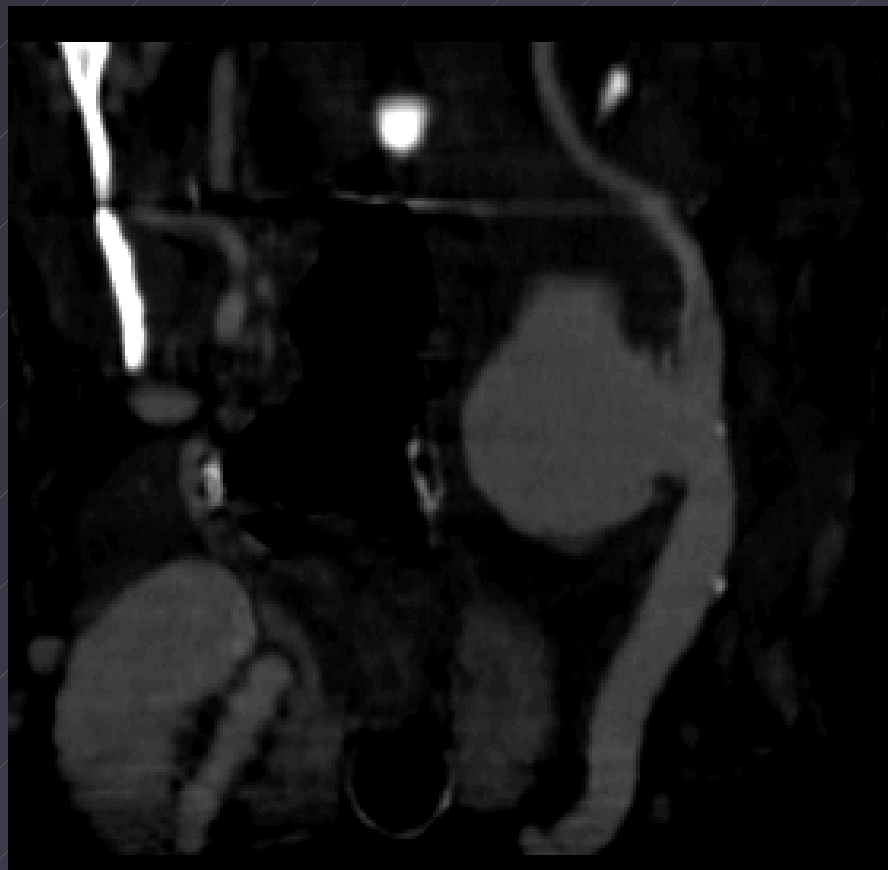


ICA stenosis:
Thin slab (5 mm) MIP

CCA pseudoaneurysm

CTA by single detector-row spiral CT

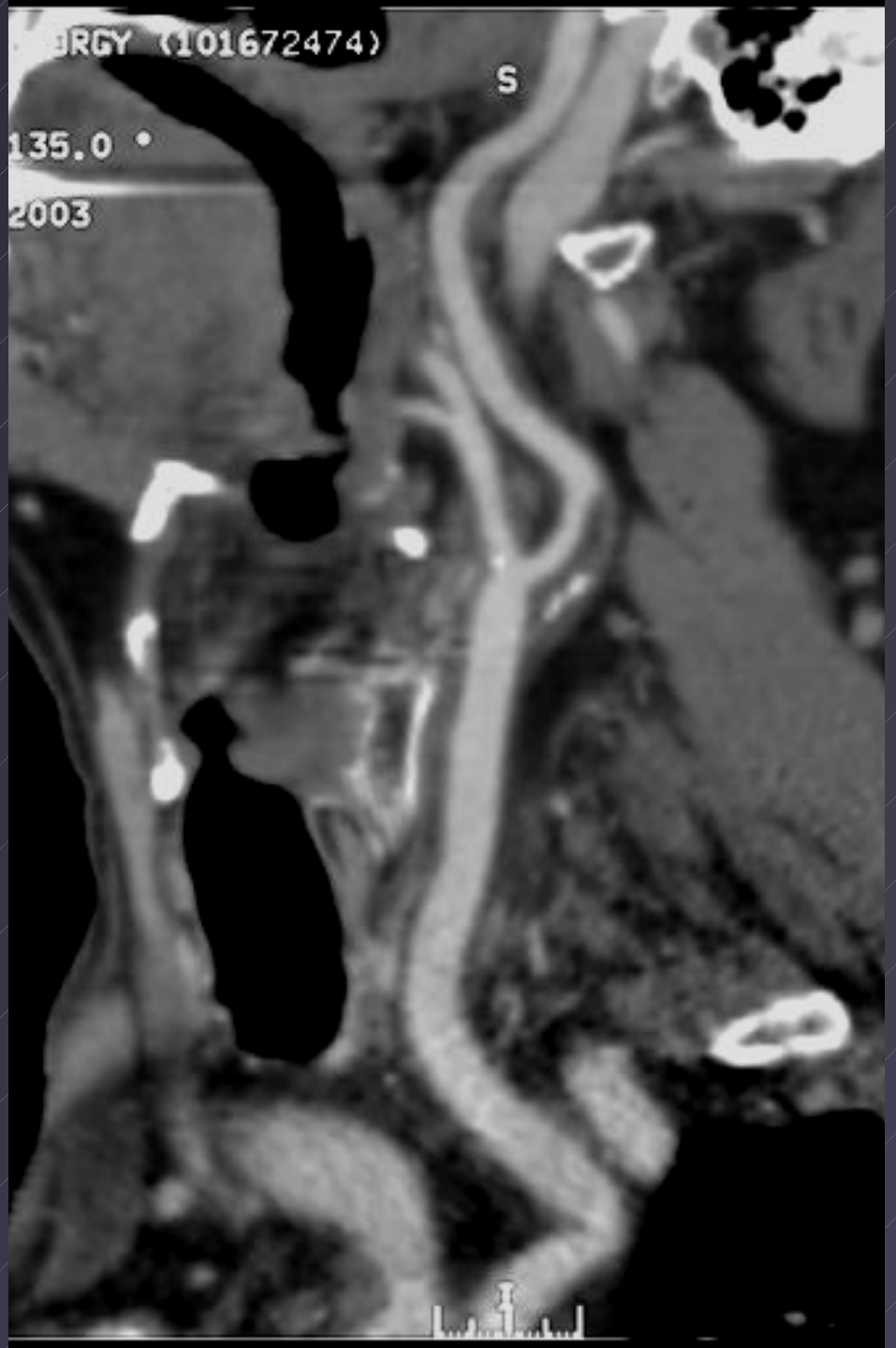




ICA stenosis

CTA by 8 detector-row spiral CT

(curved reformation, generated by semiautomatic analysis program)



Indications of CTA – MRA

- Pulmonary embolism
  - » CTA is the imaging modality of choice when the clinical suspicion of acute PE or chronic pulmonary thrombo-embolis disease arises
  - » MRA (only with the most advanced examination technique) is an alternative

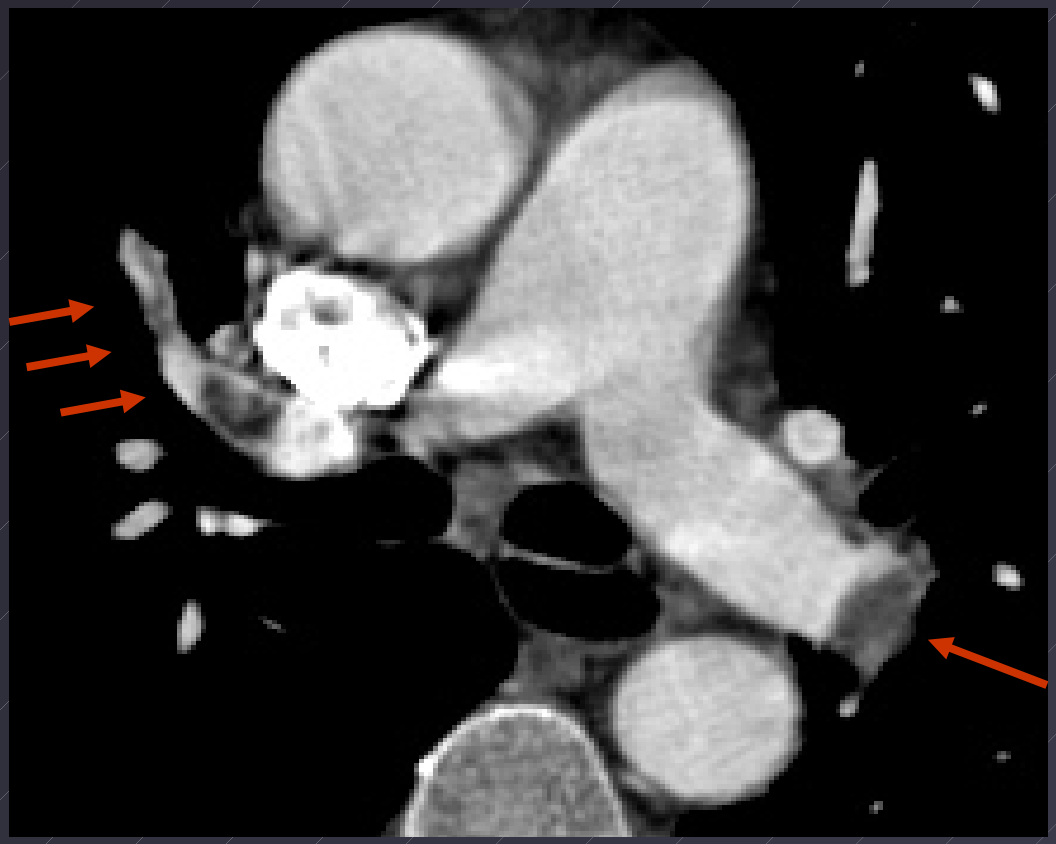
Acute PE

CTA by single detector-row spiral CT

Acute PE before and after thrombolysis

CTA by 8 detector-row spiral CT

2004.07.07.



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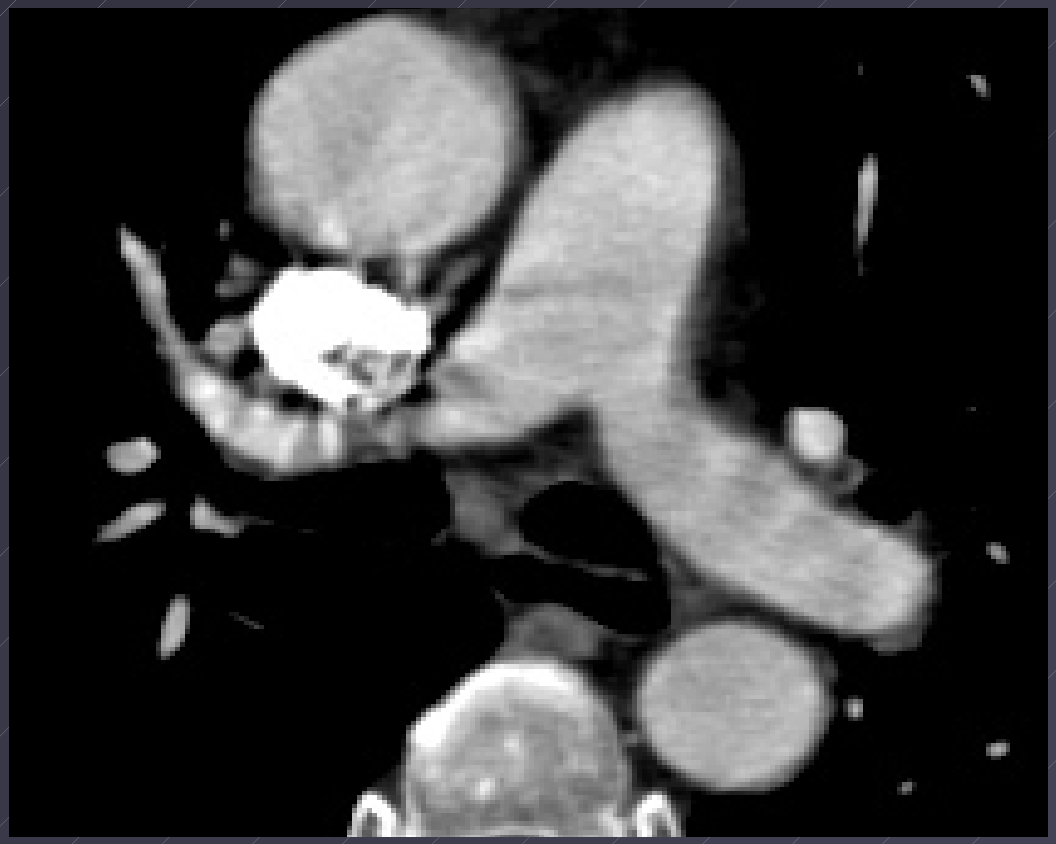

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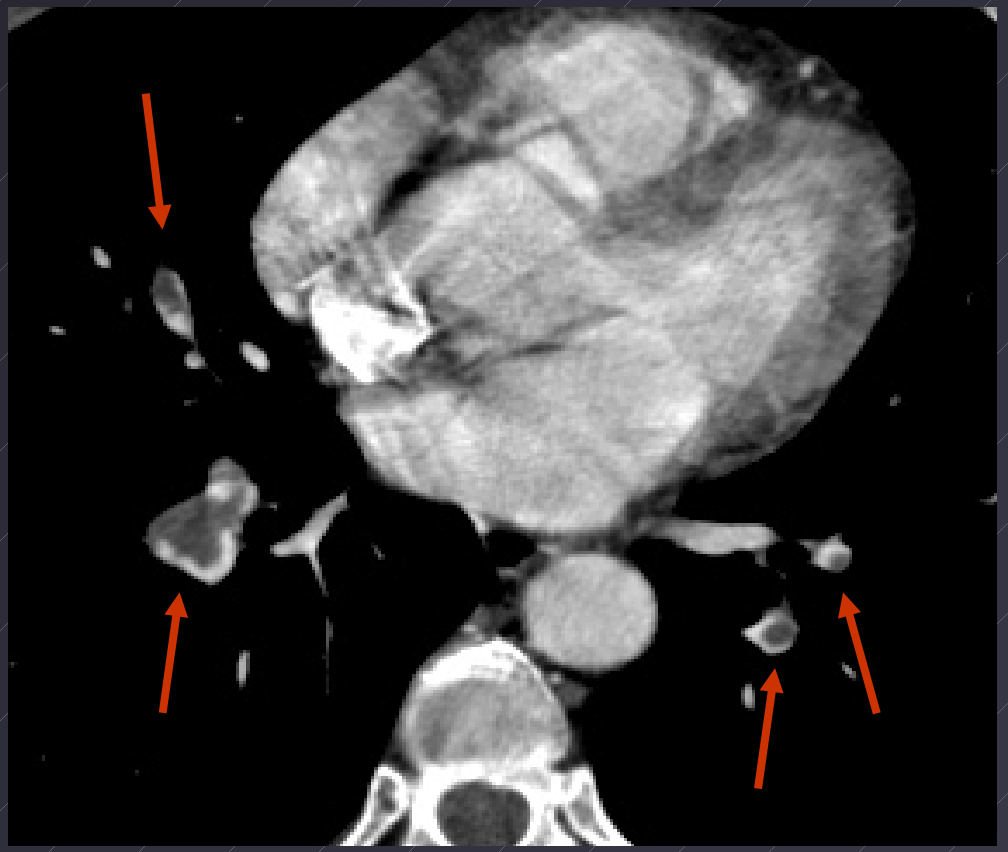

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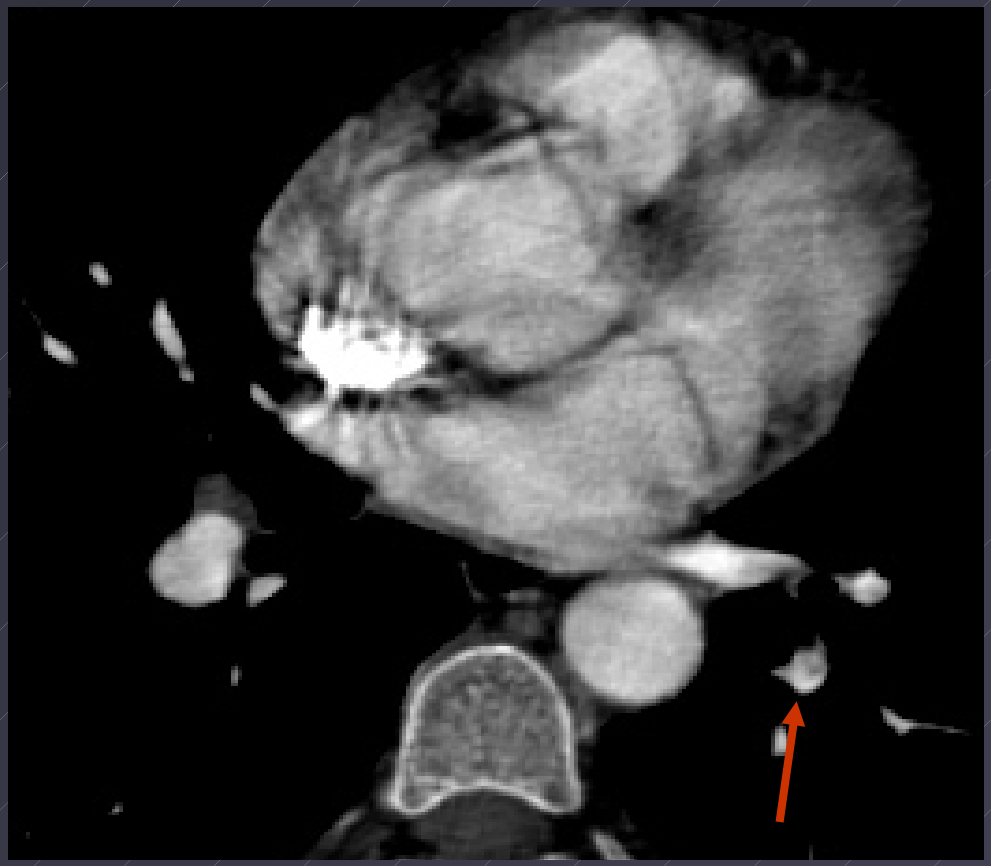

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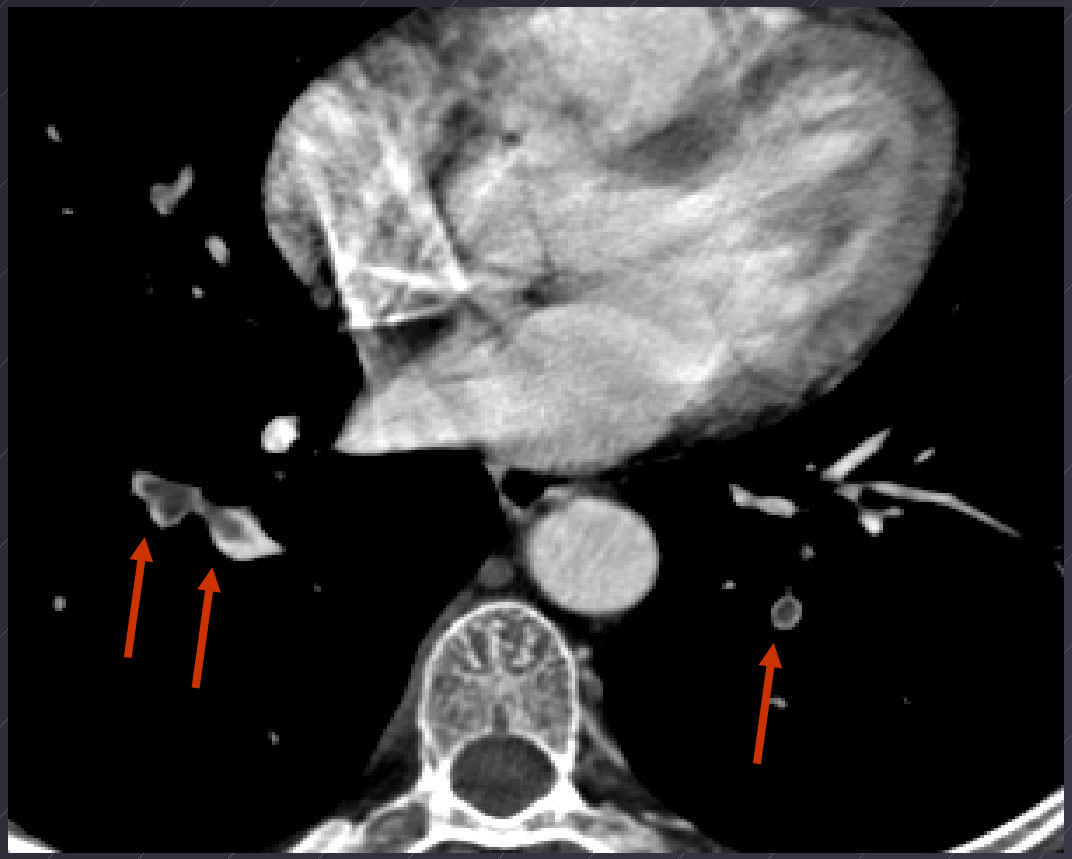

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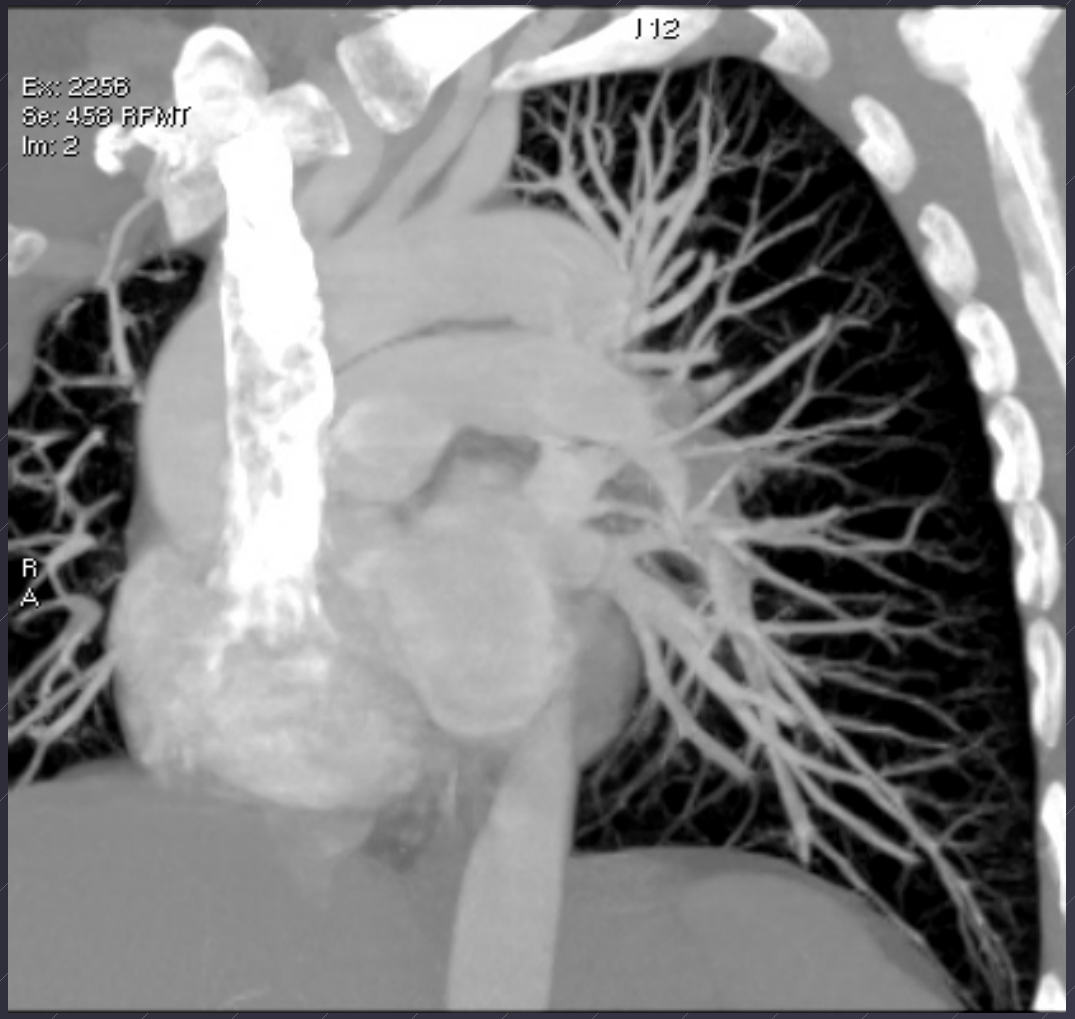
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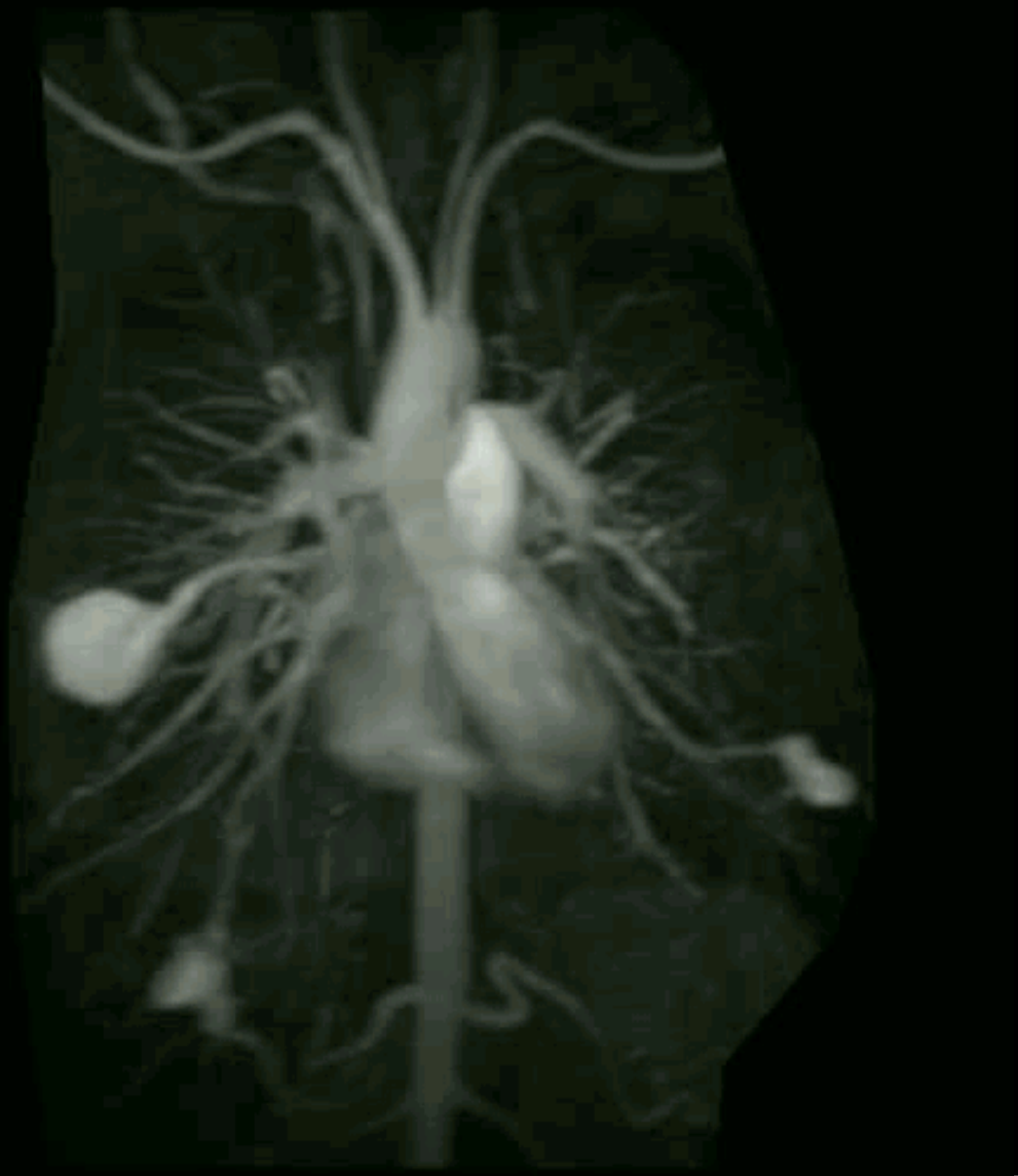
Multiplex pulmonary AVM in Rendu – Osler- Weber disease

CE-MRA MIP

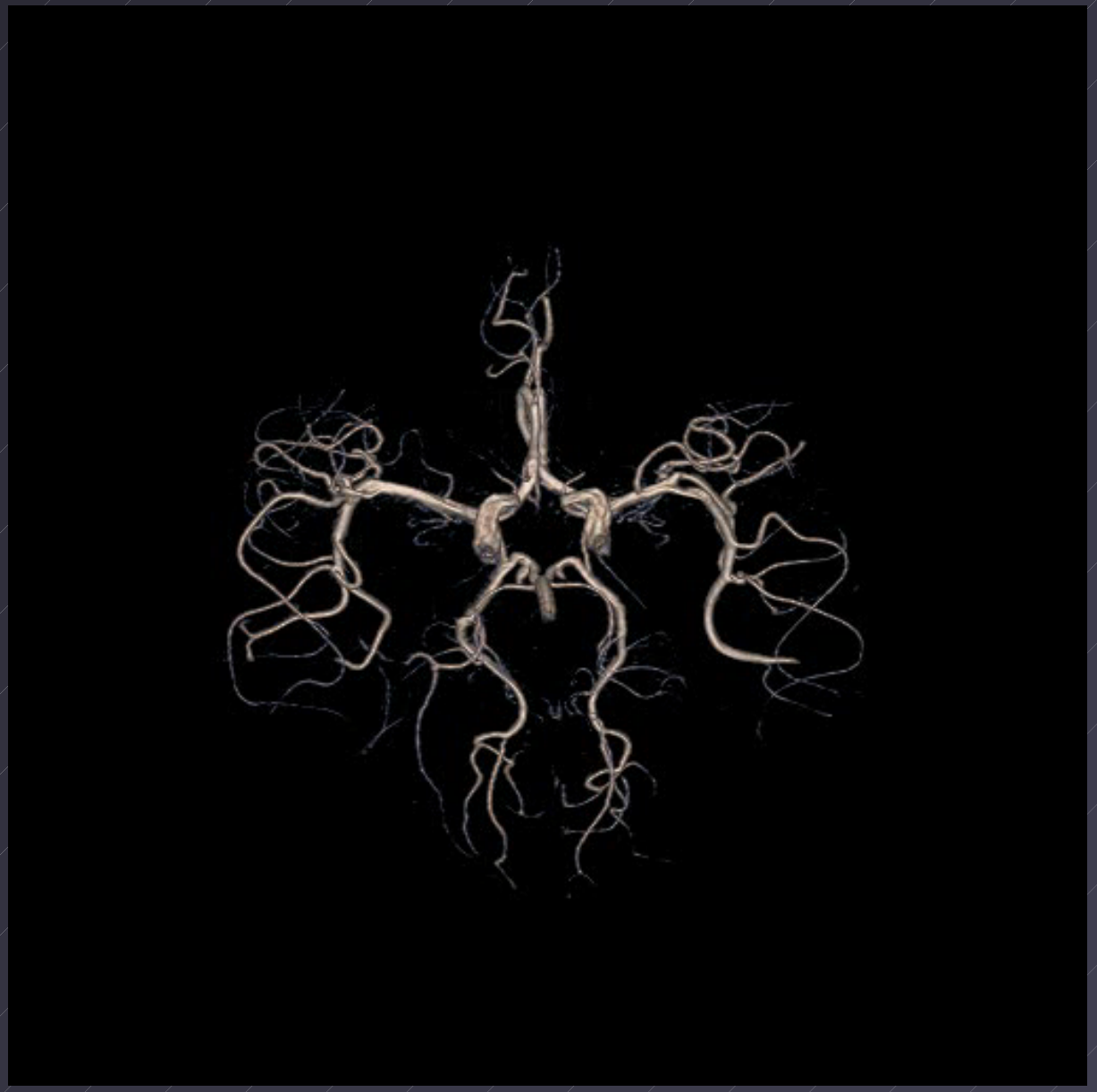


Indications of CTA – MRA

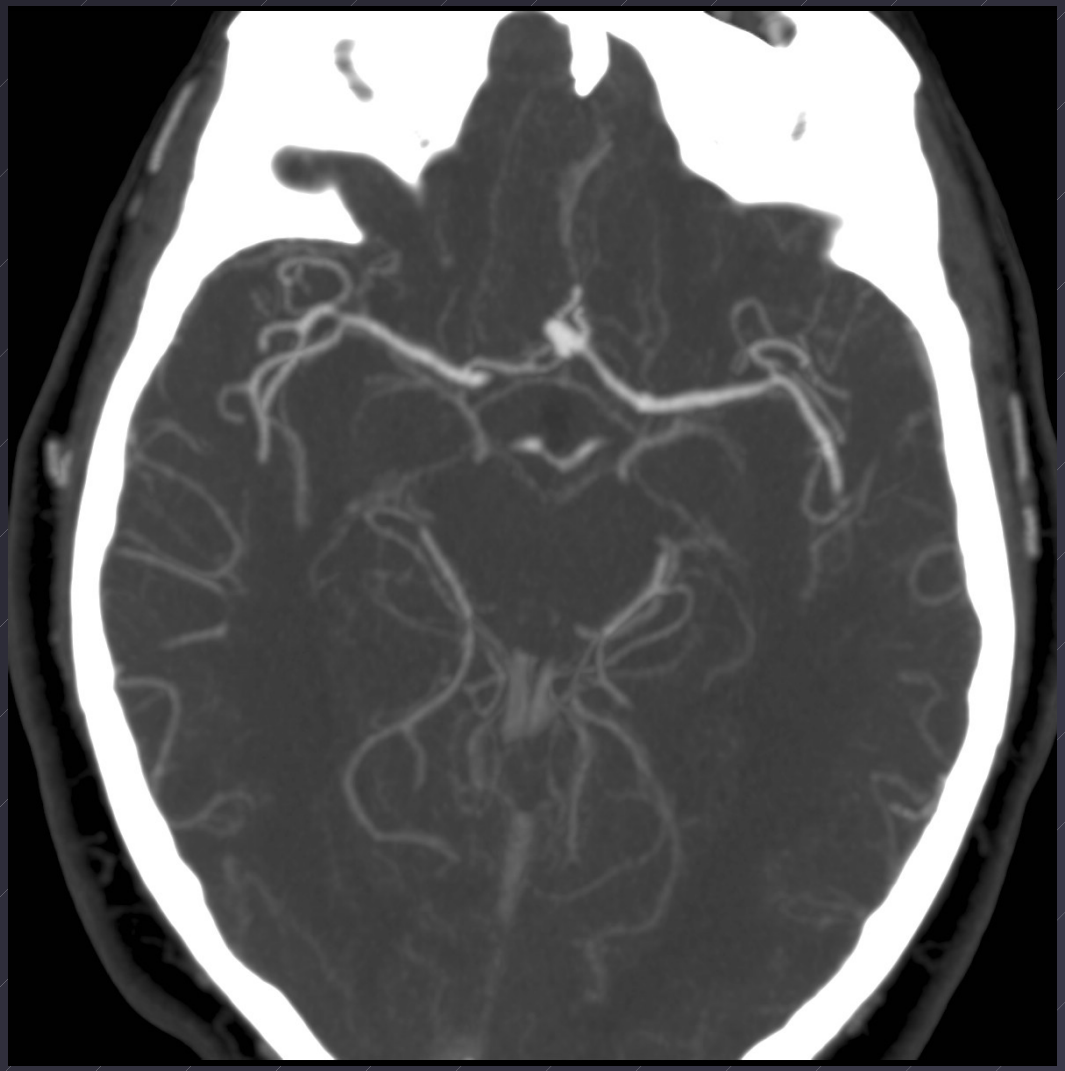
- Intracranial arteries
  - » aneurysm
    - Search for aneurysm in case of SAH
    - In case of proven (DSA, MRA) aneurysm for precise preoperative demonstration of 3D anatomy
  - » obliterative disease

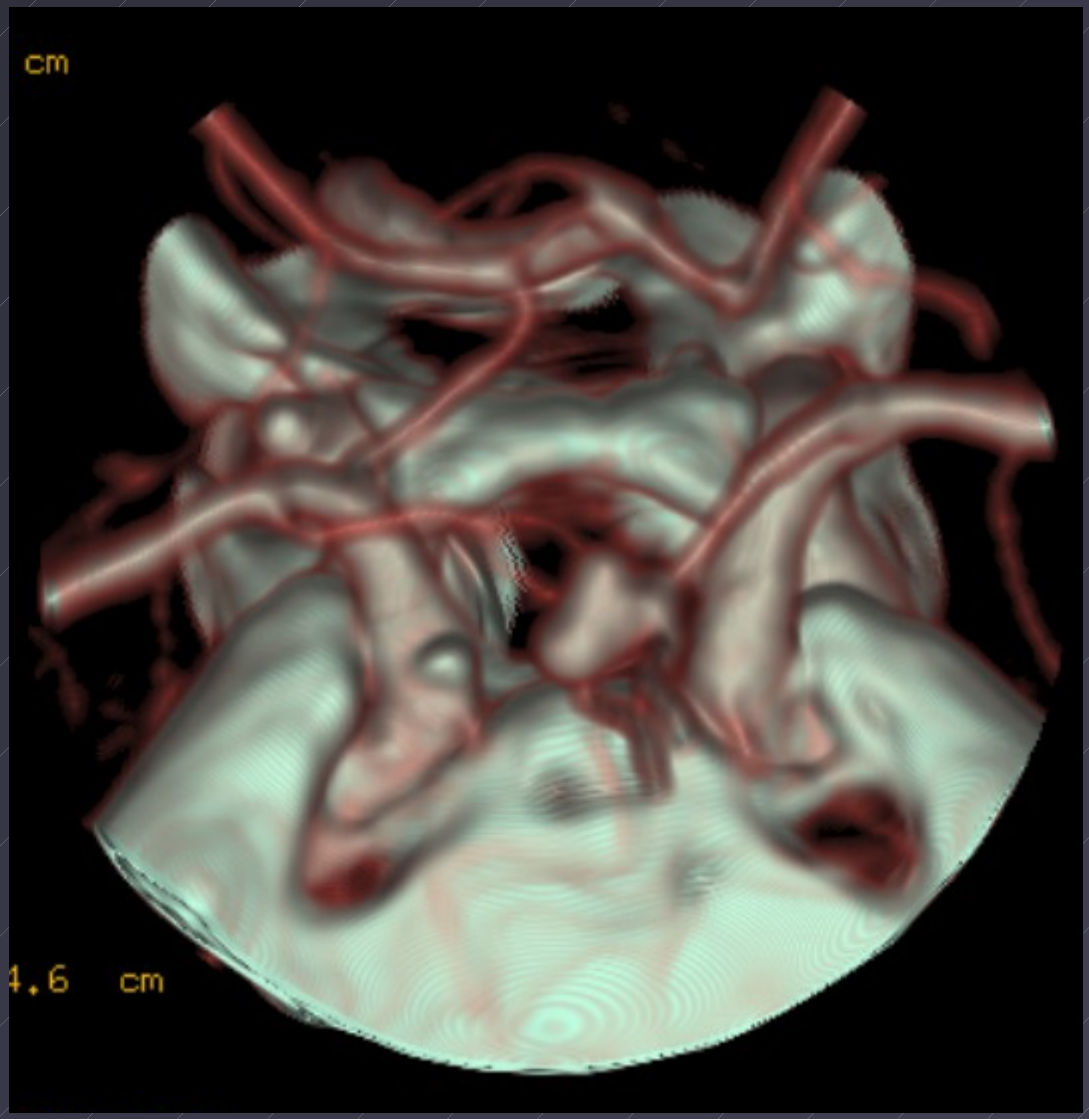
Bilateral aneurysms of posterior cerebrel arteries

TOF MRA - volume rendering



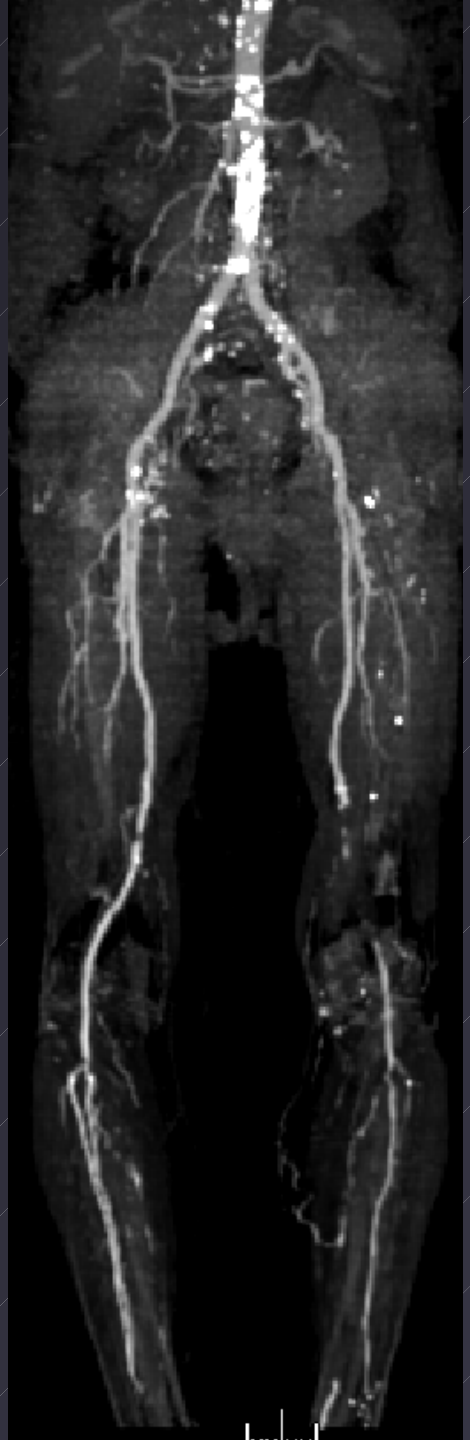
A. communicans anterior aneurysm - CTA

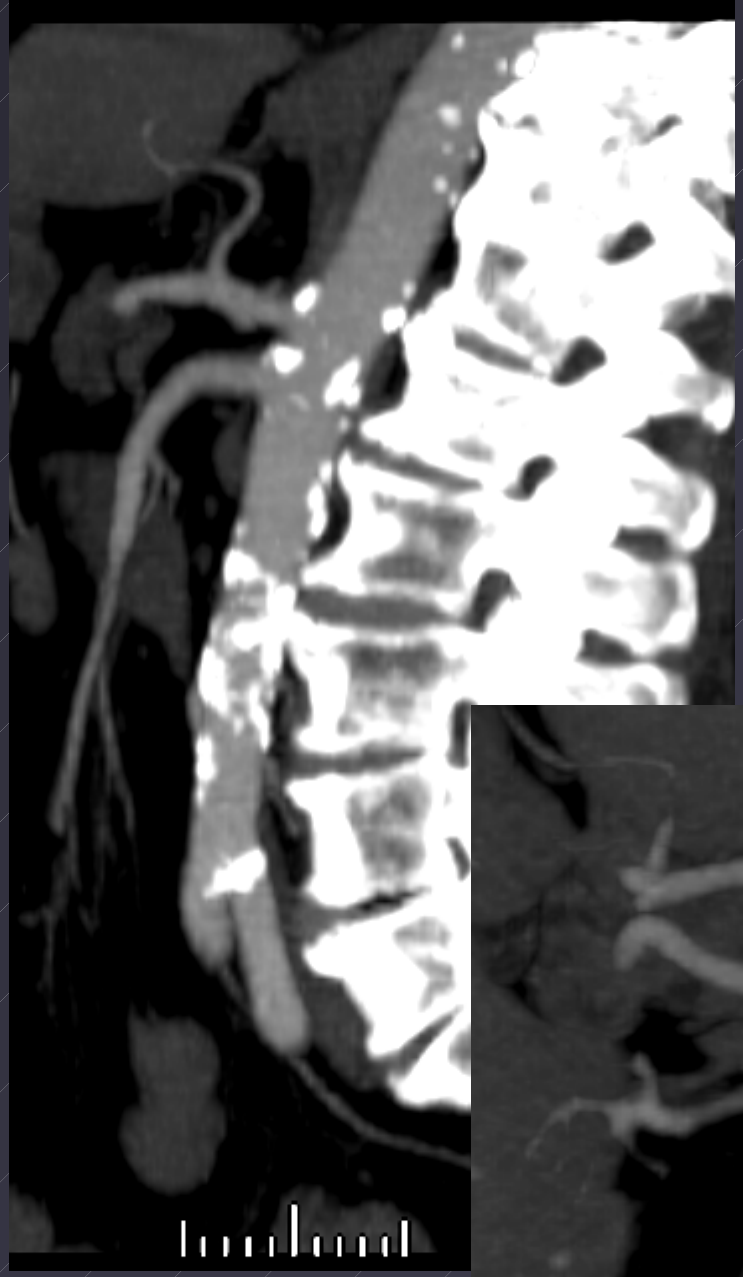




Indications of CTA – MRA

- Lower extremity arteries
  - » Alternative of DSA
  - » Only MDCT enables the imaging of long segments (whole extremity) with reasonable contrast amount and X-ray exposure



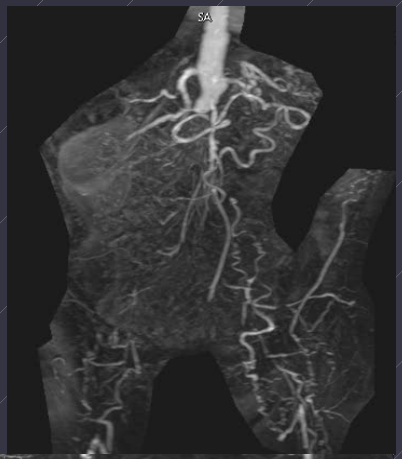


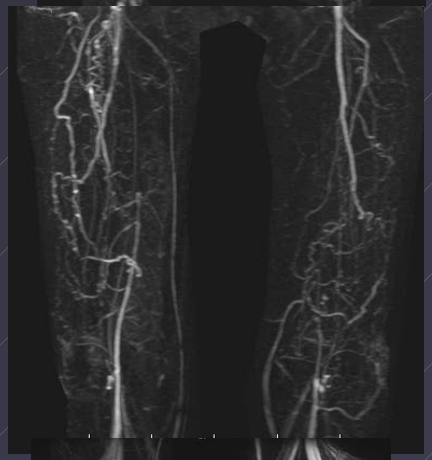
Abdominal-pelvic and lower extremity arteries

CTA by 8 detector-row spiral CT


Right

CE-MRA studies of the lower extremity arteries:





Indications of CTA – MRA

- Preoperative imaging
  - Organ transplantation
  - Oncology

Bilateral Wilms tumor in 14 months old child

Preoperative CTA

Technological background of cardiac CT

- Multidetector-row spiral-CT (MDCT)
  - Simulteneous data acquisition by 4-64 parallel detector-rows
  - Thin collimation : 0.4 - 1.25 mm
  - Rapid tube rotation: 0.35 - 0.5 sec
- Retrospective ECG-gating, image reconstruction algorythms optimised to heart frequency
- Analysis programs for morphologic $ functional analysis

Requirements on patient's side

- Eurhytmia, preferably with a heart rate < 70 / min
  - Optional use of β – blocker
- Breathholding capability (10-20 sec)

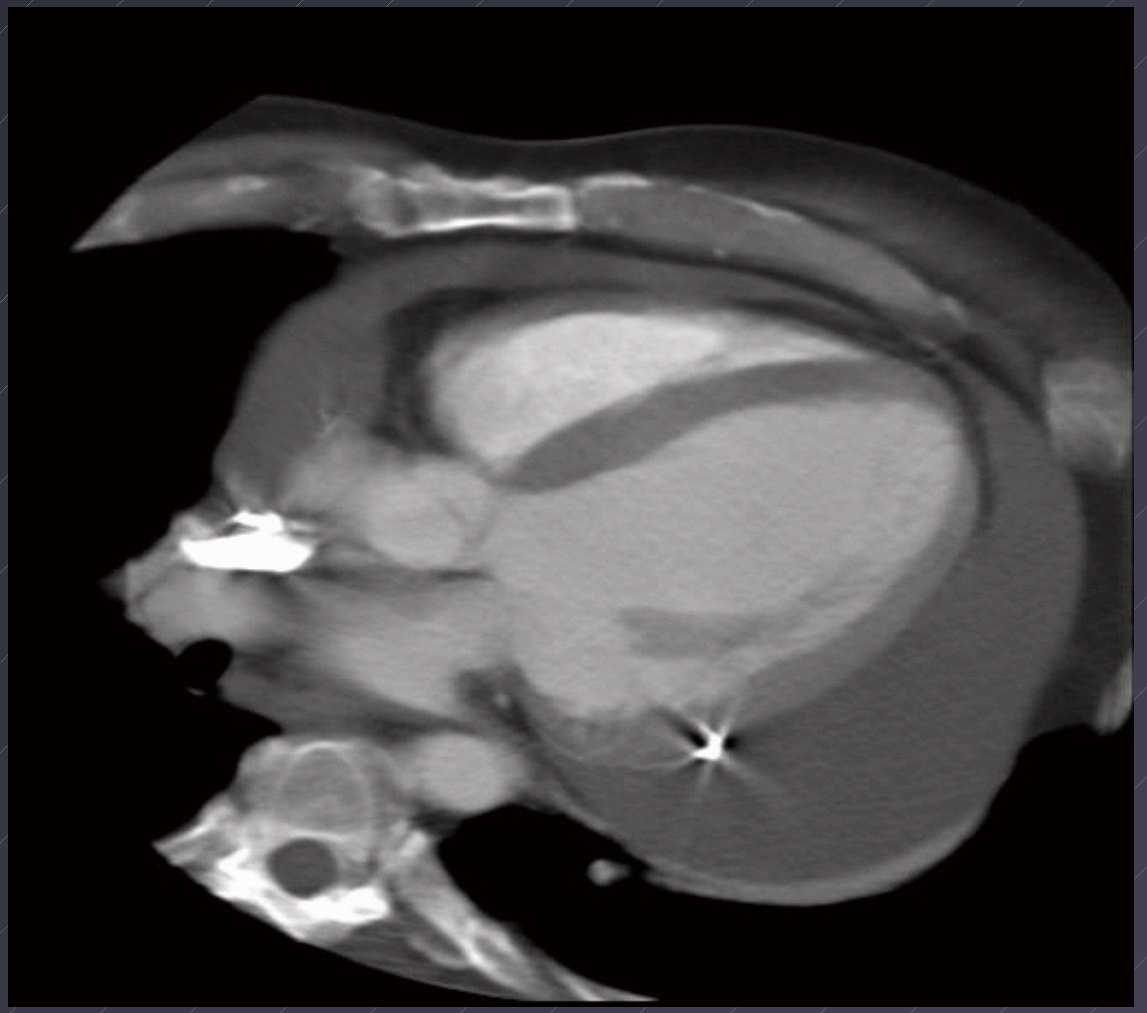
Cardiac CT

- Morphological analysis
  - Coronary calcium scoring
  - Coronary CT-angiography
  - Wall thickness, myocardial mass
  - Intraluminal thrombus, tumor
  - Valves
  - Pericardium, paracardial pathology
  - Great vessels
- Functional analysis
  - Wall motion
  - Valve function
  - Ejection fraction, stroke volume

Pericardial fluid

ECG-gated CE-CT by 8-channel MDCT:
cine rendering of multiphase images

- MRI is contraindicated due to previous pacemaker implantation, electrodes are visible on the image
- No paracardial mass detected
- Left ventricular wall motion is impaired



Coronary CT-angiography (CTCA)

- Isotrsopic imaging: ≥ 16 detector row MDCT
  - » Small FOV: pixel size ≃ 0.5 x 0.5 mm
  - » Thin collimation: section thickness = 0.4 - 0.6 mm

- Rapid acquisition: depending on heart rate and actual scanner 10-25 sec is enough for the whole heart and coronaries
- Intravenous CM bolus
  - » 100 – 150 cc (350 mg/100cc)
  - » 4 cc/sec
- Multiphase retrospectiv image reconstruction from raw date (e.g..: 20 phases every 5% of the RR cycle – optimal phase for the depiction of differnet coronary segments can be selected
- Semi-automatic vascular analysis program for vessel identification and stenosis assessment
- Volume (3D) renderings

CTCA's prospectives

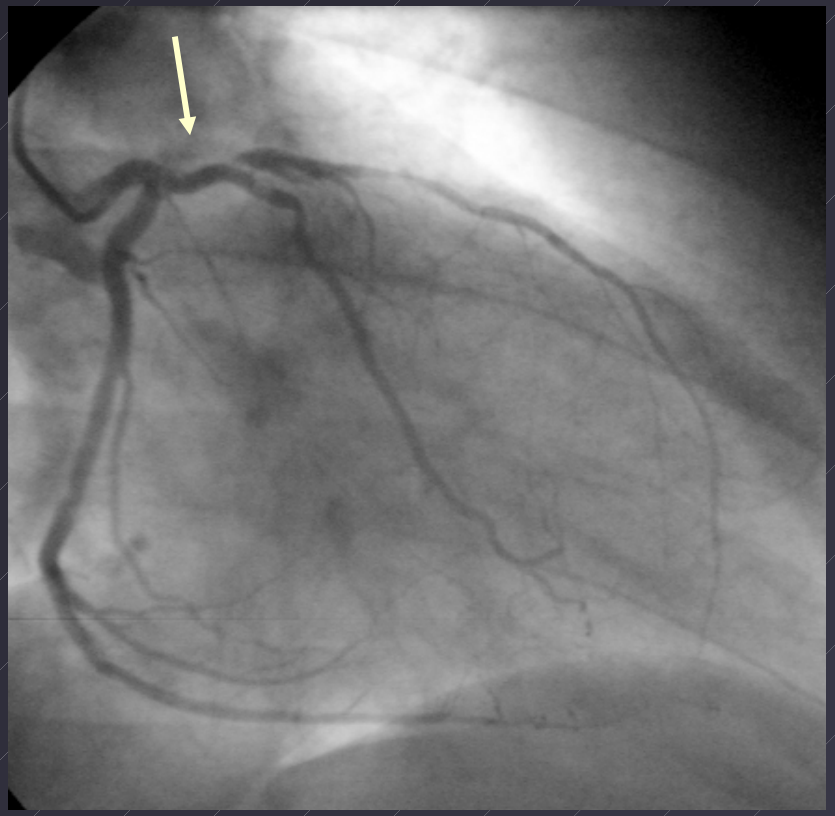
- CTCA demostrates with confidence
  - Main coronary trunks and primary branches
  - Plaques of the aortic arch and coronaries
  - Intraluminal thrombus
  - Bypass grafts (proximal anastomosis and patency)
  - Anomalous origin adn/or course of coronary arteries
- Limited demonstration
  - Distal coronaries
  - Residual lumen is stenosis
  - Accurate stenosis quantification
  - Bypass graft's distál anastomosis and outflow
  - In-stent stenosis
- Positive predictive value of CTCA is moderate (~76 %)
- Negative predictive value is high (~97 %)

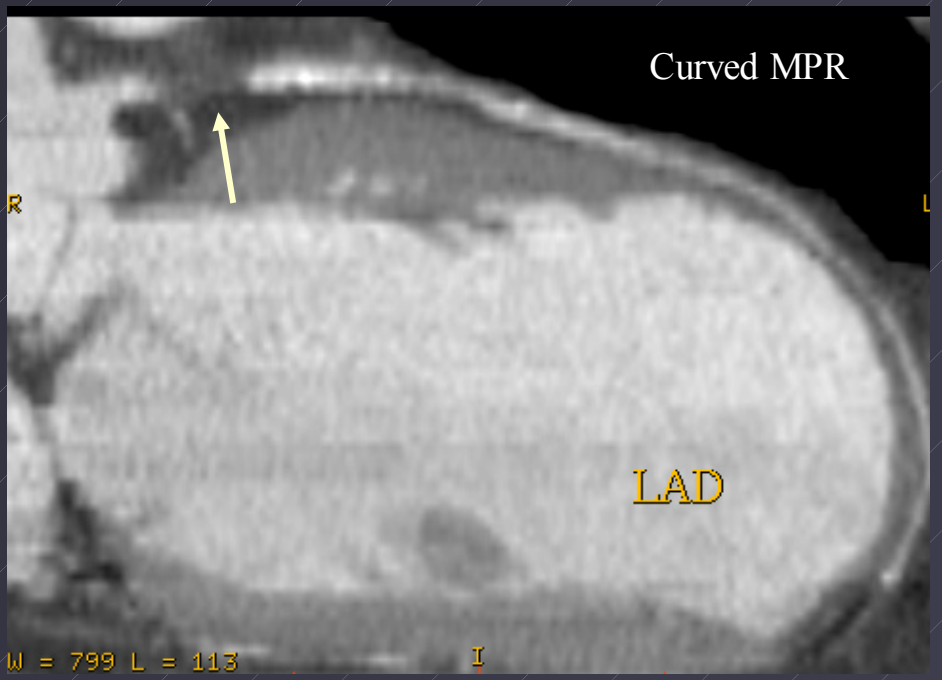
Indications of CTCA

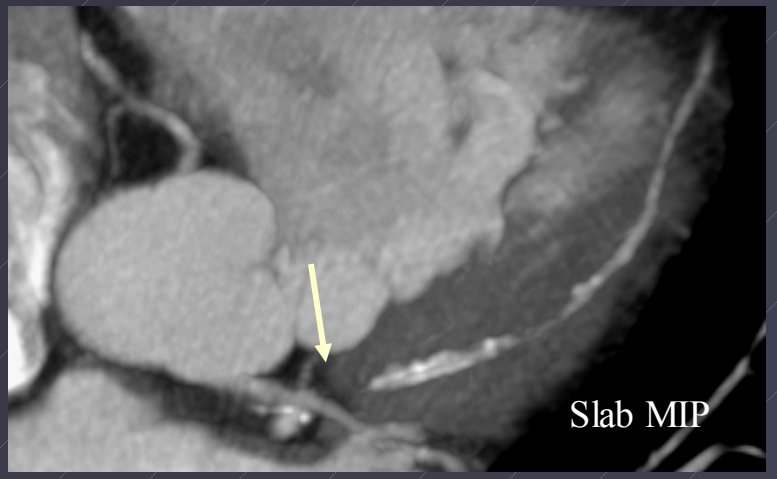
- Chronic and stable angina, except for:
  - Coronary disease is already proven
  - CCS score is high (III-IV)
- Atypical chest pain
  - To exclude coronary disease
  - To detect possible coronary anomalies
- (Instable angina without risk factors ?)
- Post CABG chest pain
  - To detect early graft occlusion
- Follow-up of PCI
- Vasculitis
  - Takayasu
  - Kawasaki
  - PAN
- High risk of catheterisation (e.g..: aortic dissection)

Segmental occlusion of proximal

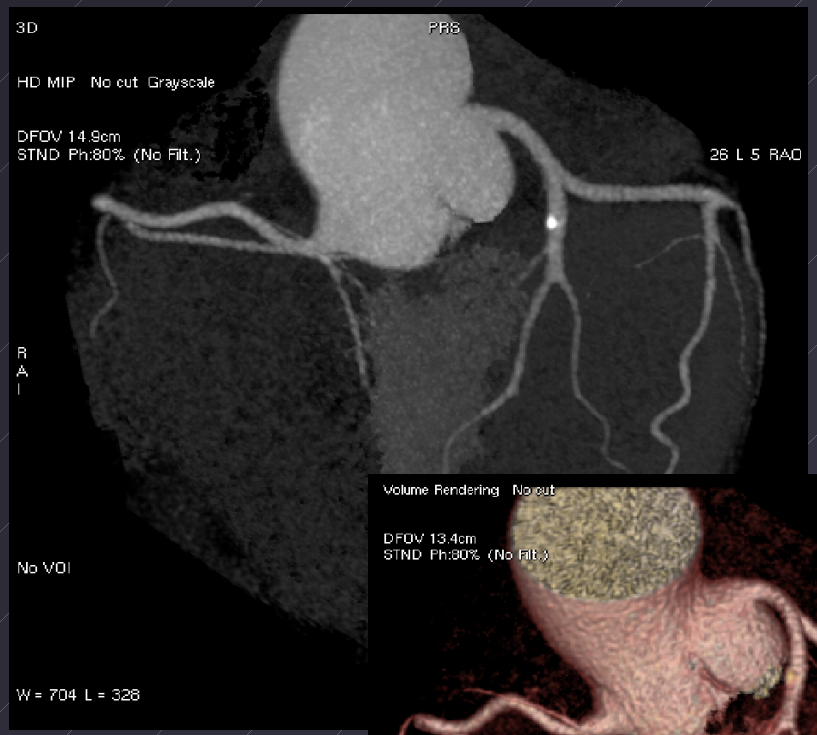
Catheter coronarography, curved MPR and MIP reformation of CTCA

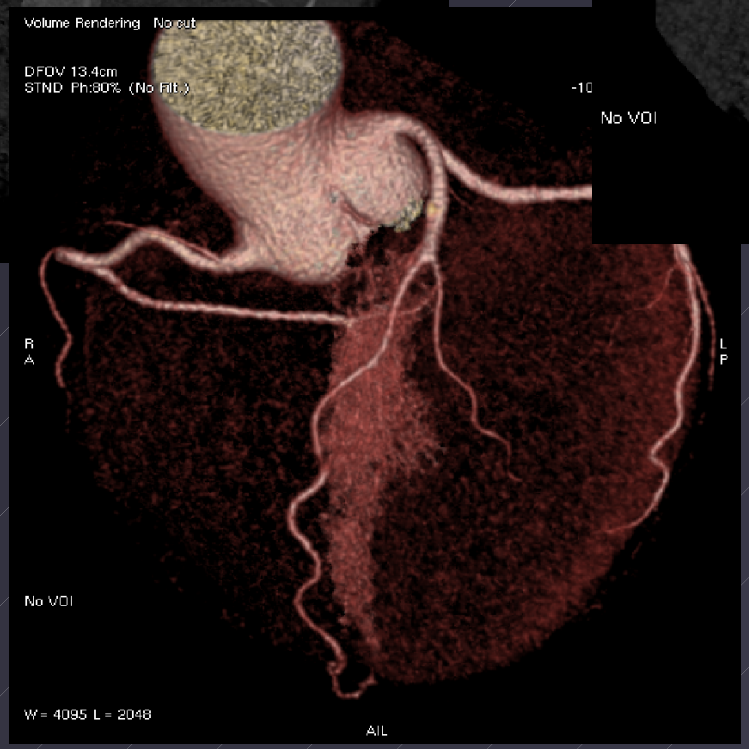


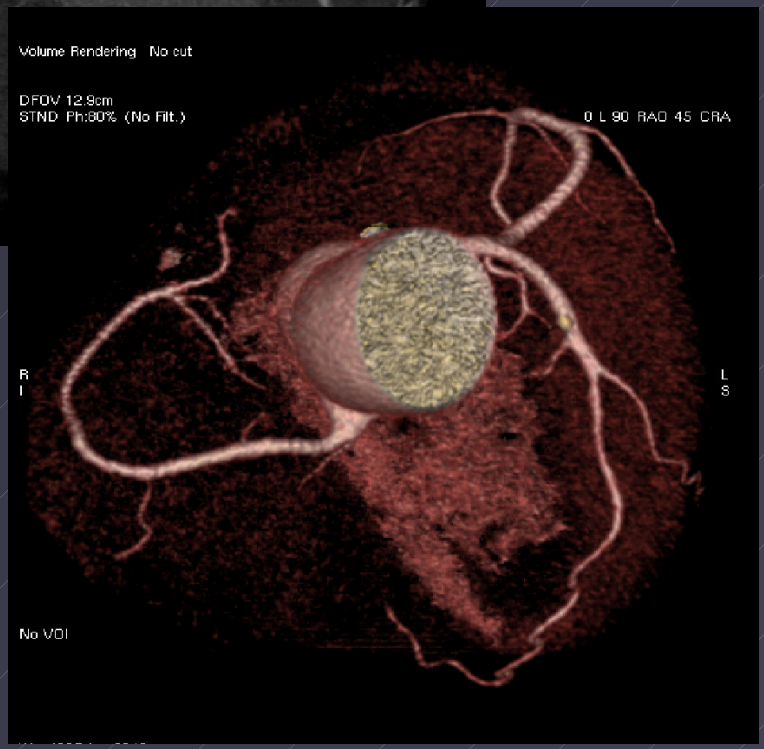




CTCA by 64 channel MDCT







Advantages of CTA

- Érlumen, érfal és perivascularis tér egyidejű direkt ábrázolódása
- Califikált plakkok jól láthatók *(néha túl jól)*
- Áramlási műtermék mentes
- Tetszőleges irányú ábrázolás
- I.v. kontrasztanyag adás - (technikailag nehezített katéterezés esetén kedvező)
- (Ma már) viszonylag hozzáférhető

CTA hátrányai

- Verticalis irányú kiterjeszthetőség (egy soros CT esetén) korlátozott- kiáramlás ??
- Időigényes post-processing
- Statikus információ
- Magas kontrasztanyag dózis (2 ml/tskg), nephrotoxicus kontrasztanyag
- Kooperáció-függő
- Röntgensugár expozíció

Limitation of CT

- Ionizing radiation
  - 50-100 times higher dose as with conventional radiography techniques!
    - direct exposure
    - scattered radiation (lower by 1-2 order)

Pl.: átlag mellkasi CT vizsgálat során a szerveket érő dózis (mGy):
tüdő – 17.6 pajzsmirigy – 5.6 szemlencse – 0.37 ovarium – 0.17

(Mini et al. Radiology 1995; 195:557-562)

CT (X-ray) contrast medium side effects - complications

- Osmotic irritation
  - Warmth
  - Vagotonic reaction, nausea, vomiting (used to be common with ionic c.m.)
- Allergyform reaction
  - Histamin mediated anphylactoid mechanism
  - Mild skin rashes (immediate or delayed by hours)
  - Quincke edema, stridor
  - Anaphylactic shock
- Nephrotoxic effect
  - Impaired renal function, elevated Se-kreatinin level is relative contraindication

MRI előnyei

- **Sugármentes, nem-invazív**
- Finom kontrasztfelbontás
  - » ép / kóros elhatárolódás
  - » legjobb elérhető szövetspecificitás
- I.v. kontrasztanyag (Gadolinium) kevesebb mellékhatást okoz, nem nefrotoxikus
- Erek kontrasztanyag nélkül is ábrázolódnak
- Direkt tetszőleges síkú ábrázolás

MRI korlátai

- Hosszabb vizsgálati idő (20-40 perc),
  - » 4-5 éves kor alatt sedálás-altatás szükséges
- Nehezebben hozzáférhető a beteg
  - » monitorozás problematikus lehet
- Finom tüdőszerkezet nem megítélhető
- Inkompatibilis: pacemaker, egyes fém implantatumok
- Korlátozottan elérhető + drága

CTA versus CE-MRA

	CTA	MRA
Térbeli felbontás, részletgazdagság	+ + +	+ +
Haemodynamicai információ	-	+
Nephrotoxicitás	++	-
Röntgensugár expozició	+ + +	-
Kooperáció függés	+ +	+ + +
Vizsgálati idő	+	++
Utólagos adatfeldolgozás	+ +	+ +
Költség	+ +	+ + +

Konklúzió

- A technológia jelentős fejlődése a keresztmetszeti képalkotó módszerek felbontását és gyorsaságát olyan mértékben javította, hogy a már korábban is ismert alkalmazások (nagyerek, mellkas, paracardialis régió…) mellett egyre inkább maga a szív és a kisebb erek anatómiai és funkcionális megítélése a cél
- Nem-invazív módszerek betegre / betegségre szabott kombinációja elégséges lehet diagnózis felállítására és a követésre
- Invazív katéteres megközelítés az esetek egy részében továbbra sem nélkülözhető, de az egyre inkább a bővülő terápiás beavatkozások vezérlő módszerévé válik