CT Venography

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Introduction

- CT venography (CTV) is a technique targeted to assess venous anatomy, determine venous patency & delineate collateral circulation
- Non-invasive, simple protocols, wide anatomic coverage, short acquisition time, and ability to be combined with arterial-phase CTA

Lecture Outline

- Basic Clinical Options for Venous Imaging
  - Venous Imaging Modalities
- CT Scan Protocols
  - Indirect CTV
  - Direct CTV
- Selected Regional Applications
  - UE
  - Chest

Venous Imaging Modalities – The competition

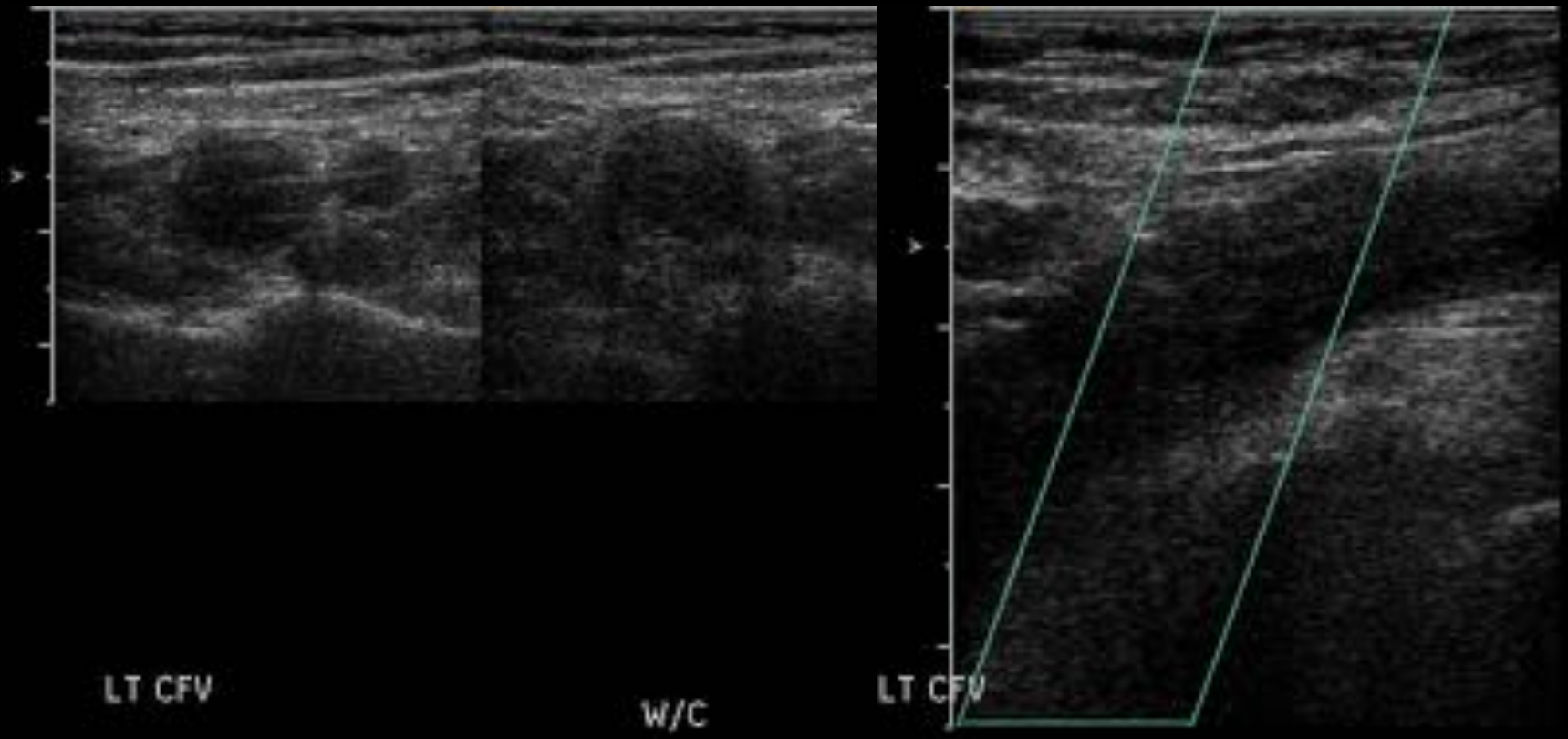
- Doppler Ultrasound (US)
- MR Venography
- Catheter venography
- Nuclear venography

Doppler US

- Well established clinical utility
- No ionizing radiation
- Portable
- Inexpensive
- Flow direction information
- Operator / Patient dependent
- Some areas inaccessible (pelvis, SVC)
- Collateral pathways not well delineated

Doppler US

- Sens/ Spec ~ 95% for fem-pop DVT in ideal situations



Performance of Doppler vs. CTV in ICU patients – LE DVT

	Sens	Spec
Indiect CTV	70	96
Doppler US	70	100

Taffoni, AJR, 2004

MR Venography - Positives

- Excellent for pelvic venous system, CNS
- May not require contrast
- SI ratio thrombus:blood higher for MRV vs. CTV
  - 3.7-8:1 vs 1.8-3.2 *
- For PE: Sens 80-95%, Spec 95%, depends on technique (Perf imaging best)+
- For DVT: Sens ~92%, Spec ~95%
- 0.25 mmol/kg Gd better than 0.125 mmol/kg

* Kluge, AJR, 2006

+Sampson, *Eur Radiol* 2007; 17:175-181

Combo MR-PA / Indirect MRV

- MRA: TRuFISP, perfusion, MRA (0.25mmol/Kg)
- MRV: 3D FLASH w/ PV coil, voxel size of 1.2x0.8x1.1 mm
  - High agreement w/ CTA/CTV but requires a change in coil and pt. position to obtain MRV after chest MRA
- Good agreement w/ Doppler in legs, moderate in pelvis

Kluge, AJR, 2006

MR Venography - Negatives

- Expensive, availability sometimes limited
- Exam may be lengthy
- Pt. cooperation?
- Spatial resolution (vs other choices)
- Limited anatomic coverage

Radionuclide Venography

- 99mTc-labeled MAA
- 99mTc-labeled RBC
- 99mTc-human serum albumin

Anatomic agents, indirect evidence

- 99mTc-labeled platelets
  - Direct evidence of acute / active DVT
  - BUT: Arduous prep, false positives – pts on heparin
- 99mTc-apcitide (GIIb/IIIa receptor binding)
  - Can tell acute (+) vs. chronic (-) clot
  - Interpreter dependent?

Catheter Venography

- Considered the “gold standard”
- Invasive (but can treat lesions)
- You only see what you can fill
- Risks:
  - Minor Complications: 18%
  - Thrombosis: 2%
  - Bronchospasm, Contrast reactions, etc

CTV: Challenges

- Goal: visualize all venous structures, with good opacification, but without artifacts

Direct CTV

Indirect CTV

CTV: Challenges

- Goal: visualize all venous structures, with good opacification, but without artifacts

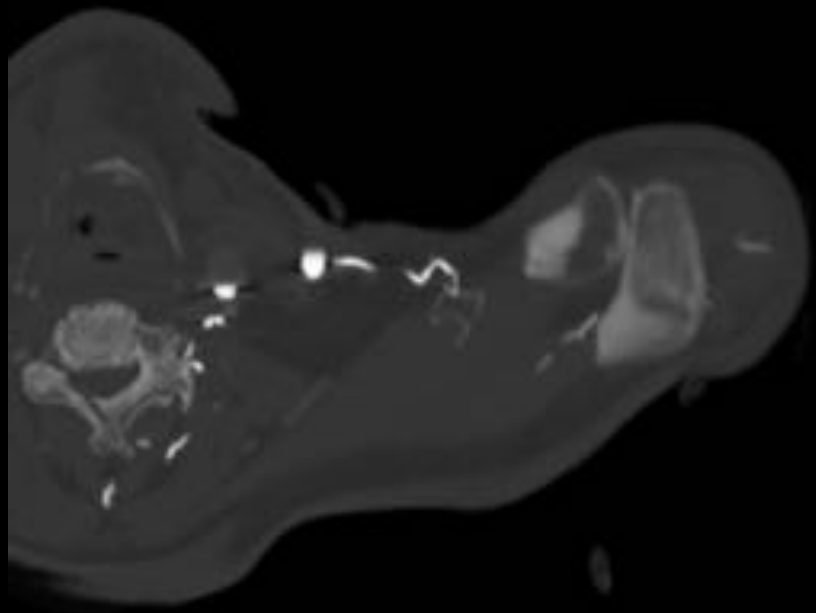
Direct CTV

- good opacification (too good; needs dilution)
- but difficult to visualize all venous structures or full extent of collateral circulation

Indirect CTV

- visualizes all veins (recirculation of CM)
- but difficult to achieve strong enhancement; timing difficulties

60M smoker, r/o lung cancer



Routine chest with contrast: 100cc contrast @ 2cc/sec, 40 sec diagnostic delay

CTV: Challenges

- Goal: visualize all venous structures, with good opacification, but without artifacts

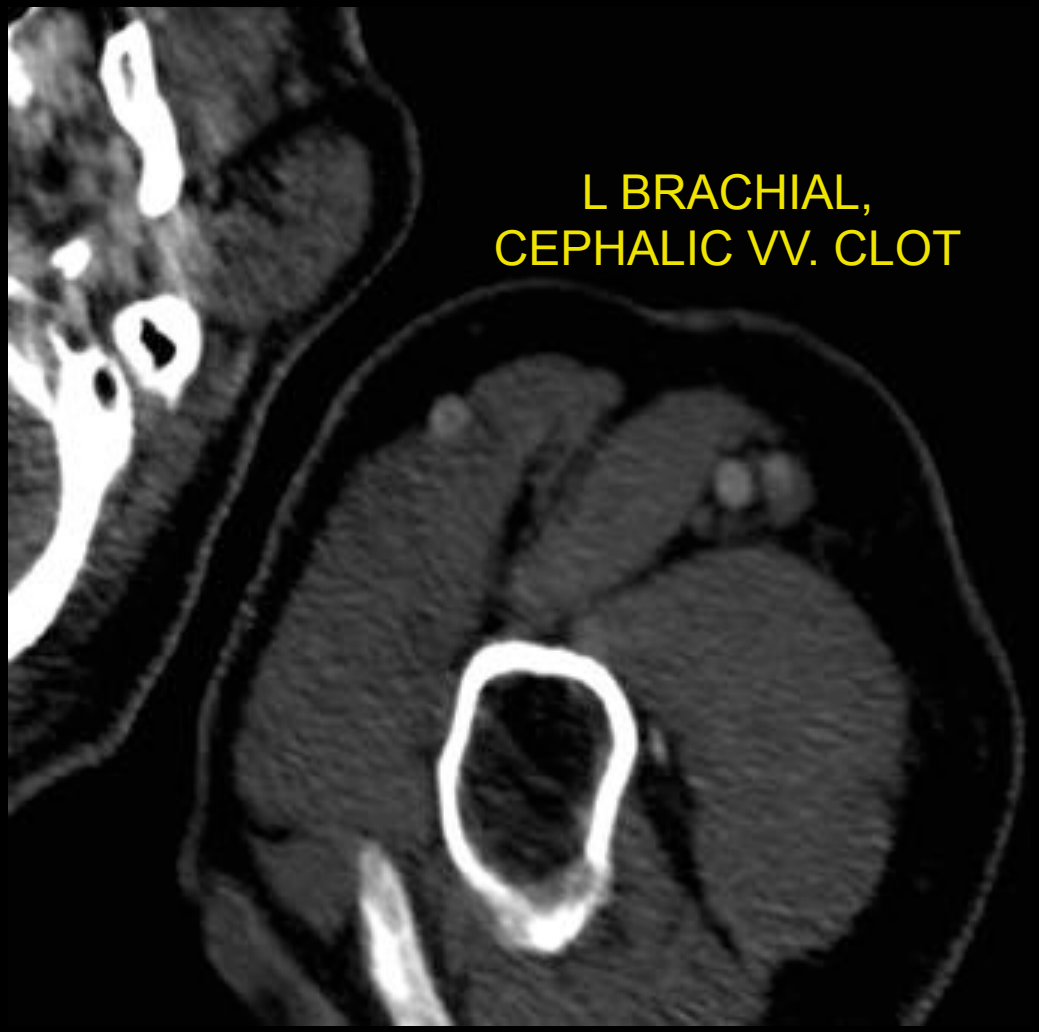
Direct CTV

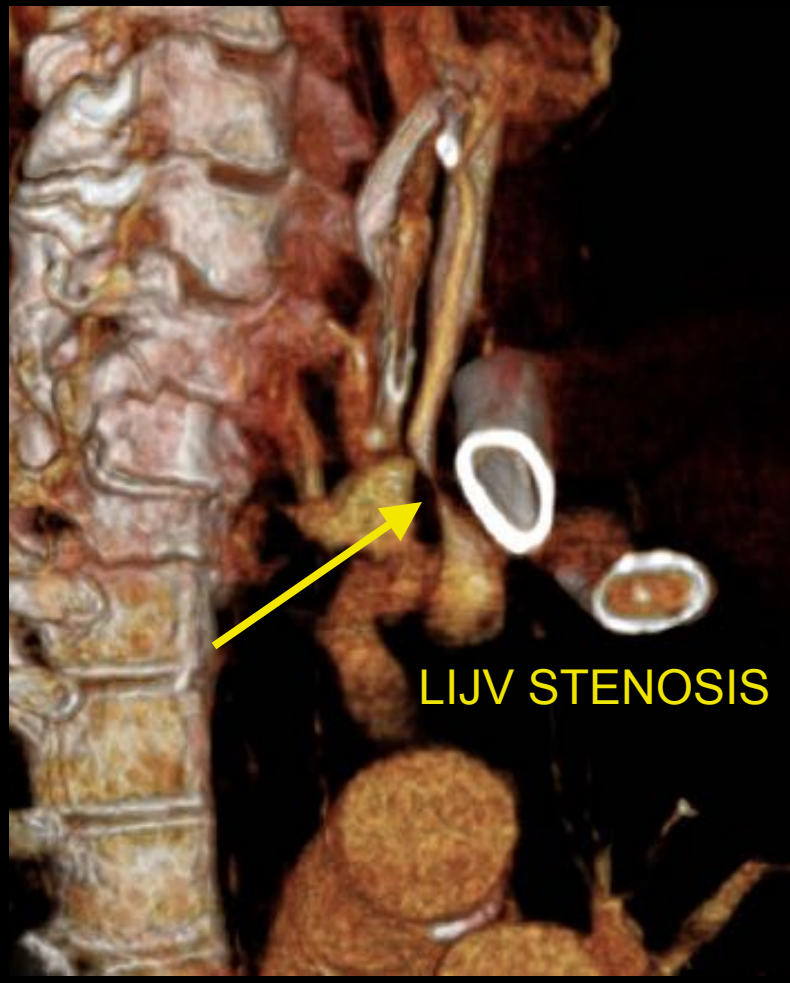
- good opacification (too good; needs dilution)
- but difficult to visualize all venous structures or full extent of collateral circulation

Indirect CTV

- visualizes all veins (recirculation of CM)
- but difficult to achieve strong enhancement; timing difficulties

Indirect CTV



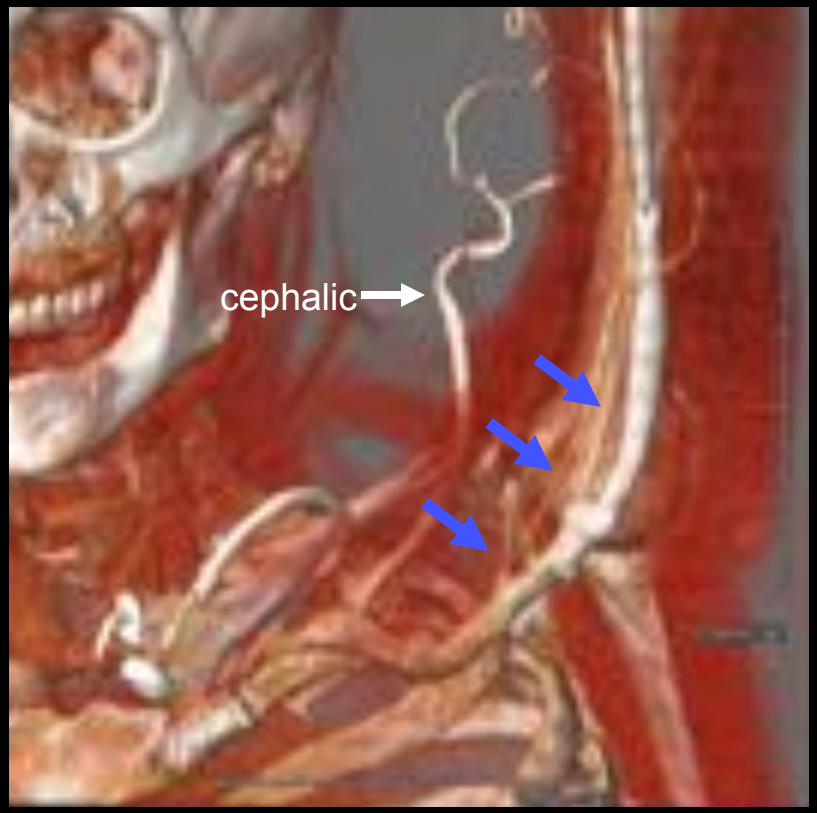


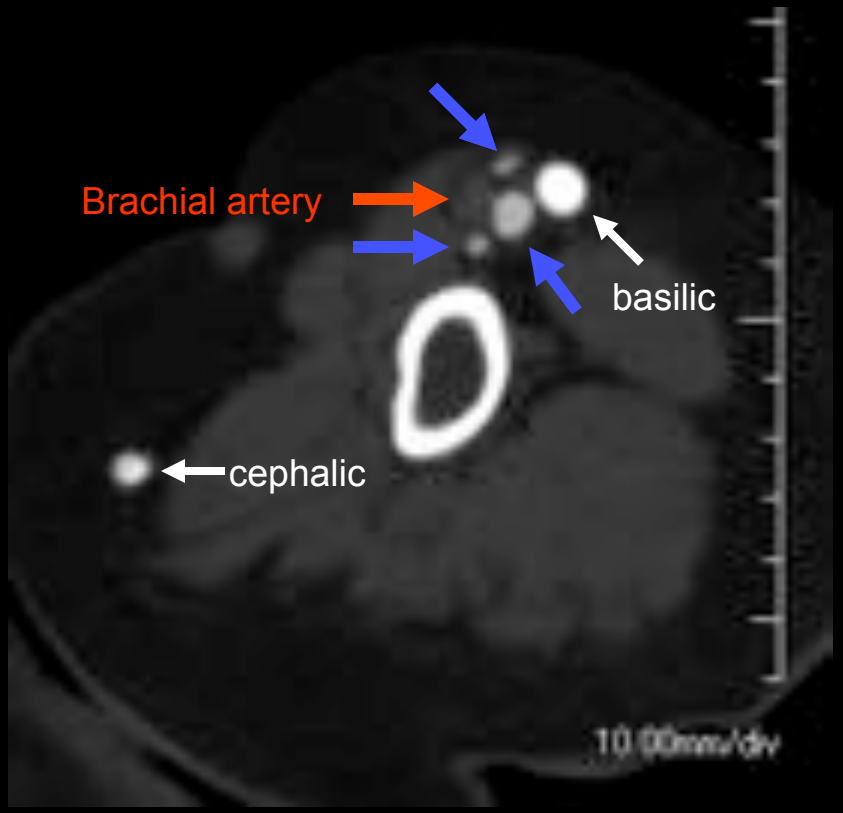
CTV: Imaging Techniques

- Direct Venography (first pass):
  - Dilute contrast (1:5 - 1:10)
  - Fill veins of interest (50cc or more)
  - Slow infusion, 1-2cc/sec
  - Start acquisition towards end of infusion
- Indirect Venography (recirculation)
  - 100-150cc contrast needed for adequate venous opacification
  - Empiric imaging delay
    - 60 seconds: upper extremity and pelvic veins
    - 3 to 3.5 min: lower extremity veins
  - Smart prep off vein of interest

Baldt MM, et al. Radiology 1996;200:423-428

40M prior left arm DVT. Acute pain and swelling of the left upper arm, rule out DVT.





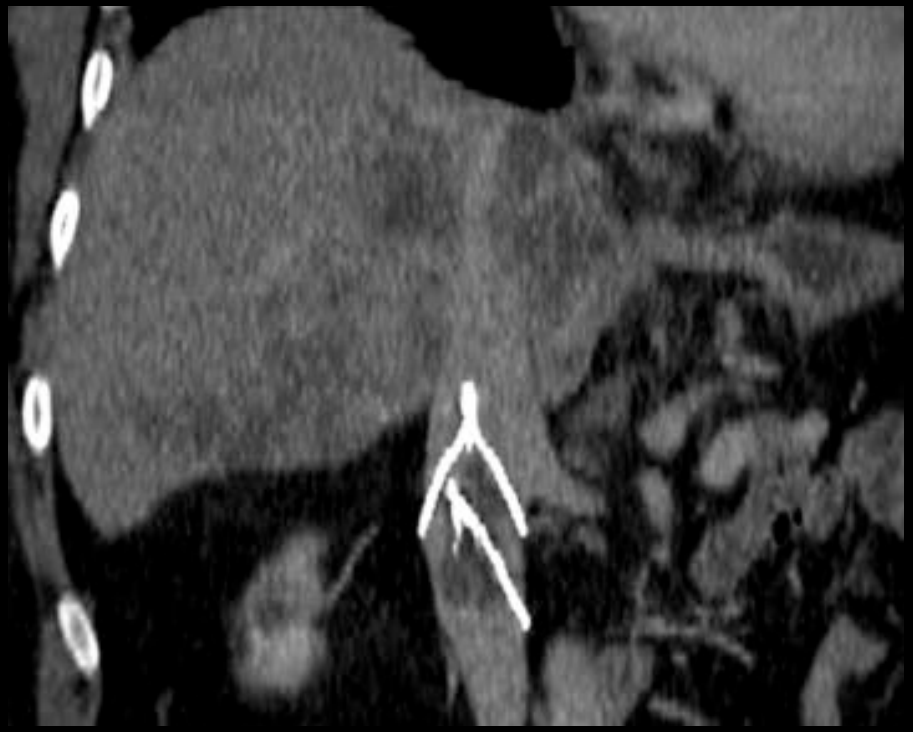
1:5 dilution (20cc contrast + 80cc NS) @ 3cc/sec. Tourniquet around biceps region, released 15 sec before initiation of scan.

CTV: Imaging Techniques

- Direct Venography (first pass):
  - Dilute contrast (1:5 or 1:6)
  - Fill veins of interest (50cc or more)
  - Slow infusion, 1-2cc/sec
  - Start acquisition towards end of infusion
- Indirect Venography (recirculation)
  - 100-150cc contrast needed for adequate venous opacification
  - Empiric imaging delay
    - 60 seconds: upper extremity and pelvic veins
    - 3 to 3.5 min: lower extremity veins
  - Smart prep off vein of interest

Baldt MM, et al. Radiology 1996;200:423-428

65M with metastatic lung ca and recent PEs. An IVC filter was placed but did not fully deploy. A second IVC filter was placed above the first one.



120cc contrast, diagnostic delay = 70sec

CTV: Imaging Techniques

- Direct Venography (first pass):
  - Dilute contrast medium (1:5 or 1:6)
  - Fill veins of interest (50cc or more)
  - Slow infusion, 1-2cc/sec
  - Start acquisition towards end of infusion

Baldt MM, et al. Radiology 1996;200:423-428

CTV: Imaging Techniques

- Indirect Venography (recirculation)
  - ~ 150cc contrast needed for adequate venous opacification (2 mL/kg)
  - Empiric imaging delay
    - 60 sec: thoracic
    - 70-80 sec: upper extremity
    - 11- sec: pelvis
    - 150 – 180 sec: lower extremity veins
  - ? Smart prep off vein of interest
  - Want veins >80HU to be diagnostic

INDIRECT CT VENOGRAPHY

- Large bolus of contrast followed by a delay to image the recirculation phase
  - 150 mL (2 mL/kg BW)

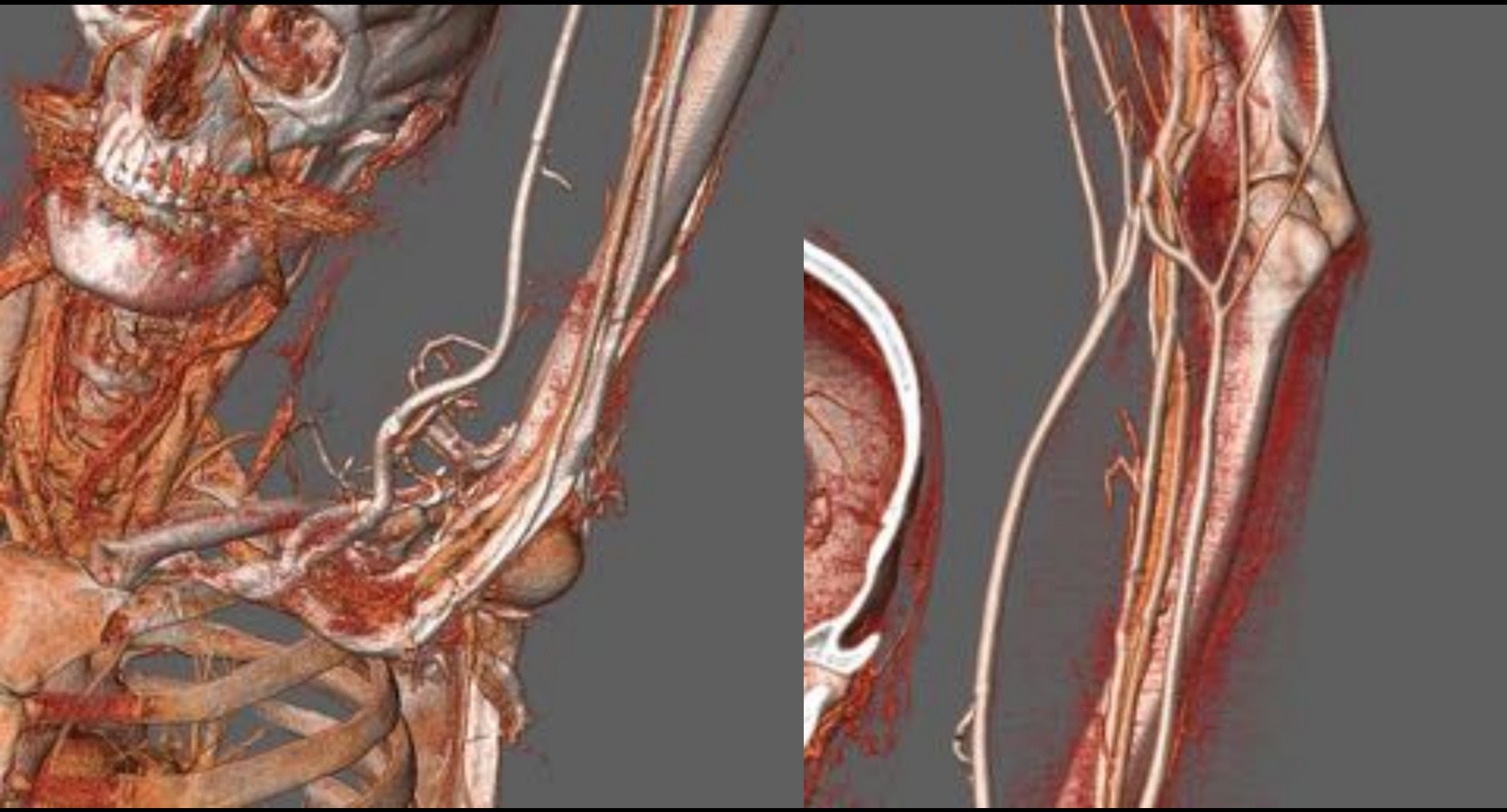
- Empiric Delay (depends on venous territory)
  - 60 seconds: thoracic
  - 70–80 seconds: upper extremity
  - 110 seconds: abdomen & pelvis
  - 180 seconds: lower extremity

- NO Bolus Trigger
  - Not an exact science, no target HU

Combo Direct / Indirect CTV

- R/O LUE venous malformation; L hand and arm swelling
- 120 mL @ 5 mL/s followed by 100 mL 1:10 dilution at 2.5 mL/s via L hand IV
- Caudocranial acquisition

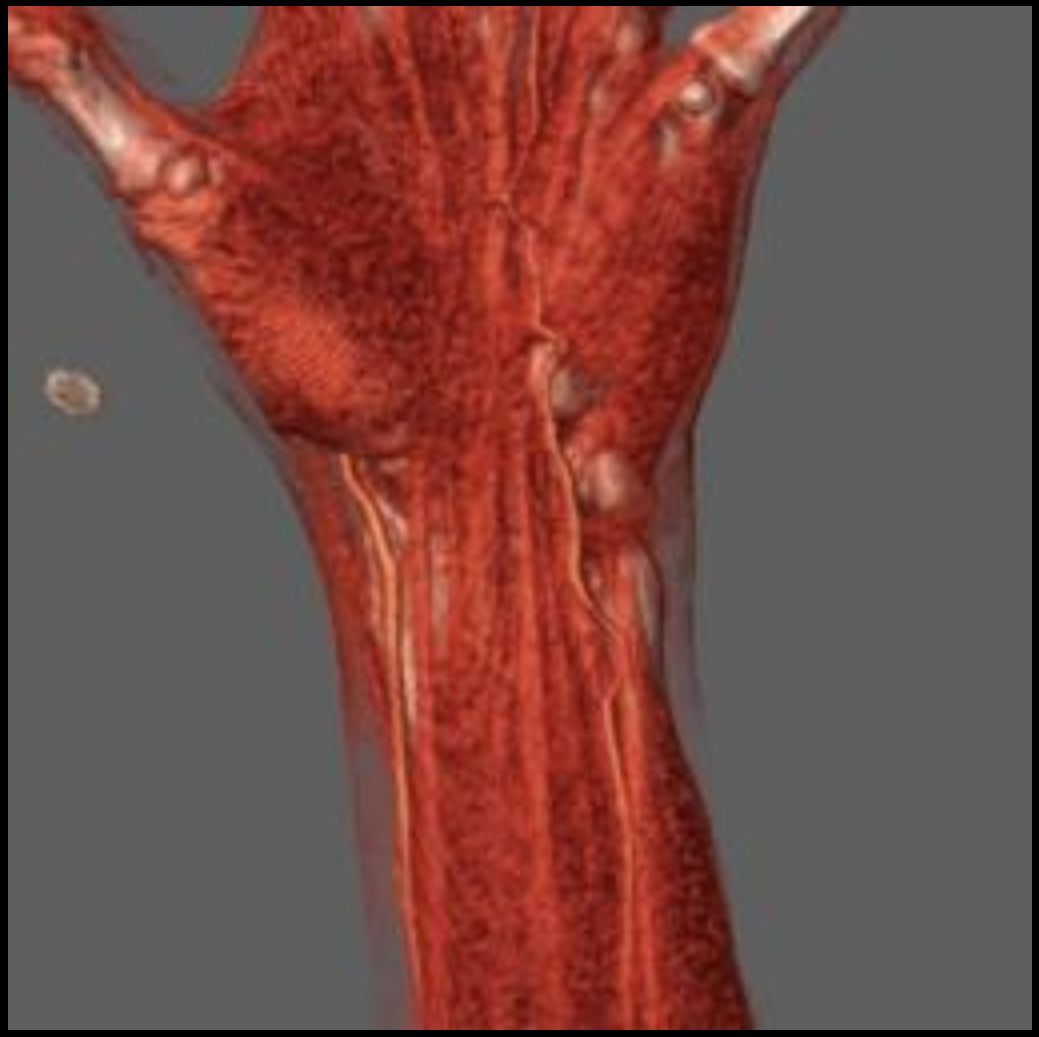
Combo Direct / Indirect CTV



Protocol and dataset courtesy of Scott Alexander, MD

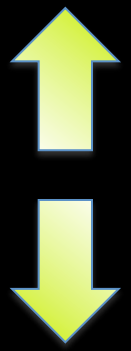
Combo Direct / Indirect CTV

Combo Direct / Indirect CTV



CTA for TOS: Combo Direct / Indirect CTA

- Ipsilateral IV, arm over head w/ palm taped up
  120 mL full-strength @ 4ml/s
- Chase: 100 mL dilute (10%) contrast @2.5 ml/s
  - Can inject contralateral arm at same time (dilute)
- 65 sec empiric delay, scan caudo-cranial
- Arm down, immediate re-scan cranio-caudal
- **Volumetric Review**

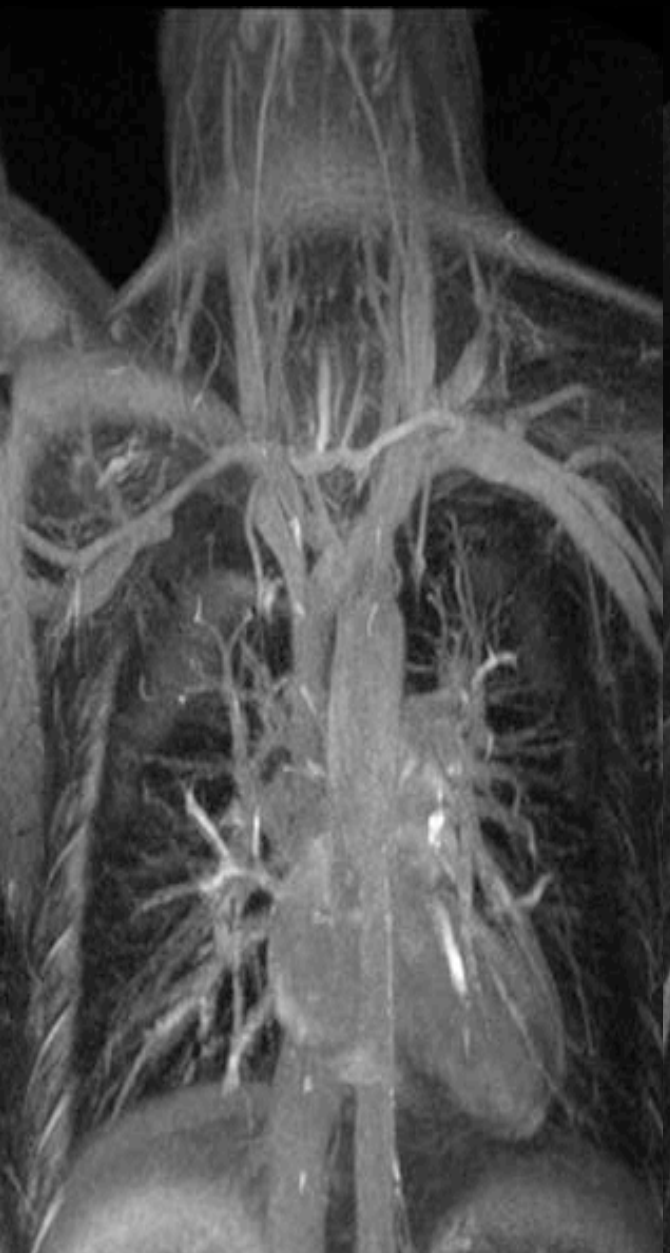


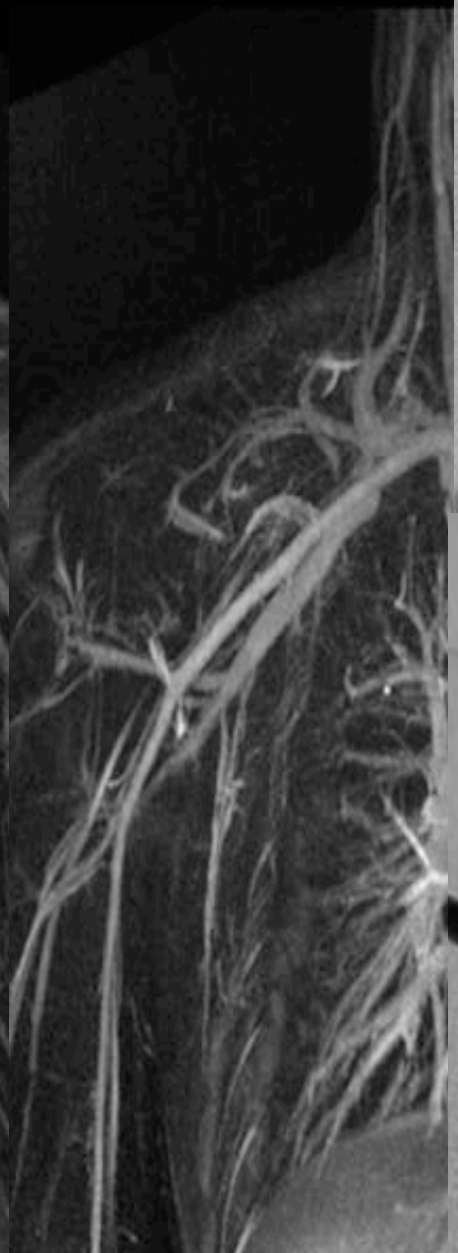
MRA for TOS: Blood Pool MRA

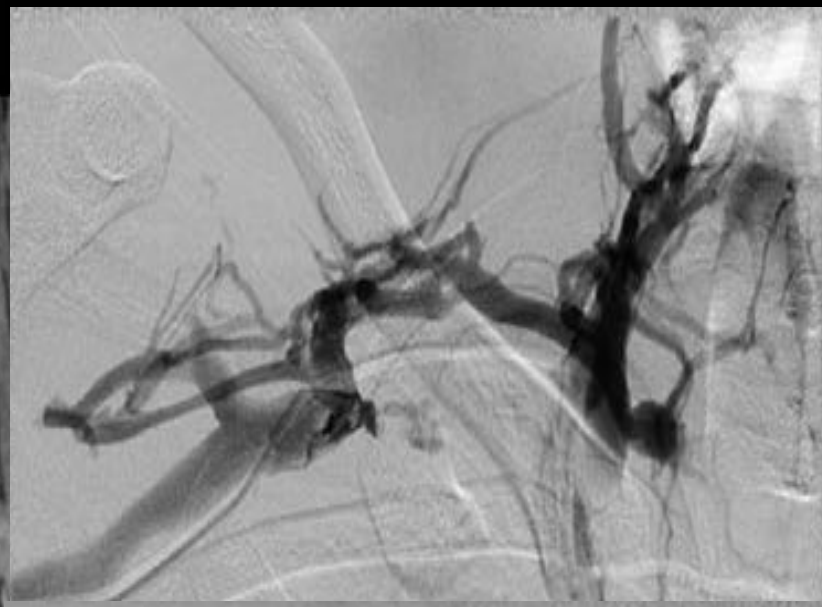
- Anatomic imaging: Oblique sag and cor T1/T2
- Relaxed and Challenged imaging:
  - Gadofosveset (blood pool agent)
  - Breath-hold FSPGR, ECG-gated, high resolution (1.8 mm ST, 448 x 448 matrix) CORONAL acquisition
    - Challenged: Arm Abducted
    - Relaxed: Arm Down

Arm UP

Arm DOWN







Venography: Common Clinical Indications

Upper Extremity / Chest

- SVC syndrome (malignancy, post-XRT)
- Catheter-related complications (clot, stenosis)
- DVT
- Thoracic Outlet syndrome
- Dialysis access

Lower Extremity

- DVT (+/- PE study)
- May-Thurner syndrome
- Pre-transplant evaluation

General

- Venous stent evaluation
- Vascular Malformations – treatment planning

SVC Obstruction

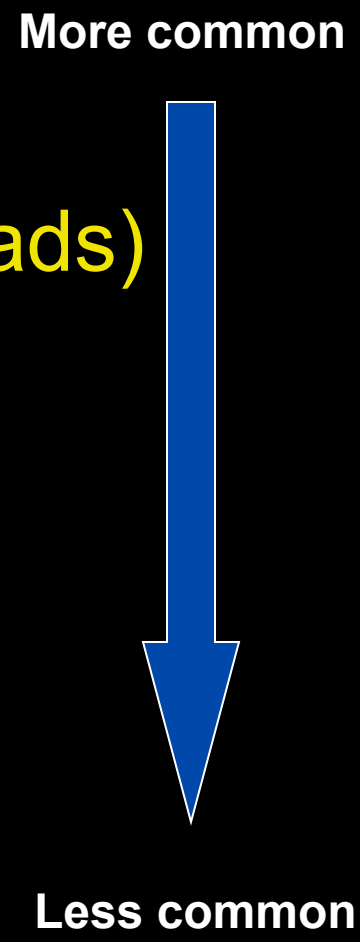
NOT A COMPREHENSIVE SYSTEM!

- Stanford, *et al*.: Venography series with 4 main collateral pathways
  - I. Partial SVC occlusion w/ patent Azygous v.
  - II. Near complete obstruction SVC w/ antegrade flow azygous → RA
  - III. Near complete obstruction SVC w/ retrograde flow azygous
  - IV. Complete obstruction SVC + one or more major tributaries (e.g. azygous v.)

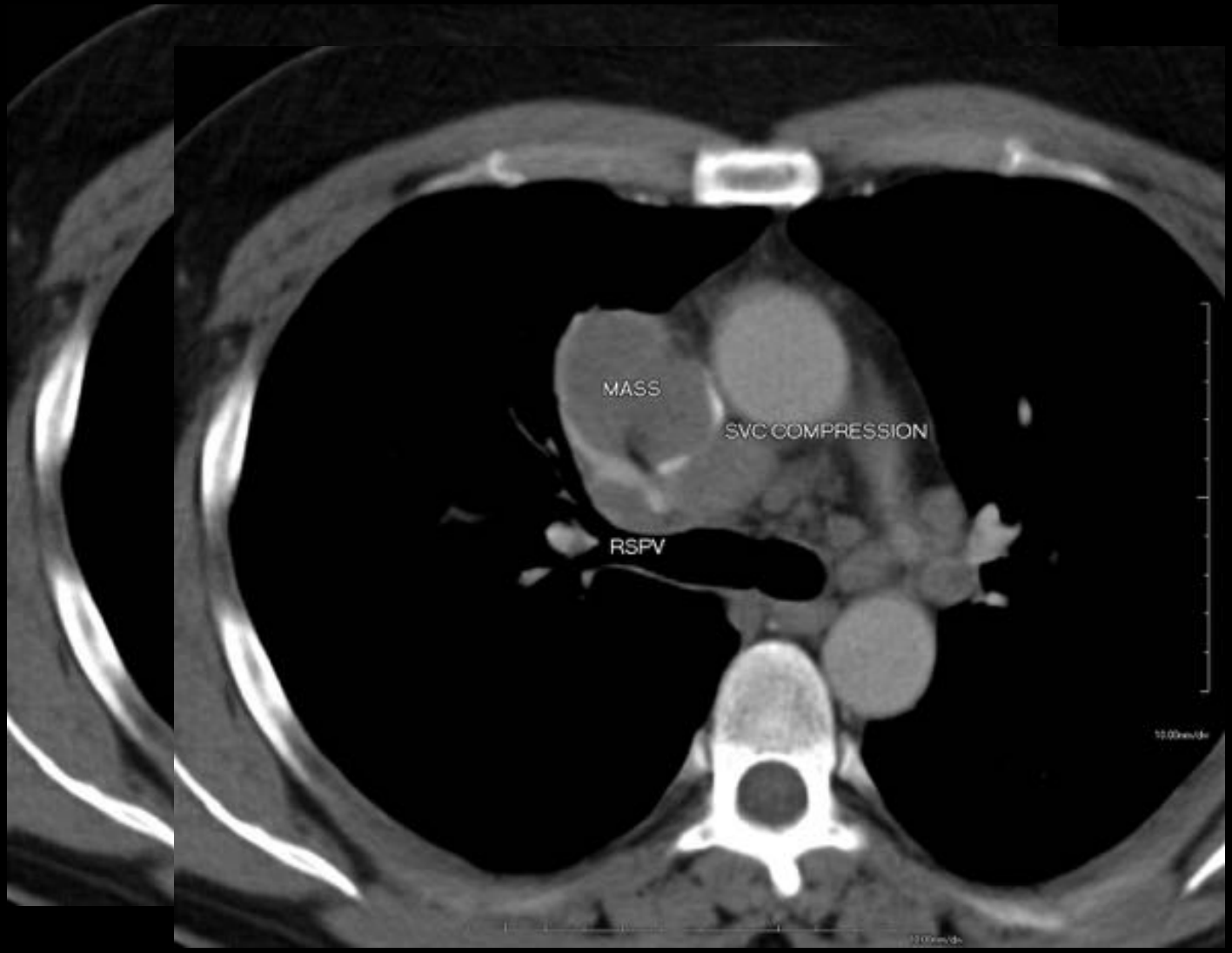
Stanford W, et al AJR 1987:148. 259-62.

SVC Occlusion

- Mass / Adenopathy
- Catheter / Device (pacer / ICD leads)
- Fibrosing Mediastinitis
- Catheter + Mass
- Catheter + pleural effusion
- Thrombus
- Catheter + lymph nodes



SVC Syndrome from Tumor



Classification of all collateral pathways one series

From: Cihangiroglu: J Comput Assist Tomogr, Volume 25(1).January/February 2001.1-8

Occlusion level[a]	Collateral pathways[b]				Stanford scheme	Other features
OSC		2			Unclassified	
OSC	1		3		Type I	
OSC	1	2		4	Unclassified	
OSC	1	2	3		Type I	
OSC	1	2	3	4	Unclassified	
OSC	1	2	3	4	Unclassified	Systemic portal shunt
SVA		2	3		Type IV	Systemic portal shunt
SVA		2		4	Type IV	
SVA	1	2	3	4	Type IV	Azygos distal opacification
BBI	1	2	3	4	Unclassified	
BBI	1	2	3	4	Type II	
SBL	1		3		Type IV	
SBL	1	2		4	Unclassified	Systemic portal shunt
SBB	1		3		Unclassified	Systemic pulmonary shunt
SBB	1		3	4	Unclassified	
SBB	1	2	3		Unclassified	
SBB	1		3	4	Unclassified	
SBB	1	2	3		Unclassified	
SBB	1		3	4	Type II	
SBB	1	2	3	4	Unclassified	
SBB	1	2	3	4	Unclassified	Systemic portal shunt

The patterns are grouped by the superior vena cava (SVC) occlusion level and presence of four major pathways. Other features represent variations from the classic pathways.

[a] OSC, only SVC; SVA, SVC + azygos vein occlusion; BBI, bilateral brachiocephalic + incomplete SVC; SBB, SVC + bilateral brachiocephalic vein; SBL, SVC + left brachiocephalic vein; SBR, SVC + right brachiocephalic vein.

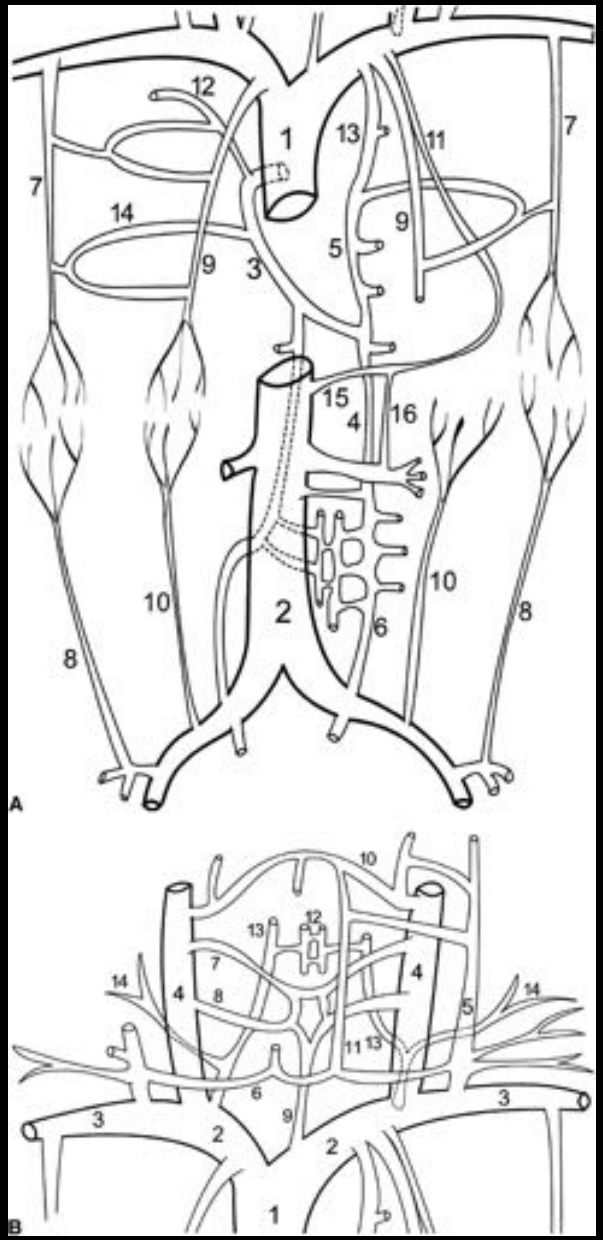
[b] Collateral pathways; 1, azygos-hemiazygos; 2, internal mammary vein; 3, lateral thoracic vein; 4, vertebral plexus.

Most common venous collaterals listed in order of frequency (n = 21).

From: Cihangiroglu: J Comput Assist Tomogr, Volume 25(1).January/February 2001.1-8

Collateral	Incidence in this cohort [n (%)]
Azygos vein	19 (90.5)
Thoracoepigastric vein	18 (85.7)
Mediastinal vein	17 (80.9)
Internal mammary vein	16 (76.2)
Hemiazygos vein	15 (71.4)
Lateral thoracic vein	15 (71.4)
Pericardiophrenic vein	15 (71.4)
Paravertebral vein	14 (66.6)
Intercostal vein	12 (57.1)
Thoracoacromion trunk	12 (57.1)
Capsular/surface liver vein[a]	11 (52.3)
Bilateral (superior/inferior) phrenic vein[a]	11 (52.3)
Thoracodorsal scapular vein	10 (47.6)
Superficial epigastric vein[a]	10 (47.6)
Superior epigastric vein[a]	9 (42.8)
Inferior epigastric vein[a]	9 (42.8)
Accessory hemiazygos vein	8 (38.1)

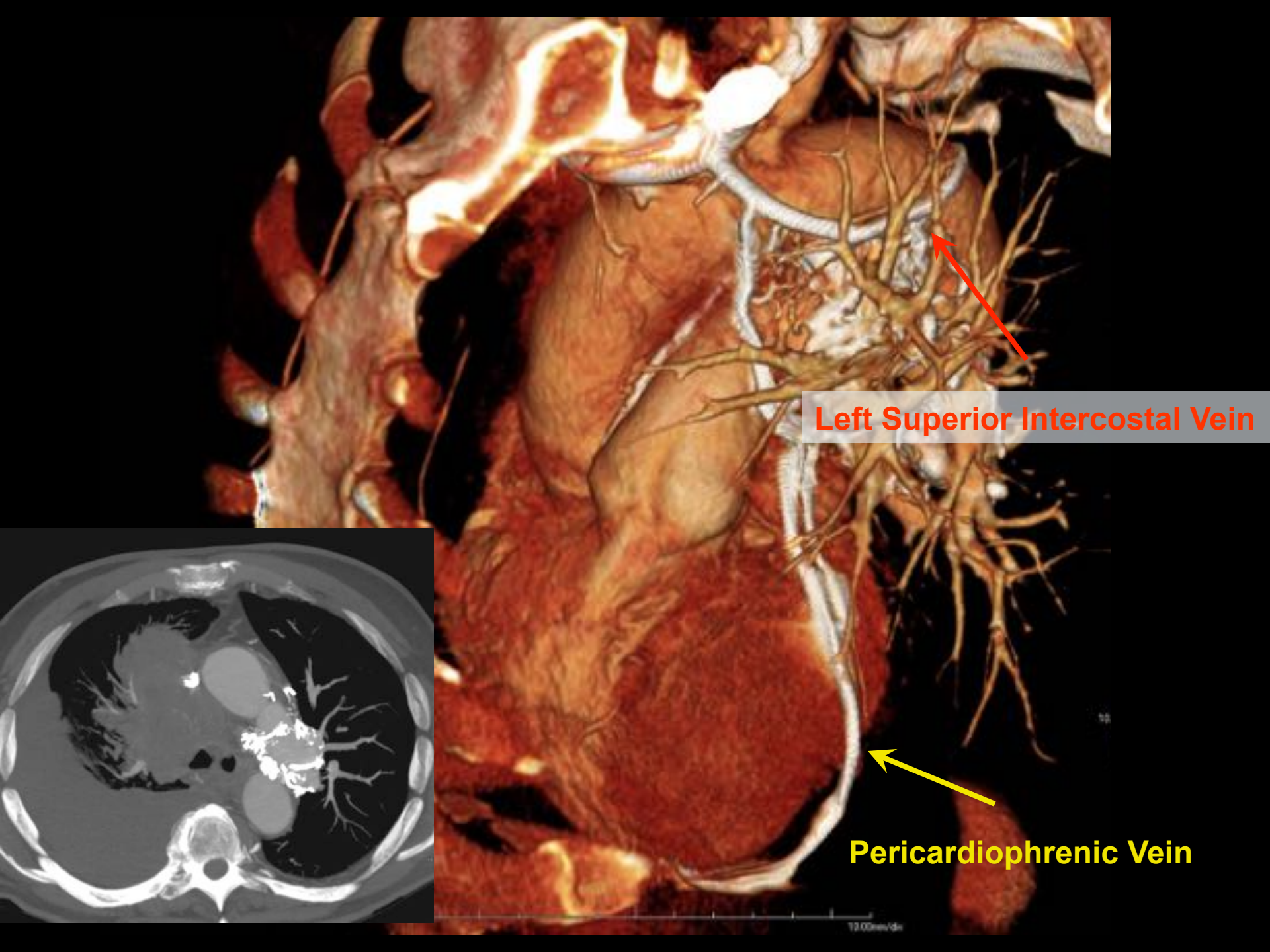
[a] Abdominal collateral.



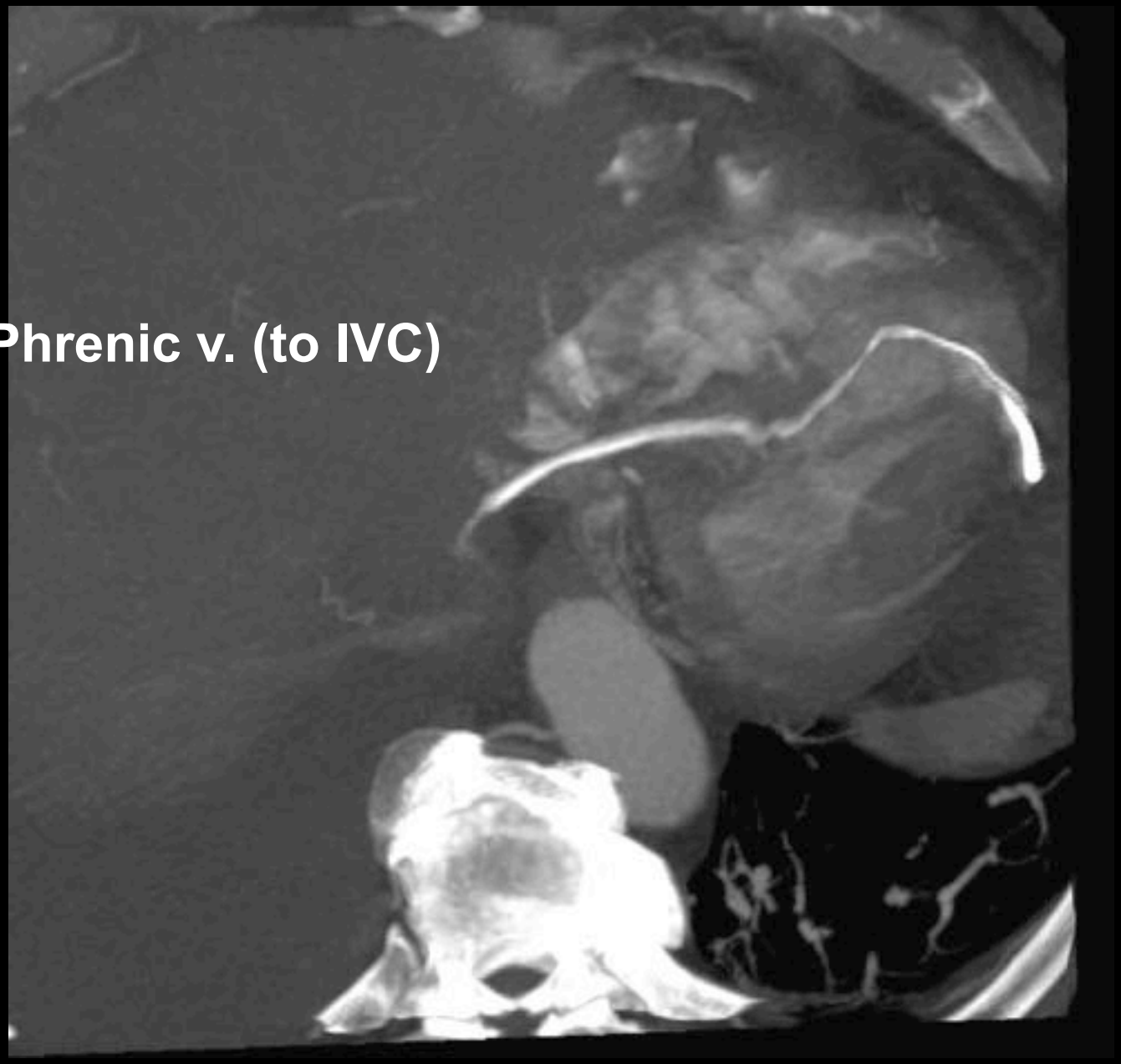
A.
1 = superior vena cava
2 = inferior vena cava
3 = azygos vein
4 = hemiazygos vein
5 = accessory hemiazygos vein
6 = ascending lumbar vein
7 = lateral thoracic vein
8 = superficial epigastric vein
9 = internal mammary vein
10 = inferior epigastric vein
11 = pericardiophrenic vein
12 = right superior (highest) intercostal vein
13 = left superior (highest) intercostal vein
14 = intercostal vein
15 = inferior phrenic vein
16 = suprarenal vein

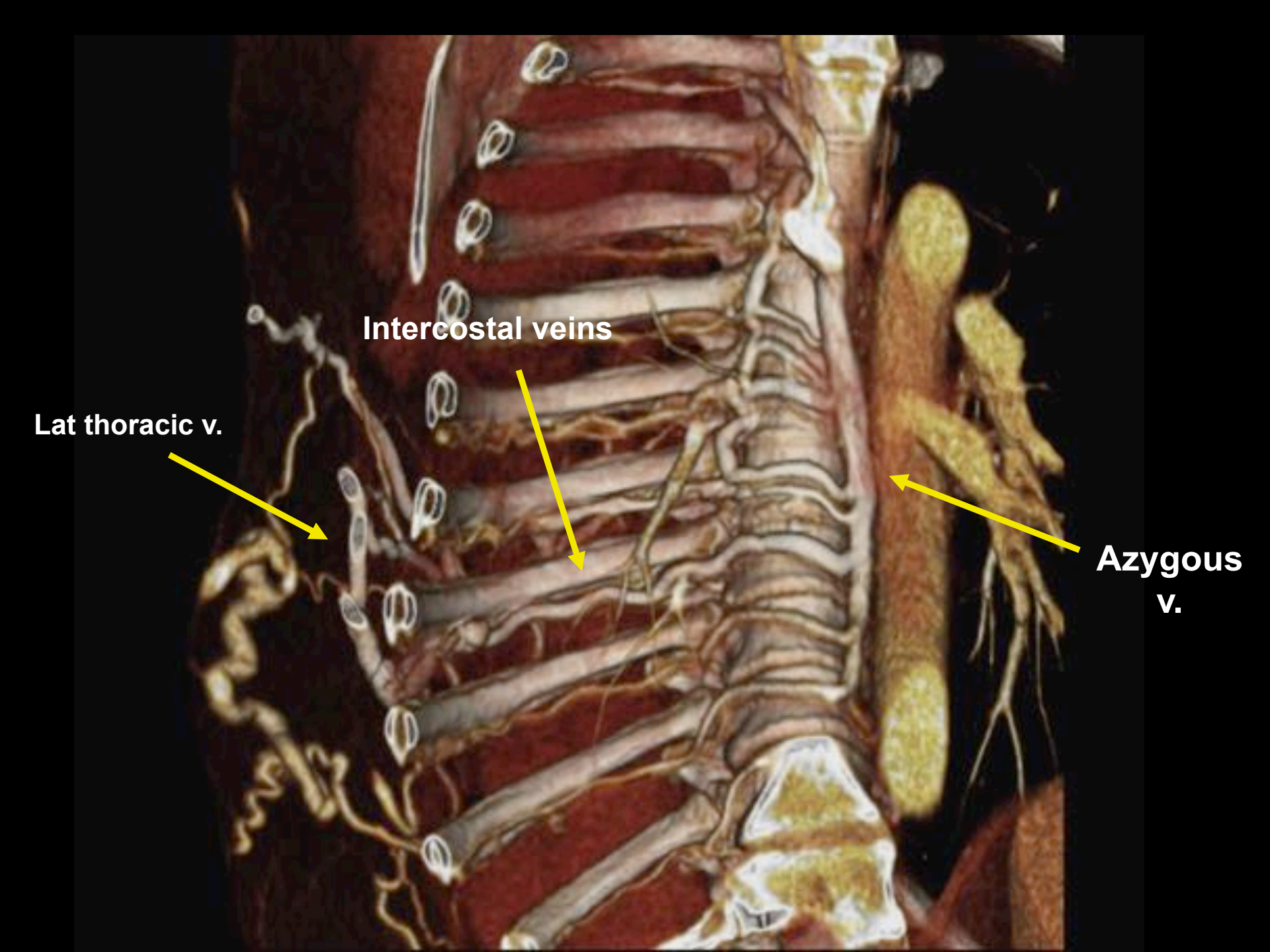
B
1 = superior vena cava
2 = brachiocephalic (innominate) vein
3 = subclavian vein
4 = internal jugular vein
5 = external jugular vein
6 = jugular venous arch
7 = superior thyroidal vein
8 = middle thyroidal vein
9 = inferior thyroidal vein
10 = facial vein
11 = anterior jugular vein
12 = vertebral venous plexus
13 = vertebral vein, and
14 = deep cervical vein

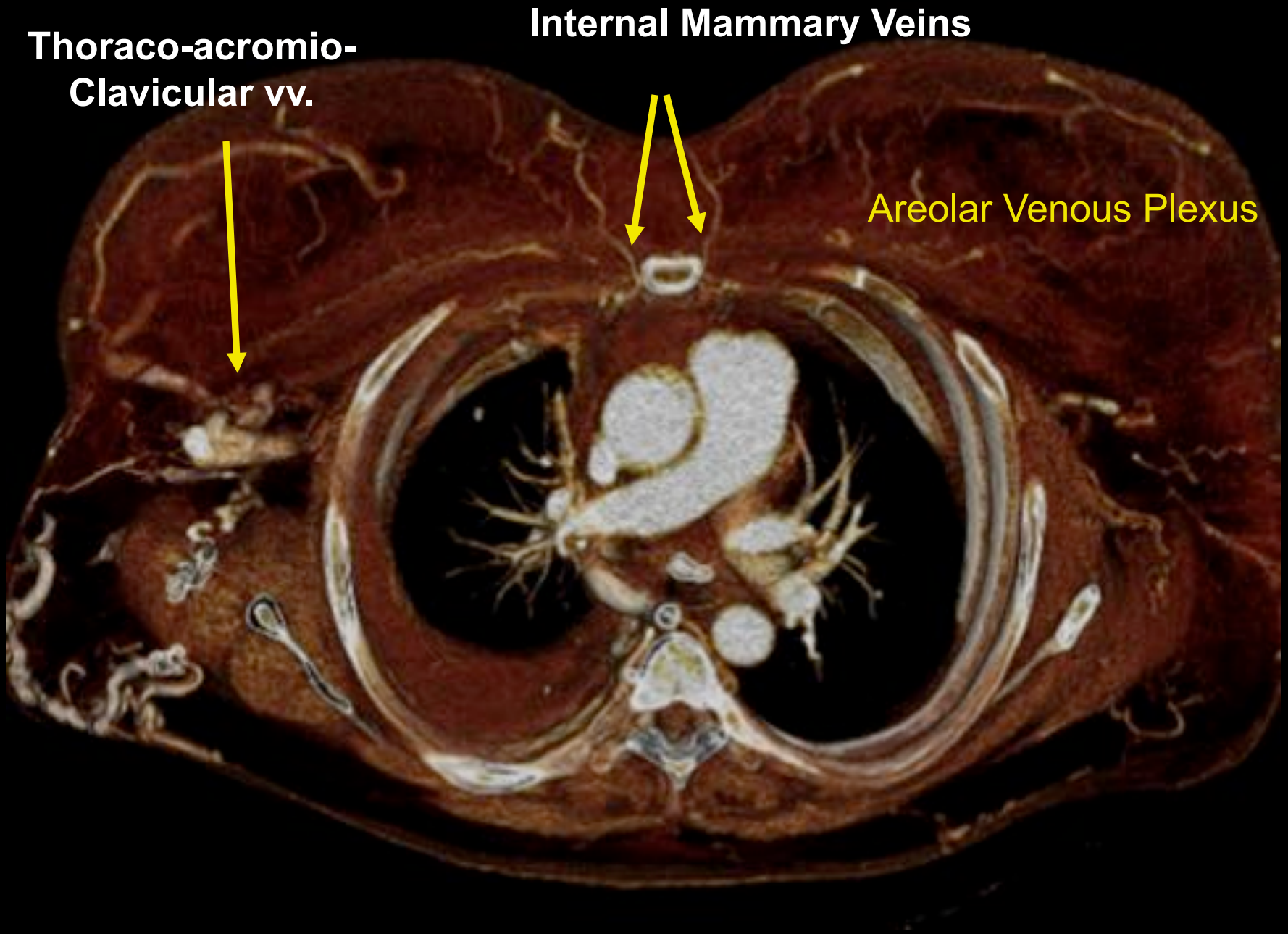
From: **Kim: J Comput Assist Tomogr, Volume 28(1).January/February 2004.24-33**

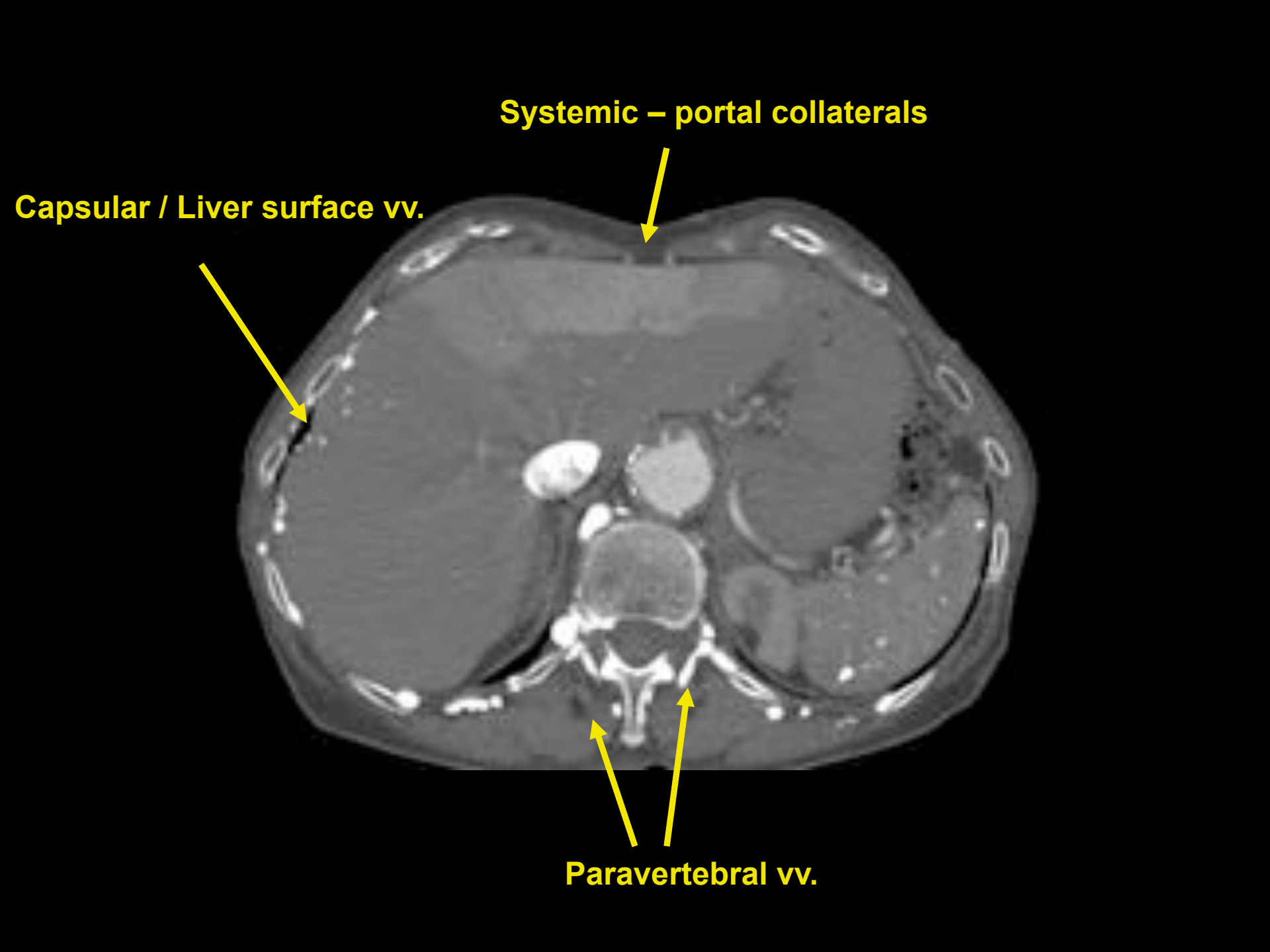

Left Superior Intercostal Vein
Pericardiophrenic Vein

Inferior Phrenic v. (to IVC)




Intercostal veins
Lat thoracic v.
Azygous v.


Thoraco-acromio-
Clavicular vv.
Internal Mammary Veins
Areolar Venous Plexus

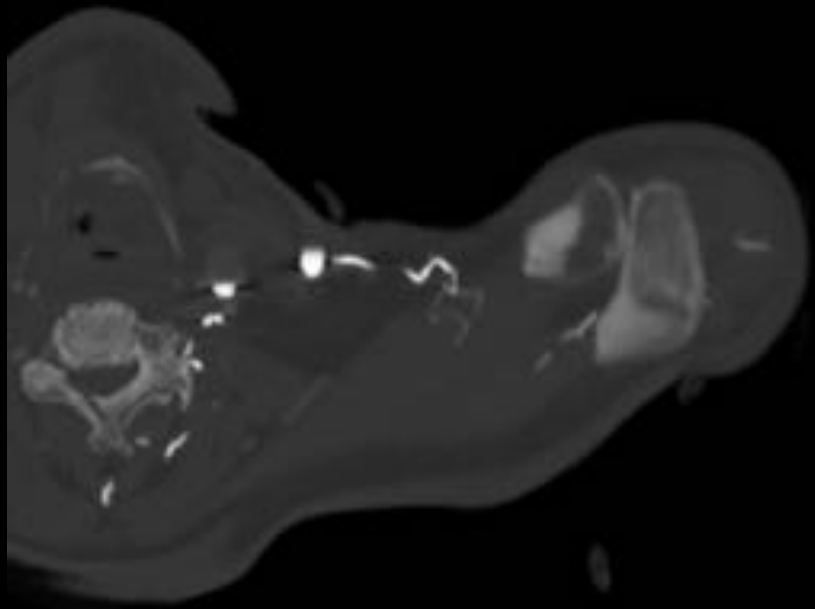

Systemic – portal collaterals
Capsular / Liver surface vv.
Paravertebral vv.

Venous collaterals organized by plexus systems – Easier, more complete to report

Suggested nomenclature	Includes these venous collaterals
Vertebral venous plexus	Paravertebral veins, vertebral veins
Mediastinal venous plexus	Mediastinal vein, pericardial veins, parietal veins, pericardiophrenic vein
Esophageal venous plexus	Paraesophageal vein, submucous venous plexus, esophageal vein, periesophageal vein
Diaphragmatic venous plexus	Superior phrenic vein, inferior phrenic vein, phrenic vein, diaphragmatic vein
Thoracoepigastric venous plexus	Thoracoepigastric vein, subcutaneous vein, areolar venous plexus, veins surrounding breast, anterior chest wall veins

Cihangiroglu: J Comput Assist Tomogr, Volume 25(1).January/February 2001.1-8

The poster child for revised venous plexus nomenclature……



Chest / Upper extremity cases

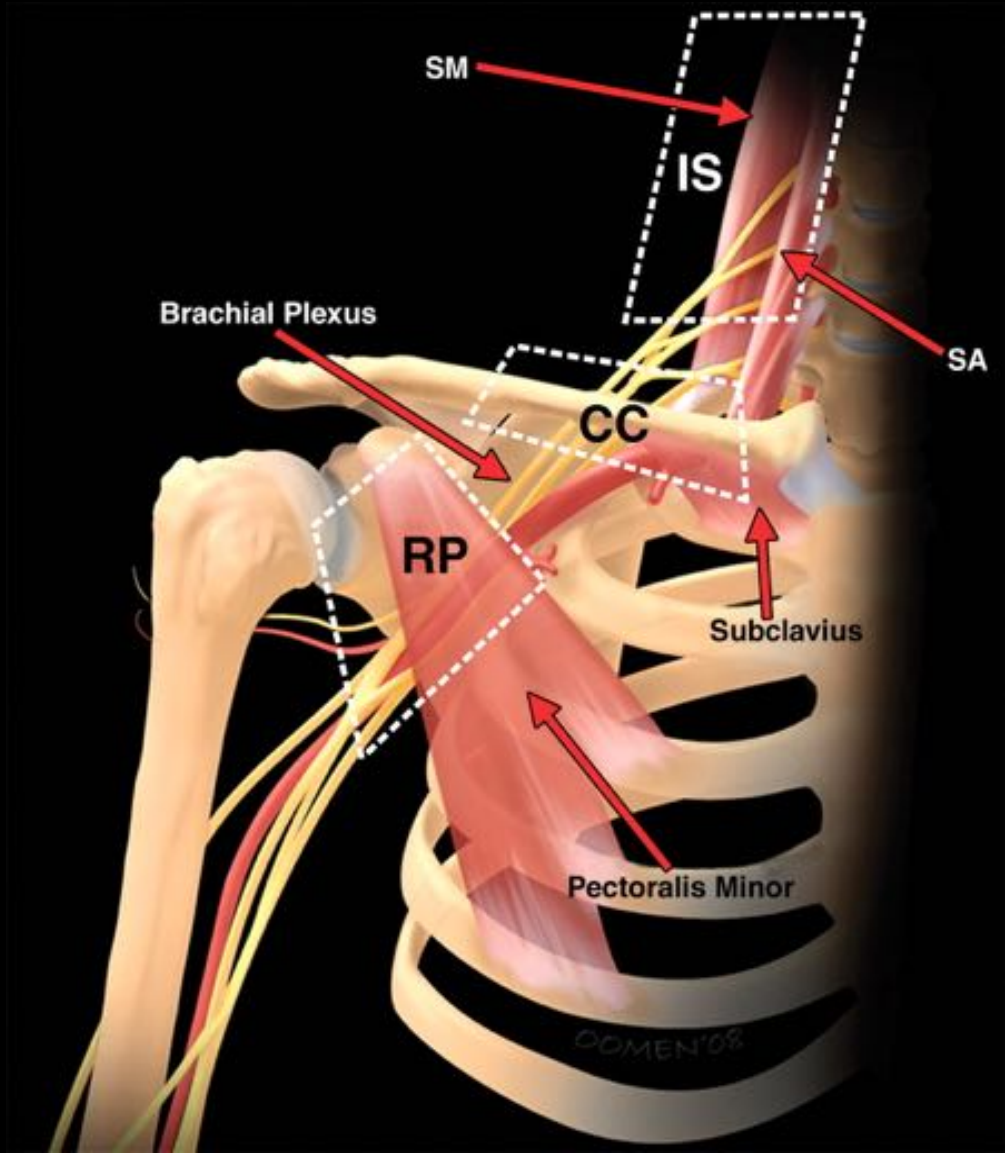
Thoracic Outlet Syndrome (TOS)

- Symptomatic compression/entrapment of neurovascular structures by bone and/or soft tissue as they pass through the cervicoaxillary canal

  - 90% Neurogenic (PT, postural Tx, NSAIDs)
  - 10% Vascular
  - Venous > Arterial

Components of Cervico-Axillary Canal

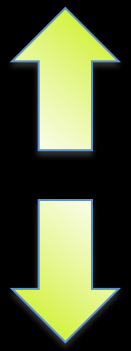
- Interscalene Triangle: #1 site of compression
- Costoclavicular Space: #1 site for vascular TOS
- Retro-pectoralis minor space: #1 site for masses



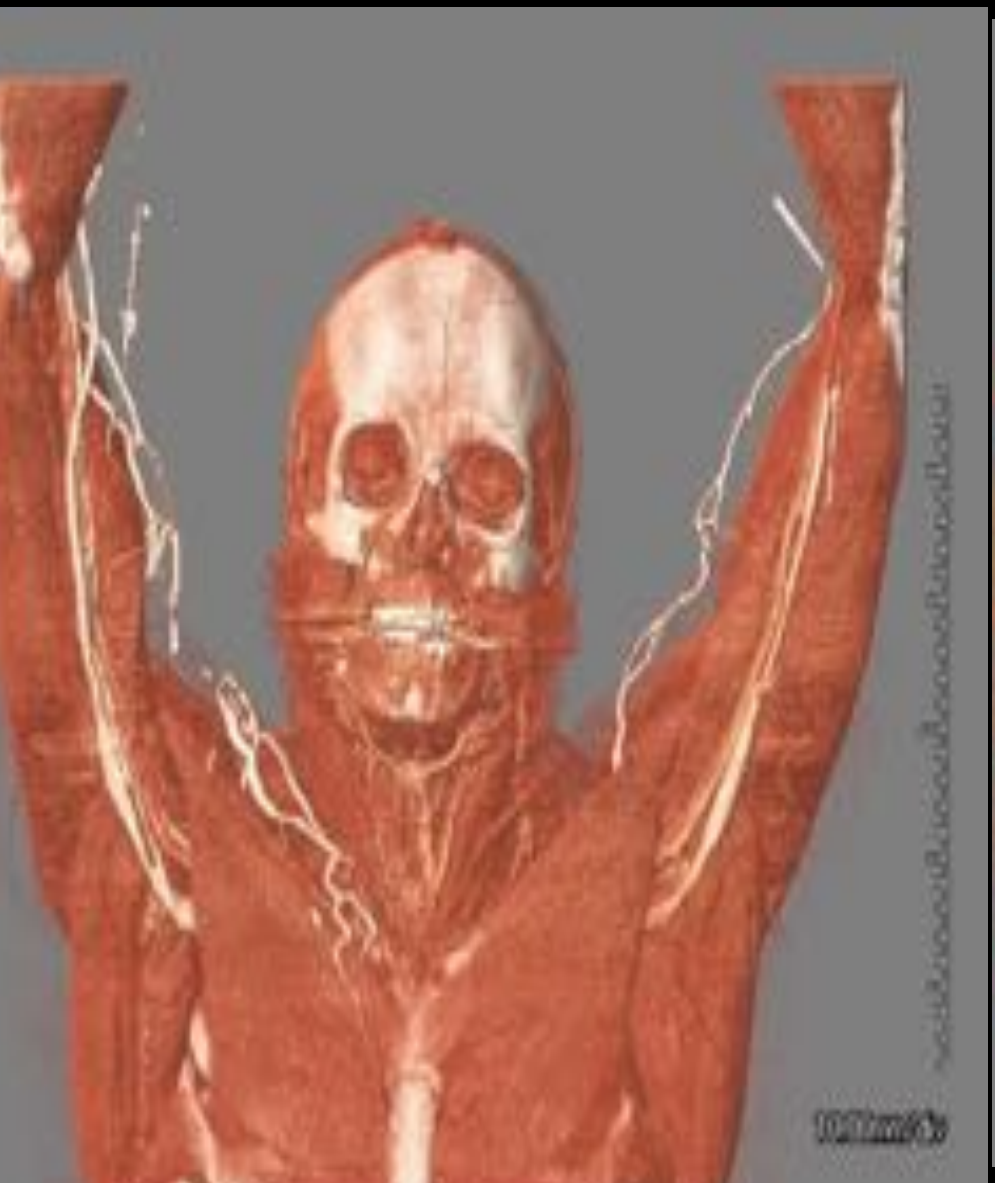
Linda D D et al. Radiographics 2010;30:1373-1400

CTA for TOS: Combo Direct / Indirect CTA

- Ipsilateral IV, arm over head w/ palm taped up
  120 mL full-strength @ 4ml/s
- Chase: 100 mL dilute (10%) contrast @2.5 ml/s
  - Can inject contralateral arm at same time (dilute)
- 65 sec empiric delay, scan caudo-cranial
- Arm down, immediate re-scan cranio-caudal
- **Volumetric Review**



Bilateral Direct / Indirect CTA

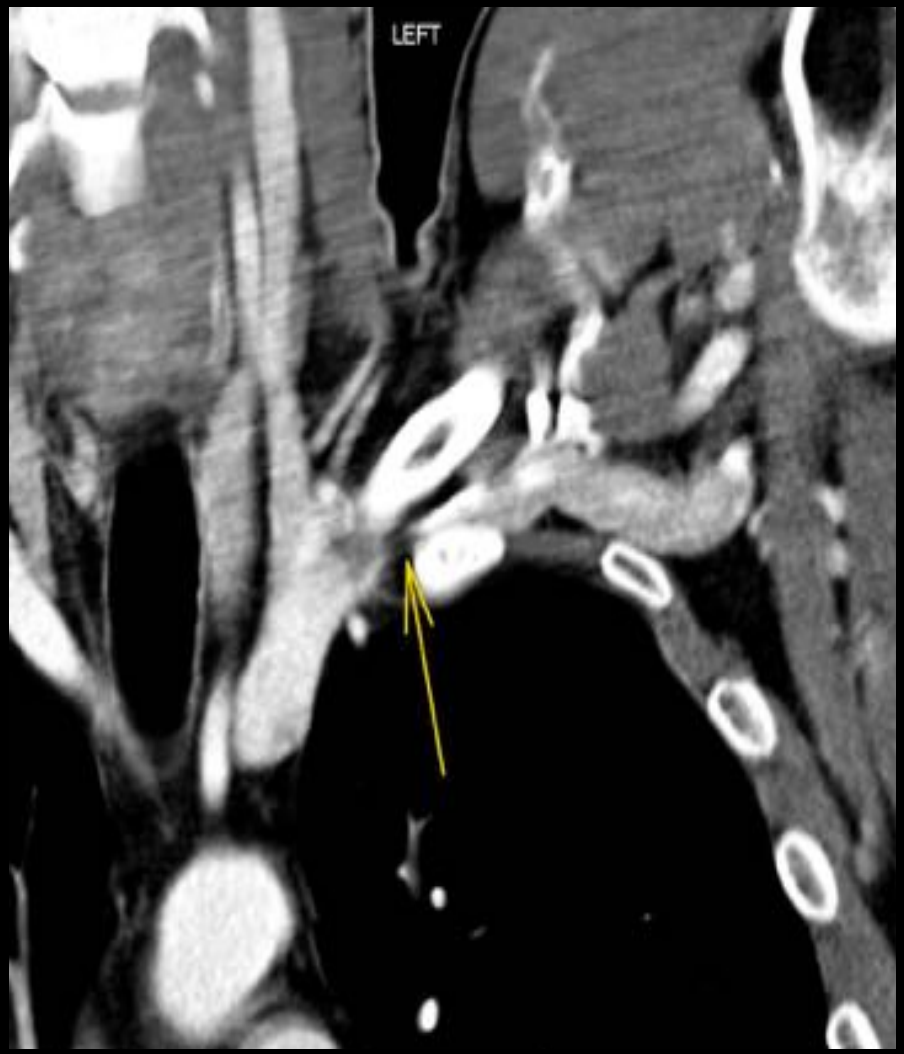


Venous TOS: "Effort Thrombosis"

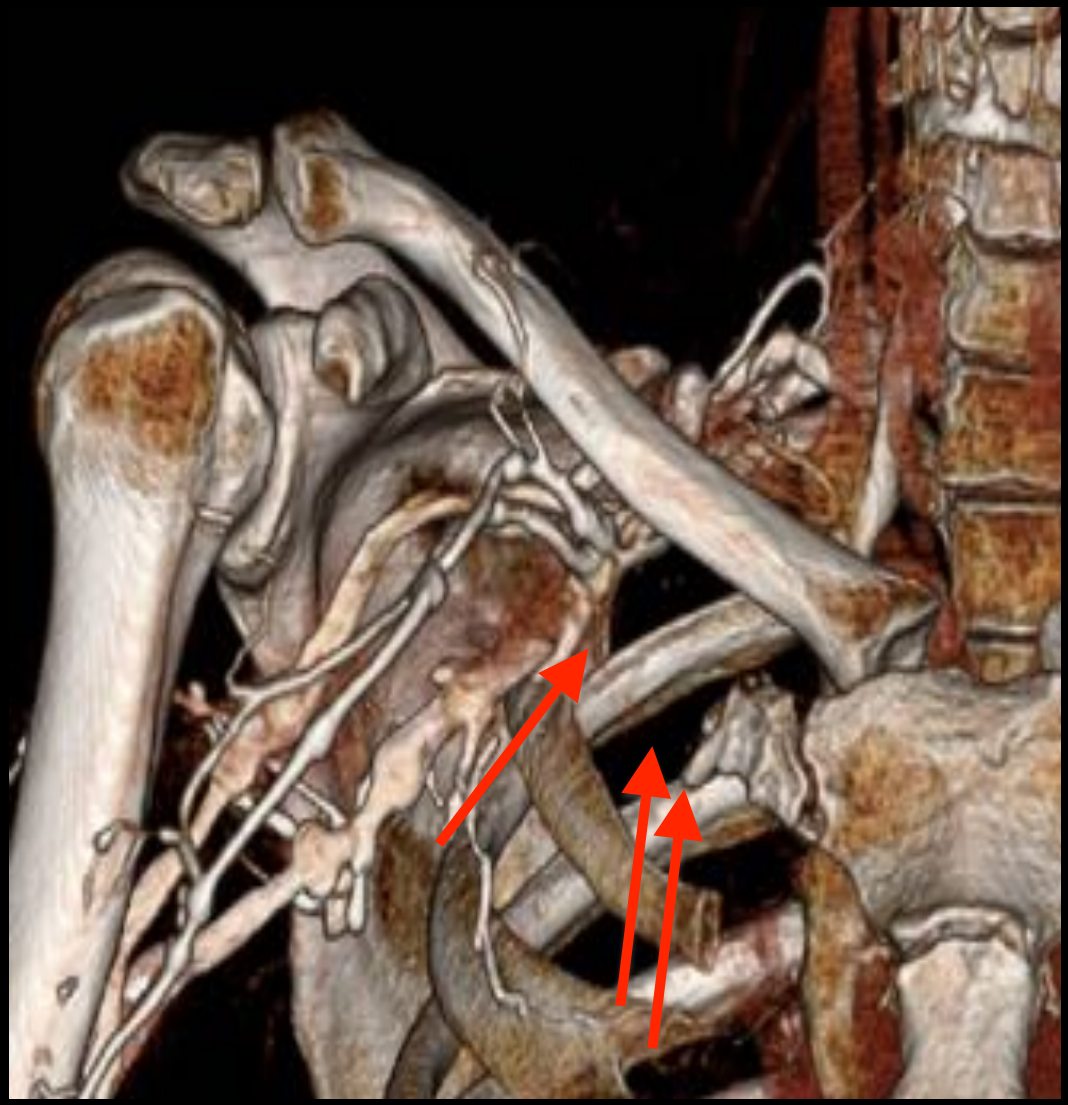
- Paget-Schroetter syndrome (PSS)
- AKA axillo-subclavian venous thrombosis
- "Overhead" athletes
- PE in up to 1/3!! *
- Post-thrombotic syndrome (later)

* Perlowski AA. Vasc Med (2010) vol. 15 (6) pp. 469-79

Effort Thrombosis:
36 YO weightlifter



Post-Op 1st rib resection

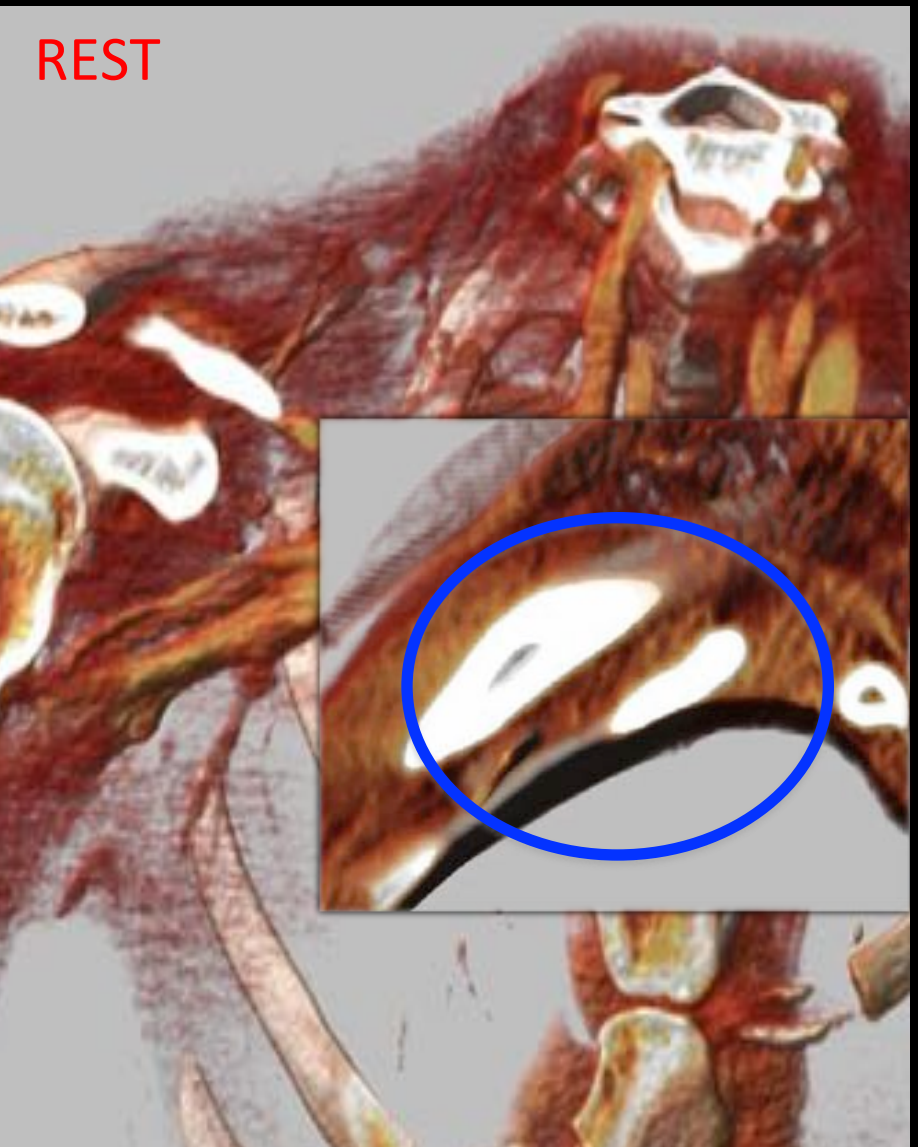


Arterial TOS

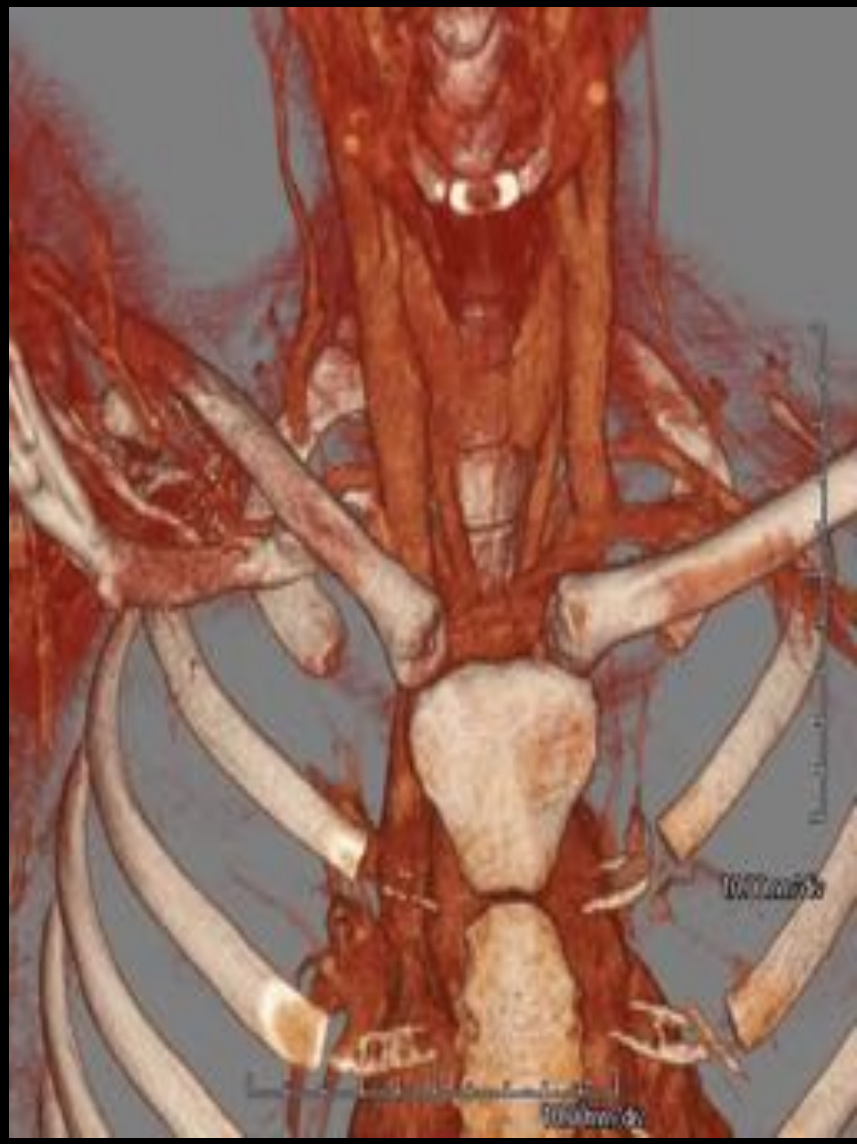
- "Overhead athletes"
- SX: Coolness, weakness, diffuse arm pain (ischemic neuritis)
- Cause: Repetitive compression injury
  - Anatomic predisposition (tight CCS)
  - Post-traumatic, bony callus
  - Scalene hypertrophy

Arterial and Venous TOS:
16 YO Volleyball Athlete

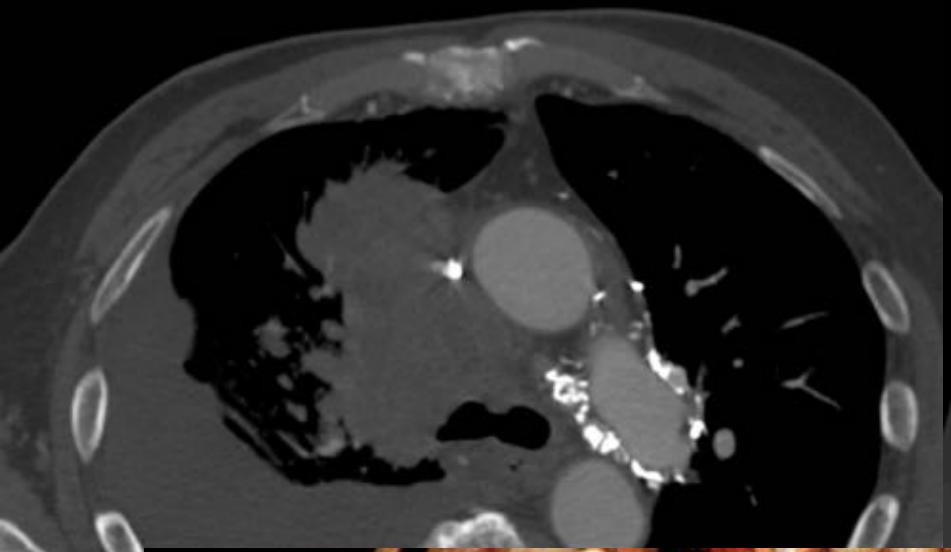
REST

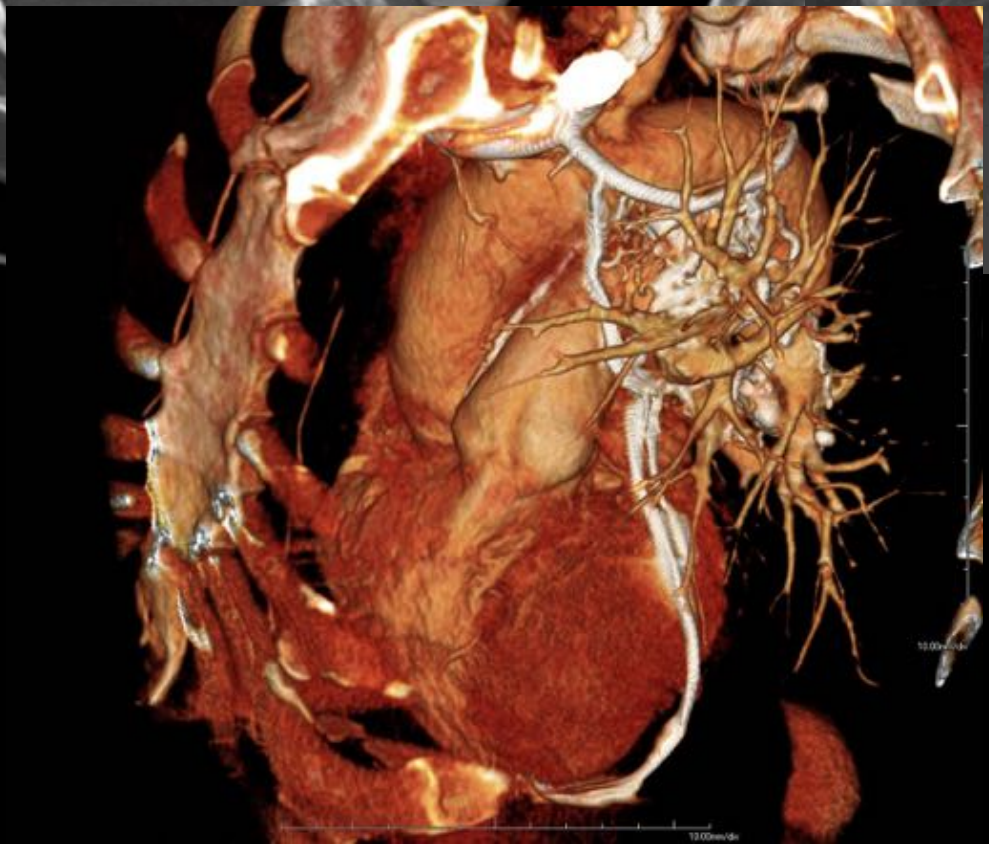


STRESS



SVC and central veins





LUNG CA
with SVC syndrome

RSCV OCCLUSION – 47 F Dialysis Pt


10 MM PTA
S/P 10 MM PTA

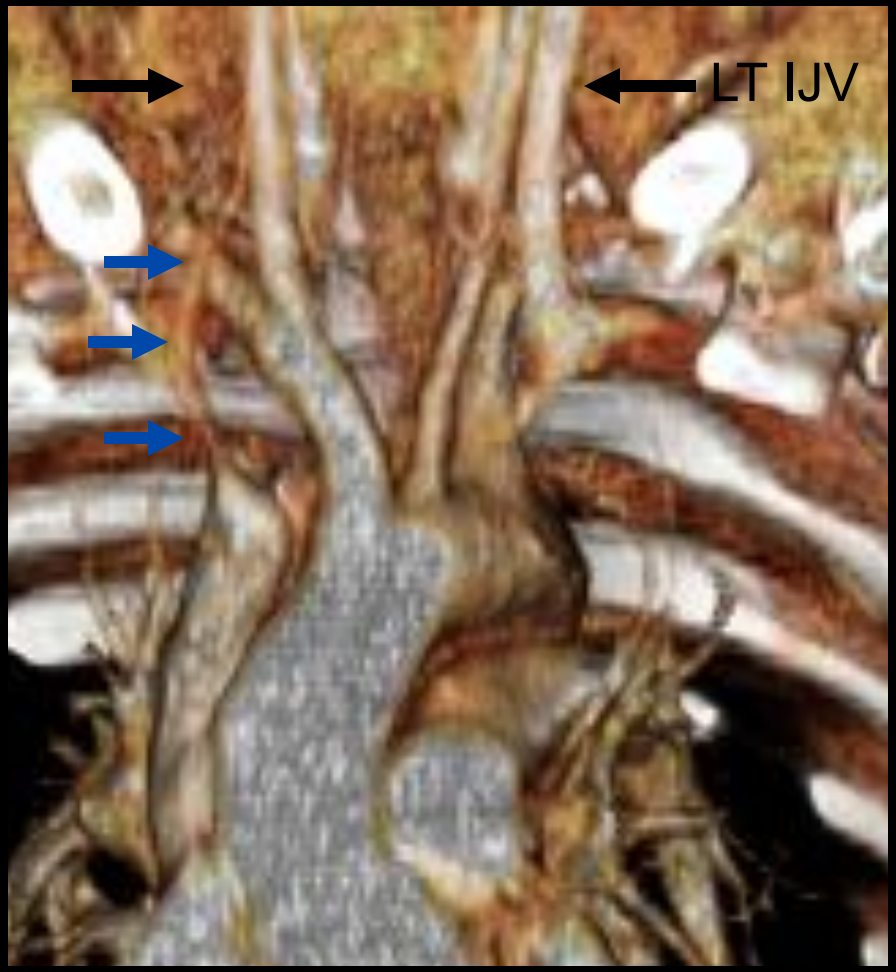
35M hx thigh sarcoma. Facial swelling & chest wall varicosities when he bent over to tie his shoes.

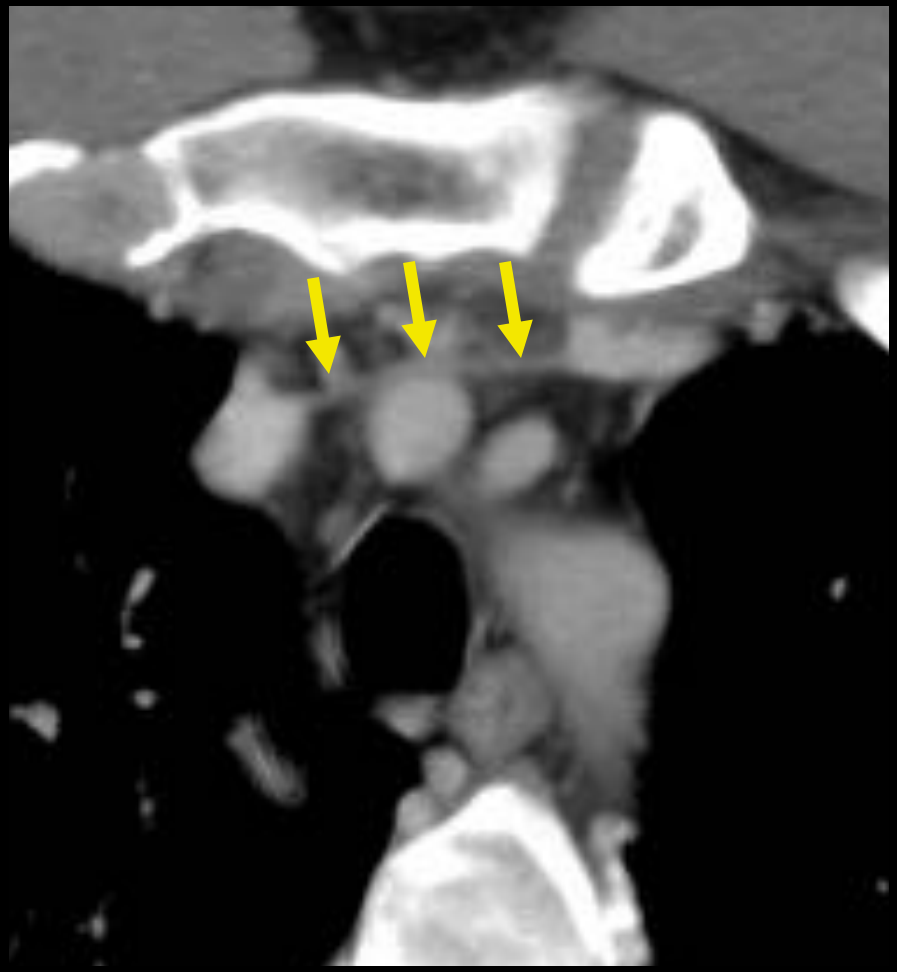
Documented central venous obstruction.

Treatment planning: Assess vascular access, particularly axillary & subclavian veins B/L.

Simultaneous bilateral arm injection:
1: 6 dilution (30cc contrast + 170 cc NS, each arm) @ 2cc/sec.

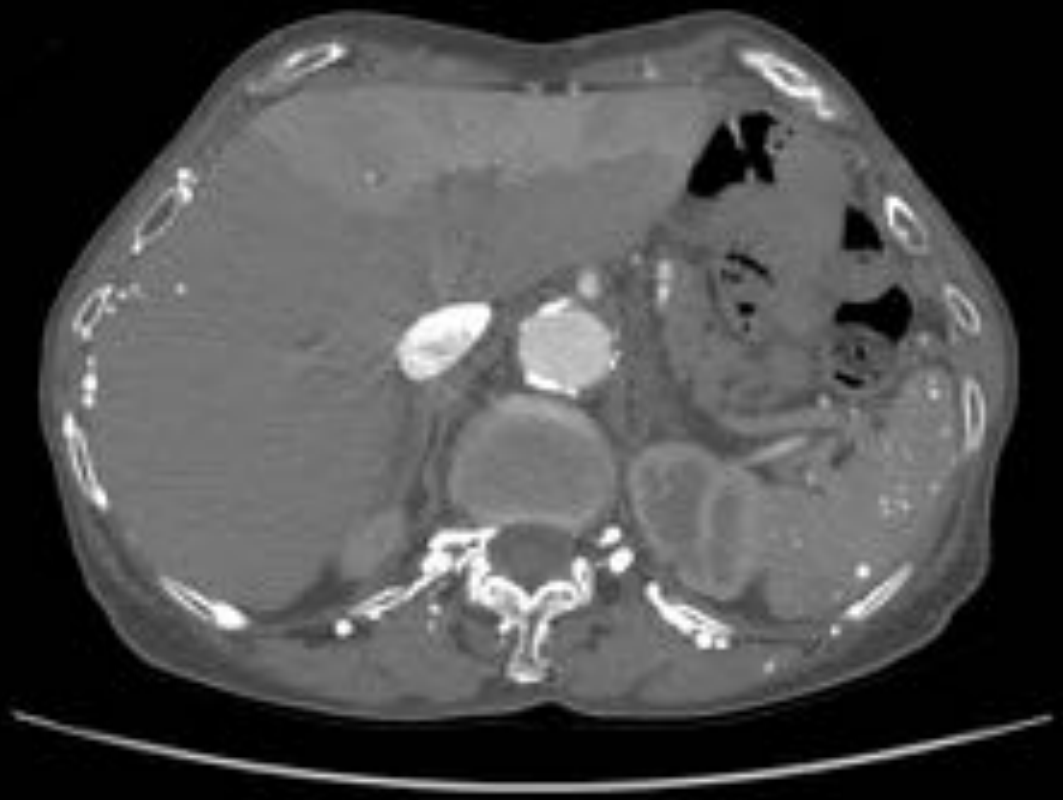
Courtesy of Anne Chin, MD



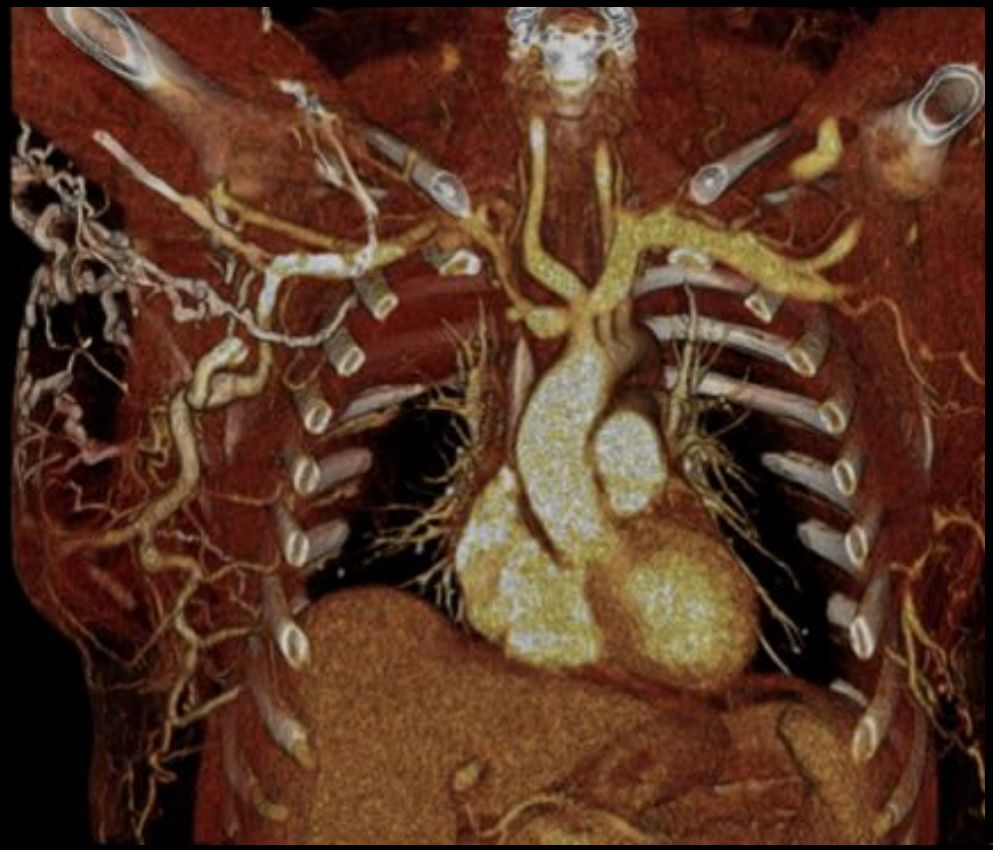


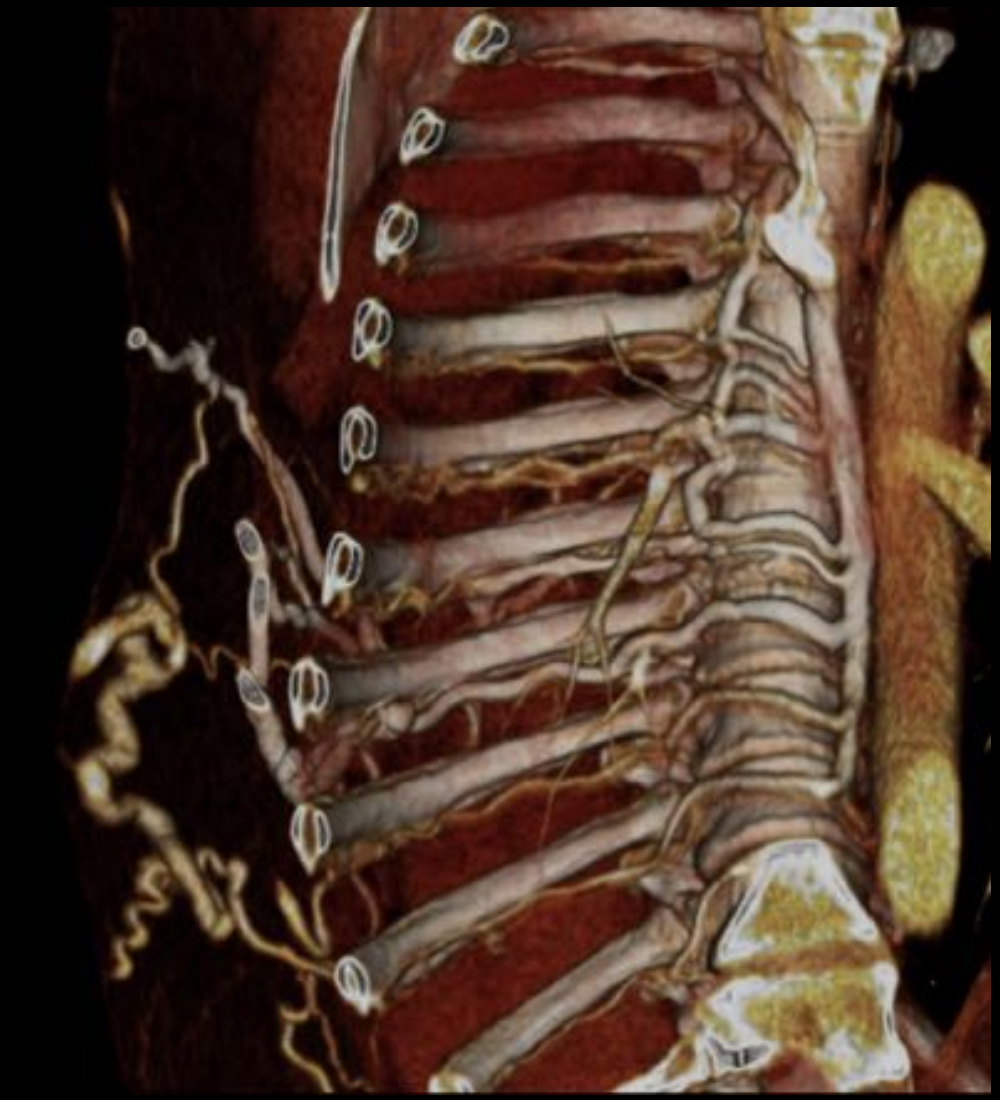
90cc contrast, 60 sec diagnostic delay.
Imaging range: angle of mandible to lesser trochanters.

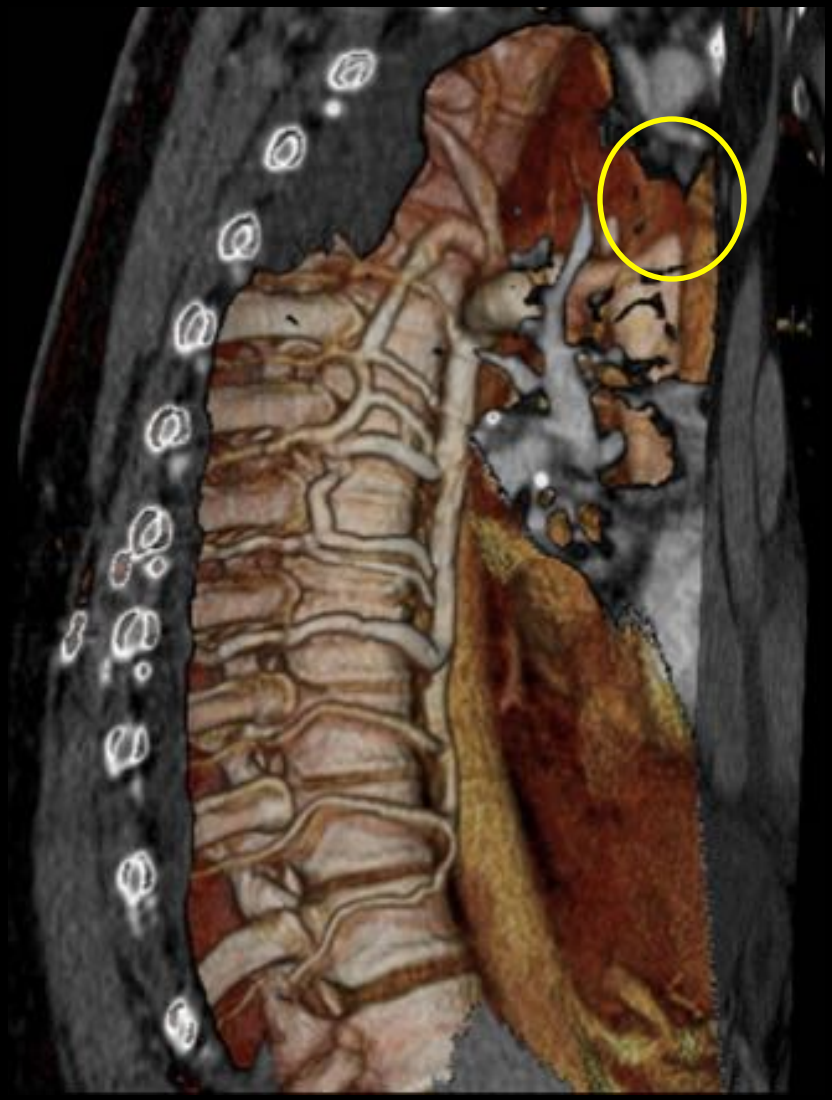
SVC Occlusion from Aneurysm

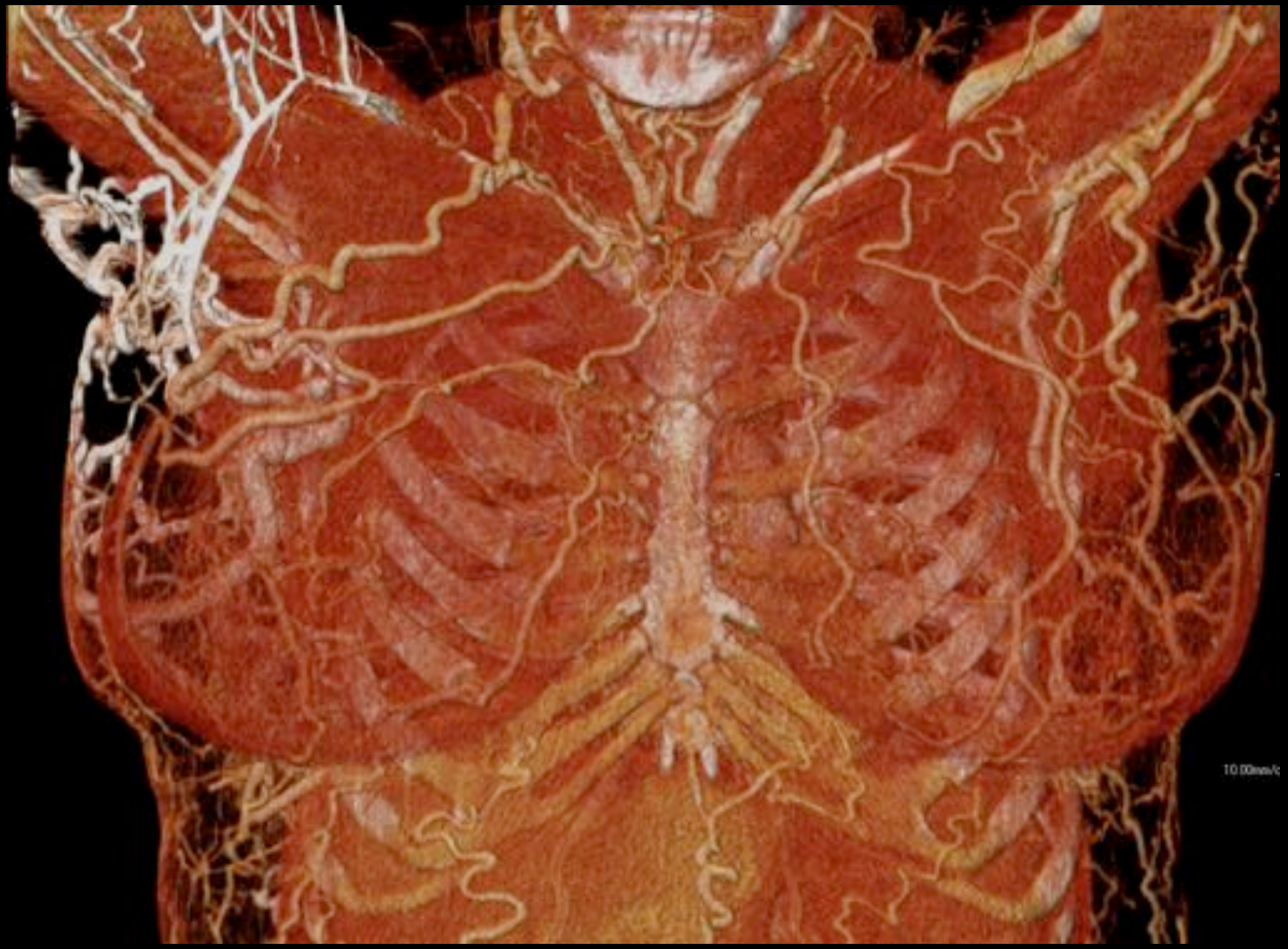


RSCV Occlusion – Previous Catheters

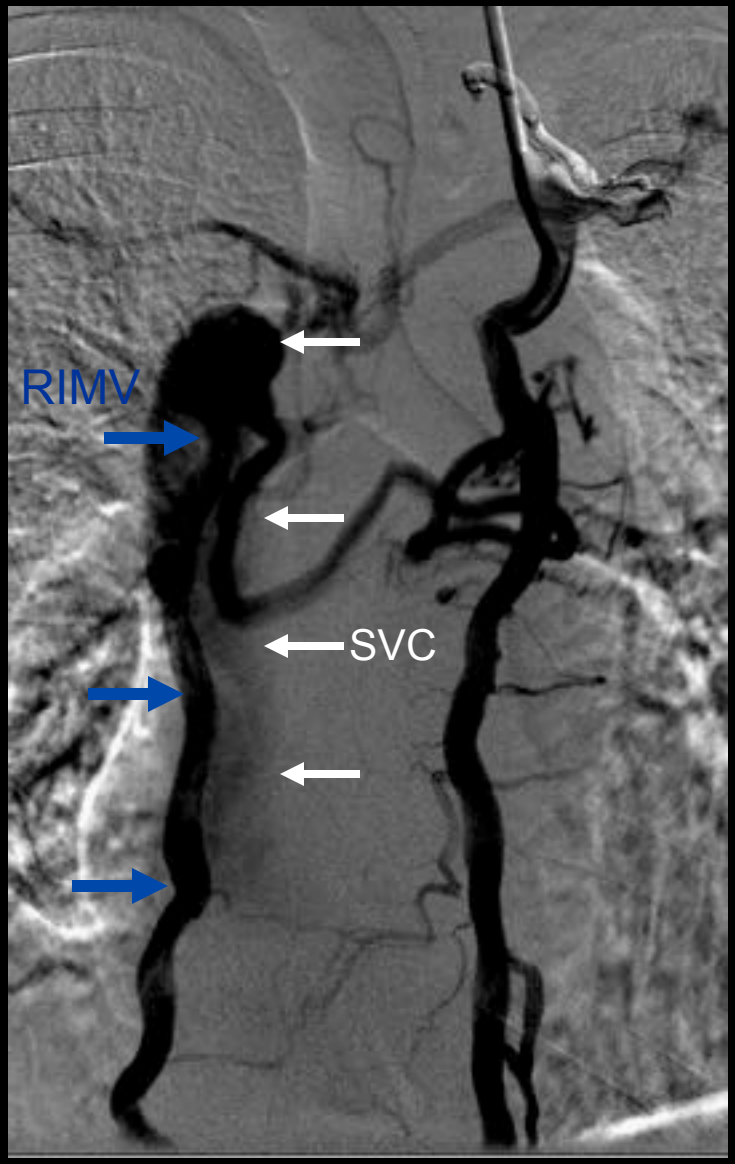






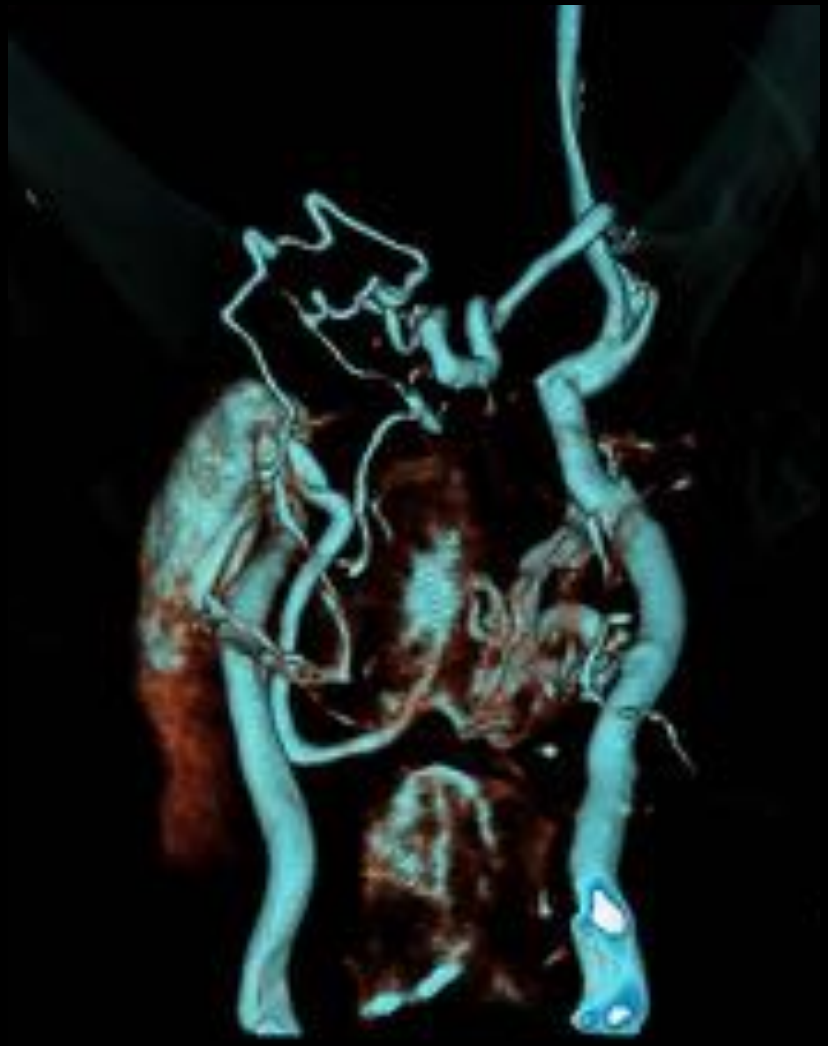


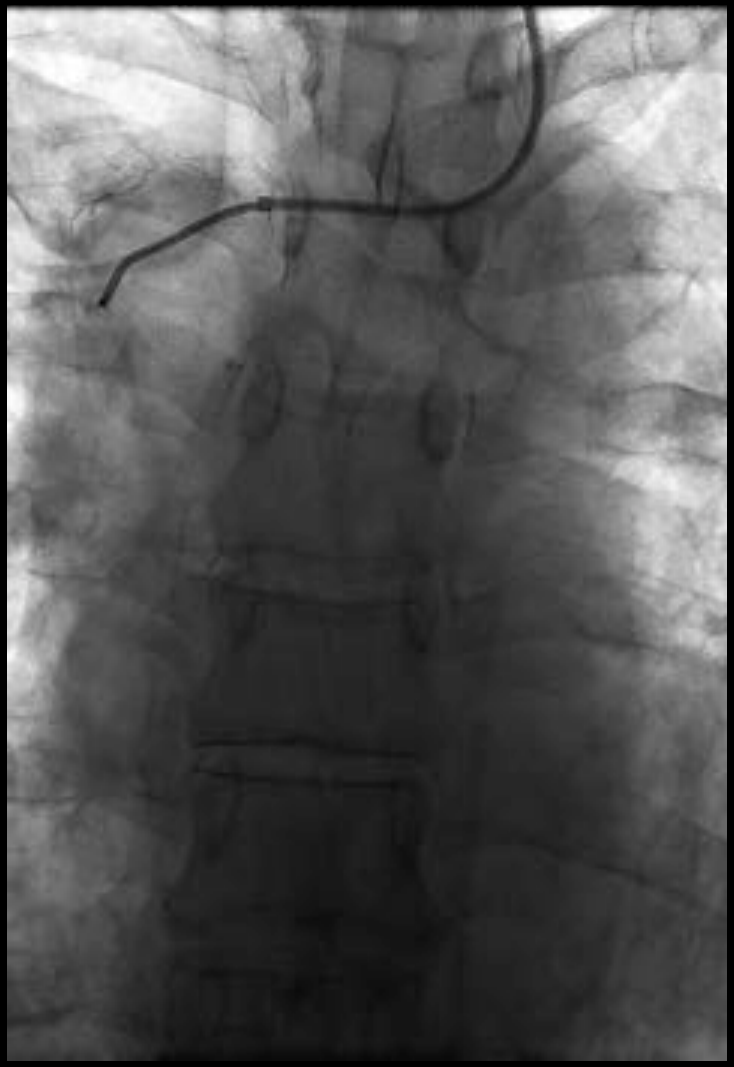
L innominate Occlusion - C-Arm CT

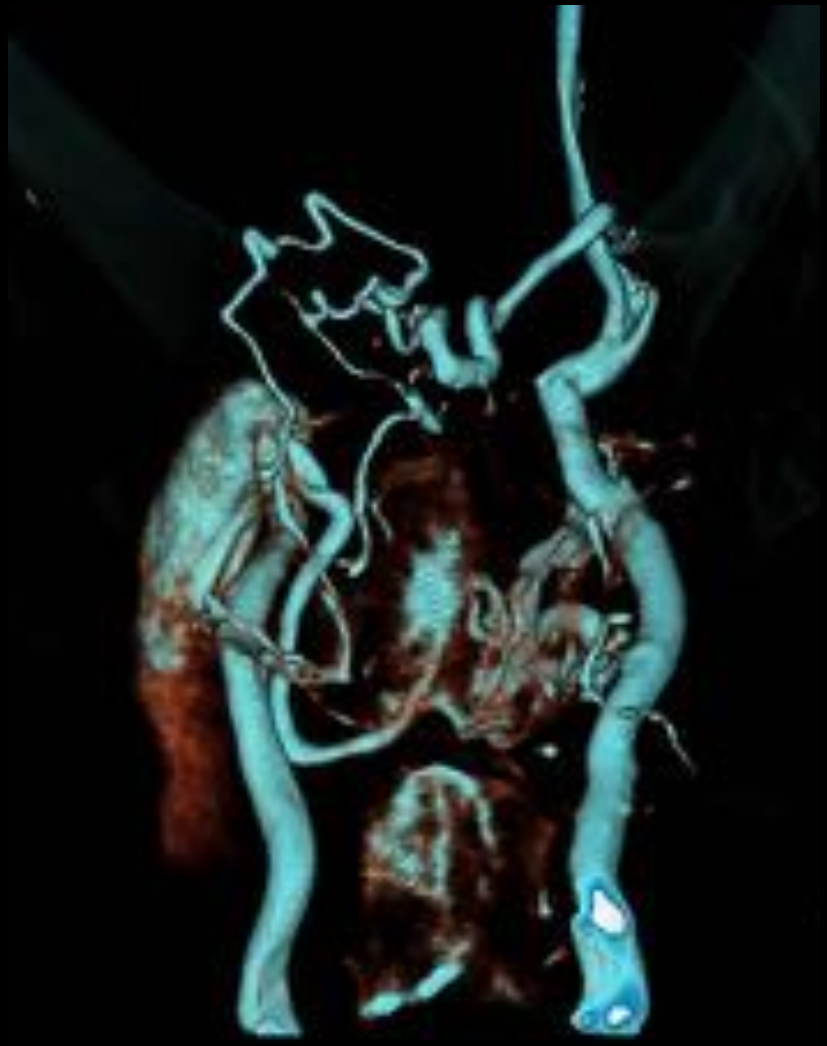


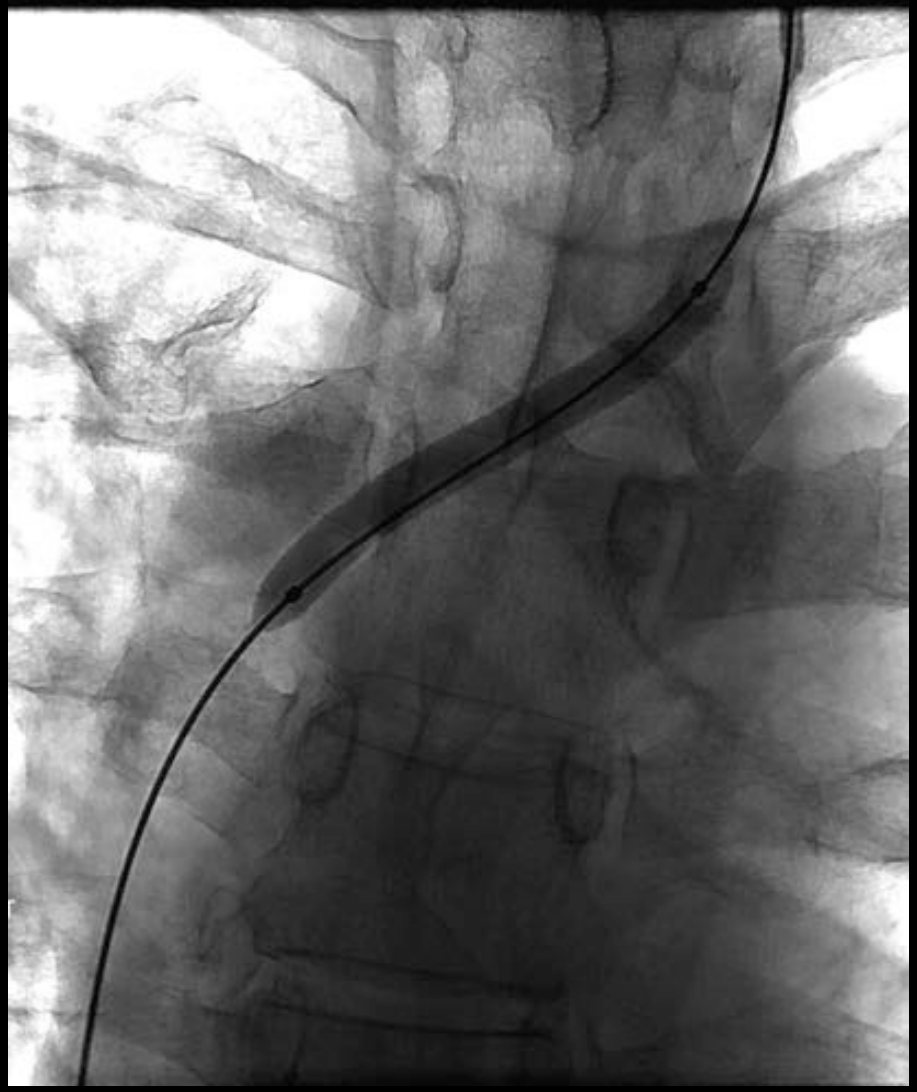
LT IJ injection 1:2 dilution (12cc contrast + 12cc NS @ 2cc/sec) acquired on flat-panel detector Dyna-CT.

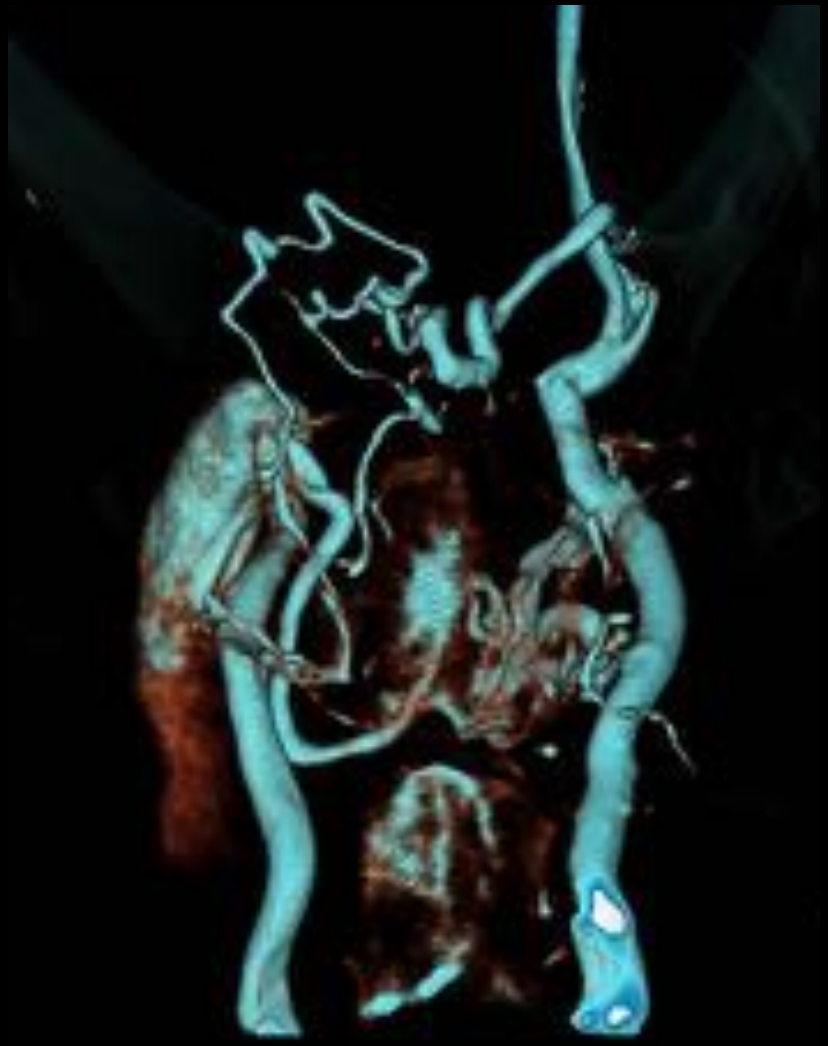
Courtesy of Anne Chin, MD

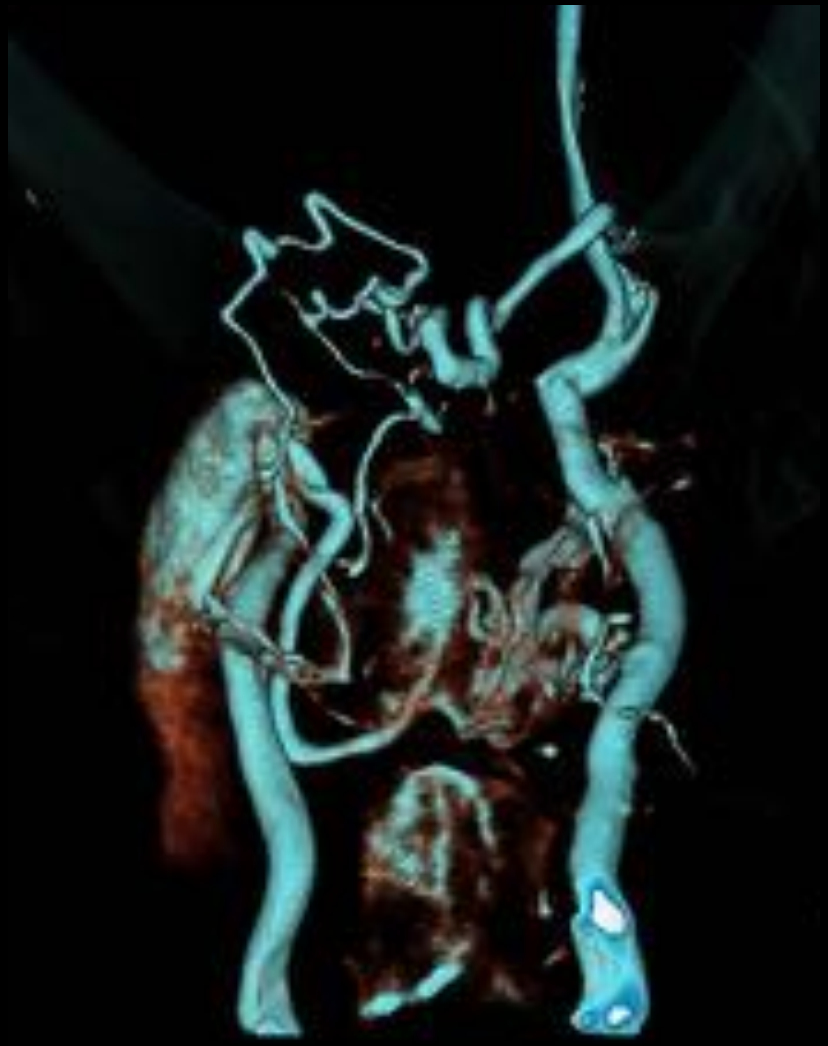




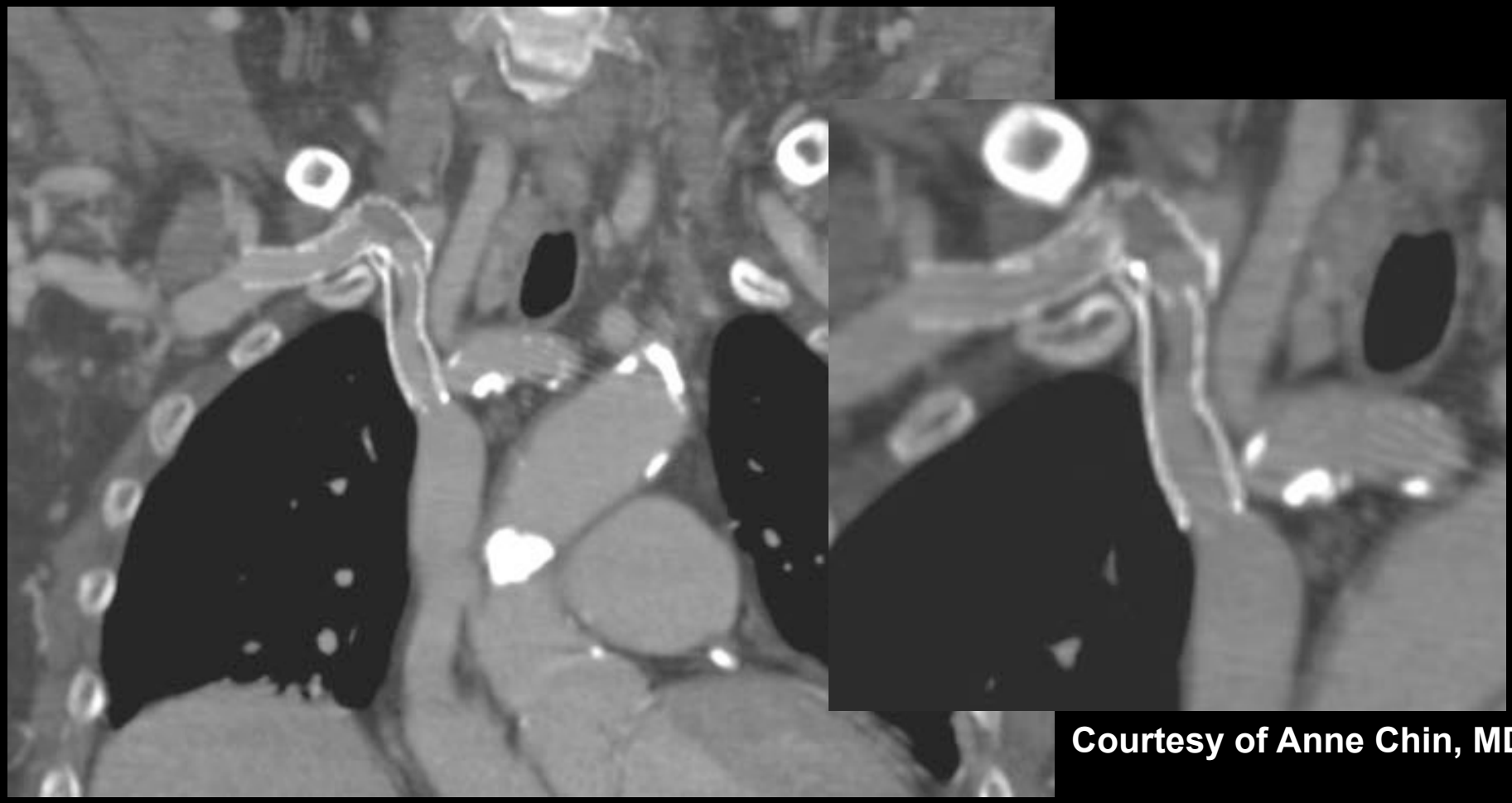








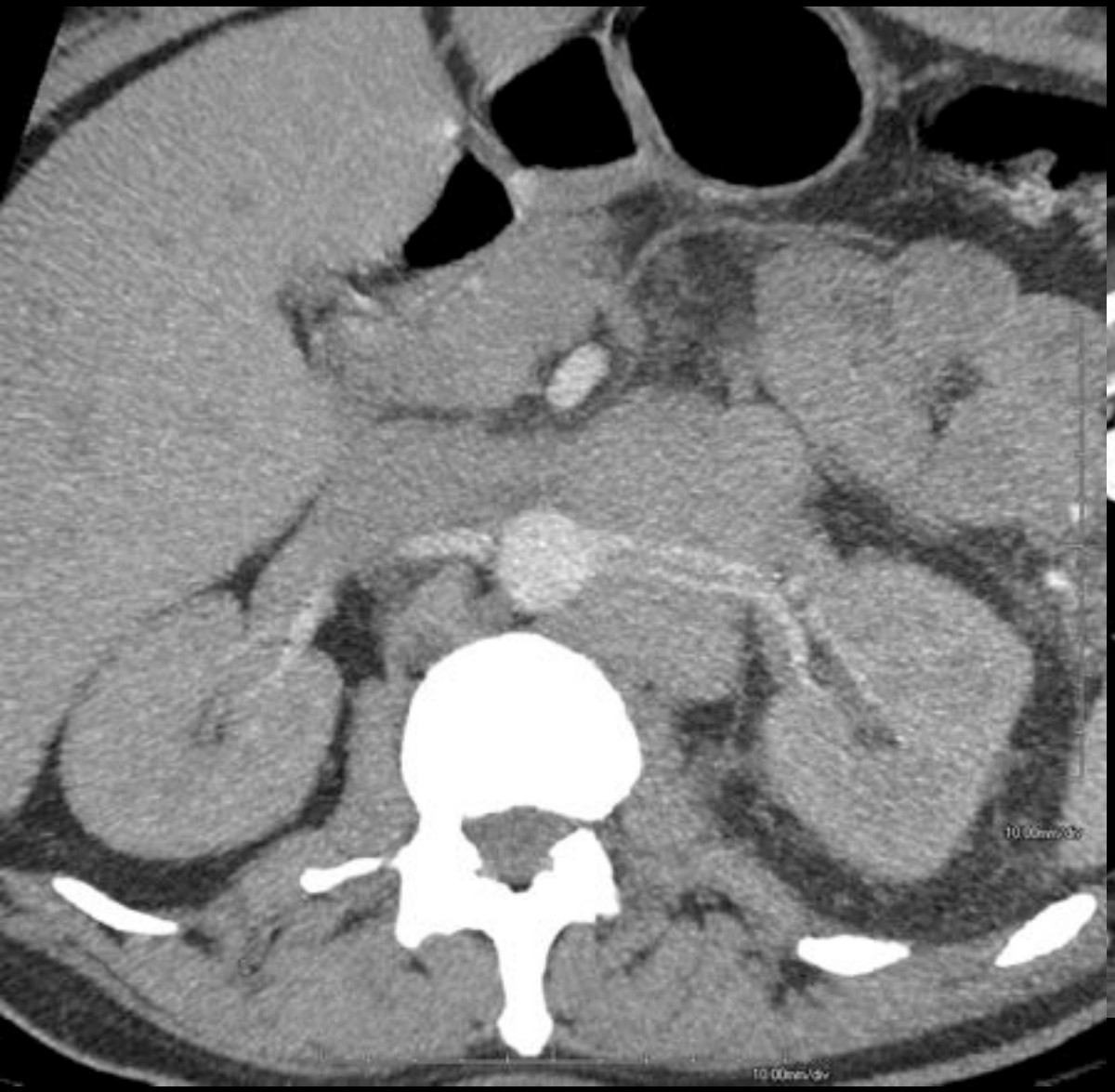
60F ESRD, 3 overlapping stents placed for venous stenosis from previous catheters.



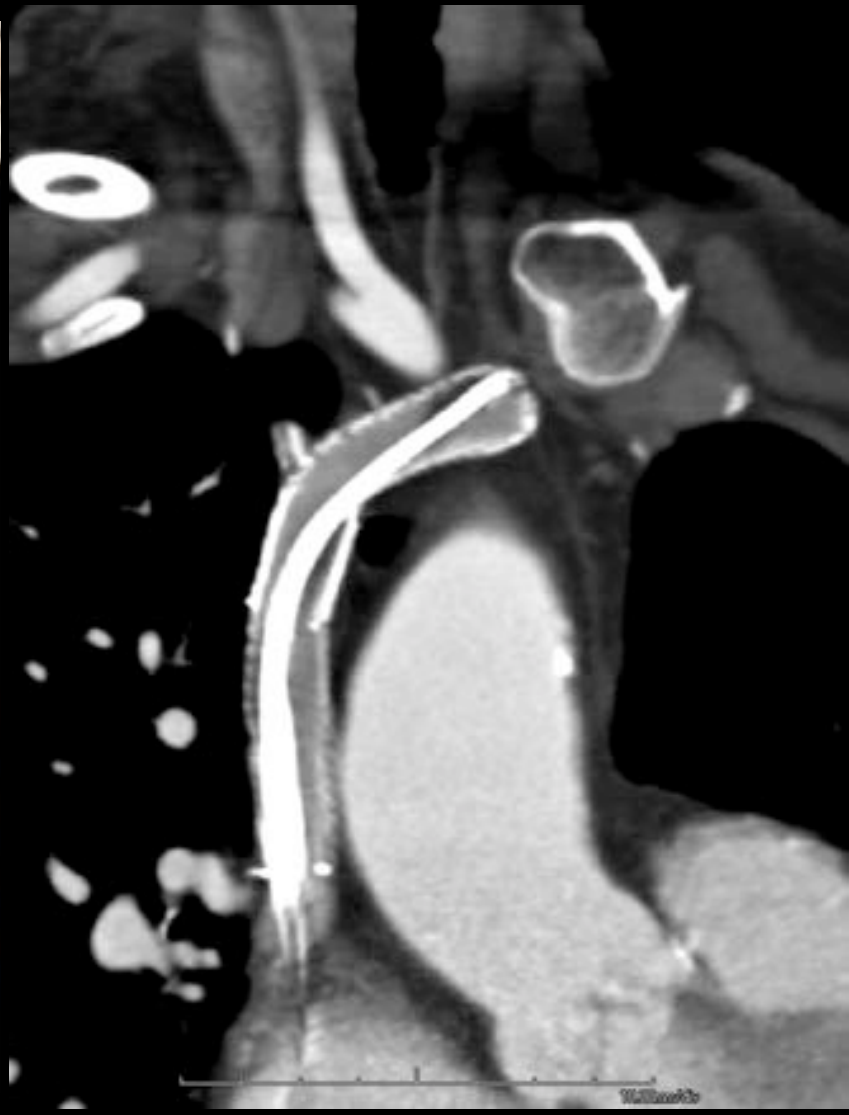
Courtesy of Anne Chin, MD

IV cannula in left arm. 100cc contrast + 20cc NS flush, diagnostic delay = 60sec.

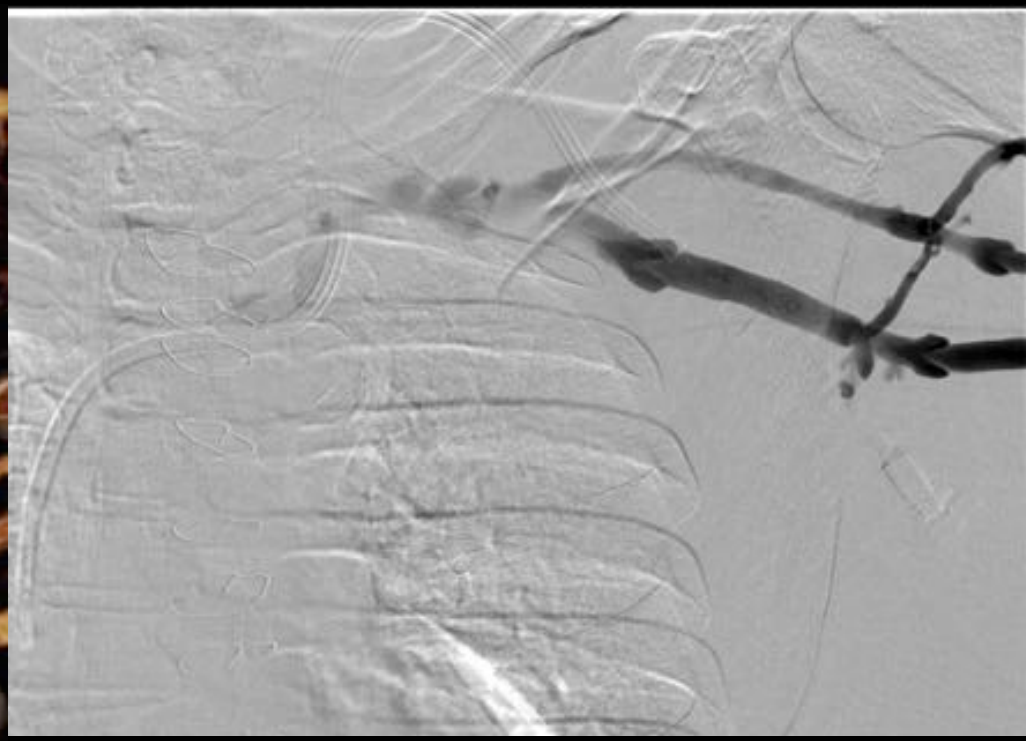
LIV encasement – Adenopathy



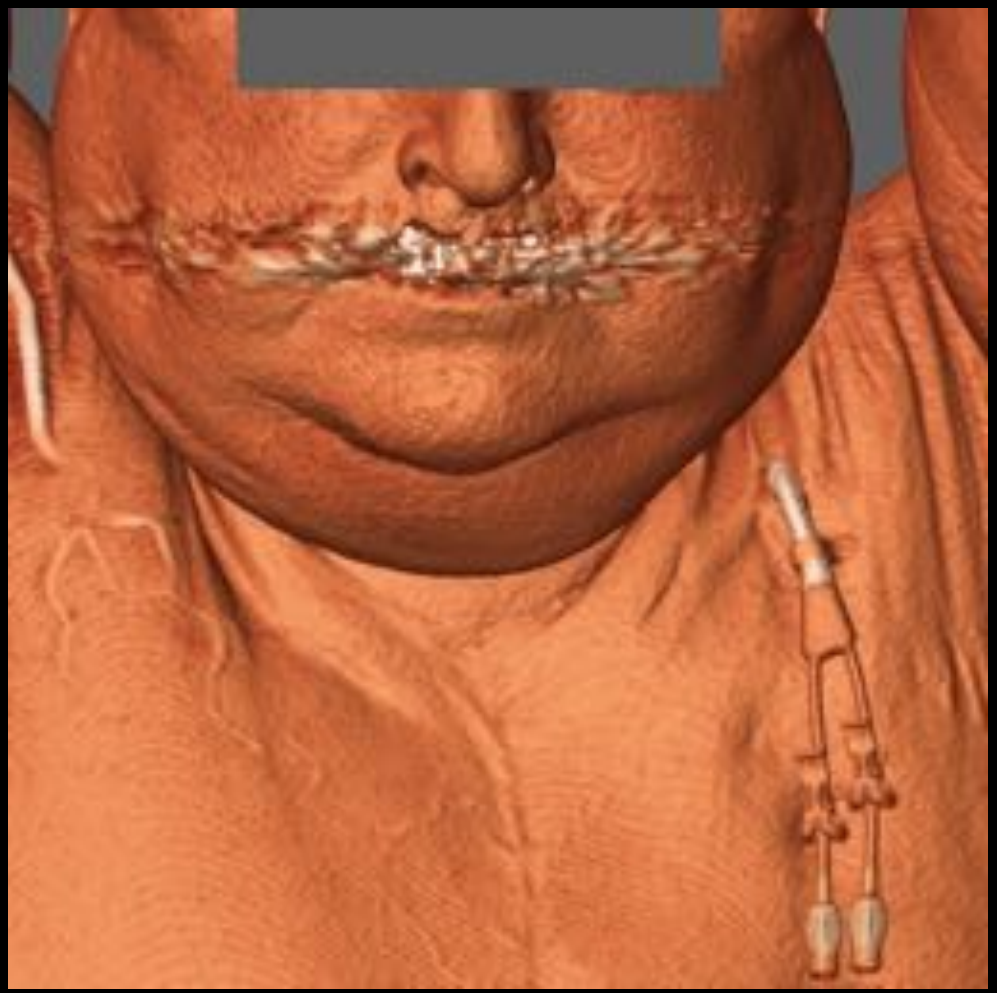
In-stent LIV / SVC thrombus

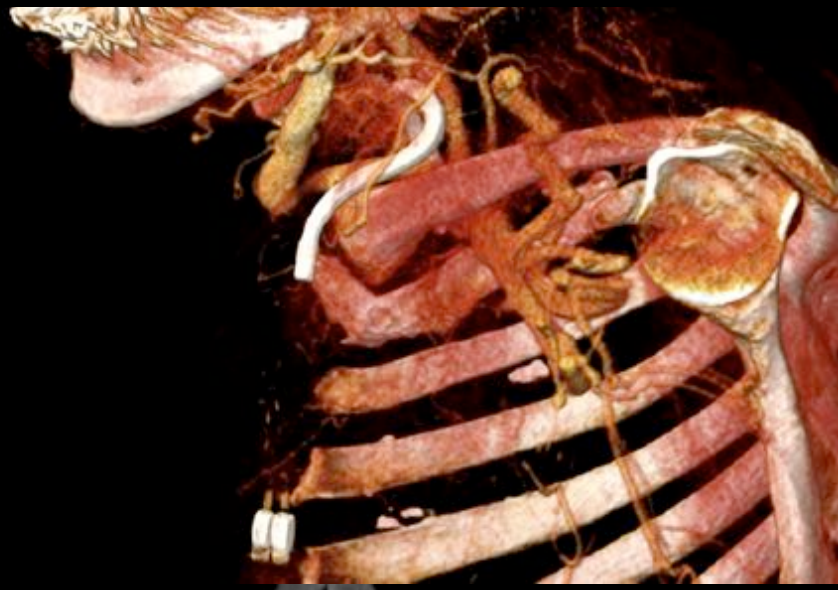


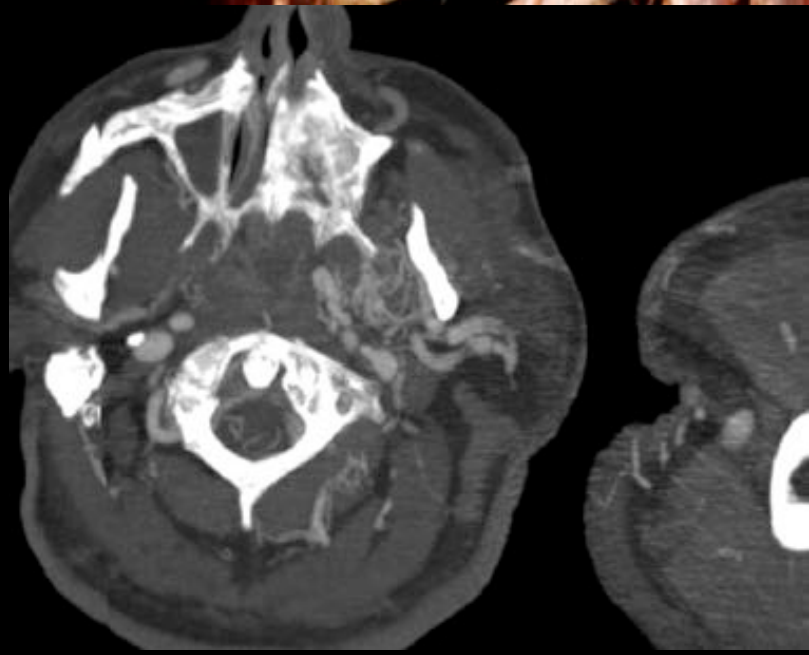
LIV Occlusion – Dialysis Patient with LUE AVF

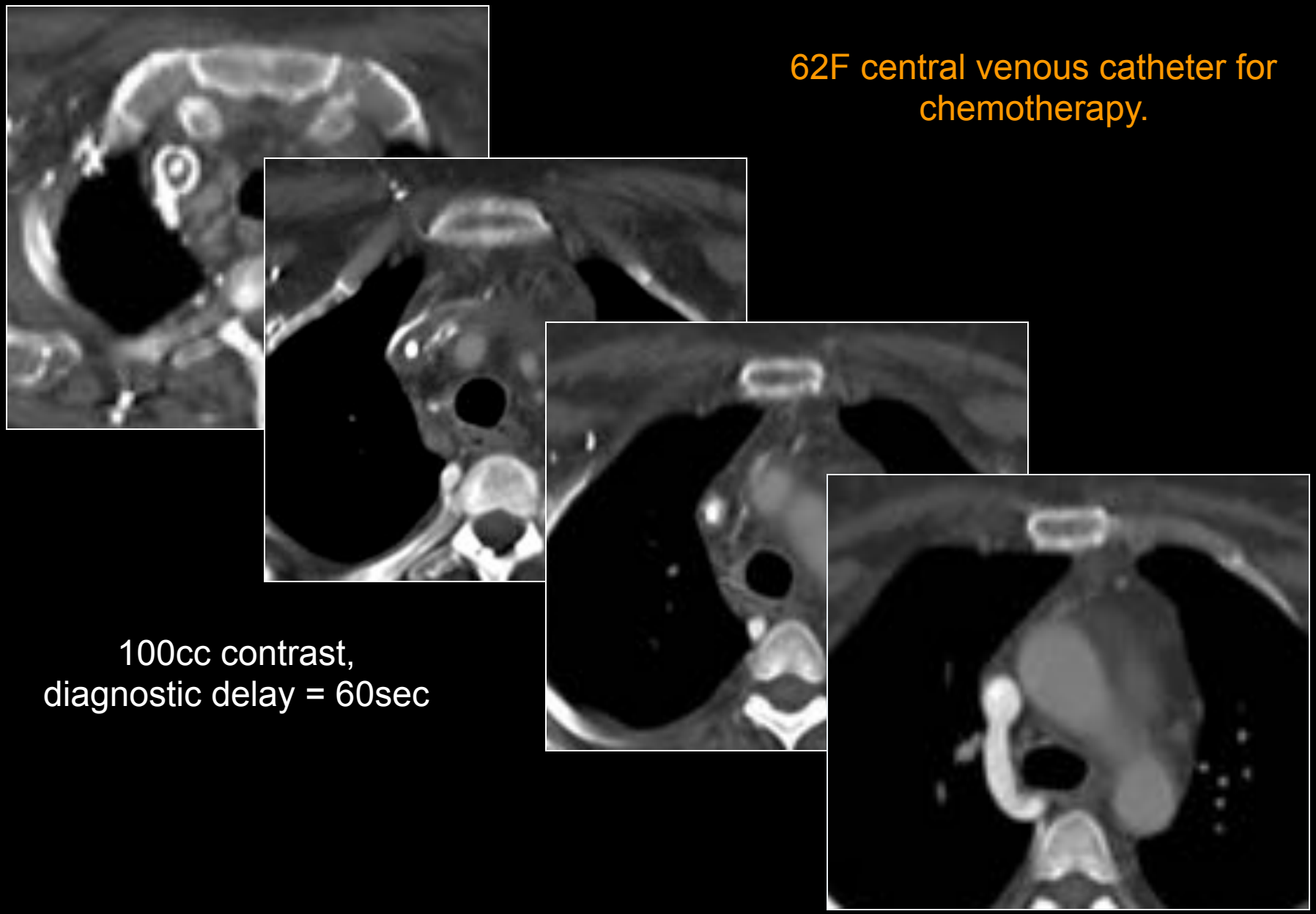


EJ arch, lat thoracic, and pharyngeal collaterals









62F central venous catheter for chemotherapy.

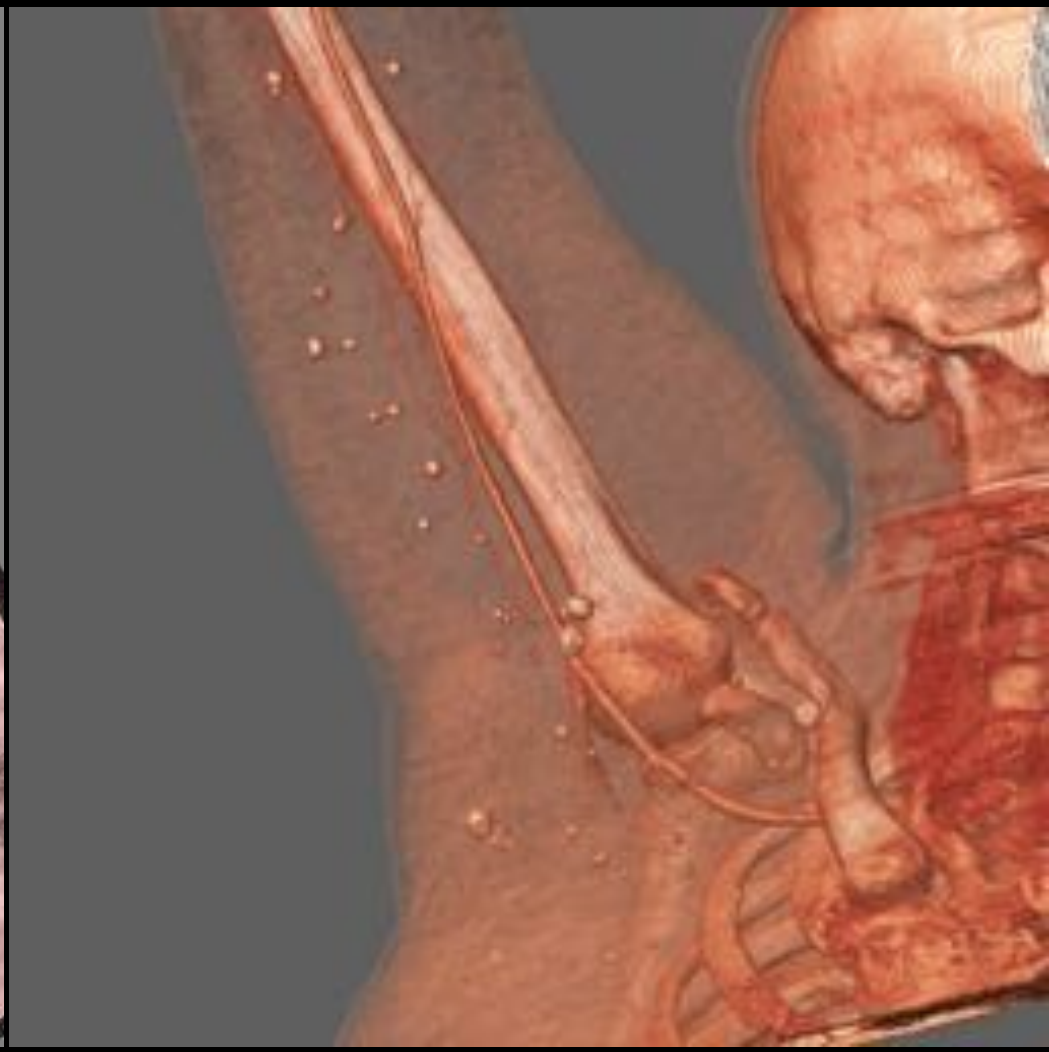
100cc contrast,
diagnostic delay = 60sec

62F central venous catheter for
otherapy.

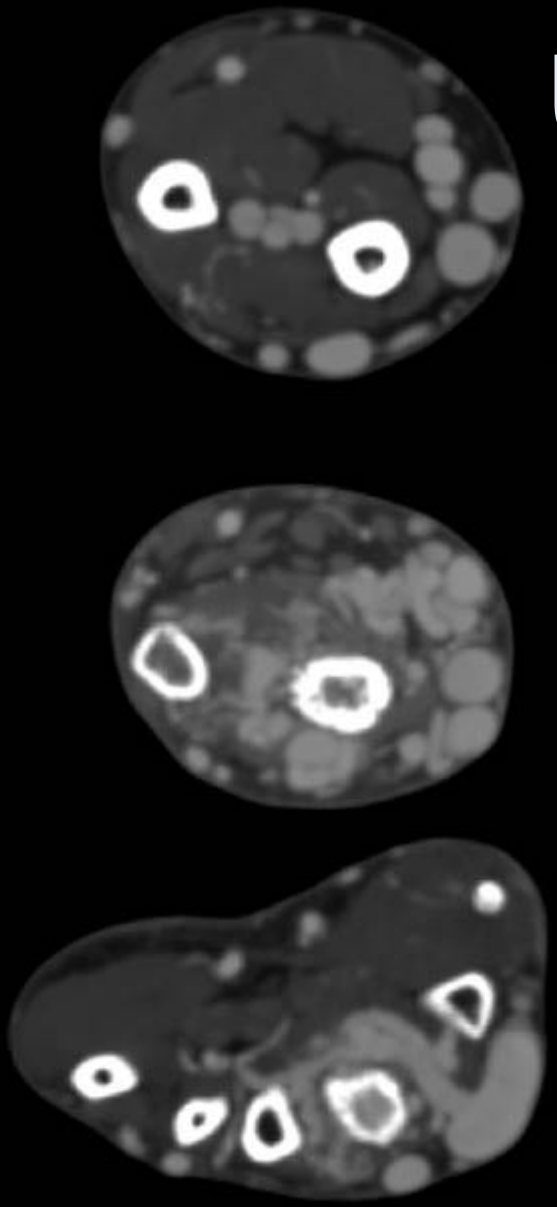
100cc cont
diagnostic delay

MISC UE Cases

RUE Hemangiomatosis

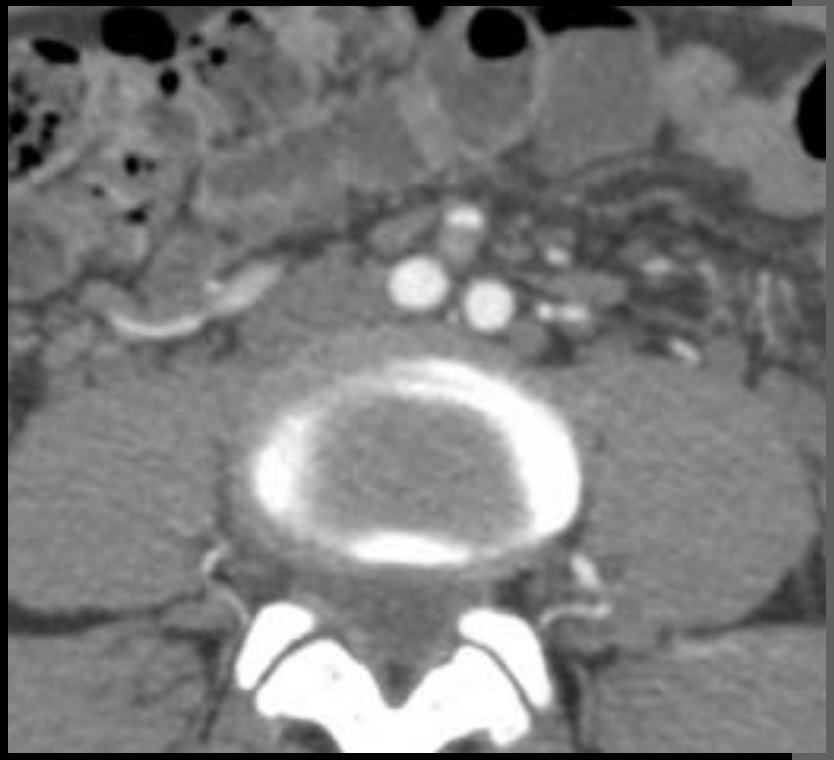


UE AVMs



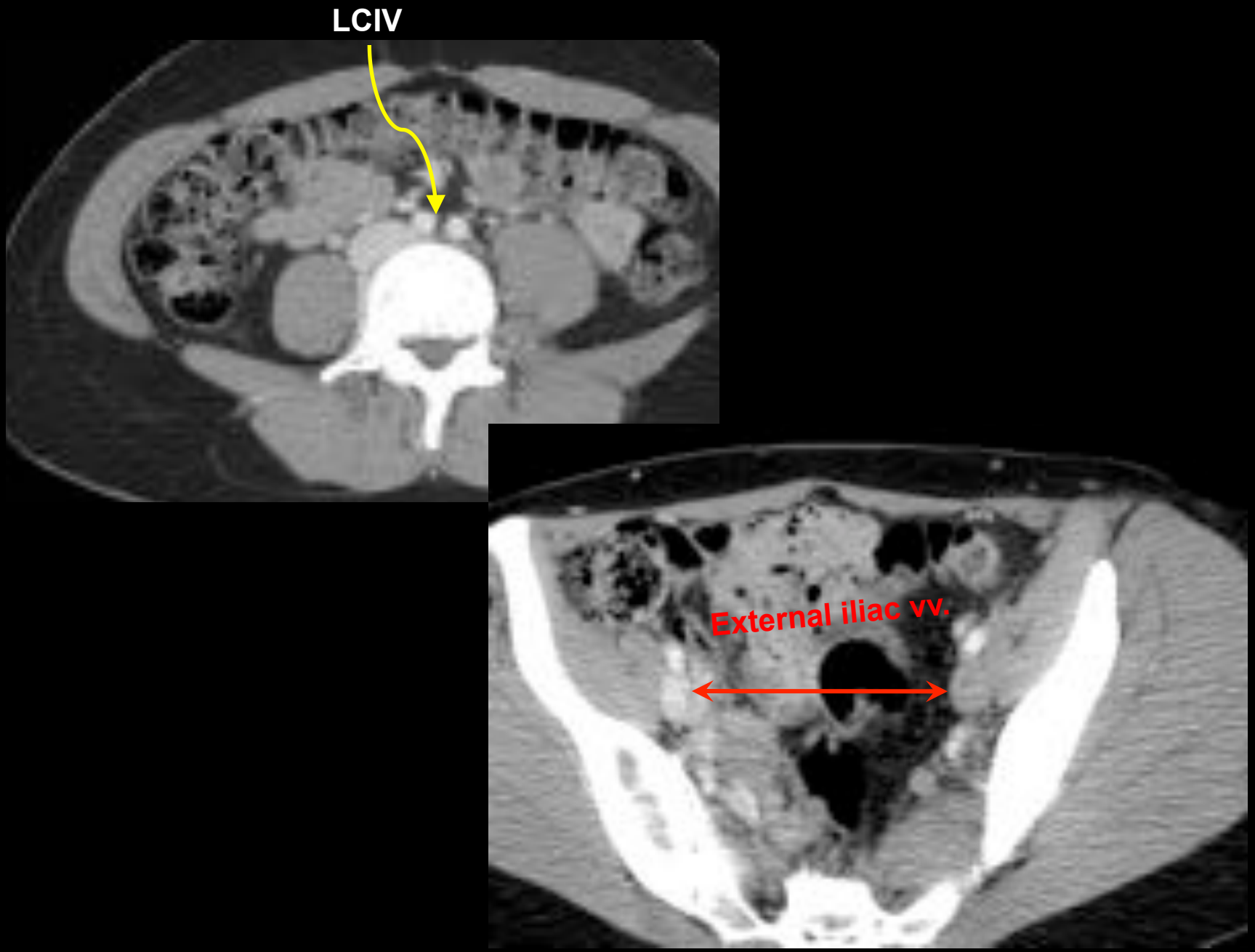
Pelvis / LE Cases

MAY-THURNER : SUPERFICIAL VENOUS VARICOSITIES



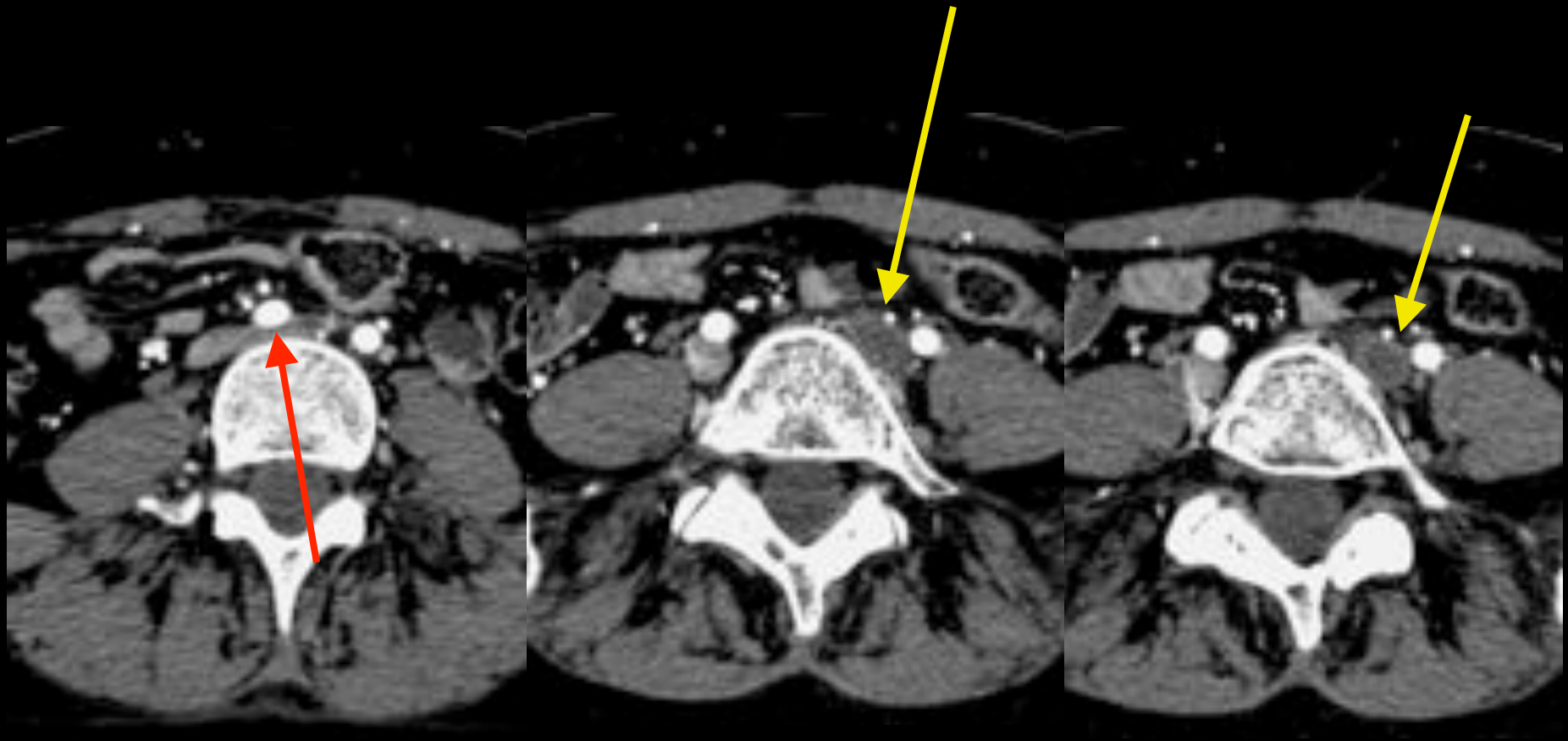
41 YO F, May - Thurner

Lack of Augmentation – “suspect upstream obstruction”

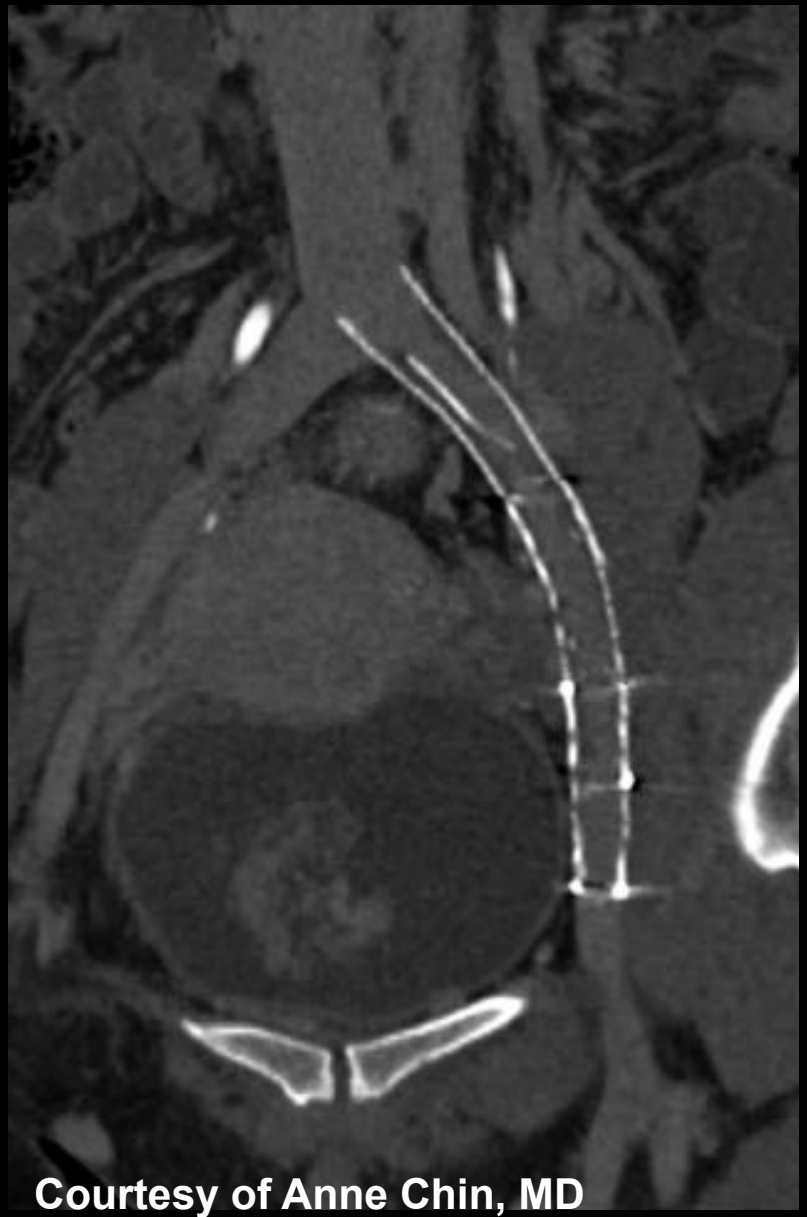

LCIV
External iliac vv.

S/P Mechnical Lysis, TPA, and PTA

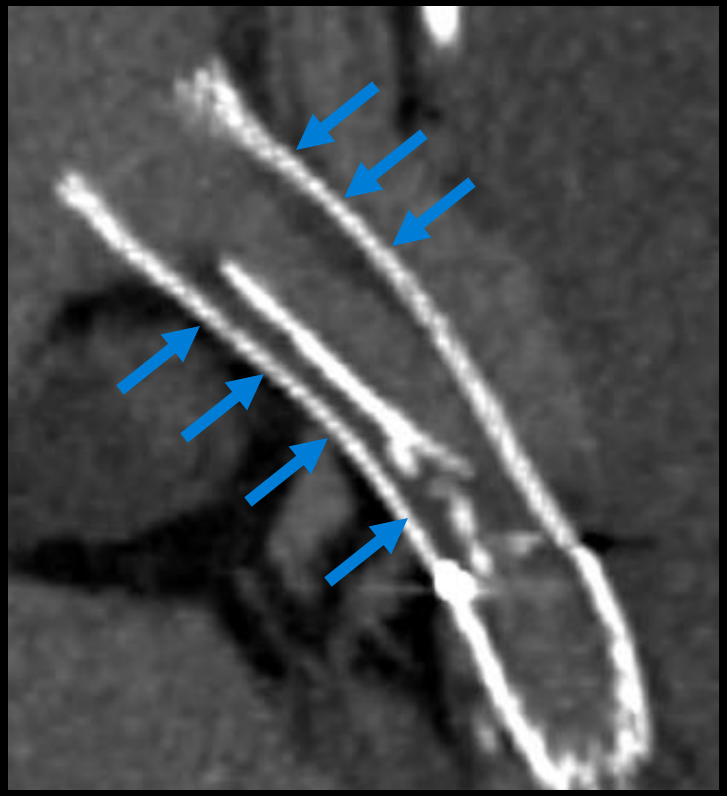
Indirect Dx by arterial CTA



F/U stenting for May Thurner



28F May-Thurner syndrome,
CIV/EIV stent placement
3 years ago



- 120 cc contrast
- Monitoring delay = 40sec
- Smart prep at infrarenal IVC

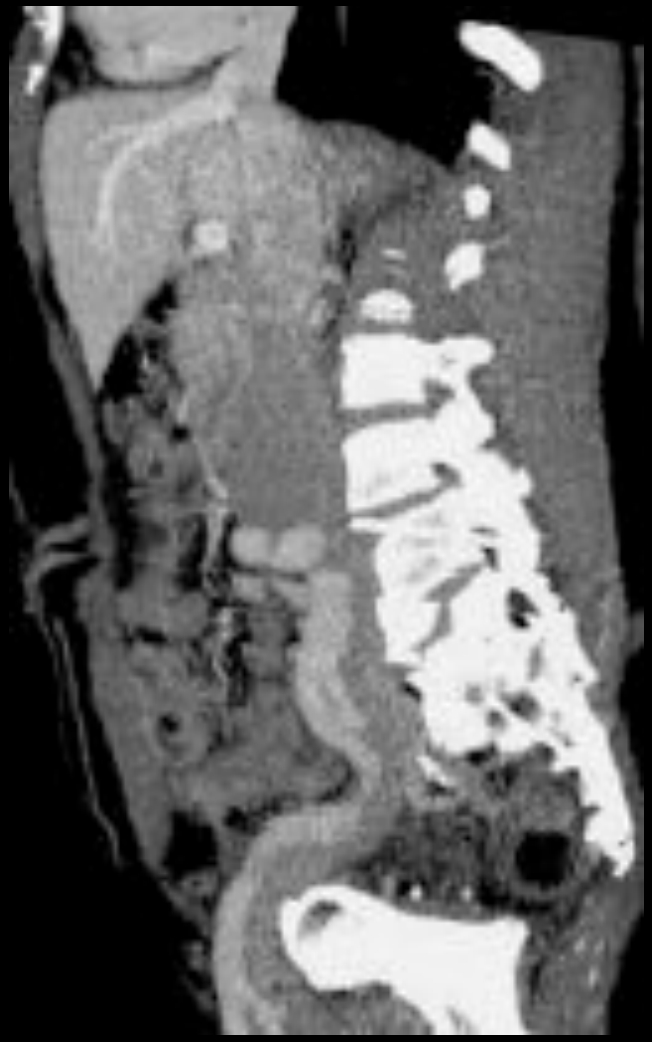
Vascular Mapping

Extremity Hemangiomatosis Venous Mapping

Protocol:
CTA Runoff; + 40 sec interscan delay;
Caudocranial scan 16x0.75mm

Major drainage routes:
LEFT 12th IC VEIN
Left Gonadal V.
Greater Saphenous V.

IVC Aneurysm



IVC Aneurysm

- Rare
- Saccular > fusiform
- Cause unknown, may be related to anomalous connections in embryologic venous systems
  - Acquired (trauma, AV fistulae)
  - May be associated with other congenital CV anomalies
- Sx: Thrombosis (7/16), pain, rupture, leg swelling
  - Massive penile bleeding (1/16)
  - PE if thrombus

Conclusions

- CTV is a robust, non-invasive technique to visualize venous anatomy, and can be combined with arterial phase CTA

- Direct CTV: better opacification, less CM needed, but only the injected and downstream veins will be visualized

- Indirect CTV: all venous anatomy is delineated, empiric delay or smart-prep at ROI, opacification occasionally unpredictable

- "Combo CTV": Perhaps the best choice for excellent and consistent venous opacification

- Provides accurate 3D visualization of venous anatomy for treatment planning

Thanks to:

Dominik Fleischmann, MD

Frandics Chan, MD PhD

Key References

Loud PA, et al. *Radiology* 2001; 219:498-502. (Sens / Spec of CTV good compared to Doppler)

Begemann PG, et al. *J Comput Assist Tomogr* 2003; 27:399-409. (Sensitivity=100%; Specificity=97% compared with ultrasonography)

Baldt MM, et al. *Radiology* 1996; 200:423-428. (Sensitivity=100%; Specificiity=96% compared with conventional venography)

Sampson, FC, et al. *Eur Radiol* 2007; 17:175-181. (Pooled sensitivity=91.5%; Pooled specificity=94.8% compared with conventional venography)

Kluge, A. et al. AJR 2006; 186:1686 – 1696 (Combo MRA/MRV for PE/DVT)

Kim, HC, et al. J Comput Assist Tomogr 2004; 28:24-33 (Collateral Pathways)

Cihangiroglu M, et al. J Comput Assis Tomogr 2001; 25: 1-8 (collaterals in SVC Obstruction)

Lawler LP, et al. Radiographics 2002; 22:S45-S60 (normal and accessory chest venous pathways)

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Kluge, A. et al. AJR 2006; 186:1686 – 1696 (Combo MRA/MRV for PE/DVT)

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Cihangiroglu M, et al. J Comput Assis Tomogr 2001; 25: 1-8 (collaterals in SVC Obstruction)

Lawler LP, et al. Radiographics 2002; 22:S45-S60 (normal and accessory chest venous pathways)

Demos TC, et al. AJR 2004; 182:1139-1150 (Venous anomalies of chest)