Cardiovascular imaging

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Imaging in cardiovascular diagnosis

- X-ray methods
  - » Catheter or direct puncture angiography
  - » Radiography, flouroscopy
- Ultrasound – Doppler methods
- CT, CT-angiography
- MR, MR-angiography

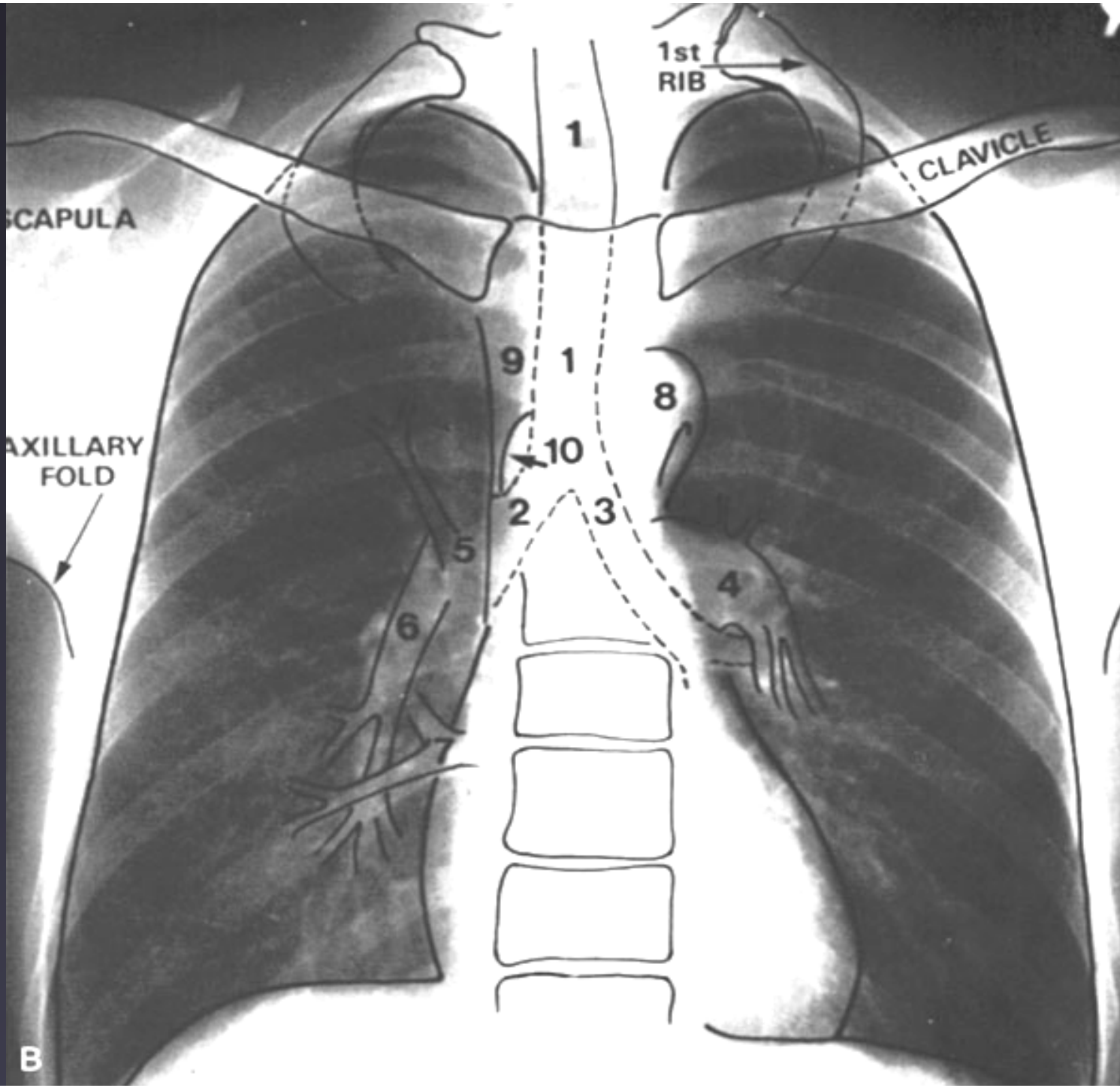
Invazive approach

Non-invazive approach

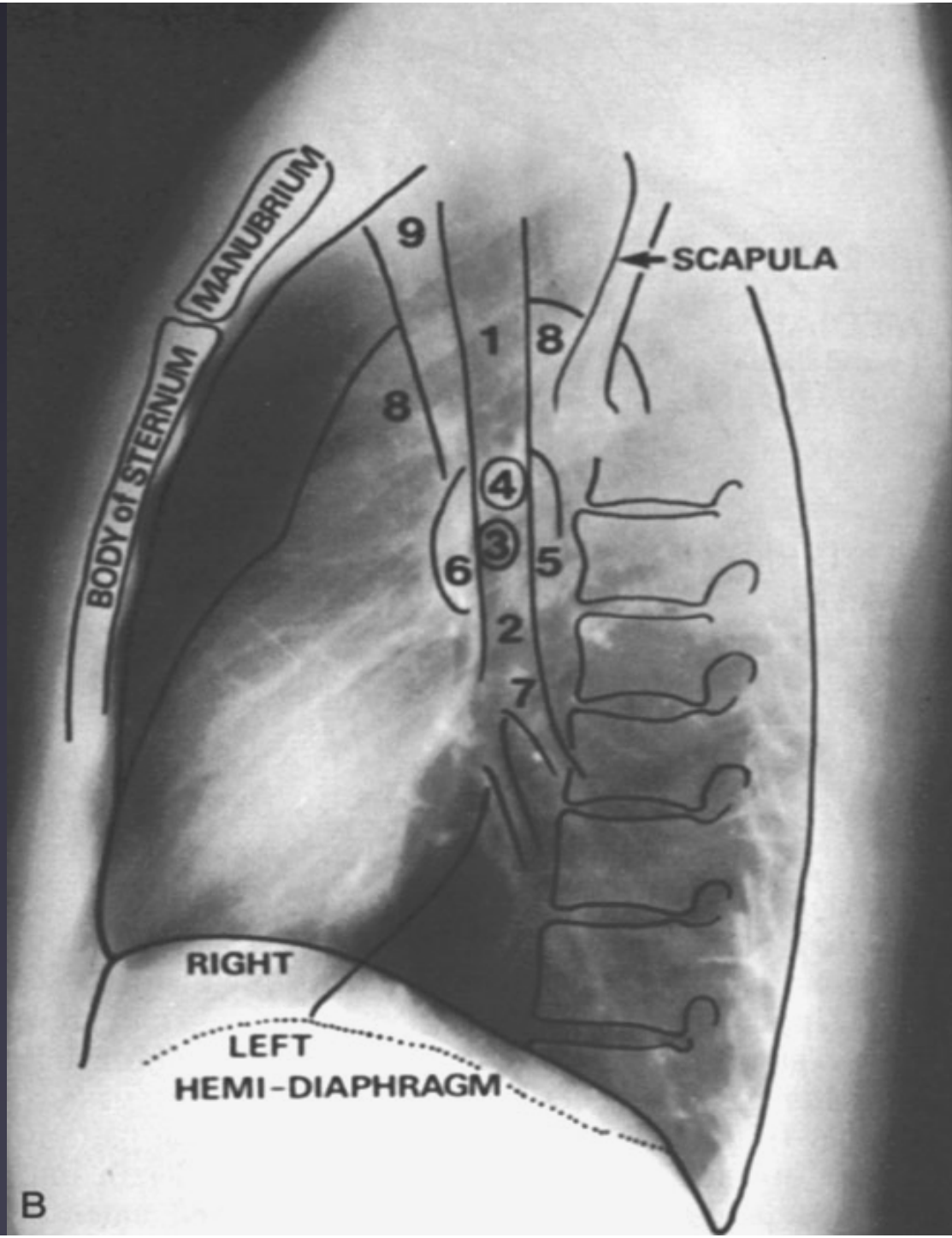
Radiography

- Analog or digital technique
- Provides summation images
  - High spatial resolution
  - Low contrast resolution
- Bi-directional (PA and lat.) chest film
  - Heart and great vessels are in the mediastinal shadow well contoured by air-containing lung
- Gives information on
  - Heart size, dilatation of specific chambers
  - Dilatation and course of mediastinal vessels
  - Caliber of pulmonary vessels
  - Cardiac and vessel-wall calcification
- Fluoroscopy
  - Pulsation of the heart and vessels
- Routine inexpensive screening modality
  - Post-op and emergency/ICU

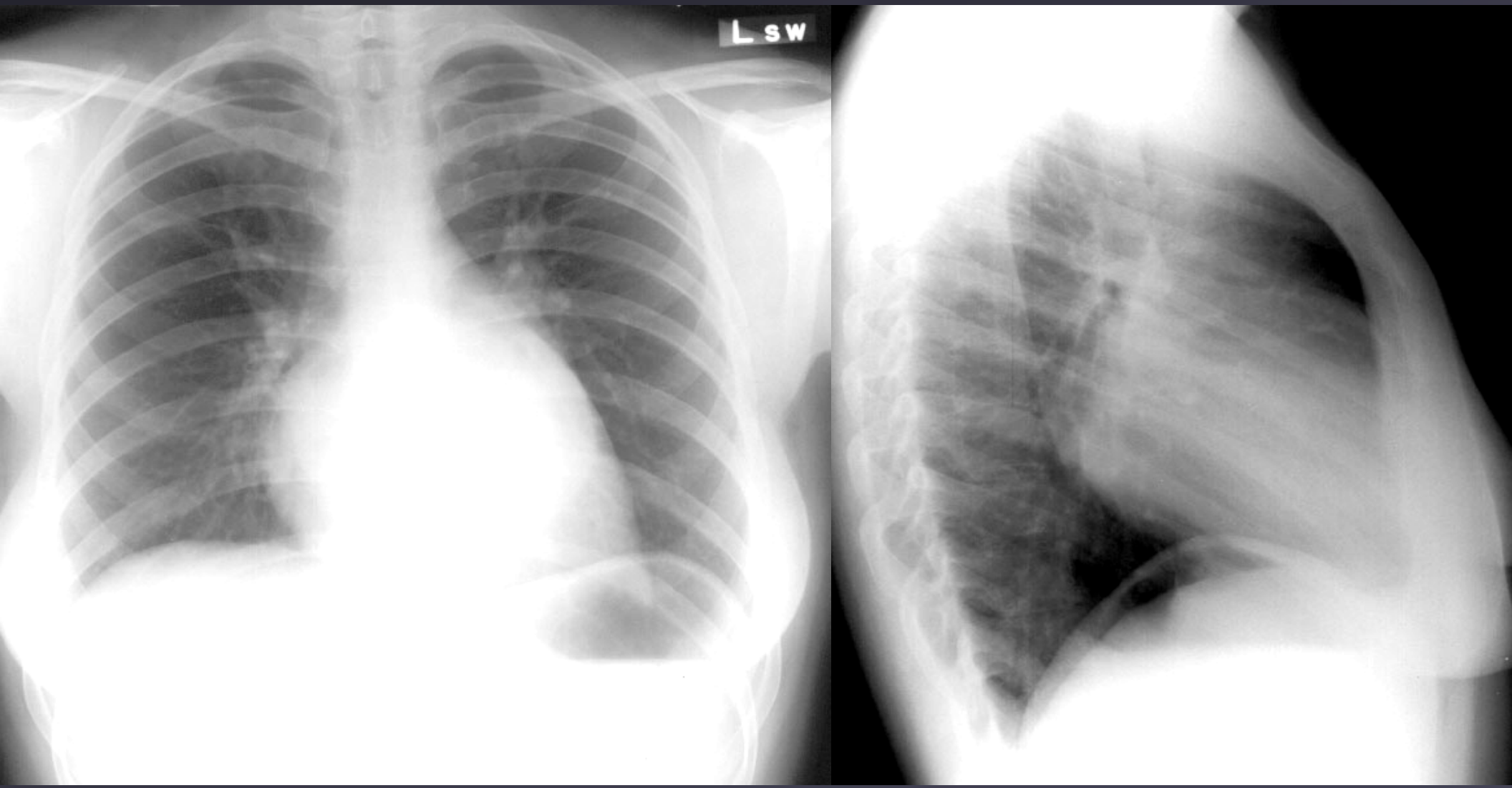
1. Trachea
2. R main bronchus
3. L main bronchus
4. L pulm artery
5. RUL pulm vein
6. R (desc) pulm artery
7. RLL and RML veins
8. Aortic arch
9. S. vena cava
10. Azygous vein



1. Trachea
2. R main bronchus
3. LUL bronchus
4. RUL bronchus
5. L pulmonary artery
6. R pulmonary artery
7. Pulmonary vein
8. Aortic arch
9. Brachiocephalic vessels



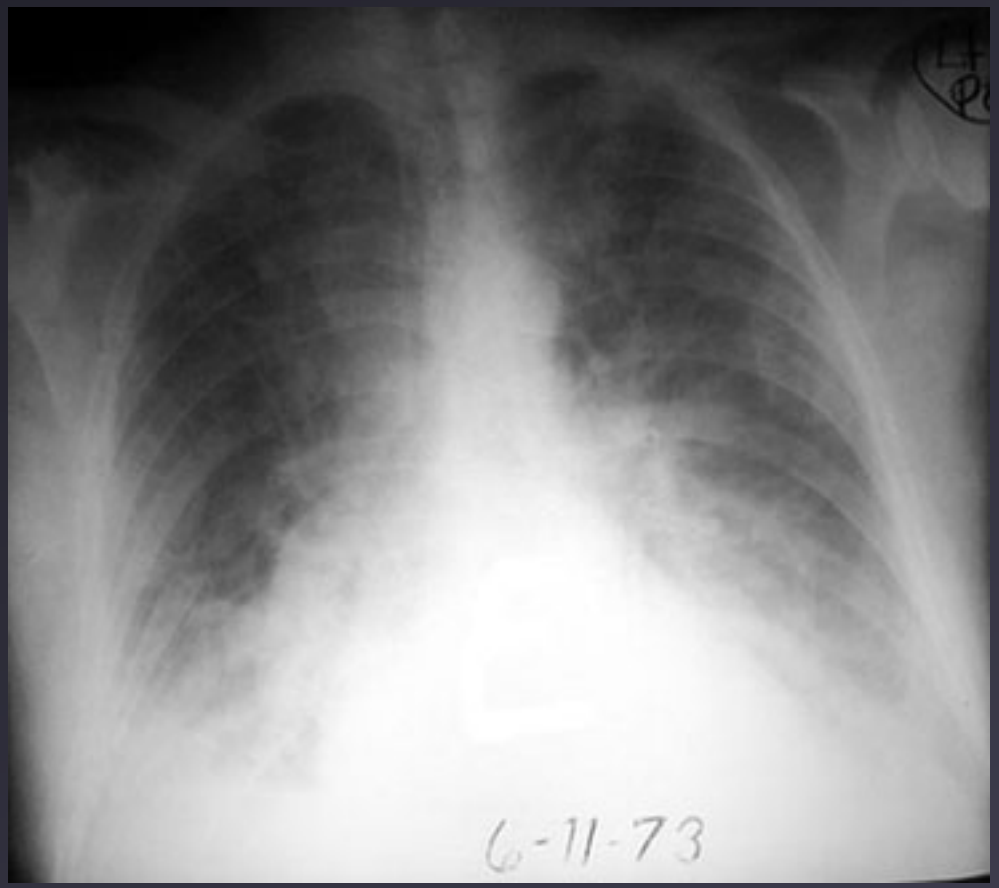
Mitral stenosis

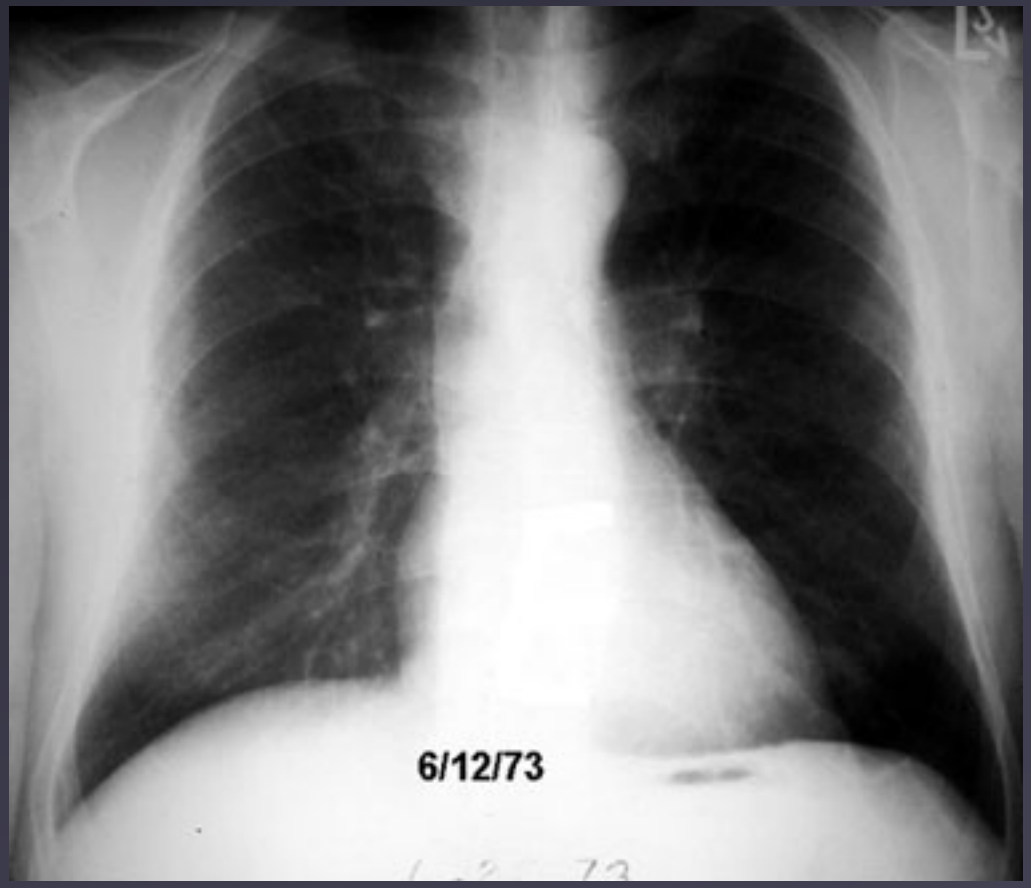


Sign of congestive heart failure

- Cephalization of pulmonary vasculature (apico-basal discrepancy)
- Kerley lines
  - Interlobular septal thickening – interstitial edema
- Diffuse alveolar edema
  - Perihilar distribution
  - Butterfly or bat-wing pattern
  - Coalescing fluffy opacities
  - Air-bronchogram
- Pleural effusion
- Enlarged heart (+/-)

Congestive heart failure

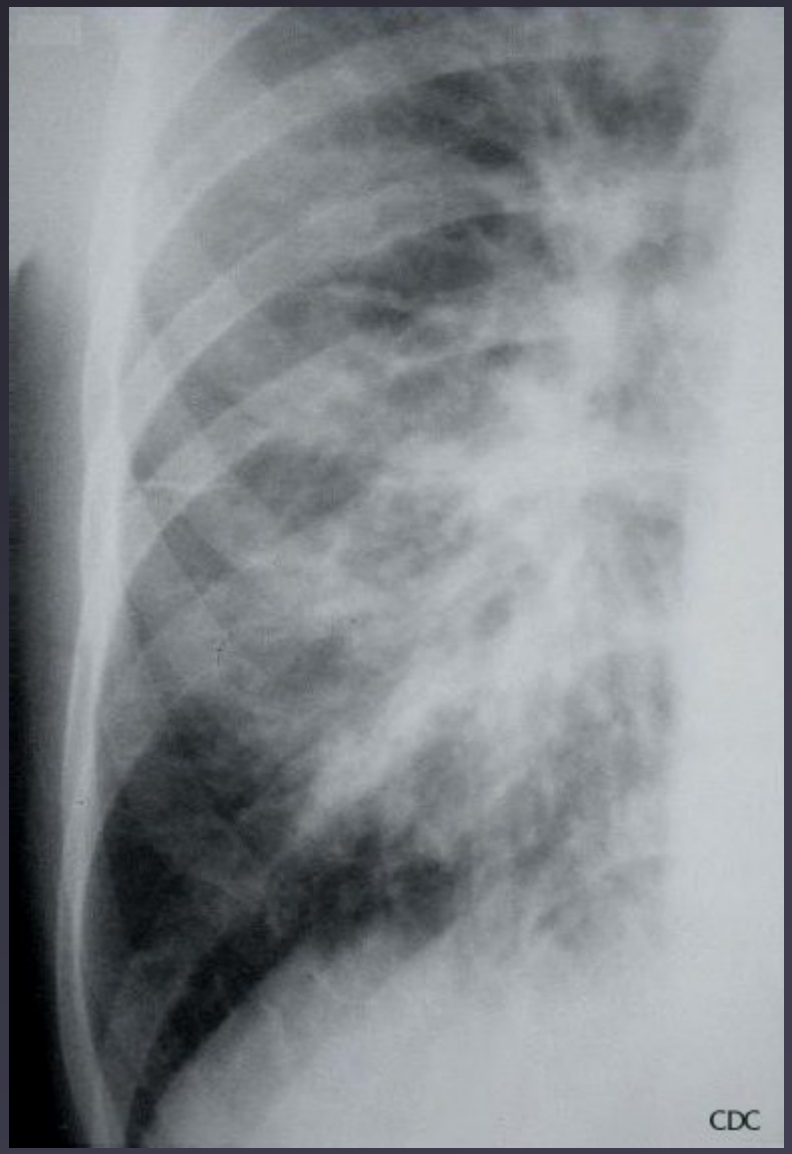




Pulmonary edema

1 day later resolution

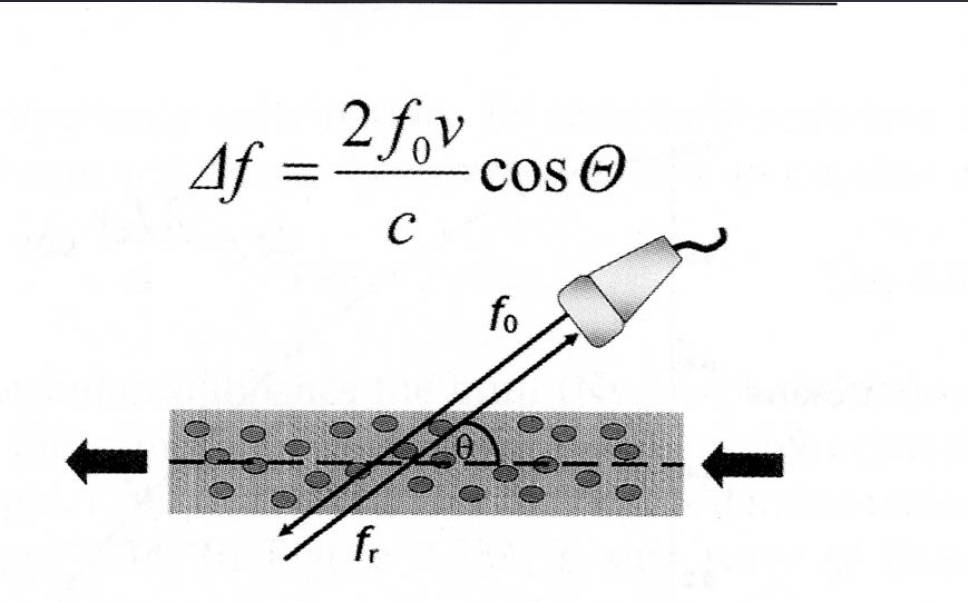
Kerley B lines



Ultrasonography

- Fluids are hypo-anechoic – blood filled vessels and heart chambers are dark on 2D ultrasound images
- Real time imaging
  - Echocardiography
- Bones and air are not penetrated by US
  - „acustic window” is needed
- High resolution imaging of vessel wall and lumen
  - For superficial vessels
  - Plaque analysis

Doppler techniques



- Accurate velocity measurement – haemodynamic analysis
- Color Doppler - Flow map

- 2D ultrasound images + spectrum Doppler = duplex ultrasound

Main indications of duplex sonography

- (Echocardiography)
- Cerebrovascular disease
  - Carotid stenosis
  - Transcranial Doppler
- Obliterative arterial disease of the extremities
  - Atherosclerotic chronic disease
  - Acute embolic occlusion
- Deep venous thrombosis of the extremities
- Abdominal vessels
  - AAA (aneurysm of the abdominal aorta)
  - Renal artery stenosis
  - Abdominal angina (mesenteric artery stenosis)
  - Portal hypertension
- Soft tissue vascularization (e.g. tumors)
- Post-op. conditions

Advanced CT és MRI techniques in cardiovascular imaging

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

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*

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

MR angiography 1.: Without contrast material

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

1. *"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*

Post-processing

- Retrospective reconstruction of overlapping slices from helical CT 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 slices
  - These contain all the information provided by the study, any further processing may result in data loss
- MIP
  - DSA-like demonstration of global vascular anatomy
  - „slab MIP" – target volume, stenosis analysis
- MPR, CR
  - stenosis / plaque analysis
- 3D Volume Rendering (VR), SSD
  - Demonstration of complex anatomy of vessels / bones / parenchymal organs
  - To let clinicians see and believe what we basically diagnose from the 2D sectional images

Indications – thoracoabdominal aorta

Aneurysms

- Primary assessment
  - Diameters, length
  - Anatomy of proximal and distal necks
  - Origin of branches
  - Intraluminal thrombus (source of potential distal embolization)
  - Vessel wall thickness, periaortic tissues – inflammation ?
  - Signs of imminent rupture
- Follow-up – growth ?
  - d > 5.5 - 6 cm is indication for intervention
- Postoperative follow-up (tubing or grafting)
  - Anastomoses, signs of pseudoaneurysm formation ?
  - Early complications
  - Late complication: aorto-duodenal fistula

Indications – thoracoabdominal aorta

Aortic dissection

- Acute
  - Presence or absence of dissection
  - Type: Stanford A or B ?
  - Possible dissection variant ?
    - Intramural hematoma
    - Penetrating ulcer, circumscribed dissection
  - Anatomy of true and false lumen, diameter ?
  - Side branches (supraaortic, renal, splanchnic, iliac)
    - Origin from true or false lumen
    - Dissection affecting the aortic branch
    - Signs of stenosis, thrombosis, hypoperfusion
- Chronic
  - Progression of secondary aneurysm
  - Signs of imminent rupture
  - Side branches
- Follow-up after operative / conservative treatment

Indications – thoracoabdominal aorta

Stent-graft implantation

- Pre-procedural assessment
  - » Sizing
    - – Accurate diameters of proximal and distal vessel segments
    - – Distance from proximal end distal braches, bifurcations
- Post-procedural follow-up
  - » Endoleak ?
    - – Type (source)
    - – Degree, progression

Stenosis - occlusion

- Congenital
  - Aortic coarctation
  - Aortic arch hypoplasia (long segment coarctation)
  - Middle aortic syndroma (abdominal coarctation)
- Acquired
  - Atherosclerotic stenosis-occlusion
    - Leriche syndrome

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 ?
  - » Assessment of the arterial supply of transplanted kidney
  - » Post-operative / stent follow-up
- Renal artery aneurysm
- Renal artery anomalies
  - » Lower polar arery causing (?) ureteral stenosis

Indications of CTA – MRA

Cerebrovascular system

- Extracranial 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
- Stenosis of intracranial arterial segments ?
- Vasculitis – Takayasu
- Aneurysm of extracranial carotid segments
- Aneurysm of intracranial arteries
  - » Search for aneurysm in case of SAH
  - » Precise preoperative demonstration of the 3D anatomy of an aneurysm proven by DSA or MRA

Pulmonary circulation

- Acute 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
- Chronic pulmonary thrombo-embolic disease
  - » Clinical signs of pulmonary arterial hypertension
  - » Known embolic episode(s) in clinical history
- Pulmonary arterio-venous fistulas
  - » Rendu-Osler-Weber disease: multiple AVF-s
- Pulmonary artery aneurysm
  - » Mostly associated to CHD

Indications of CTA – MRA

Extremity arteries

- Obliterative disease
  - Alternative of DSA
  - Special MRA technique is required with table stepping
  - Only MDCT enables the imaging of long segments (whole extremity) with reasonable contrast amount and X-ray exposure
- Femoro-popliteal aneurysms

Indications of CTA – MRA

Preoperative imaging

- Organ transplantation
  - » Living donor liver trx
  - » Bone transplantation (e.g.: replacement of jaw by fibula)
- Oncology
  - » Assessment of vascular anatomy before complex surgery (liver, kidney, neck, pelvis…)