Review on Emergent Cardiovascular Radiology

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Part I. Plain Chest Films

Priority

- Images are only a kind of confirmatory supplement instead of making a surprise.
- Before learning how to read an image, be sure to know when to order it.
- Expect what the image will be before reading.
- Every image may become an evidence in legal issues.

Common Imaging Modalities

- Plain films: most important radiological imaging study to diagnose CVD, followed by
- Ultrasound (US), mainly echocardiography
- Isotope scanning: nuclear medicine study
- Computed tomography (CT scan)
- Magnetic resonance imaging (MRI & MRA)

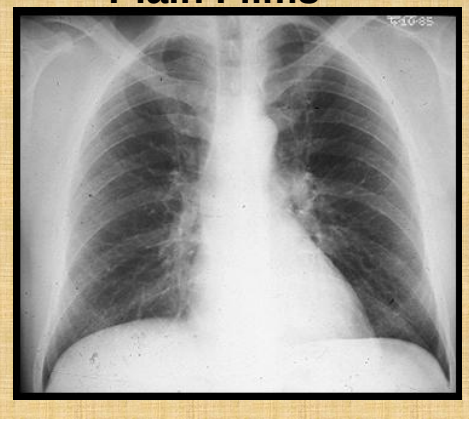
CT & MRI modified ways of looking at the anatomy of the heart

- Arteriography : inject a contrast media inside a vessel to see if anything wrong with it

Learning Objectives

- An sequential approach of plain films
- For adult heart disease
  - (congenital or acquired)
- Asking systematic set of questions
- Answers based on certain fundamental observations
- Visible on frontal chest x-ray alone
- Case/Scenario-based review

Plain Films



Plain Films
Overall

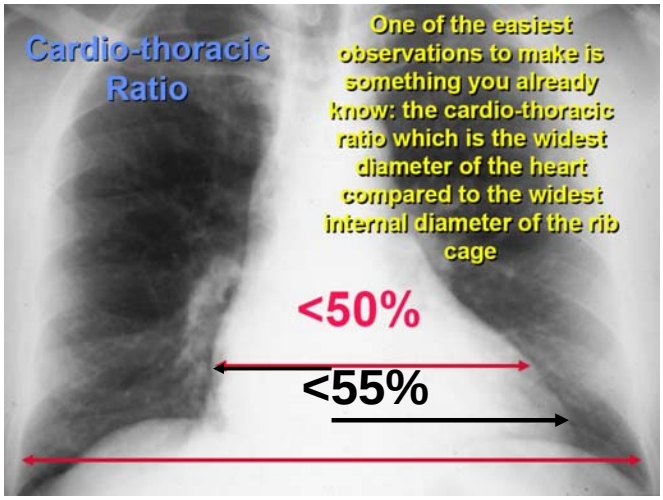
- Airway
- Bone
- Cardiovascular / Cartilage
- Diaphragm
- Esophagus
- Fat
- Gastric
- Hilum
- Infiltration
- Joint

Read as your favor, but keep constant

Plain Films
Cardiovascular

- Evaluate heart size and chamber enlargement
- On a standard chest projection, the ratio of the cardiac diameter to that of the maximum internal diameter of the chest should be no greater than 0.50 (0.55) on full inspiration
- Look at: RA, LA, RV, LV, Aorta, Pulmonary vessels, SVC, IVC, lungs, bones

Anatomical and Physiological Consideration



CT Ratio

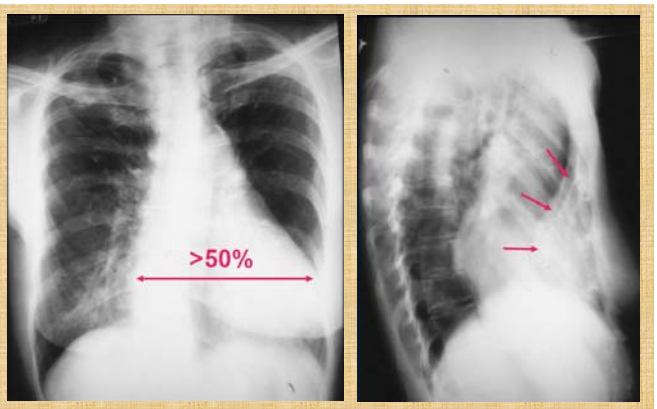
- Everyone knows CTR should be less than 0.50 (0.55%), but I wonder if it should have a lower limit of normal range.
- So, the lower limit of CTR will be …

0.22

COPD (Emphysema)→

Sometimes, CTR is more than 50% But Heart is Normal

- Extracardiac causes of cardiac enlargement
  - Portable AP films
  - Obesity
  - Pregnant
  - Ascites
  - Pectus excavatum
  - Straight back syndrome / Ankylosing spondylitis



Pectus Excavatum Deformity

Sometimes, CTR is less than 50% But Heart is Abnormal

- Obstruction to outflow of the ventricles
  - Ventricular hypertrophy
- Must look at cardiac contours

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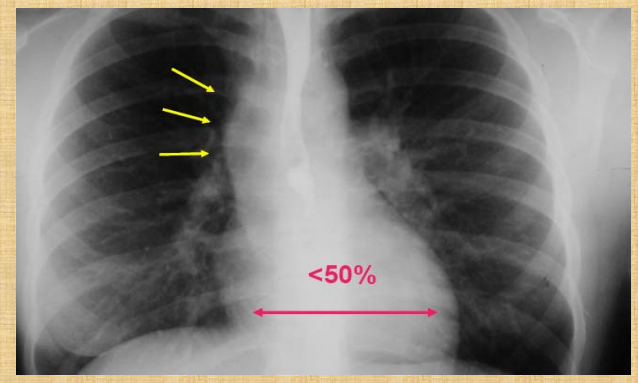

Aortic Stenosis (LVH)

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Cardiac Position

- Normal
  - 1/3 right cardiac silhouette
  - 2/3 left cardiac silhouette
- Right ≥ Left (or Right >> 1/3)
  - Rotation
  - Right atrial enlargement
- Right << 1/3
  - Rotation
  - Absence of Pericardium

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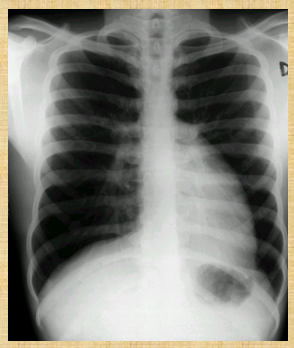
Congenital Complete Absence of Pericardium



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Endomyocardial Fibrosis

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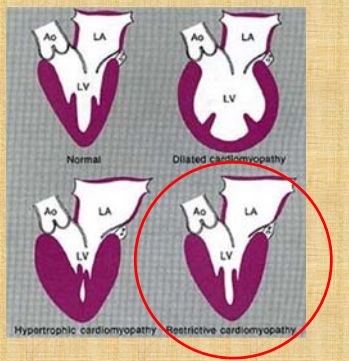
Endomyocardial Fibrosis



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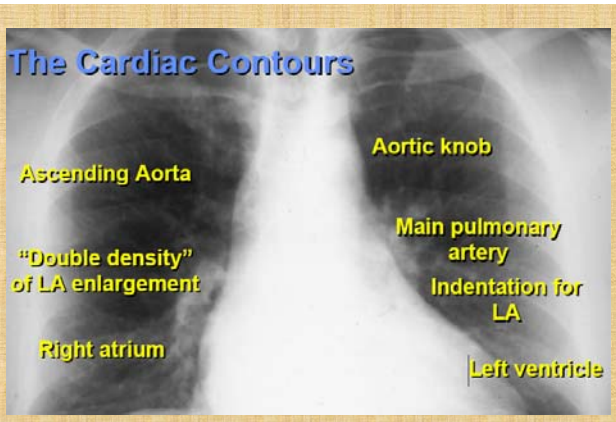

Seven contours to the heart in the frontal projection in this system

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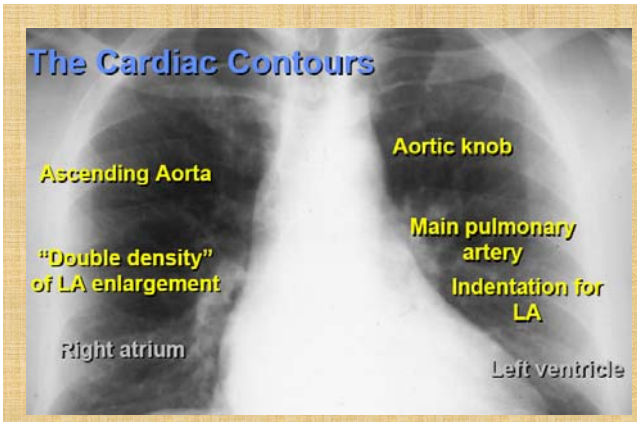

But only the top **five** are really important in making a diagnosis.

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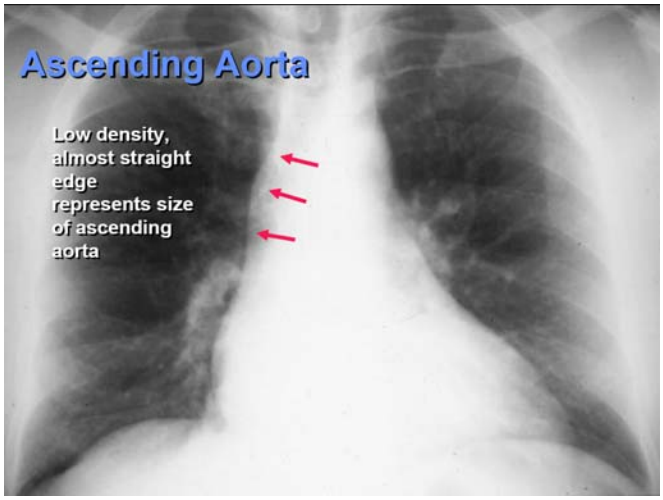

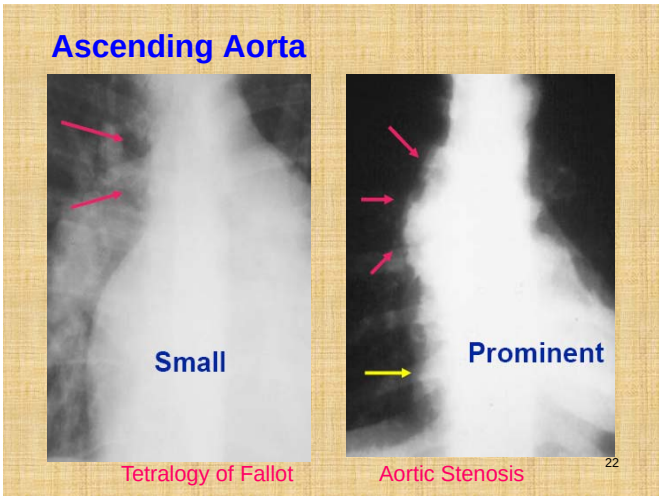

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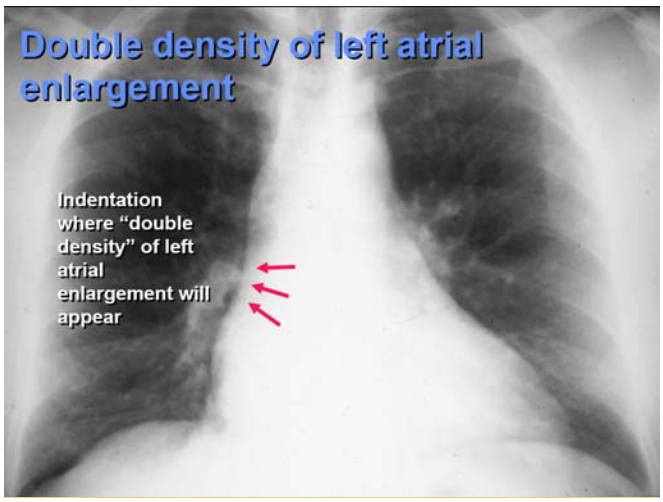
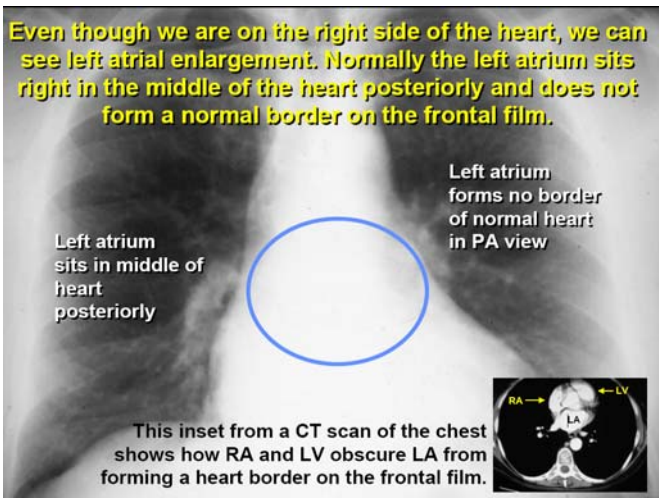
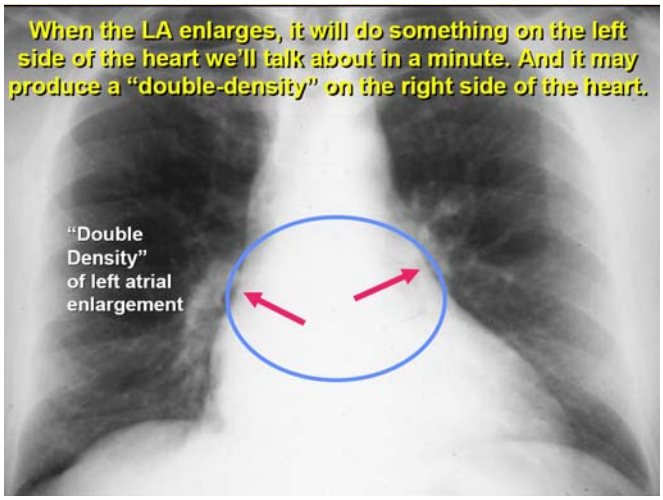
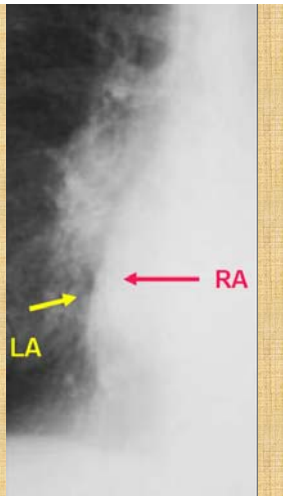




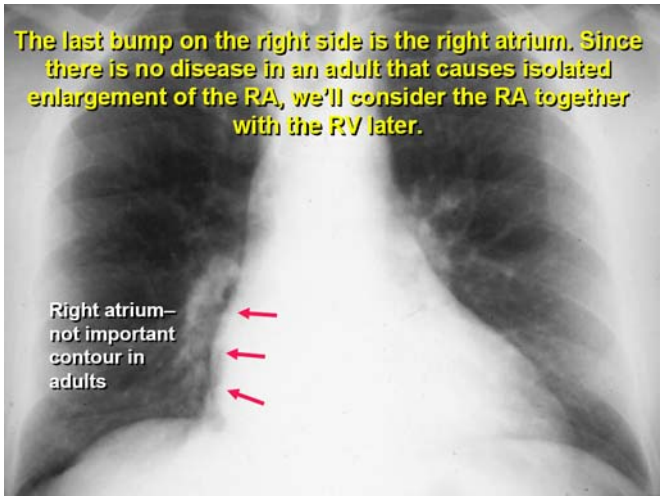
When the LA enlarges, it will do something on the left side of the heart we'll talk about in a minute. And it may produce a "double-density" on the right side of the heart.



Two shadows, the yellow arrow pointing to LA and the red arrow to RA overlap each other where the indentation between the ascending aorta and right heart border meet

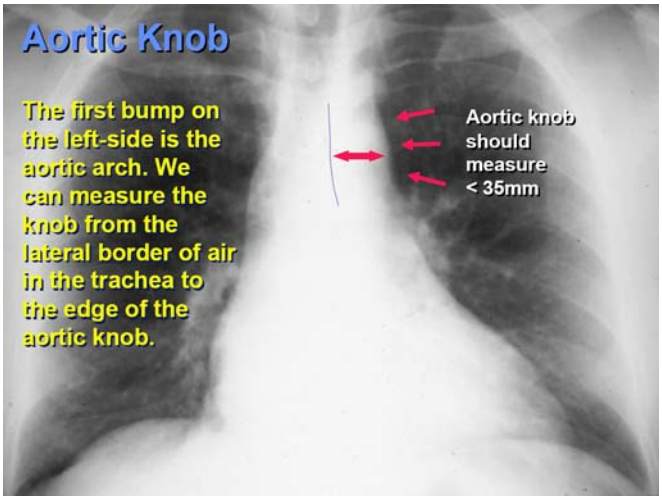


The last bump on the right side is the right atrium. Since there is no disease in an adult that causes isolated enlargement of the RA, we'll consider the RA together with the RV later.



Aortic Knob

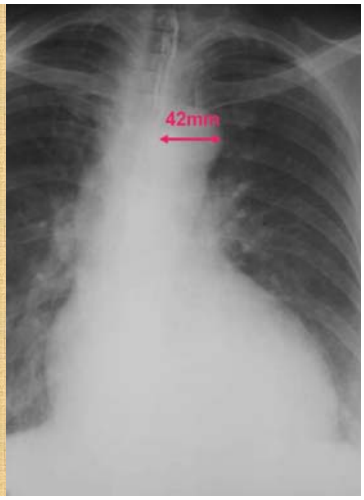
The first bump on the left-side is the aortic arch. We can measure the knob from the lateral border of air in the trachea to the edge of the aortic knob.



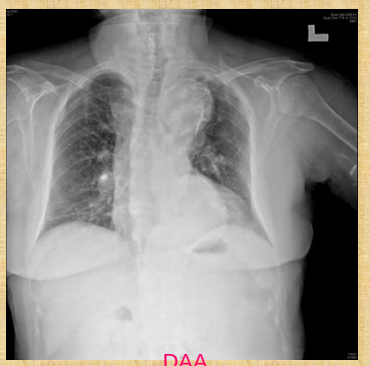
Aortic Knob

Enlarged with:

- Increased pressure
- Increased flow
- Changes in aortic wall



Calcium Sign



Calcium Sign

Table 4

Presenting signs of aortic dissection

History
- Severe, abrupt-onset pain in patients with:
  - Altered mental status
  - Heart failure
  - Hypertension
  - Marfan syndrome

Physical examination
- Pulse differentials in legs and/or arms and/or blood pressure differentials >20 mm Hg OR
- Hypertension and/or diastolic murmur of aortic insufficiency

Chest radiography
- Mediastinum bulging to the right (with ascending aorta dissection) or left (with descending aorta dissection)
- Widening of distal aortic knob (see Figure 4) past the origin of left subclavian artery
- Aortic wall thickness indicated by width of aortic shadow beyond intimal calcification, displacement of the calcification in aortic knob
- Double aortic shadow, disparity in the sizes of the ascending and descending aortas
- Pleural effusion, most often on the left

Note: Presence of acute chest and/or back pain, pulse and/or blood pressure differentials, and mediastinal widening and/or aortic widening (on chest x-ray) indicate high risk for aortic dissection.

Sources: References 6, 23.

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Mediastinal Widening

- A measured width greater than 8 cm on PA chest X-ray
- 7 common pathologies
  - Aortic aneurysm
  - Hilar lymphadenopathy
  - Esophageal rupture
  - Mediastinal mass
  - Inhalation anthrax
  - Pericardial effusion
  - Thoracic vertebral fracture

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Cardiomegaly

On a plain film:

- **Left atrium**: the only chamber that can be reliably diagnosed when it is enlarged as follows
  - Double contour to the R't heart border,
  - Splaying of carina with upward displacement of the left main bronchus,
  - Posterior bulging on lateral CXR
- **Right atrium**: prominence R't heart border → Draw a line from intraspinal process; if > 40 mm, this means RA enlargement
- **Right ventricle**: upward displacement of the cardiac apex with anterior enlargement of the heart border on lateral CXR
- **Left ventricle**: increased convexity of the left heart border. Apex displaced inferiorly

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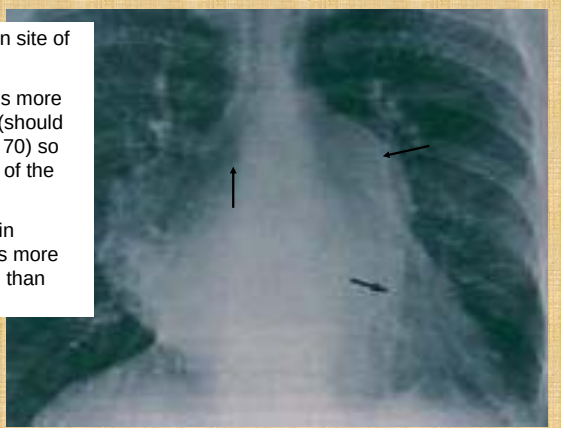
Left Atrial Enlargement

-Bulge on site of LA

-Carina is more than 70 (should be up to 70) so splaying of the carina

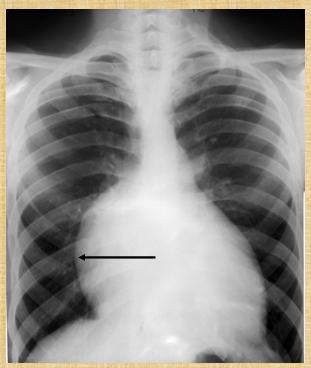
-Left main bronchus more elevated than usual



Right Atrial Enlargement

-Cardiac position: Left = Right

-Right border to midline > 40 mm



Ebstein's anomaly

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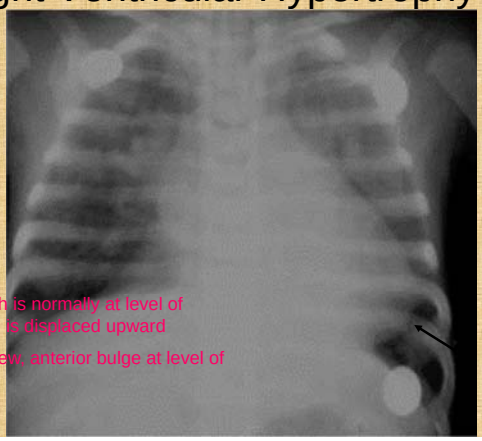
Right Ventricular Hypertrophy



Apex, which is normally at level of diaphragm, is displaced upward

In lateral view, anterior bulge at level of RV

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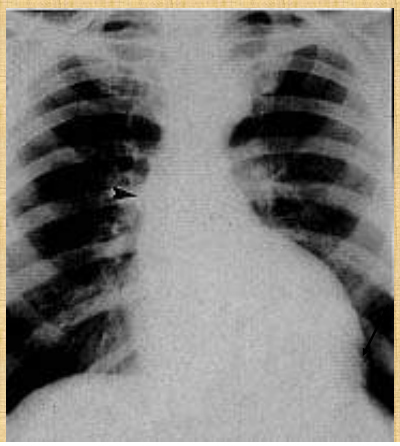
Left Ventricular Enlargement



The reverse of RVE

Apex displaced inferiorly

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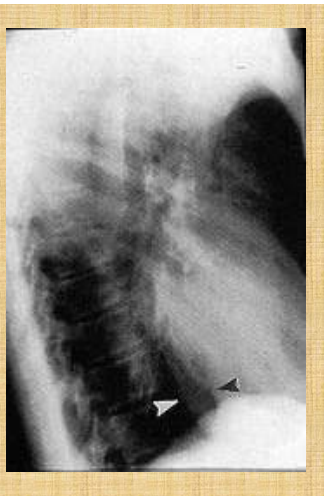
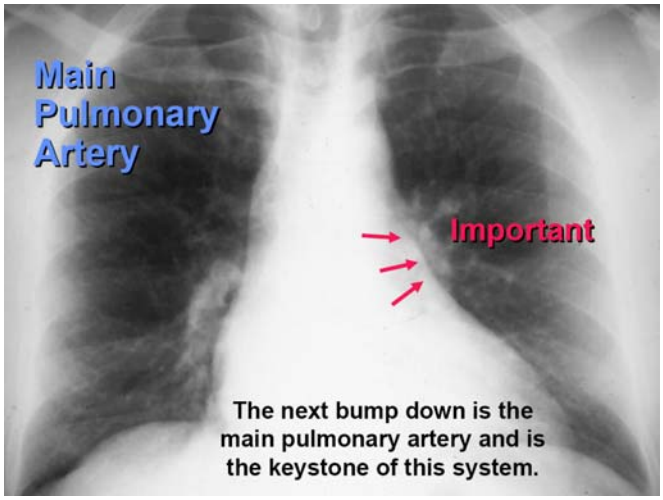
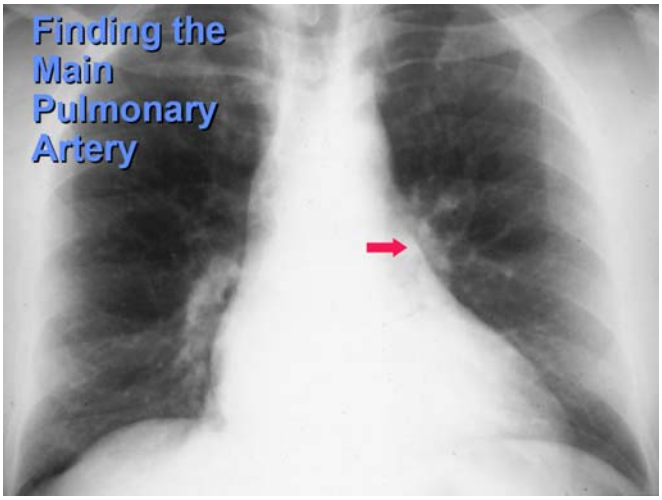
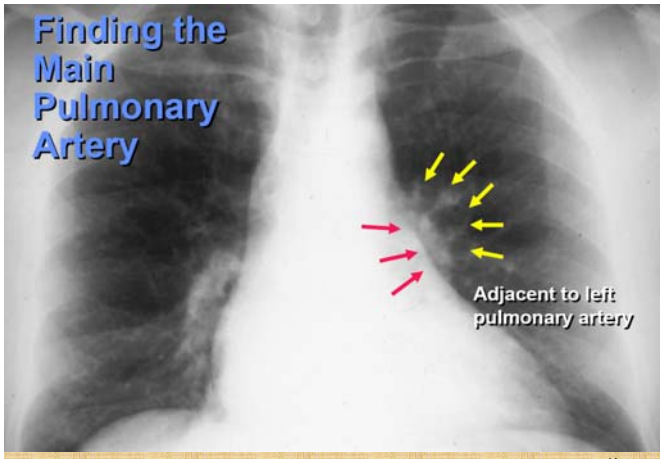
Left Ventricular enlargement posterior bulge









Next: measure the MPA

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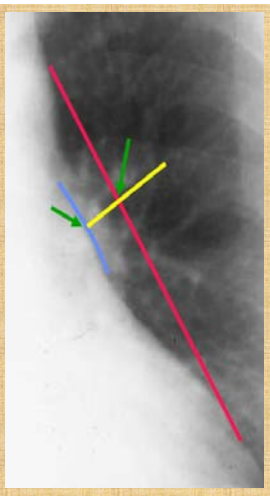
If we draw a tangent line from the apex of the left ventricle to the aortic knob (red line) and measure along a perpendicular to that tangent line (yellow line)



The distance between the tangent and the main pulmonary artery (between two small green arrows) falls in a range between 0 mm (touching the tangent line) to as much as 15 mm away from the tangent line

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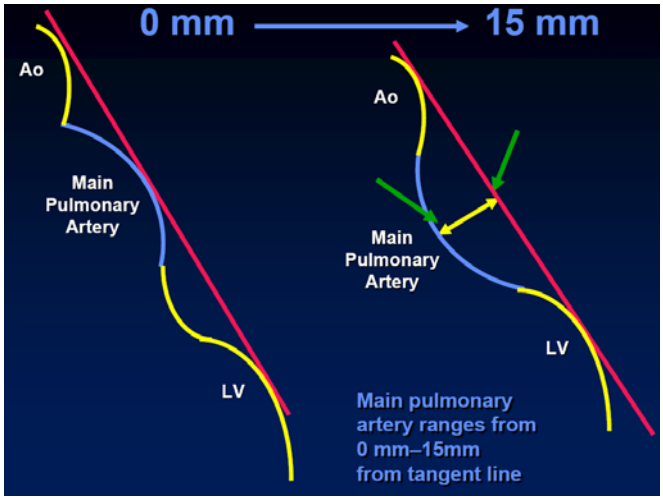


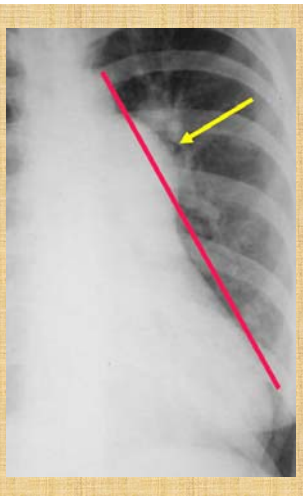
Two Major Classifications

- The main pulmonary artery (MPA) projects beyond the tangent line
- The main pulmonary artery is more than 15 mm away from the tangent line
  - Because the MPA is small or absent
  - Because the tangent line is being pushed away from the MPA

Main pulmonary artery projects beyond tangent

Increased Pressure

Increased flow

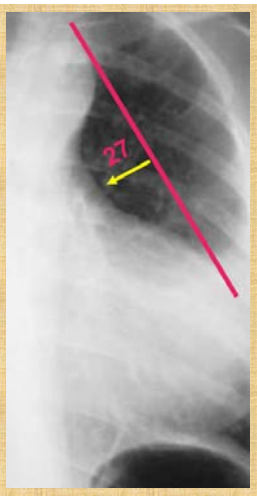


Main pulmonary artery is more than 15 mm from tangent

Small pulmonary artery

Truncus arteriosus

Tetralogy of Fallot

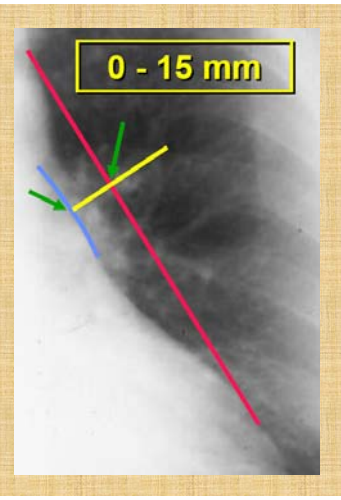


Main pulmonary artery is more than 15 mm from tangent

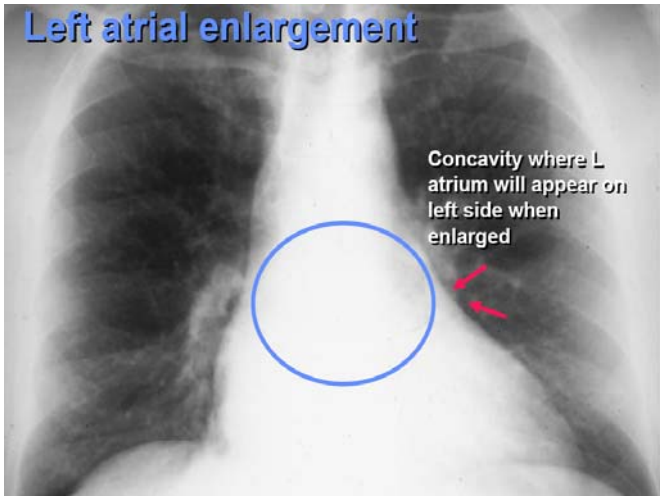
Left ventricle and/or aortic knob push the tangent away

Common

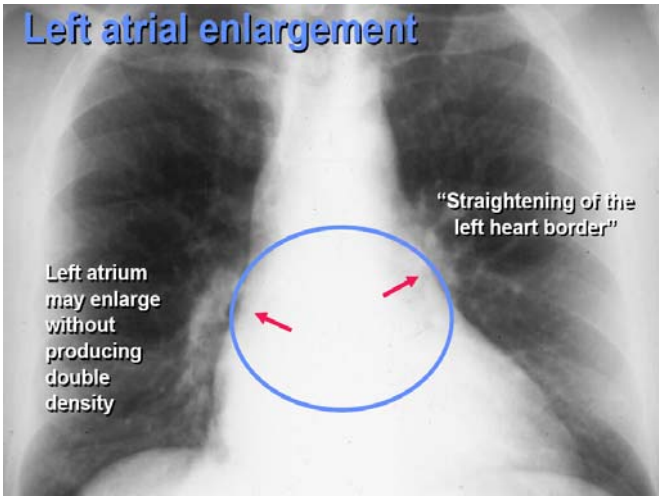
To recapitulate:



Left atrial enlargement

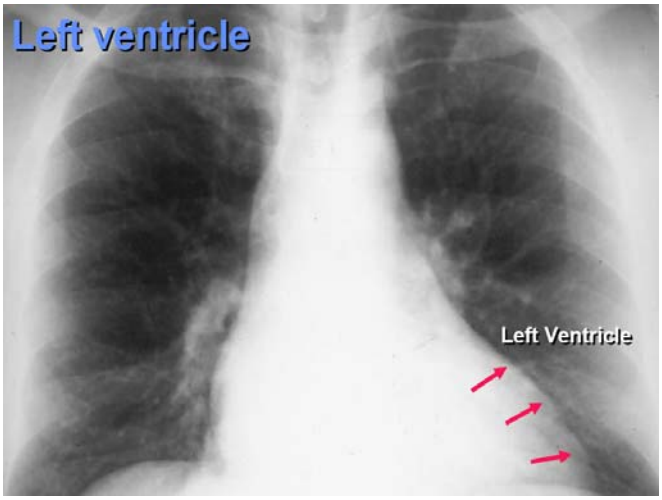


Left atrial enlargement

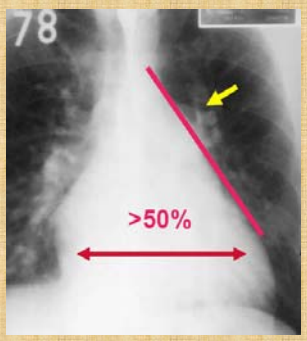


In the example on the right, not only is the left atrium enlarged, but the left atrial appendage is too. So there is a convexity outward where there is normally a concavity inward.

Left ventricle



Which Ventricle is Enlarged?



Heart is Enlarged, And Main Pulmonary Artery is Big

Then Right Ventricle is Enlarged

Which Ventricle is Enlarged?

If Heart Is Enlarged, And Aorta is Big

Then Left Ventricle >50% is Enlarged

Which Ventricle is Enlarged?

- The best way to determine which ventricle is enlarged is to look at the corresponding outflow tract for each ventricle
  - Aorta for the LV
  - MPA for the RV
- Once one ventricle is enlarged, it's impossible to tell if other ventricle is also enlarged

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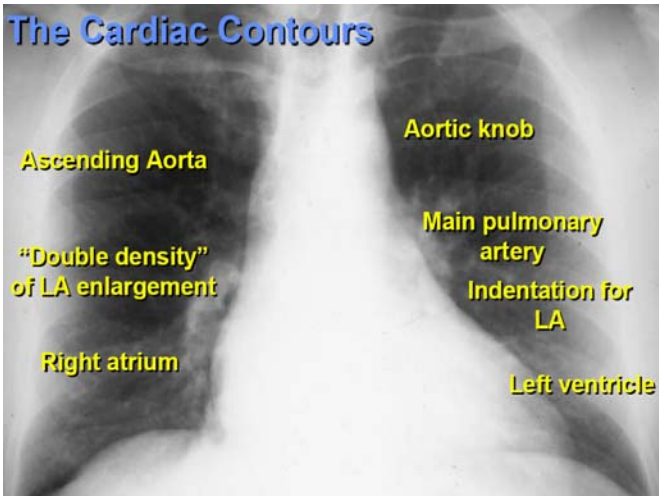

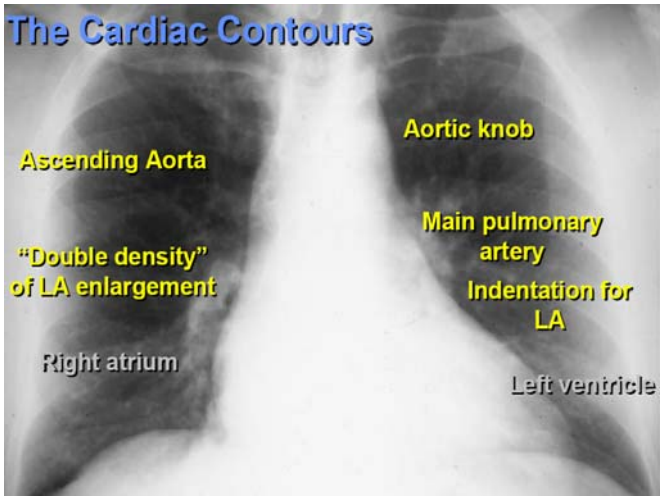

Pulmonary Vasculature: Five States

- Normal
- Pulmonary venous hypertension
- Pulmonary arterial hypertension
- Increased flow
- Decreased flow

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What We're Going to Evaluate

- Right Descending Pulmonary Artery
  1. Distribution of flow in the lungs
  2. Upper versus lower lobes
  3. Central versus peripheral

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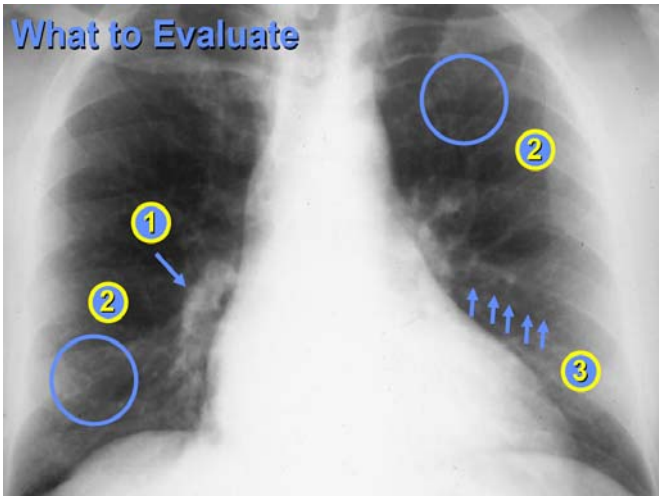
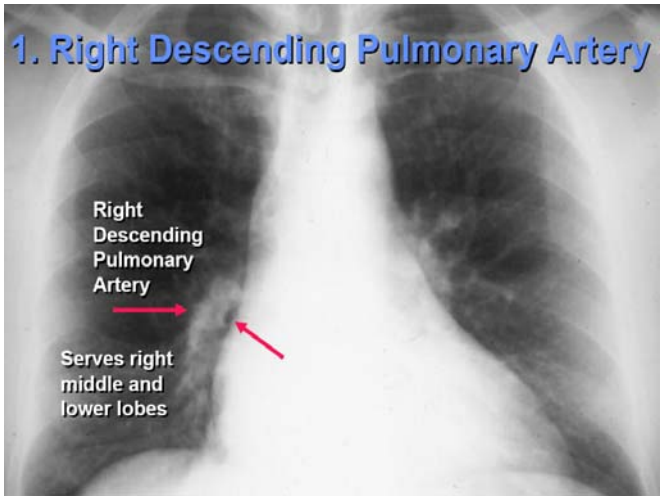
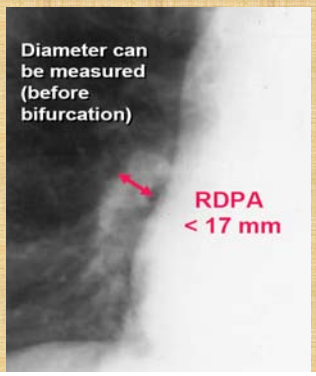




1. Right Descending Pulmonary Artery



Normally, the right descending pulmonary artery should not be more than 17mm in diameter

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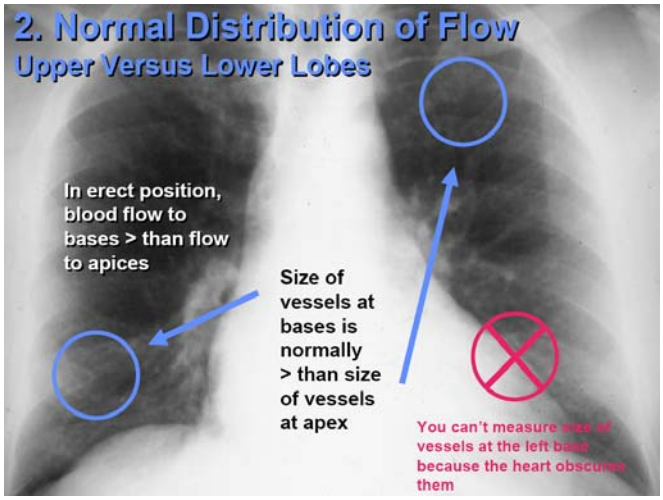
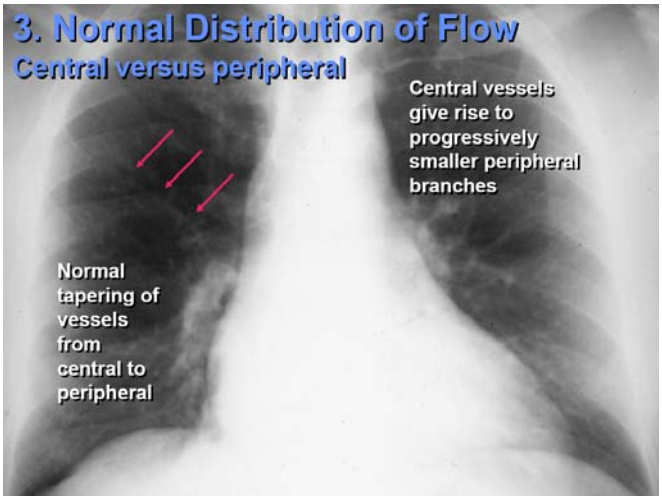
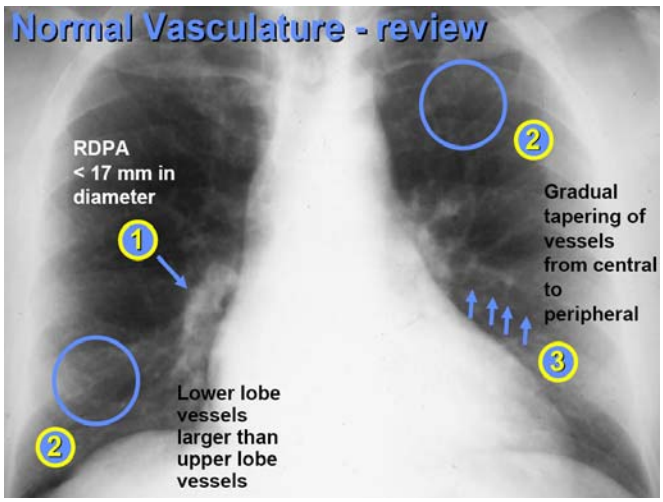
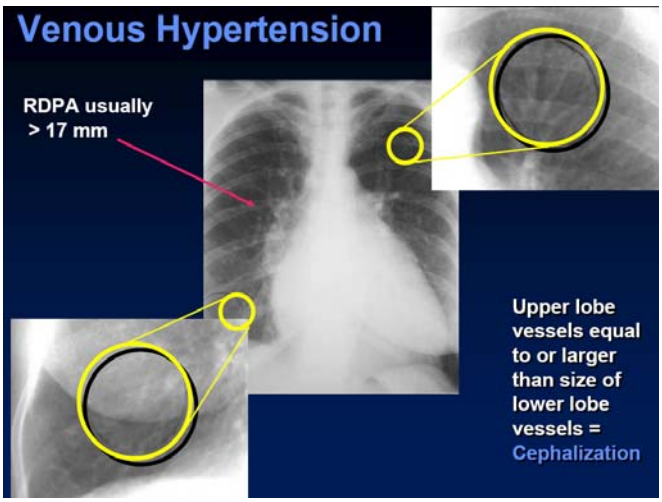
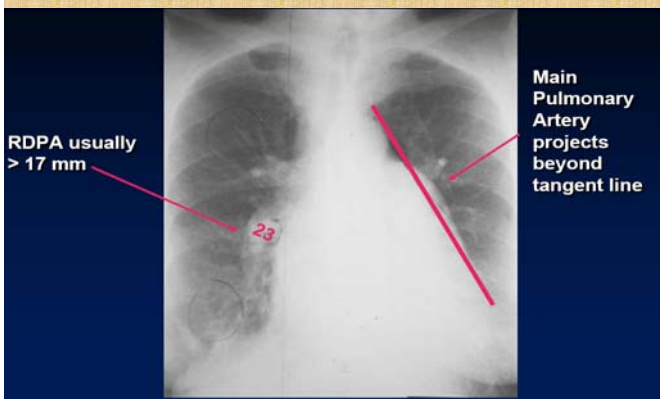




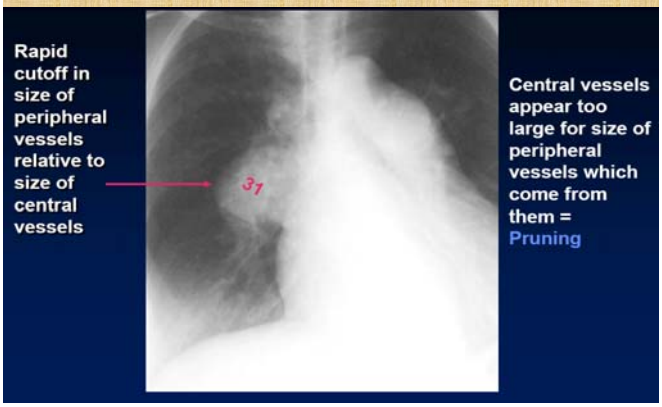




Pulmonary Arterial Hypertension



Pulmonary Arterial Hypertension



Increased Flow

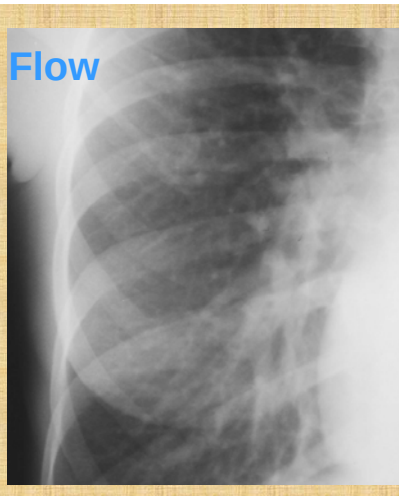
All of blood vessels everywhere in lung are bigger than normal

Increased Flow

Distribution of flow is maintained as in normal

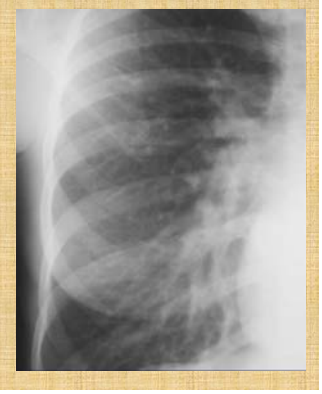
Gradual tapering from central to peripheral

Lower lobe vessels bigger than upper lobe

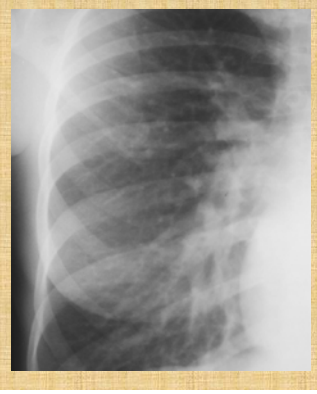


Normal

Increased Flow



Increased Flow



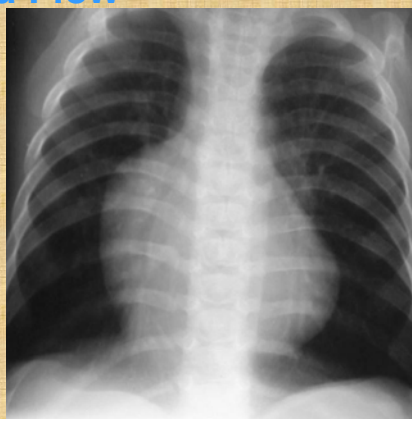
PAH

Decreased Flow

Unrecognizable most of the time

Small hila

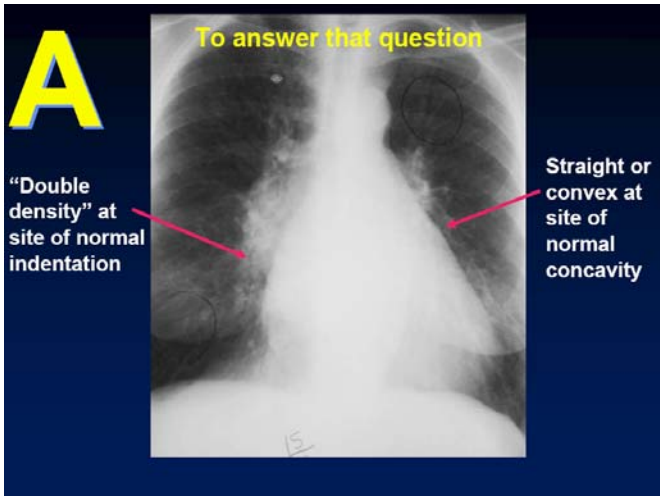
Fewer than normal blood vessels

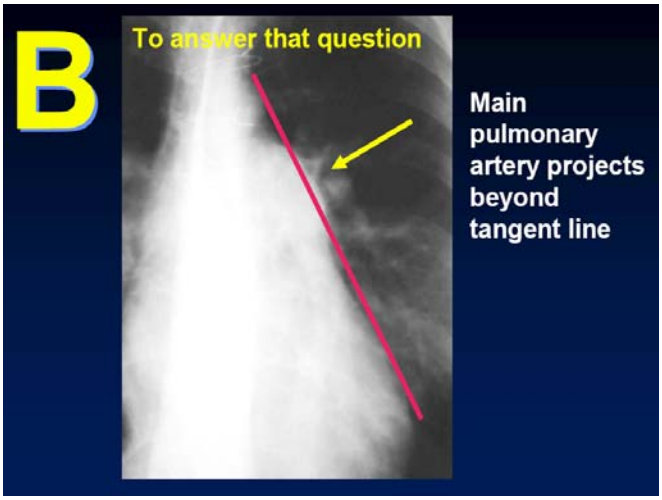


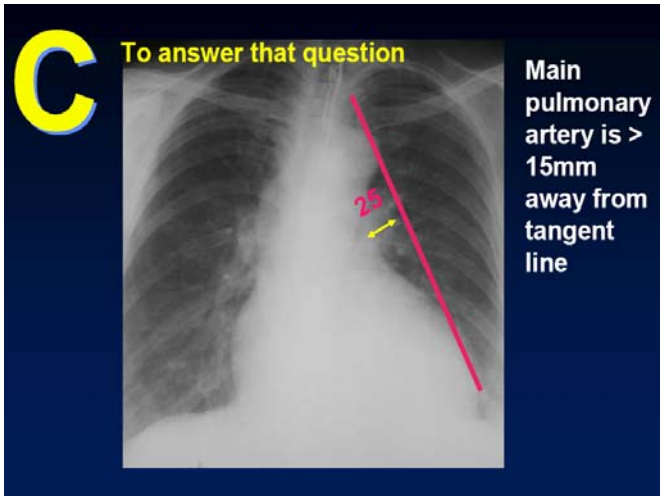
The Sequential Questions

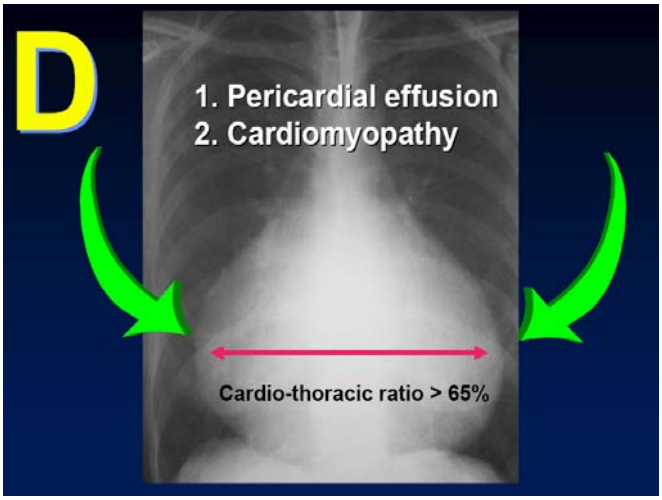
Systematic Review of CV System

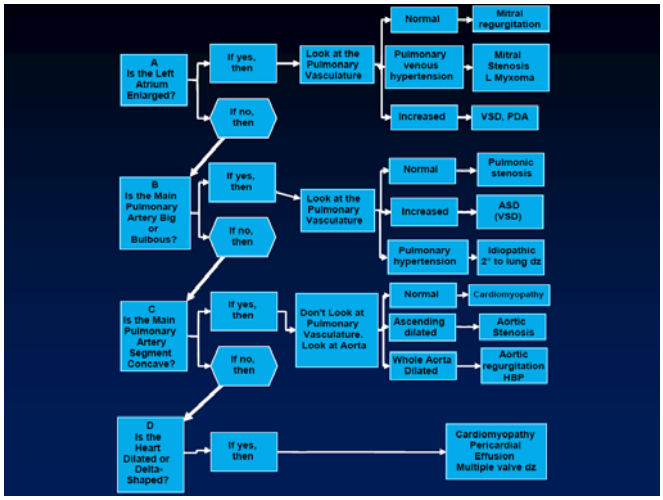
- A: Is the LA enlarged?
- B: Is the MPA big or bulbous?
- C: Is the MPA segment concave?
- D: Is the heart dilated or delta-shaped?











Part II. Case Scenarios

Life-Threatening Chest Pain

- Acute Coronary Syndrome
- Dissecting Aortic Aneurysm
- Pulmonary Embolism
- Tension Pneumothorax
- Cardiac Tamponade
- Esophageal Rupture

Case 1

- A 70-year-old patient was transferred to our ED under the diagnosis of ACS. His present chief complaint is SOB for more than 2 days (R1 recorded). He consulted another ED and has gotten the treatment of Clexane for 2 days.
- AVPU
- BP 136/72, PR 100/min, RR 18/min, SpO2 97%

Case 1

- Risk factors: Uncontrolled hypertension
- Physically essentially normal
- Biochemistry including cardiac enzymes was WNL.

Case 1

Case 1

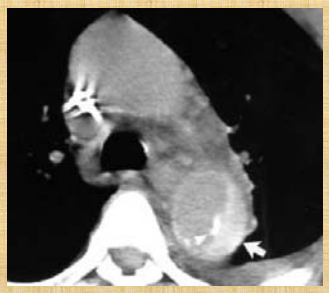
85

Case 1

Crescent Sign

86

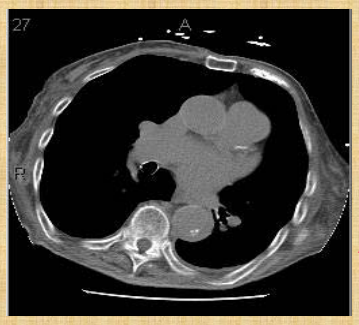
Case 1



Crescent Sign

87

Case 1



Atheroma

88

Case 1

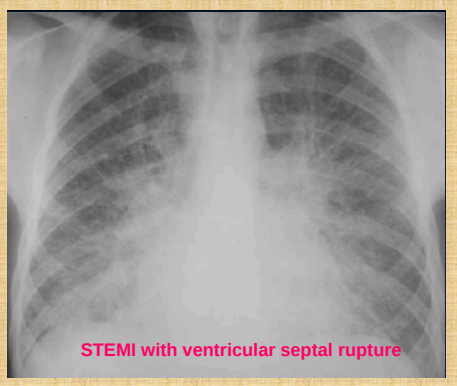
89

Case 2

- A 52-year-old female consulted ED due to intermittent chest tightness for one week and progressive dyspnea for 3 days.
- PMH: DM, Hypertension
- AVPU
- BP 108/54, PR 104/min, RR 28/min, SpO2 88%
- Bilateral wheezing
- Gr. III/VI pansystolic murmur over apex

90

Case 2



STEMI with ventricular septal rupture

Mitral Regurgitation
Causes

- Thickening of valve leaflets 2°rheumatic disease
- Rupture of the chordae tendinae
  - Posterior leaflet more often-Trauma, Marfan's
- Papillary muscle rupture or dysfunction
  - Acute myocardial infarction
- LV enlargement →dilatation of mitral annulus
  - Any cause of LV enlargement
- LV aneurysm→valvular dysfunction
  - Acute myocardial infarction

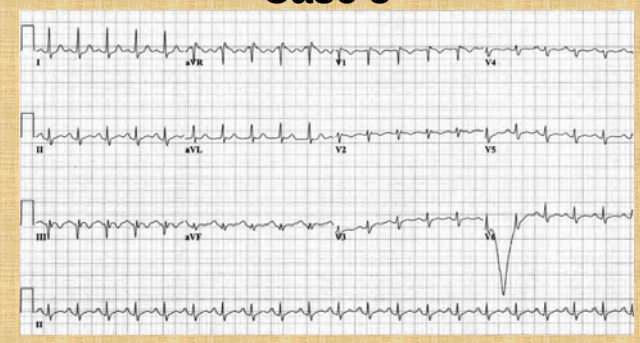
Pansystolic Murmur
Causes

- Mitral regurgitation due to valvular involvement in RHD
- Ventricular septal defect (congenital)
- Ventricular septal rupture (acquired, unreperfused myocardial infarction)

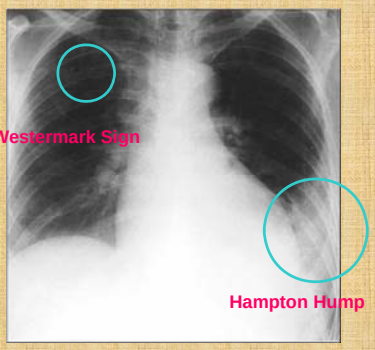
Case 3

- A 66-year-old male consulted ED due to fever, chest discomfort and progressive dyspnea for 3 days.
- PMH: DM, prostate ca. No travel history.
- AVPU
- BP 116/58, PR 110/min, BT 38'C, RR 24/min, SpO2 93%
- Rapid test: A(+)

Case 3



Case 3



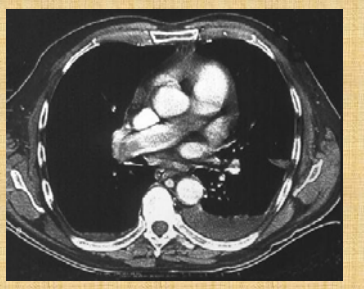
Case 3

Hampton Hump

Case 3

- Hampton Hump
  - Peripheral: pleural-based opacity
  - Wedge-shaped: points to hilum
  - Homogeneous: no air bronchogram
  - Resolves like a “melting ice cube”, not patchy resolution

Case 3

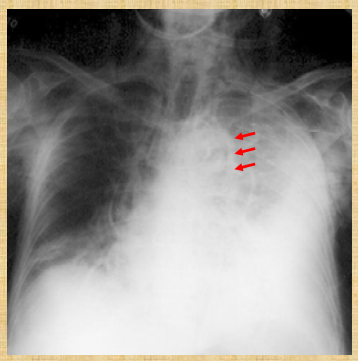


MPA Pulmonary Embolism

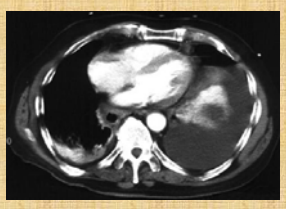
Case 4

- A 70-year-old male consulted GI clinic due to dysphagia for 1 month. Panendoscope was arranged. Esophageal cancer over lower third of esophagus was impressed.
- Two hours later, he consulted ED due to chest pain and dyspnea.
- AVPU
- BP 108/50, PR 110/min, RR 28/min, SpO2 89%

Case 4



Case 4



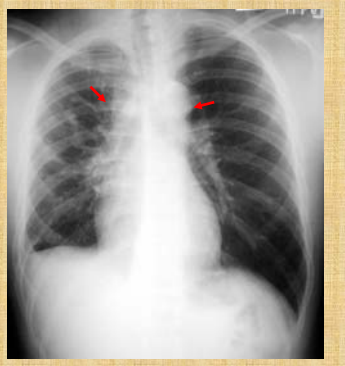
Case 4

- Boerhaave's syndrome
  - Iatrogenic: endoscope (75%)
  - penetrating injuries
  - blunt trauma
  - severe vomiting
  - caustic ingestion
  - neoplasm

Case 5

- A 24-year-old patient felt progressive facial edema for more than one month. Severe facial edema was found after sleeping over the night. The symptom can gradually subside after waking up from the bed.
- AVPU
- BP 122/64, PR 100/min, RR 18/min, SpO2 98%

Case 5



Case 5

- SVC syndrome
  - Clinical Presentations are Key points.
  - Treat underlying diseases.
  - No IV/IC over upper extremities or neck.

Case 5
Clinical Features of SVC

SYMPTOMS	FREQUENCY
Short of Breath	50%
Chest Pain	20%
Cough	20%
Dysphagia	20%

Markman, M. Cleveland Clinic Journal of Medicine, 1999

Case 5
Clinical Features of SVCS

SIGNS	FREQUENCY
Thorax Vein Distention	70%
Neck Vein Distention	60%
Facial Swelling	45%
UE/Trunk Swelling	40%
Cyanosis	15%

Markman, M. Cleveland Clinic Journal of Medicine, 1999

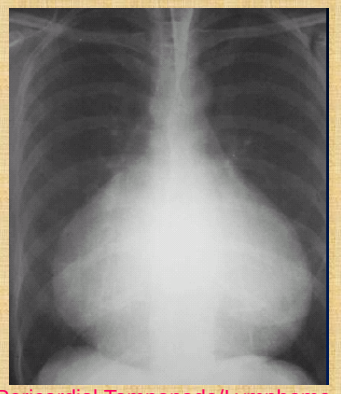
Case 5
Etiology of SVC

- Malignancy
  - Lung cancer
  - Lymphoma
  - Thymoma
  - Metastatic
  - Germ Cell
- "Benign"
  - Infection/Inflammation
  - Benign Neoplasms
  - Iatrogenic
  - Trauma

Case 6

- A 26-year-old man consulted ED due to gradual onset dyspnea and night sweating for 3-4 days. Mild body weight loss of 3 Kgs was noted in recent one month.
- AVPU
- BP 88/44, PR 115/min, RR 24/min, SpO2 94%
- PMH: Nil.

Case 6



Pericardial Tamponade/Lymphoma

Case 6

- Differential Diagnosis
  - Panvalvular disease
    Severe univalvular disease
    Cardiomyopathy
    Endomyocardial Fibrosis
    Pericardial effusion
    Ebstein's anomaly
    Uhl's anomaly

Pulmonary Venous Congestion

Case 7

- A 32-year-old man who was admitted with peptic ulcer developed sudden onset dyspnea and chest pain associated with hypotension and tachypnea.
- AVPU
- BP 96/44, PR 118/min, RR 26/min, SpO2 94%
- Precordial examination showed faint heart sound with splash and metallic tinkling sounds.

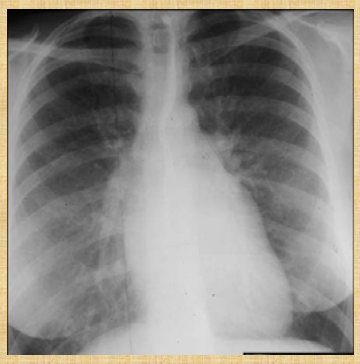
Case 7

Pneumopericardium/Tamponade/PPU

Case 8

- A 52-year-old female visited ED due to progressive dyspnea for 2 days.
- AVPU
- BP 104/50, PR 112/min, RR 26/min, SpO2 90%
- She was known to have valvular heart disease for 20 years.
- Irregular rhythm and a Gr. II/VI mid-diastolic rumbling murmur over apex were noted.

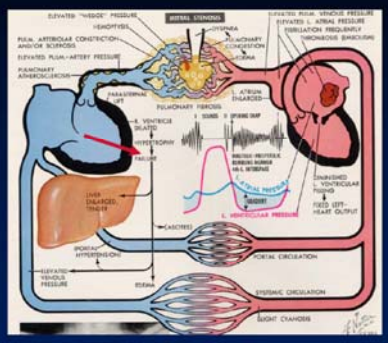
Case 8



Mitral Stenosis

Time course of MS in adult

- Mitral stenosis occurs
- Left atrial pressure ↑
- Left atrium enlarges
- Cephalization
- PIE
- PAH develops
- PVR increases
- RV enlarges
- Pulmonic regurg develops
- Tricuspid annulus dilates
- Tricuspid insufficiency
- RV failure



X-Ray Findings of MS
Cardiac Findings

- Usually normal or slightly enlarged heart
  - Enlarged atria do not produce cardiac enlargement; only enlarged ventricles
- Straightening of left heart border
- Or, convexity along left heart border 2° to enlarged atrial appendage
  - Only in rheumatic heart disease

Mitral Stenosis
Cardiac X-Ray Findings

- Small aortic knob due to decreased cardiac output
- Double density of left atrial enlargement
- Rarely, right atrial enlargement from tricuspid insufficiency

Mitral Stenosis
Calcification

- Calcification of valve--not annulus--seen best on lateral film and at angio
- Rarely, calcification of left atrial wall 2° fibrosis from long-standing disease
- Rarely, calcification of pulmonary arteries from PAH

Mitral Stenosis
Pulmonary X-Ray Findings

- Cephalization
- Elevation of left mainstem bronchus (especially if 90° to trachea)
- Enlargement of main pulmonary artery 2° pulmonary arterial hypertension
  - Severe, chronic disease
- Multiple small hemorrhages in lung
  - Pulmonary hemosiderosis

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Etiology of MS

- MS 2° to rheumatic disease 99.8% of cases
- Others
  - Congenital mitral stenosis
  - Infective endocarditis
  - Carcinoid syndrome
  - Fabry's Disease
  - Hurler's syndrome
  - Whipple's Disease
  - Left atrial myxoma

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Pulmonary Edema
X-ray Findings

- Staging:
  - I: pulmonary congestion
    - (cephalization)
  - II: butterfly edema pattern
  - III: basal pulmonary edema
    - with/without Kerley's B line
  - IV: III + pleural effusion

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Congestive Heart Failure
Causes

- Coronary artery disease
- Hypertension
- Cardiomyopathy
- Valvular lesions
  - AS, MS
- L to R shunts

124

Congestive Heart Failure
Clinical

- Usually from left heart failure
  - Shortness of breath
  - Paroxysmal nocturnal dyspnea
  - Orthopnea
  - Cough
- Right heart failure
  - Edema

125

Left Atrial Pressures
Correlated With Pathologic Findings

Normal	5-10 mm Hg
Cephalization	10-15 mm
Kerley B Lines	15-20
Pulmonary Interstitial Edema	20-25
Pulmonary Alveolar Edema	> 25

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Pulmonary Circulation
Physiology

- **Very low pressure circuit**
- **Pulmonary capillary bed only has 70cc blood**
- **Yet, it could occupy the space of a tennis court if unfolded**
- **Therefore, millions of capillaries are "resting," waiting to be recruited**

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Pressure and Flow

Pressure = Flow x Resistance

Normally, resistance is so low that flow can be increased up to 3x normal without increase in pressure

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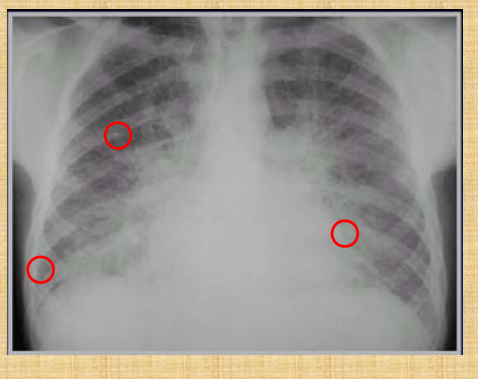
Pulmonary Interstitial Edema
X-ray Findings

- Thickening of the interlobular septa
  - Kerley B lines
- Peribronchial cuffing
  - Wall is normally hairline thin
- Thickening of the fissures
  - Fluid in the subpleural space in continuity with interlobular septa
- Pleural effusions

129

Pulmonary Interstitial Edema
X-ray Findings



130

Kerley B Lines

- B=distended interlobular septa
- Location and appearance
  - Bases
  - 1-2 cm long
  - Horizontal in direction
  - Perpendicular to pleural surface

131

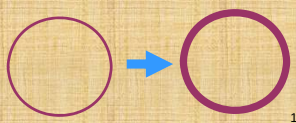
Kerley A and C Lines

- A=connective tissue near bronchoarterial bundle distends
  - Location and appearance
    - Near hilum
    - Run obliquely
    - Longer than B lines
- C=reticular network of lines
  - C Lines probably don't exist

132

Peribronchial Cuffing

- Interstitial fluid accumulates around bronchi
- Causes thickening of bronchial wall
- When seen on end, looks like little "doughnuts"



133

Fluid in the Fissures

- Fluid collects in the subpleural space
- Between visceral pleura and lung parenchyma
- Normal fissure is thickness of a sharpened pencil line
- Fluid may collect in any fissure
- Major, minor, accessory fissures, azygous fissure

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Fluid in the Fissures

- Laminar effusions collect beneath visceral pleura
  - In loose connective tissue between lung and pleura
  - Same location for "pseudotumors"

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Cephalization
A Proposed Mechanism

- If hydrostatic pressure > 10 mm Hg, fluid leaks in to interstitium of lung
- Compresses lower lobe vessels first
  - Perhaps because of gravity
- Resting upper lobe vessels "recruited" to carry more blood
- Upper lobes vessels increase in size relative to lower lobe

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Left Atrial Pressures
Correlated With Pathologic Findings

Normal	5-10 mm Hg
Cephalization	10-15 mm
Kerley B Lines	15-20
Pulmonary Interstitial Edema	20-25
Pulmonary Alveolar Edema	> 25

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Pulmonary Edema

- Cardiogenic
- Non-Cardiogenic
  - ARDS
  - Neurogenic
  - Increased Capillary permeability

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Case 8-1

Mitral Regurgitation

Mitral Regurgitation
X-ray Findings

- In acute MR
  - Pulmonary edema
  - Heart is not enlarged
- In chronic MR
  - LA and LV are markedly enlarged
  - Volume overload
  - Pulmonary vasculature is usually normal
  - LA volume but not pressure is elevated

Case 8-2

Aortic Stenosis

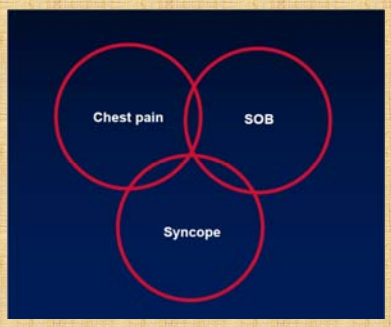
Aortic Stenosis
X-Ray Findings

- Depends on age patient/severity of disease
  - In infants, AS→CHF/pulmonary edema
- In adults
  - Normal heart size
    - Until cardiac muscle decompensates
  - Enlarged ascending aorta 2° post-stenotic dilatation 2° turbulent flow
  - Normal pulmonary vasculature

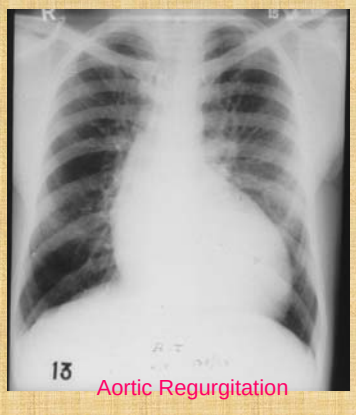
Post-stenotic Dilatation of Aorta

- From turbulent flow just distal to any hemodynamically significant arterial stenosis
  - Jet effect also plays role
- Occurs mostly with valvular aortic stenosis
  - May occur at any age

Aortic Stenosis
Clinical Triad



Case 8-3

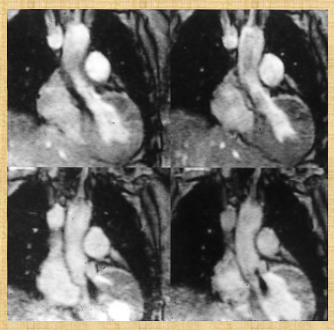


Aortic Regurgitation

Aortic Regurgitation
X-Ray Findings

- X-ray hallmarks are
  - Left ventricular enlargement
  - Enlargement of entire aorta
- Cine MRI (gradient refocused MRI)
  - "White blood" technique
  - Signal loss coming from Ao valve into LV during diastole
- Color Doppler is also diagnostic

Aortic Regurgitation
MRI Findings



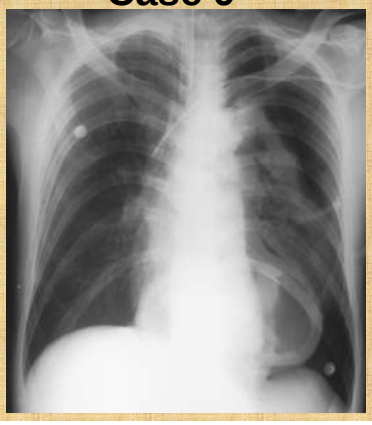
Aortic Regurgitation
Causes

- Rheumatic heart disease
- Marfan's syndrome
- Luetic aortitis
- Ehlers-Danlos syndrome
- Endocarditis
- Aortic dissection

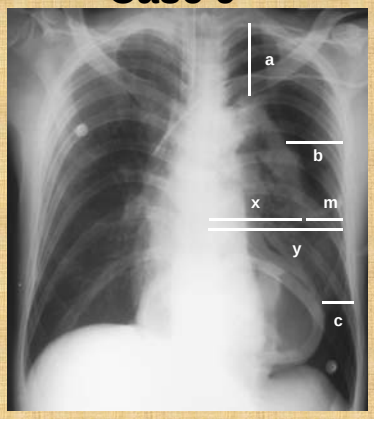
Case 9

- A 58-year-old male with septic shock is referred to our ED after intubation. At arrival, he complains progressive dyspnea during transportation.
- AVPU
- BP 102/48, PR 102/min, RR 26/min, SpO2 91%
- A CVP was placed via left subclavian vein.
- Breathing sound diminished over left chest.

Case 9



Case 9



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Case 9

- Pneumothorax Size Calculation
  - Rhea (1981): Ptx% = (5+9) x AID
  - Collins (1995): Ptx% = (4+14) x AID
  - Light formula: Ptx% - (1 – x3/y3) x 100
  - ACCP (2001): “small” a <3cm; “large” a >3cm
  - BTS (2003): “small” m <2cm; “large” m >2cm

Average Interpleural Distance (AID) = (a+b+c) / 3

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To be Continued…

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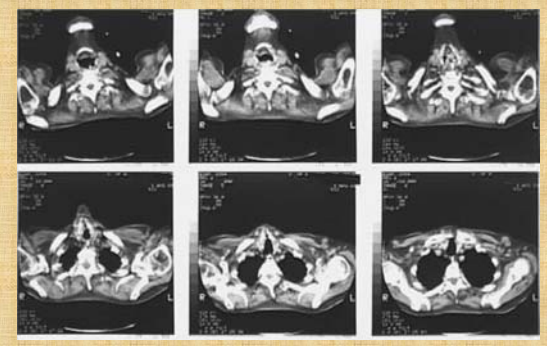
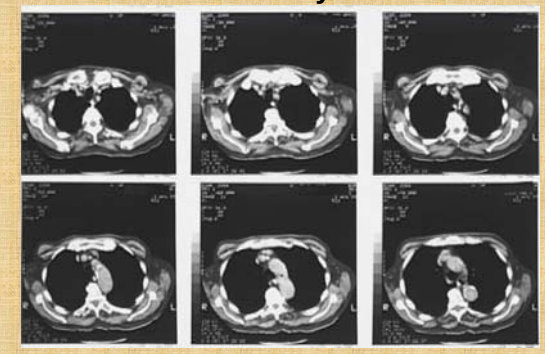
Cardiac CT
Anatomy



154

Cardiac CT
Anatomy



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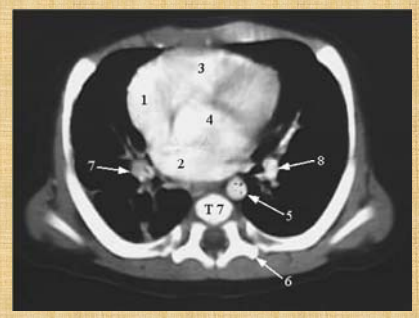
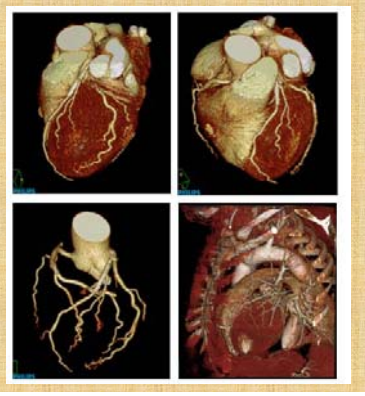
Cardiac CT
Anatomy

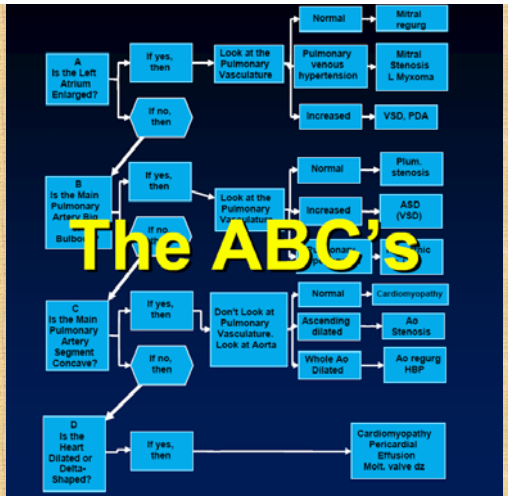
156

Cardiac CT
Anatomy



Cardiac CT
Advanced Technique





The ABC's