V/Q scan

KH Lin

Anatomy

- Pulmonary system: lungs, airways, pulmonary and bronchial circulation, chest wall
- Airways:
  - Upper airways: nasopharynx, oropharynx
  - Lower airways: trachea, bronchi, bronchioles, alveolar ducts

Anatomy - Lung

- Lungs: lobe → segments, lobules
  - Right: 3 (upper, middle, lower)
  - Left: 2 (upper, lower)

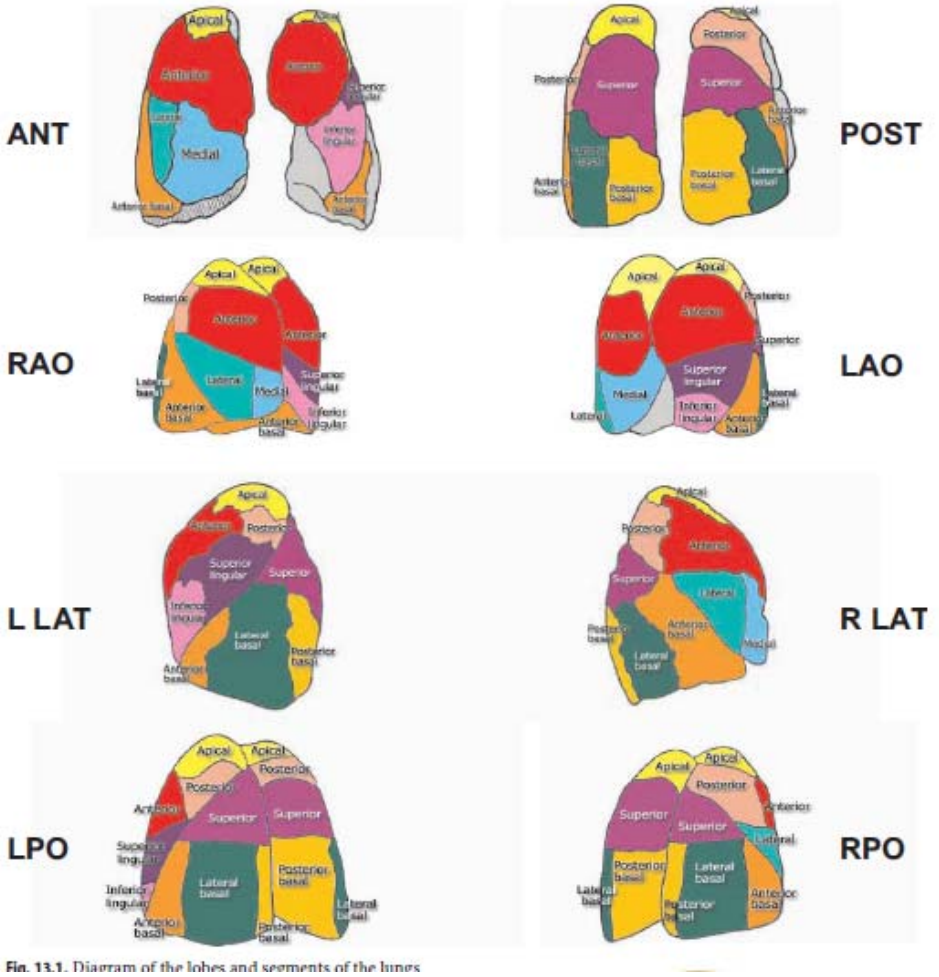

Fig. 13.1. Diagram of the lobes and segments of the lungs

Anatomy - Airways

- Upper airway:
  - nose →nasopharynx → oropharynx
- Lower airway:
  - conducting system:
    - trachea → main bronchus → lobar bronchi → segmental/subsegmental bronchi → bronchioles →→ tiny terminal bronchioles
  - gas exchange system:
    - start after terminal bronchioles

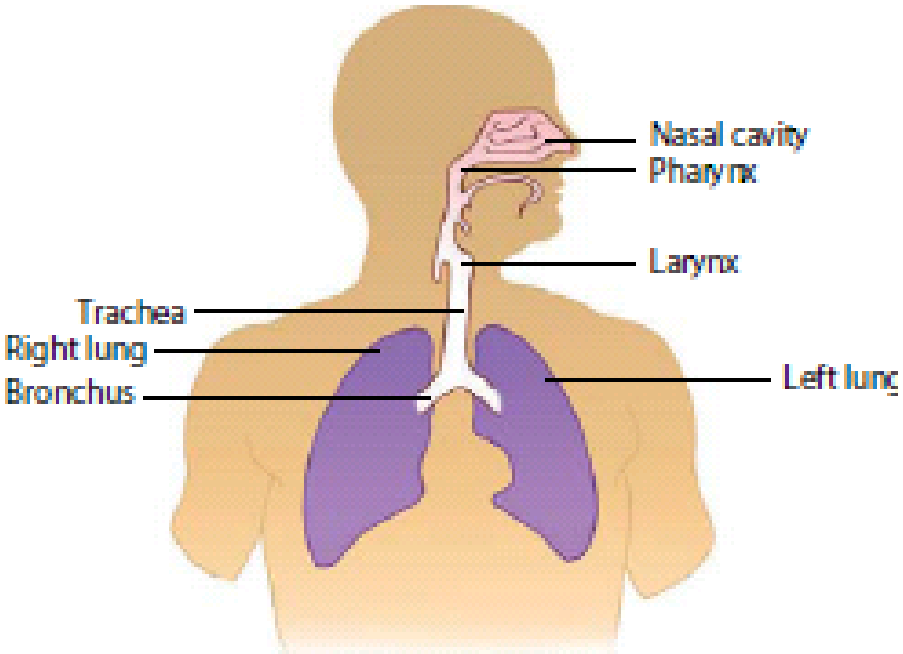

Fig. 13.2. Simple diagram of the upper and lower airways
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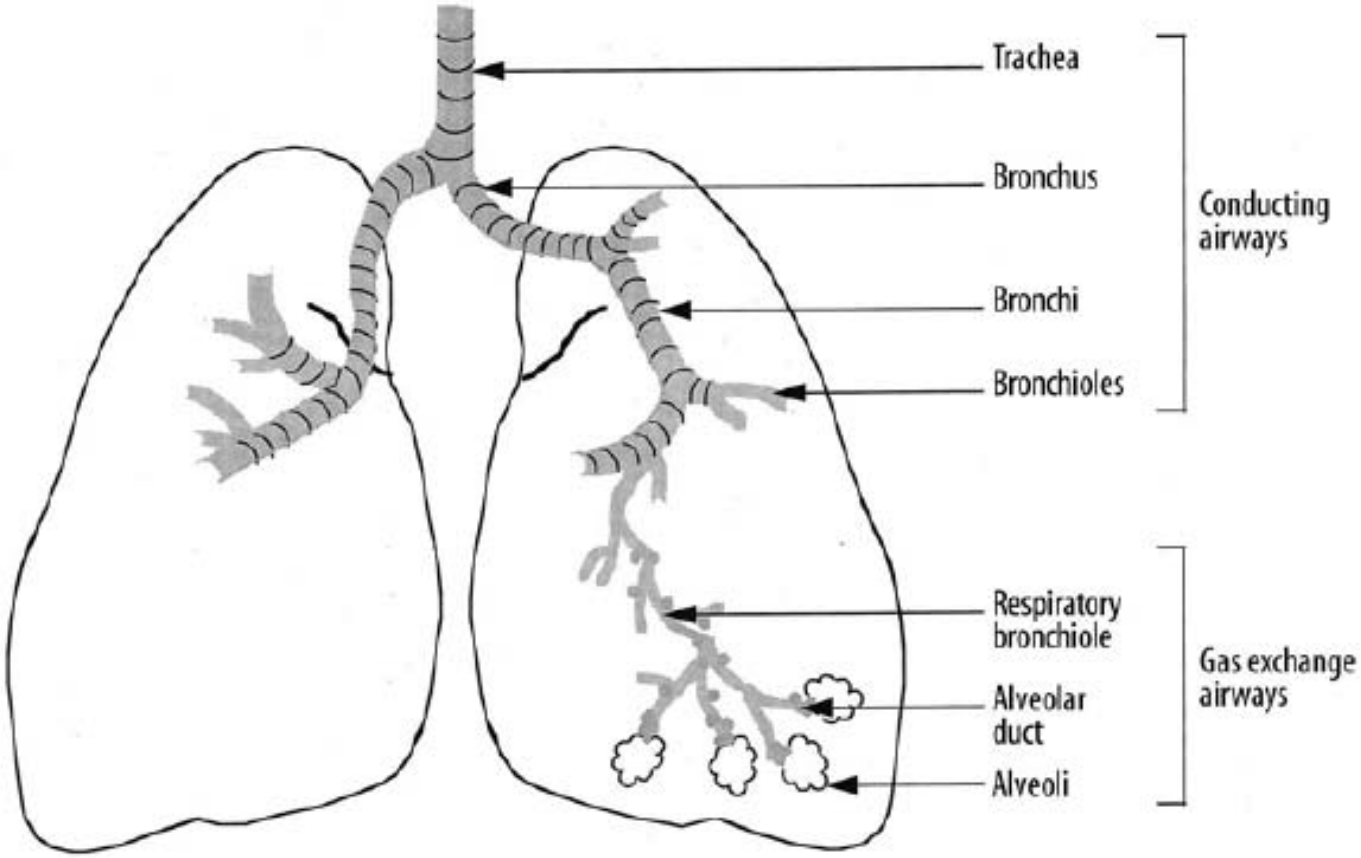

Fig. 13.3. The trachea, bronchi, and bronchioles form the tracheobronchial tree, so called since it resembles an inverted tree. The conducting system is composed of the trachea, bronchi, and bronchioles up to the 16th division and is lined by ciliated mucosa. The gas exchange system consists of the more distal bronchioles (respiratory) and the alveoli that are lined by nonciliated mucus membrane

Anatomy - Vasculature

- Pulmonary circulation:
  - Oxygen enters and carbon oxide is removed.
  - Pulmonary artery →→
    → More proximal terminal arterioles (100 μ m)
    → precapillary arterioles (35 μ m)
    → capillaries (7-10 μ m, number 300 billion in adults)
  - **The size of particles of perfusion scan: less than *100* μ *m***
- Bronchial circulation:
  - 5%, systemic circulation
  - Supply oxygenated blood to the lung tissue itself.

Distribution of ventilation and perfusion

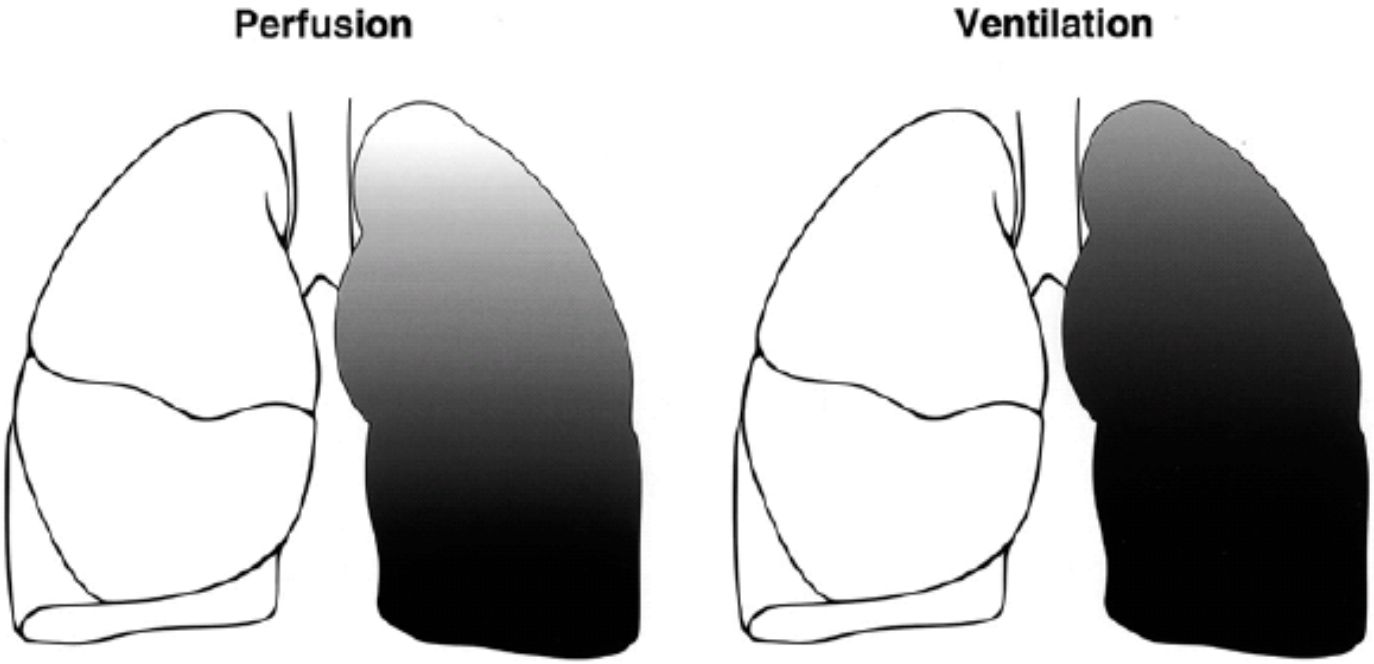

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Fig. 13.4. The gradient pattern in perfusion and ventilation of the lungs. (From [21] with permission)

- The lower zones of the lungs are better perfused and ventilated because of the effect of gravity.
- The gradient is more pronounced in perfusion than in ventilation.
- ^{99m}Tc-MAA is injected while the patient is in the supine position to minimize the gradient.
- Injection while the patient is taking a deep breath also helps.

Pulmonary thromboembolism

Pathogenesis and risk factors

- Deep vein:
  - 90% from lower extremities and pelvis:
    - thigh, pelvis > calf and feet
  - Right heart, bronchial, cervical veins
- Fat emboli: long bone fracture, liposuction
- Air emboli
- Tumor emboli: RCC with invasion IVC

Deep vein thrombosis

- The best solution to the problem of embolism is to prevent it.
- Identify who is at risk of PE: = at risk of deep venous thrombosis
- Virchow risk triad:
  - venous stasis
  - intimal injury
  - alteration in coagulation:
    - deficiencies of antithrombin III, protein C, protein S and protein Z

Table 13.1. Risk factors for deep vein thrombosis and pulmonary thromboembolism

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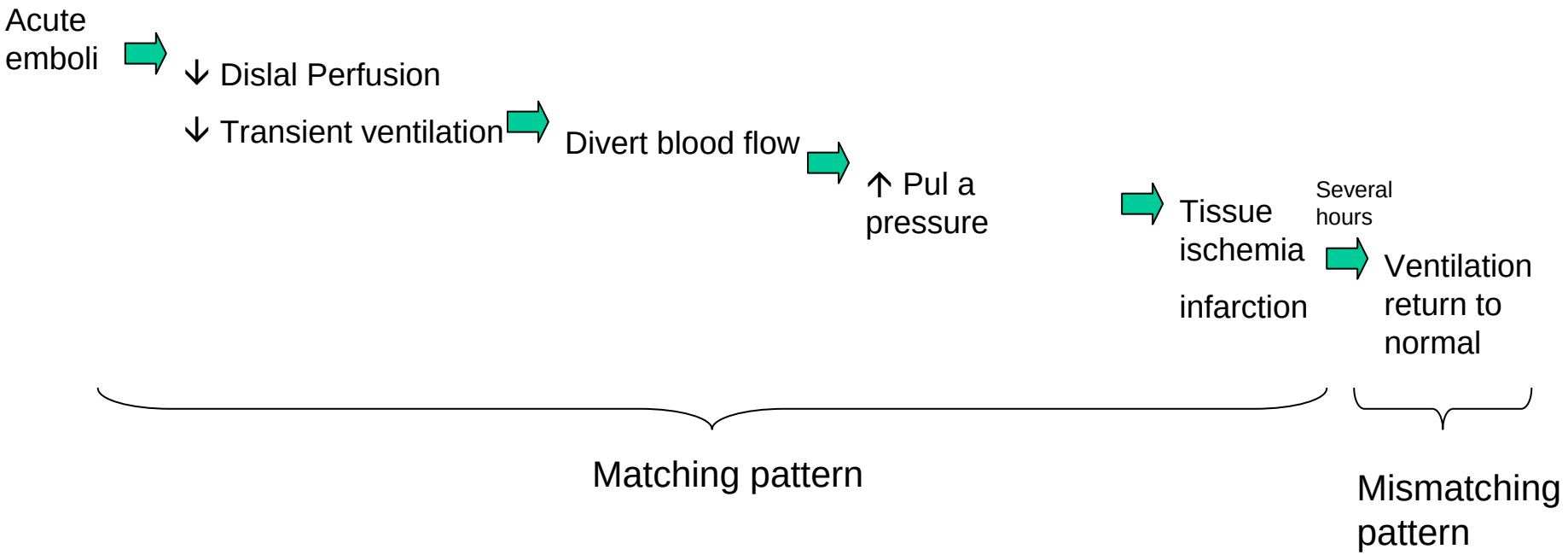
1. Postoperative state especially following operations on the abdomen and pelvis
2. Trauma, including fractures, particularly of the lower extremities
3. Neoplasms
4. Prior history of thromboembolic disease
5. Venous stasis
6. Vascular spasm
7. Intimal injury
8. Hypercoagulability states
9. Immobilization
10. Infection of the area in the immediate vicinity of veins
11. Heart disease, especially:
    Myocardial infarction
    Atrial fibrillation
    Cardiomyopathy
    Congestive heart failure
12. Pregnancy
13. Polycythemia
14. Hemorrhage
15. Obesity
16. Old age
17. Varicose veins
18. Certain drugs such as oral contraceptives, estrogens
19. Following cerebrovascular accidents

PE - Consequences

- Preferential site: lower lobes, right side



✓The duration of symptoms

PE - Consequences

- Depend on
  - the size of the emboli mass
  - the general status of the pulmonary circulation.

PE - Resolution

- Pulmonary emboli may, spontaneously or with treatment, fragment into smaller portions that travel distally and block smaller arterioles. (Fig 13.5)
  → make new, smaller perfusion defects on a follow-up scan

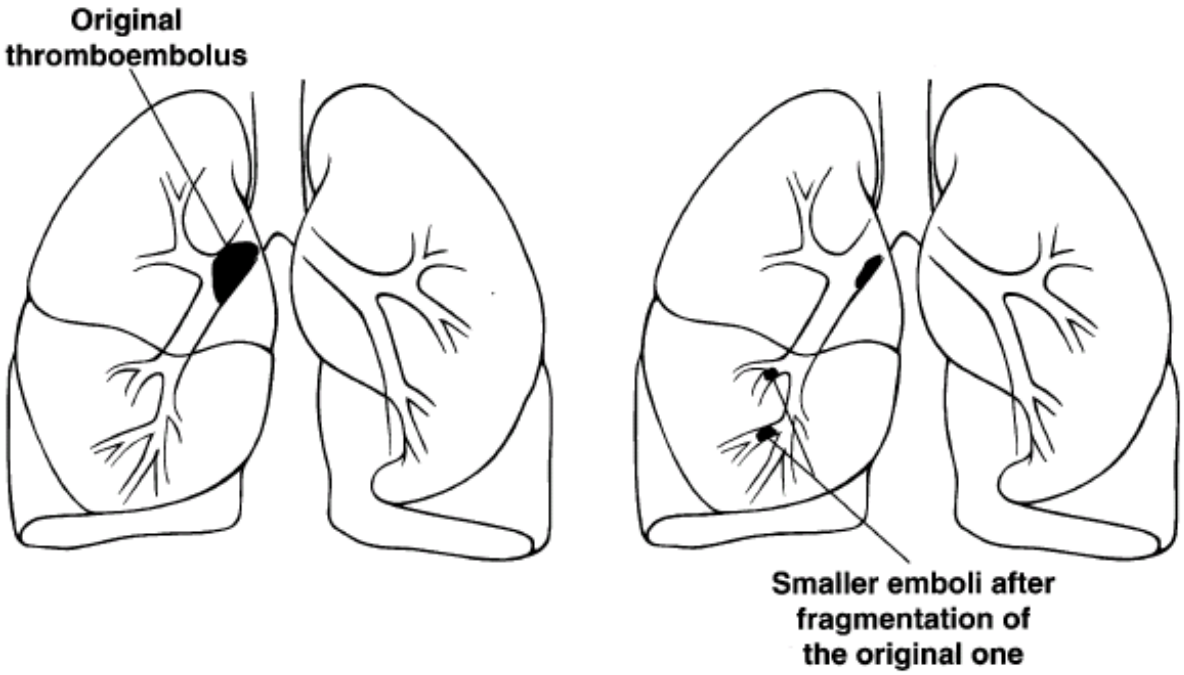


Fig. 13.5. The phenomenon of fragmentation of the thromboemboli. (From [26] with permission)

• Resolution may start within hours, progressively up to 3 months, with insignificant after 6 months. (Fig 13.6)

→ Follow-up scan is performed **3 months** after the incident.

• Chronic PE → pulmonary hypertension.

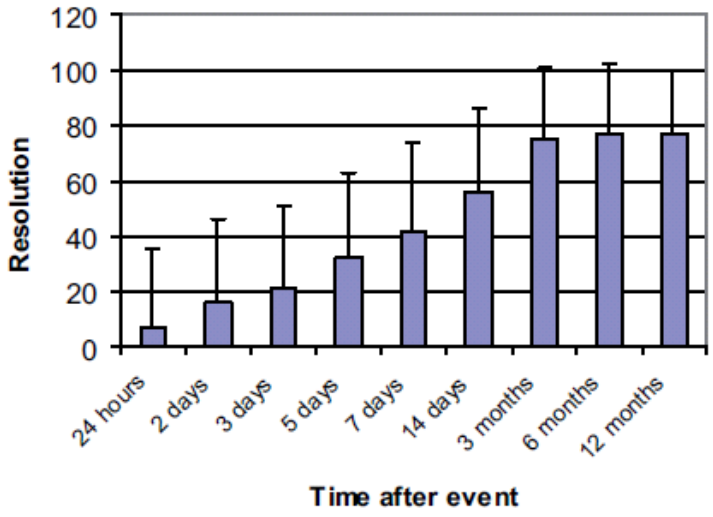


Fig. 13.6. Histogram illustrating the percent resolution of pulmonary emboli. Note that there is progressive increase of the percentage overtime until 3 months after the event with no significant increase afterwards. These data are based on the Urokinase Study [13, 14]

PE - Clinical

- Nonspecific symptoms and signs, lab and CxR
- S/S:
  - The presentation is commonly more difficult and atypical in older age groups.
  - Asymptomatic: 24%
- Mortality: > 30% (untreated)→ 2.5-8% (treated)

PE - Imaging

- CxR
- Angiography
  - Most accurate, accuracy 96%
  - Invasive, not suitable as a screening modality
- Scintigraphy
  - Most cost-effective, noninvasive
  - To guide selective angiography
  - DVT (+) 93% probability, DVT (-) 50% probability
- Spiral CT
  - Useful in detecting central emboli
- MRI pulmonary angiography, MR V/Q imaging

Perfusion scan- ^{99m}Tc-MAA

- 10-90 (10-30) μ m (90% of particles)
- 2-6 ($\geqq$ 1) x 10^5 particles
- Slowly IV
- precapillary arterioles (or capillary), $\leqq$ **0.1%** of their total number
- Critical organ: lung
- Biological half-life: 6-8 (2-4) hours

Table 13.5. Causes of abnormal perfusion lung scintigraphy

Emphysema
Inflammatory diseases
Pneumonia
Abscess
Granulomatous disease (sarcoidosis, tuberculosis)
Pulmonary fibrosis
Bronchial obstruction
Infection
Neoplasm
Acute and chronic asthma
Mucus plug
Foreign body
Rib fractures (reduced lung excursion)
Congenital hypoplasia or absence of the pulmonary arteries
Peripheral pulmonary artery stenosis
Thromboembolic disease
Thrombus
Tumor embolism
Fat embolism
Air embolism
Extrinsic vessel compression (tumor, inflammation)
Left ventricular failure
Mitral valve disease
Veno-occlusive disease
Prior lung resection
Radiation

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Perfusion scan

- Normal perfusion study rules out any clinically significant pulmonary emboli.

Table 13.6. Features of perfusion defects associated with higher probability of pulmonary emboli

Size	Moderate and large Larger relative size compared with that of chest X-ray densities
Location	Pleural based defects Lower lobes
Shape	Wedge-shaped
Type	Segmental
Relation to ventilation pattern	Mismatching
Number	Multiple

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- Perfusion defect size:
  - –Small: 25 %
  - –Moderate: 25-75 %
  - –Large: 75%

Perfusion scan

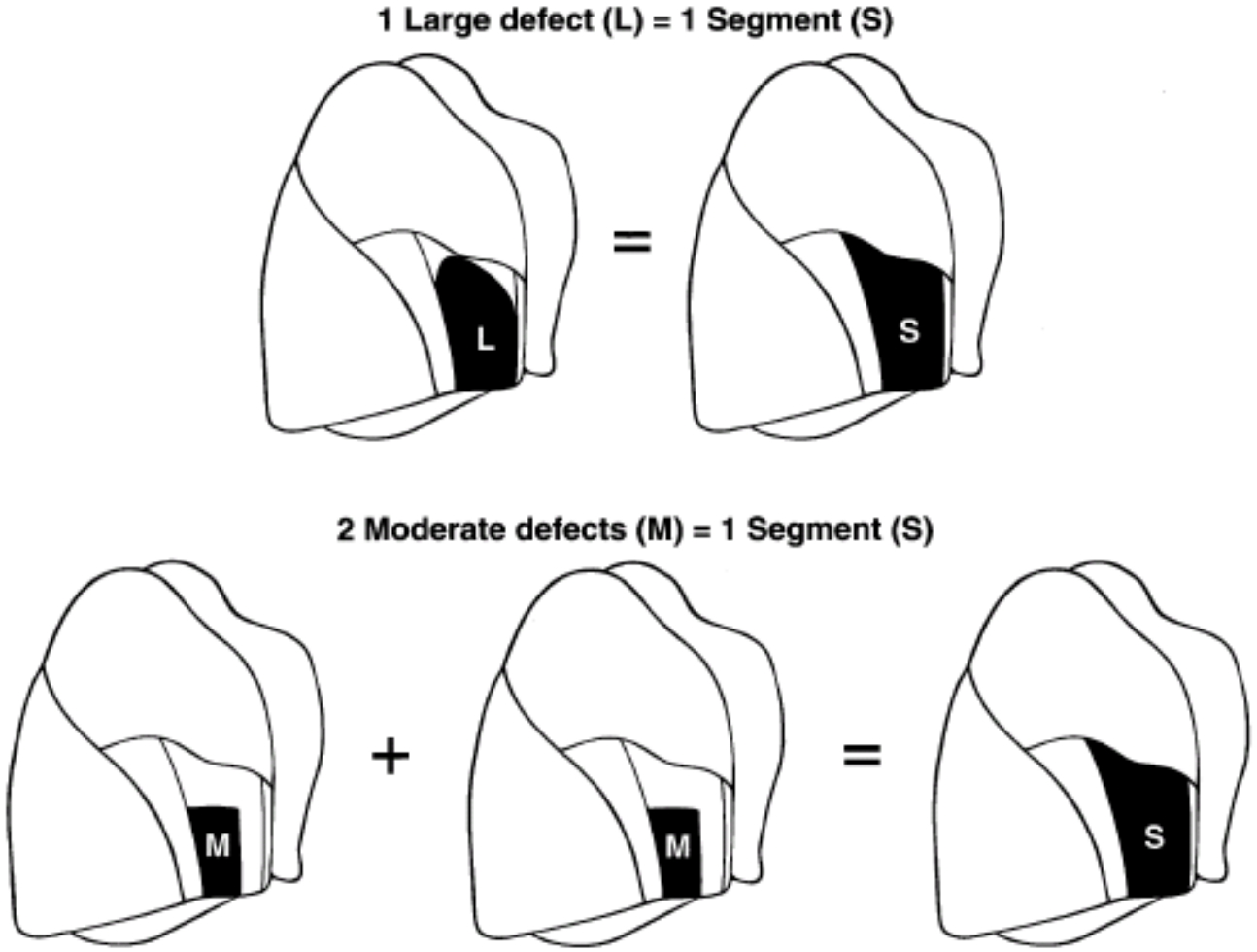

Fig. 13.13. The segment equivalent concept. (From [26] with permission)

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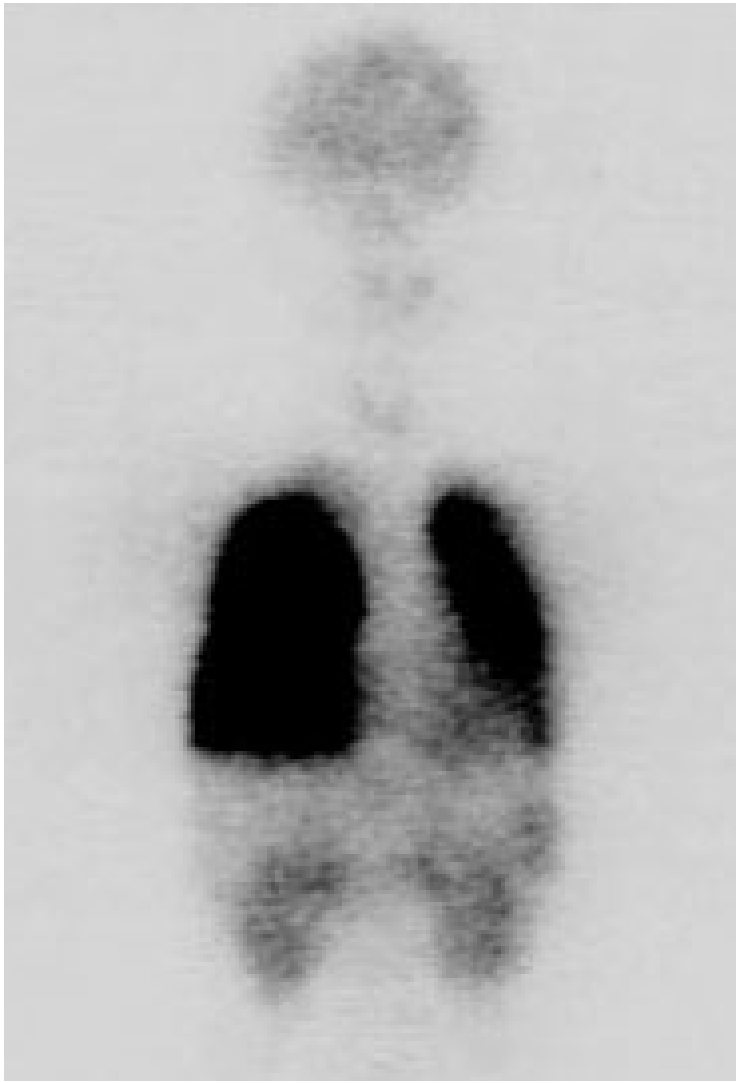
Right-to-left shunt

Presence of renal, spleen, brain activity



Ventilation scan

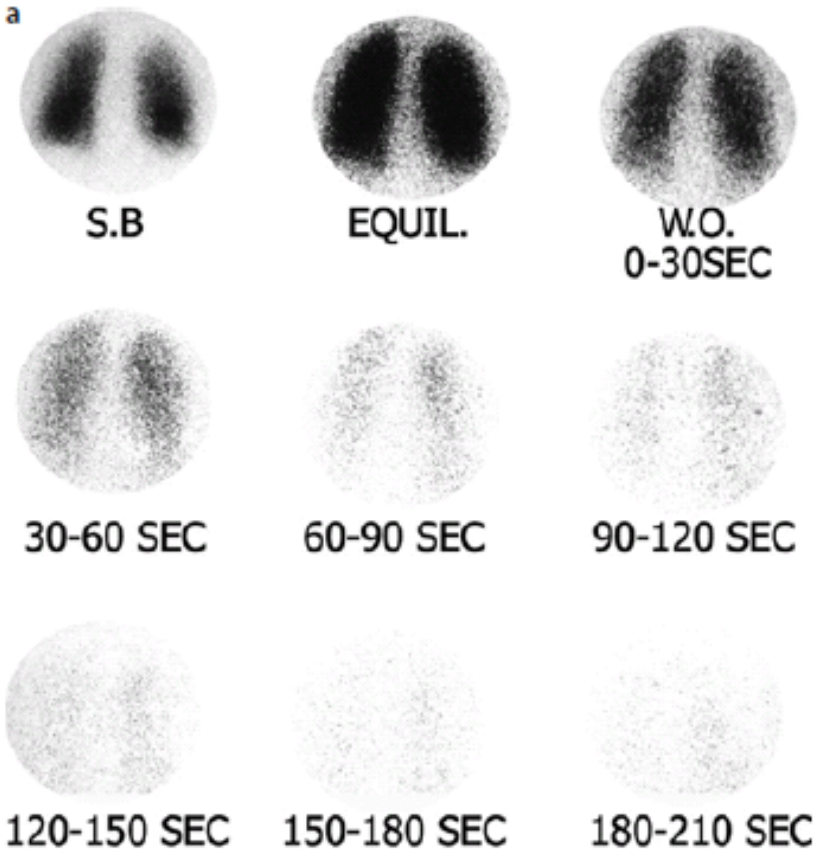
1. Xe-133
2. Kr-81
3. ^{99m}Tc-DTPA aerosol
4. Technegas
   - Heating ^{99m}Tc-pertechnetate to 2500℃ in the presence of 100% argon gas
   - Small particle: 0.05-0.15 μ m
   - Half-clearance time: 4-6 h
   - Only a few inspiration (typically 2-10) are needed to reach an adequate dose.
   - Not adequate in ill patients
5. Pertechnegas:
   - A vapor of pertechnetate, in the presence of 2-5% oxygen

Table 13.3. Ventilation agents The pathophysiologic basis of nuclear medicine

Agent	Advantages and limitations
Aerosols	
^{99m}Tc-DTPA aerosol	Lung half clearance time = 58 min Pre or post perfusion Multiple projections
^{99m}Tc-pyrophosphate aerosol	Post perfusion Suitable for SPECT
Technegas	Multiple projections Good peripheral deposition
Gases	
Xenon-133	Ability to obtain single breath, equilibrium and washout images Very sensitive for obstructive airway disease Only posterior view is possible in most patients Low energy of 81 keV Pre-perfusion acquisition
Krypton-81m	Expensive – available only in some areas Energy: 190 keV Half-life: 13 s Multiple views Pre or post perfusion

1. Xenon-133 ventilation: 81keV, T1/2: 5.2days, 5–20 mCi

Single breath → equilibrium → washout



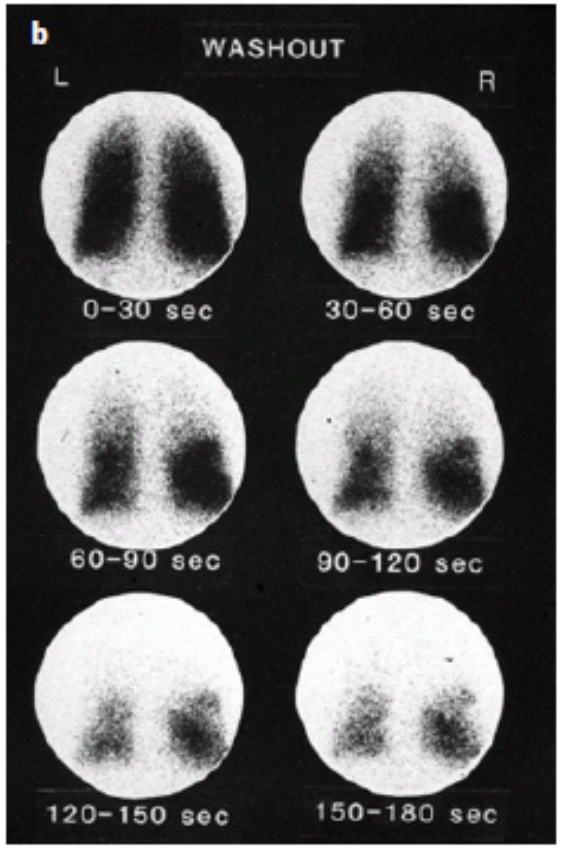


Fig. 13.8a,b. Xenon-133 ventilation studies. **a** Normal study with uniform distribution of the radiotracer in both lungs on single breath and equilibrium images. The washout images reveal prompt clearance with no significant retained activity. **b** Washout images of a patient with obstructive airway disease showing retained activity in lower zones of both lungs by the end of the study

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2. Kr-81 ventilation:

- 190keV
- T1/2: 13sec
- 1–10 mCi

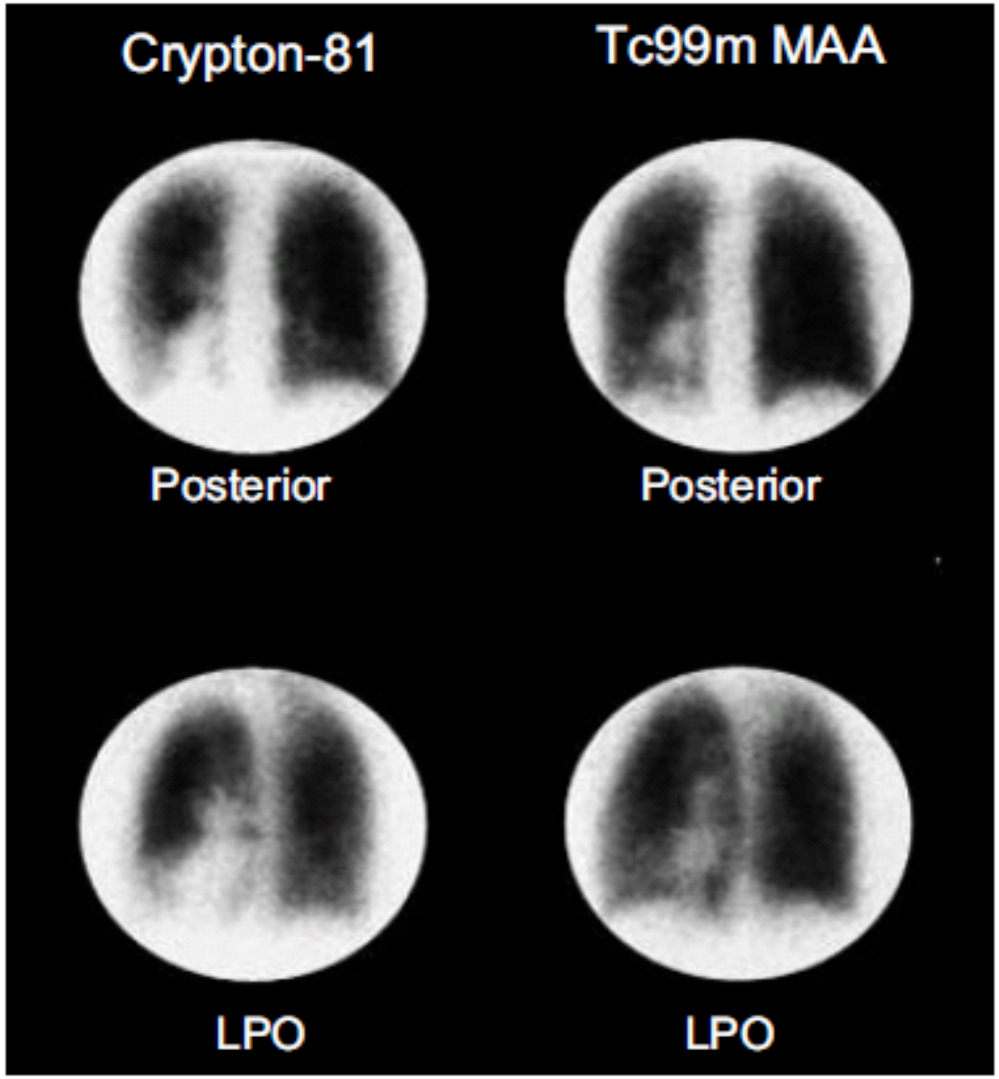

Fig. 13.9. Representative images of krypton-81 ventilation study obtained post perfusion. Note the good quality of images and two projections obtained to evaluate the ventilation status at the regions of the perfusion abnormalities seen on the same projections

3. ^{99m}Tc-DTPA ventilation:

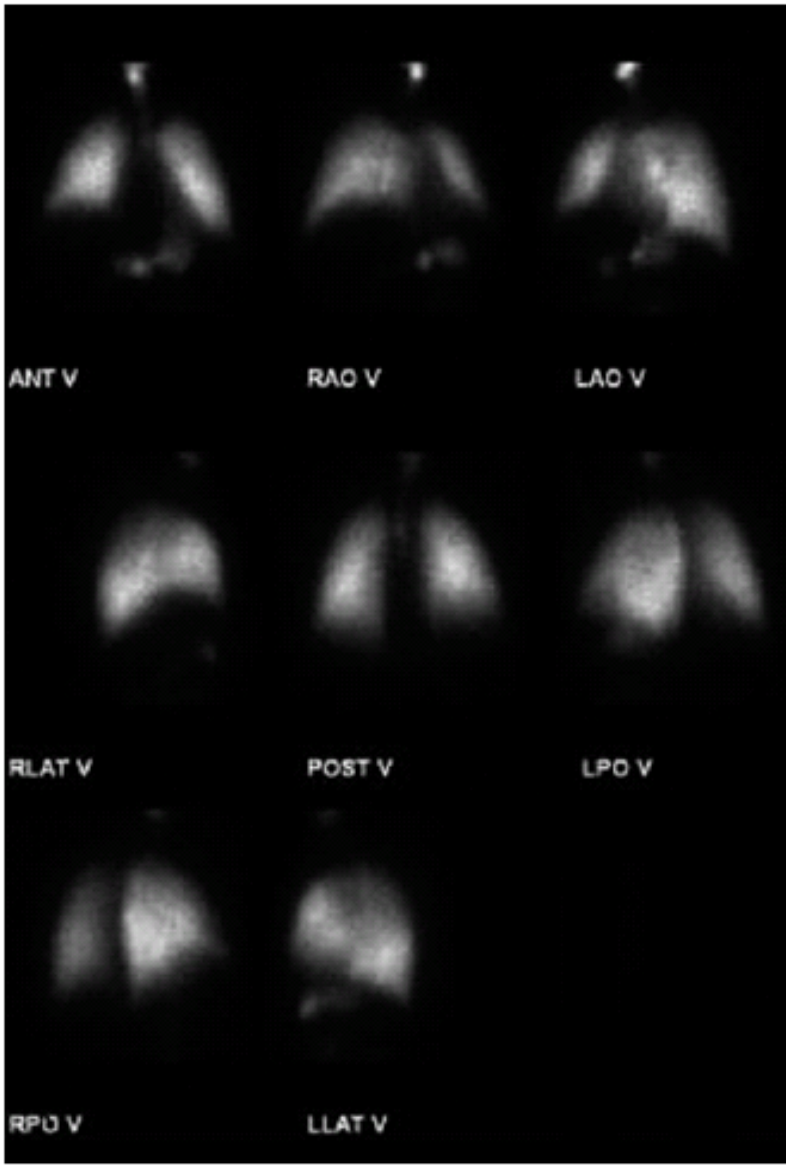

Fig. 13.10. ^{99m}Tc-DTPA aerosol ventilation study. Images show no abnormalities. Observe the activity in the esophagus and stomach due to swallowed activity

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4. ^{99m}Tc-technegas ventilation:

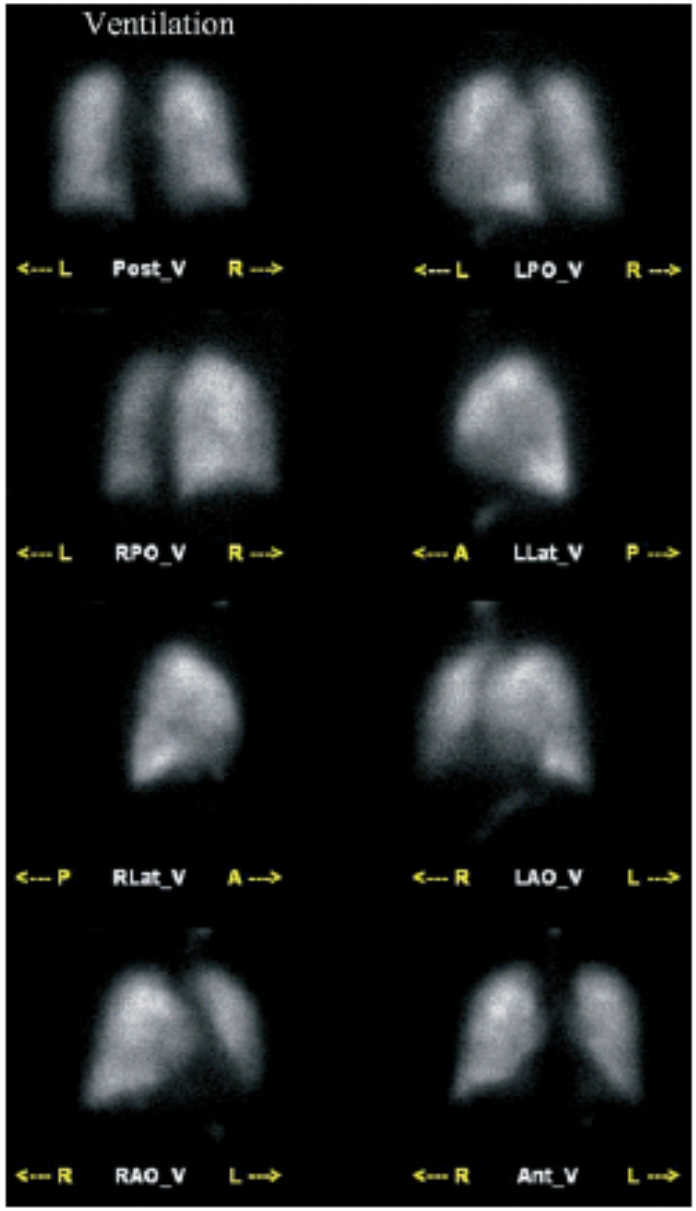


Fig. 13.11. ^{99m}Tc-Technegas ventilation study for a patient suspected of having pulmonary embolism. The study shows no abnormalities and illustrates the good quality of ventilation studies obtained using this agent. The perfusion on the other hand reveals perfusion defects in both lungs and no matching ventilation or X-ray abnormalities, indicating a high probability of pulmonary embolism

PIOPED II criteria for V/Q scan

Essentials of NM imaging p178

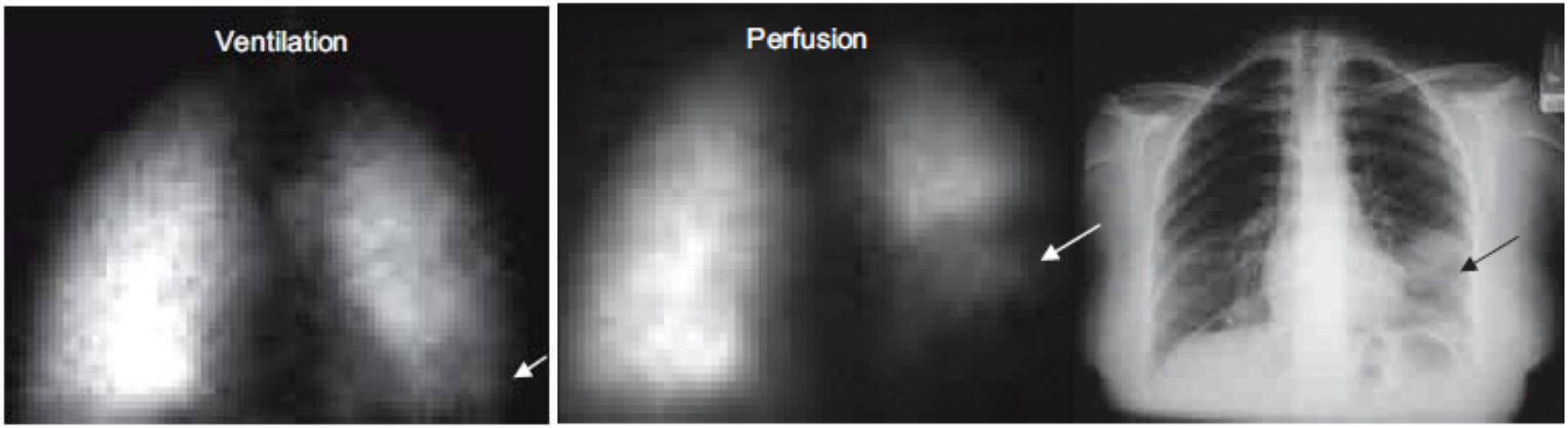
- High probability
  - ≧2 mismatched large segmental defects without a radiographic abnormality
- Intermediate probability
  - 1 moderate or ＜2 large segmented mismatched defects
  - Difficult to categorize as high or low
  - 1 moderate or large segmental size triple match in lower zone
- Low probability
  - 1 large or moderate matched defect
  - ＞3 small segmental lesions.
  - Absent perfusion in an entire lung
  - 1 lobar mismatch
  - Moderate sized pleural effusion (greater than CP angle, less than 1/3)
  - Heterogeneous perfusion

PIOPED II criteria for V/Q scan

Essentials of NM imaging p178

- Very low probability
  - Nonsegmental lesion with no other perfusion defect in either lung
  - Perfusion defect smaller than radiographic lesion
  - ≧2 matched defects
  - 1 triple matched defect in the mid or upper lung zone (a single segment)
  - Stripe sign around the perfusion defect
  - Pleural effusion ≧1/3 of pleural cavity
- Normal

3 matched defects (CxR, perfusion, ventilation)



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✓3 Matched defects in

Upper/intermediate lung zones→ low probability

Lower lung zone → intermediate probability

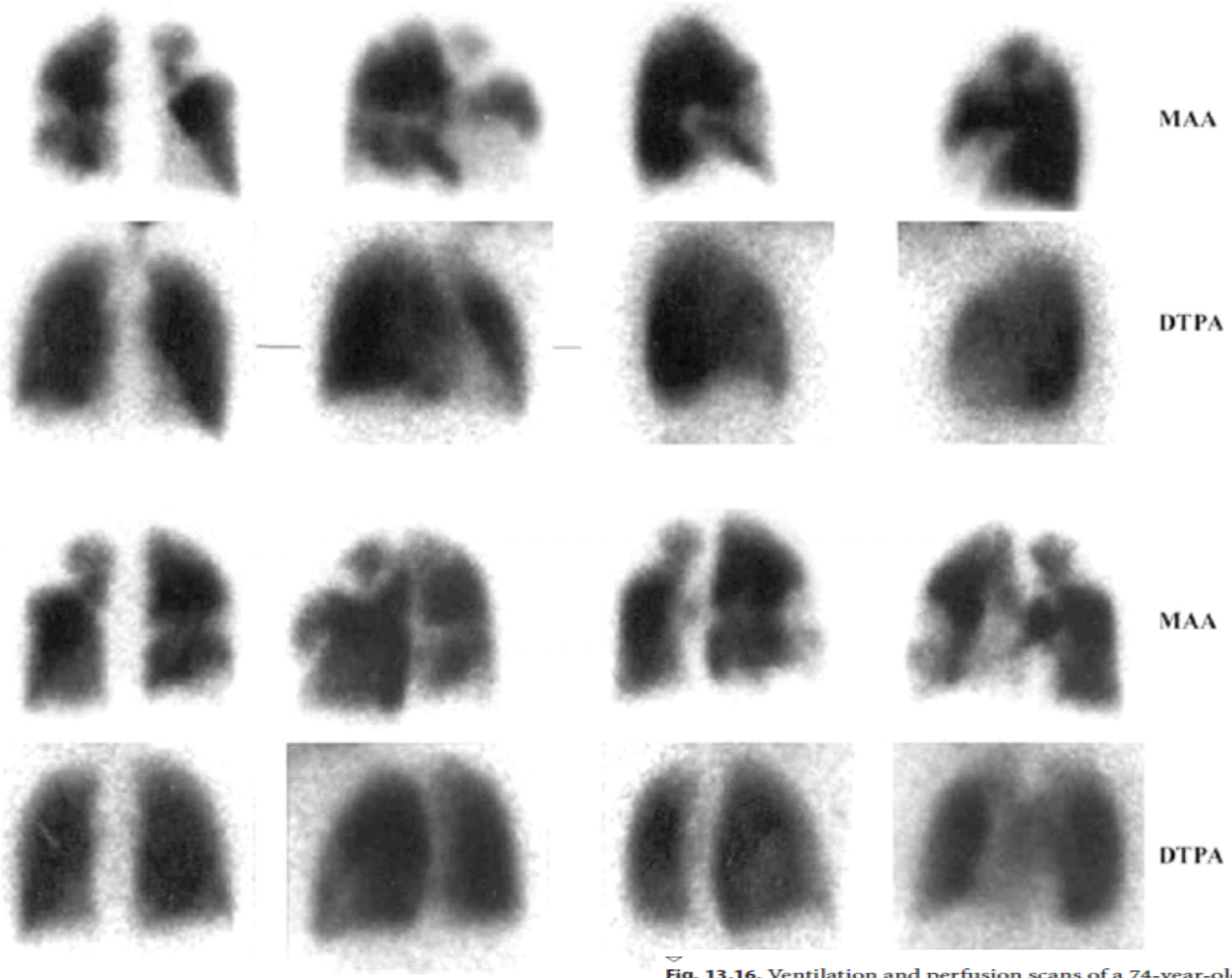
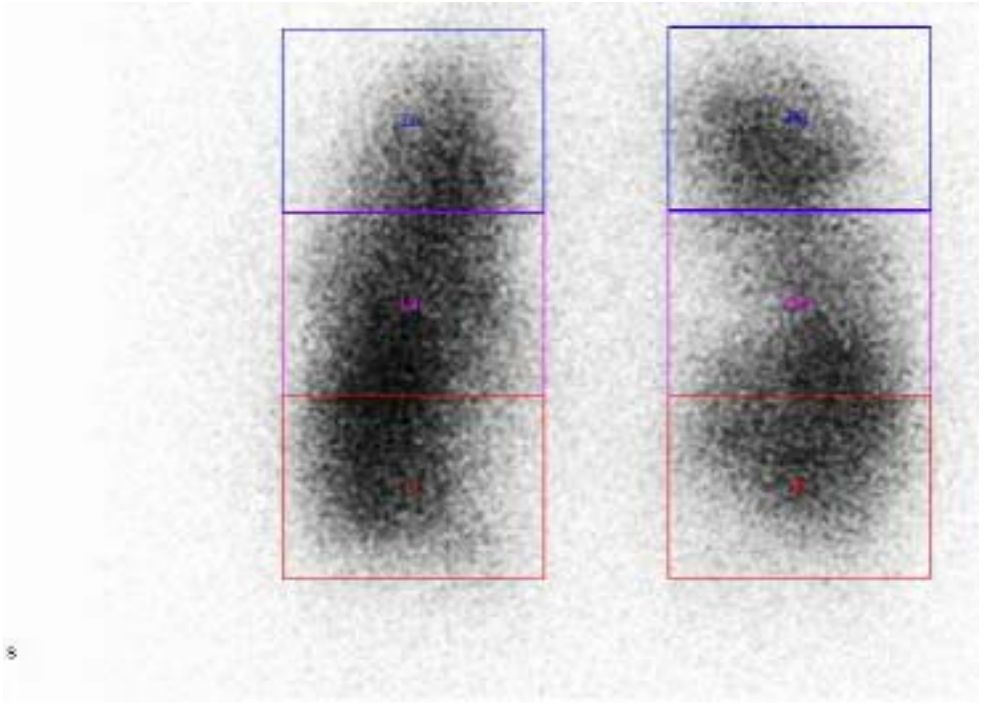


Fig. 13.16. Ventilation and perfusion scans of a 74-year-old man with a history of fracture of left femur treated with internal fixation 3 days earlier. The patient was referred to rule out pulmonary emboli because of acute onset of shortening of breath. Perfusion study shows multiple perfusion defects equivalent to more than two segments with no matching abnormalities on ventilation study and no corresponding changes in the chest X-ray, which was normal. This illustrates a typical pattern of high probability of pulmonary emboli on ventilation/perfusions scans

Lung cancer

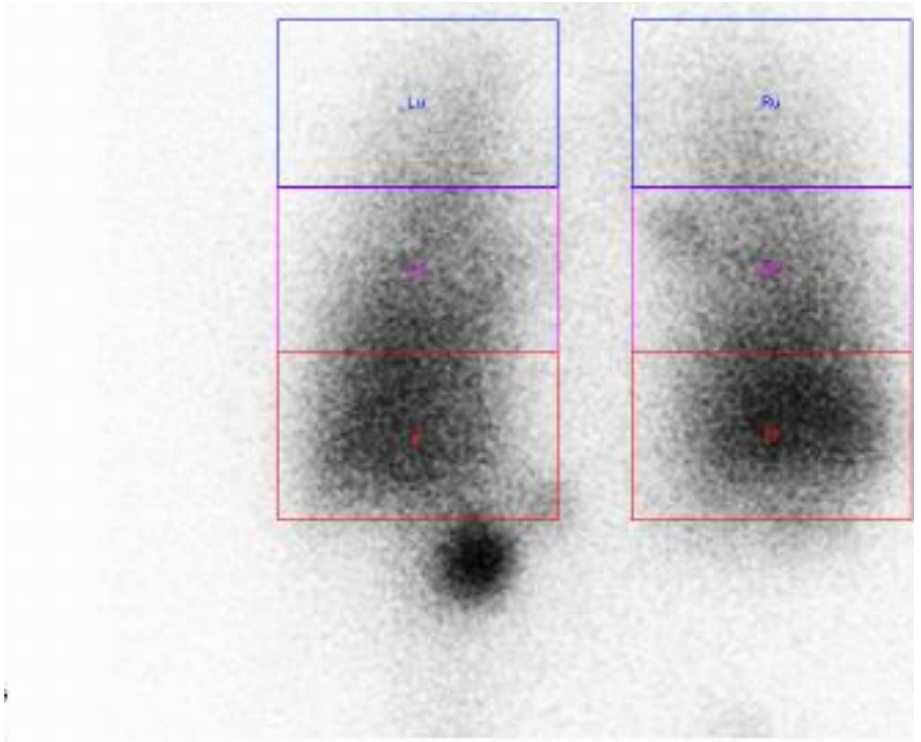
- Cell types:
  - Squamous
  - Adenocarcinoma
  - Small cell carcinoma
  - Adenosquamous carcinoma
  - Anaplastic carcinoma
- Tumor uptake: ^{18}F-FDG, ^{67}Ga, ^{201}Tl, ^{99m}Tc-MIBI
- When pneumonectomy is planned for lung cancer, postoperative lung function can be predicted with optimal accuracy by a preoperative perfusion scan in upright or supine positions.
- The ventilation scan is less accurate.

Perfusion



	Left Lung		Right Lung	
	%	Kct	%	Kct
Upper Zone:	12.4	32.90	12.5	33.11
Middle Zone:	23.7	62.92	16.7	44.28
Lower Zone:	18.3	48.76	16.5	43.81
Total Lung:	54.4	144.59	45.6	121.20

Ventilation



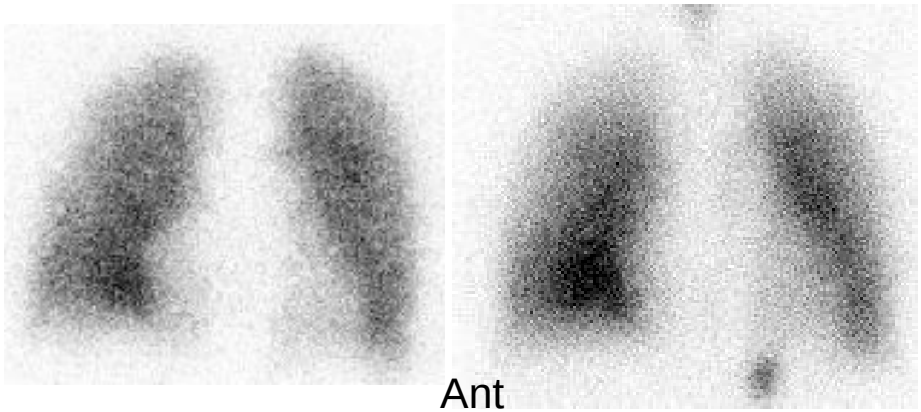
	Left Lung		Right Lung	
	%	Kct	%	Kct
Upper Zone:	7.0	26.61	7.2	27.50
Middle Zone:	17.7	67.03	18.2	69.21
Lower Zone:	24.5	92.98	25.4	96.25
Total Lung:	49.2	186.62	50.8	192.96

In our institute

- Venography:
  - ^{99m}Tc-MAA 1 mCi X 2 , iv from bilateral feet
  - Dynamic imaging
- Perfusion:
  - ^{99m}Tc-MAA 1 or 2 mCi, iv in supine position
  - Ant, Post, RPO, LPO, R lat, L lat
  - SPECT/CT
- Ventilation:
  - ^{99m}Tc-DTPA aerosol 40 mCi
  - Ant, Post, RPO, LPO, R lat, L lat

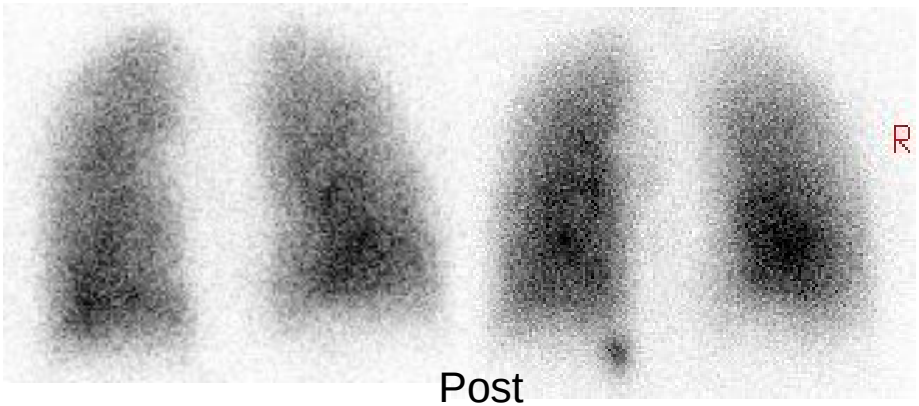
Case 1

38 y/o woman
SLE with pulmonary HTN
20081020 V/Q scan



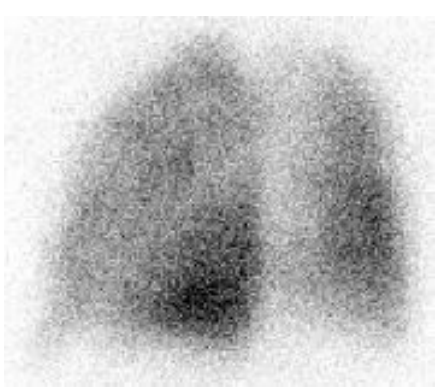
Ant

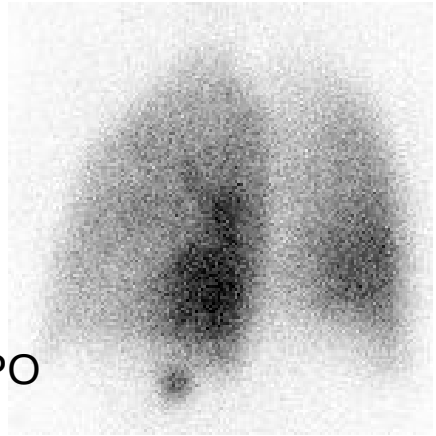
MAA DTPA



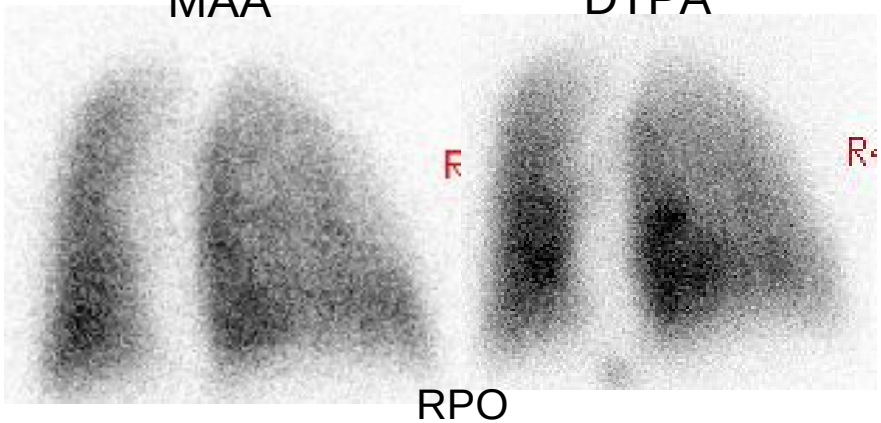
Post

MAA DTPA





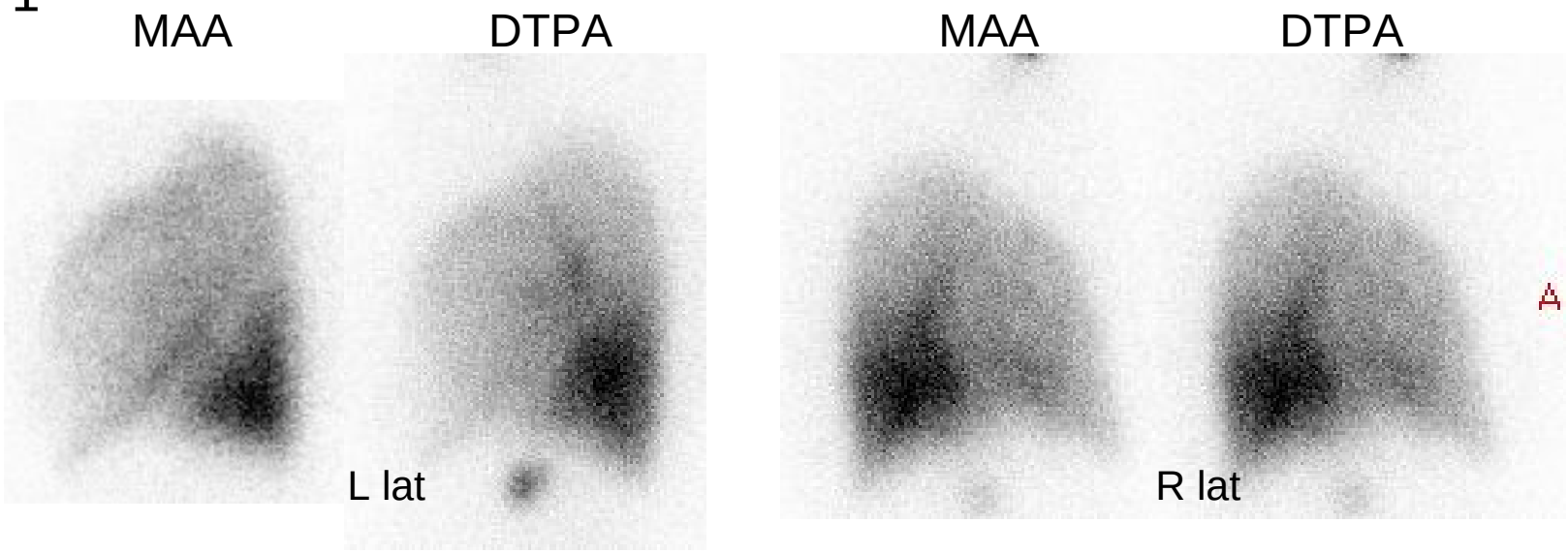
LPO



RPO

VGHKS

Case 1

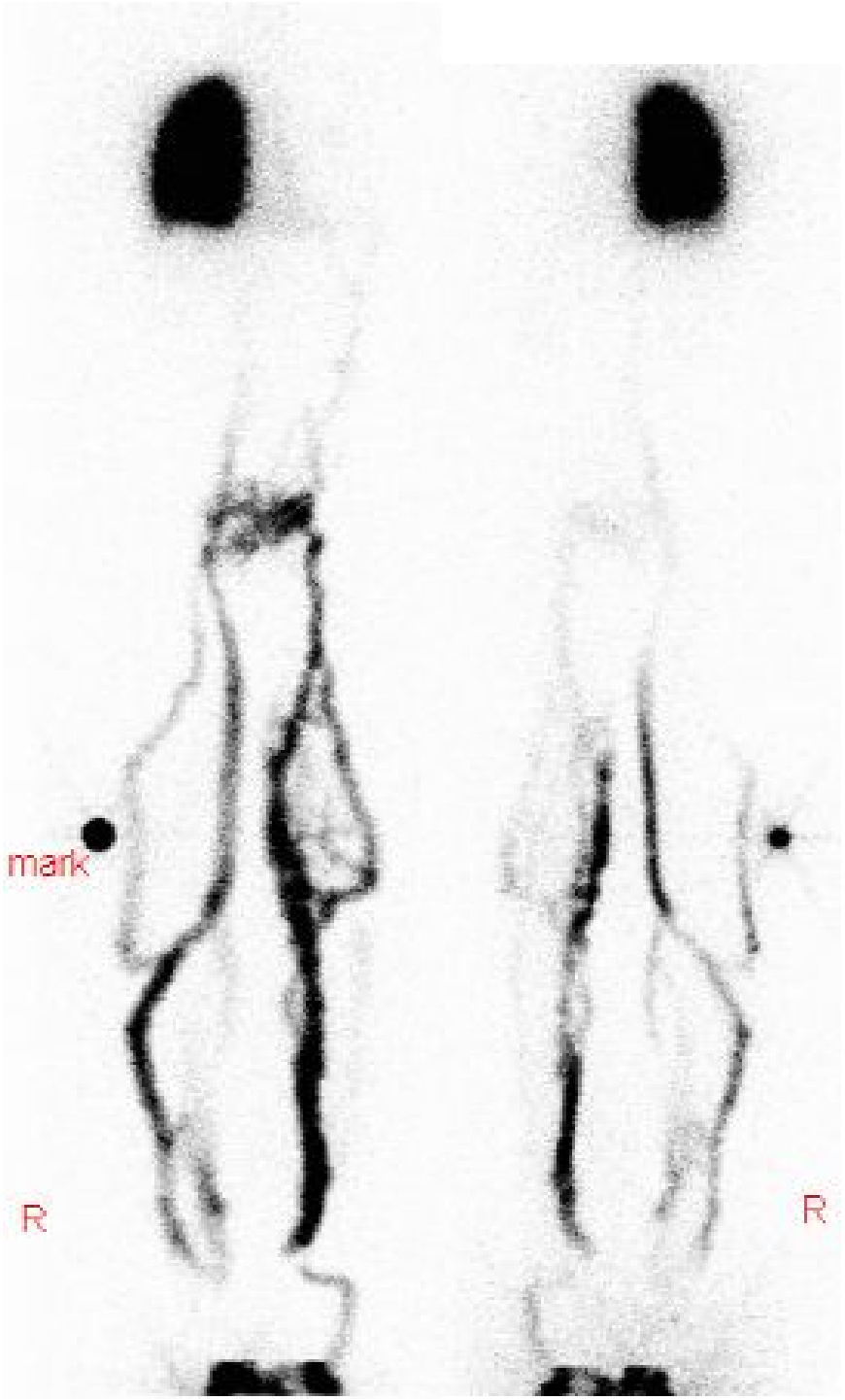


V/Q: normal distribution of radiotracer in both lungs.

→ No scintigraphic evidence of pulmonary embolism is demonstrable.

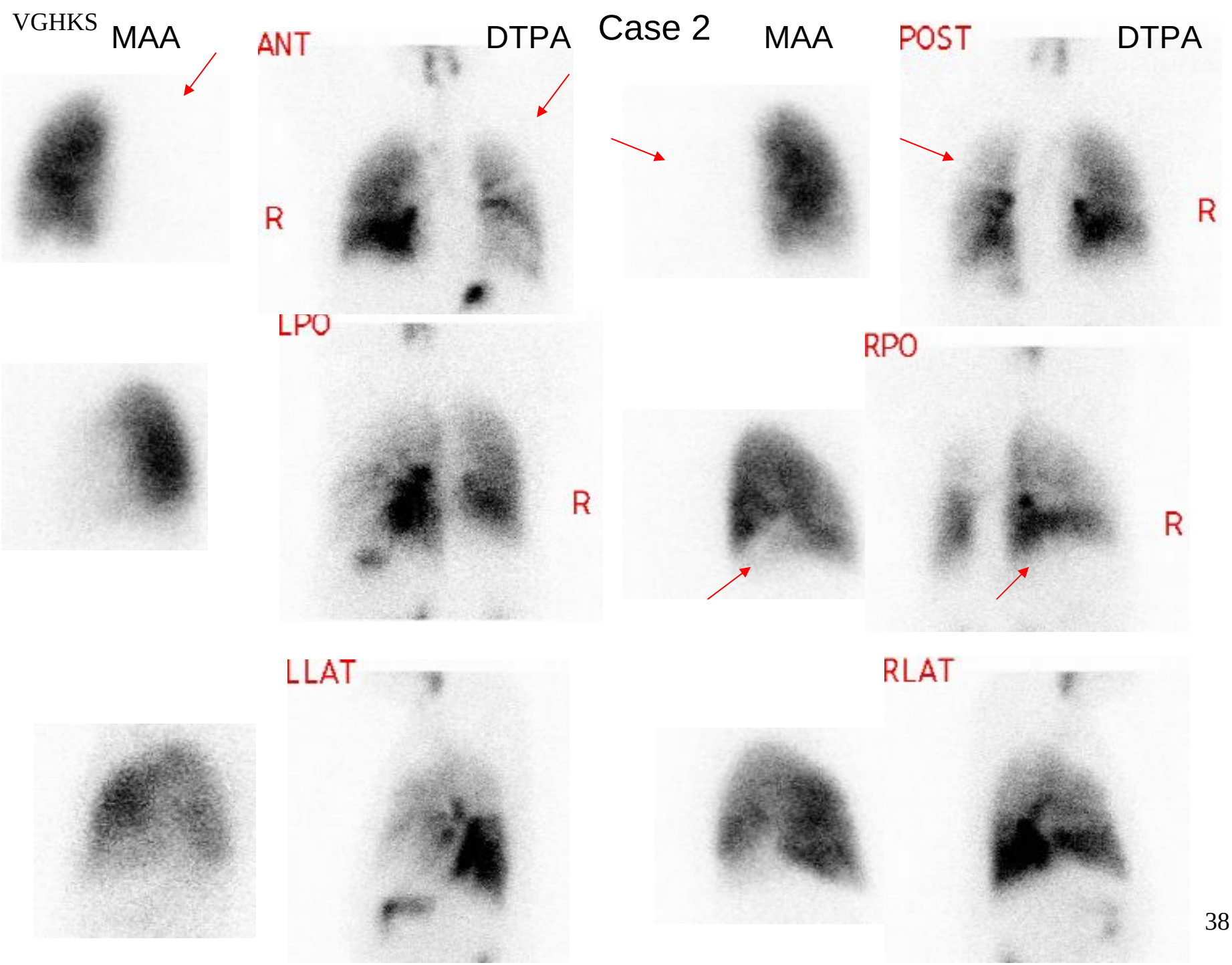
Case 2

54 y/o male
DVT with PE
20081128 V/Q scan
20081222 venography and V/Q scan

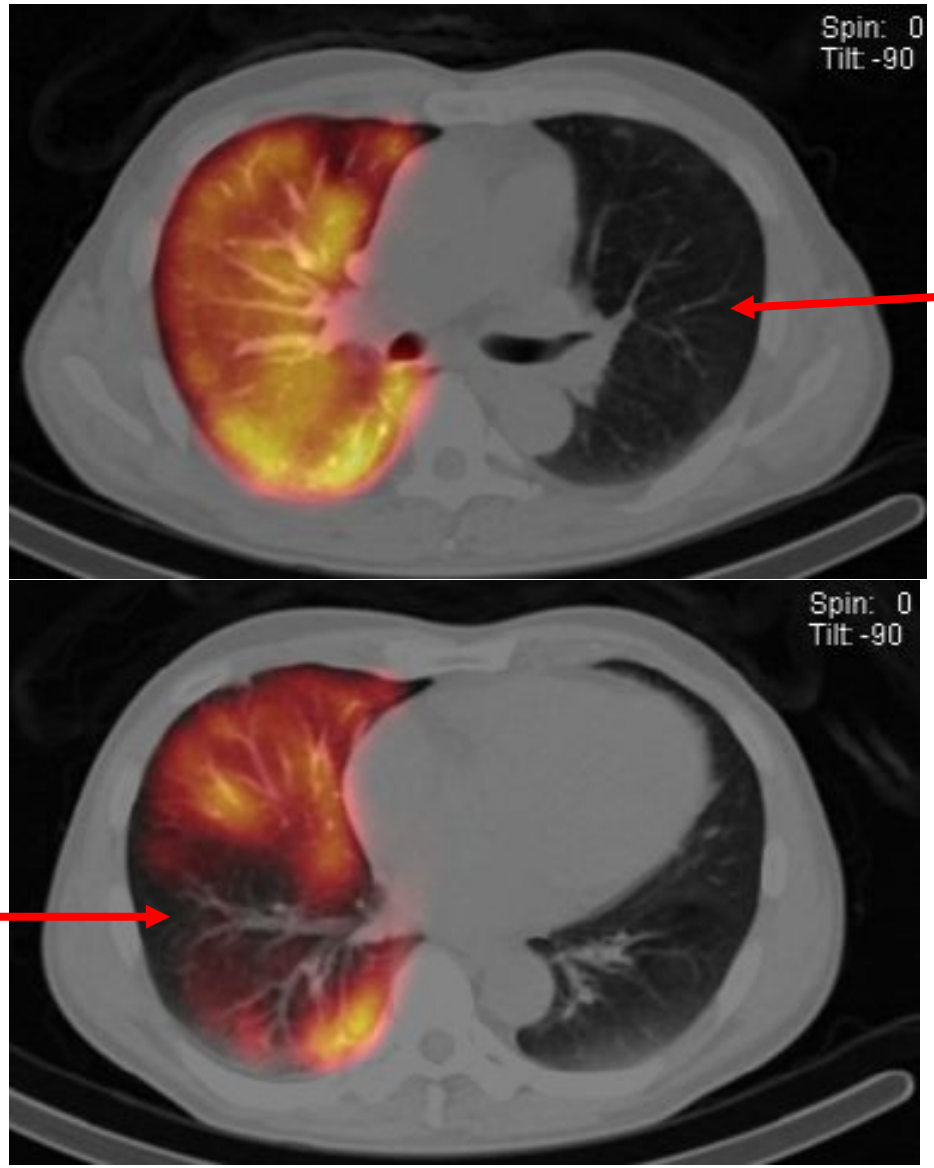


VGHKS

Case 2



Case 2



Imp:

1. Deep venous thrombosis in left common iliac vein and bilateral lower extremities
2. High probability of pulmonary embolism

The end