

Contraindications

- pulmonary hypertension. Dose (number of particles) must be adjusted down if study is to be done.
- Studies on patients with known active pneumonia or other known debilitating lung disease will yield a nondeterminable result for PE.
- Right to left shunts (unless it is the reason for the scan). Particles are shunted into the systemic circulation.
- Hypersensitivity to human serum albumin.

- o Acquire static images for 500,000–1 million counts each (750K)
- Images (typically): anterior, RAO, RPO, posterior, LPO, and LAO.

Lung Ventilation

(Usually Performed with Lung Perfusion)

Radiopharmaceutical

- ^{99m}Tc -Technegas
- Others - ^{99m}Tc -DTPA (diethylenetriaminepentaacetic acid); ^{133}Xe : gas

Localization

- Compartmental by inhalation into lung space

Adult Dose Range

- ^{99m}Tc -Technegas: about 15mCi
- ^{99m}Tc -DTPA: 25–40 mCi (925–1480 MBq)

Method of Administration

- Inhalation through mask or mouth apparatus, PO

Preparation (Technegas)

- Inject dose into crucible
- Machine started to create ultrafine Tc gas
- Once ready, instruct patient to breathe in gas – about 10 minutes

^{99m}Tc -DTPA – aerosolized using nebuliser

Contraindications

- known active pneumonia or other known debilitating lung disease will yield a nondeterminable result for PE.

Acquisition

- static images (350K counts) usually same views as perfusion

V/Q SPECT

- Radiopharmaceutical doses as stated for Perfusion and Ventilation
- 128 x 128 matrix
- 360 degrees acquisition, 3 degree steps
- 8 sec/step for Perfusion; 12 sec/step for Ventilation
- Iterative Reconstruction recommended

- Advantages
 - more sensitive, more specific
 - Less inconclusive studies
 - Easier to interpret (once learnt)

Interpretation

- Normal Perfusion → NO PE
- Perfusion Defect → possible PE
 - High, Low or Intermediate/Indeterminate probability
 - Measures to improve specificity
 - Pattern of perfusion defect
 - Ventilation pattern – Ventilation Study
 - CXR
 - Confirmatory/supporting tests; Pretest Probability

Mismatched	Matched	
<ul style="list-style-type: none"> ○ Pulmonary embolism (thrombotic, septic, marrow, or air), acute or old ○ Pleural effusion ○ Tumor (hilar or mediastinal) ○ Pulmonary artery atresia or hypoplasia ○ Fibrosing mediastinitis ○ Fat emboli ○ Radiation therapy ○ Vasculitis 	<ul style="list-style-type: none"> ○ Bulla or cyst ○ Localized hypoxia due to asthma, bronchitis, emphysema, COPD ○ Surgery (e.g., pneumonectomy) ○ Metastasis (hematogenous or lymphangitic) ○ Mucus plug ○ Hilar adenopathy (lymphoma, sarcoidosis) ○ Pneumonia ○ Pulmonary edema ○ Atelectasis ○ Fibrosis (postinflammatory, postradiation, pleural thickening) 	<p>Decreased perfusion to one lung:</p> <ul style="list-style-type: none"> ○ Pulmonary agenesis or stenosis ○ Swyer-James syndrome ○ Embolus ○ Pneumothorax ○ Massive effusion ○ Mediastinal fibrosis ○ Tumor ○ Aortic dissection

TABLE 1: Sets of Criteria Used to Assess Radionuclide Scans for the Probability of Pulmonary Embolism on Angiograms

Category	McNeil [8]	Biello [9]	PIOPED [10]
Normal	1. Normal perfusion	1. Normal perfusion	1. Normal perfusion
Very low probability	–	–	2. One to three small ^a perfusion defects; normal chest radiograph; ventilation irrelevant
Low probability	2. Single ventilation/perfusion mismatch, segmental or subsegmental; chest radiograph clear	2. Small ^a ventilation/perfusion mismatch(es)	3. Nonsegmental perfusion defects ^b
	3. Ventilation/perfusion match(es) alone	3. Ventilation/perfusion matches without corresponding changes on chest radiograph	4. Single moderate ^c perfusion defect; chest radiograph normal; ventilation irrelevant
	4. Multiple ventilation/perfusion mismatches, subsegmental; chest radiograph clear	4. Perfusion defect substantially smaller than chest film density	5. Any perfusion defect substantially smaller than chest film defect; ventilation irrelevant
			6. Ventilation/perfusion match $\leq 50\%$ of lung including $\leq 75\%$ of one lung zone ^d with normal or almost normal chest radiograph
			7. More than three small ^a perfusion defects; chest film and ventilation irrelevant
			8. Three or fewer small perfusion/chest film matches; ventilation irrelevant
Indeterminate or intermediate	5. Mixed ventilation/perfusion match and mismatch	5. Severe diffuse obstructive pulmonary disease with perfusion defects	9. Abnormality that is not defined clearly by other criteria
	6. Perfusion defect with matched density on chest radiograph	6. Perfusion defect same size as change on chest film	
		7. Single medium ^e ventilation/perfusion mismatch	
High probability	7. Single ventilation/perfusion mismatch, lobe or larger, with normal chest film	8. Single large ^e ventilation/perfusion mismatch	10. Two or more large ^f perfusion defects; ventilation and chest film normal
	8. Multiple ventilation/perfusion mismatches, segmental or larger; chest film normal	9. Perfusion defect substantially larger than density on chest film	11. Two or more large ^f perfusion defects in which perfusion defect is substantially larger than either matching ventilation or chest film defect
		10. Multiple medium or large ^e ventilation/perfusion mismatches without matched density on chest film	12. Two or more moderate ^c perfusion defects and one large ^f perfusion defect; ventilation and chest film normal
			13. Four or more moderate ^c perfusion defects; ventilation and chest film normal

Problem with V/Q study

- In the PIOPED study, only 40% of patients with PE had a high probability V/Q scan result, whereas another 40% of patients with PE had an indeterminate result and 14% had a low probability result
- Large proportion of inconclusive studies (Intermediate and low probability)
- PIOPED criteria best predicted the presence of PE, but were inferior for the exclusion of PE*

Modified PIOPED

- Normal (PE excluded)
- Very low probability (0–10%):
- Low probability (10–19%):
- Intermediate probability (20–79%):
- High probability (80% or better):

Normal:

- No perfusion defects, ventilation and chest x-ray normal or abnormal (scoliosis, pneumonectomy). Perfusion image outlines the shape of the lungs.

Criteria for a Very Low Probability of PE (<10% PPV)*

1. Nonsegmental perfusion abnormalities. These are enlargement of the heart or hilum, elevated hemidiaphragm, linear atelectasis, or costophrenic angle effusion with no other perfusion defects in either lung.
2. Perfusion defect smaller than corresponding radiographic lesion
3. >2 matched V/Q defects with regionally normal chest radiograph and some areas of normal perfusion elsewhere in the lungs
4. 1 to 3 small segmental perfusion defects (<25% of a segment)
5. Solitary triple matched defect (defined as a matched V/Q defect with associated matching chest radiographic opacity) in the middle or upper lung zone confined to a single segment.
6. Stripe sign, which consists of a stripe of perfused lung tissue between a perfusion defect and the adjacent pleural surface (best seen on a tangential view).
7. Pleural effusion equal to one third or more of the pleural cavity with no other perfusion defect in either lung.

*From Gottschalk et al. JNM 2007

Low probability (10–19%):

- One moderate or large matched defect,
- greater than three small perfusion defects with negative chest x-ray,
- one lung not perfusing,
- single lobar mismatch,
- moderate pleural effusion (more than costophrenic angle but less than one third of pleural cavity) and no other perfusion defects in lungs,
- heterogeneous perfusion.

Intermediate probability (20–79%):

- One moderate to less than two large mismatched perfusion defects or equivalent in moderate or large and moderate defects.*
- one matched ventilation/perfusion defect with a negative chest x-ray (may be classified as low probability)
- any that are difficult to place in low or high probability.

*A large segmental defect or >75% of a segment equals one segmental equivalent, a moderate defect or 25–75% of a segment, equals 0.5 segmental equivalents, and a small defect or <25% of a segment is not counted),

High probability (80% or better):

- Two or more large mismatched segmental perfusion defects or equivalent in moderate or large and moderate defects with negative chest x-ray.

Diagnosis of PE

- Diagnostic strategies should include pretest clinical probability, D-dimer assays, and imaging tests (chest radiography, echocardiography, ultrasonography of the leg veins)

Diagnosis of PE

- Clinical probability assessment has become a mandatory step in the investigation of patients with clinically suspected PE
- High (likely) → definitive imaging Ix
- Low or intermediate (unlikely) → D-dimer → PE excluded or definitive imaging Ix

Table 6.—Pulmonary Embolism (PE) Status*

Scan Category	Clinical Science Probability, %							
	80-100		20-79		0-19		All Probabilities	
	PE + /No. of Patients	%	PE + /No. of Patients	%	PE + /No. of Patients	%	PE + /No. of Patients	%
High probability	28/29	96	70/80	88	5/9	56	103/118	87
Intermediate probability	27/41	66	66/236	28	11/68	16	104/345	30
Low probability	6/15	40	30/191	16	4/90	4	40/296	14
Near normal/normal	0/5	0	4/62	6	1/61	2	5/128	4
Total	61/90	68	170/569	30	21/228	9	252/887	28

*PE + indicates angiogram reading that shows pulmonary embolism or determination of pulmonary embolism by the outcome classification committee on review. Pulmonary embolism status is based on angiogram interpretation for 713 patients, on angiogram interpretation and outcome classification committee reassignment for 4 patients, and on clinical information alone (without definitive angiography) for 170 patients.

Table 1 Wells Criteria for Objective Clinical Assessment of PE*

Clinical Features	Score (Points)
Clinical signs and symptoms of DVT (objectively measured leg swelling and pain with palpation in deep vein system)	3.0
Heart rate >100 beats/min	1.5
Immobilization >3 consecutive days (bed rest except to access bathroom) or surgery in previous 4 weeks	1.5
Previously objectively diagnosed PE or DVT	1.5
Hemoptysis	1.0
Malignancy (cancer patients receiving treatment within 6 month or receiving palliative treatment)	1.0
PE as likely or more likely than alternative diagnosis (based on history, physical exam, chest radiograph, EKG, and blood tests)	3.0

Score: ≤ 4 = low probability, ≥ 4.5 = high probability.

*Based on Wells et al²⁴ and modification.²⁵

- Canada study
 - Anderson et al: Computed tomographic pulmonary angiography vs. ventilation-perfusion lung scanning in patients with suspected pulmonary embolism. A randomized controlled trial. JAMA 298:2743-2753, 2007
- Montefiore Study
 - Freeman LM: Don' t bury the V/Q scan: It' s as good as multidetector CT angiograms with a lot less radiation exposure. J NuclMed 49:5-8, 2008

- primary outcome was the development of either DVT or PE in the ensuing 3 months in patients in whom PE had been excluded by either the V/Q or CTA study
- Positive for PE or DVT
 - 101 (14.2%) in V/Q group
 - 133 (19.2%) in CTA group
- subsequently developed either PE or DVT
 - 6 of 661 (1%) of the initially negative V/Q group
 - 2 of 561 (0.4%) of the initially negative CTA group
 - **statistically insignificant difference**

Continuing role of Lung V/Q

- Clinical probability
- CXR → Normal or near normal → Lung V/Q
- CXR → infiltrates, atelectasis, & pleural effusions → CTPA
- Increased no of Lung V/Q studies
- Similar performance,
 - positive V/Q studies was quite low (3.5%) as compared with CTAs (13%)
 - False negative rates on 3-month follow-up were an identical 1.1% for both procedures
- reduced radiation exposure to patients

Diagnosis*

- Clinical presentation
 - clinical signs, symptoms and routine laboratory tests do not allow the exclusion or confirmation of acute PE but increase the index of its suspicion
- Assessment of clinical probability
 - clinical evaluation makes it possible to classify patients into probability categories corresponding to an increasing prevalence of PE, whether assessed by implicit clinical judgement or by a validated prediction rule

- D-Dimer

- a negative D-dimer result in a highly sensitive assay safely excludes PE in patients with a low or moderate clinical probability,
- a moderately sensitive assay excludes PE only in patients with a low clinical probability.
- When using a recently introduced two-level clinical probability assessment scheme,
 - a negative D-dimer result excludes PE safely in PE-unlikely patients either by a highly sensitive or moderately sensitive assay

- Compression ultrasonography and computed tomographic venography
 - searching for a proximal DVT in patients with PE by CUS yields a positive result in around 20% of patients. CUS can be used either as a backup procedure to reduce the overall false-negative rate when using single-detector CT (see Diagnostic strategies) or it can be performed to avoid CT when positive in patients with contraindications to contrast dye and/or irradiation. Combining CT venography with CT angiography adds a significant amount of radiation and is not useful when using MDCT.

- Ventilation–perfusion scintigraphy
 - a normal perfusion scan is very safe for excluding PE.
 - Although less well validated, the combination of a non-diagnostic V/Q scan in a patient with a low clinical probability of PE is an acceptable criterion for excluding PE.
 - A high-probability ventilation–perfusion scan establishes the diagnosis of PE with a high degree of probability,
 - but further tests may be considered in selected patients with a low clinical probability due to the lower PPV of a high-probability V/Q scan result in such patients.
 - In all other combinations of V/Q scan result and clinical probability, further tests should be performed

- Computed tomography
 - a SDCT or MDCT showing a thrombus up to the segmental level can be taken as adequate evidence of PE in most instances,
 - the necessity to treat isolated subsegmental thrombi in a patient without a DVT is unclear.
 - In patients with a non-high clinical probability, a negative SDCT must be combined with negative CUS to safely exclude PE, whereas MDCT may be used as a stand-alone test.
 - Whether further testing is mandatory in the rare patients who have a negative MDCT despite a high clinical probability is not settled

- Pulmonary angiography
 - pulmonary angiography is a reliable but invasive test and is currently useful when the results of non-invasive imaging are equivocal. Whenever angiography is performed, direct haemodynamic measurements should be performed

- Echocardiography

- in a patient with suspected PE who is in a critical condition, bedside echocardiography is particularly helpful in emergency management decisions. In a patient with shock or hypotension, the absence of echocardiographic signs of RV overload or dysfunction practically excludes PE as a cause of haemodynamic compromise. The main role of echocardiography in non-high-risk PE is further prognostic stratification to the intermediate or low-risk category

Table 10 Validated diagnostic criteria for diagnosing PE in patients without shock and hypotension (non-high-risk PE) according to clinical probability

Diagnostic criterion	Clinical probability of PE		
	Low	Intermediate	High
Exclusion of pulmonary embolism			
Normal pulmonary angiogram	+	+	+
D-dimer			
Negative result, highly sensitive assay	+	+	–
Negative result, moderately sensitive assay	+	–	–
V/Q scan			
Normal lung scan	+	+	+
Non-diagnostic lung scan ^a	+	–	–
Non-diagnostic lung scan ^a and negative proximal CUS	+	+	±
Chest CT angiography			
Normal SDCT and negative proximal CUS	+	+	±
Normal multidetector CT alone	+	+	±

Table 10 Validated diagnostic criteria for diagnosing PE in patients without shock and hypotension (non-high-risk PE) according to clinical probability

Diagnostic criterion	Clinical probability of PE		
	Low	Intermediate	High
Confirmation of pulmonary embolism			
Pulmonary angiogram showing PE	+	+	+
High-probability V/Q scan	±	+	+
CUS showing a proximal DVT	+	+	+
Chest CT angiography			
Single or multidetector helical CT scan showing PE (at least segmental)	±	+	+
Single or multidetector helical CT scan showing subsegmental PE	±	±	±

Valid criterion (no further testing required), +, green; invalid criterion (further testing necessary), –, red; controversial criterion (further testing to be considered), ±, yellow.

^aNon-diagnostic lung scan: low or intermediate probability lung scan according to the PIOPED classification.

CUS = compression venous ultrasonography; DVT = deep venous thrombosis; PE = pulmonary embolism;

V/Q scan = ventilation–perfusion scintigraphy.

Suspected high-risk PE
i.e. with shock or hypotension

CT immediately available*

no

yes

Echocardiography

RV overload

no

yes

CT available and
patient stabilized

CT

positive

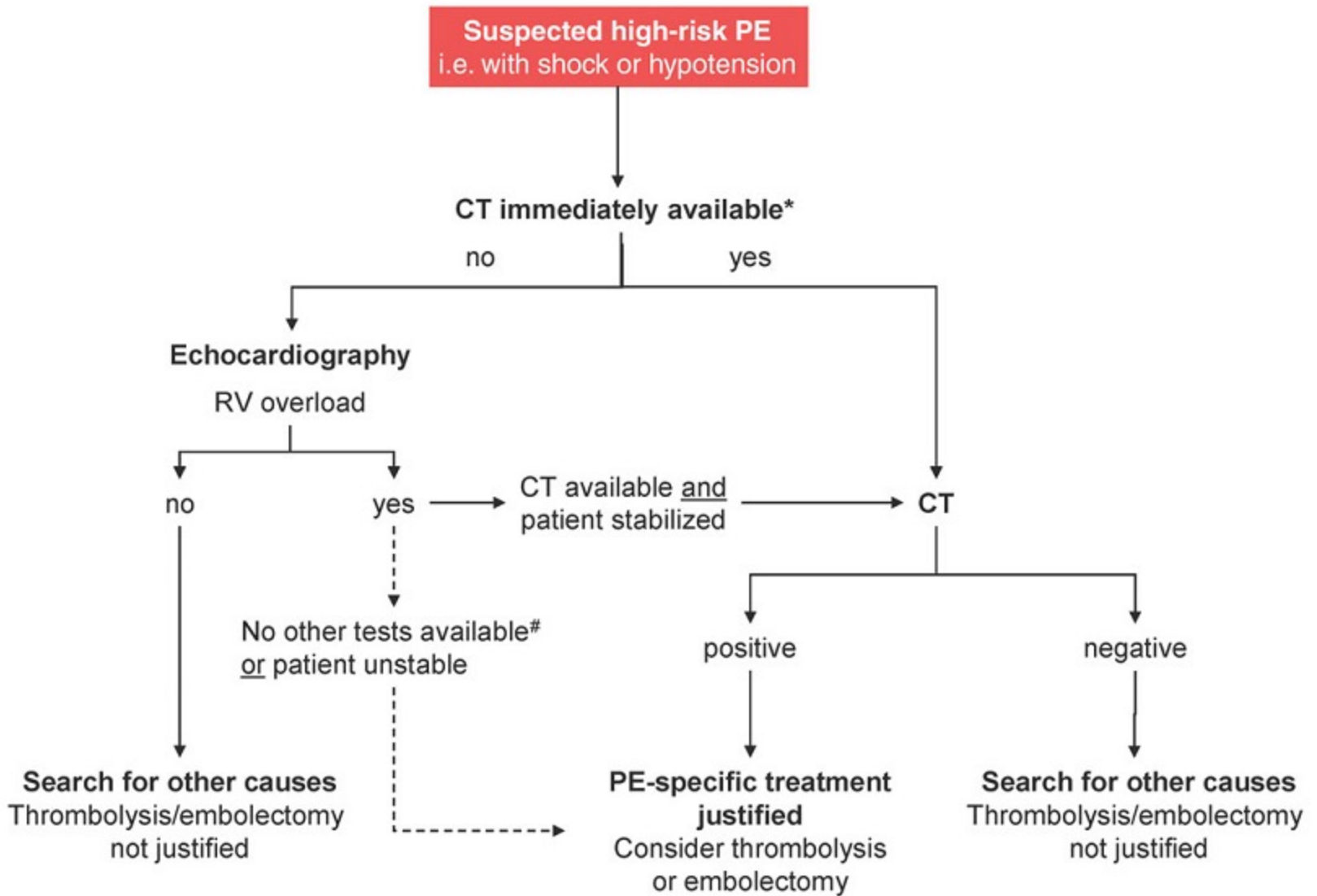
negative

Search for other causes
Thrombolysis/embolectomy
not justified

No other tests available[#]
or patient unstable

**PE-specific treatment
justified**
Consider thrombolysis
or embolectomy

Search for other causes
Thrombolysis/embolectomy
not justified



Suspected non-high-risk PE
i.e. without shock or hypotension

Assess clinical probability of PE
Implicit or prediction rule

Low/intermediate clinical probability
or "PE unlikely"

High clinical probability
or "PE likely"

D-dimer

negative
No treatment*

positive
Multidetector CT

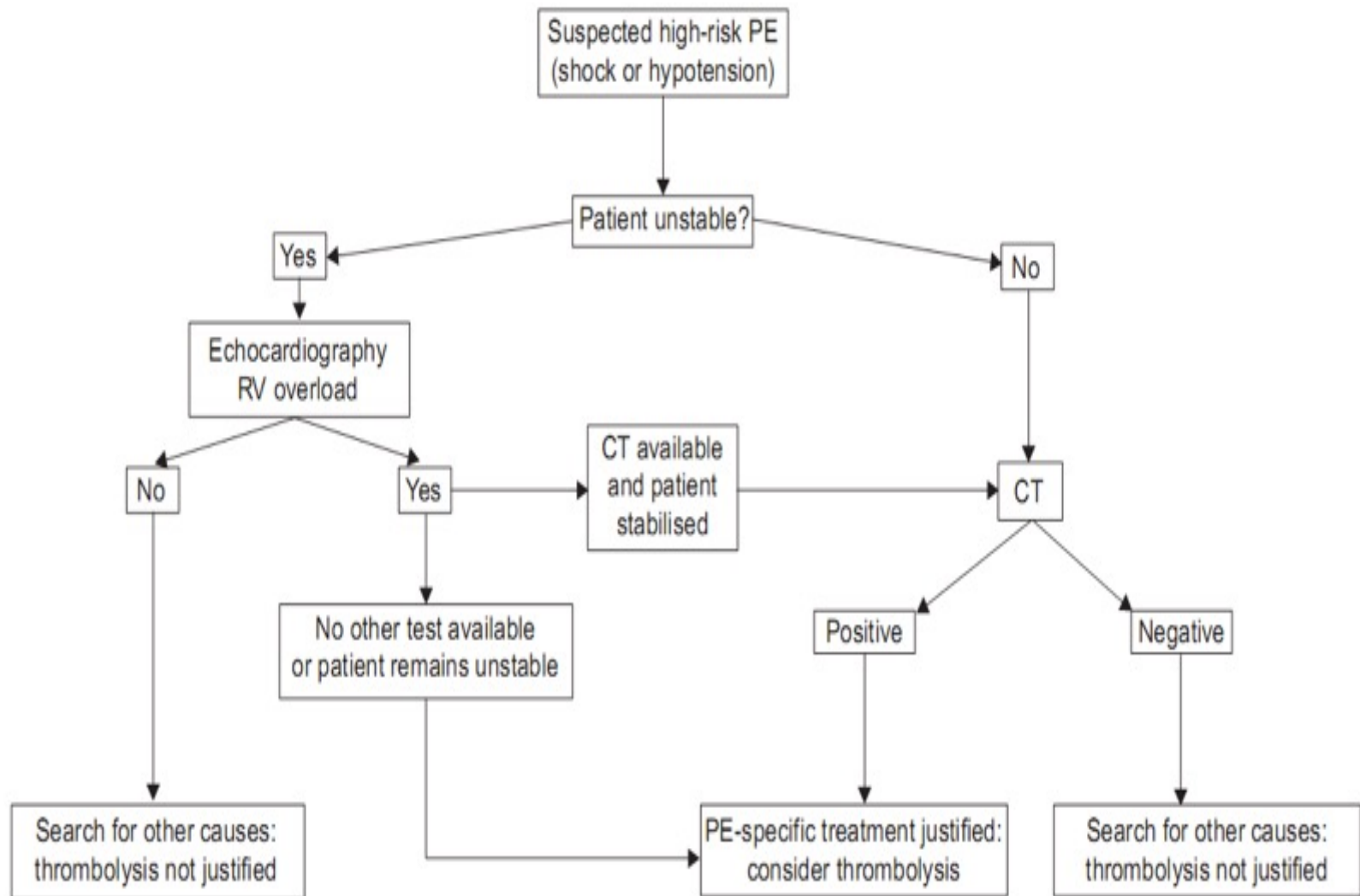
No PE[‡]
No treatment*

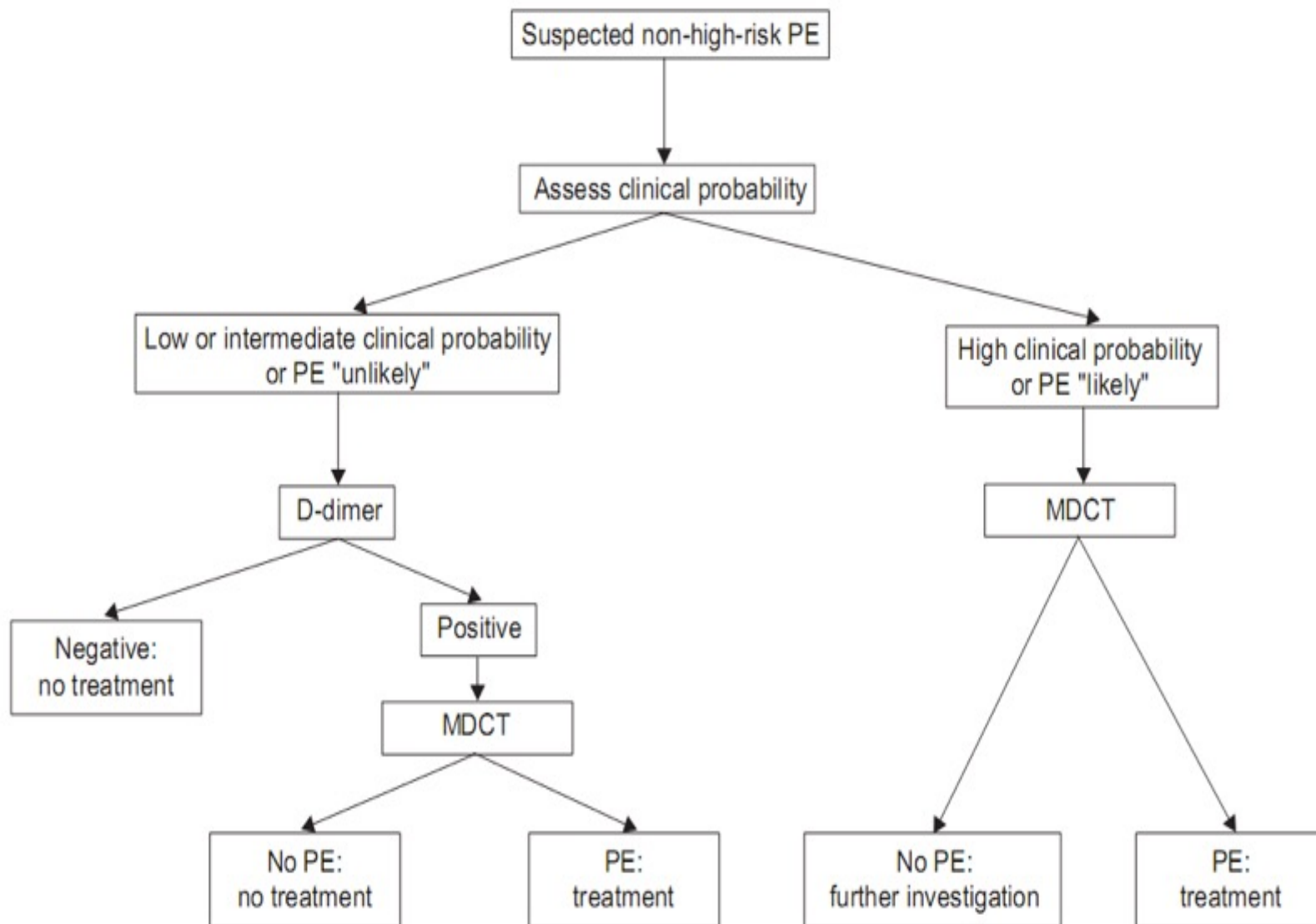
PE[†]
Treatment*

Multidetector CT

No PE
**No treatment* or
investigate further[#]**

PE
Treatment*





Role of V/Q scintigraphy

- In centres where V/Q scintigraphy is readily available, it remains a valid option for patients with an elevated D-dimer and a contraindication to CT, such as allergy to iodine contrast dye or renal failure.
- Breast radiation exposure a consideration in choice of imaging procedure

- Breast radiation estimates
 - 4-slice CTA → from 20 to 60mSv
 - 64-slice coronary artery CTA → 50 to 80 mSv to the breast.
 - a full V/Q study delivers only 0.28 to 0.9 mSv.

Conclusion

- Diagnostic strategy incorporating clinical probability of PE, d-dimer, leg u/sound, imaging studies important for accurate diagnosis
- Diagnosis of PE via imaging studies largely taken over by MDCT angiography
- Role of V/Q scan in lies in patients who have contraindications to CT scanning, allergy to contrast injections and possibly young females
- Better sensitivity and specificity may be achievable with SPECT V/Q

	Xenon 133	Tc-99m DTPA
Mode of decay	Beta minus	Isometric
Half life	5.5 days	6 hours
Biological half life	30 seconds	45 minutes
Photo energy	81 keV	140 keV
Multiple view imaging	No	Yes
Useful for severe COAD	Yes	-/+
Used after perfusion scan	No	No

Tc-99m MAA

Size	10 – 90 μm
Minimum number of particles to be used in adults	100000 unless pulmonary hypertension and right to left shunt
Ideal number of particles	200000 - 500000
Biological half life	4 – 8 h
Injection	Care should be taken not to cause particle aggregates that can produce hot spot
Safety	Particles block $<1/1000$ of the capillaries and precapillary arterioles

Terminology

V/Q match defect	Both scans abnormal in same area and equal size
V/Q mismatch	Abnormal perfusion Normal ventilation
Triple match	V/Q matching with CXR
Segmental defect	Wedge shape and pleural base Large > 75% Moderate 25 -75% Small < 25%
Reversed mismatch	Abnormal ventilation Normal perfusion

Xenon-133 ventilation scintigraphy

Patient preparation	None
Dosage	10-20 mCi inhale
Collimator	LEGP
Photopeak	20% window centered at 81 keV
Positioning	Patient is seated Place nose clamps on patient and connect mouthpiece for several minutes Center camera over chest posteriorly Patient breathes continuously through mouthpiece for several minutes
Acquisition	First breath - patients exhales fully and is ask to minimally inspire and hold it long enough to obtain 100000 count or 10-15 seconds Equilibrium -obtain 2 sequential 90 seconds images while patient breath normally Washout -turn system to exhaust Obtain 3 sequential 45 seconds posterior images then right and left posterior oblique and final posterior image

Tc-99m DTPA ventilation scintigraphy

Patient preparation	None
Dosage	30 mCi Tc-99m DTPA nebulizer
Collimator	LEGP
Photopeak	20% window centered at 140 keV
Positioning	Place nose clamps on patient and connect mouthpiece for several minutes Center camera over chest posteriorly Patient breathes continuously through mouthpiece for several minutes
Acquisition	Acquire posterior image for 250k and mark time Views: posterior/anterior/right and left lateral/right and left posterior oblique

Tc-99m MAA perfusion scintigraphy

Patient preparation	None
Patient precaution	Pulmonary hypertension : reduces particle to 100000 Right to left cardiac shunt : reduced particle number
Dosage	2-5 mCi IV over several respiratory cycle with patient supine
Collimator	LEGP
Photopeak	20% window centered at 140 keV
Acquisition	Acquire posterior image for 500k counts/image Views: posterior/anterior/right and left lateral/right and left posterior oblique

Understanding the report

Mismatched or matched V/Q scan	<p>Mismatched – decreased perfusion with normal ventilation</p> <p>Matched – abnormal perfusion and abnormal ventilation</p> <p>Ventilation abnormal image shows – slow to wash in/ slow to wash out (wash in images are obtained in all ventilation agent but wash out only with xenon gas)</p>
Understanding probability	<p>Normal scan- low probability of PE (0-5%)</p> <p>Low probability scan -PE (10-15%)</p> <p>Intermediate probability -PE (25-30%)</p> <p>High probability –PE (80-100%)</p>
Qualitative lung scan	<p>Describe the percent contribution to global perfusion of each lung</p> <p>Combined with pulmonary function test</p>

Potential problems

False positive	Conditions that can mimic high probability-vasculitis / pulmonary arterial anomalies i.e. hypoplasia and stenosis
Clinical pretest probability of PE	Useful for deriving post test probability
Interpretations of defect size	High probability – 2 moderate / large mismatched perfusion defects If patient with cardiopulmonary disease- 4 mismatched defects Moderate – 25-27% area lung segment Large 75% segment 2 defects each 50% of segment can be counted as 1 large defect
Widespread ventilatory abnormalities	Widespread ventilatory abnormalities = intermediate probability of PE i.e. pulmonary infarction or pneumonia showed matched V/Q and matched CXR infiltrate
Right to left shunt	Number of particle can be reduced for patients with right to left shunt i.e. children.

V/Q scan probability for PE	Clinical pre scan probability		
	High	Intermediate	Low
High	97%	88%	56%
Intermediate	66%	28%	16%
Low	40%	16%	4%

Suspected high-risk PE
i.e. with shock or hypotension

CT immediately available*

no

yes

Echocardiography

RV overload

no

yes

CT available and
patient stabilized

CT

positive

negative

Search for other causes
Thrombolysis/embolectomy
not justified

No other tests available#
or patient unstable

**PE-specific treatment
justified**
Consider thrombolysis
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Search for other causes
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Suspected non-high-risk PE
i.e. without shock or hypotension

Assess clinical probability of PE
Implicit or prediction rule

Low/intermediate clinical probability
or "PE unlikely"

High clinical probability
or "PE likely"

D-dimer

negative

No treatment*

positive

Multidetector CT

No PE[‡]

No treatment*

PE[†]

Treatment*

Multidetector CT

No PE

**No treatment* or
investigate further[#]**

PE

Treatment*

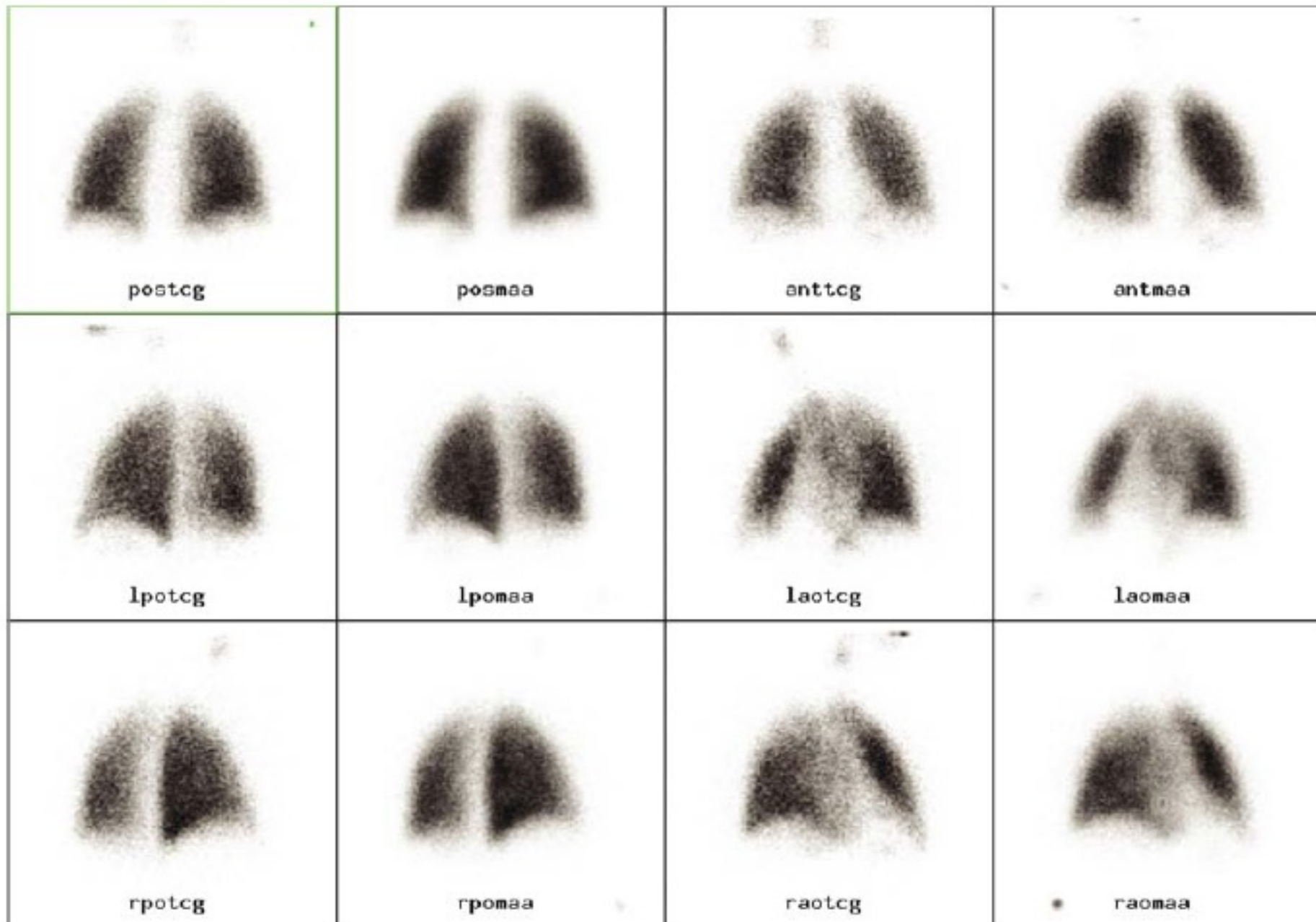


Figure 10.5. Normal category 6-view Technegas ventilation (left) and perfusion (right) scan of each pair performed sequentially. Count rate of perfusion was > 5 times that of ventilation images.



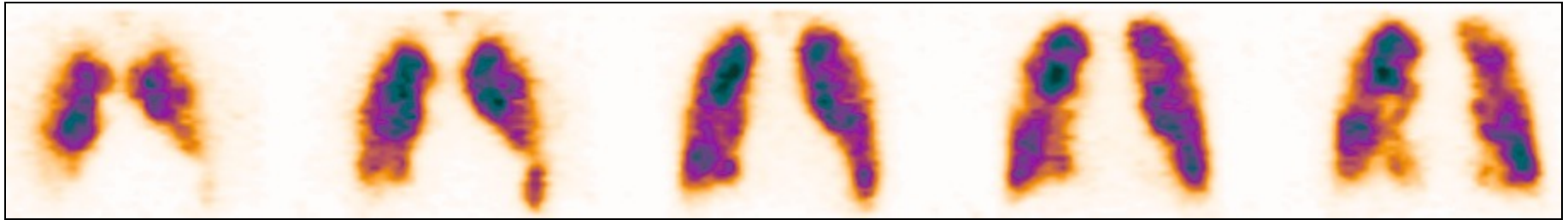
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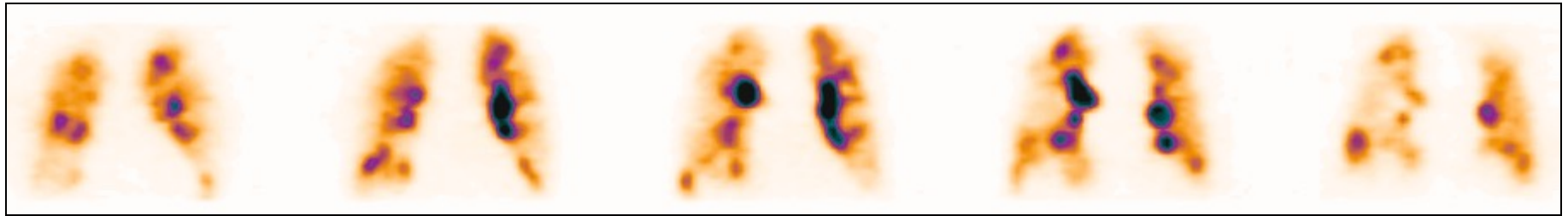
postem

Figure 10.9. Technegas ventilation image with a central deposition of tracer and poor peripheral penetration with focal deposition peripherally. Patchy perfusion (right) confirms chronic parenchymal lung disease.

Technegas (ventilation)



DTPA (perfusion)



Patient with COPD

Table 10.7. Neoclassical criteria for VQ scan interpretation: modified PLOPED

High probability

Two or more moderate/large mismatched perfusion defects.*

Prior heart and lung disease probably requires more abnormalities (i.e. four or more).

Triple match in one lung with one or more mismatches in the other lung field.

Intermediate probability

Difficult to categorise or not described as very low, low or high, including all cases with a chest X-ray opacity, pleural fluid or collapse.

Single moderate VQ match or mismatch without corresponding radiograph abnormality.

Low probability

Large or moderate focal VQ matches involving no more than 50% of the combined lung fields with no corresponding radiograph abnormalities.

Small VQ mismatches with a normal chest X-ray.

Very-low probability

Small VQ matches with a normal chest X-ray.

Near-normal

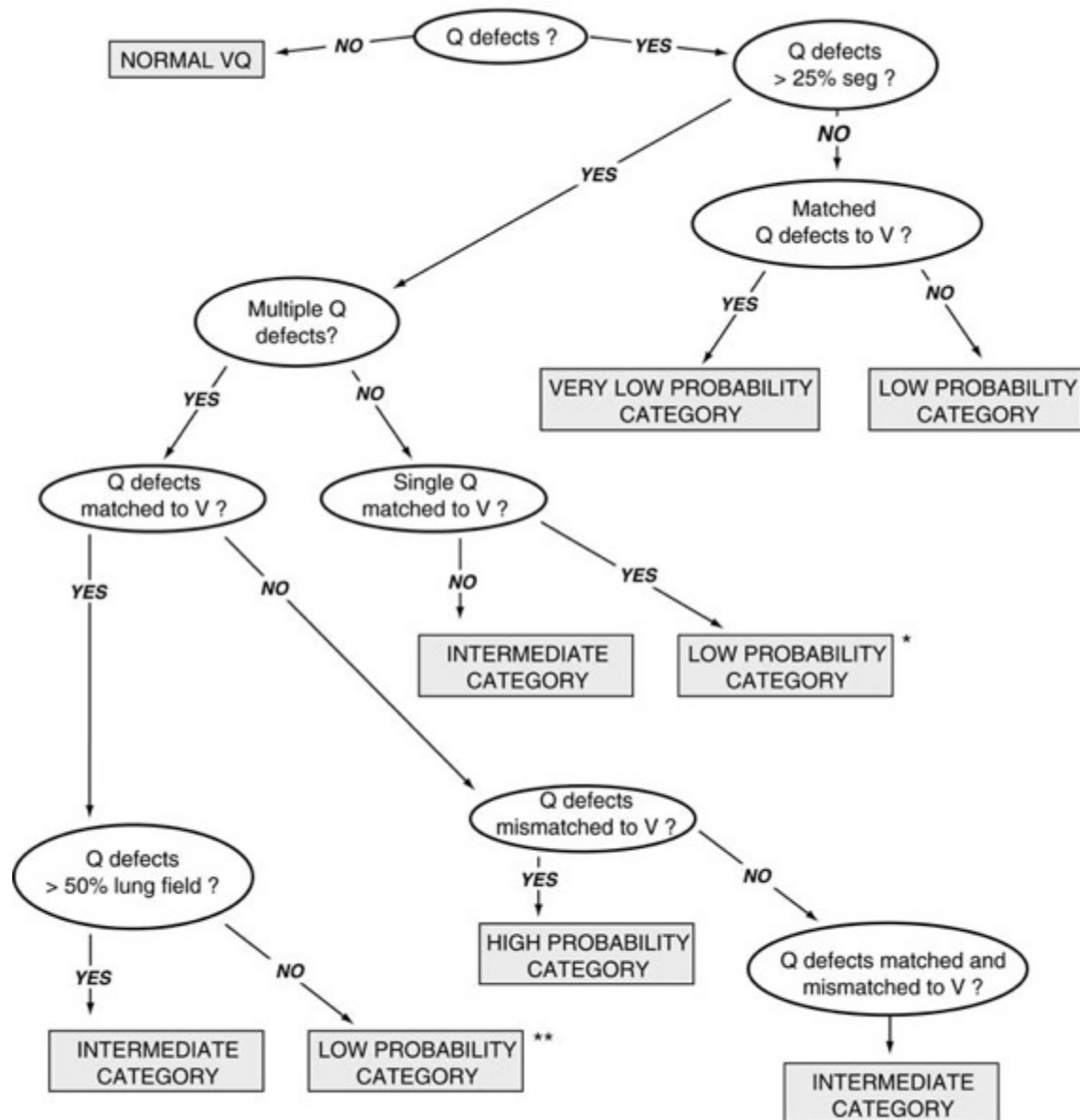
Perfusion defects due to raised hemi diaphragm, cardiomegaly, enlarged hila or aorta.

Normal

No perfusion abnormalities.

*Large defects are > 75% segment, moderate defects are 25–75% segment and small defects are <25% segment.

This algorithm starts with a normal chest X-ray. Q = Perfusion and V = Ventilation



* PE likelihood is higher than with multiple matches.

** Multiple matched segmental abnormalities should raise suspicion of PE.

Causes of perfusion defect

Primary vascular lesion

PE

Vasculitis

Septic/fat/air emboli

Pulmonary artery hypoplasia or atresia

Primary ventilation abnormality

Pneumonia

Atelectasis

Pulmonary edema

Asthma

COPD

Bullae

Mass effect

Tumor

Adenopathy

Pleural effusion

Iatrogenic

Surgery

Radiation fibrosis

V/Q mismatched defect

Acute PE

Chronic PE

Vasculitis

Mediastinal or hilar
adenopathy

hypoplasia or aplasia of
pulmonary artery

Post radiation therapy

Bronchogenic carcinoma

Septic/drug abuse

V/Q matched defect

COPD

Air space disease

Tumor

Pleural effusion

Asthma

Lung infarction

**V/Q reversed
mismatched defect**

Pneumonia

Mucus plugging

Alveolar pulmonary edema

Unilateral lung perfusion abnormality

Pneumonectomy

Mediastinal fibrosis

Pneumothorax

Tumors

Mucous plug

Pulmonary embolus

Pulmonary artery stenosis

Swyer-James syndrome

Massive pleural effusion

Non segmental defect

Pacemaker

Bullae

Trauma

Tumors

Hemorrhage

Cardiomegaly

Hilar adenopathy

Atelectasis

Pleural effusion

Pneumonia

Perfusions defect	ventilation	CXR	Probability category
Moderate to large			
≥ 2 segments	Mismatch	clear	high
< 2	Mismatch	clear	Intermediate
	Match	LL zone	Intermediate
	Match	UL zone	Low
Multiple	Match	Clear	Low
Small (<25% of a segments)			
> 3	N/A	Clear	Low
1 - 3	N/A	Clear	Very low
Non segmental			
	N/A	Shows anatomical reason for perfusion abnormality	Very low
None			
	N/A	N/A	Normal

Wells clinical prediction rule for the diagnosis of pulmonary embolism (PE)

Variable	Points
Clinical signs and symptoms of DVT	3
Alternative diagnosis is less likely than PE	3
Heart rate > 100 bpm	1.5
Immobilization or surgery in the previous 4 weeks	1.5
Previous DVT or PE	1.5
Hemoptysis	1
Malignancy	1

**Risk categories based on Wells score
(version used in PLOPED II)**

Risk category	Cumulative score
Low	<2
Intermediate	2-6
High	>6

**Risk categories based on Wells score
(version used in Christopher study)**

Risk category	Cumulative score
PE unlikely	≤ 4
PE likely	> 4

Diagnostic criterion	Clinical probability of PE		
	Low	Intermediate	High
Exclusion of pulmonary embolism			
Normal pulmonary angiogram	+	+	+
D-dimer			
Negative result, highly sensitive assay	+	+	−
Negative result, moderately sensitive assay	+	−	−
V/Q scan			
Normal lung scan	+	+	+
Non-diagnostic lung scan ^a	+	−	−
Non-diagnostic lung scan ^a and negative proximal CUS	+	+	±
Chest CT angiography			
Normal SDCT and negative proximal CUS	+	+	±
Normal multidetector CT alone	+	+	±
Confirmation of pulmonary embolism			
Pulmonary angiogram showing PE	+	+	+
High-probability V/Q scan	±	+	+
CUS showing a proximal DVT	+	+	+
Chest CT angiography			
Single or multidetector helical CT scan showing PE (at least segmental)	±	+	+
Single or multidetector helical CT scan showing subsegmental PE	±	±	±

Table 4 Principal markers useful for risk stratification in acute pulmonary embolism

Clinical markers	Shock Hypotension ^a
Markers of RV dysfunction	RV dilatation, hypokinesis or pressure overload on echocardiography RV dilatation on spiral computed tomography BNP or NT-proBNP elevation Elevated right heart pressure at RHC
Markers of myocardial injury	Cardiac troponin T or I positive ^b

BNP = brain natriuretic peptide; NT-proBNP = N-terminal proBNP;

RHC = right heart catheterization; RV = right ventricle.

^aDefined as a systolic blood pressure <90 mmHg or a pressure drop of ≥ 40 mmHg for >15 min if not caused by new-onset arrhythmia, hypovolaemia or sepsis.

^bHeart-type fatty acid binding protein (H-FABP) is an emerging marker in this category, but still requires confirmation.

PE-related early MORTALITY RISK		RISK MARKERS			Potential treatment implications
		CLINICAL (shock or hypotension)	RV dysfunction	Myocardial injury	
HIGH >15%		+	(+) ^a	(+) ^a	Thrombolysis or embolectomy
NON HIGH	Intermediate 3–15%	—	+	+	Hospital admission
			+	—	
			—	+	
	Low <1%	—	—	—	Early discharge or home treatment

Modified PLOPED criteria for diagnosis of PE

[Edit Article](#)

The **modified PLOPED criteria for diagnosis of PE** determine the probability of PE following a VQ scan :

Levels of probability

High probability

- 2 or more large mismatched segmental defects or equivalent moderate/large defects with a normal x-ray
- any perfusion defect substantially larger than radiographic abnormality

Intermediate probability

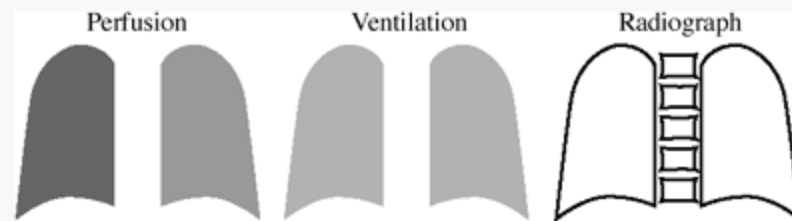
- multiple perfusion defects with associated radiographic opacities
- greater than 25% of a segment and less than 2 mismatched segmental perfusion defects with:
 - normal radiograph
 - one moderate segmental
 - one large or two moderate segmental
 - one large and one moderate segmental
 - three moderate segmental
- triple match : solitary moderate-large matching segmental defect with matching radiograph
- difficult to characterize as high probability or low probability

Low probability

- nonsegmental defects-small effusion blunting costophrenic angle, cardiomegaly, elevated diaphragm, ectatic aorta
- any perfusion defect with substantially larger radiographic abnormality
- matched ventilation and perfusion defects with normal chest radiograph
- small subsegmental perfusion defects

Normal scan

- no perfusion defects



No V/Q defects & normal ventilation & normal CXR = **normal**



Matching nonsegmental V/Q defects & normal CXR = **low probability**



No definite V/Q mismatch & normal CXR = **moderate probability**

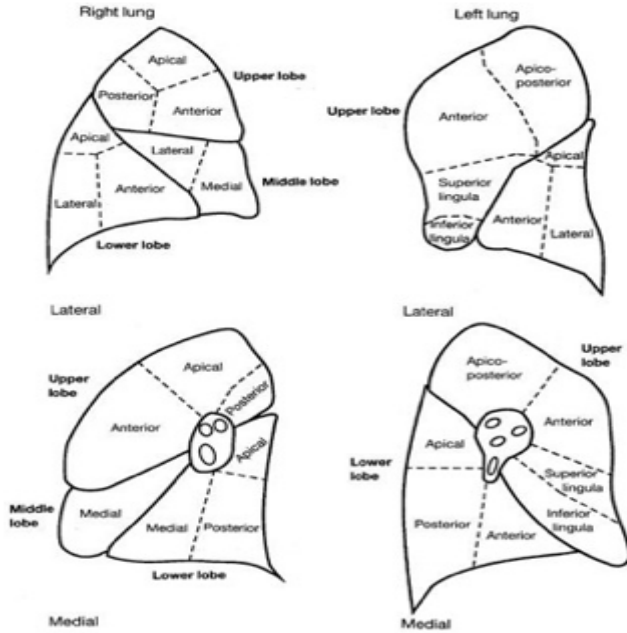


Segmental perfusion defect & normal ventilation = **high probability**



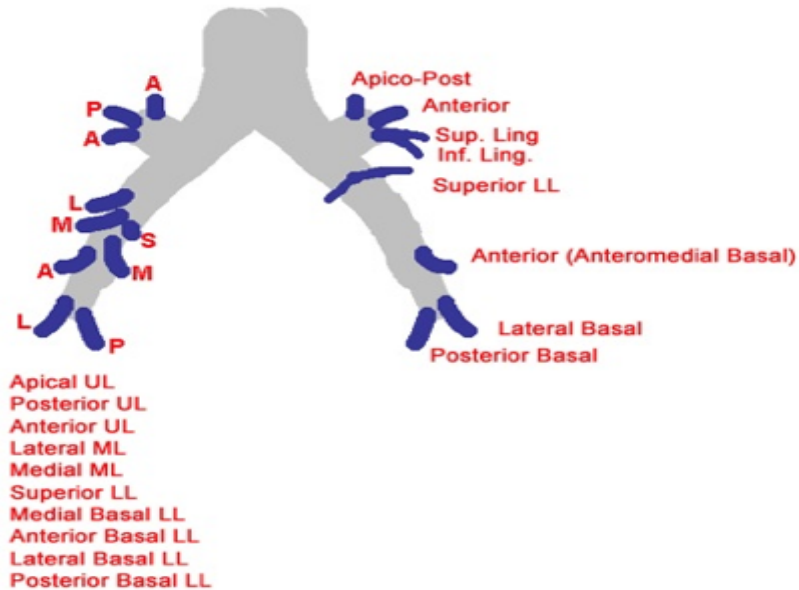
Matching segmental V/Q defect & CXR opacity = **indeterminate**

VQ Analysis



PIOPED Criteria

Low Prob:	Small (<25%) defect(s) Matched defects Upper lobe triple match
Intermediate:	Everything else
High Prob:	Two large (or equivalent) mismatches
Matched Defects:	Mucus Plug Central Airway Obstruction Endobronchial Lesion Aplasia/Hypoplasia Effusion Radiation



Most common symptoms of PE (PIOPED study)	Dyspnea (73%)
	Pleuritic chest pain (66%)
	Coughing (37%)
	Hemoptysis (13%)

Atypical presentations of PE

Abdominal/ pelvic pain

Decreasing level of
consciousness

Fever

Productive cough

Seizures

Syncope

Wheezing

Conditions associated with D- Dimer production

AMI

Acute stroke

DIC

Advanced age

Heart failure

Connective tissue disease

Infection

Malignancy

Post operative

Pregnancy

Renal failure

Trauma

Sickle cells

DVT

The following associated with matched ventilation/perfusion defects of lung scans

- A. IV drug abuse
- B. Congenital rubella syndrome
- C. Histoplasmosis
- D. Thymolipoma
- E. Haematogenous metastases

The following associated with matched ventilation/perfusion defects of lung scans

- TFTFF

The following may cause perfusion defects on lung scan

- A. SLE
- B. TB
- C. Sarcoidosis
- D. Retrosternal goitre
- E. Radiation pneumonitis
- F. Anomalous pulmonary artery
- G. Bronchial carcinoma
- H. Congenital lobar emphysema
- I. Haemangioendotheliomatosis

The following may cause perfusion defects on lung scan

- TTTTTTTTTT

Concerning PE

- A. A single perfusion defect separated from the pleural surface by a rim of normal perfusion is rarely due to embolus
- B. Normal perfusion exclude clinically significant PE
- C. The combination of clinical impression and lung scan results is a better predictor of PE than either taken alone
- D. Patients with a low probability scan and no evidence of venous thrombosis may be safely left untreated
- E. He particle count of Tc-99 MAA may need to be increased in patients with pulmonary hypertension to achieved diagnostic images

Concerning PE

- TTTTF

Total loss of perfusion to one lung occurs in

- A. Bullous emphysema
- B. Beckwith-Wiedemann syndrome
- C. Following a Blalock-Taussig shunt
- D. Pleural effusion
- E. Swyer-James syndrome

Total loss of perfusion to one lung
occurs in

- TFTTT

Regarding V/Q scanning in the following up of confirmed PE

- A. Perfusion defects may clear at 24 hours
- B. A perfusion defect still present at three months is likely to persist indefinitely
- C. A persistent defect implies lung infarction
- D. Underlying heart failure may enhance the resolution of perfusion defects
- E. A repeat V/Q scan should be performed prior to stopping anticoagulation

Regarding V/Q scanning in the following up of confirmed PE

- TTFFT

The fissure sign occurs in

- A. Sub pulmonic effusion
- B. Cystic fibrosis
- C. Sarcoidosis
- D. PE
- E. Emphysema

The fissure sign occurs in

- TTFTT

Reverse V/Q mismatched occurs in

- A. Pulmonary atelectasis
- B. PE
- C. Alveolar proteinosis
- D. Bronchogenic carcinoma
- E. Pleural effusion

Reverse V/Q mismatched occurs in

- TFFTT

The visualization of the kidneys on Tc-99m MAA perfusion scan can be caused by:

- A. Right to left shunt
- B. Free Tc-99m
- C. MAA particle less than 10 μm in size
- D. Kidney obstruction
- E. Less dehydration

The visualization of the kidneys on Tc-99m MAA perfusion scan can be caused by:

- TTTFF

A. Low probability

B. Intermediate probability

C. High probability

1. Clear CXR with multiple matched V/Q defects
2. Single large segmental V/Q mismatch
3. Perfusion defect < radiological infiltrate
4. Multiple small perfusion defect
5. Perfusion defects equal to radiographic infiltrate
6. Lobar V/Q mismatch

A. Low probability

B. Intermediate probability

C. High probability

1. Clear CXR with multiple matched V/Q defects. A
2. Single large segmental V/Q mismatch. B
3. Perfusion defect < radiological infiltrate. A
4. Multiple small perfusion defect. A
5. Perfusion defects equal to radiographic infiltrate. B
6. Lobar V/Q mismatch. C

Stripe sign generally is reflective of

- A. PE
- B. Non embolic disease such as COPD
- C. Pulmonary hypertension
- D. Pleural fluid
- E. Asthma

Stripe sign generally is reflective of

- FTFFF

Matched absence or near absence of perfusion and ventilation in the entire lung may be associated with?

- A. Lung carcinoma
- B. Aspirated foreign body
- C. Swyer James syndrome

Matched absence or near absence of perfusion and ventilation in the entire lung may be associated with?

- TTT

Regarding V/Q

- A. Kr-81m is generator produced
- B. Rb-81 is cyclotron produced
- C. Albumin macroaggregates remain in the pulmonary capillary bed for weeks, limiting the number of follow up perfusion scans that can be safely performed.
- D. The biologic half life of MAA is longer than albumin microspheres
- E. A patient with high pretest probability of PE, the negative predictive value of a normal scan exceeds 95%

Regarding V/Q

- TTFFT

Regarding V/Q

- A. In a patient with low pretest probability of PE, the positive predictive value of positive scan exceeds 95%
- B. The presence of the triad has a positive predictive value of PE exceeding 95%
- C. V/Q scan is nondiagnostic in most patients with pulmonary edema
- D. Most patients with PE show infiltrate or effusion on properly exposed CXR
- E. Absence of perfusion to an entire lung is common with PE

Regarding V/Q

- FFFFFF

What are two commonly used radiopharmaceuticals for ventilation imaging? What are their advantages and disadvantages

What are two commonly used radiopharmaceuticals for ventilation imaging? What are their advantages and disadvantages

- Xenon-133 and Tc-99m DTPA aerosol. Xenon-133 demonstrates more clearly the physiology of respiration and is very sensitive to detection of obstructive airways disease manifested by slow washout. The disadvantages is the rapid washout, its suboptimal view due to low photopeak (81 keV) and poor count rate image.
- Tc-99m DTPA aerosol allows high count images in all projections, however the images are comparable only to the inspiratory phase of xenon-133.

What is minimum number of particles
recommended for pulmonary
perfusion imaging?

What is minimum number of particles recommended for pulmonary perfusion imaging?

- This requires at least 100,000 particles in normal adults and many authorities recommend a minimum of 200000 – 500000 particles.

What is the size range of MAA particles?

What is the size range of MAA particles?

- In commercial preparations the majority of particles are 20 to 40 μm with a range of 10 – 90 μm .

What is the biological fate of MAA particles?

What is the biological fate of MAA particles?

- MAA particles are easily broken down in the lung. Delayed imaging performed several hours after pharmaceutical administration demonstrates activity in the reticuloendothelial system because of phagocytosis of the breakdown particles.

Pearl

- One way to determine whether radioactivity outside of the lungs is caused by free Tc-99m or shunted Tc-99m MAA is to image the brain. Free pertechnetate should localize in the brain, whereas Tc-99m MAA particles that gain access to the systemic circulation will lodge in the first capillary bed that they encounter, including the capillary bed in the brain.

What is the preferred patient position during administration of Tc-99m MAA?

What is the preferred patient position during administration of Tc-99m MAA?

- Administering Tc-99m MAA with the patient supine results in a more homogenous distribution of particles in the lung than when the patient is sitting or standing.

What is the stripe sign?

What is the stripe sign?

- Stripe sign refers to a stripe or zone of activity seen between a perfusion defect and the closest pleural surface. Because PE are typically pleura based, the stripe sign suggests another diagnosis, often emphysema.

What is physiological basis for perfusion defects in areas of poor ventilation?

What is physiological basis for perfusion defects in areas of poor ventilation?

- The classic response to hypoxia at the alveolar level is vasoconstriction. Shunting a blood away from the hypoxic lung zone maintains oxygen saturation.

What is the shrunk lung sign?

What is the shrunken lung sign?

- The lung may appear smaller than usual in patient sustaining multiple small emboli, such as fat emboli, that distribute uniformly around the lung periphery

What is the classical appearance of multiple PE on lung perfusion scintigraphy?

What is the classical appearance of multiple PE on lung perfusion scintigraphy?

- Multiple pleura-based, wedged shaped areas of significantly diminished or absent perfusion. The size of the defect may vary from subsegmental to segmental or may involve an entire lung or lobe.

What is the sensitivity of the high probability scan category for detecting pulmonary embolism?

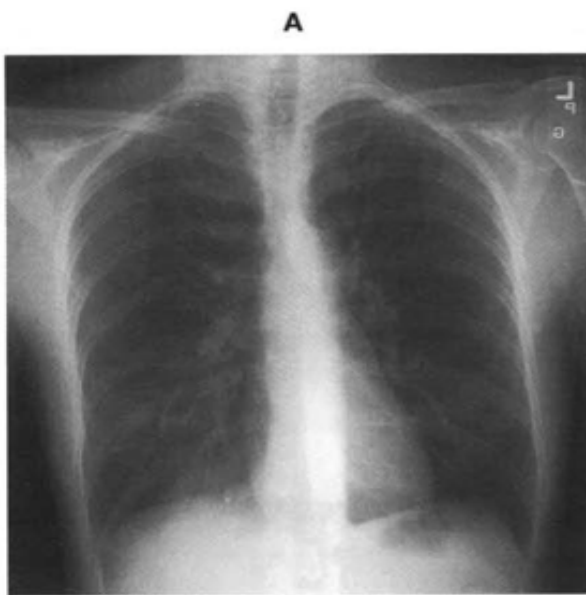
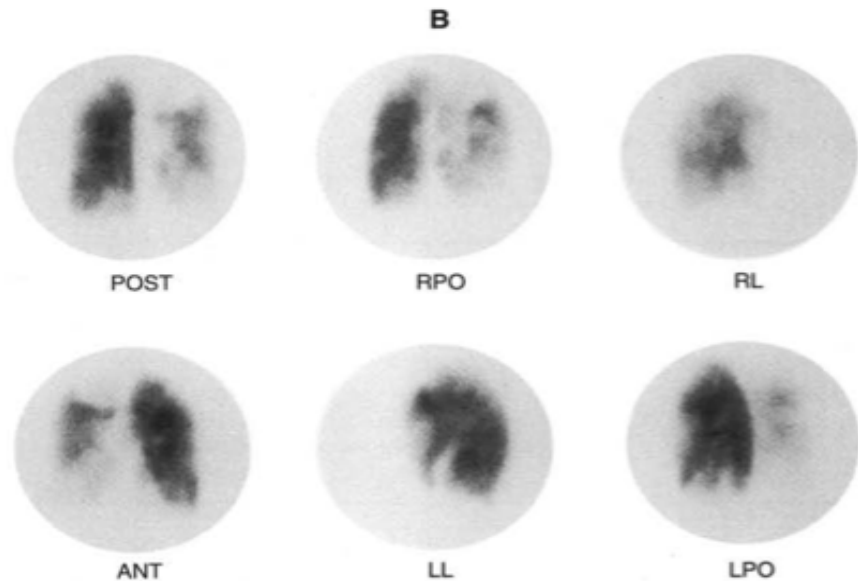
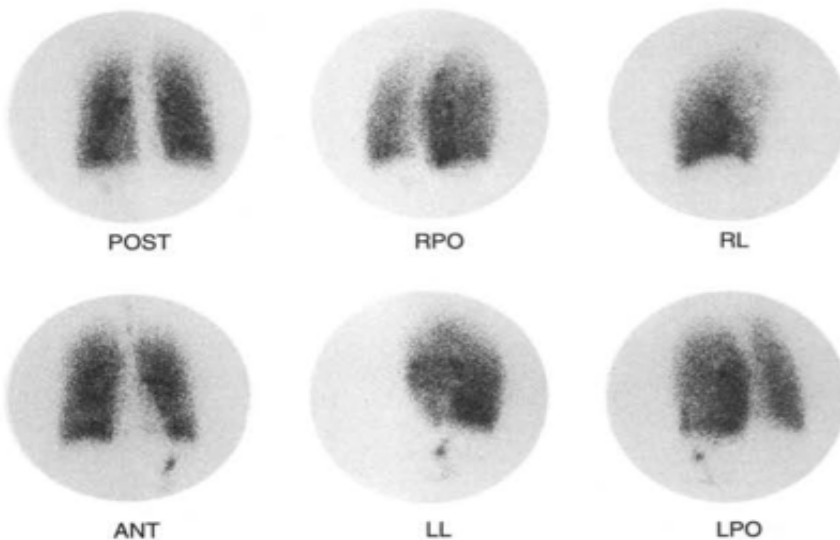
What is the sensitivity of the high probability scan category for detecting pulmonary embolism?

- In the PIOPED study, 41 % of patients with PE had a high probability scintigraphy pattern.

What are the most common clinical signs and symptoms in patients with confirmed PE?

What are the most common clinical signs and symptoms in patients with confirmed PE?

- In PIOPED, the three most common presenting symptoms, dyspnea 80%, pleuritic chest pain 60% and cough 40%.
- On physical examination, lung crackles 60 %, leg swelling 30% or pleural friction rub 5%.

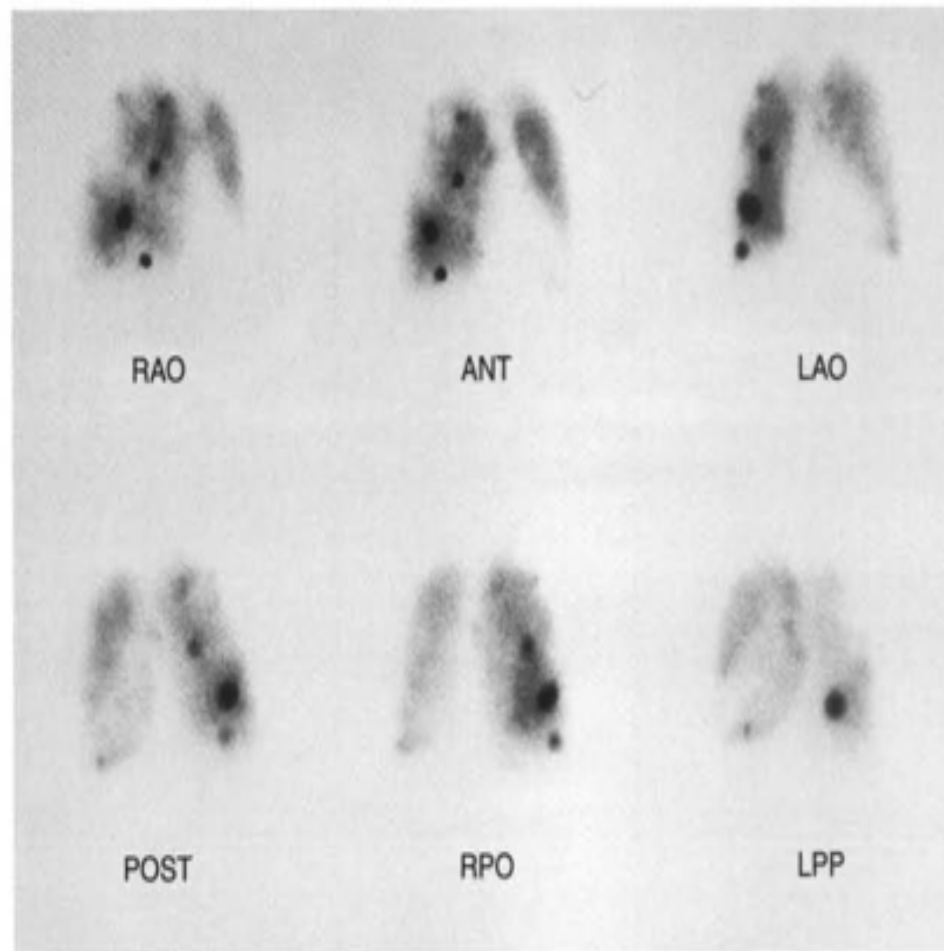


A 62-year-old patient has right-sided chest discomfort and shortness of breath. *A*, Posteroanterior chest radiograph; *B*, perfusion; *C*, ventilation.

1. Describe the ventilation-perfusion image findings.
2. Interpret the study. Give your reasoning.
3. What is the likelihood of pulmonary embolus in this patient?
4. What are the most common chest x-ray findings in patients with pulmonary emboli?

High probability of PE

1. Perfusion is decreased in the right lower lobe except for the superior segment. Ventilation is truncated in the right lower lobe consistent with subpulmonic effusion
2. High probability for PE. Mismatch between perfusion and ventilation is evident in the basal segment. The perfusion defect is considerably larger than the effusion on the X-ray
3. > 90%
4. Most common : Normal
5. Next most common : atelectasis

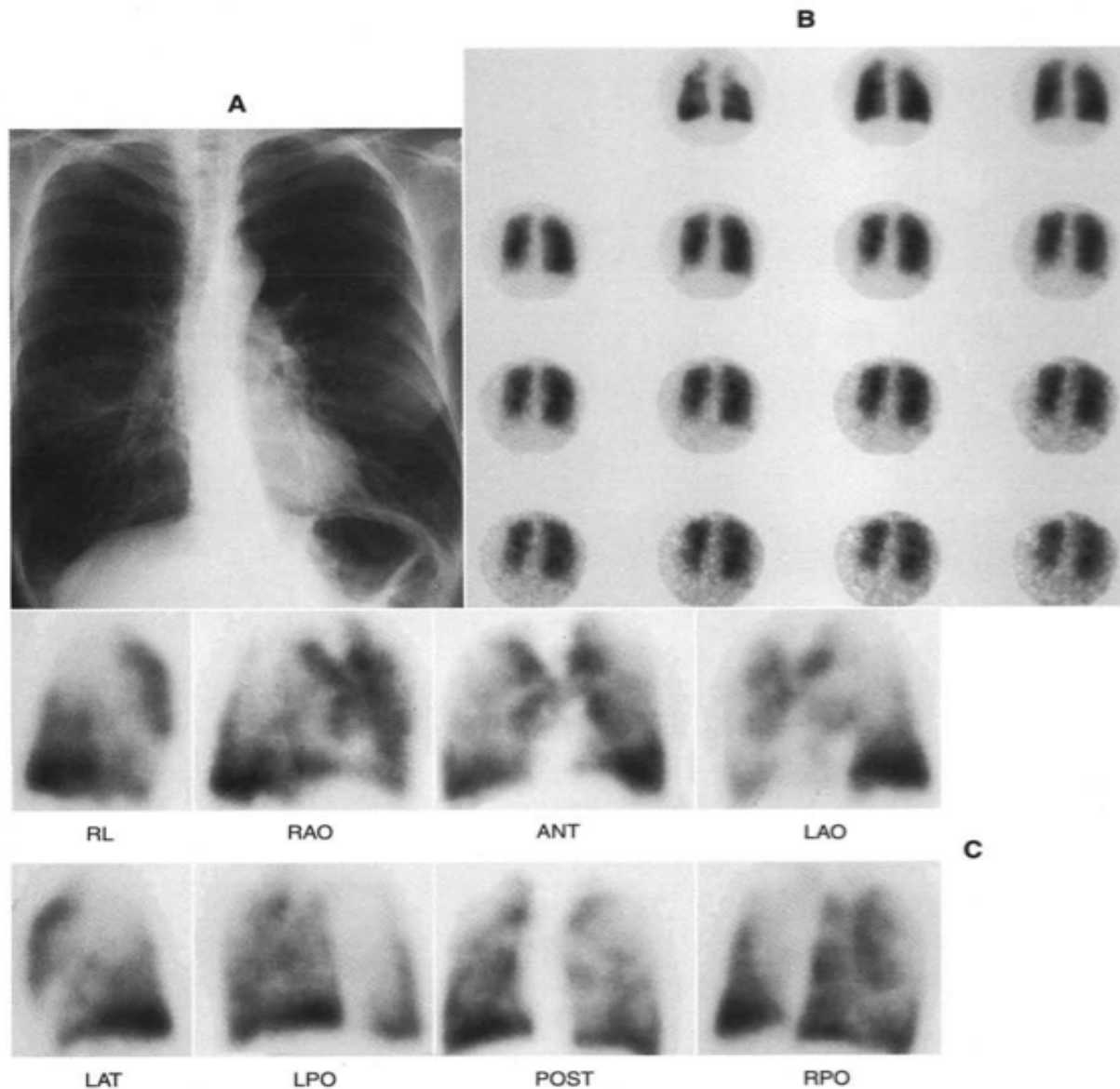


A 45-year-old woman was referred for a ventilation-perfusion study. The perfusion scan only is shown.

1. Describe the abnormal scintigraphic findings.
2. What is the most likely cause for the findings?
3. What is the radiation dose to the patient from a perfusion study? From a ^{133}Xe ventilation study?
4. Given the longer physical half-life and larger administered dose of ^{133}Xe , compared with $^{99\text{m}}\text{Tc}$ macro-aggregated albumin (MAA), explain the lower resulting radiation dose to the lungs.

Hot spots on lung scan

1. Multiple hot spots are present in the upper and lower lobes, predominately in the right lung field
2. Radioactive emboli as a result of poor technique caused by drawing back blood into the syringe containing the Tc-99m MAA before injection of the radiotracer, causing clumping
3. The lungs, the target organ, received 5 mCi from Tc-99m MAA. Approximately 0.2 rads to the lung from a 20 mCi xenon study
4. The biological half life is brief. The patient breathes Xe-133 gas to equilibrium, then expels it into a trap. Only Xe-133 absorbed as a result of fat solubility has any appreciable biological half life

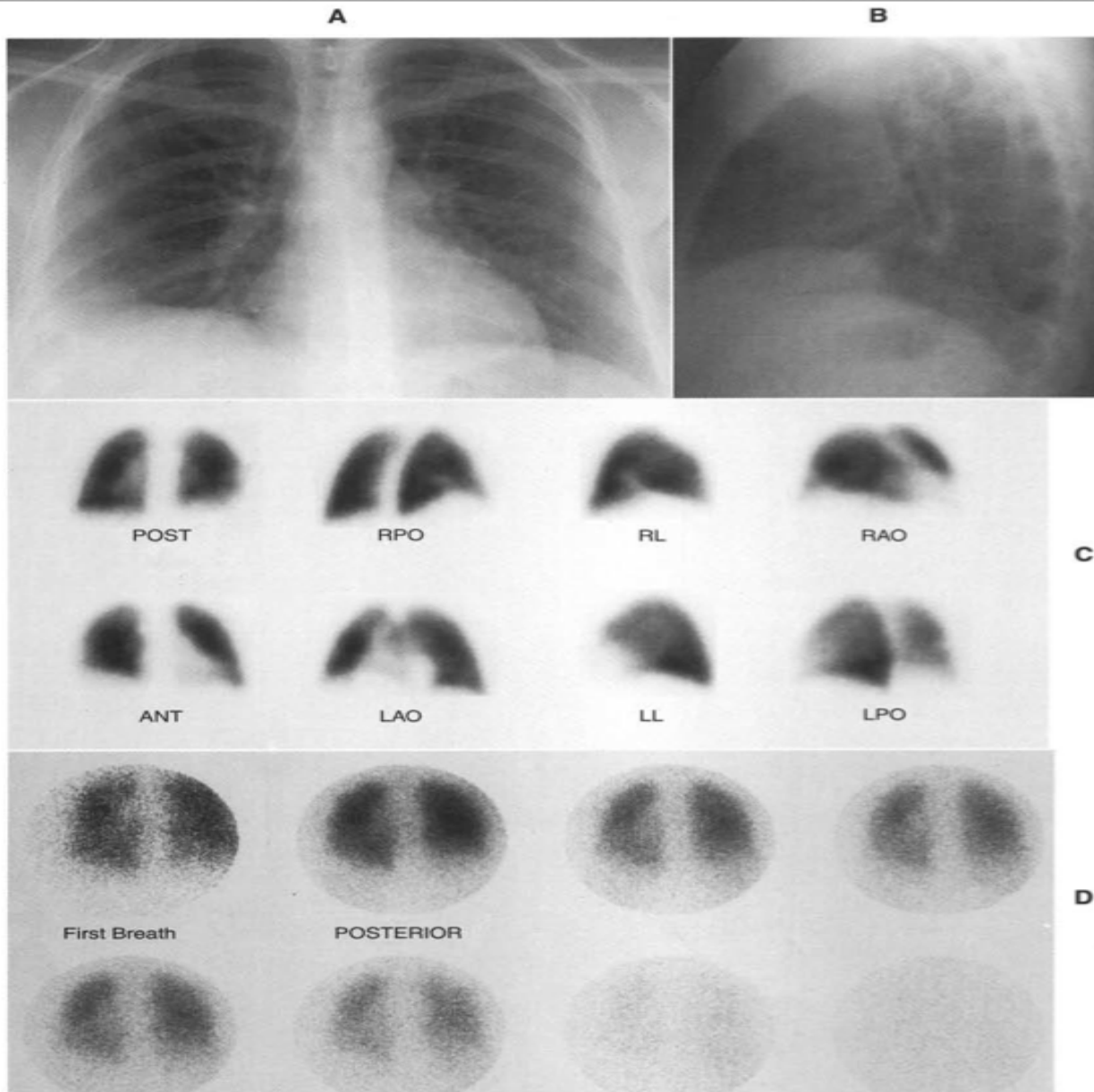


A chest radiograph (A), posterior ^{133}Xe ventilation (B), and eight-view perfusion study (C) were performed for shortness of breath.

1. Describe the findings on the ventilation study.
2. Describe the findings on the perfusion study.
3. Provide an interpretation regarding the presence or absence of pulmonary embolism.
4. What term could be applied to this perfusion pattern?

Ventilation perfusion stripe sign, emphysema

1. Decreased upper lobe ventilation is seen on the single breath with air trapping in both upper lobes and the right lower lobe on washout images
2. Decreased perfusion to the majority of both lungs, with preserved perfusion in the subpleural lung, most evident at the lung bases and medial aspect of both upper lobes
3. Low probability
4. Stripe sign

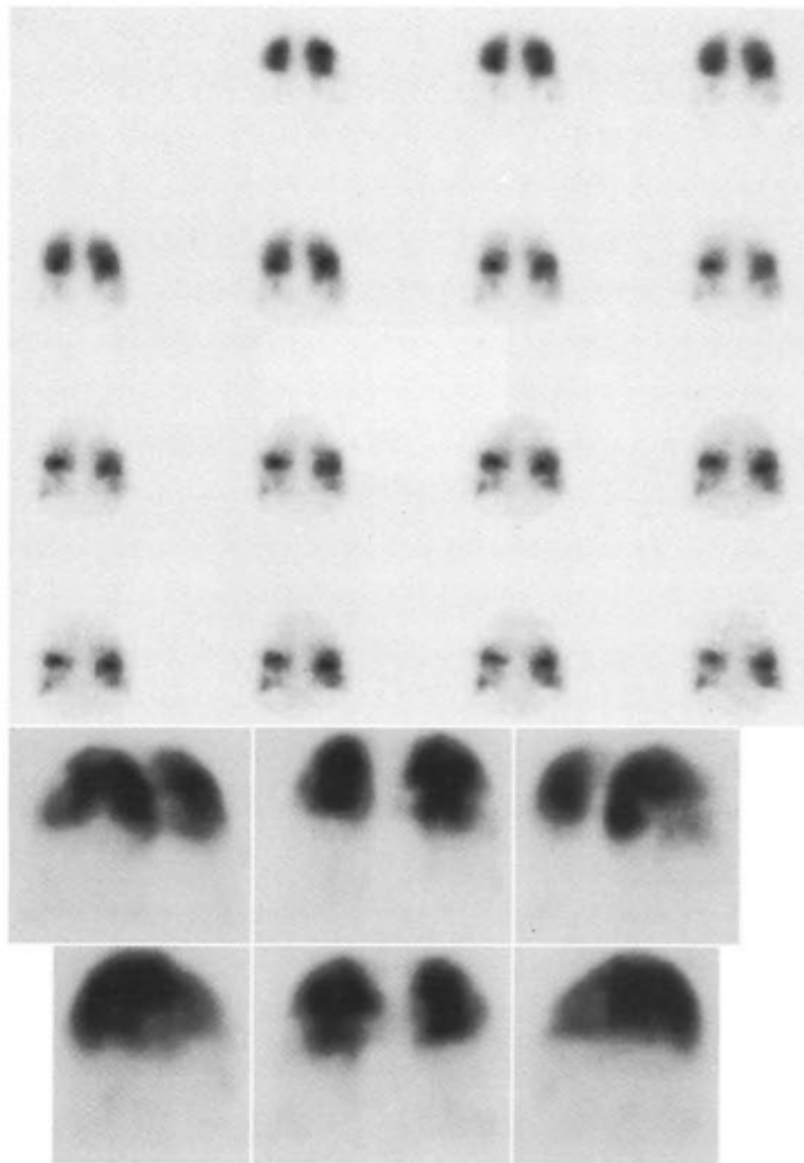


A young female patient presents at the emergency department with chest pain. Chest radiographs (*A*, *B*), perfusion scan (*C*), and ventilation study (*D*) are shown.

1. Describe the findings on the chest radiograph.
2. Describe the perfusion and ventilation scans.
3. Categorize the study regarding the presence or absence of pulmonary embolism using PIOPED criteria.
4. What is the most common finding on chest radiographs with thromboembolism?

Hampton's Hump – intermediate probability

1. Posteroanterior and lateral chest radiographs demonstrate a pleural based opacity in the lateral right lung base
2. A single wedge shape, pleural based defect in the same location as the radiographic abnormality, probably the anterobasal segment of the right lower lobe. Normal Xe-133 ventilation study
3. Intermediate probability for PE
4. CXR findings in PE without infarction are uncommon. When present, they are usually associated with a large, central embolus. Discoid atelectasis is the next most common finding

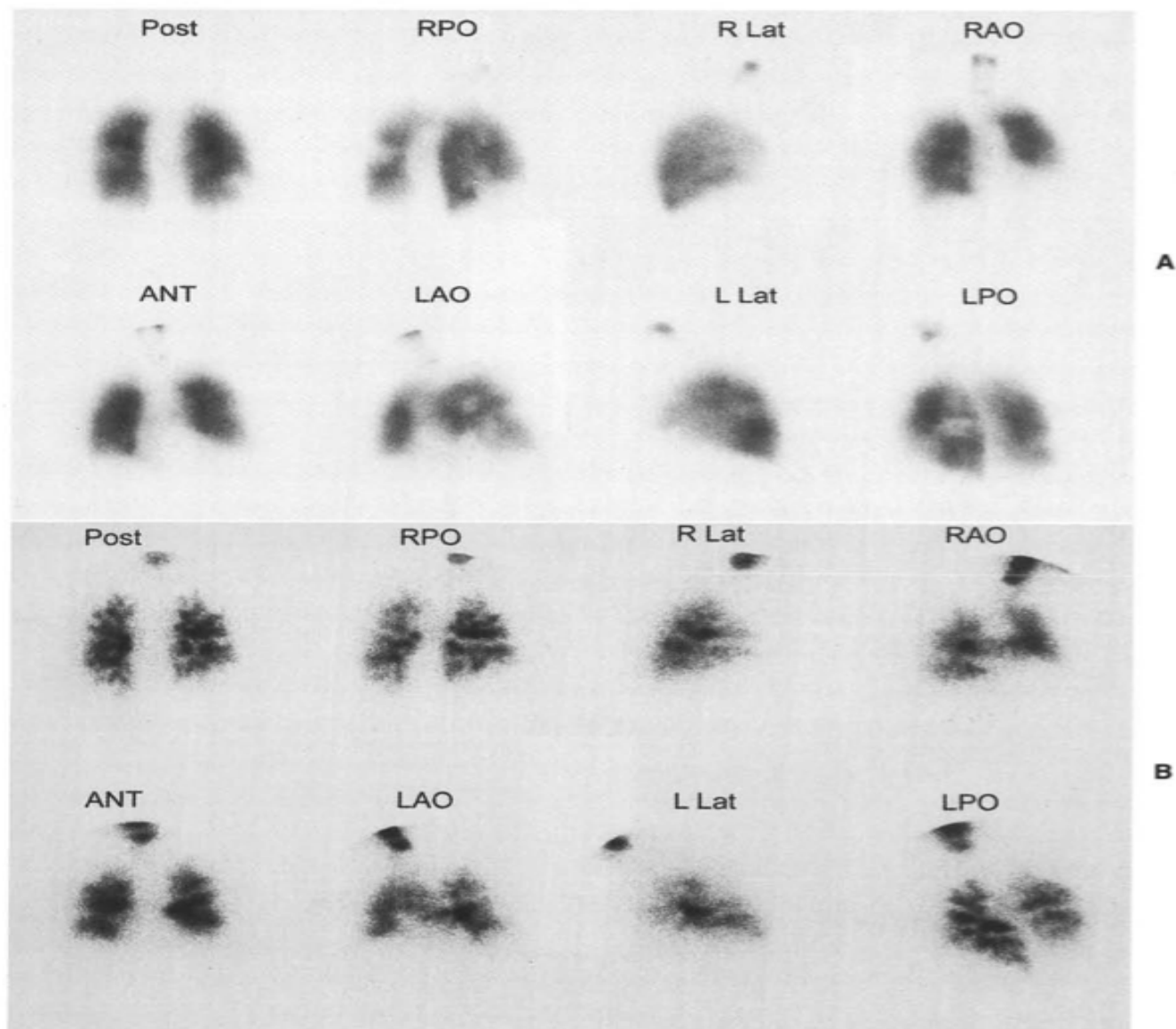


A 35-year-old man with increasing dyspnea was referred for ventilation-perfusion (V/Q) study. The chest film was clear of infiltrate, mass, or pleural disease.

1. Name the three phases of a ^{133}Xe ventilation scan.
2. Describe the phases.
3. Describe the findings on the ventilation and perfusion scans.
4. Provide an interpretation and offer a diagnosis for the underlying disease.

Emphysema caused by alfa 1 antitrypsin deficiency

1. Single breath or wash in, equilibrium and wash out phase
2. Single breath : patient breathes in and holds a single maximum deep inspiration while a 100000 count image is acquired. Equilibrium : patient breathes a mixture of air and xenon while serial images are obtained every 60 – 90 seconds for 3 minutes. Washout : patient breathes room air and exhales xenon while serial images are obtained
3. Ventilation : nonuniform in the upper lung zones bilaterally, initial near absent at the bases. As upper lobes wash out, xenon fills and is retained in both bases indicating severe air trapping. Perfusion : heterogeneous to both upper lung zones that match the early ventilation images. The extensive perfusion abnormalities in both lower lung zones are matched with areas of washout air trapping
4. Low probability for PE, alfa 1 antitrypsin deficiency

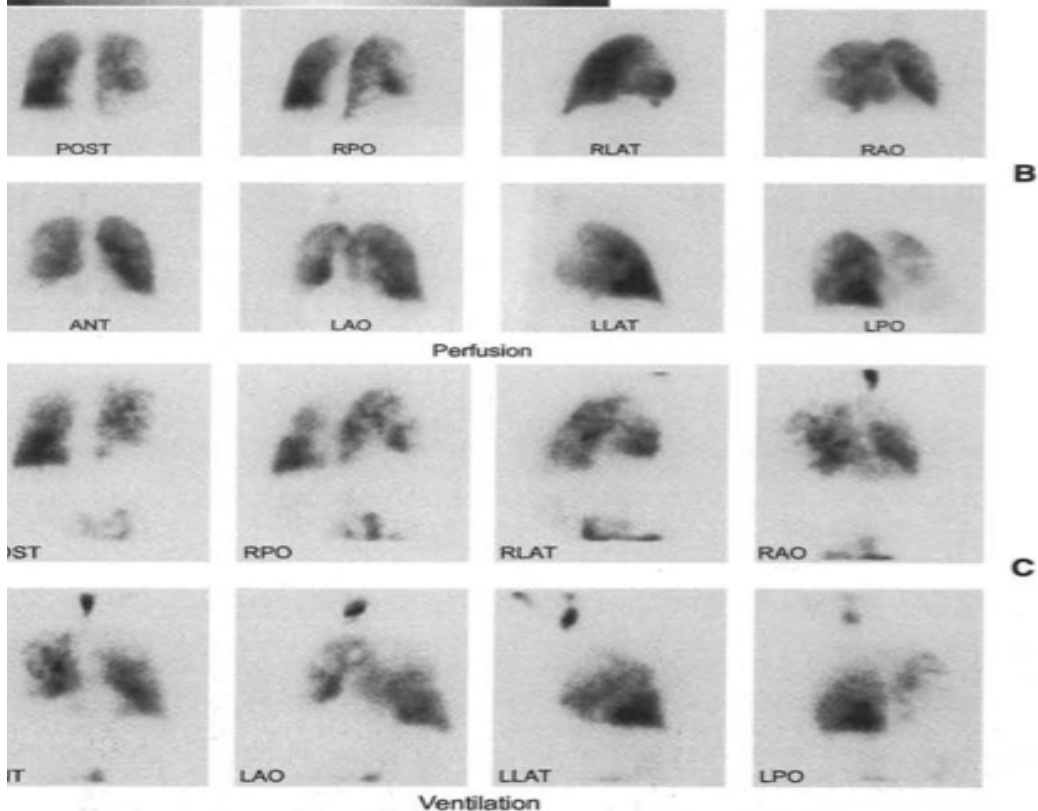


A 64-year-old man has recent onset of shortness of breath. The chest x-ray was clear.

1. Describe the image findings (*A*, perfusion; *B*, ventilation) and give an interpretation.
2. What is the ventilation study radiopharmaceutical, and what is its mechanism of distribution? What are the likely reasons for their appearance on this study?
3. Is the ventilation or perfusion study usually performed first and why?
4. What is another commonly used ventilation radiopharmaceutical that could be used, and what are the advantages and disadvantages?

Tc-99m DTPA ventilation study with aerosol clumping

1. Multiple perfusion defects in upper and lower lung fields. Many appear segmental e.g., the lateral of the right lower lobe, superior segment of the left lower lobe. Ventilation shows extensive diffused clumping within the air ways throughout both lung fields making determination of matching or mismatching difficult. The study was interpreted as intermediate probability since ventilation study could not be interpreted, however the segmental perfusion defect pattern is suspicious for embolus
2. Tc-99m DTPA aerosol provide (0.1 – 0.5 μm) normally distribute on first impact within alveoli. With airway turbulence e.g., asthma or COPD, particles impact proximally within bronchi and appear as focal hot spot
3. Tc-99m DTPA aerosol ventilation is performed first. The patient breathes in less than 1 mCi at tidal volume until an adequate count rate is obtained the sixfold larger Tc-99m MAA perfusion dose (5 mCi) overwhelms the retained ventilation dose, allowing the two consecutive Tc-99m studies
4. Xe-133 an inert gas, is advantageous for patients with COPD and asthma. Delayed filling and clearance in regions of obstructive disease can be seen. Disadvantage : only posterior views are possible because of rapid exhalation



54-year-old man with known cardiopulmonary disease complains of increasing dyspnea. *A*, Chest radiograph; *B*, perfusion scan; *C*, ventilation scan.

What are the scintigraphic findings and interpretation?

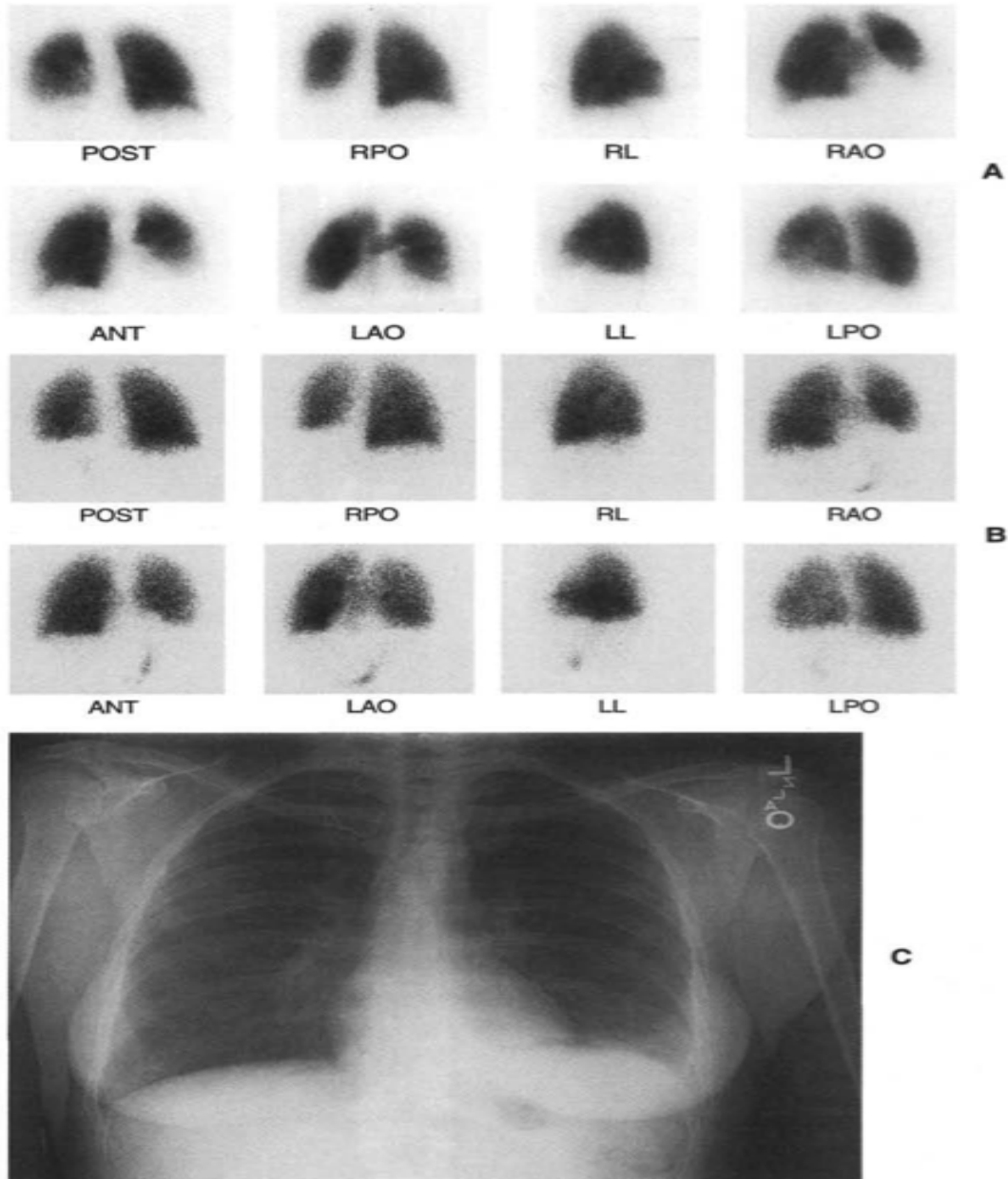
What is the likelihood of pulmonary embolus in this patient?

What is the likelihood of pulmonary embolus in a patient with a normal scan?

How are perfusion defects classified as to size?

Low probability V/Q scan

1. Bilateral inhomogeneous distribution. Matched perfusion and ventilation abnormalities throughout the upper and lower lobes, especially in the right lower lobe basal segments. Minimal atelectasis in the lower lobes in chest x-ray. Low probability for PE
2. < 20%
3. < 1 %
4. Large (segmental): > 75% of a segment
Moderate (subsegmental): 25% to 75% of a segment
Small (small subsegmental): < 25% of a segment



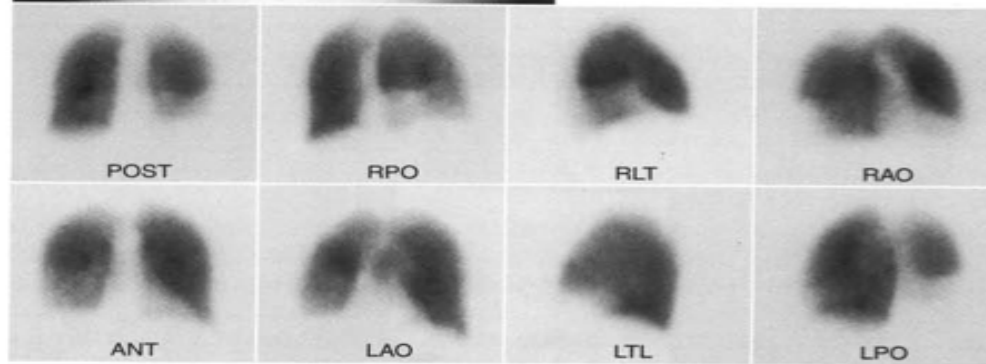
- A 29-year-old pregnant woman has a history of asthma and recent onset of dyspnea.
1. Is any patient preparation indicated?
 2. Would the patient's pregnancy change the V/Q protocol?
 3. Describe the perfusion (A) and ventilation (B) images and radiograph findings (C).
 4. Give your interpretation of the study.

Intermediate probability and pregnancy

1. Bronchodilator therapy before V/Q scan as an asthmatic therapeutic trial
2. PE are life threatening to the patient and fetus. The radiation dose to the patient and fetus is low (< 2 rads). The benefit/risk ratio is high. No change in procedure is required. In young, nonsmoking patients without cardiopulmonary disease, one might reduce the dose, conduct only a perfusion study or both
3. Hypoperfusion of the left lower lobe, except the superior segment. Better ventilation than perfusion with mismatching in the anterior basal and part of the lateral basal segments. No ventilation in the posterior basal and part of the lateral basal. Costrophenic angle loss seen in the left lateral and LPO views. CXR: atelectasis/ infiltrate with elevation of the left diaphragm
4. Intermediate probability for PE. One large/ one moderate segmental mismatch and one large and one moderate segmental match corresponding to the x-ray atelectasis/infiltrate

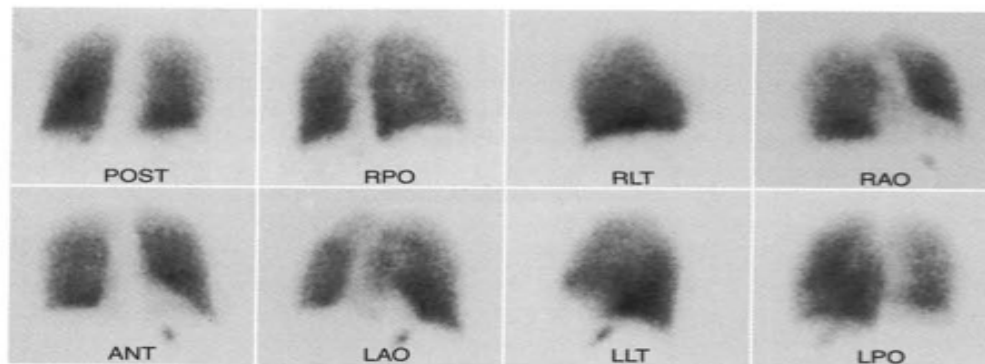


A



B

Perfusion



C

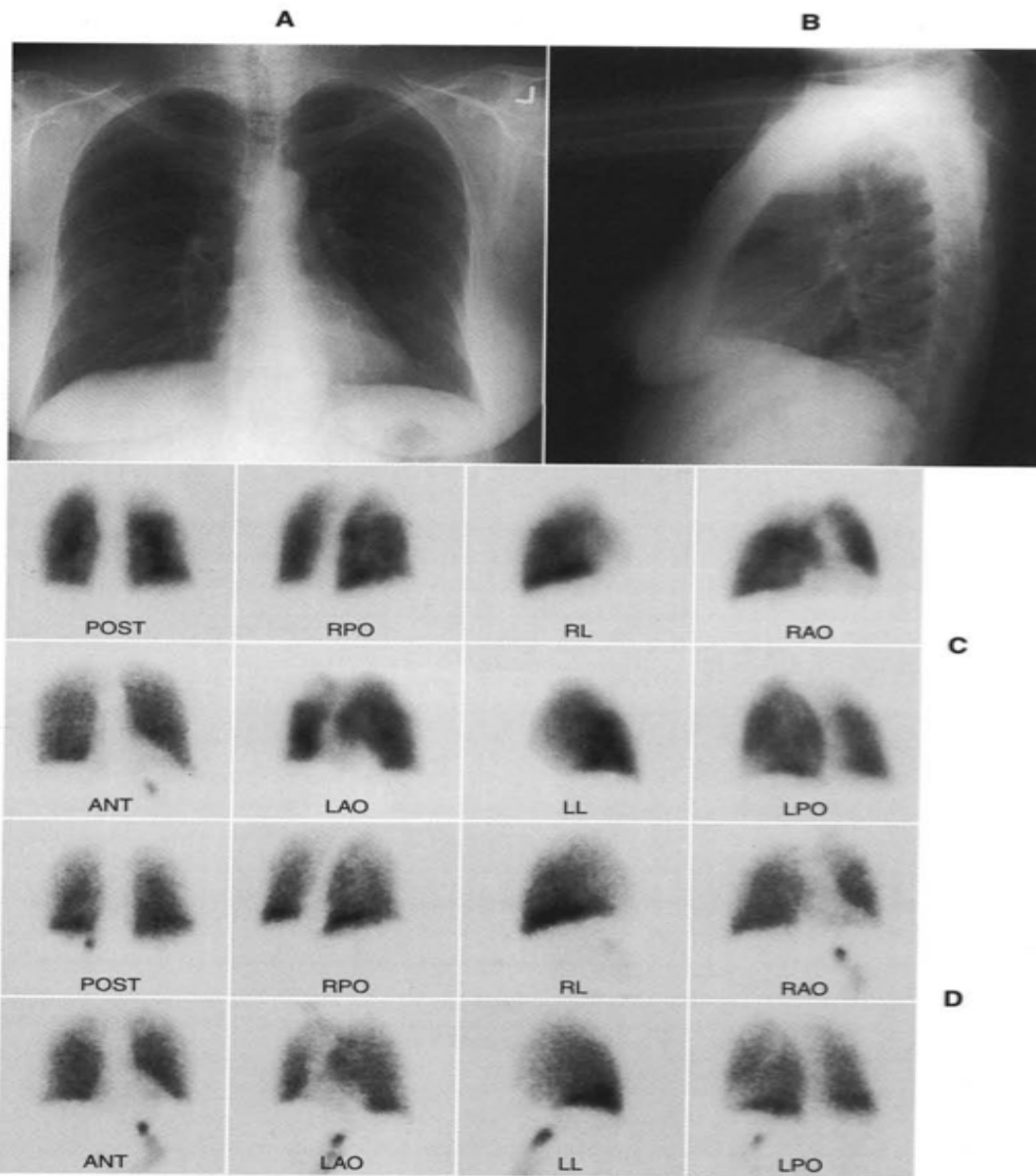
Ventilation

A 62-year-old patient with right-sided chest discomfort and shortness of breath. *A*, Posteroanterior chest radiograph; *B*, perfusion; *C*, ventilation.

1. Describe the ventilation perfusion image findings.
2. Interpret the study. Give your reasoning.
3. What is the likelihood of pulmonary embolus in this patient?
4. What are the most common chest x-ray findings in patients with pulmonary emboli?

High probability of PE

1. Perfusion: decreased right lower lobe except for the superior segment. Ventilation: normal except for mildly truncated right lower lobe consistent with subpulmonic effusion
2. High probability of PE. Mismatch between perfusion and ventilation in the basal segments. The perfusion defect is considerably larger than the pleural effusion on the radiograph
3. > 80%
4. Most common: normal, next most common: atelectasis

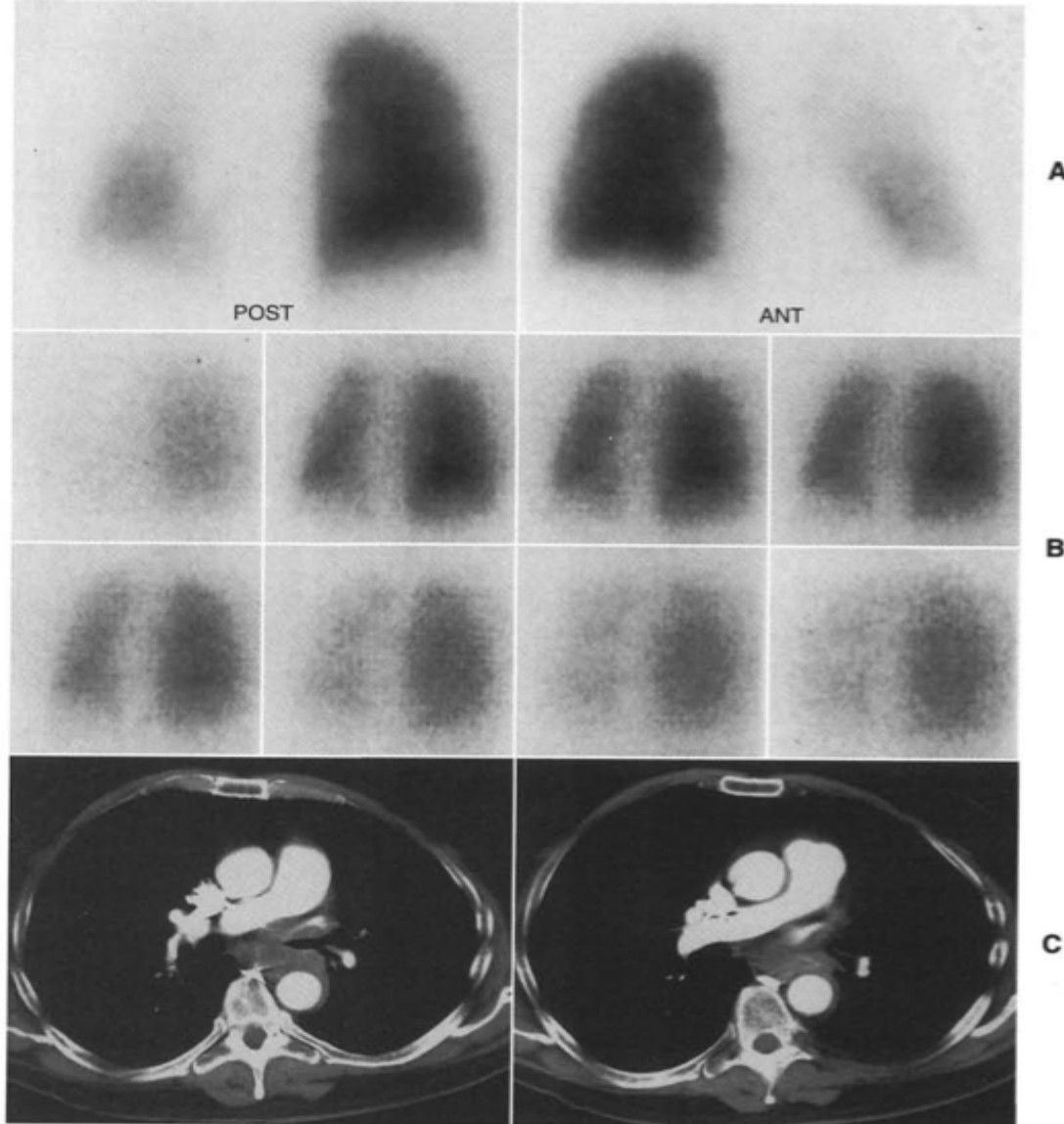


A 59-year-old patient with COPD complains of right-sided chest discomfort and shortness of breath. *A*, Posteroanterior chest radiograph; *B*, lateral chest; *C*, perfusion; *D*, ventilation.

1. Describe the ventilation-perfusion image findings.
2. Interpret the study.
3. What is a stripe sign and what is its significance?
4. What is the physiological basis of a stripe sign?

Stripe sign

1. Decreased perfusion in the right upper lobe (apical and anterior segment). Stripe sign of the posterior segment of the right upper lobe. Normal ventilation
2. Two segmental mismatched. High probability of PE
3. Its presence signifies perfused lung tissue between a perfusion defect and the adjacent pleural surface. Its presence can be use to classify a segment as not related to PE.
4. Usually a manifestation of airway obstruction. The sign has been correlated with CT and PET showing spared perfusion of the cortex of the lung in asthma and emphysema



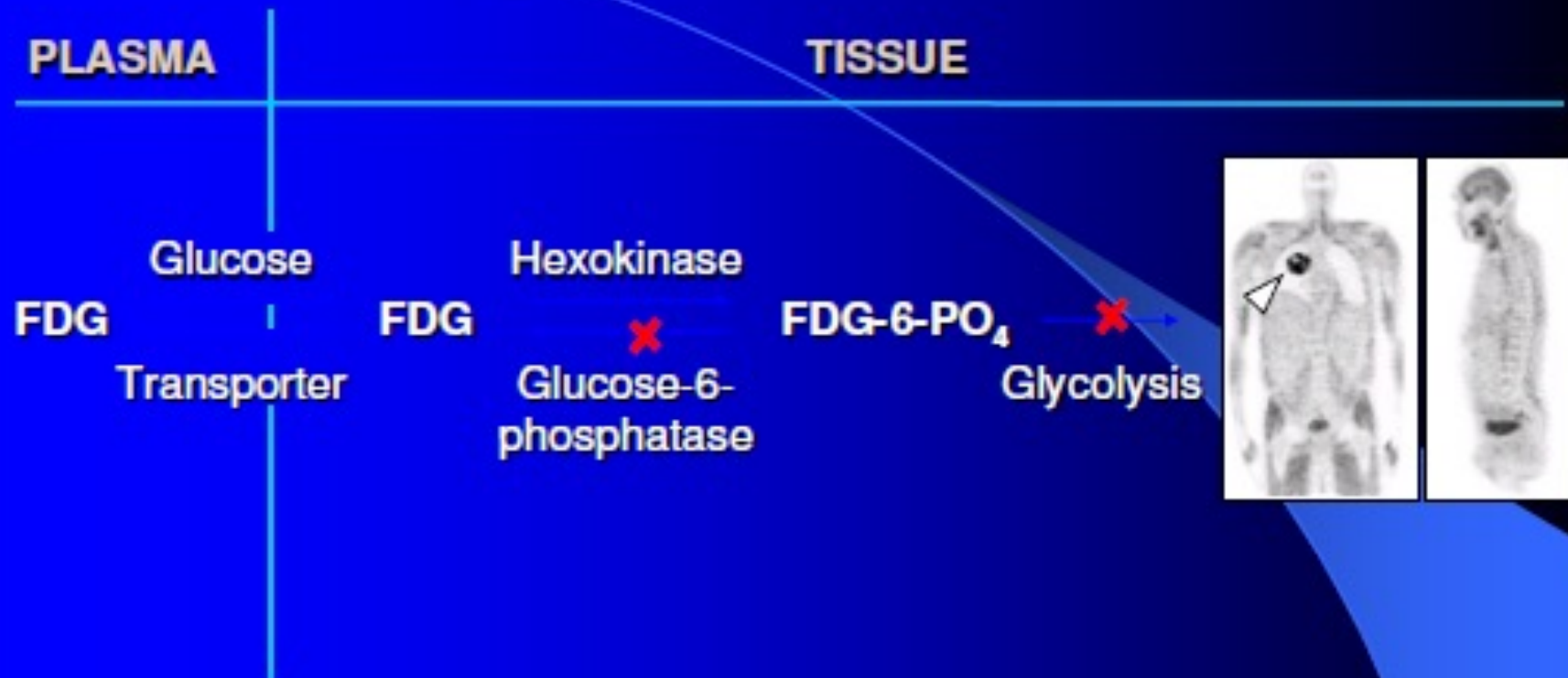
A ventilation-perfusion lung scan is ordered for increasing shortness of breath. Chest radiograph (not shown) findings were negative.

1. Describe the scintigraphic findings (A, perfusion, anterior and posterior only; B, ^{133}Xe washin-washout ventilation image sequence; C, CT).
2. What pulmonary embolus probability category would you assign?
3. Provide the differential diagnosis.
4. A chest CT was performed to further evaluate for the symptoms. What is the most likely diagnosis?

Unilateral matched V/Q abnormality

1. Perfusion: global decreased perfusion to the entire left lung, more striking than the ventilation. Xe-133 ventilation images: decreased and delayed ventilation of the entire left lung. Washout images show no significant air trapping
2. Low probability
3. Hilar mass, severe unilateral parenchymal lung disease, prior shunt for congenital heart disease
4. Lung cancer

PET and oncology



Trapping of FDG in Cell

How PET isotopes work

511 keV
gamma
photon

Electron (e^-) in
atoms of normal
matter

Positron e^+

511 keV
gamma
photon

PET isotope
nucleus
(unstable)



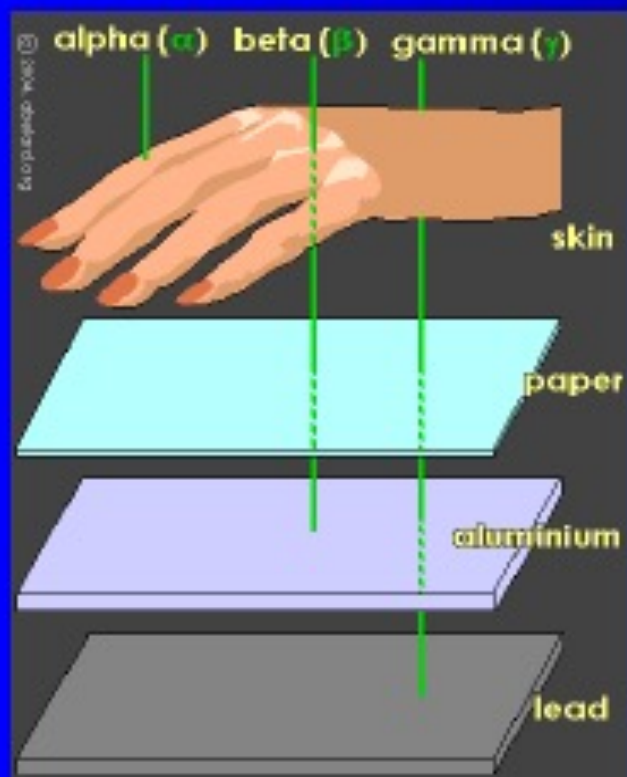
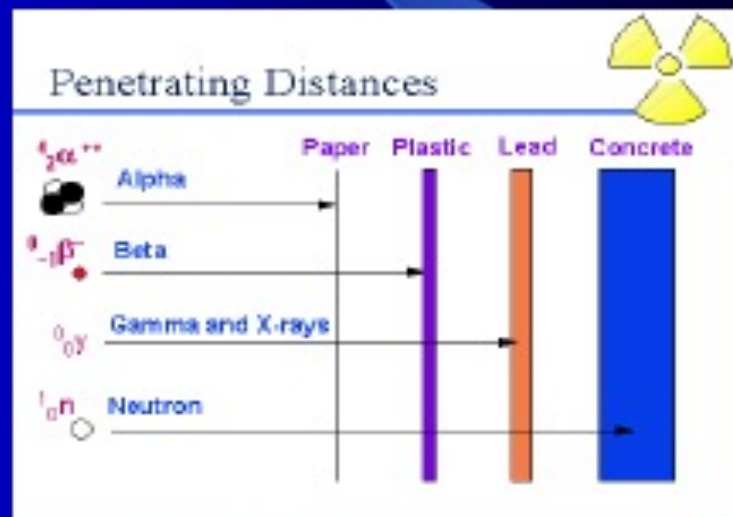
Positron emitting radionuclides

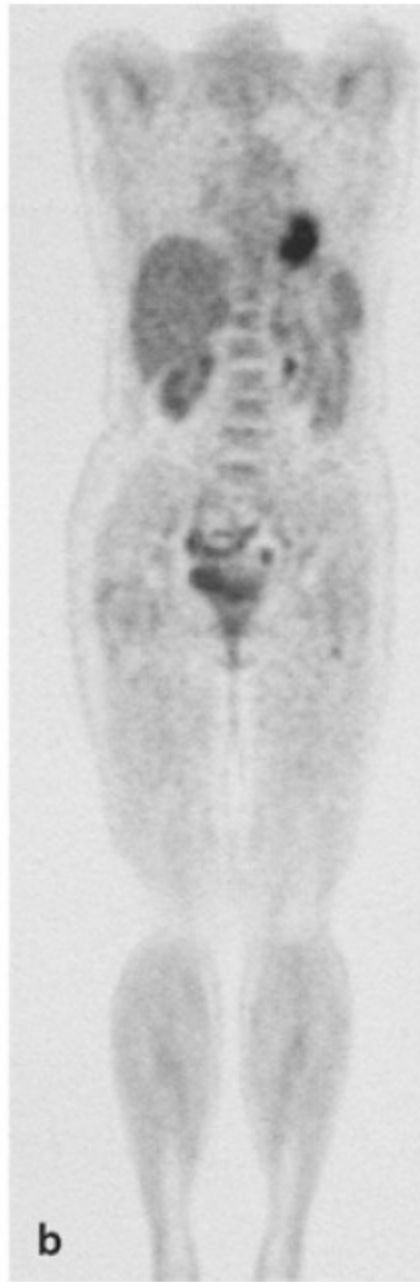
	T1/2
^{11}C	20.4 min
^{13}N	10.0 min
^{15}O	2.0 min
^{18}F	109.8 min

What is SUV?

- SUV = Standardized uptake value
- It is a qualitative evaluation which measures regional tracer concentration
- $$\text{SUV} = \frac{\text{activity concentration in tissue (Bq/gm)}}{\text{administered activity (Bq/body weight (gm))}}$$

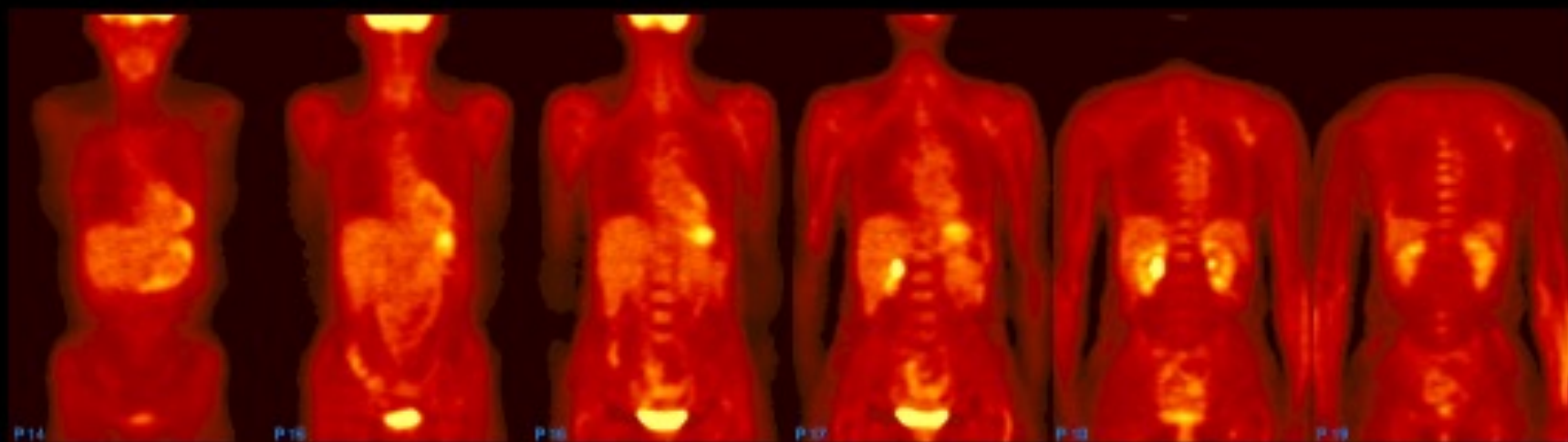
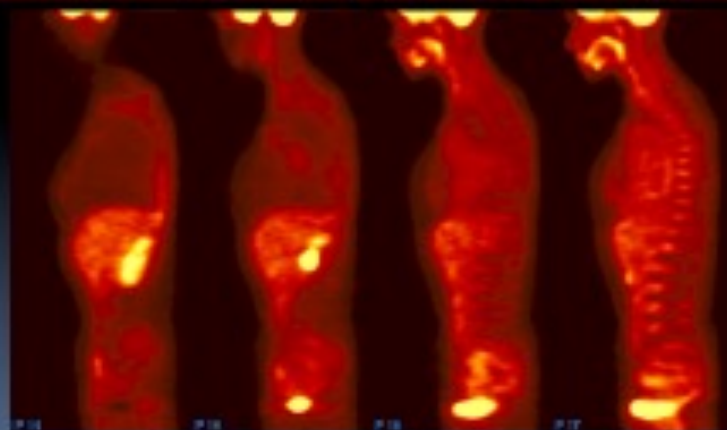
WHAT STOPS THEM !!!





- A : without attenuation corrected
- B : with attenuation corrected

F-18 FDG: Normal Distribution



Normal Physiologic Uptake

- The normal physiologic accumulation of ^{18}F FDG in the body is based on glucose metabolism, which can be variable. Physiologic uptake is normally seen in the brain, heart, liver, spleen, gastrointestinal tract, urinary collecting system (including the bladder), and bone marrow

Thymus in Children

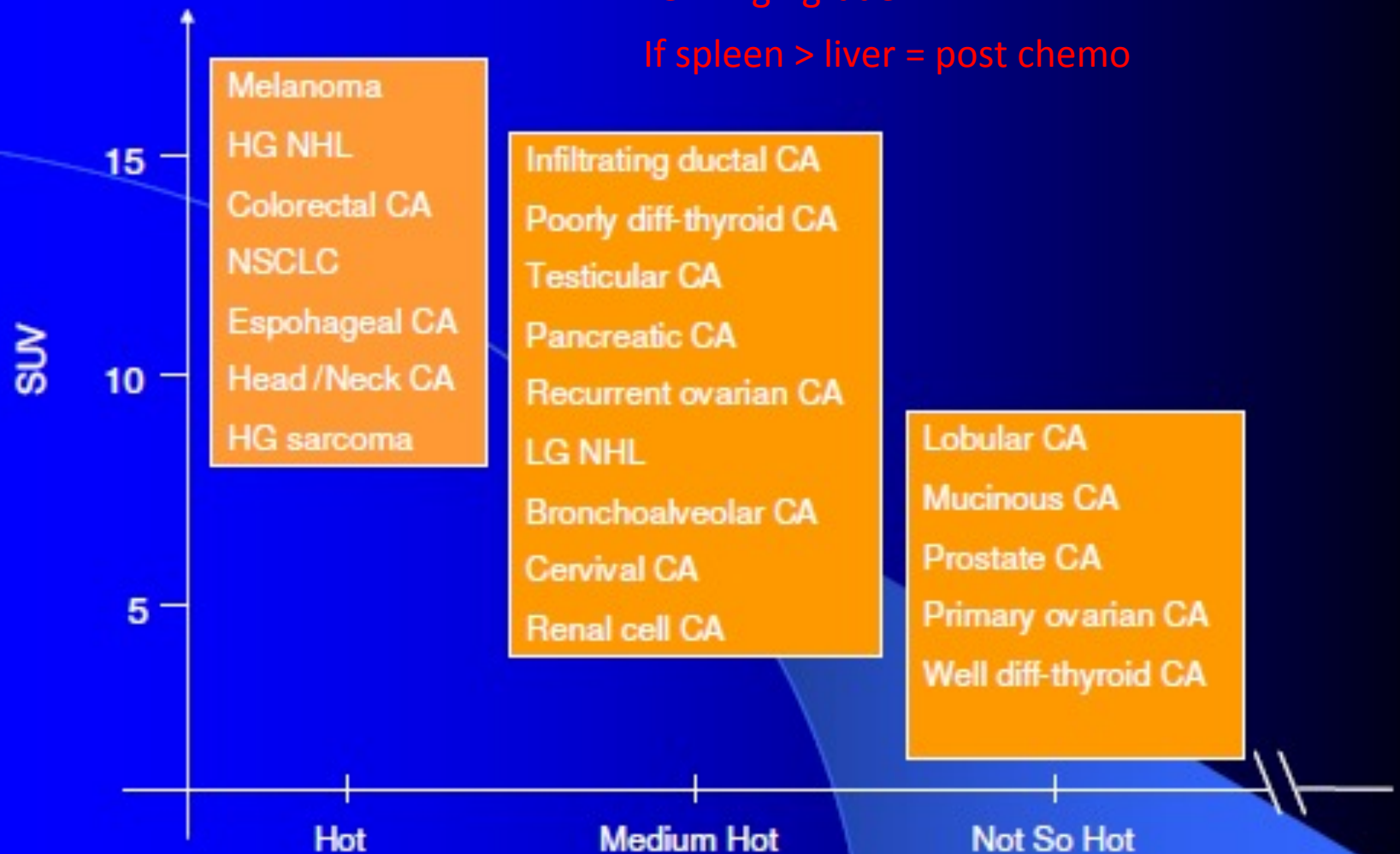
- **Thymus**
- Diffuse and homogeneous uptake in the thymus is common in healthy children
- The uptake is bilobed with an inverted V shape on coronal views
- Generally, physiologic uptake in the thymus disappears during adolescence in conjunction with involution of the thymus
- Prominent thymic uptake may also be seen following chemotherapy; homogeneous thymic uptake at post-therapy FDG PET and the absence of uptake at pretherapy FDG PET indicate posttherapy thymic hyperplasia
- Thymic hyperplasia (or “rebound”) is seen following chemotherapy more often in children than in adults

PET Scan: Patient Preparation Protocol

- Pregnancy & Breast feeding
- Fast except water 4-6 hours
- Oral hydration encouraged
- Aim diabetic control to < 8.3 mmol/L
- Stop all iron containing tablet and avoidance of vegetables, fruits , red meat , cereal, brown bread and yellow cheese
- Avoid strenuous exercise a day before and on the day of scan

HG = high grade

If spleen > liver = post chemo



False positive

Physiologic FDG uptake

- Lymphoid tissue
- Brown adipose tissue
- Glandular tissue
- Muscular system
- GI tract GU tract

Inflammation

- Therapy-related
- Ostomies, drainage tubes, stents (percutaneous),
- radiation therapy ,
- Chemotherapy

False positive

Trauma

Infection

Abscesses,

Acute cholecystitis,

Acute cholangitis,

Acute pancreatitis (chronic pancreatitis but uncommon),

Inflammatory bowel disease, Diverticulitis

Granulomatous disease: TB, fungi

Table 1 Inflammatory Lesions Showing Increased Uptake of ^{18}F -FDG in the Head and Neck Region

Location	Lesion Type
Sinonasal cavity	Sinusitis
Ear and mastoid	Otitis, mastoiditis
Mouth, pharynx, and larynx	Dental abscess, pharyngitis, tonsillitis, rheumatoid nodule in paraepiglottic space
Salivary glands	Sialadenitis

Table 2 Inflammatory Lesions Showing Increased Uptake of ^{18}F -FDG in the Chest

Location	Lesion Type
Tracheobronchial tree Lung	Tracheitis, infected bronchiectasis Viral, bacterial, fungal infection, abscess, ILD, COP, lipoid pneumonia, Langerhans cell histiocytosis, vasculitis, sarcoidosis, Wegner's granulomatosis, inhalational lung disease
Pleura	Empyema
Breast	Infected cyst (fibrocystic disease), fat necrosis, leaking breast implant

ILD, interstitial lung disease; COP, cryptogenic organizing pneumonia.

Table 3 Inflammatory Lesions Showing Increased Uptake of ^{18}F -FDG Along the Gastrointestinal Tract

Location	Lesion Type
Nonspecific inflammation	Esophagitis, gastritis, gastric ulcer, enterocolitis, appendicitis, diverticulitis, inflammatory bowel disease (Crohn's disease, UC), perianal fistula
Infection	Typhlitis
Post-therapy inflammation	Acute radiation enterocolitis, pouchitis, graft-versus-host disease

UC, ulcerative colitis.

Table 4 Inflammatory Lesions Showing Increased Uptake of ^{18}F -FDG in the Liver, Gallbladder, Biliary Tree, Pancreas, Spleen, and Peritoneum

Location	Lesion Type
Liver, gallbladder, and biliary tree	Bacterial, fungal, amebic, echinococcal abscess Acute cholangitis Acute cholecystitis
Pancreas	Acute pancreatitis
Spleen	Granulomatous infection (tuberculosis, <i>Brucella melitensis</i>) sarcoidosis
Peritoneum and mesentery	Peritonitis, abscess, fistula, sclerosing mesenteritis, primary epiploic appendagitis

Table 5 Inflammatory Lesions Involving the Genitourinary Tract

Location	Lesion Type
Kidney	Acute pyelonephritis Xanthogranulomatous pyelonephritis
Female genital tract	Hydrometros due to cervical stenosis Infected Gardner's duct cyst
Male genital tract	Epididymoorchitis prostatitis, prostatic abscess

Table 6 Inflammatory Lesions Involving the Musculoskeletal System

Location	Lesion Type	
Bones and joints	Infectious	Osteomyelitis, including discitis; SAPHO syndrome
	Inflammatory	Metallic implants (loosening, infection)
Muscles and supporting structures		Radiation necrosis
		Osteoarthritis
		Rheumatoid arthritis
		Seronegative arthritis
		Bursitis
		Tendinitis
		Synovitis Rotator cuff tear
		Polymyalgia rheumatica
		Myositis (infectious, paraneoplastic dermatomyositis)

SAPHO, synovitis, acne, pustulosis, hyperostosis, and osteitis.

Table 7 Inflammation Involving Skin, Lymph Nodes, and Blood Vessels

Skin/subcutaneous	Post-therapy	Postoperative scar
		Postradiation
		BCG or interferon injection
	Infectious	Cellulitis, furuncle, pressure ulcer
		Herpes zoster
	Inflammatory	Granulomatous changes around surgical clips
		Eosinophilic fasciitis
		Fat necrosis
		Sarcoidosis in surgical scar
		Skin vasculitis
Lymph node		Lymphedema
		Reactive (cat scratch disease, noncaseating granuloma)
		Rosai-Dorfman disease
Blood vessels	Veins	Deep or superficial vein thrombosis
		Varicose veins
	Arteries	Atheromatous plaque
		Chronic aortic dissection
		Vasculitis
		Vascular graft (including infection)

BCG, bacillus Calmette-Guérin.

Table 8 Benign Tumors and Tumor-Like Conditions Showing Increased Uptake of ^{18}F -FDG in the Head and Neck, Chest, and Abdomen

Head and neck	Pituitary	Adenoma
	Nose & nasal sinus	Inverted papilloma (nasal)
	Parapharyngeal space	Benign hemangiopericytoma
	Thyroid	Adenoma
Chest	Lung	Multinodular goiter
	Breast	Amyloidosis
		Papilloma
		Fibroadenoma
		Diabetic mastopathy
Abdomen	Liver and biliary tract	Hepatic adenoma
		Benign neuroendocrine tumor
	Gastrointestinal tract	Hyperplastic polyp, adenoma
	Spleen	Gaucher's disease
	Adrenal	Adenoma
		Benign Pheochromocytoma
	Genitourinary: female	Hemorrhagic ovarian cyst, endometrioma
		Ovarian cystadenoma
	Genitourinary: male	Uterine leiomyoma
		Prostatic adenoma

Table 9 Benign Tumors and Tumor-Like Conditions Showing Increased Uptake of ^{18}F -FDG in the Skin and Musculoskeletal, Cardiovascular, and Nervous Systems

Skin/subcutaneous	Hibernoma
	Eosinophilic fasciitis
Musculoskeletal	Spur
	Exostosis
	Schmorl's node
	Nonossifying fibroma
	Enchondroma
	Eosinophilic granuloma
	Fibrous dysplasia
	Paget's disease
	Avascular necrosis
	Gaucher's disease
	Erdheim-Chester disease
Cardiovascular	LHIS
Nervous system	Neurofibroma
	Schwannoma

LHIS, lipomatous hypertrophy of the inter-atrial septum.

PET Limitations: False Positive

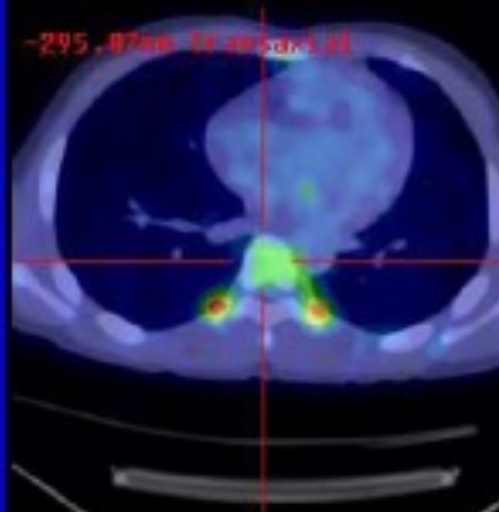
- GIT & Urinary activity
- Myocardial activity
- Breast, thymus
- Inflammation
- Trauma, surgery, fracture
- Skin contamination
- Reconstruction, metallic artefacts
- Motion artefacts
- Skeletal muscle & Brown fat

P5

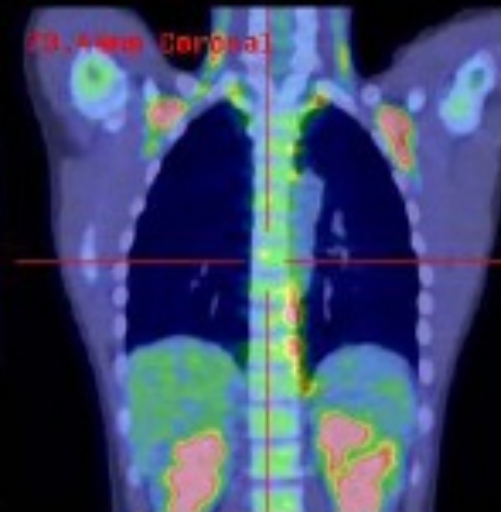
Sagittal



-295.87mm Transaxial

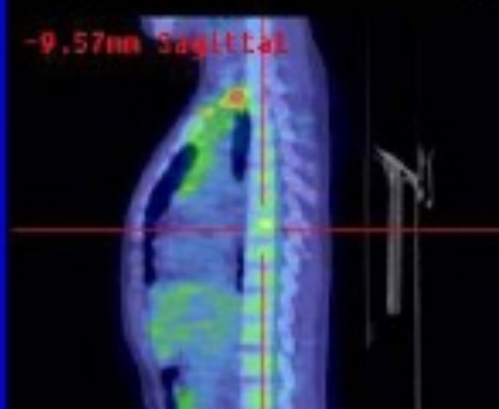
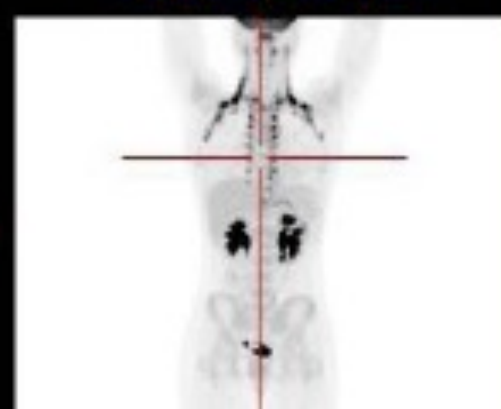


29.44mm Coronal



**Muscles &
Brown Fat**

-9.57mm Sagittal



False negative

Small lesions(<5-10 mm, i.e. ampullary carcinomas, miliary carcinomatosis)

Low cellular density

- Tumors of the infiltrating type (cholangiocarcinomas)
- Tumors with large mucinous components
- Tumor necrosis

Some low grade tumors: Lymphoma, sarcoma,...

Low sensitivity: ~ 50-80%

- GU: Prostate, Renal cell
- GYN: Ovarian (mucinous, miliary spread)
- Hepatocellular
- Differentiated neuroendocrine
- Bronchioalveolar

Hyperglycemia and/or insulin less than 3 H prior to FDG

WHEN TO SCAN?

- Radiotherapy: > 4 weeks
- Chemotherapy: > 2 weeks
- Post surgery: > 4 weeks

Brown Fat

- Sedation
- Adrenergic blocking agents

High FDG uptake

Higher tumor grade

Large number of variable
cells

Increased tumor blood flow

Inflammation

Tumor hypoxia

Acute radiation

Recent chemotherapy

Recent surgery

Low FDG uptake

Benign lesion

Necrosis

Mucinous , bronchoalveolar carcinoma

Hyperglycemia

High insulin

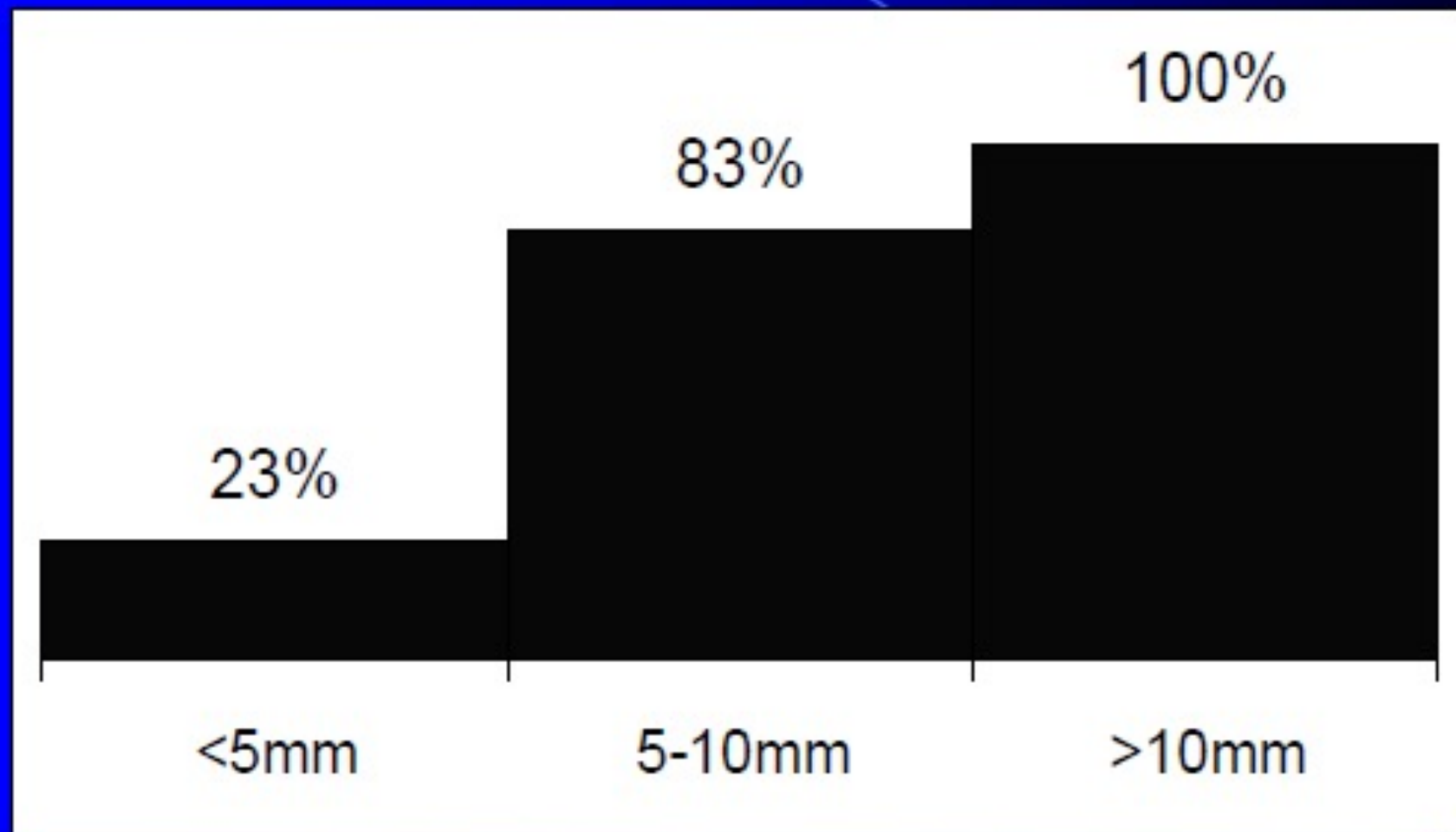
Chronic radiation

Scar

Prior chemotherapy

History	Course of action
Prior surgery	Delay scan 4-6 weeks
Chemotherapy	Delay scan several weeks or schedule scan just before next cycle
Radiation therapy	Delay scan at least 3 months
Colony stimulating factor	Delay scan for 1 week for short acting agents or several weeks for long acting agents
Serum glucose > 200	Reschedule scan
Insulin administration	Wait at least 2 hours
Breastfeeding	Discontinue scan at least 6 hours

Which size of lymph node metastases can FDG PET detect?



FDG PET Literature Summary in Oncology

**JNM 2001; 42:1S-93S
(419 articles: 1993-2000)**

- **Average FDG PET accuracy**

Sensitivity: 84% (84-87%) n=18402

Specificity: 88% (88-93%) n=14264

Accuracy : 87% (87-90%) n= 9994

- **Average management change**

30% n=5062

FDG-PET during therapy (H&N)

- **Brun (EANM 2003, Sweden): n=47**

**early change in FDG uptake
associated better outcome**

- **5 year survival : 72% vs 35%**
- **locoregional control : 96% vs 55%**

PET and Cancer Treatment

- Useful in making treatment decision in 89-96%
- Treatment was changed in 45-60%
based on PET scan
- Predicts treatment outcome and response

(After 1 cycle chemotherapy)

PET (+)	→	90% relapse
PET (-)	→	85% remission

Kostakoglu et al. JNM, 2002

Which of these statements is true regarding F-18 FDG PET?

- A. F-18 FDG uptake is normally high in brain and heart
- B. The mechanism of F-18 FDG uptake and metabolism is identical to that glucose
- C. Oncology patients should fast for at least 4 hours prior to injection
- D. Unlike glucose, F-18 FDG is excreted through the genitourinary system

Which of these statements is true regarding F-18 FDG PET?

- TFFT

The sensitivity of FDG PET is high for detection of many malignancies. For which of the following tumors is the sensitivity of FDG PET not high?

- A. Colorectal cancer
- B. Melanoma
- C. Hepatocellular carcinoma
- D. Renal cell carcinoma
- E. Lymphoma

The sensitivity of FDG PET is high for detection of many malignancies. For which of the following tumors is the sensitivity of FDG PET not high?

FDG PET has poor sensitivity for primary hepatocellular carcinoma, renal cell carcinoma and prostate cancer.

This is less true of metastatic disease than primary tumors.

Concerning F-18 FDG PET in lung cancer staging

- A. The sensitivity for detection is high for tumors of 5mm and greater size.
- B. Sensitivity and specificity of FDG PET is higher than CT for mediastinal staging for lung cancer.
- C. False negatives may be seen with hyperglycemia.
- D. False negatives may occur with bronchoalveolar carcinoma

Concerning F-18 FDG PET in lung cancer staging

- FTTT

What are the advantages CT PET over PET alone?

- A. Automated hardware and software fusion for anatomical fusion
- B. Diagnostic CT at the same time as the PET scan.
- C. CT is used for more rapid attenuation correction.
- D. Eliminates false positive interpretation.

What are the advantages CT PET over PET alone?

- TFTF

What are some limitations of FDG PET
in tumor staging?

What are some limitations of FDG PET in tumor staging?

- PET imaging does not detect microscopic metastases, tumor involvement in local LNs may be obscured by activity in an adjacent tumor, concurrent infection/inflammatory process may cause false positive and sensitivity for intracranial metastases is low.

What are limitations of tumor
restaging by PET?

What are limitations of tumor restaging by PET?

- Post therapy effect of surgery, chemotherapy and radiation therapy may cause increased F-18 FDG uptake, which can be confused activity from active tumor.
- Even patients scheduled for imaging after an appropriate delay after therapy may require follow up imaging.

What are some differences between nonattenuation corrected and attenuation corrected PET images?

What are some differences between nonattenuation corrected and attenuation corrected PET images?

Nonattenuation
corrected

- Structures near surface more intense
- The skins more intense
- The lungs more intense

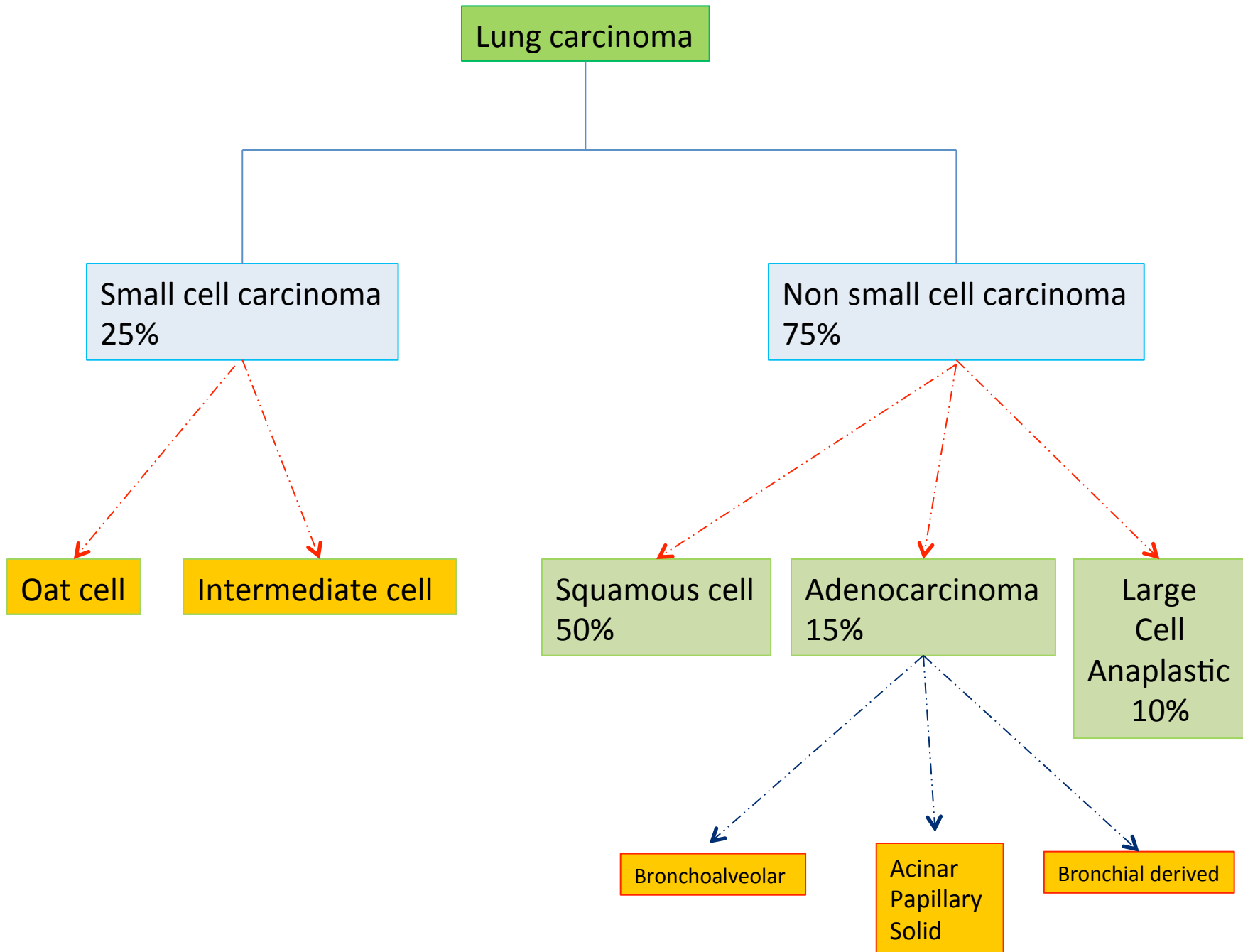
Lung carcinoma

- PET sensitivity in 1 node is 75%
- Pet sensitivity for mediastinal involvement is 91%
- Adrenal is most common metastasis site

Lung carcinoma

Epidemiology

- UK = 38000 cases
- 22000 men and 16000 women
- Death = 34000 per annum
- Peak incidence in Europe 60-70 years
- 3 x more common in men



Lung carcinoma

Symptoms

- Cough
- Hemoptysis
- Dyspnea
- Chest pain
- Recurrent chest infection