Embolie pulmonaire pendant la grossesse ou l'allaitement : angioscanner ou scintigraphie ?

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5è journée de Radiologie Pédiatrique Pratique
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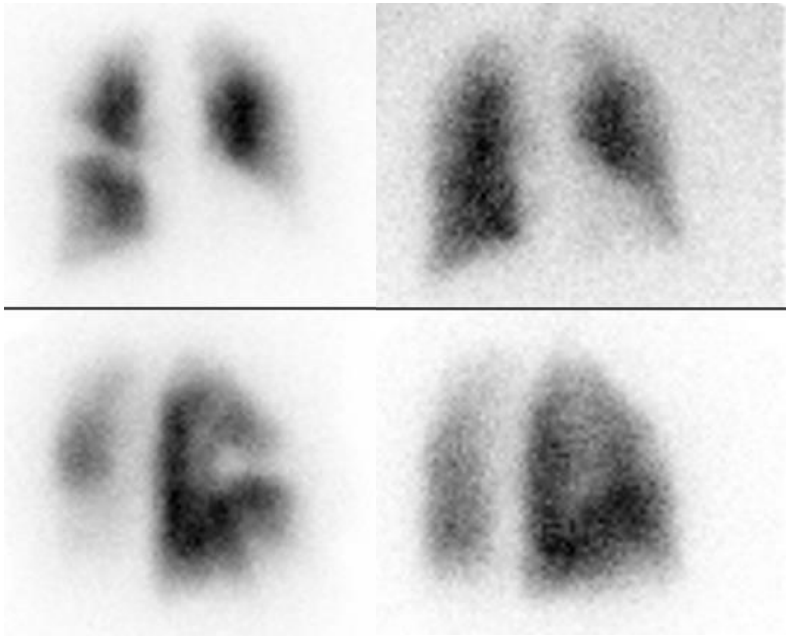
Introduction

- Pregnant women: 4 to 5 x higher risk of VTE
- PE incidence: 10,6 / 100000
- PE: 2 -14% of all maternal deaths worldwide
- PE prevalence: 3 to 6% of women with signs and symtoms
- Guidelines developped for non-pregnant population not developed nor validated in pregnant pts
- Wells score and revised Geneva: not valuable in the pregnant and post partum population
- D-dimer levels lose diagnostic accuracy due to a physiological increase during normal pregnancy

Tromeur et al. Haematologia, 2019.
Touhami et al. Eur J Obs and Gyn and Repr Biol, 2017.
Van der Pol et al. Blood reviews, 2017.
Leung et al. Am J Respir Crit Care Med , 2011.

Introduction

- Imaging tests remain the cornerstone of evidence based diagnostic management of suspected PE in pregnancy
- **CTPA** **V-Q lung scanning**



- → exposure of the fetus and patients' breasts to radiation.

The guidelines ?

Guideline summary on V/Q scan and CTPA for suspected PE in pregnancy.

Guideline	Recommendation
Working Group in Women's Health the Society of Thrombosis and Haemostasis (GTH 2016)	"If lung scintigraphy is available, a low-dose perfusion scan is the preferred imaging technique to diagnose or exclude pregnancy-associated PE in women with normal chest X-ray (CXR) because this method exposes maternal breasts to less radiation than CTPA. If an initial CXR is abnormal or if lung scintigraphy is non-conclusive or not available, CTPA should be prioritized."
Royal College of Obstetrician and Gynecologist (RCOG 2015)	"In women with suspected PE without symptoms and signs of DVT, a V/Q lung scan or a CTPA should be performed." (Grade C recommendation) "When the CXR is abnormal and there is clinical suspicion of PE, CTPA should be performed in preference to a V/Q scan." (Grade D recommendation) "Alternative or repeat testing should be carried out where V/Q scan or CTPA is normal but the clinical suspicion of PE remains." (Grade C recommendation)
European Society of Cardiology (ESC 2014)	"Perfusion scintigraphy may be considered to rule out suspected PE in pregnant women with normal CXR." (Class IIb recommendation) "CTPA should be considered if the CXR is abnormal or if lung scintigraphy is not readily available." (Class IIa recommendation)
Society of Obstetricians and Gynecologist of Canada (SOGC 2014)	"For the diagnosis of PE, either V/Q scan or CTPA can be used." (Class A recommendation) "In pregnant women, a V/Q scan is the preferred test." (Class B recommendation)
Australia and New Zealand Guidelines (ANZ), endorsed by ASTH & SOMANZ (2012)	"V/Q scanning is the preferred investigation in pregnant or postpartum women with suspected PE who have a normal CXR." (Level 1 group consensus) "CTPA should be used in women with an abnormal CXR or where V/Q scanning is inconclusive or not available." (Level 1 group consensus)
American Thoracic Society/Society of Thoracic Radiology (ATS/STR 2011)	"In pregnant women with suspected PE and a normal CXR, we recommend lung scintigraphy as the next imaging test rather than CTPA." (Strong recommendation) "In pregnant women with suspected PE and an abnormal CXR, we suggest CTPA as the next imaging test rather than lung scintigraphy." (Weak recommendation)
European Association of Nuclear Medicine (EANM 2009)	"In pregnancy, particularly during the first trimester, a 2-day protocol starting with a perfusion-only scan followed if necessary by a second day ventilation study." (Grade C recommendation)

Optimal choice of imaging test to rule out or confirm acute PE in pregnant patients is highly debated …

Wan et al. Thrombosis Research 2017.

Chest X-ray

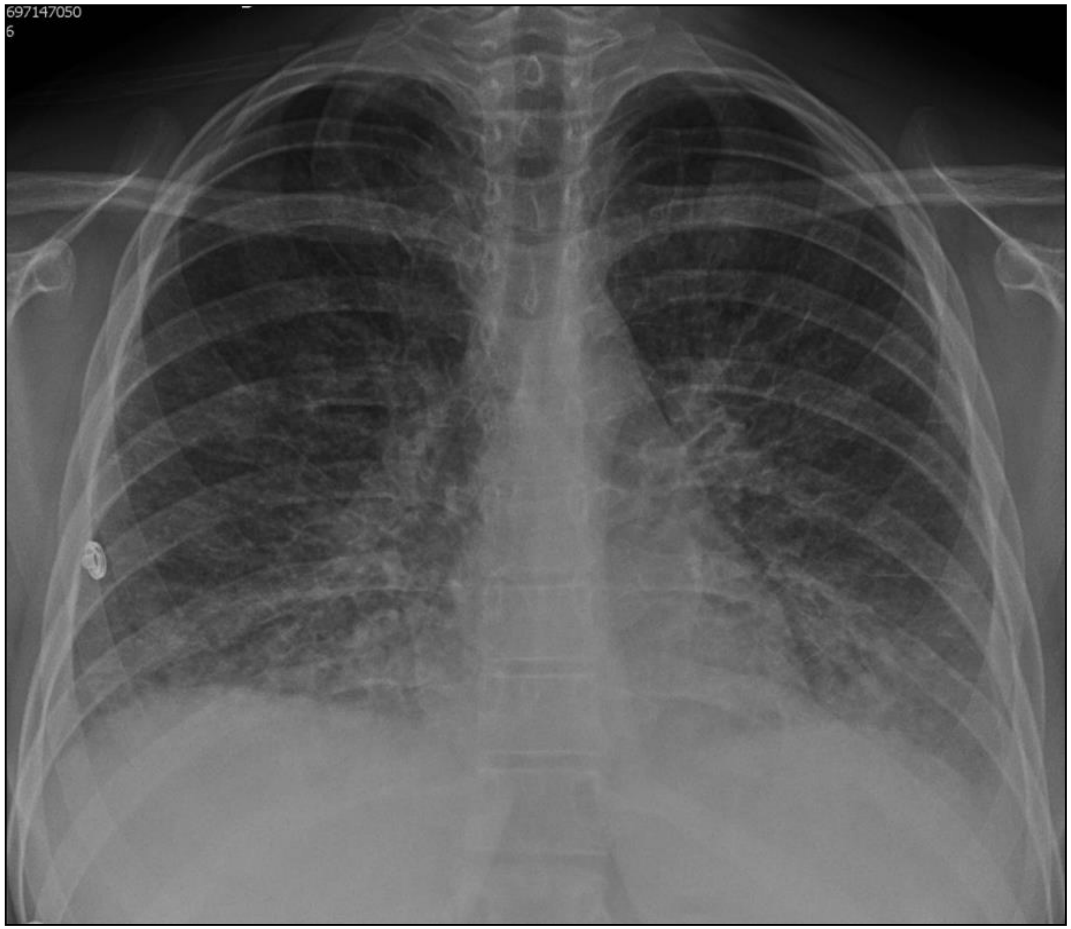
Advantages

- Helps triage between CTPA and LS
- Helps alternative diagnosis
  - Signs of pulmonary congestion
    - Preeclampsia
    - Tocolytic treatment
    - Pregnancy-related cardiomyopathy
  - Consolidation
    - Infection
    - Amniotic fluid embolism

Disavantages

- Less sensitive than CTPA and scintigraphy for diagnosing PE
- Radiation but precautions (0,05 mSeV)

Chest X-ray



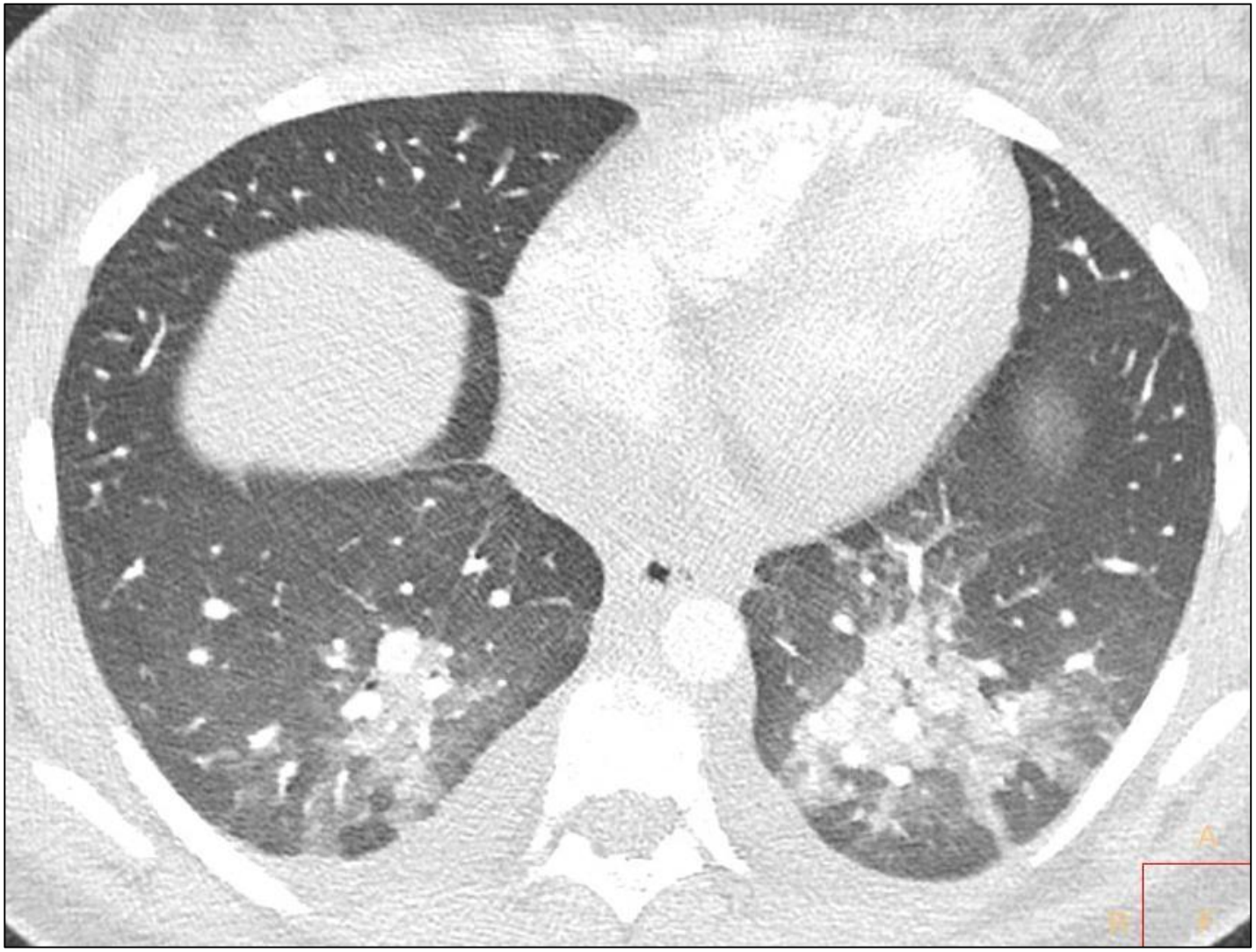
Courtesy MP Revel-Paris

Mycoplasma pneumoniae infection @ 25 weeks' gestation

Chest X-ray

21-year old woman-chest pain and dyspnea-33W

Chest X-ray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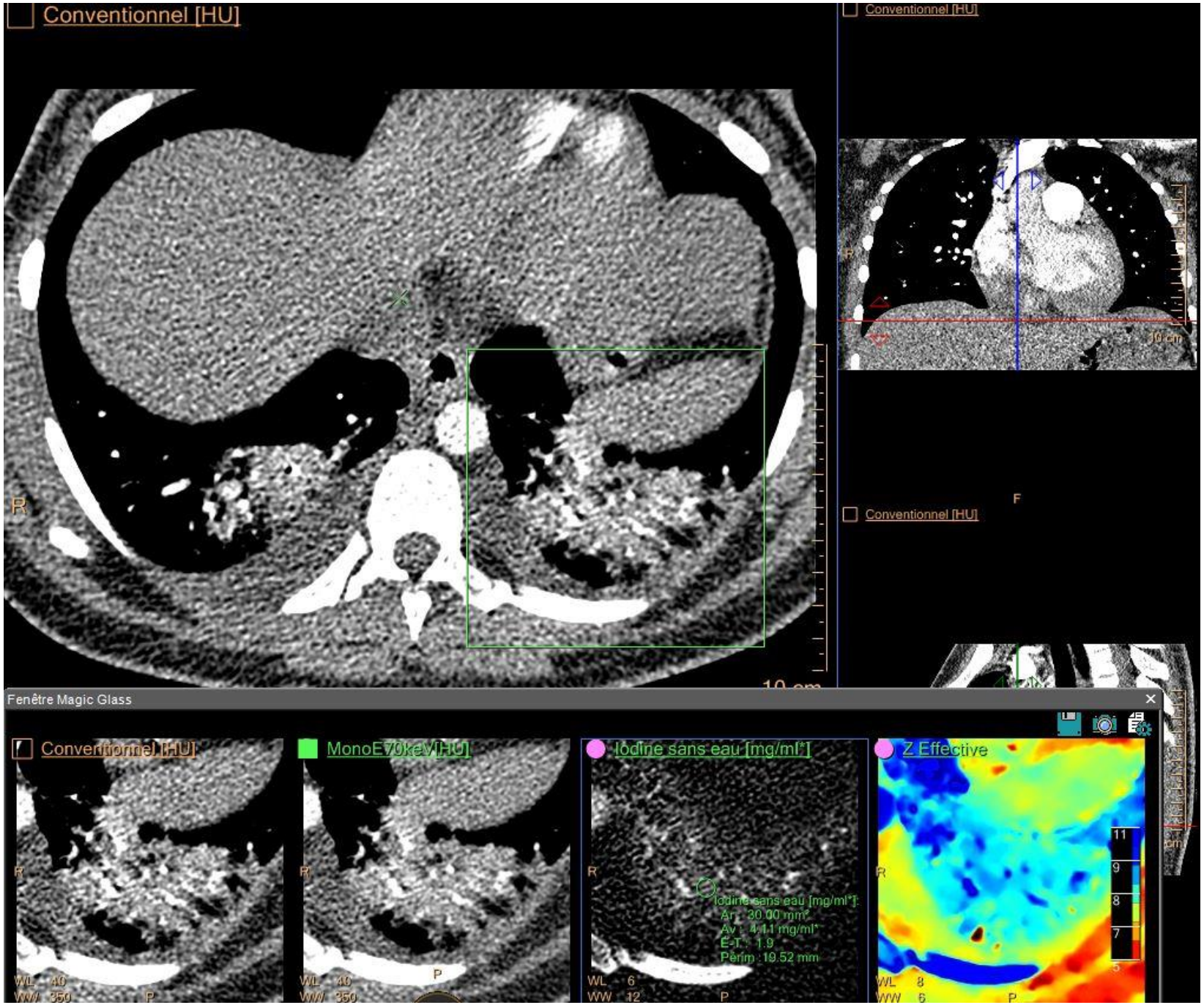
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Iodine sans eau [mg/ml*]
Z Effective
Iodine sans eau [mg/ml*]:
Ar : 30.00 mm²
Av : 4.11 mg/ml*
E-T. : 1.9
Périm : 19.52 mm
WL 40
WW 350
WL 6
WW 12
WL 8
WW 6
11
9
8
7
5

Diagnosis of DVT

- During pregnancy
  - US (MR without contrast?)
    - Gadolinium & CT venography are contra-indicated
- Postpartum
  - Phlebovenography: diagnosis of utero-ovarian vein thrombosis
    - **Increased Detection of thromboembolic disease (+12%)**

Journal of Thrombosis and Haemostasis, **6**: 1478–1481 DOI: 10.1111/j.1538-7836.2008.03078.x

ORIGINAL ARTICLE

Contribution of indirect computed tomographic venography to the diagnosis of postpartum venous thromboembolism

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Venous Ultrasound

Advantages

- No radiation to the mother/baby
- Confirm the diagnosis of PE if positive on proximal in patients with thoracic symptoms
- If negative on proximal and distality: rule out with confidence the diagnosis of PE*

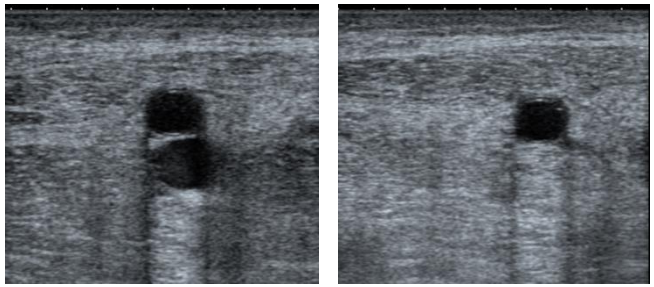
Disadvantages

- Does not explore the pelvic veins
- If negative, necessitates other tests in patients with suspicion of PE

*Le Gal et al. BMJ 2012

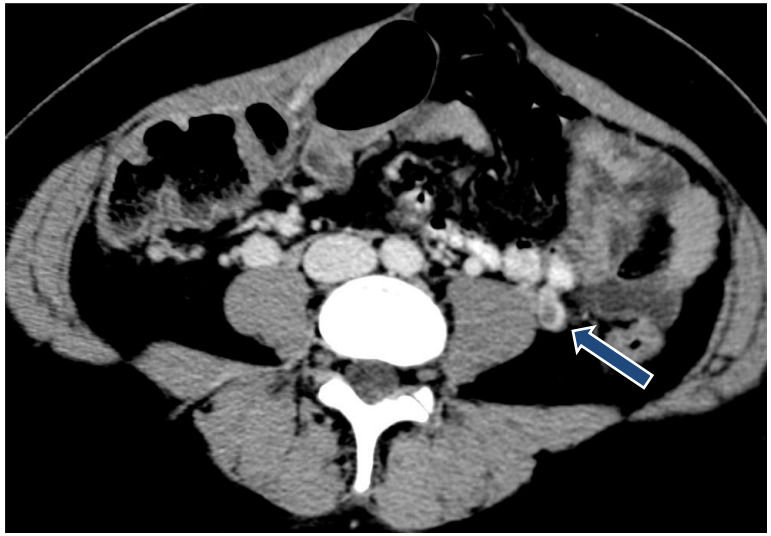
Venous Ultrasound

- In patients suspected of PE (thoracic symptoms) finding a proximal DVT (popliteal vein or above) is sufficient to warrant anticoagulant treatment
  - A positive proximal CUS, in a patient with PE suspicion (thoracic symptoms), has 99 % specificity for the presence of PE on MSCT



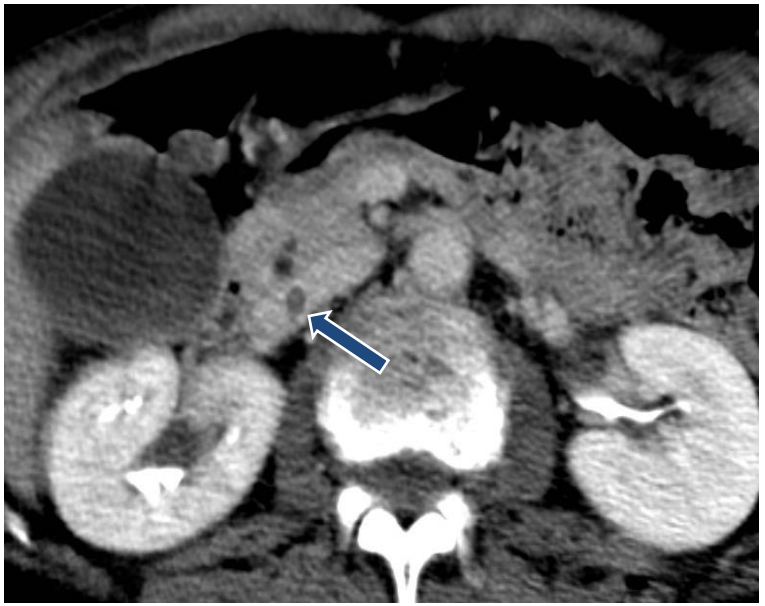
*Le Gal et al. BMJ 2012

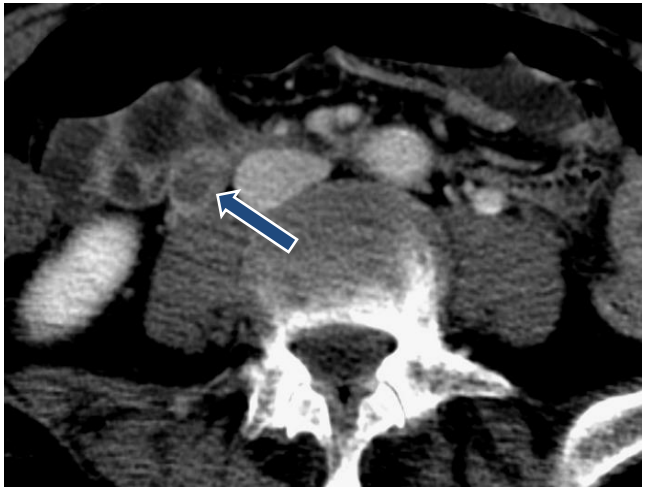
CT Venography (Post Partum)



Courtesy MP Revel-Paris

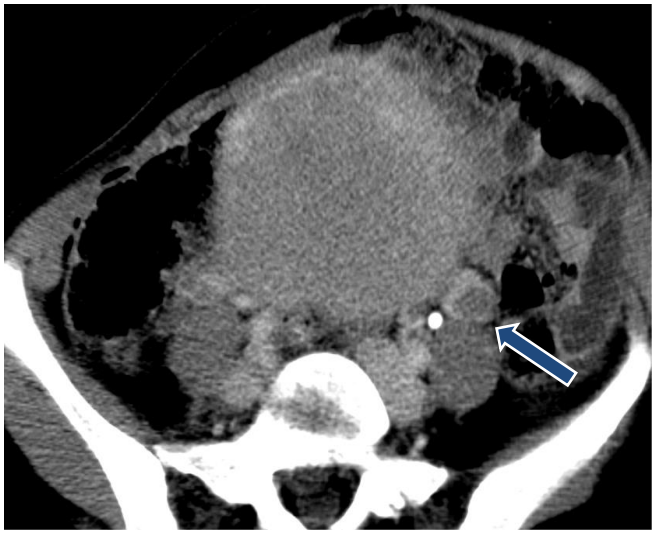
CT Venography (Post Partum)

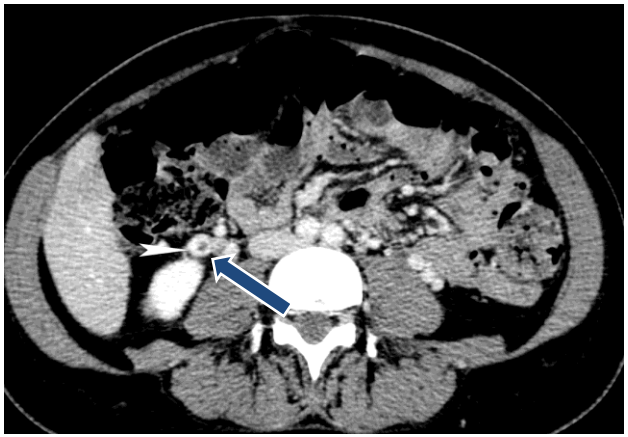




Courtesy MP Revel-Paris

CT Venography (Post Partum)





Courtesy MP Revel-Paris

CT ANGIOGRAPHY

CT angiography

- Radiation exposure
  - Fetal dose < scintigraphy (both are low)
  - **Maternal breasts: 10-70 mGy vs 0.28 mGy for scintigraphy**
- Iodinated Contrast medium
  - Risk of fetal dysthyroidism?
    - Bourjeily et al*: 334 exposed new borns, all had a normal T4 at birth
- Inconclusive results >> general population

−

- Direct visualisation of the clots, High diagnostic performance
- Alternative diagnoses

+

*Bourjeily et al. Radiology 2010

CT angio versus scintigraphy

Table 6 Relative strengths and weaknesses of MDCT pulmonary angiography and lung scintigraphy in the evaluation of PTE

Modality	Strengths	Weaknesses
MDCT pulmonary angiography	High overall accuracy	High relative radiation burden
	High interobserver agreement	Patient safety issues: contrast reactions; renal impairment; injection site trauma
	Provision of alternative diagnoses	Dilemma of "incidental" PTE
	High out-of-hours availability	Higher relative cost
	Rapidity of acquisition	Variable worldwide availability
	Assessment of haemodynamic surrogates for prognosis	Not suitable for follow-up
Lung scintigraphy	High NPV in low pretest probability	Lower overall specificity
	High PPV in high pretest probability	Lower interobserver agreement of intermediate probability scans (PIOPED)
	Relative safety in certain patient groups	Poorer out-of-hours availability in some areas
	Lower radiation dose	Longer acquisition time
	Lower relative cost	Does not provide alternative diagnoses
	Suitable for follow-up	
	Higher worldwide availability	

Reid JH, Coche EE, Inoue T, et al. International Atomic Energy Agency Consultants'group.
Is the lung scan alive and well? Facts and controversies in defining the role of lung scintigraphy for the diagnosis of pulmonary embolism in the era of MDCT. Eur J Nucl Med Mol Imaging . 2009 Mar;36(3):505-21. doi: 10.1007/s00259-008-1014-8.

Diagnostic Accuracy

Pulmonary Embolism during Pregnancy: Diagnosis with Lung Scintigraphy or CT Angiography?[1]

Marie-Pierre Revel, MD, PhD
Stéphanie Cohen, MD
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Marie-Anne Collignon, MD
Rokhaya Thiam, MS
Alban Redheuil. MD

Radiology

Purpose: To evaluate the rate of positive, negative, and indeterminate results and the agreement between initial and expert readings for lung scintigraphy and computed tomographic (CT) angiography performed in patients suspected of having pulmonary embolism (PE) during pregnancy.

128 patients, @22weeks' GA, 43 CTA & 94 LS

RESULT	LS	CTA	P
+	10/94 (11%)	7/43 (16%)	0.35
-	64/94 (68%)	28/43(65%)	0.73
Inconclusive	20/94 (21%)	8/43 (19%)	0.72
Alternative diagnosis	NA	12/43 (28%)	NA

Revel MP, Cohen S, Sanchez O, et al. Pulmonary embolism during pregnancy: diagnosis with lung scintigraphy or CT angiography? Radiology (2011);258(2):590-8.

Implications for Patient Care

- CT angiographic injection protocols should be optimized when performed for PE suspected during pregnancy.
- CT angiographic protocols should be optimized to reduce maternal radiation dose.

Advances in Knowledge

- The rate of indeterminate results for pulmonary embolism (PE) suspected during pregnancy is similar for lung scintigraphy (17 of 91 patients [19%]) and CT angiography (eight of 43 patients [19%]), even in patients with normal chest radiographs.
- Seventy-five percent of indeterminate CT angiographic results (six of eight patients) were due to poor arterial opacification.
- Interobserver agreement is better for CT angiography than for lung scintigraphy, especially with regard to positive results.
- CT angiography enabled the identification of an alternate diagnosis not suspected at chest radiography in five of 43 pregnant patients (12%) suspected of having PE.
- The mean maternal radiation dose with CT angiography was higher than that with lung scintigraphy (7.3 mSv vs 0.9 mSv, respectively).

Revel MP, Cohen S, Sanchez O, et al. Pulmonary embolism during pregnancy: diagnosis with lung scintigraphy or CT angiography? Radiology (2011);258(2):590-8.

Diagnostic Accuracy

- 13 retrospective studies between 1997 and 2017 on 1270 pts
- Prevalence of PE: 0 – 22% ; median: 4,1%
- Follow-up: 3 to 24 months → 0% of false negative CTPA

Table 2. Analysis of the rate of false negative test results after V-Q lung scans and CTPA.

Study	Number of patients subjected to imaging test (n)	Baseline PE prevalence	Number of true negative test (n)	Number of VTE during follow-up (n)	NPV (%), 95% CI	Duration of follow-up (months)
			CTPA			
Scarsbook *et al.* 2007	9	22.2% (2/9)	6	0	100, (60.97-100)	24.5
Litmanovitch *et al.* 2009	26	0% (0/26)	26	0	100, (87.13-100)	18
Shahir *et al.* 2010	106	3.7% (4/106)	95	1	98.96, (94.33-99.82)	3
Revel *et al.* 2011	43	16% (7/43)	28	0	100, (87.94-100)	3
Bourjeily *et al.* 2012	343	2.6% (9/343)	335	0	100, (98.86-100)	3 months or 6 weeks postpartum
Browne *et al.* 2014	70	1.4% (1/70)	69	0	100, (94.73-100)	6
Nijkeuter *et al.* 2013	143	4.2% (6/143)	129	0	100, (97.11-100)	3
Sheen *et al.*2017	97	4.1% (4/97)	84	2	97.94, (99.43-92.79)	3

PE: pulmonary embolism; VTE: venous tromboembolism; NPV: negative predictive value; CI: confidence intervals; NP: not provided; V-Q scanning: ventilation perfusion scanning. CTPA: computed tomography pulmonary angiography; *one PE was diagnosed after 3 months of follow-up. **very low PE probability V-Q lung scans are considered as normal V-Q lung scans.

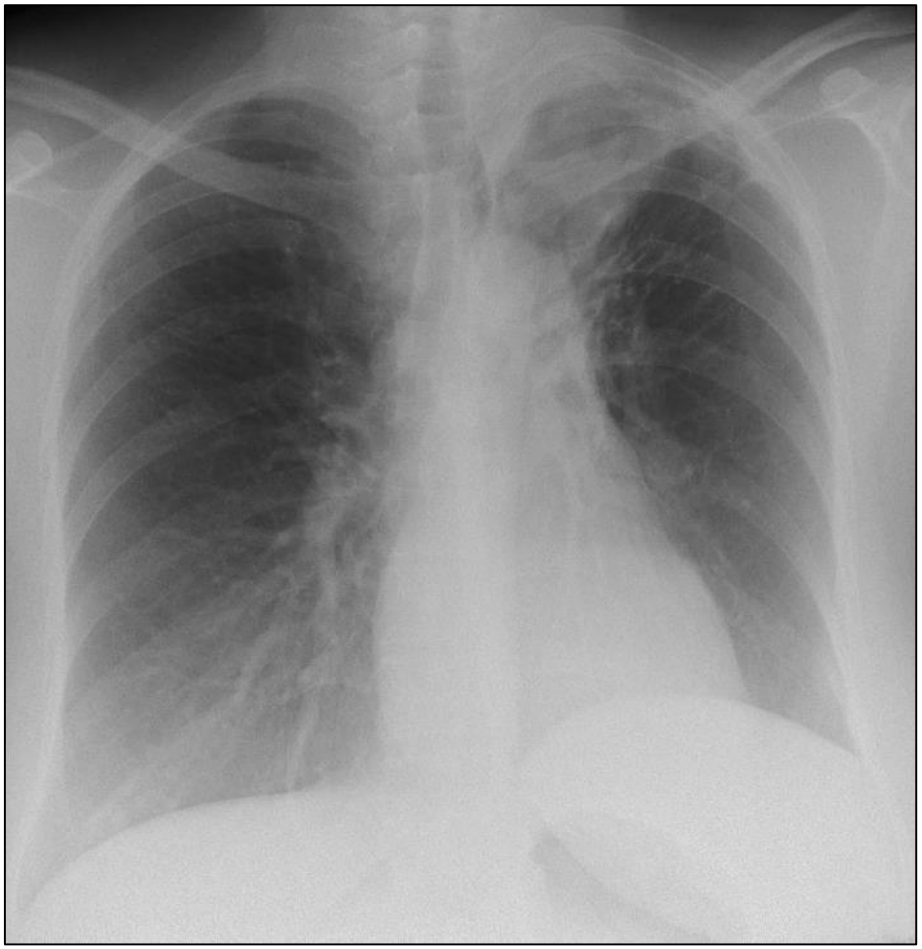
Tromeur C, et al. Computed tomography pulmonary angiography versus ventilation-perfusion lung scanning for diagnosing pulmonary embolism: a systematic review and meta-analysis. Haematologica (2019);104(1): 176-188

Alternative Diagnosis

- Dyspnea:
  - Peri-partum Cardiomyopathy
  - Lung edema induced by tocolysis
  - Pneumonia
  - Amniotic embolus
- Chest pain:
  - Hamman' syndrome*
  - Eclampsy complications

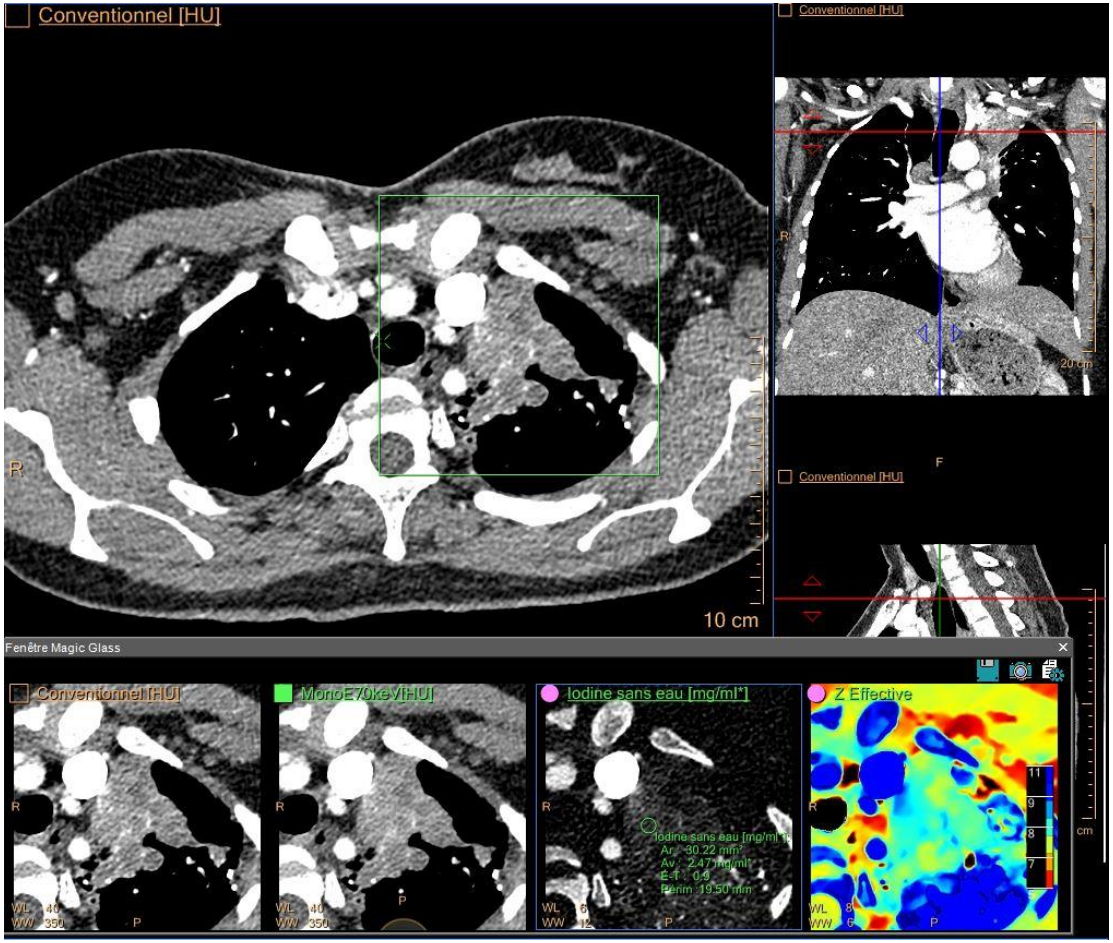
*Majer S, Graber P. Postpartum pneumomediastinum (Hamman's syndrome). CMAJ. 2007;177:32.

Dyspnea



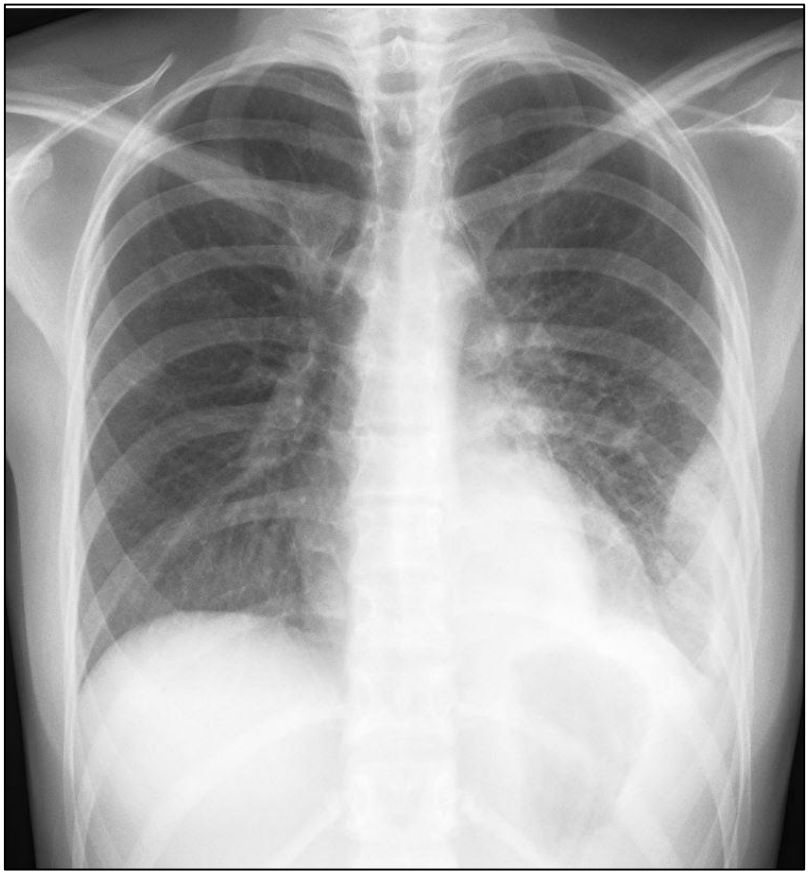
42-year old woman-dyspnea since 8 months-33W
Previous tuberculosis

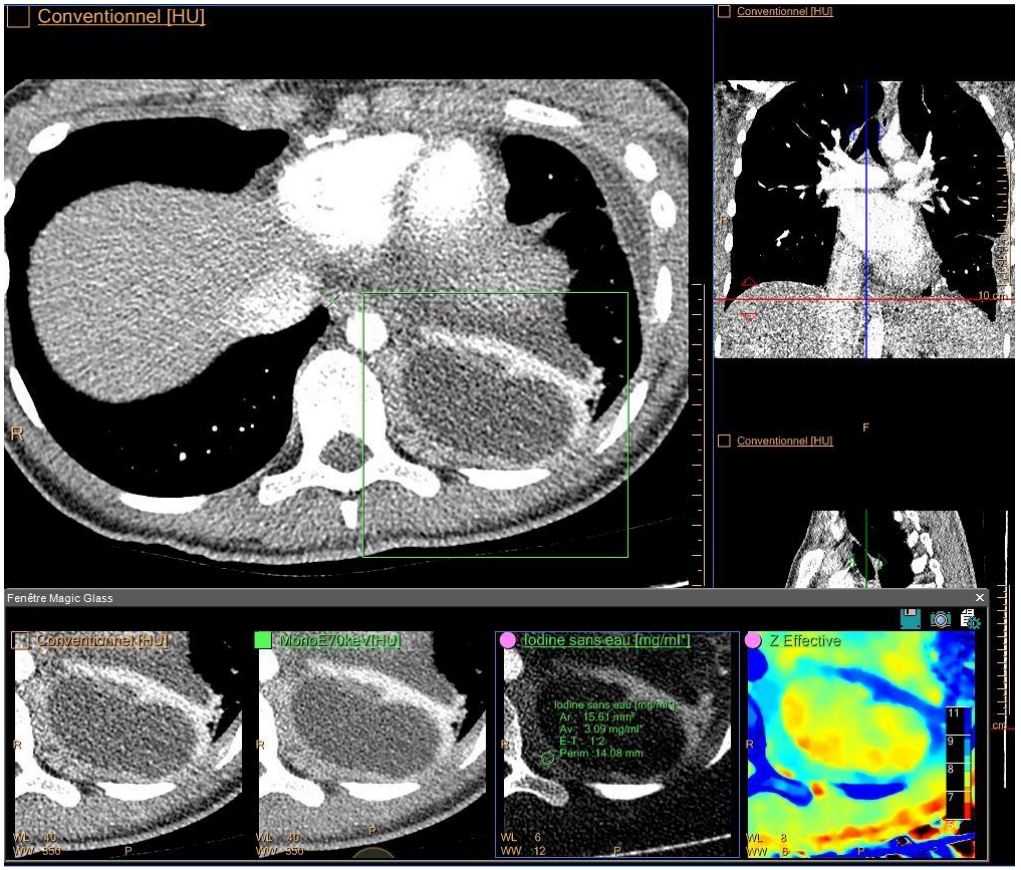
Dyspnea



Rifampicine – Isoniazide – Pyrazinamide – Ethambutol, Pyridoxine, during 2 months

Chest pain





21-year old woman- left basi-thoracic chest pain-10 W

Chest pain on post partum

Hamman's syndrome: Pneumomediastinum

- ➢1 in 100 000 deliveries (prolonged labour)
- Increased intra-thoracic pressure
- Appears several days post partum
- Self limiting

*Majer S, Graber P. Postpartum pneumomediastinum (Hamman's syndrome). CMAJ. 2007;177:32.

Chest pain on post partum

Cesarian for pre-eclampsia
Right basal thoracic pain

Subcapsular hematoma

Vigil-De Gracia P. Pre-eclampsia/eclampsia and hepatic rupture.Int J Gynaecol Obstet. 2012 ;118:186-9.

Non Diagnostic results

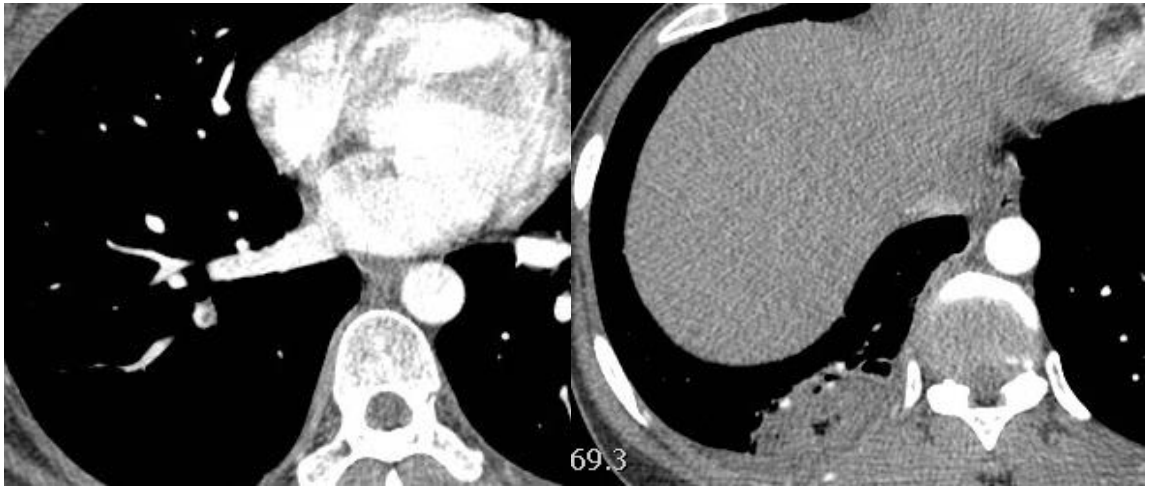
General population	Pregnancy	Postpartum
5 to 10%	17% Cahill Obstet Gynecol 2009	20% Revel J Thromb Haemost 2009
	21% Revel Radioloy 2011	
	27.5% U-Kim-Im Eur Radiol 2009	
	32% Ridge AJR 2009	

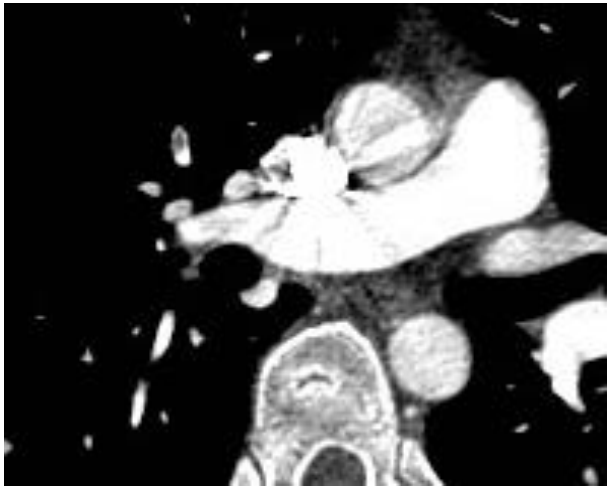
Main cause: bad arterial opacification

- Haemodynamic modifications during pregnancy (persistent in postpartum)
  - Increased blood pool, hyperpulsatility, bad mixing
- Especially if deep inspiration which promotes the venous return from inferior vena cava (non opacified blood)

Optimisation of injection protocol

- Avoid deep inspiration
- Use sufficient amount of contrast and high injection rate





Litmanovich et al. J Comput Assist Tomogr 2009

Ridge et al. AJR 2011

Technique for pregnant patients

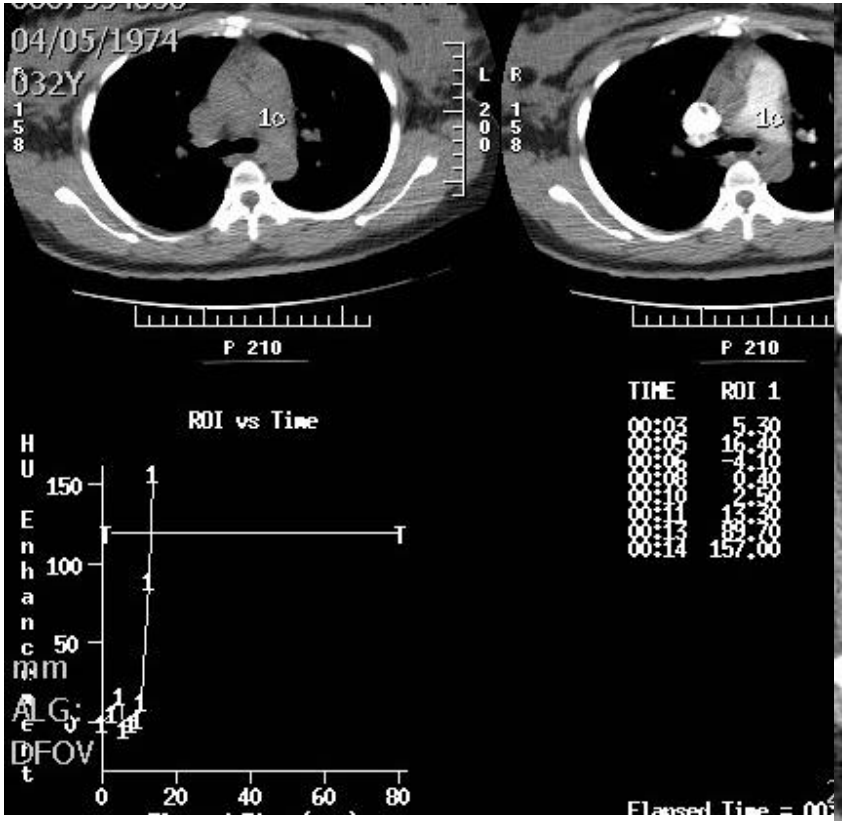
- Technical issues
  - Higher cardiac output and circulating blood volume

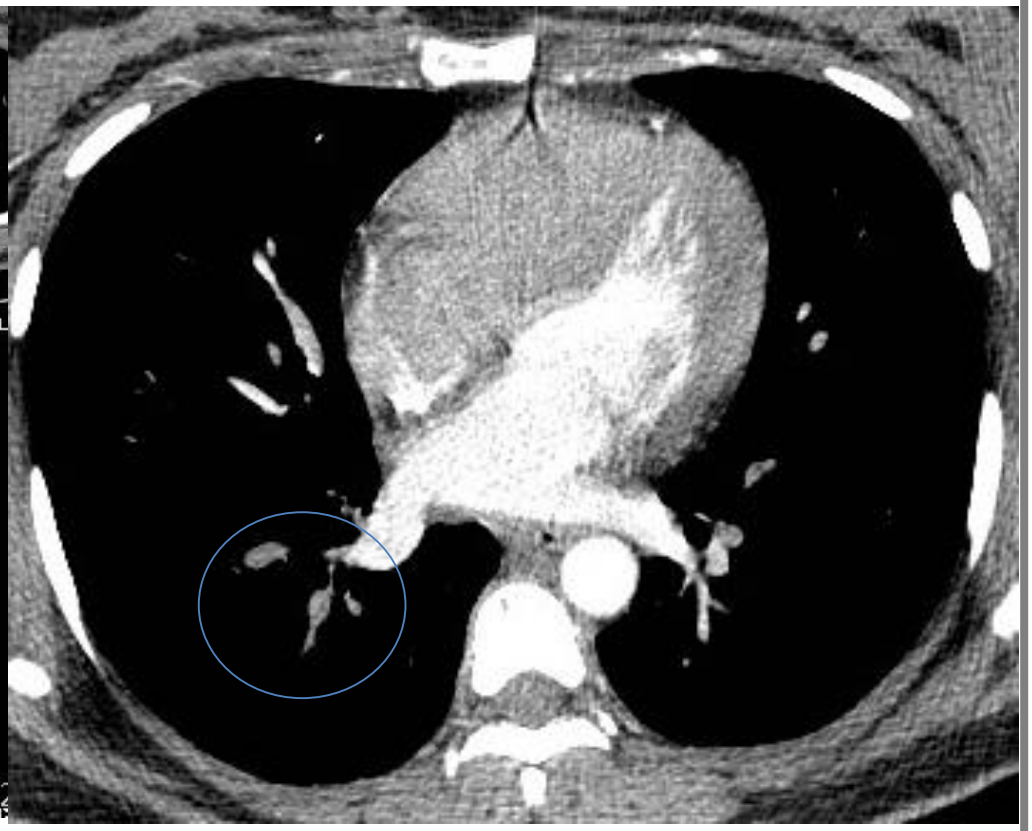
Methods to improve the image quality and to reduce the radiation dose of CTA for acute PE during pregnancy.

Improvement of image quality
Short scan duration (choosing the fastest scanner)
High iodine influx (↑ increase of flow and / or iodine concentration, e.g., 6 ml /s and 400 iodium/ml)
No maximal inspiration or even shallow breathing
Reduction of radiation dose:
Reduction of tube current
Reduction of tube voltage (e.g., 100 kVp)
Reduction of z-axis (limited scan range)
Increase in pitch (1.5–2)
Increase in collimation (1.5 mm)
Standard use of dose modulation

Hartmann I, et al. Imaging of acute pulmonary embolism using multi-detector CT angiography: An update on imaging technique and interpretation. Eur j radiol (2010);74(1):40-9.

Failure of CM in pregnant patients





Deep inspiration favors inferior vena cava flow

Failure of CM in pregnant patients

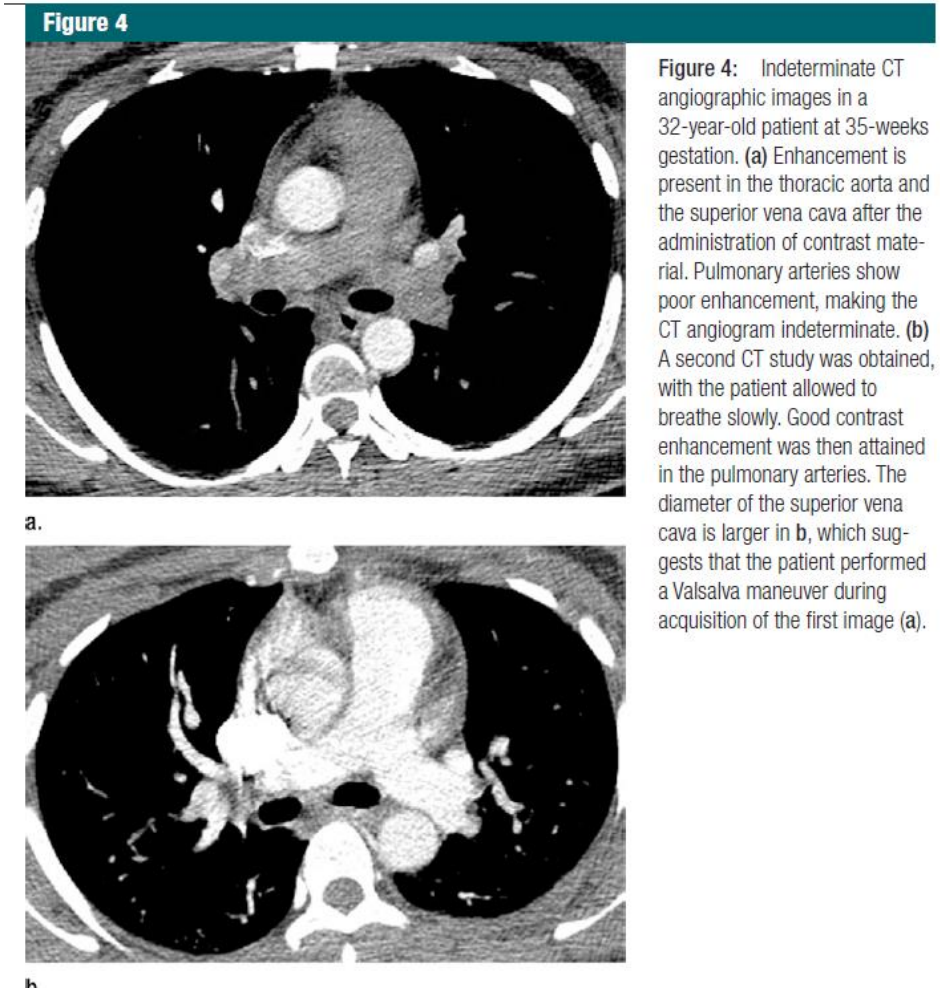
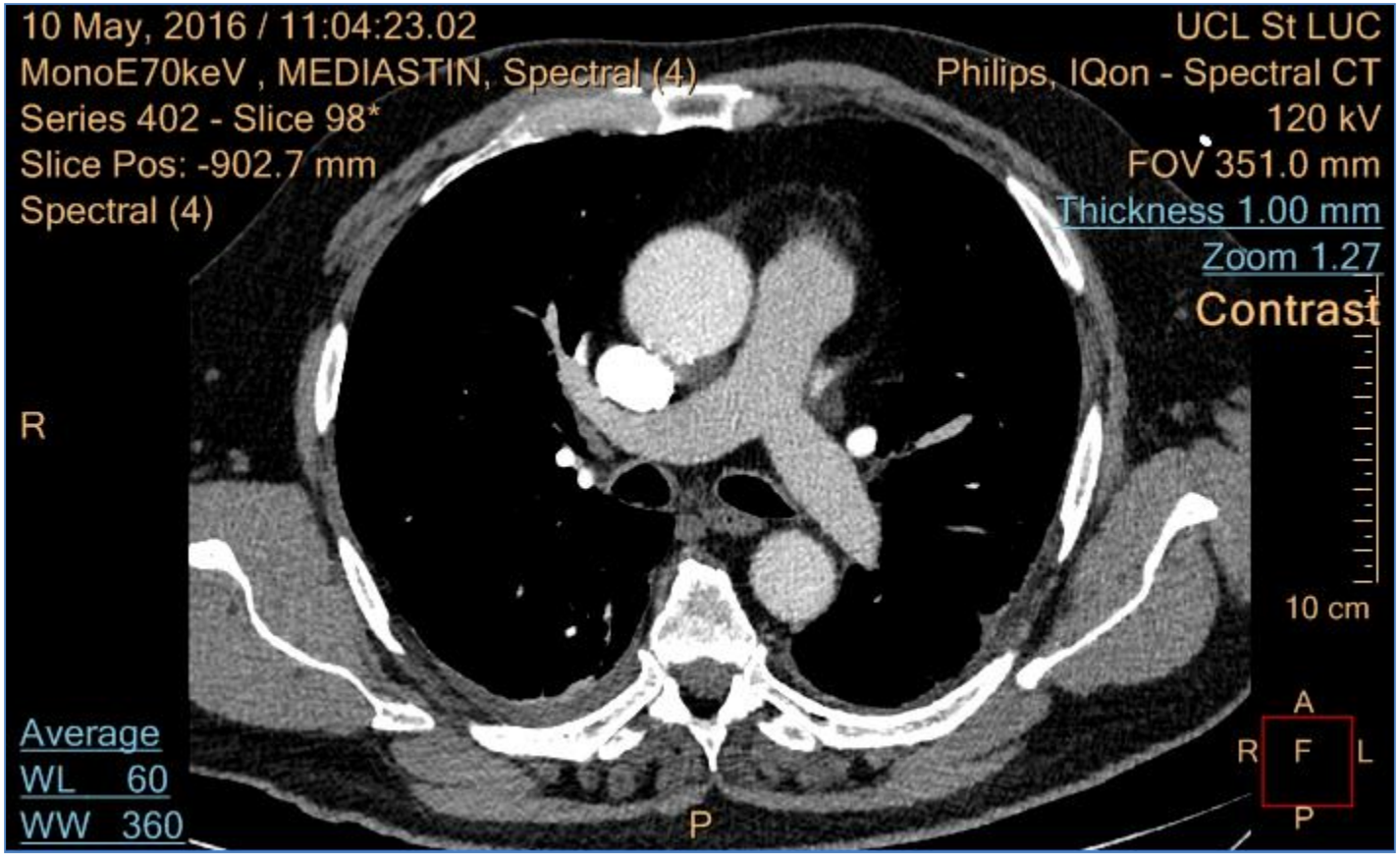


Figure 4: Indeterminate CT angiographic images in a 32-year-old patient at 35-weeks gestation. **(a)** Enhancement is present in the thoracic aorta and the superior vena cava after the administration of contrast material. Pulmonary arteries show poor enhancement, making the CT angiogram indeterminate. **(b)** A second CT study was obtained, with the patient allowed to breathe slowly. Good contrast enhancement was then attained in the pulmonary arteries. The diameter of the superior vena cava is larger in **b**, which suggests that the patient performed a Valsalva maneuver during acquisition of the first image (**a**).

Revel MP, Cohen S, Sanchez O, et al. Pulmonary embolism during pregnancy: diagnosis with lung scintigraphy or CT angiography? Radiology (2011);258(2):590-8.

Suspicion of Pulmonary Embolism
Valsalva -> bad opacification of Pulmonary Arteries

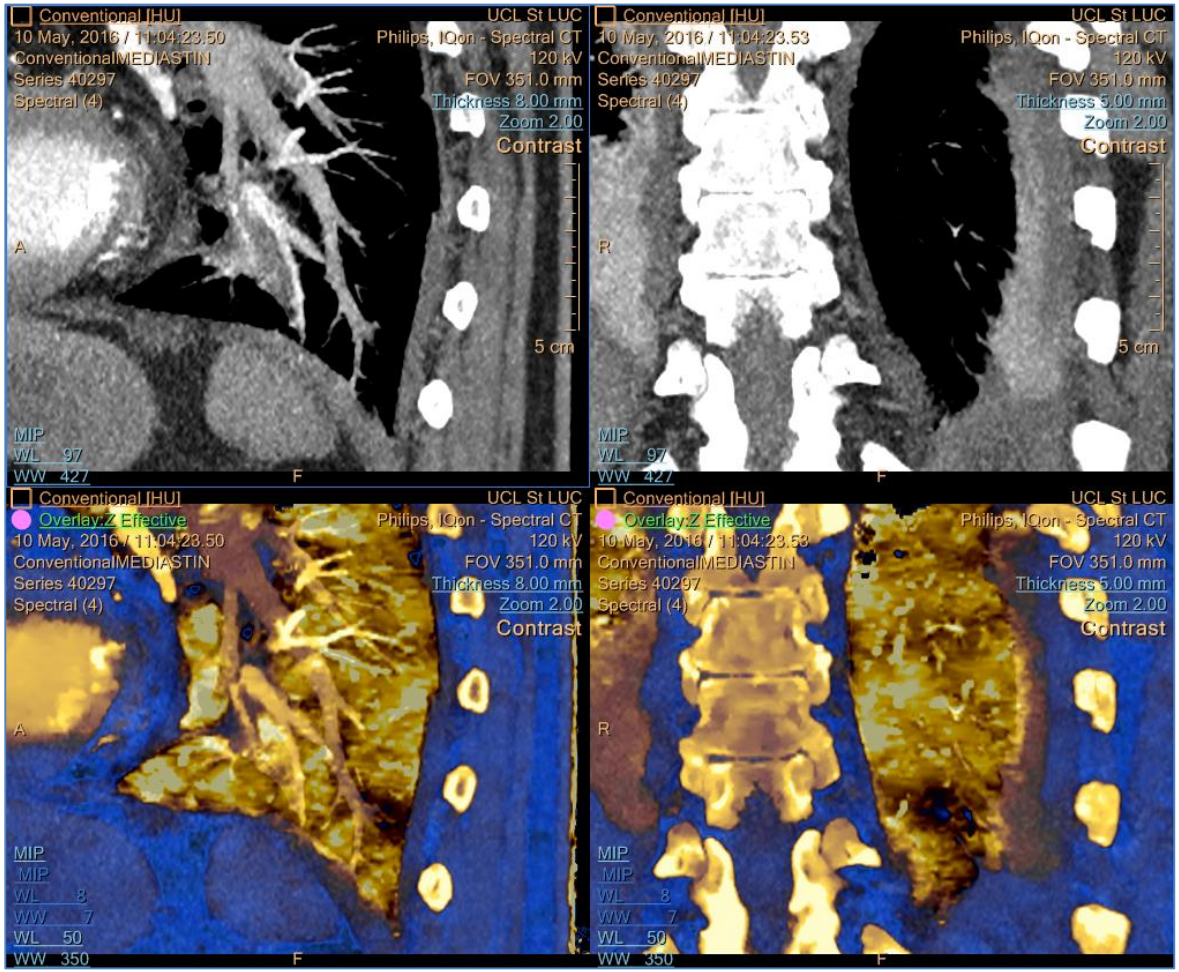


Reference

SPECTRAL CT

Perfusion Defect visible on Zeff (red arrow), artifact ?

No clot visible on conventional CT



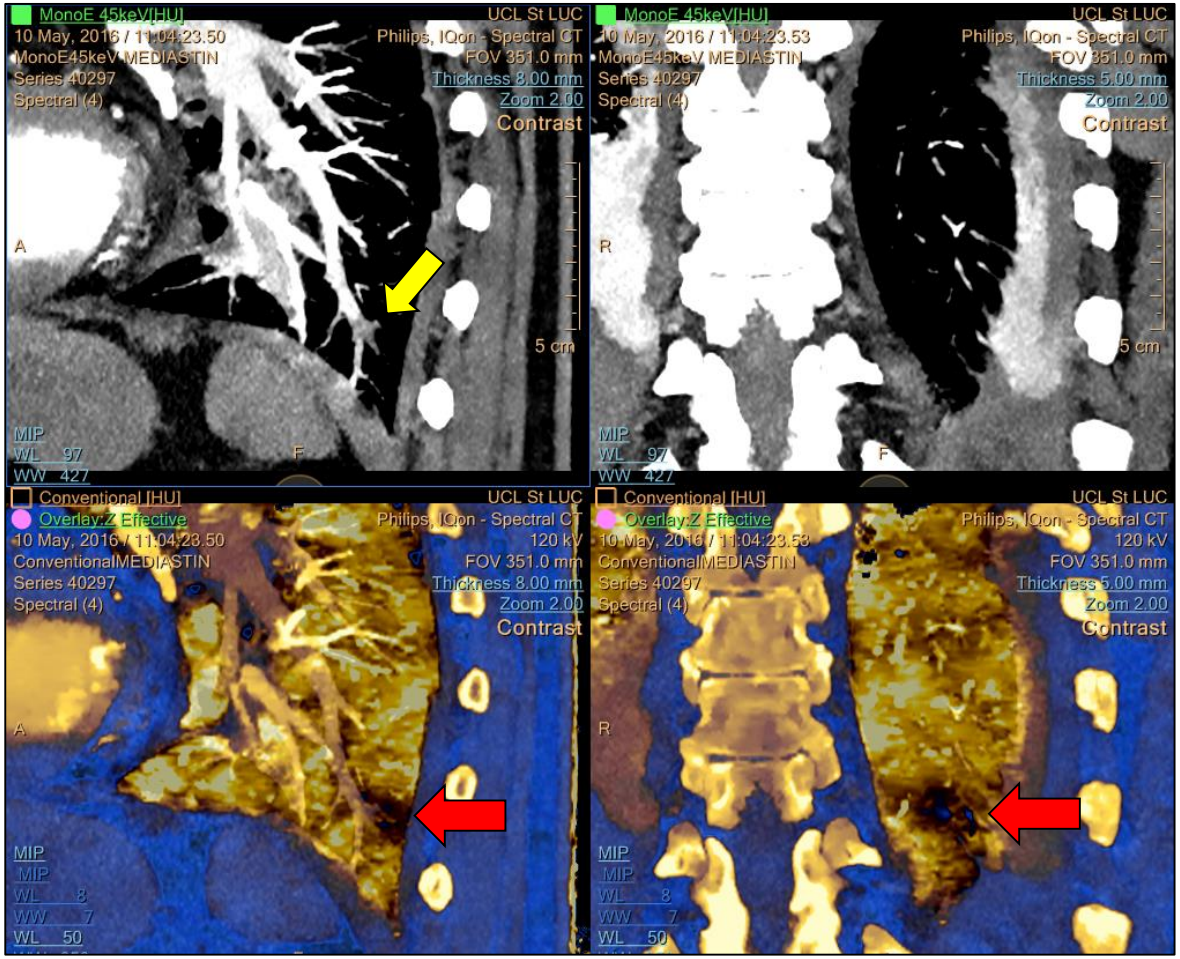
Bae K[1,2], Jeon KN[1,2], Cho SB[2], Park SE[2], Moon JI[2], Baek HJ[1,2], Choi BH[2]

Improved Opacification of a Suboptimally Enhanced Pulmonary Artery in Chest CT: Experience Using a Dual-Layer Detector Spectral CT.

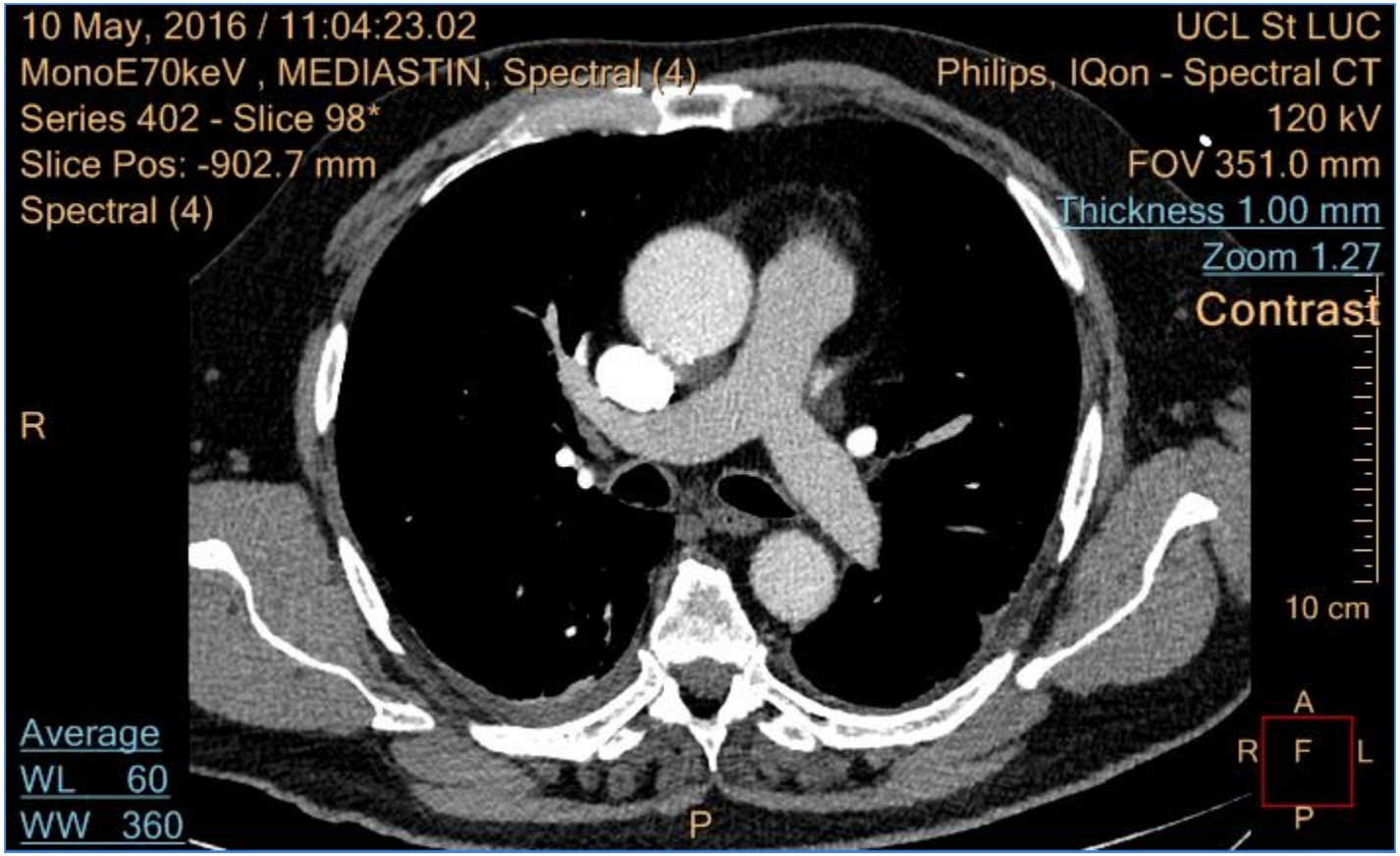
AJR Am J Roentgenol. 2018 Apr;210(4):734-741.

SPECTRAL CT

Perfusion Defect visible on Zeff (red arrow)
clot visible at 45 keV (yellow arrow)



In doubt: Patient reinjected

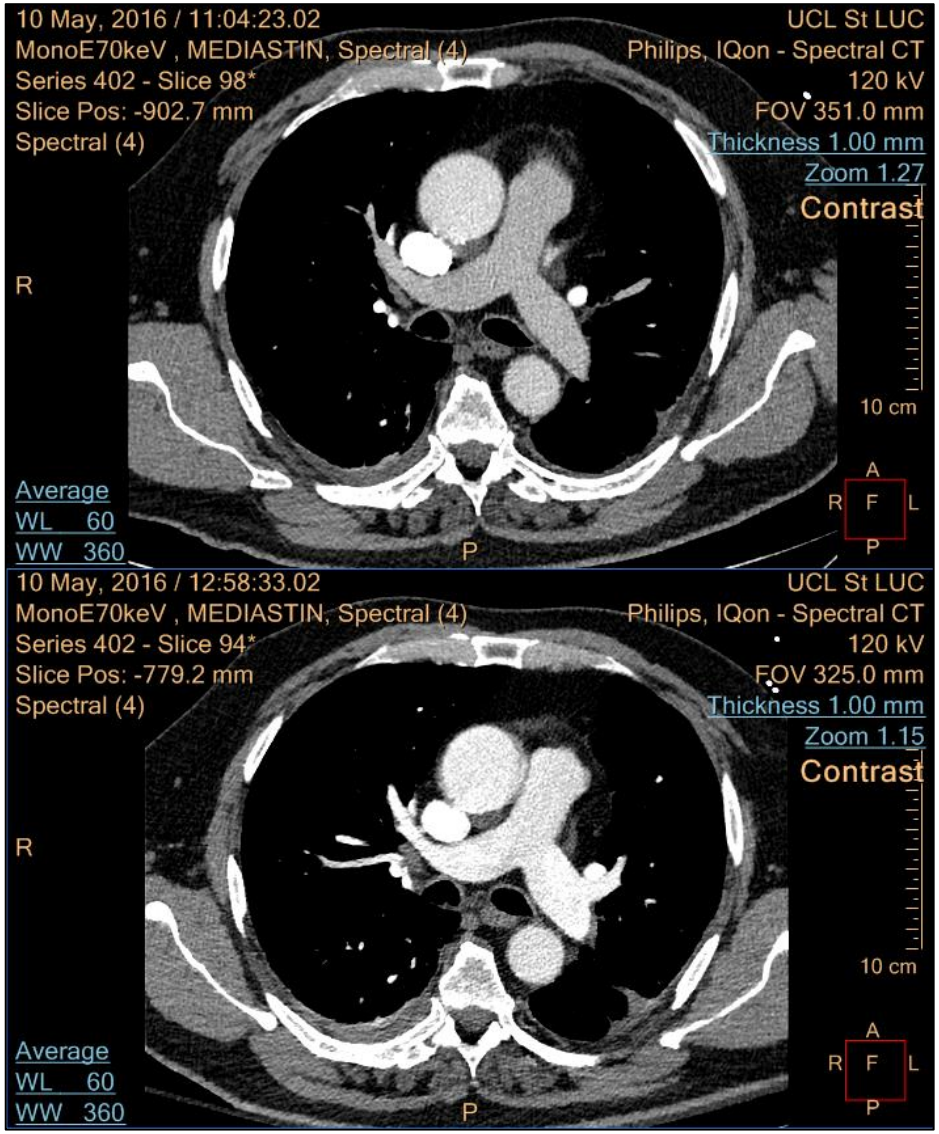


Reference

In doubt: Patient reinjected

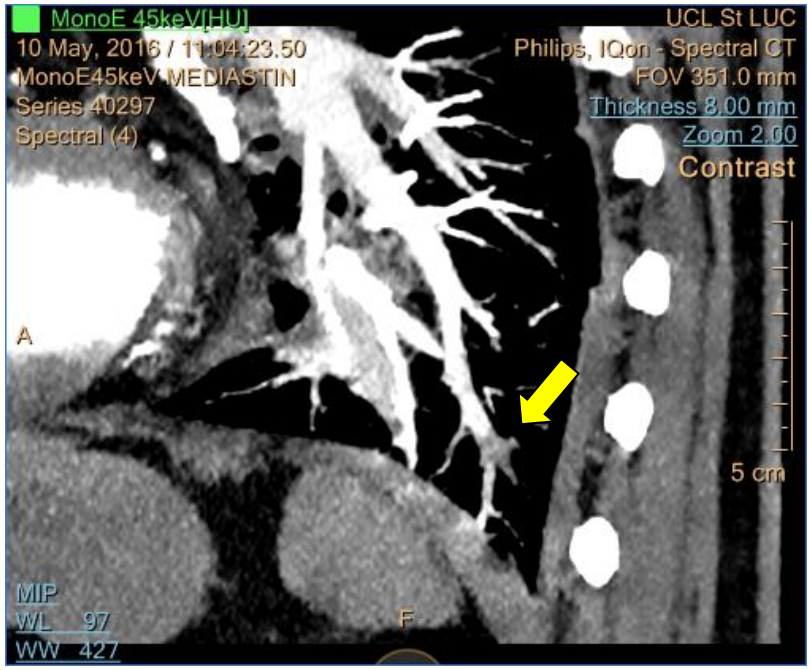
Injection 1

Injection 2

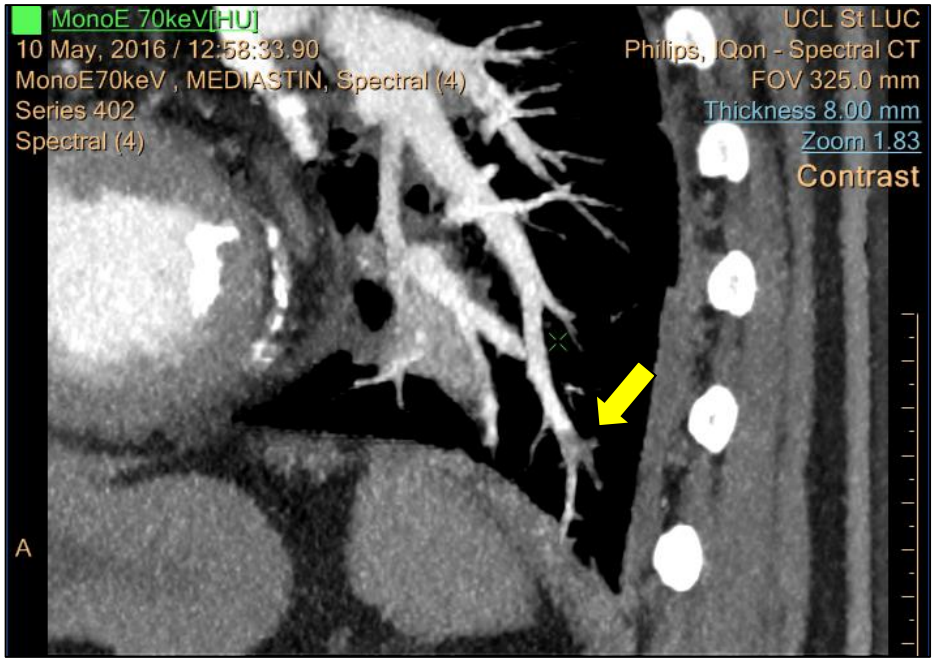


Reference

Suspicion of PE: Patient reinjected
Presence of clot confirmed



Injection 1, 45 keV



Injection 2, 70 keV

COMBINATION OF IODINE MAP AND MONOCHROMATIC IMAGES

Radiation exposure

Tableau I. Doses d'irradiation délivrées par l'angio-scanner pulmonaire

Série	Dose (mGy)
Fœtus	
Winer-Muram, 2002[31]	0,003-0,131
Nijkeuter, 2004[40]	0,013-0,026
Cook, 2005[41]	0,01
Hurwitz, 2006[19]	0,24-0,66
Doshi, 2008[22]	0,06-0,23
Glande mammaire	
Cook, 2005[41]	10
Parker, 2005[20]	20
Hurwitz, 2006[19]	43-66
Hurwitz, 2007[36]	35-42,3

Soulier V, Righini M, Perrier A. Diagnostic de l'embolie pulmonaire chez la femme enceinte: comment faire? Rev.Med Suisse

Radiation exposure

Whereas, it has been estimated that the average breast exposure from half-dose perfusion scintigraphy can be up to 150 times lower than that of CTPA [ref 1].

Conversely, it is accepted that scintigraphy imparts a higher dose to the fetus (640–800 μGy) than CTPA (3–131 μGy), and this notion must be given due consideration [ref 2].

Unfortunately (or fortunately), no conclusive data yet exist to firmly prove or disprove the risks of carcinogenesis to breast tissue or the fetus from diagnostic tests.

1. Parker MS, Hui FK, Camacho MA, Chung JK, Broga BW, Sethi NN. Female breast radiation exposure during CT pulmonary angiography. AJR Am J Roentgenol 2005;185:1228–33.
2. Scarsbrook A, BradleyK,Gleeson F. Perfusion scintigraphy still has important role in evaluation of majority of pregnant patients with suspicion of pulmonary embolism. Radiology 2007;244:623–5.

Radiation optimisation

Low kilovoltage

Reduced z-axis length: acquisition from roof of the aorta to the dome of diaphragm

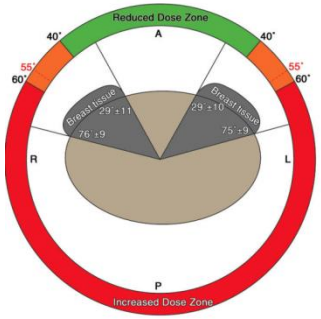
Shielding?

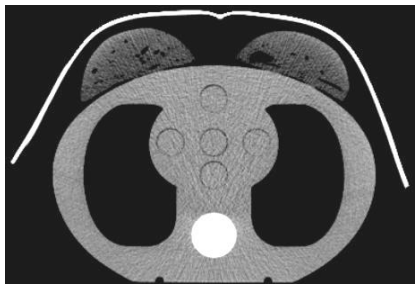
- Used for pediatrics
- Adults: controversial data
  - Hurwitz- AJR 2009: 55% dose reduction , no quality loss
  - Yilmaz- JCT 2007: 40% dose reduction, no quality loss
  - Vollmar - Eur Radiol 2008: 50% dose reduction, 40% noise increase and artefacts

OBTCM: not a good option

- Taylor et al Radiology 2015

Iterative reconstructions





Bismuth shields

Phantom study*: Bismuth shielding versus a low kilovoltage for different breast thicknesses

Greater breast dose reduction is achieved by shielding for breast thicknesses less than 4 cm

But during pregnancy:

- Breast thickness is increased
- Low kilovoltage reinforces arterial enhancement

USE OF A LOW KILOVOLTAGE 80 to 100 kV IS THE BEST OPTION

* Revel et al. AJR 2015

Radiation optimisation

In conclusion, application of the HIR iDose^{4TM} in 80 kV CTPA significantly improved image quality and PE conspicuity, and reduced image noise in comparison with FBP images. Diagnostic image quality in low dose CTPA with effective doses close to 1 mSv is feasible in patients weighing less than 80 kg with the use of the HIR technique iDose^{4TM}.

Fig. 4. CTPA of a 65-year-old patient (77 kg; BMI of 24.5) using a tube voltage of 80 kV ($CTDI_{vol}$: 2.3 mGy; DLP: 64.7 mGy cm; effective dose: 1.1 mSv). Transverse images of 1 mm thickness being reconstructed with (a) FBP and ((b)–(d)) the three increasing iDose levels (L2, L4 and L6) demonstrating central right-sided pulmonary embolism (arrows). With increasing iDose^{4TM} levels, image quality improved and streak artifacts were reduced, enabling a better conspicuity of the filling defects.

Laqmani A, Regier M, Veldhoen S, et al. Improved image quality and low radiation dose with hybrid iterative reconstruction with 80 kV CT pulmonary angiography. Eur J radiol (2014);1962-1969

Breast feeding

Eur Radiol (2005) 15: 1234–1240
DOI 10.1007/s00330-004-2583-y

CONTRAST MEDIA

Judith A. W. Webb
Henrik S. Thomsen
Sameh K. Morcos
Members of Contrast Media Safety Committee of European Society of Urogenital Radiology (ESUR)

The use of iodinated and gadolinium contrast media during pregnancy and lactation

- The very small potential risk associated with absorption of contrast medium may be considered insufficient to warrant stopping breast-feeding for 24 h following either iodinated or gadolinium contrast agents »

Neonatal Thyroid Function: Effect of a Single Exposure to Iodinated Contrast Medium in Utero[1]

Radiology

Ghada Bourjeily, MD
Michel Chalhoub, MD
Chanika Phornphutkul, MD
Thelma C. Alleyne, MD

Purpose: To evaluate the effect of in utero exposure to a single dose of water-soluble intravenous iodinated contrast medium on thyroid function at birth.

thyroid-stimulating hormone (TSH) levels were measured at birth. A total of 344 maternal and 343 newborn records were reviewed. A descriptive analysis was performed, and means, standard deviations, and confidence intervals were reported.

Results: Mean gestational age at the time of administration of the contrast material was 27.8 weeks ± 7.4. The mean dose of total iodine administered was 45000 mg/L ± 7321. All newborns had a normal T_4 level at birth; only one newborn had a transiently abnormal TSH level at birth, which normalized at day 6 of life. This newborn was born to a mother who had many drug exposures during pregnancy.

Conclusion: A single, high-dose in utero exposure to water-soluble, low-osmolar, iodinated intravenous products, such as iohexol, is unlikely to have a clinically important effect on thyroid function at birth.

Costs

Technical Act : 459550 :N260 Chest CT

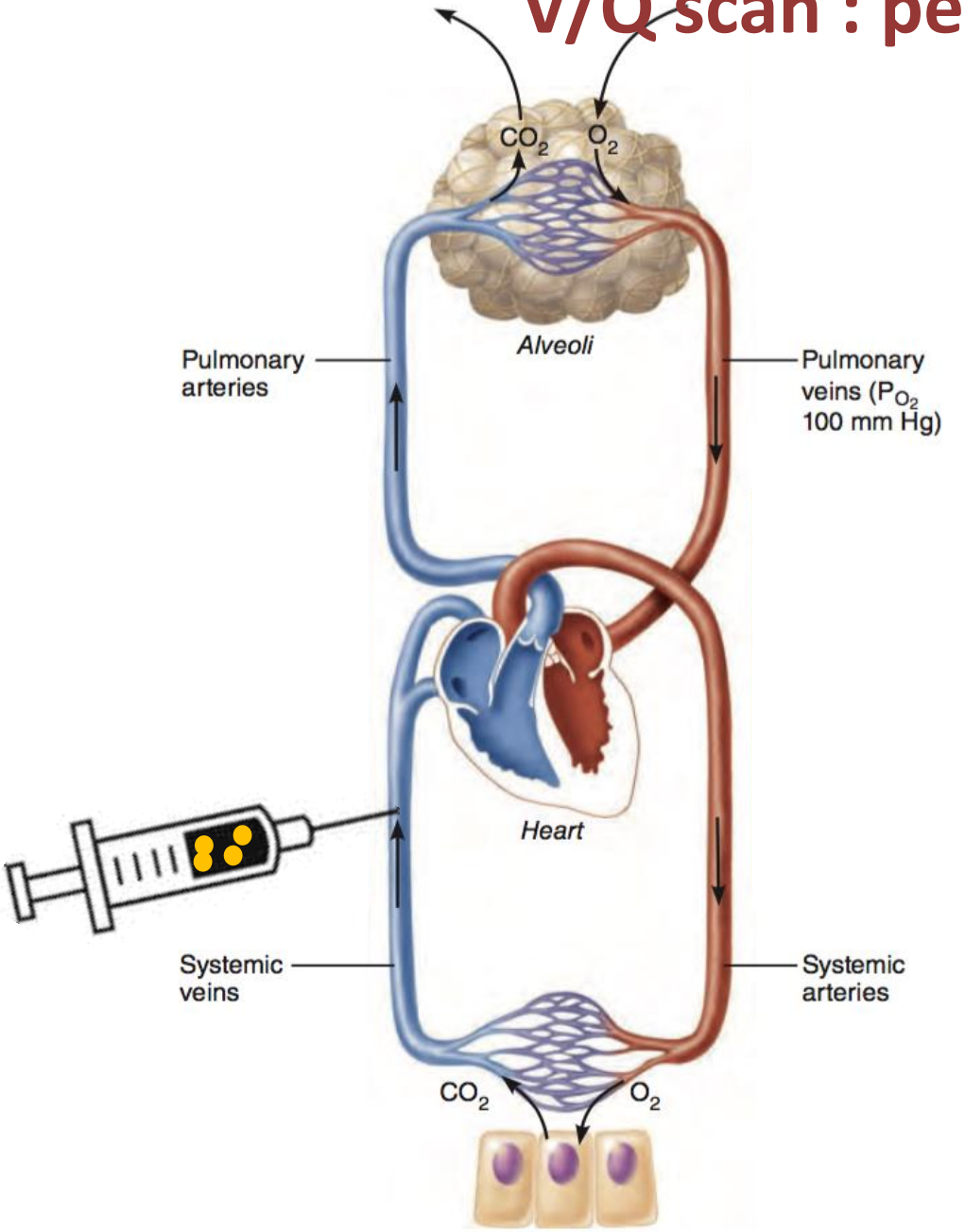
Act 459550	Amount: 135 eur
Consultance fees : 466670	Amount: 25.31 eur
Flat rate 461016	Amount: 44.70 eur

Contrast :
Xenetix : 100 ml : 30.80 euros
Iomeron : 100ml : 47.17 euros.

Total: ≥ 235,21 Euros

V/Q SCINTIGRAPHY

V/Q scan : perfusion

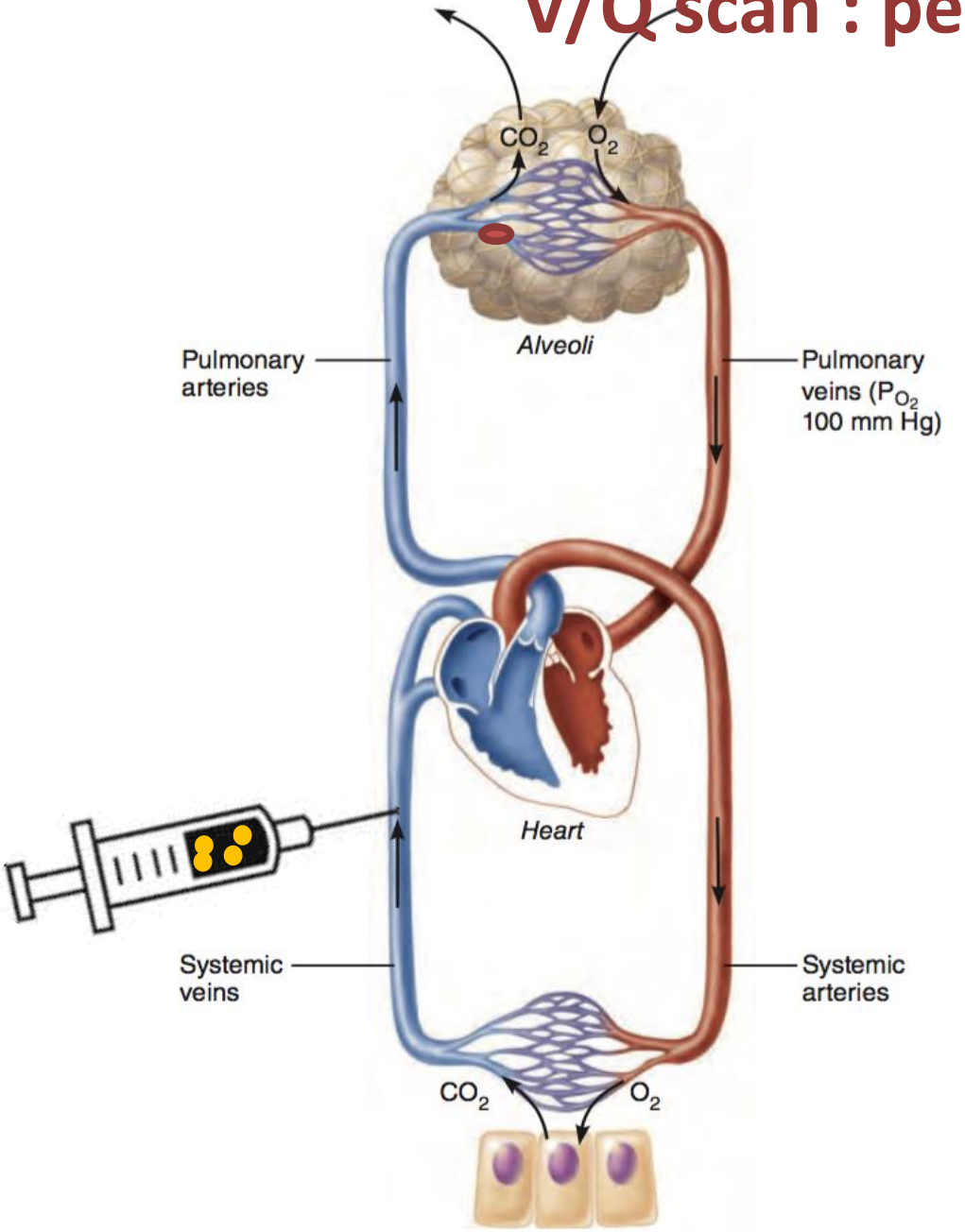


Perfusion: MAA-Tc-99m

(15 – 100 µm)

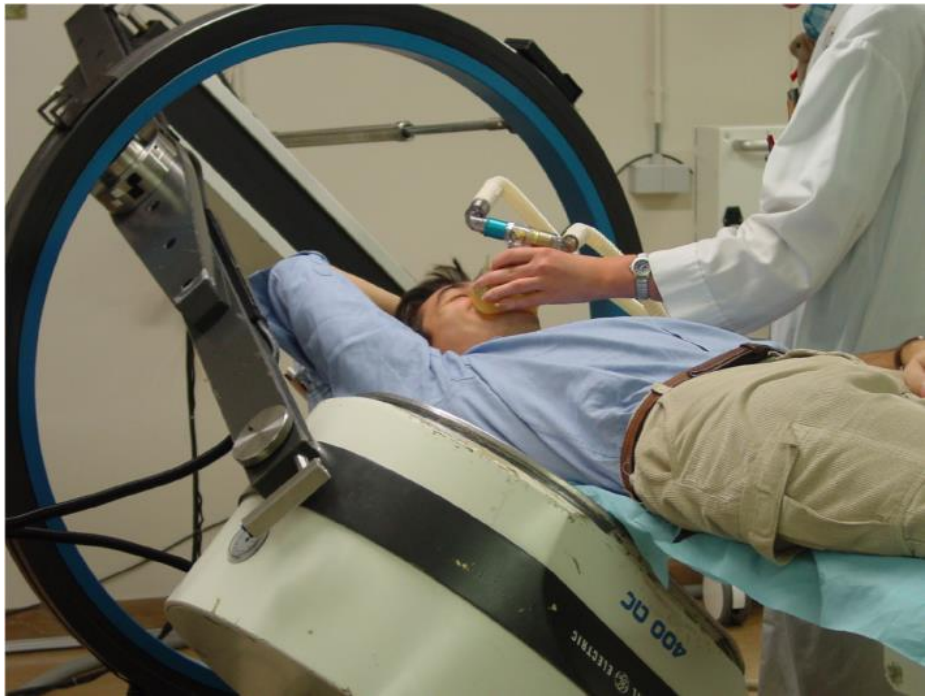
Obstruction of ± 1 % of capillaries

V/Q scan : perfusion



Perfusion: MAA-Tc-99m

V/Q scan : ventilation

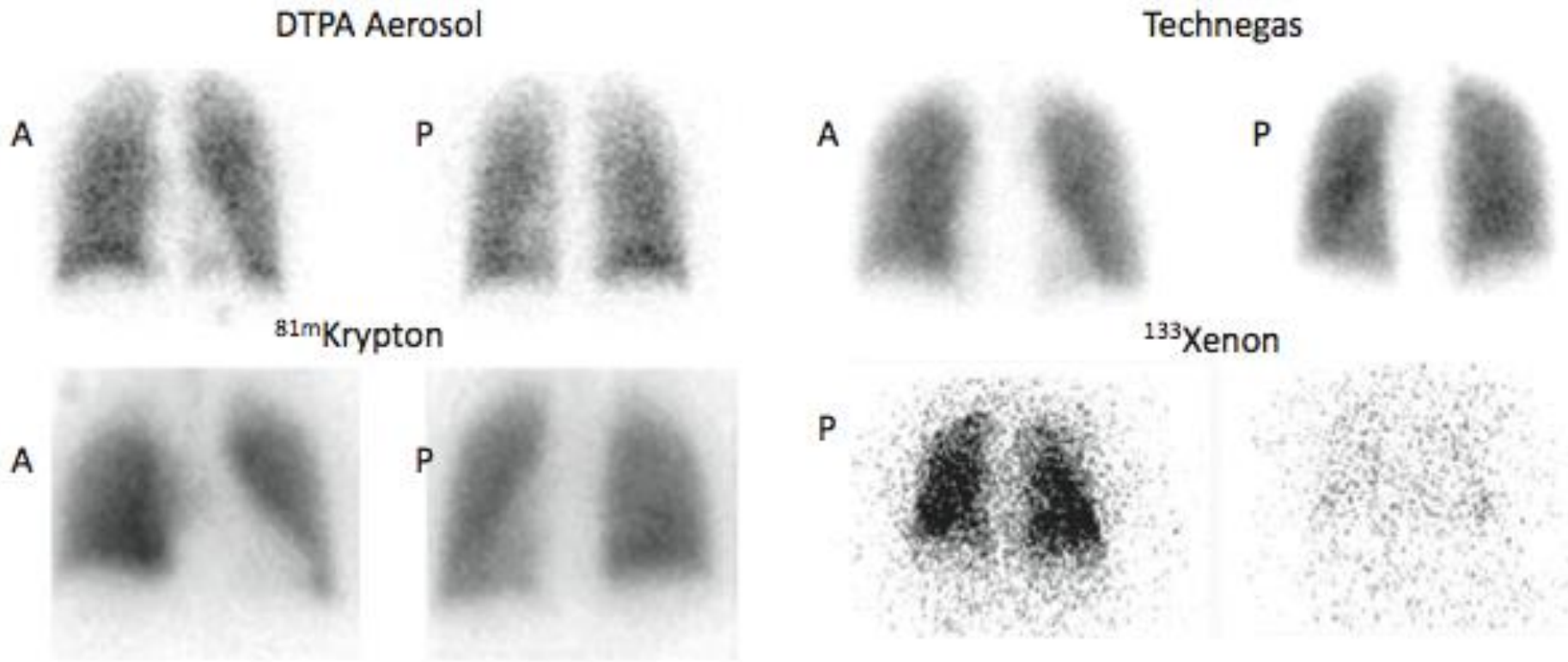


→ Gaz : Kr-81m

→ Aérosols-Tc-99m : Technegas-Tc-99m (0.005 à 0.2 µm)

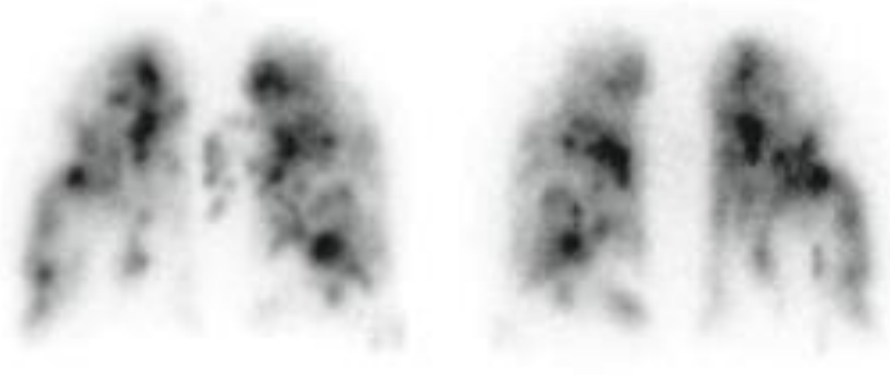
Venticis II –Tc-99m (0,1 à 0,5 µm)

V/Q scan : ventilation



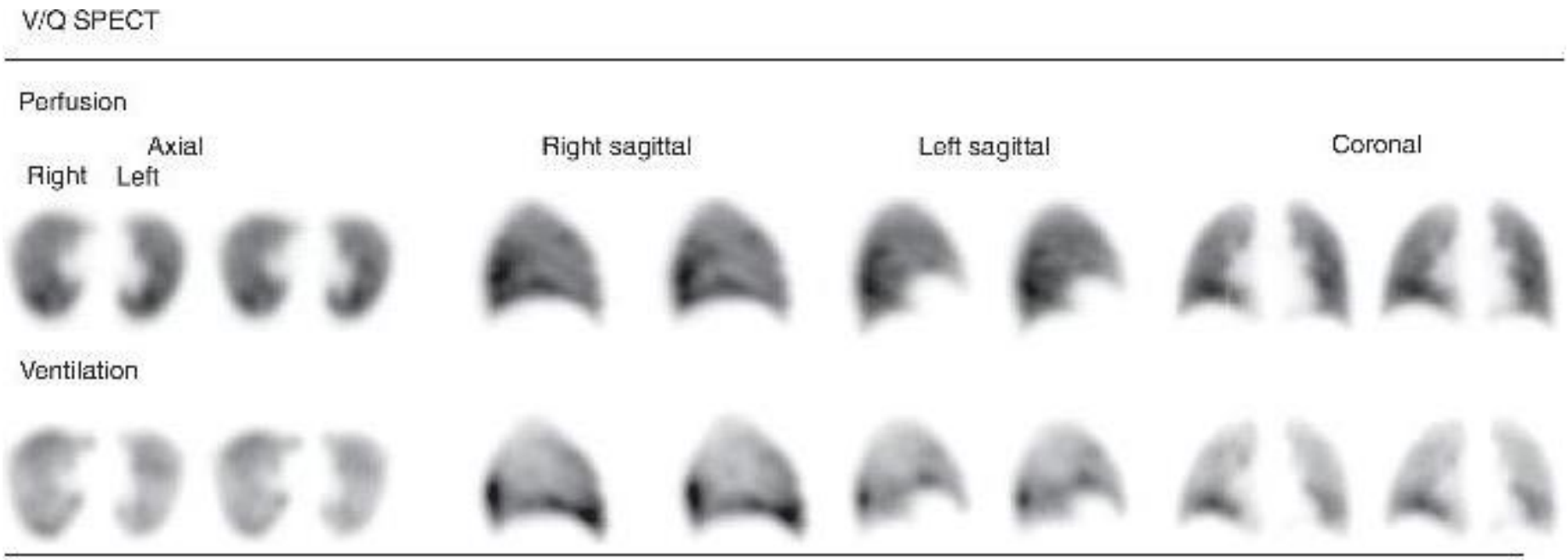
V/Q scan : ventilation

Mild COPD with central airways deposition (Technegas)

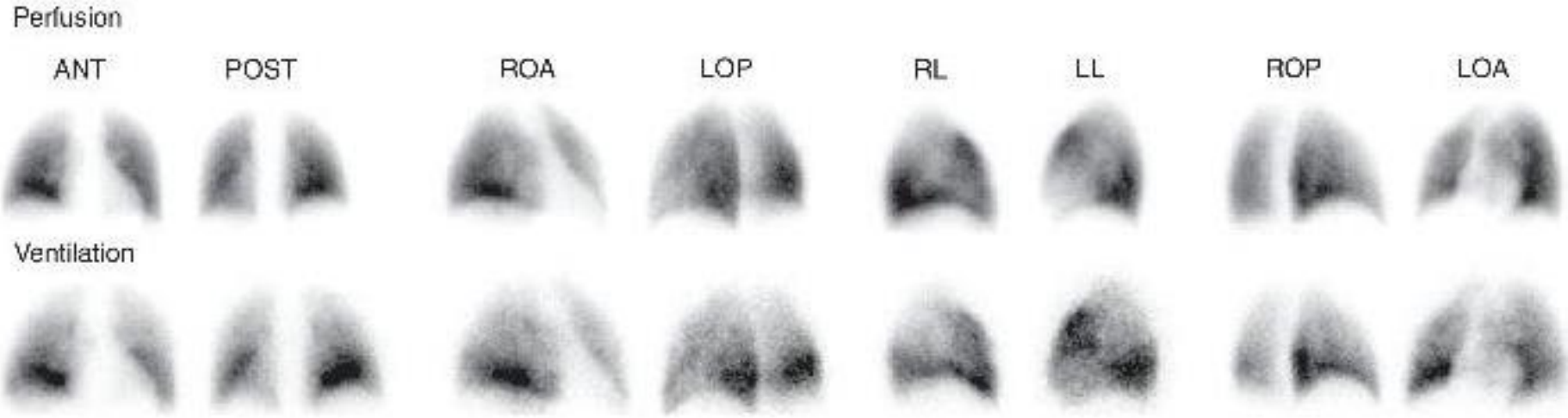


Severe COPD with central airways deposition (DTPA Aerosol)

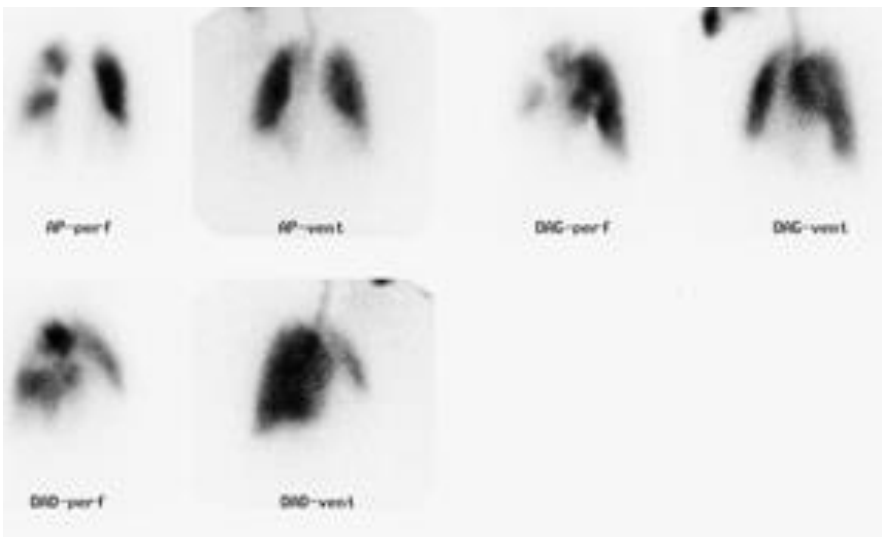
V/Q scan : SPECT

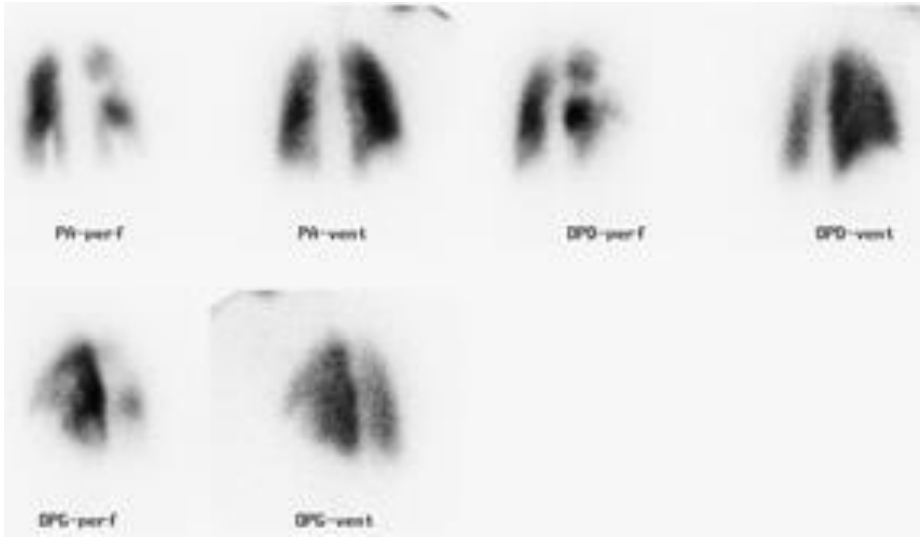


Normal planar



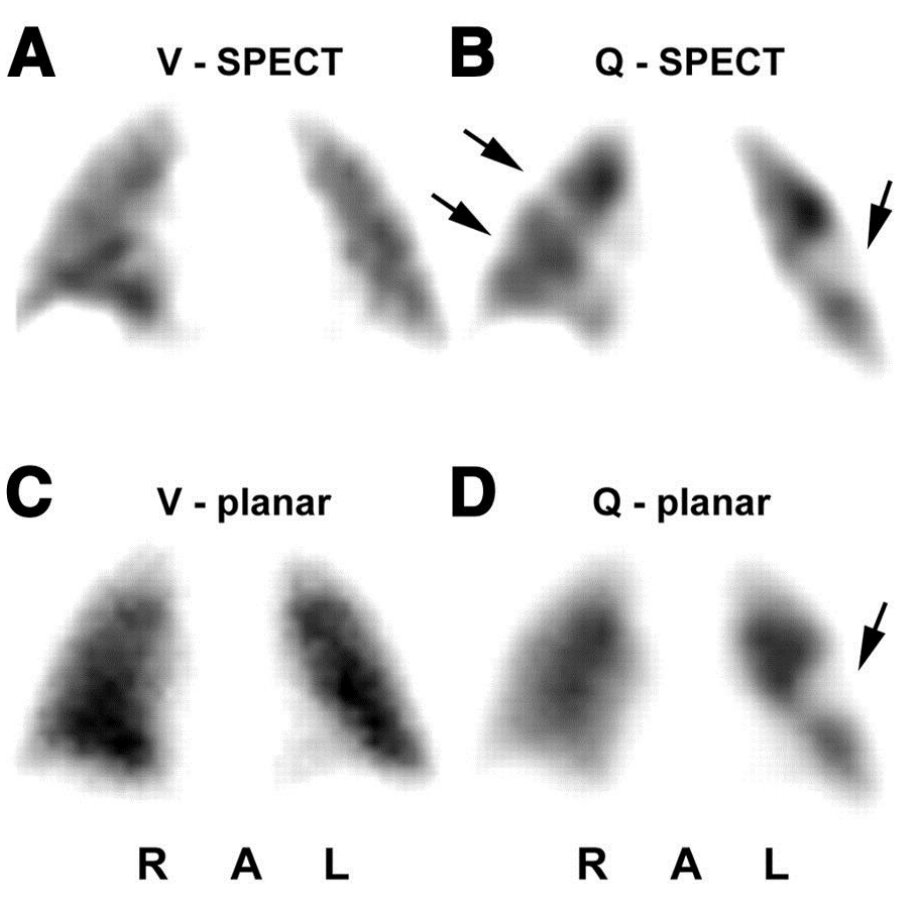
Pulmonary embolism

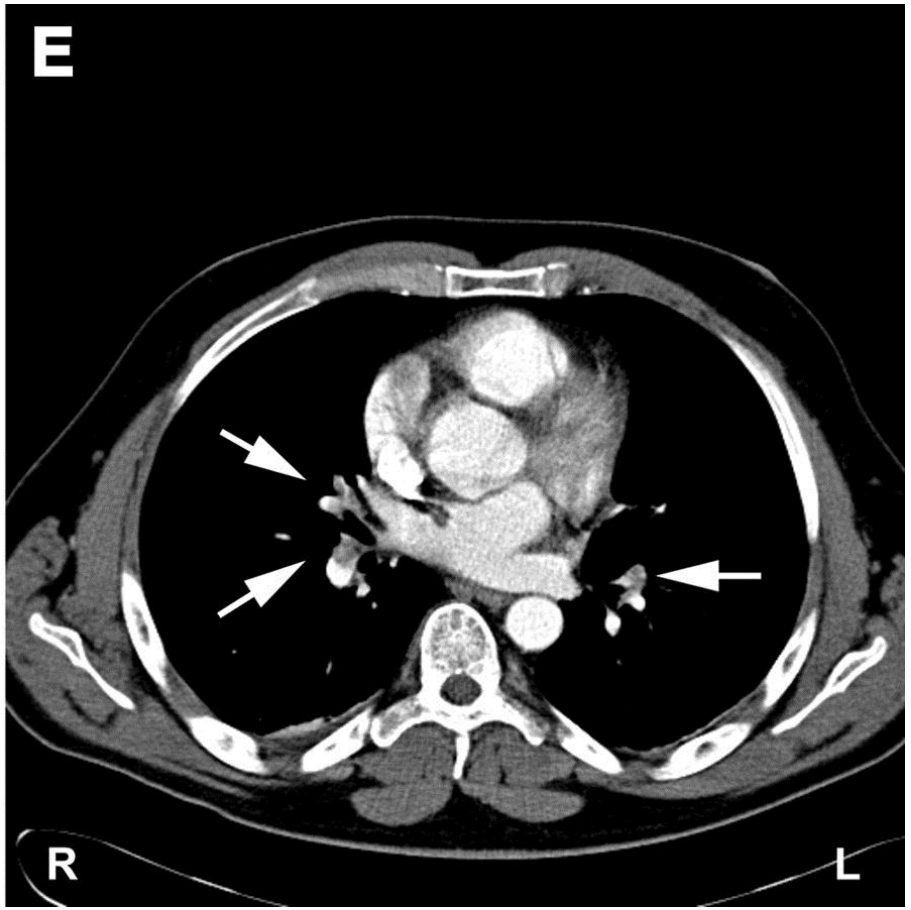




V/Q scan : SPECT

→ improvement of defect visualisation





V/Q scintigraphy in pregnant woman

- Diagnostic quality in near 100%
- Can be used in pts with contrast allergy or impaired renal function
- As low as reasonably achievable ("ALARA") → to minimize risks while maintaining diagnostic quality
-

Table 4
Methods of Reducing Fetal Radiation Dose at Lung Scintigraphy

Reduce dose of perfusion agent **: quarter of the usual administrated dose**
Reduce dose of ventilation agent
Eliminate ventilation portion of scan
Either encourage patient to void frequently or insert Foley catheter to reduce fetal exposure to radiotracer in the bladder

Pahade J et al. RadioGraphics 2009.

V/Q scintigraphy: technic for pregnant woman

- **Day 1: perfusion : Tc-99m-MAA : injected activity of 50 MBq (1,35 mCi)**

  ventilation with Kr-81m if needed

- **Day 2 : 20 – 30 MBq of lung deposited activity if aerosol**

Bajc et al., EJNMMI in revision

V/Q scan : interpretation

- Knowledge and experience of the interpreter according to the principle of "gestalt" [94, 95]
- Pretest probability in accordance with the principle of Holistic interpretation

Furthermore, to be clinically useful, interpretation of an imaging test should be affirmative or negative with respect to PE (PE: yes or no) and should not be based on probability categories [77].

The recommended basic criteria for reading V/P_{SPECT} and V/P_{PLANAR} are the following:

No PE is reported if there is (are):

- Normal perfusion pattern conforming to the anatomic boundaries of the lungs
- Matched or reversed mismatch V/P defects of any size, shape or number in the absence of mismatch
- Mismatch that does not have a lobar, segmental or subsegmental pattern

PE is reported if there is:

- V/P mismatch of at least one segment or two subsegments that conforms to the pulmonary vascular anatomy

Nondiagnostic for PE is reported if there are:

- Multiple V/P abnormalities not typical of specific diseases.

EANMMI, guidelines 2009.

V/Q scintigraphy: diagnostic accuracy

- Results of studies in nonpregnant pts cannot be extrapolated to pregnant women : younger and less concomitant respiratory illnesses
- 13 retrospective studies between 1997 and 2017 on 1270 pts
- Prevalence of PE: 0 – 22% ; median: 4,1%
- Follow-up: 3 to 24 months → 0% of false negative scans

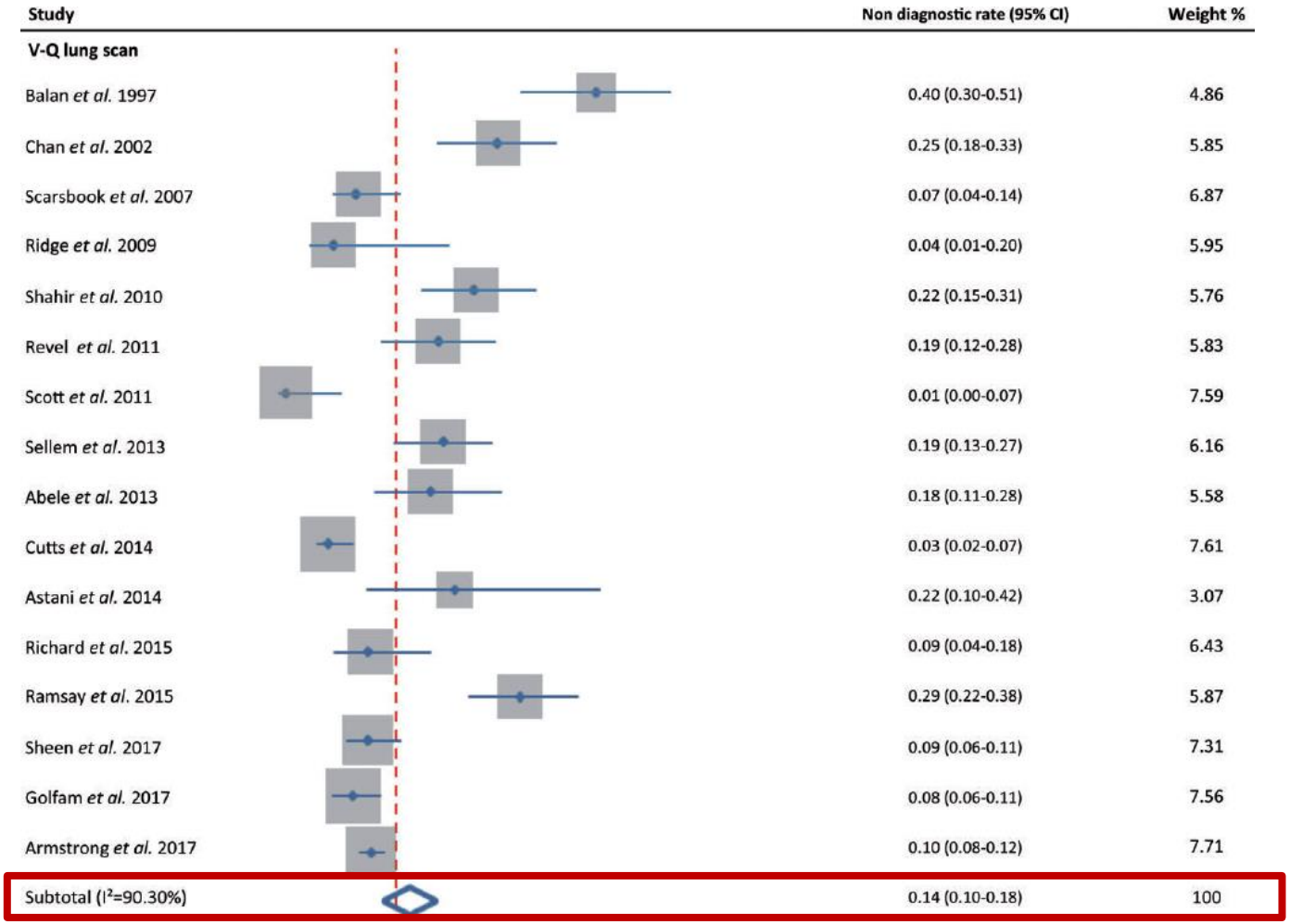
Table 2. Analysis of the rate of false negative test results after V-Q lung scans and CTPA.

Study	Number of patients subjected to imaging test (n)	Baseline PE prevalence	Number of true negative test (n)	Number of VTE during follow-up (n)	NPV (%), 95% CI	Duration of follow-up (months)
V-Q lung scanning						
Balan *et al.* 1997	82	22% (18/82)	31	0	100, (88.97-100)	NP
Chan *et al.* 2002	113	7.1% (8/113)	83	0	100, (95.58-100)	6
Scarsbook *et al.* 2007*	96	1.0% (1/96)	89	0	100, (95.86-100)	24.5
Ezwawah *et al.* 2008	19	NP	19	0	100, (83.18-100)	3
Shahir *et al.* 2010**	99	1% (1/99)	77	0	100, (95.25-100)	3
Revel*et al.* 2011	91	11% (10/91)	64	0	100, (94.34-100)	3
Cutts *et al.* 2014	183	2.2% (4/183)	173	0	100, (97.83-100)	NP
Sheen *et al.* 2017	225	2.7% (6/225)	198	0	100 (98.10-100)	3
Golfam *et al.* 2017	362	4.7% (17/363)	316	0	100 (98.95-100)	3

Tromeur et al. Haematologia, 2019.

V/Q scintigraphy: non-diagnostic results

- 30 studies between 1997 and 2017 on 2535 pts
- Rate of non-diagnostic results: 1,3 to 40% (intermediate and low-probability scans according to PIOPED criteria)



Tromeur et al. Haematologia, 2019.

V/Q scintigraphy: fetal radiation exposure

Table 4 Fetal absorbed dose (mGy) calculated to the stage of gestation after i.v. injection of ^{99m}Tc-MAA and inhalation of ^{99m}Tc-Technegas in 127 pregnant women undergoing V/P SPECT for suspected PE

Stage of gestation	Absorbed dose after 50 MBq ^{99m}Tc-MAA	Absorbed dose after 30 MBq ^{99m}Tc-Technegas	Absorbed dose after 120 MBq ^{99m}Tc-MAA
Early	0.14	0.007	0.34
3 months	0.20	0.007	0.48
6 months	0.25	0.011	0.60
9 months	0.20	0.014	0.48

Bajc, EJNMMI, 2015.

V/Q scintigraphy: radiation exposure

Tableau 2. Doses d'irradiation délivrées par la scintigraphie

Série	Perfusion, dose (mGy)	Ventilation, dose (mGy)
Fœtus		
Nijkeuter, 2004[40]	0,11-0,2	0,0001
Cook, 2005[41]	0,12	
Hurwitz, 2006[19]	0,21-0,3	0,04-0,15
Glande mammaire		
ICRP 53, 1987[42]	0,224	0,076
Cook, 2005[41]	0,28	

Up to 0,7 mGy

Soulier et al. Rev. Med Suisse, 2014.

- **Fetal dose of perfusion SPECT : ≤ 0,12 mGy**
- **Maternal dose to the breast : 0,5 – 0,8 mSv**

Bajc, EJNMMI, in revision.

V/Q scintigraphy: breast feeding

- A number of radionuclides are excreted in breast milk. It is recommended that breast feeding is suspended as follows:
  - Completely after ^{131}I therapy
  - 3 weeks after ^{131}I, ^{125}I, ^{67}Ga, ^{22}Na, and ^{201}Tl
  - 12 h after ^{131}I hippurate and all ^{99m}Tc compounds except as below
  - 4 h after ^{99m}Tc red cells, DTPA, and phosphonates

V/Q scintigraphy: breast feeding

Table 2 Effective half-times of the various radiopharmaceuticals, total fractions excreted in the breast milk, effective doses to the newl recommendations on breastfeeding interruption

Radiopharmaceutical	Effective half-time (h)	Total fraction excreted in breast milk (% injected activity)	Effective dose to the newborn infant ($mSv_{infant}/MBq_{mother}$)
^{99m}Tc-labelled compounds			
DTPA	3.5 (3.2 – 3.8)	0.012 (0.010 – 0.014)	2.2×10^{-5} (1.8×10^{-5} – 2.7×10^{-5})
HMPAO-leucocytes	7.5	0.11	2.0×10^{-4}
MAA	4.0 (3.5 – 4.7)	3.7 (0.51 – 8.5)	7.0×10^{-3} (9.7×10^{-4} – 1.6×10^{-2})
MAG3	4.2 (3.6 – 4.9)	0.073 (0.020 – 0.10)	1.4×10^{-4} (3.8×10^{-5} – 1.9×10^{-4})
MDP (blocked)	4.9 (4.6 – 5.2)	0.010 (0.0084 – 0.011)	1.2×10^{-5} (9.9×10^{-6} – 1.3×10^{-5})
MDP (not blocked)	3.6	0.027	5.2×10^{-5}
MIBI	5.4 (5.2 – 5.6)	0.048 (0.039 – 0.056)	9.0×10^{-5} (7.3×10^{-5} – 1.1×10^{-4})
Pertechnetate (not blocked)	3.4 (2.7 – 3.9)	10 (5.3 – 19)	1.9×10^{-2} (9.9×10^{-3} – 3.6×10^{-2})
Pertechnetate (blocked)	5.2 (4.5 – 5.9)	0.82 (0.68 – 0.95)	9.6×10^{-4} (8.0×10^{-4} – 1.1×10^{-3})
RBC (in vivo)	6.7	0.0057	6.7×10^{-6}
Tetrofosmin	4.8	0.082	1.5×10^{-4}

Leide-Svegborn, EJNMMI, 2016.

V/Q scintigraphy: cost

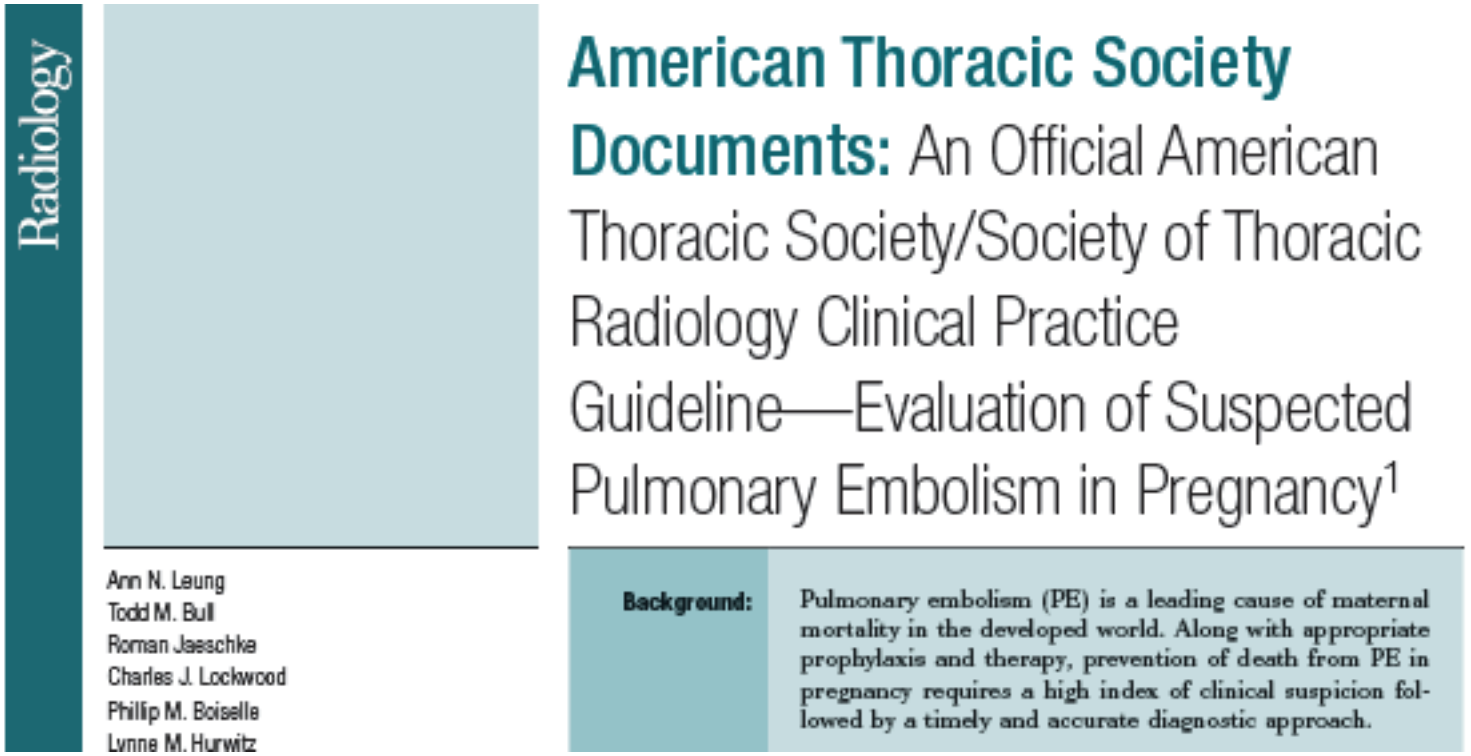
- Perfusion : 157,07 €
- Perfusion + SPECT : 255,17 €
- Perfusion + ventilation : 175,66 €
- Perfusion + ventilation + SPECT : 273,76 €
- Perfusion + SPECT/CT : 309,67 €
- Perfusion + Ventilation SPECT/CT : 328,26 €

→ between 157 and 274 €

V/Q scintigraphy: summary

Advantages	Disadvantages
Lower radiation exposure to maternal breast than CTPA	Non –diagnostic in ~ 10% of cases, e.g. in pts with pre-existing lung disease
High sensitivity and NPV in case of normal chest XR	Cannot provide differential diagnosis
Diagnostic alternative in case of allergy to iodine or renal failure	

DIAGNOSTIC ALGORITHM



Radiology

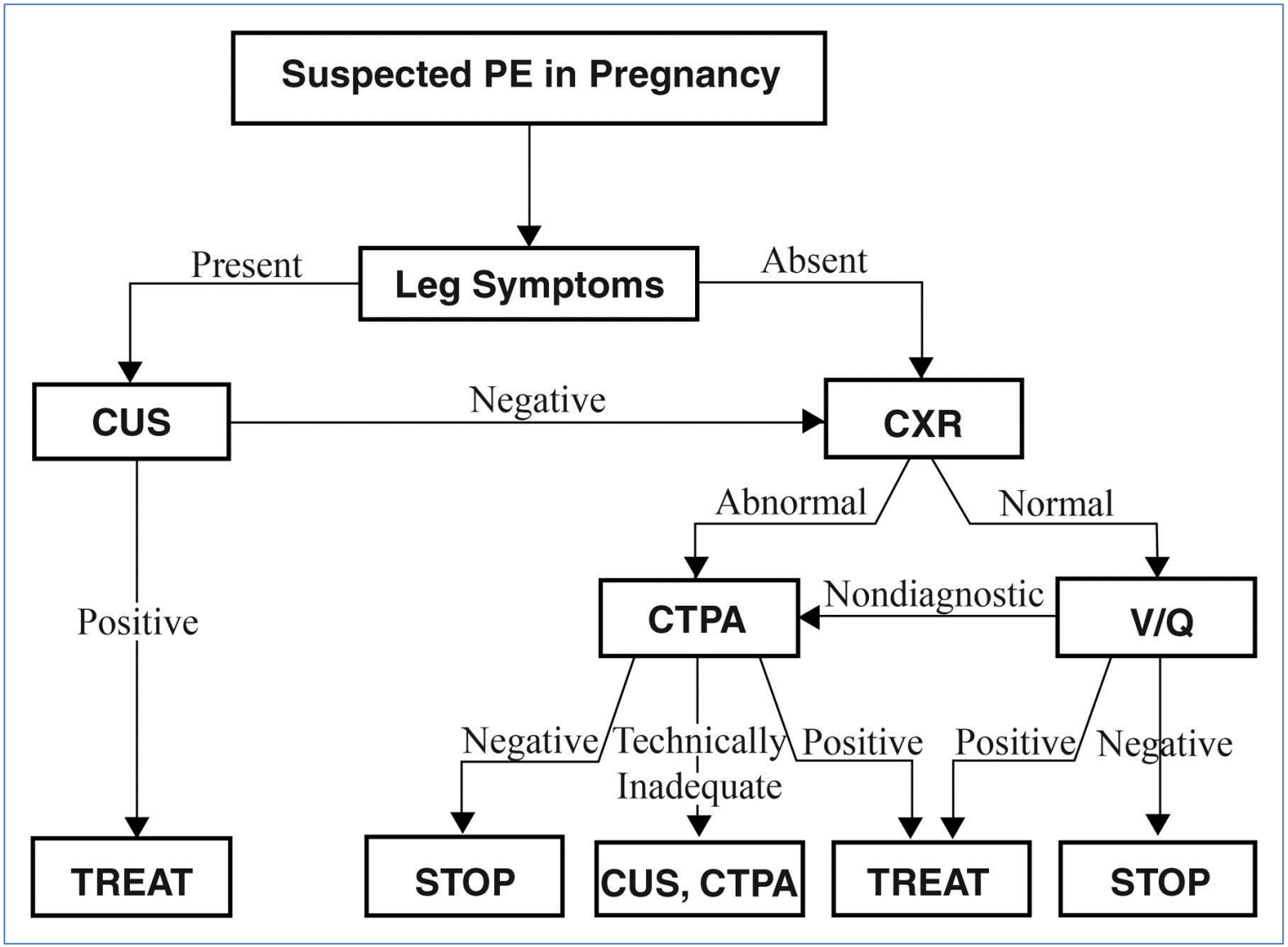
American Thoracic Society Documents: An Official American Thoracic Society/Society of Thoracic Radiology Clinical Practice Guideline—Evaluation of Suspected Pulmonary Embolism in Pregnancy[1]

Ann N. Leung
Todd M. Bull
Roman Jaeschke
Charles J. Lockwood
Phillip M. Boiselle
Lynne M. Hurwitz

Background: Pulmonary embolism (PE) is a leading cause of maternal mortality in the developed world. Along with appropriate prophylaxis and therapy, prevention of death from PE in pregnancy requires a high index of clinical suspicion followed by a timely and accurate diagnostic approach.

*Leung et al. Radiology 2012

Leung et al. Radiology 2012;262:635-46.



Leung et al. Radiology 2012;262:635-46.

Conclusions

- Lack of direct comparisons and studies evaluating state-of-the art imaging protocols does not allow for definite conclusions.
- The negative predictive value and rates of non-diagnostic tests were comparable between V-Q lung scans and CTPA.
- All reported radiation measurements for both imaging techniques were clearly below the established harmful threshold of 100 mGy.
- Decisions regarding the imaging modality of choice should be based on local availability of techniques combined with use of optimal scan protocols tailored to the pregnant patient.

Acknowledgements

- Marie-Pierre Revel, MD, Hôpital Cochin, Paris-France
- Benoît Ghaye, MDPhD, Cliniques Universitaires St-Luc-Bruxelles-Belgique