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

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Service de Médecine Nucléaire

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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 symptoms
- Guidelines developed for non-pregnant population not developed nor validated in pregnant pts
- Wells score and revised Geneva: not valuable in the pregnant and postpartum population
- D-dimer levels lose diagnostic accuracy due to a physiological increase during normal pregnancy

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

## 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

### Disadvantages
- 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
21-year old woman - chest pain and dyspnea - 33W
Chest X-ray
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%)
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 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
## Diagnostic Accuracy

### Pulmonary Embolism during Pregnancy: Diagnosis with Lung Scintigraphy or CT Angiography?

*Marie-Pierre Revel, MD, PhD*
*Stephanie Cohen, MD*
*Olivier Sanchez, MD*
*Maria-Anna Collignon, MD*
*Rokhaya Thiam, MS*
*Ahlan Redhaoui, MD*

**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, @22 weeks’ GA, 43 CTA & 94 LS

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


**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).

**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.
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 \(\rightarrow\) 0% of false negative CTPA

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of patients subjected to imaging test (n)</th>
<th>Baseline PE prevalence</th>
<th>Number of true negative test (n)</th>
<th>Number of VTE during follow-up (n)</th>
<th>NPV (%), 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scarsbook et al. 2007</td>
<td>9</td>
<td>22.2% (2/9)</td>
<td>6</td>
<td>0</td>
<td>100, (60.97-100)</td>
</tr>
<tr>
<td>Litmanovich et al. 2009</td>
<td>26</td>
<td>0% (0/26)</td>
<td>26</td>
<td>0</td>
<td>100, (87.13-100)</td>
</tr>
<tr>
<td>Shahir et al. 2010</td>
<td>106</td>
<td>3.7% (4/106)</td>
<td>95</td>
<td>1</td>
<td>98.96, (94.33-99.82)</td>
</tr>
<tr>
<td>Revel et al. 2011</td>
<td>43</td>
<td>10% (7/70)</td>
<td>28</td>
<td>0</td>
<td>100, (87.94-100)</td>
</tr>
<tr>
<td>Bourjeily et al. 2012</td>
<td>343</td>
<td>2.6% (9/348)</td>
<td>335</td>
<td>0</td>
<td>100, (98.86-100)</td>
</tr>
<tr>
<td>Browne et al. 2014</td>
<td>70</td>
<td>1.4% (1/70)</td>
<td>69</td>
<td>0</td>
<td>100, (94.73-100)</td>
</tr>
<tr>
<td>Nijkeuter et al. 2013</td>
<td>143</td>
<td>4.2% (6/143)</td>
<td>129</td>
<td>0</td>
<td>100, (97.11-100)</td>
</tr>
<tr>
<td>Sheen et al. 2017</td>
<td>97</td>
<td>4.1% (4/97)</td>
<td>84</td>
<td>2</td>
<td>97.94, (99.43-92.79)</td>
</tr>
</tbody>
</table>

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

Alternative Diagnosis

• **Dyspnea:**
  - Peri-partum Cardiomyopathy
  - Lung edema induced by tocolysis
  - Pneumonia
  - Amniotic embolus

• **Chest pain:**
  - Hamman’ syndrome*
  - Eclampsy complications

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

Chest pain on post partum

Cesarian for pre-eclampsia
Right basal thoracic pain

Subcapsular hematoma

### Non Diagnostic results

<table>
<thead>
<tr>
<th>General population</th>
<th>Pregnancy</th>
<th>Postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 10%</td>
<td>17% Cahill Obstet Gynecol 2009</td>
<td>20% Revel J Thromb Haemost 2009</td>
</tr>
<tr>
<td></td>
<td>21% Revel Radioloy 2011</td>
<td></td>
</tr>
<tr>
<td></td>
<td>27.5% U-Kim-Im Eur Radiol 2009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32% Ridge AJR 2009</td>
<td></td>
</tr>
</tbody>
</table>

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

Failure of CM in pregnant patients

Deep inspiration favors inferior vena cava flow
Failure of CM in pregnant patients

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, Jeon KN, Cho SB, Park SE, Moon JI, Baek HJ, Choi BH
SPECTRAL CT
Perfusion Defect visible on Zeff (red arrow)
clot visible at 45 keV (yellow arrow)
In doubt: Patient reinjected
In doubt: Patient reinjected

Injection 1

Injection 2

Reference
Suspiccion 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

<table>
<thead>
<tr>
<th>Série</th>
<th>Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foetus</strong></td>
<td></td>
</tr>
<tr>
<td>Winer-Muram, 2002$^{31}$</td>
<td>0,003-0,131</td>
</tr>
<tr>
<td>Nijkeuter, 2004$^{40}$</td>
<td>0,013-0,026</td>
</tr>
<tr>
<td>Cook, 2005$^{41}$</td>
<td>0,01</td>
</tr>
<tr>
<td>Hurwitz, 2006$^{19}$</td>
<td>0,24-0,66</td>
</tr>
<tr>
<td>Doshi, 2008$^{22}$</td>
<td>0,06-0,23</td>
</tr>
<tr>
<td><strong>Glande mammaire</strong></td>
<td></td>
</tr>
<tr>
<td>Cook, 2005$^{41}$</td>
<td>10</td>
</tr>
<tr>
<td>Parker, 2005$^{20}$</td>
<td>20</td>
</tr>
<tr>
<td>Hurwitz, 2006$^{19}$</td>
<td>43-66</td>
</tr>
<tr>
<td>Hurwitz, 2007$^{36}$</td>
<td>35-42,3</td>
</tr>
</tbody>
</table>

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

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™ 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™.

**Fig. 4.** CTPA of a 65-year-old patient (77 kg; BMI of 24.5) using a tube voltage of 80 kV (CTDI<sub>100</sub>: 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™ levels, image quality improved and streak artifacts were reduced, enabling a better conspicuity of the filling defects.
Breast feeding

- 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

Ghada Bourjeily, MD
Michel Chalhoub, MD
Chanika Phomphutkul, MD
Thelma C. Allayee, 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.

Results: 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.

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 T₄ 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
Consultance fees: 466670
Flat rate: 461016

Amount: 135 eur
Amount: 25.31 eur
Amount: 44.70 eur

Contrast:
Xenetix: 100 ml: 30.80 euros
Iomeron: 100 ml: 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 SPECT

### Perfusion

<table>
<thead>
<tr>
<th>Right</th>
<th>Axial</th>
<th>Right sagittal</th>
<th>Left sagittal</th>
<th>Coronal</th>
</tr>
</thead>
</table>

### Ventilation

<table>
<thead>
<tr>
<th>Right</th>
<th>Axial</th>
<th>Right sagittal</th>
<th>Left sagittal</th>
<th>Coronal</th>
</tr>
</thead>
</table>
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

<table>
<thead>
<tr>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce dose of perfusion agent</td>
</tr>
<tr>
<td>Reduce dose of ventilation agent</td>
</tr>
<tr>
<td>Eliminate ventilation portion of scan</td>
</tr>
<tr>
<td>Either encourage patient to void frequently or insert Foley catheter to reduce fetal exposure to radiotracer in the bladder</td>
</tr>
</tbody>
</table>

: quarter of the usual administrated dose

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.
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.

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

<table>
<thead>
<tr>
<th>Study</th>
<th>Non diagnostic rate (95% CI)</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Q lung scan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balan et al. 1997</td>
<td>0.40 (0.30-0.51)</td>
<td>4.86</td>
</tr>
<tr>
<td>Chan et al. 2002</td>
<td>0.25 (0.18-0.33)</td>
<td>5.85</td>
</tr>
<tr>
<td>Scarsbook et al. 2007</td>
<td>0.07 (0.04-0.14)</td>
<td>6.87</td>
</tr>
<tr>
<td>Ridge et al. 2009</td>
<td>0.04 (0.01-0.20)</td>
<td>5.95</td>
</tr>
<tr>
<td>Shahir et al. 2010</td>
<td>0.22 (0.15-0.31)</td>
<td>5.76</td>
</tr>
<tr>
<td>Reveil et al. 2011</td>
<td>0.19 (0.12-0.28)</td>
<td>5.83</td>
</tr>
<tr>
<td>Scott et al. 2011</td>
<td>0.01 (0.00-0.07)</td>
<td>7.59</td>
</tr>
<tr>
<td>Sellem et al. 2013</td>
<td>0.19 (0.13-0.27)</td>
<td>6.16</td>
</tr>
<tr>
<td>Abele et al. 2013</td>
<td>0.18 (0.11-0.28)</td>
<td>5.58</td>
</tr>
<tr>
<td>Cutts et al. 2014</td>
<td>0.03 (0.02-0.07)</td>
<td>7.61</td>
</tr>
<tr>
<td>Astari et al. 2014</td>
<td>0.22 (0.10-0.42)</td>
<td>3.07</td>
</tr>
<tr>
<td>Richard et al. 2015</td>
<td>0.09 (0.04-0.18)</td>
<td>6.43</td>
</tr>
<tr>
<td>Ramsay et al. 2015</td>
<td>0.29 (0.22-0.38)</td>
<td>5.87</td>
</tr>
<tr>
<td>Sheen et al. 2017</td>
<td>0.09 (0.06-0.11)</td>
<td>7.31</td>
</tr>
<tr>
<td>Golfam et al. 2017</td>
<td>0.08 (0.06-0.11)</td>
<td>7.56</td>
</tr>
<tr>
<td>Armstrong et al. 2017</td>
<td>0.10 (0.08-0.12)</td>
<td>7.71</td>
</tr>
<tr>
<td><strong>Subtotal (I²=90.30%)</strong></td>
<td><strong>0.14 (0.10-0.18)</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>Stage of gestation</th>
<th>Absorbed dose after 50 MBq $^{99m}$Tc-MAA</th>
<th>Absorbed dose after 30 MBq $^{99m}$Tc-Technegas</th>
<th>Absorbed dose after 120 MBq $^{99m}$Tc-MAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>0.14</td>
<td>0.007</td>
<td>0.34</td>
</tr>
<tr>
<td>3 months</td>
<td>0.20</td>
<td>0.007</td>
<td>0.48</td>
</tr>
<tr>
<td>6 months</td>
<td>0.25</td>
<td>0.011</td>
<td>0.60</td>
</tr>
<tr>
<td>9 months</td>
<td>0.20</td>
<td>0.014</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Bajc, EJNMMI, 2015.*
### V/Q scintigraphy: radiation exposure

#### Tableau 2. Doses d’irradiation délivrées par la scintigraphie

<table>
<thead>
<tr>
<th>Série</th>
<th>Perfusion, dose (mGy)</th>
<th>Ventilation, dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fœtus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nijkeuter, 2004</td>
<td>0,11-0,2</td>
<td>0,0001</td>
</tr>
<tr>
<td>Cook, 2005</td>
<td>0,12</td>
<td></td>
</tr>
<tr>
<td>Hurwitz, 2006</td>
<td>0,21-0,3</td>
<td>0,04-0,15</td>
</tr>
<tr>
<td>Glande mammaire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICRP 53, 1987</td>
<td>0,224</td>
<td>0,076</td>
</tr>
<tr>
<td>Cook, 2005</td>
<td>0,28</td>
<td></td>
</tr>
</tbody>
</table>

Up to 0.7 mGy

- **Fetal dose of perfusion SPECT**: ≤ 0.12 mGy
- **Maternal dose to the breast**: 0.5 – 0.8 mSv

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 newborn infant.

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

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

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

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.

Suspected PE in Pregnancy

Leg Symptoms

- Present
  - CUS
    - Positive
      - TREAT
    - Negative
      - CXR
        - Abnormal
          - CTPA
            - Negative
              - STOP
            - Technically Positive
              - CUS, CTPA
        - Normal
          - V/Q
            - Positive
              - TREAT
            - Negative
              - STOP

- Absent
  - Negative
  - Normal
    - Nondiagnostic
      - CTPA
        - Negative
          - STOP
        - Inadequate
          - CUS, CTPA
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.
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