V/Q Scan for Pulmonary Embolism in Pregnancy

Stephen Fiascone
Harvard Medical School, Year III
Gillian Lieberman, MD
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
Index Patient: 29 F

- CC: “SOB”
- HPI: Chest tightness, winded easily x3d. In ER c/o “feeling like something is wrong with her L lung.”
- PMH: Asthma, dyspnea 2 years ago relieved with lorazepam in BIDMC ED, anxiety.
- SH: 1 pack cigarettes / month.
Ddx dyspnea in a 29 F

- Respiratory: asthma, pneumonia, bronchitis, PE, pneumothorax...
- Cardiovascular: acute coronary syndrome, pericarditis, hypertrophic cardiomyopathy...
- Other: MSK, anemia, hypothyroidism, anxiety, pregnancy, myasthenia gravis...
Index Patient: Physical Exam

PHYSICAL EXAMINATION

Temp: 98.4 HR: 59 BP: 110/73 Resp: 16 O(2) Sat: 100 normal

Constitutional: Comfortable
Oropharynx within normal limits
Chest: Clear to auscultation
Cardiovascular: Regular Rate and Rhythm, Normal first and second heart sounds
Abdominal: Soft, Nontender, Nondistended
Rectal: Heme Negative
Extr/Back: No cyanosis, clubbing or edema
Skin: No rash, Warm and dry
Neuro: Speech fluent
Psych: Normal mood, Normal mentation

RADIOLOGY

Interpreted by me

Note(s): CXR -

OMR, BIDMC
Index Patient: Pertinent Labs

- WBC 5.5, Hct 35.5 (36-48)
- UCG positive
- D-dimer: 538 (0-500)
Index Patient: Chest PA & Lateral Radiographs

PACS, BIDMC

Stephen Fiascone, HMS III
Gillian Lieberman, MD
Companion Patient 1: Hampton’s Hump on frontal CXR

In the right lower-lung field, there is a small wedge-shaped opacity that abuts the pleura, representing consolidation distal to lung infarction.

Image Source: http://imaging.birjournals.org/content/vol18/issue3/images/large/122fig24.jpeg
Companion Patient 2: Westermark Sign on frontal CXR

In the right mid-lung field, there is an area of focal oligemia.

Image Source: http://www.wikiradiography.com/page/Westermark+Sign
Last accessed: 6/16/11.
MEDICAL DECISION MAKING

29 y/o female with 2 seemingly separate chief complaints. Given the fact that she is found to be pregnant, probably explains her nausea/vomiting. But also makes the possibility of PE realistic, with her "SOB" and chest discomfort. D-dimer should be useful in 1st trimester if negative, will start with that and proceed to CT if positive. Also will hydrate, check lytes, quant hcg.
-d-dimer +, has allergy to iodine --> perfusion scan pending
-u/a + for uti, will tx even though asymptomatic b/c is pregnant
-at this point pending perfusion scan, if normal plan to d/c home

Final ED Diagnosis 1: shortness of breath
2: vomiting
3: pregnancy

<table>
<thead>
<tr>
<th>Drug or Allergen Group</th>
<th>Reaction(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine</td>
<td>Anaphylaxis</td>
</tr>
<tr>
<td></td>
<td><em>Level of Certainty: Moderately Certain</em></td>
</tr>
<tr>
<td></td>
<td><em>Additional information: Reaction to SHRIMP, no reaction to beladine</em></td>
</tr>
</tbody>
</table>
An aside: Iodine “allergies”

- “Iodine is not and cannot be an allergen.”
- “How seafood allergies and ‘iodine’ allergies became linked is unclear… the major allergens in shellfish are tropomyosins.”
- “Reactions to intravenous contrast are not allergic and therefore not anaphylactic.”
- “The risk of reactions to [radiocontrast media] was similarly elevated (about a 3-fold risk compared to average) for persons with allergy to egg, milk or chocolate, indicating that a general atopic disposition…”

(Schabelman & Witting, 2010)
# Radiologic Menu of Tests

**American College of Radiology**  
**ACR Appropriateness Criteria**

<table>
<thead>
<tr>
<th>Clinical Condition:</th>
<th>Acute Chest Pain — Suspected Pulmonary Embolism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiologic Procedure</strong></td>
<td><strong>Rating</strong></td>
</tr>
<tr>
<td>X-ray chest</td>
<td>9</td>
</tr>
<tr>
<td>CTA chest (noncoronary) with contrast</td>
<td>9</td>
</tr>
<tr>
<td>CTA chest with contrast with CT venography</td>
<td>7</td>
</tr>
<tr>
<td>US lower extremity with Doppler</td>
<td>7</td>
</tr>
<tr>
<td>Tc-99m V/Q scan lung</td>
<td>6</td>
</tr>
<tr>
<td>Pulmonary angiography with right heart catheterization</td>
<td>5</td>
</tr>
<tr>
<td>MRA pulmonary arteries</td>
<td>4</td>
</tr>
<tr>
<td>US echocardiography transesophageal</td>
<td>2</td>
</tr>
<tr>
<td>US echocardiography transthoracic</td>
<td>2</td>
</tr>
</tbody>
</table>

**Rating Scale:** 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level*

**Image Source:** http://acsearch.acr.org/  
V/Q Scan

- **Principle**: compares ventilation (V) and perfusion (Q) of lung segments (look for V without Q; anti-shunt)
- **Preparation**: need CXR before, to evaluate for underlying lung disease
- **Order**: Q before V, as normal Q rules out PE
- **Q Contrast**: Q contrast agent: Tc-99m MAA (technetium-99m macroaggregated albumin)
- **V Contrast**: Xe-133 (*Q first) or Tc-99m (*V first)
Lung: Segmental Anatomy

Image Source: http://www.drmaryonline.com/toprad/vq_scan.html
Last accessed 6/15/11.
Modified PIOPED: Interpreting V/Q Scans

- **High Probability**: 2 or more mismatched segmental defects, or defects much larger than CXR abnormality
- **Intermediate Probability**: Does not change pretest probability
- **Low Probability**: Nonsegmental defects, matched V/Q defects, subsegmental Q defects
- **Very Low Probability**: No perfusion defects

(Freitas et al., 1995)
Index Patient: Perfusion Scan

Image courtesy of Dr. Kevin Donohoe (BIDMC Radiology), and BIDMC PACS
Index Patient: Ventilation Scan

Image courtesy of Dr. Kevin Donohoe (BIDMC Radiology), and BIDMC PACS
Index Patient: Compare the Perfusion (Q) and Ventilation (V) Scans

Images courtesy of Dr. Kevin Donohoe (BIDMC Radiology), and PACS, BIDMC
Our Index Patient had a normal perfusion scan and no areas of discrepancy between her perfusion and ventilation scans. Her V/Q scan was interpreted as very-low probability for PE, and she was discharged home from the ED. She delivered a healthy boy at term 30 weeks later.
Companion Patient 3: High-probability V/Q Scan

- 69 F, acute onset SOB, clear CXR. Renal failure (CTA contraindicated on presentation due to contrast load).
- Underwent CTA two days later while team considered thrombectomy.

Images courtesy of Dr. Kevin Donohoe (BIDMC Radiology), and PACS, BIDMC
Companion Patient 3: Look for V/Q mismatch on this high-probability scan.
Companion Patient 3: High-probability V/Q Scan

Multiple perfusion defects

Corresponding ventilation is intact

Images courtesy of Dr. Kevin Donohoe (BIDMC Radiology), and PACS, BIDMC
Companion Patient 3: CT Angiogram (landmark anatomy)

SVC: Superior Vena Cava  PA: Pulmonary Artery
AA: Ascending Aorta  DA: Descending Aorta  T: Trachea

PACS, BIDMC
Companion Patient 3: PE on CT Angiogram (1)

There is an intravascular area of low attenuation where the left pulmonary artery branches.
Companion Patient 3: PE on CT Angiogram (2)

At the level of the trachea’s bifurcation, there is another intravascular area of low attenuation which appears to occlude most if not all of the right pulmonary artery.
Companion Patient 3: PE on CT Angiogram (3)

This pulmonary embolism appears to “saddle” the pulmonary trunk, affecting both the right and left pulmonary arteries.
Companion Patient 3: PE on CT Angiogram (4)

This PE extends laterally and occludes segmental arteries bilaterally.
Companion Patient 3:
Cardiac findings of PE on CT Angiogram

Finally, the RV is wider than the LV; a ratio above 1 suggests RV strain.

The interventricular septum is slightly deviated into a more straightened configuration.
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
Global Maternal Mortality

- >500,000 maternal deaths in 2005.
  - 99% in developing countries (85% of world’s population)
- WHO estimates that in Niger, a woman’s lifetime odds of dying due to childbirth are 1 in 7.
- Ireland: 1 in 47,600.

(World Health Organization, 2005)
Global Maternal Mortality

Maternal mortality ratios (MMR) per 100,000 live births (2005)

Last accessed 6/26/11.
## Domestic Maternal Mortality


<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Live birth (n = 2,519)</th>
<th>Stillbirth (n = 275)</th>
<th>Ectopic (n = 237)</th>
<th>Abortion† (n = 165)</th>
<th>Molar (n = 14)</th>
<th>Undelivered (n = 438)</th>
<th>Unknown (n = 552)</th>
<th>All outcomes (%)</th>
<th>PRMR (N = 4,200)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embolism</td>
<td>21.0</td>
<td>18.6</td>
<td>2.1</td>
<td>13.9</td>
<td>28.6</td>
<td>25.1</td>
<td>18.3</td>
<td>19.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>2.7</td>
<td>21.1</td>
<td>93.3</td>
<td>21.8</td>
<td>7.1</td>
<td>8.7</td>
<td>8.7</td>
<td>17.2</td>
<td>2.0</td>
</tr>
<tr>
<td>PIH§</td>
<td>19.3</td>
<td>20.0</td>
<td>0</td>
<td>0.6</td>
<td>0</td>
<td>12.3</td>
<td>11.8</td>
<td>15.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Infection</td>
<td>11.7</td>
<td>18.9</td>
<td>2.5</td>
<td>33.9</td>
<td>14.3</td>
<td>11.0</td>
<td>12.9</td>
<td>12.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Cardiomyopathy</td>
<td>10.1</td>
<td>5.1</td>
<td>0.4</td>
<td>1.8</td>
<td>0</td>
<td>3.4</td>
<td>11.2</td>
<td>8.3</td>
<td>1.0</td>
</tr>
<tr>
<td>CVA†</td>
<td>5.7</td>
<td>0.7</td>
<td>0</td>
<td>1.2</td>
<td>0</td>
<td>3.9</td>
<td>8.5</td>
<td>5.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Anesthesia</td>
<td>1.8</td>
<td>0.7</td>
<td>1.3</td>
<td>9.7</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
<td>1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Other**</td>
<td>17.1</td>
<td>14.9</td>
<td>0.4</td>
<td>16.4</td>
<td>50.0</td>
<td>33.6</td>
<td>27.9</td>
<td>19.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.6</td>
<td>0</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>2.1</td>
<td>0.4</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>11.8</td>
</tr>
</tbody>
</table>

* Pregnancy-related deaths per 100,000 live births.
† Includes spontaneous and induced abortions.
§ Pregnancy-induced hypertension.
¶ Cerebrovascular accident.
** The majority of the other medical conditions were cardiovascular, pulmonary, and neurologic problems.
†† Percentages might not add to 100.0 because of rounding.

(Chang et al., 2003)
VTE is common in pregnancy; PE is less common

- **1 per 500-2000**: Venous thromboembolism in pregnancy (VTE, encompasses deep venous thrombosis and pulmonary embolus) (Heit et al., 2005)

- **1.2 per 100,000**: Deaths due to pulmonary embolus in Western World pregnancies (Hansen et al., 2011)
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
Virchow’s Triad

- Stasis
- Endothelial Damage
- Hypercoagulable State

Rudolf Virchow (1821-1902): Father of Pathology, also pioneer of Social Medicine

Image Source: http://en.wikipedia.org/wiki/Rudolf_Virchow
Virchow’s Triad: Stasis

- Venous stasis in pregnancy: swelling of the lower extremity veins due to lower extremity edema (decreased linear velocity despite increased overall return)
- Bed rest
- Compression of abdominal and pelvic veins by the gravid uterus
  - Incidence of pelvic DVTs is about 12x normal during pregnancy
  - Even the IVC gets compressed!

(Goodrich & Wood, 1964)
(James et al., 2006)
Virchow’s Triad: Hypercoagulable State

- Elevated fibrin and coagulation factors II, VII, VIII, X, decreased protein S.  (Marik & Plante, 2008)

- 5-10x risk of venous thromboembolism during pregnancy.  (Hansen et al., 2011)

- Risk for VTE is approximately equal across all three trimesters, but postpartum VTE is more common than antepartum.  (Simpson et al., 2001)
  - VTE after C-section is 5-9x as common as after vaginal delivery.  (Rosenberg & Lockwood, 2007)

- 24% of untreated DVTs progress to PE.  (Wessler, 1976)
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
During pregnancy the traditional symptoms, signs and labs of DVT and PE are (even) less reliable.
Pregnancy is a dyspneic state

- Physiologic (dilutional) anemia of pregnancy
- Increased Cardiac Output (first by increase in stroke volume, then heart rate)
  - \( \text{CO} = \text{SV} \times \text{HR} \)
- Progesterone stimulates compensated respiratory alkalosis to aid fetal excretion of waste
- Air hunger. 25% by week 12, 80% by week 36

(Prowse & Gaensler, 1964)
Pregnancy alters values for labs used to detect PE

- Blood gas: it can be normal to have respiratory alkalosis during pregnancy.
- D-dimer: generally used to rule out PE; elevated in pregnancy with no established “normal” range.
  - D-dimer <500 ng/mL: 50% first trimester, 22% second trimester, and 0% third trimester. (79% preconception!)
  - Attempts to use D-dimer to stratify thrombosis risk were inaccurate. (Bombeli et al., 2001)
  - ‘Normal’ D-dimer in pregnancy may provide false reassurance. (Damodaram et al., 2009)

(Kline et al., 2005)
Wells criteria is less helpful during pregnancy

### Wells criteria and modified Wells criteria: clinical assessment for pulmonary embolism

| Clinical symptoms of DVT (leg swelling, pain with palpation) | 3.0 |
| Other diagnosis less likely than pulmonary embolism         | 3.0 |
| Heart rate >100                                            | 1.5 |
| Immobilization (≥3 days) or surgery in the previous four weeks | 1.5 |
| Previous DVT/PE                                            | 1.5 |
| Hemoptysis                                                 | 1.0 |
| Malignancy                                                  | 1.0 |

<table>
<thead>
<tr>
<th>Probability</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.0 to 6.0</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;2.0</td>
</tr>
</tbody>
</table>

**Simplified clinical probability assessment (Modified Wells criteria)**

<table>
<thead>
<tr>
<th>Probability</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE likely</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>PE unlikely</td>
<td>≤4.0</td>
</tr>
</tbody>
</table>

For these reasons, the standard algorithm is less helpful during pregnancy.
Other algorithms exist for PE workup in pregnancy*

*These algorithms, however, fail to distinguish between V/Q Scan or CT Angiogram as the first-line diagnostic imaging study.
Other algorithms exist for PE workup in pregnancy*

*These algorithms, however, fail to distinguish between V/Q Scan or CT Angiogram as the first-line diagnostic imaging study.
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
Potential concerns regarding V/Q Scans

- Fetal radiation exposure
- Maternal radiation exposure
- Possibility of “intermediate probability”
- Cannot pinpoint perfusion defect
- Takes longer to perform
- Physician unfamiliarity
PIOPED: V/Q Accuracy

- High clinical probability + high-probability V/Q: 95% likelihood PE
- Indeterminate probability V/Q does not change pre-test (clinical) probability
- Low clinical probability + low-probability V/Q: 4% likelihood PE
- Very low probability (no perfusion defect) virtually rules out PE

(PIOPED Investigators, 1990)
During pregnancy, V/Q Scans are diagnostic more frequently

- While non-pregnant patients have “nondiagnostic” V/Q rates of 47-59%, nondiagnostic V/Q studies in pregnancy were only 25% in one series.
- Pregnant women tend to be both younger and healthier than most patients who need chest imaging, thus pregnant women have better ventilation and perfusion scans.

(Chan et al. 2002)
During pregnancy, CT Angiograms are diagnostic less frequently

- CTA: Supine study with deep inspiration
- Sixfold increase in IVC pressure during third trimester
- In the inadequate CTA studies, ~90% blood to the right atrium came from IVC
- IV contrast comes from the SVC, and gets interrupted
- CTA “diagnostic inadequacy” rate of 36%

(Ridge et al. 2009)
In other words: with pregnancy, the diagnostic accuracy of V/Q scans increases, while the accuracy of CTA decreases.
Radiation Risks to Fetus

- Doses < 50 mGy: no evidence supporting increased risk to fetus
  - (fetal anomalies, intellectual disability, growth restriction, pregnancy loss) (ACOG Committee Opinion, 2004)
- Q scan with Tc-99m: .06-.12 mGy
- V scan: .01-.19 mGy
- CT chest: .30 mGy
- CT abdomen: 2.5 mGy

(Bentur, 1994)
Roadmap & Learning Objectives

- **Case Presentation** (There is no such thing as an iodine allergy.)
- **Epidemiology** (Maternal mortality rates differ by 4 orders of magnitude across the world.)
- **Science** (Pregnancy is a hypercoagulable state.)
- **Clinical** (For physiologic reasons, it is extra-difficult to diagnose PE during pregnancy.)
- **Discussion** (For most pregnant women, V/Q scan is the test of choice for imaging PE. This is controversial.)
References


References


References

Acknowledgements

- Dr. Gillian Lieberman
- Dr. Kevin Donohoe
- Dr. Monica Agarwal
- Emily Hanson
- Gelareh Homayounfar, Amar Kishan, Tom Kolokotrones, Christine Westra