IMPORTANCE OF V/Q IMAGING IN THE ASSESSMENT OF PULMONARY EMBOLISM: COMPARISON WITH CTA

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Pulmonary Embolism

- 650,000 cases annually
- Autopsy results: 60% of patients dying in hospitals have PE; diagnosis missed in 70%
- Clinical symptoms non-specific.
Methods for the Assessment of Pulmonary Embolism

- Ventilation/Perfusion Lung Scan
- CT Angiography
Ventilation-Perfusion Scan: The Basics

Definition

- A physiologic map that evaluates the primary functions of the lung, pulmonary vascular perfusion, and segmental bronchioalveolar tree ventilation.
Pulmonary Segmental Anatomy

- **Apical**
- **Posterior**
- **Anterior**
- **Lateral**
- **Medial Superior**
- **Medial Basal**
- **Ant. Medial Basal**
- **Lateral Basal**
- **Post. Basal**

**LPO**
- **RAO**
- **LAO**

- **Post. Basal**
- **Lateral Basal**
- **Anterior Basal**
- **Apical Posterior**
- **Sup. Lingual**
- **Inf. Lingual**

Colored by Marc G. Cote, D.O.
Indications
- Suspected PE
- Others
  • Monitoring pulmonary function of lung transplants
  • Preoperative estimates of lung function in planned pneumonectomy patients
  • Evaluation of right to left shunts
  • Pre and post operative evaluation of lung transplant
Ventilation Perfusion Scan: The Basics

Physiology of ventilation and perfusion: A dynamic system

- Normal scan
  - Capillary perfusion and alveolar ventilation are matched in order to maximize gas exchange.
  - Scan demonstrates both normal perfusion and ventilation
Normal V/Q
Ventilation Perfusion Scan: The Basics

Physiology of ventilation and perfusion: A dynamic system

• Abnormal scans
  – Diversion of blood flow away from pulmonary segment.
  – Perfusion of non aerated pulmonary region
  – Abnormal ventilation = Obstructive Airway with or without normal perfusion
V/Q Scans: Radiopharmaceuticals

Ventilation:
- Technetium-99m aerosols (Tc-99m DTPA, Technegas)
- Xenon-133

Perfusion:
- Tc-99m-MAA
  - 20-40 micron size; RBC = 7 microns
Clinical Information

Correlation with clinical info and additional imaging tests

- History
- CXR
- D-Dimer
- Duplex US / nuclear venogram
- Chest CT angiogram
- Catheter angiogram
V/Q Scans: Reporting the Results

Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) Classification

- Normal
- Very low probability (<10%)
- Low probability (<19%)
- Intermediate probability (20-80%)
- High probability (>80%)
Revised PIOPED Criteria

NORMAL

No perfusion defects – perfusion outlines exactly the shape of the lungs seen on the chest radiograph (note that hilar and aortic impressions may be seen, and the chest radiograph and/or ventilation study may be abnormal)
Normal V/Q
Revised PIOPED Criteria

HIGH Probability (≥ 80%)

Two or more large (>75% of a segment) mismatched segmental perfusion defects or the equivalent in moderate or large and moderate mismatched defects
High Probability V/Q
Revised PIOPED Criteria

LOW Probability ($\leq 19\%$)

- Any perfusion defect with a substantially larger chest radiographic abnormality
- Any number of small ($< 25\%$) perfusion defects with a normal chest radiograph
Revised PIOPED Criteria

LOW Probability (≤ 19%)

- Perfusion defects matched by ventilation abnormality provided that there are (a) clear chest radiograph and (b) some areas of normal perfusion in the lungs.
Revised PIOPED Criteria
(Data from Pioped II)

VERY LOW Probability (< 10%)*

- Nonsegmental lesion, e.g., prominent hilum, cardiomegaly, elevated diaphragm, linear atelectasis, costophrenic angle effusion with no other perfusion defect in either lung

- Perfusion defect smaller than radiographic lesion, regardless of findings on ventilation

Revised PIOPED Criteria

VERY LOW Probability (< 10%)

• Matched defects representing the only perfusion defects in two or three zones of a single lung and accompanied by regionally normal CXR

• One to three small (<25%) segmental perfusion defects with regionally normal CXR, independent of ventilation
Revised PIOPED Criteria

VERY LOW Probability (<10%)

- A solitary triple matched defect in the mid or upper lung zones
- Stripe sign present around the perfusion defect
- Pleural effusion of one third or more of the pleural cavity with no other perfusion defect in either lung
VERY LOW Probability Scan:
Nonsegmental Perfusion Defect
Stripe Sign
Very Low Probability Scan:
Matched ventilation-perfusion scan defects
Chest x-ray “normal”
VERY LOW Probability Scan:
1 to 3 small subsegmental perfusion defects
Revised PIOPED Criteria

INTERMEDIATE Probability (20% to 80%)

- One moderate (25-75%) to two large (>75%) mismatched segmental perfusion defects or the arithmetic equivalent in moderate or large perfusion defects

- One matched ventilation-perfusion defect with clear chest radiograph (very extensive matched defects can be characterized as low probability)
Revised PIOPED Criteria

INTERMEDIATE Probability (20% to 80%)

• Triple matched defects in the lower zones.
• Difficult to categorize as low or high, or not described as low or high
"New" reporting system (Trinary) *

- Pioped probability system is complex
- Physicians would like to have a report stating PE - Yes or No
  - Most CTA reports are Yes or No for PE
- New reporting system (Trinary) being evaluated in which report is PE Yes or No *
  - Normal, low or very low probability combined

“New” reporting system (Trinary)

• False-Negative rate (based on follow-up events) 1.5% (9/585) (similar to Pioped)
• High probability = 8.4% compared to 4.9% for Pioped
  • Due to more aggressive criteria for PE present group, especially inclusion of single segmental mismatch
Technologists Expectations

- Technologist’s ability to correctly interpret a V/Q will ensure obtaining a complete history and produce a high quality image set.
- Production of a complete history and quality image set allows reliable physician interpretation.
- Technologist needs to be tactful when interpreting the V/Q when attending/resident is present.
Spot Quiz
High Probability V/Q
CT Angiogram
High Probability V/Q
“Intermediate” Probability (< 2 Seg. Equiv) Pioped
High Probability for PE (Trinary)
Intermediate/Low Probability (Pioped)
No PE (Trinary)
High Probability V/Q
Unknown
What is the probability for P.E.?
High Probability (pattern)
Diagnosis: Congenital absence of the pulmonary artery to the right upper lobe
QUIZ: What is the diagnosis?
Pleural Effusion + Possible R to L Shunt
Any Other Views?
Probability for P.E.?
Technologist induced emboli (blood in syringe)
Other Causes of V/Q Mismatch

- Chronic PE
- Vasculitis
- Radiation Therapy
- Extrinsic compression of the pulmonary artery (tumor, adenopathy, vascular anomalies)
- Intraluminal PA involvement by tumor
- Hypoplastic PA
False Negatives

- Partially occlusive thromboembolic disease (rare)
Reduced Utilization of V/Q Studies

• New technology (CT Angiography)

• Unacceptable prevalence of non-diagnostic V/Q results
  • PIOPED I 76% (32.6% low, 44% Intermediate)
  • PIOPED II 26.5% (9.8% low, 16.7% intermediate)

• Results misleading if one does not compare specificity in patients with normal vs abnormal CXR
Additional Factors
CTA vs V/Q

• Alternate anatomic diagnosis (CTA)
  – Dissecting aneurism
  – Pneumothorax

• Diagnostic superiority
  – Often function of reader expertise
  – PIOPED II; CTA and V/Q equivalent

• Availability ? 24/7
  – Portable technology for unstable patients
PIOPED II*
(CTA)

824 patients

51 patients
Poor quality CTA

773 patients
Adequate CTA

Sensitivity 83%  Specificity 96%

* CTA for Acute PE
Sostman, et al. Sensitivity and Specificity of Perfusion Scintigraphy Combined with Chest Radiography for Acute PE in PIOPED II
CTA Issues

• Technically inadequate studies (6-10%)
• Potential iodine allergy
• Impact on renal function
• Radiation issues
• Airway / parenchymal disease often missed on CTA
V/Q Issues

- Non-diagnostic or intermediate interpretations
  - PIOPED I - 44% Intermediate / 33.2% low
  - PIOPED II – 16.7% Intermediate / 9.8% low
    - Results included patients with abnormal chest x-rays
- Inadequate/unable to complete ventilation
  - Negative Perfusion valuable information
Impact of Pre-Test Likelihood *

- Utilization of objective scoring system (Wells)
- D-Dimer **
- Results for positive and negative predictive values influenced by pre-test likelihood
  - PPV for CTA 96% for clinical high prob, 92% for intermediate, 58% for low
  - NPV for CTA 60% for clinical high prob, 89% for intermediate, and 96% for low

* CTA for Acute PE

Clinical Probability of PE * (Wells)

<table>
<thead>
<tr>
<th>Clinical Features</th>
<th>Score (Points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Clinical Signs and symptoms of DVT (Objectively measured leg swelling and pain with palpation in deep vein system)</td>
<td>3.0</td>
</tr>
<tr>
<td>• Heart rate &gt; 100 beats/min</td>
<td>1.5</td>
</tr>
<tr>
<td>• Immobilization ≥ 3 consecutive days (bedrest except to access bathroom) or surgery in previous 4 wk</td>
<td>1.5</td>
</tr>
</tbody>
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Score: <2.0, low probability; 2.0–6.0, moderate probability; >6.0, high probability.

### Clinical Probability of PE *(Wells)*

**Clinical Features**

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<td>Previous Objectively diagnosed PE or DVT</td>
<td>1.5</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1.0</td>
</tr>
<tr>
<td>Malignancy (cancer patients receiving treatment within 6 mo or receiving palliative treatment)</td>
<td>1.0</td>
</tr>
<tr>
<td>PE as likely as or more likely than alternative diagnosis (based on history, physical examination, chest radiograph, electrocardiogram, and blood tests)</td>
<td>3.0</td>
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**Score:**
- $<2.0$, low probability
- $2.0-6.0$, moderate probability
- $>6.0$, high probability

Issues Regarding Radiation

• CT Pulmonary Angiography
  • Total DLP (Dose Length Product) approx 600-800 mGy-cm, dependent on patient size.
  • Conversion gives total 11-15mSv (= 1.1 - 1.5rem)
  • The effective dose to the breasts is 2rem, approx 10 times the dose to the breasts from a 2 view mammogram.

• VQ scan
  • Total effective dose is 2.5mSv (= 0.25rem)
  • Breast radiation 0.28- 0.9mSv (=0.028 - 0.09rem)

* 1 mSv = 100 mrem 1 millisievert (mSv) = 100 millirem (mrem)
Breast Radiation Issues

• Breast radiation using 4-slice CT = 20-60 mSv
• Breast radiation using 64-slice CTA = 50-80 mSv
• Breast radiation from V/Q is 0.28 - 0.9 mSv
• The difference = 65 - 250X greater for CT
Breast Radiation Issues

• 2-view mammogram = 3-4 mSv
• CTA = 10-20 mammograms
• Lifetime attributable risk of breast cancer from CTA = 1 in 143 for a 20yo woman and 1 in 284 in a 40yo woman * (this is higher than most other estimates)
• International Commission on Radiation Protection (ICRP) "CT doses may exceed limits shown to result in an increased risk for cancer" **

*Einstein, HA. JNMA 2007; 298: 317-323
** Ann ICRP 2000; 30:7- 45
V/Q vs CTA
Low to moderate clinical likelihood
(Modified Wells Criteria < 6)

D Dimer Normal *

D Dimer Abnormal

CXR**

Normal CXR

Abnormal CXR

CTA Ineligible ***

CTA

No PE

VQ


** If minimal findings, consider as normal

*** CTA ineligible: iodine allergy, renal impairment, lack of adequate iv access
V/Q vs CTA
High clinical likelihood
( Modified Wells Criteria >6)

- Normal CXR
  - VQ
  - CTA
  - Intermediate probability.

- Abnormal CXR
  - CTA
  - Ineligible

** If minimal findings, consider as normal
Pregnant Patient

- PREGNANT PATIENT
  - Perfusion only lung scan can be used for detection of PE, and is the lowest radiation option. CTA only if CXR is abnormal beyond basilar atelectasis.

- Perfusion only
  - 0.5-1 mCi perfusion with no initial ventilation
  - Ventilation may be performed following day if indicated (>95% perfusion studies are normal)
  - If chest x-ray abnormal, consider CTA as test of choice
Special Cases: The Pregnant Patient

D Dimer Testing

D Dimer Normal *

- No PE

Pregnant (low dose Q)

D Dimer Abnormal

LE Dupplex

+ DVT → Anticoagulate

- DVT

CXR**

Normal CXR

VQ

CTA Ineligible

Abnormal CXR

CTA

Intermediate probability.


** If minimal findings, consider as normal
Special Cases: Patient in Extremis
(Hemodynamically Unstable)

Move to Imaging Dept.

**NO**
- Portable V/Q
- Bedside LE Doppler
- Bedside Echo for RV strain

**YES**
- Yes, Stable to Move to CT
- CTA ineligible

* Test of choice for hemodynamically unstable patient
Special Circumstances

• CHEST PAIN WITH AORTIC DISSECTION IN DIFFERENTIAL OR OTHER ANATOMIC BASES FOR PATIENT SIGNS OR SYMPTOMS
  – Do CTA.
Special Cases: Differential Dx Includes PE and Acute Aortic Dissection

V/Q for PE Evaluation + Trans Echo Esophagram for AD Evaluation

* Test of choice
Special Circumstances

• PRIOR PULMONARY EMBOLISM
  – The imaging test should be the same as the test previously performed to document presence and extent of PE. VQ should be done (if not done prior) to establish baseline for follow up.
Case Examples
Case 1

45 year old female smoker on BCP presents with acute dyspnea the night following a 20 hour plane ride where she was unable to move about in the cabin due to an acute ankle fracture.

PMHx: breast cancer, treated with lumpectomy and chemo
All: none

VS: 80/40. HR 130, RR 32, Sat 80%
Exam shows an ill appearing cyanotic female in moderately severe respiratory distress. Lungs are clear. Injured leg with edema above short cast extending to the upper thigh.
EKG sinus tach with right sided strain
CXR normal

What is pre-test clinical suspicion for PE?
What is the better test: VQ or CT?
Case 1

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EKG sinus tach with right sided strain
CXR normal

What is pre-test clinical suspicion for PE? **HIGH**
What is the better test: VQ or CT? **V/Q (CTA if in extremis)**
Case 2

76 year old patient with CAD, HTN, AS, on chemo for treatment of metastatic colon cancer presents with acute dyspnea with precordial chest pain radiating to the upper back.

All: none

Exam shows an ill appearing elderly male in pain, BP 190/110, HR 120, RR 24, Sat 90% RA.

Neck veins are mildly distended and lungs are clear. Heart is distant, but regular with 3/6 systolic murmur.

EKG is paced

CXR is read as “NAD”

Labs are at baseline, Cr 1.0.

What is pre-test clinical suspicion for PE?

What is the best test: VQ or CT?
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What is pre-test clinical suspicion for PE? **INTERMEDIATE**

What is the best test: VQ or CT? **CTA (\textit{?aortic dissection})**
Case 3

30 year old female smoker on BCP presents with acute dyspnea and right sided pleuritic chest pain without other respiratory or cardiac history or symptoms.

PMHx: none
All: none

VS: 120/70. HR 90, RR 24, Sat 98%
Exam is normal except pain noted when she takes a deep breath.

EKG sinus, otherwise normal
CXR normal

What is pre-test clinical suspicion for PE?
What should be the next test?
Case 3

30 year old female smoker on BCP presents with acute dyspnea and right sided pleuritic chest pain without other respiratory or cardiac history or symptoms.

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What is pre-test clinical suspicion for PE? INTERMEDIATE
What should be the next test? D-DIMER
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Exam is normal except pain noted when she takes a deep breath.

EKG sinus, otherwise normal
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What is pre-test clinical suspicion for PE?
What is the next test?

D-dimer is 890 (normal is < 250 µg/L)

What is the better test: VQ or CT?
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What is pre-test clinical suspicion for PE?
What is the next test?

D-dimer is 890

What is the better test: VQ or CT? VQ
“New” Directions

• SPECT V/Q
  • Some sites have used SPECT V/Q for over 20 years
  • European Guidelines recommend SPECT V/Q
  • Greater sensitivity due to improved contrast resolution

• SPECT/CT-V/Q
  • Improved specificity over SPECT alone
- 65 year old female with pulmonary hypertension and pulmonary fibrosis

- Patient is being evaluated for lung transplant
Quantitative Perfusion

ANT PERF
LT ANT LUNG (%) = 62
RT ANT LUNG (%) = 38

POST PERF
LT POST LUNG (%) = 57
RT POST LUNG (%) = 43

LPO PERF
LT UPPER LOBE (%) = 40
LT LOWER LOBE (%) = 60

RPO PERF
RT UPPER LOBE (%) = 59
RT MIDDLE LOBE (%) = 13
RT LOWER LOBE (%) = 28

LEFT GEOMETRIC MEAN (%) = 60
RIGHT GEOMETRIC MEAN (%) = 40
Summary

• V/Q and CTA are excellent tests when used appropriately

• Reader expertise important in determining which test is best utilized at any given institution

• Start with your clinical suspicion
  • Establish pre-test likelihood
Summary

• D-Dimer often helpful when clinical suspicion is low or moderate
  • Negative D-Dimer significantly reduces need for CTA or V/Q

• Radiation considerations important especially in young (female) population (<50).

• X-ray helpful in selecting most appropriate test
  • Significant abnormalities on x-ray use CTA when possible
Conclusions

- The algorithms proposed in this presentation have been based as much as possible on evidence based medicine.

- Non-evidence based conclusions (experience/perception) cannot be dismissed but may have consequences.
Truth vs Perception