Acute Pulmonary Embolism Diagnosis and Methods for Improved Detection

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Disclosures

• Philips Healthcare
  – Consultant

• Amirsys
  – Author
Purpose

• Compare main modalities used for diagnosis of acute PE
  – Ventilation Perfusion Imaging (V/Q scan)
  – CT Pulmonary Angiography (CTPA)
• Discuss importance of detecting even the smallest emboli
• Review newer technologies to improve detection of PE
• Briefly discuss interventional treatment for acute PE
PIOPED I
V/Q scans

- 33% prevalence of PE
  - High probability (13%)
    • >90% prevalence
    • 96% with high clinical suspicion
  - Intermediate probability (39%)
    • 33% prevalence
  - Low probability (34%)
    • 10-15% prevalence
  - Near-normal/normal (14%)
    • <5% prevalence
    • <4% with low clinical suspicion

- With other combinations, PE was present in 16-88% of patients
  - Requires additional testing
Ventilation/Perfusion (V/Q) Scanning

Advantages
- No contrast required
  - Renal failure
  - Contrast allergy
  - Precise timing of a bolus not required
- Physiologic data obtained
- Less radiation dose to breasts
- Patients do not have to hold breath

Disadvantages
- Requires normal radiograph
- Very little anatomic data available
  - Cannot provide alternate diagnosis
  - Cannot differentiate between primary and secondary causes of vascular obstruction
- Studies take longer to acquire
- Not available 24/7/365 at most institutions
- Can not reliably differentiate between acute and chronic thromboembolic disease
- Variability in interpretation
Lung transplant patient with SOB undergoing V/Q quantification

High probability
>2 segmental defects on perfusion
Normal ventilation
Intermediate Probability
33% prevalence
CTPA Positive for PE
Intermediate Probability
33% prevalence of PE
CTPA Negative
33 year-old man with SOB

Triple match
Intermediate probability
33% prevalence of PE
Use of V/Q Scan at our Institution

- Patients with renal failure
- Transplant patients
- Patients with severe contrast allergy
- Problem solving
- Patients unable to comply with instructions
CTPA in 23 year-old morbidly obese woman a few hours postpartum
Patient undergoes V/Q scan

Normal V/Q
CTPA

Advantages

• Excellent spatial resolution
  – Resolution now around 0.6mm
  • All vessels <1mm in diameter can be assessed
• Allows simultaneous evaluation of entire thorax
  – Other causes of SOB
• Assessment of right heart
  – Prognostic significance
• Available 24/7/365
• Quick study
  – Scan takes less than 5 seconds
• Can visualize clot
  – Not based on probability
  – Less reader variability

Disadvantages

• Uses iodinated contrast
  – Renal failure
  – Contrast allergies
  – Precise timing of bolus
• Uses ionizing radiation
  – Newer techniques reduce dose
• Requires good IV access
  – At least 20g above wrist
• Requires patient compliance
  – Patients need to hold breath
  • Breath holds now less than 5 seconds
  • Doesn’t seem to be helping
• Requires competent technologists
• Requires competent radiologists
• Lots of images acquired
  – Leads to small PEs being missed
PIOPED II

- CTA alone and CTA-CTV
- Multidetector CT (4,8,16 DCT)
  - Many hospitals in US have at least 64 slice MDCT
- 824 patients [51 (6%) – nondiagnostic]
- Composite standard of reference used
- CTPA
  - Sensitivity – 83%
  - Specificity – 96%
- CTA-CTV:
  - Sensitivity – 90%
  - Specificity – 95%
- Best with concordant clinical impression

Stein, NEJM, 2006
Main advantages of CTPA

• Visualization of thrombus
• Alternative diagnoses
  – 512 CTs, 124 (24%) had PE
    • 130 (25%), CTPA suggested other Dx:
      – Pneumonia (N=67)
      – Tumor (N=22)
      – Pleural fluid (N=10)
      – Heart disease (N=10)
      – COPD (N=6)
      – Other (N=15)

• Assess prognosis

Visualization of Clot
66 year-old lung transplant patient with SOB and concern for PE

Matched ventilation and perfusion defects
Low Probability
10-15% incidence of PE
Patient undergoes CTPA

No PE

Diagnosis of fungal PNA and obliterative bronchiolitis
48 year-old woman with multiple episodes of SOB and numerous negative CTPAs

High Probability V/Q Scan
Undergoes repeat CTPA 1 hour later
Extrinsic vascular narrowing due to sarcoidosis. CTPA is negative for PE.
70 year-old man with SOB and history of IV contrast allergy (hives)

Perfusion - 1 segmental defect

Ventilation - normal

Intermediate Probability
33% prevalence
Patient receives premedication and receives CTPA 12 hours later

CTPA Negative for PE
Hilar Mass Encasing Lingular and LLL PA
56 year-old man with RCC and SOB
Assessment of RV Strain
Predictors of Adverse Outcomes
Cardiac Findings

• Septal bowing
• RV/LV axial diameter ratio >1.5
• RV/LV diameter ratio on 4-chamber view >1
• RVV/LVV > 1.2
• RV short axis diameter >5.4 cm

Kang et al. CT Signs of Right Ventricular Dysfunction Prognostic Role in Acute Pulmonary Embolism. JACC 2011
Ghaye et al. Severe Pulmonary Embolism: Pulmonary Artery Clot Load Scores and Cardiovascular Parameters as Predictors of Mortality. Radiology 2006
Van de Meer et al. Right ventricular obstruction and pulmonary obstruction index on helical CT: Prediction of clinical outcome during 3-month follow up in patient with acute PE. Radiology 2005
Predictors of Adverse Outcomes

Venous Findings

- IVC reflux of contrast
- SVC diameter > 23mm
- Azygos vein diameter > 13mm

van de Meer et al. Right ventricular obstruction and pulmonary obstruction index on helical CT: Prediction of clinical outcome during 3-month follow up in patient with acute PE. Radiology 2005
CT EVALUATION OF ACUTE PE

What is the predictive value of a negative CT for PE? (i.e. How often will pt. come back later with PE?)

- 17 month follow-up period (CT vs. VQ)

<table>
<thead>
<tr>
<th>Technique</th>
<th>N</th>
<th>Negative</th>
<th>NPV</th>
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</thead>
<tbody>
<tr>
<td>CT (single)</td>
<td>126</td>
<td>78</td>
<td>99%</td>
</tr>
<tr>
<td>V/Q (NL)</td>
<td>352</td>
<td>46</td>
<td>100%</td>
</tr>
<tr>
<td>V/Q (Low)</td>
<td>132</td>
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<td>96%</td>
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</table>

- With MDCT, NPV equals that of PA gram

Garg, AJR 1999
Negative V/Q Scan
<5% prevalence of PE

Ventilation- normal

Perfusion- normal
Single isolated non-occlusive subsegmental PE on CTPA
40 year-old with SOB

Low probability V/Q scan
CTPA ordered 4 hours later
Read as negative and patient discharged
Causes of loss of accuracy in CTPA

- Respiratory motion
- Poor bolus timing
- Image noise
- Human error
Loss of accuracy due to respiratory motion
Loss of accuracy due to respiratory motion

• Requires patient compliance
  – Technologists need to talk to patients before exam
  – Stress importance of breath hold

• Less of an issue with modern scanners
  – Most CTPA studies take less than 4 seconds to complete

• Consider V/Q scan
Loss of accuracy due to poor bolus
Loss of accuracy due to poor bolus timing

• Moved from bolus tracking technique to test bolus
  – 20mL contrast at 5cc/sec
  – Graph of PA enhancement over time
  – Start of scan set for peak enhancement + 5sec
• Personalized bolus
  – Weight and injection rate
• Patients should not take deep breath before initiation of scan
  – Should instruct patient to stop breathing
  – Prevents transient interruption of the bolus
• Consider V/Q scan

Low probability V/Q scan
Test Bolus
Loss of accuracy due to image noise

- Two main reasons for increased image noise in CTPA
  - Obese patients
  - Dose reduction

Missed PE in CTPA limited by suboptimal bolus and image noise
• 67 year-old woman in ICU with shortness of breath. Patient is 5’3” tall and weighs 180 kg (396lbs) for a BMI 70.1 (morbidly obese >40)
100kV, 523mAs, 21.22mGy, 671.1mGy*cm, 9.4mSv
100kV, 523mAs, 21.22mGy, 671.1mGy*cm, 9.4mSv
80kV, 110mAs
2.33 mGy
78.1 mGy*cm
Dose=1.09mSv
80kV, 110mAs 2.33 mGy, 78.1 mGy*cm Dose=1.09mSv
• 60 year-old woman with a BMI of 61 presents to the ED with SOB
Iterative Model Reconstruction

FBP

IMR
Noise Comparison FBP to IMR

![Graph showing noise comparison between FBP and IMR across different patients.](image-url)
Loss of Accuracy due to Human Error

• Even with optimal studies, PEs missed
• Reasons are numerous
  – PE factors
    • Isolated PE
    • Small size
    • Peripheral location
    • Inplane clot on axial imaging
  – Radiologist factors
    • Lots of images
    • Increased volume
    • Satisfaction of search
    • Poor radiologist

Missed segmental PE in the RUL
4mm thick slices
120 images
3mm thick slices
243 slices
1.5 mm thick slices
486
0.9 mm thick slices
811 slices
Small isolated subsegmental PE missed on initial interpretation
Repeated misses by different radiologists in one patient
Repeated misses by different radiologists in one patient
Repeated misses by different radiologists in one patient

1/14/13

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PE-CAD detection of missed PEs

- PE-CAD identified at least one PE in 77.4% of instances (41/53)
  - 23/23 cases (100%) with multiple PE
  - 18/30 (60%) cases with solitary PE
The PE-CAD program identified at least one PE in 77.4% of instances (41/53). PE-CAD correctly marked at least one PE in 23/23 cases (100%) with multiple and 18/30 (60%) cases with solitary PE (p<0.001).
PE-CAD miss (red arrow) with 2FPs

PE-CAD hit (red arrows) with 12FPs
Satisfaction of search

9/20/12

11/9/12
PE-CAD
# Missed PE Outcomes

<table>
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<tr>
<th>Embolic Burden</th>
<th>NO NEW PULMONARY EMBOLUS</th>
<th>NEW PULMONARY EMBOLUS</th>
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<tr>
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<td>Prior PE Improved#</td>
<td>Prior PE unchanged</td>
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<tr>
<td>HIT</td>
<td>MISS</td>
<td>HIT</td>
</tr>
<tr>
<td>Single SS</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Single S</td>
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<td>1</td>
</tr>
<tr>
<td>Multiple SS</td>
<td>2</td>
<td></td>
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<tr>
<td>Multiple S</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
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<td>3</td>
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- 9/12 isolated subsegmental PE returned with additional PE at later date
- Patients with multiple segmental PE either returned with larger PE or were rescanned within 3 days due to continued symptoms
Acute Intervention of PE

- PE without any evidence of right heart strain
  - Systemic anticoagulation

- Extensive PE with RV strain but w/o hypotension
  - Systemic anticoagulation

- Massive PE with acute RV failure, systemic hypotension, syncope, or cardiac arrest
  - Systemic anticoagulation
  - Intervention
Surgical Embolectomy

- First successfully performed in 1924
- High mortality rates
  - 20% over past two decades
- Limited to centers with surgical expertise
Percutaneous therapies

• Immediate and minimally invasive
• Combination of fragmentation and suction thrombectomy
  – Mechanical or ultrasonographic fragmentation
• Direct catheter based thrombolysis

Angiojet catheter
Mechanical fragmentation and suction thrombectomy
EKOS Ultrasound Catheter
Summary

- Numerous benefits of CTPA to V/Q scan
  - V/Q scan still has its uses

- Various factors that can lead to decreased accuracy in CTPA
  - Respiratory motion
    - Talk to patients
  - Poor contrast opacification
    - Test bolus
    - Personalized bolus

- Image Noise
  - Iterative and model based reconstruction techniques

- Human error
  - PE-CAD
  - Take your time

- Various methods of acute intervention
  - Surgical thrombectomy
    - High mortality
  - Interventional thrombectomy
    - Better tolerated