The MD-CTPA; Technique, Diagnosis and Pitfalls

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Purpose

• Describe the techniques used to improve the quality of MD-CTPA
• Illustrate the diagnostic criteria of chronic and acute pulmonary emboli
• Illustrate common artifacts and pitfalls in imaging and diagnosis
PE

• Third most common acute cardiovascular disease, after myocardial infarction and stroke

• Estimated 200,000 – 300,000 hospitalizations/year in US

• Estimated 37,000 – 44,000 deaths per year in US

• Overall 3 month mortality rate of 15-17.5%
Imaging Tests for Detection
Non-imaging Tests

- ABG
- ECG
- D-dimer
- Troponin assays
D-dimer

- 2002, Brown et al
- Meta-analysis, 11 studies, N = 2160
- Sensitivity 95%
- Specificity 45%
- Lower if symptoms were chronic


Image courtesy Siemens, Diagnostics
Algorithm

PE Symptoms, +D-dimer, +/- DVT symptoms

Lower extremity US

- CTA
  - TREAT
  + TREAT

+ TREAT

Good Quality CTA
  STOP

Poor quality CTA
  Repeat CTA
  ?Angiogram
  ?V/Q
PIOPED

• Prospective investigation of Pulmonary Embolism, 1990
• Large multicenter trial compared ventilation/perfusion (V/Q) scintigraphy with pulmonary angiography (gold standard)
• V/Q: sensitivity of 98% with specificity of 10%
CTPA

• Godwin et al in 1980 were the first to describe pulmonary embolism on contrast-enhanced CT
• CTPA has now become the test of choice and de facto standard of care
• Thin slice MD-CTA has been shown in recent studies to have a sensitivity of 90-100% and specificity of 89-94%, using angiography as the gold standard
PIOPED II key points

- CTPA sensitivity 83%, specificity of 96%
- Pts. With low or intermediate clinical probability of PE with a normal CTPA had a high negative predictive value for PE (96% and 89%)
- Negative predictive value was only 60% in patients with high clinical probability of PE
- The positive predictive value was high, as expected, in both the high and intermediate clinical categories
- Therefore, results suggested that additional testing was necessary when the clinical probability is inconsistent with imaging results
PIOPED II, Problems

- The composite gold standard used for the study was not 100% accurate for the diagnosis of PE
- Therefore, it follows that the performance of CT was likely better than indicated
- Of 824 pts with performed CT scans, 51 studies were “indeterminate” due to poor image quality
Causes for the Indeterminate CTPA

- Motion
- Poor enhancement
- Parenchymal disease
- Body habitus
- Streak artifacts
BUMC – One Year Snapshot

- Average 4.3 MD-CTPA examinations/day
  - High 14
  - Low 0
- Average 0.3 V/Q examinations/day
- Equipment 3 64D-CT, 1 16D-CT
  - All scanners accessible to ER population
CTPA, how we do it

- Pt. lies supine, with arms up
- 80-100cc cc Optiray 370 (370 mgI/ml) into antecubital vein using 18 or 20g iv.
- Injection rate 4cc/sec
- Test bolus 20cc at 4cc/sec
- Scan delay = time to peak + 5 seconds
  - Usually 20-25 seconds
- Total scan time for typical pt under 10 seconds
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Number of Acquisitions</td>
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<tr>
<td>Oral Contrast</td>
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<tr>
<td>First Acquisition</td>
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<td>Landmarks</td>
<td>Thoracic inlet to lowest diaphragm</td>
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<tr>
<td>IV Contrast</td>
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<tr>
<td>Volume</td>
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<tr>
<td>Injection Rate</td>
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<tr>
<td>Dual Injection</td>
<td>yes, 30mL normal saline chase</td>
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<tr>
<td>Timing Bolus</td>
<td>Main PA, using 10mL contrast</td>
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<tr>
<td>Delay</td>
<td>time to peak + 5 seconds</td>
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<tr>
<td>Slice thickness</td>
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<td>Pitch</td>
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<td>Table speed</td>
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<td>Reconstruction interval</td>
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<td>Noise index</td>
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<tr>
<td>Algorithm</td>
<td>standard</td>
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<tr>
<td>Reconstruction</td>
<td>coronal, axial 10mm MIPS; 2.5mm lung and standard</td>
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Diagnostic Criteria of Acute PE

• Complete arterial occlusion with failure to opacify vessel lumen. Artery may be enlarged as compared to others of the same order
• Central filling defect surrounded by contrast
• Peripheral intraluminal filling defect that makes an acute angle with the arterial wall
Acute PE

Acute angles
Diagnostic Criteria for Chronic PE

- Complete occlusion of vessel that is smaller than others of same order of branching
- Peripheral filling defect that makes obtuse angles with the vessel wall
- Contrast flowing through vessels that appear thick-walled due to recanalization
Chronic PE

Obtuse angles
Pulmonary Artery Enhancement

- Acute emboli 33 H (SD 15 H)
- Chronic emboli 87 H (SD 31 H)
- We cannot perceive emboli if SD (mean of clot) > Mean attenuation of lesion - Mean attenuation of blood
- Theoretically, using 3SD, this amounts to 93 and 211 H as the minimum blood attenuation necessary to see acute and chronic emboli, respectively
Theoretically, using 3SD, this amounts to 93 and 211 H as the minimum blood attenuation necessary to see acute and chronic emboli, respectively.
Acute PE
Acute PE
Chronic PE
Chronic PE
Subesegmental PE
Subsegmental PE
Subsegmental PE
CPE/Infarct
Saddle Embolus
Clot Burden and Right Ventricular Strain
Strain Ratio

S.R. = x/y

Risk of Death

RV

LV

x

y

Risk of death

1 1.3 1.7 1.9 2.1 2.3
Strain Ratio
Artifacts, Image Quality and the Indeterminate CTPA
Breathing/Motion
Breathing

- Image inferior to superior
- Avoid exaggerated hyperventilation techniques
- Technologist training
- Less of an issue with quick MD-CTPA techniques
Timing of Bolus

• High injection rate (4cc/sec) with uniphase injection bolus preferred method
• Two components; first pass and recirculation
  – First pass optimized by concentration of iodine (370mg I/mL)
  – Recirculation depends on injection duration
Timing of Bolus

- First pass recirculation
Timing Pearls

• Optimize recirculation effect by adding 5 seconds to timing peak for MD-CTPA

• If injection rate is decreased (IV access catheter limitations), the delay time needs to increase to increase recirculation effect
  – Typically add 10 seconds
Poor timing, too early
Poor timing, too late
Timing

If an indeterminate scans still occurs due to poor enhancement and there is no contrast extravasation and the timing was adequately compensated, there then is likely poor venous flow from stenosis or obstruction.

- We consider repeat CTPA after hydration or another test.
Flow Artifacts

Transient interruption of flow-column of contrast agent due to increased unopacified blood flow from IVC

Interface between high and low attenuation areas ill-defined

Limit pre-scan hyperventilation techniques
Flow artifacts - other causes

• Localized increase in vascular resistance
  – Atelectasis, consolidation
• Focal slow flow may mimic PE
• Similar appearance to other flow artifacts
Streak Artifacts

- Contrast column in SVC may cause attenuation artifacts in subsegmental pulmonary arteries
- Proper timing with added recirculation effect, saline chasers ameliorate this effect
Body Habitus

• Image noise
  – Increase radiation dose
  – Increase reconstruction width to 2.5mm

• Contrast volume
  – May need to increase volume in patients over 250lbs to adequately opacify pulmonary arteries (up to 130mL of 370mg I/mL).
The Indeterminate CTPA

• Reasons?
  – Can they be resolved with a repeat CTPA with appropriate modifications to the protocol?

• Level?
  – To what level is the study indeterminate?
  – If subsegmental and clinical pretest probability low, further imaging may not be required.

• Consider U/S, V/Q or pulmonary angiography
Conclusions

• CTPA has become the test of choice and de facto standard of care for diagnosis of PE
• Diagnostic criteria for the appearance of acute and chronic clot are well established
• The indeterminate CTPA study can be limited with proper technique and an understanding of common imaging pitfalls and artifacts
Selected References

- The PIOPED Investigators. PIOPED, Value of the ventilation/perfusion scan in acute pulmonary embolism; results of the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED), JAMA 1990;263:2753-2759
- Wittram, C. How I Do It: CT Pulmonary Angiography, AJR 2007; 188:1255-1261
- Prologo J.D., Gilkeson R.C., Diaz M. Cummings M. The Effect of Single-Detector CT vs. MDCT on Clinical Outcomes in Patients with Suspected Acute Pulmonary Embolism and Negative Results on CT Pulmonary Angiography. AJR 2005; 184:1231-1235.