MDCT Evaluation of PE in Children

What is New?

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Introduction

- Pulmonary embolism (PE) is a potentially life-threatening condition
  - Tapson VF. Acute PE. NEMJ. 2008

- Historically, the incidence (0.73 – 4.2%) of PE has been believed to be low

- Recent studies showed much higher incidence (14 – 15%) of PE in children
Objectives

- Discuss up-to-date information on PE in children

- Review currently available imaging modalities & techniques
  - MDCT parameters
  - Post-processing techniques
    - 2D imaging
    - 3D imaging (MIP)

- Provide practical recommendations on imaging management of PE in children
Three Key Facts about PE in Children

- The incidence of PE in children is much less than in adults

- Protective mechanisms:
  - Reduced capacity to generate thrombin
  - Increased capacity of alpha-2 macroglobulin to inhibit thrombin
  - Enhanced antithrombotic potential by the vessel wall
Three Key Facts about PE in Children

- Neonates & infants are at greatest risk of childhood thrombosis

- Risk factors:
  - Peripartum asphyxia
  - Dehydration
  - Septicemia
  - Trauma / surgery
  - Central venous lines

Three Key Facts about PE in Children

• Idiopathic PE occurs uncommonly in children
  - ~4% in children vs. ~30% in adults

• Most PE occurs in association with underlying risk factors
  - Interrelated & multiple risk factors

Lee EY, et al. Unsuspected PE in Pediatric Oncology Patients: Detection with MDCT. AJR 2010
Next: Ingredients for a Proper DX of PE

Clinical Findings

Laboratory Tests

Imaging Evaluation

Clinical Evaluation for PE

• Variable Clinical Presentation
  – Chest pain (70%)
  – Tachypnea (70%)
  – Cough (40%)
  – Tachycardia (33%)
  – SOB (25%)
  – Pulmonary HTN (5%)

EKG & Laboratory Tests

- **EKG Findings**
  - Sinus tachycardia
  - ST-T segment changes
  - Right axis deviation & bundle branch block

- **Blood Findings**
  - Hypocapnia
  - Hypoxemia with a-ACO2 gradient
Evaluation of PE in Children: Imaging Evaluation

- No published studies documenting the sensitivity & specificity
  - Clinical evaluation
  - Diagnostic imaging tests

- Imaging protocols have been usually extrapolated from adult studies
  - Little justification
  - Lack of applicability
## Currently Available Imaging Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CXR</td>
<td>Easy to perform, Relatively cheap, Fast</td>
<td>Not sensitive, Not specific</td>
</tr>
<tr>
<td><strong>V/Q Scan</strong></td>
<td>Low radiation, No IV contrast, High spec/prob</td>
<td>Lung Dz, Interm. prob, Long (~45 min)</td>
</tr>
<tr>
<td><strong>CTPA</strong></td>
<td>High Sen / Spec, Fast, R/O other Dx</td>
<td>Radiation, IV contrast</td>
</tr>
<tr>
<td><strong>Angio</strong></td>
<td>Gold Standard, Embolectomy</td>
<td>Invasive, + Radiation, Long</td>
</tr>
</tbody>
</table>
What Are We Currently Doing for PE Evaluation in Children?

- Survey of PE Evaluation in Children
  - To determine the current policies & practices of SPR members
  - Survey sent electronically to the 1575 members (416 institutions) of the SPR
Pulmonary Embolism in Children: Survey Items

- Existence of written policies
- Imaging study of choice
- Currently used CTPA techniques
- Modifications of protocols for radiation dose reduction

Original Investigation

Pulmonary Embolism in Pediatric Patients:

Survey of CT Pulmonary Angiography Practices and Policies

Edward Y. Lee, MD, MPH, David Zurakowski, PhD, Phillip M. Boiselle, MD
Results

- 28% (118/416) response rate on an institutional basis
- Written policy only in 25% institutions
- CXR performed before CTPA (64%)
- CTPA = imaging modality of choice (89%)

<table>
<thead>
<tr>
<th>Technical Parameters</th>
<th>Response Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of IV contrast</td>
<td>Don't know</td>
</tr>
<tr>
<td>2 mL/kg</td>
<td>1.0 mL/kg</td>
</tr>
<tr>
<td>(68; 65%)</td>
<td>(7; 7%)</td>
</tr>
<tr>
<td>1.5 mL/kg</td>
<td>3.0 mL/kg</td>
</tr>
<tr>
<td>(12; 12%)</td>
<td>(5; 5%)</td>
</tr>
<tr>
<td>Methods of IV contrast administration</td>
<td>2.5 mL/kg</td>
</tr>
<tr>
<td>Mechanical injection</td>
<td>Hand injection</td>
</tr>
<tr>
<td>(58; 56%)</td>
<td>(3; 3%)</td>
</tr>
<tr>
<td>Timing of CTPA scan initiation</td>
<td>Fixed time method</td>
</tr>
<tr>
<td>Tailored bolus tracking method</td>
<td>Don't know</td>
</tr>
<tr>
<td>(80; 77%)</td>
<td>(22; 21%)</td>
</tr>
<tr>
<td></td>
<td>Dependents on the size of the IV catheter</td>
</tr>
<tr>
<td></td>
<td>(43; 41%)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results: Radiation Dose Reduction

- 60 Respondents (58%) modify CTPA imaging protocols

Acad Rad. 2010
MDCT Imaging Techniques: CTPA

- Sedation / Intubation
  - Usually < 5 years old
  - Conscious sedation
  - Sedative medications
    - Oral chloral hydrate
    - IV Pentobarbital sodium
  - Adequate cardiorespiratory support

Imaging Techniques:

CTPA Parameters

- 64 MDCT
- Detector thickness = 0.6 mm
- kVp
  - 80 kVp for infants (up to 1 year of age)
  - 100 kVp for children (up to 4 years of age / 40 kg)
  - 120 kVp for older children
- mAs (using dose modulated tube current)
- Rotation time = 0.33 sec. (0.5 sec for 2nd phase)
- Pitch = 0.2 (0.55 for 2nd phase)
- Slice thickness = 1 mm (1.5 mm for 2nd phase)
- Scan in caudal to cranial direction

MDCT Techniques:
Optimizing Contrast Opacification

- Contrast dose = 1.5 cc/kg (Isovue 370)
- Contrast injection rate depends on size & stability of IV catheter
- Suggested injection rates

<table>
<thead>
<tr>
<th>Catheter Size (gauge)</th>
<th>Injection Rate (mL/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>1 – 1.5 (by hand)</td>
</tr>
<tr>
<td>22</td>
<td>2.0 – 2.5</td>
</tr>
<tr>
<td>20</td>
<td>3.0 – 4.0</td>
</tr>
<tr>
<td>18</td>
<td>4.0 – 5.0</td>
</tr>
</tbody>
</table>
MDCT Technique:
Scan Analysis & Post-processing

• MPR (Multiplanar)
  – Coronal & sagittal reformats

• 3D Volume Rendered Reconstructions
  – Maximum Intensity Projection (MIP) images

• Are these post-processed CT images helpful?
CTPA: Value of MPR Reformatted Images in Detecting PE in Children

Results

TABLE 1: Comparison of Axial and Multiplanar Reformatted MDCT of Suspected Pulmonary Embolism in Children

<table>
<thead>
<tr>
<th>Reviewer No.</th>
<th>Experience</th>
<th>Axial MDCT</th>
<th>Multiplanar Reformatted MDCT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diagnostic Accuracy (%)</td>
<td>Confidence Level</td>
</tr>
<tr>
<td>1</td>
<td>Faculty pediatric radiologist</td>
<td>96.7</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>Faculty pediatric radiologist</td>
<td>98.3</td>
<td>4.2</td>
</tr>
<tr>
<td>3</td>
<td>Radiology resident</td>
<td>93.3</td>
<td>2.9</td>
</tr>
<tr>
<td>4</td>
<td>Radiology resident</td>
<td>91.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Results

Case 1

16-year-old boy with sudden onset of SOB and right chest pain
17-year-old girl with left arm swelling for 2 days, sudden SOB & history of oral contraceptive use
Next: CT Imaging Findings in Children with PE
Imaging Findings: Location of PE

**Lobar Distribution of Pulmonary Emboli**
- Total number of emboli = 33

**Pulmonary Artery Location of Pulmonary Emboli**
- Total number of emboli = 31

<table>
<thead>
<tr>
<th>Pleuroparenchymal findings</th>
<th>With PE (N=22)</th>
<th>Without PE (N=22)</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wedge-shaped peripheral consolidation</td>
<td>8 (36)</td>
<td>2 (9)</td>
<td>5.7</td>
<td>1.1–31.1</td>
<td>0.03a</td>
</tr>
<tr>
<td>Other forms of consolidation</td>
<td>3 (14)</td>
<td>4 (3)</td>
<td>3.3</td>
<td>0.5–34.7</td>
<td>0.26</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>10 (46)</td>
<td>5 (23)</td>
<td>2.8</td>
<td>0.8–10.4</td>
<td>0.11</td>
</tr>
<tr>
<td>Linear opacity</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Ground-glass opacity</td>
<td>6 (27)</td>
<td>5 (23)</td>
<td>1.3</td>
<td>0.3–5.0</td>
<td>0.73</td>
</tr>
<tr>
<td>Mosaic attenuation pattern</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Nodule</td>
<td>2 (9)</td>
<td>2 (9)</td>
<td>1.0</td>
<td>0.1–7.8</td>
<td>0.99</td>
</tr>
<tr>
<td>Mass</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Focal patchy increased attenuation</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>5 (23)</td>
<td>4 (18)</td>
<td>1.3</td>
<td>0.3–5.8</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Parenchymal Findings in PE:
Wedge-shaped Peripheral Opacity
Parenchymal Findings in PE:

Wedge-shaped Peripheral Opacity
Beyond the Pulmonary Arteries: Alternative Diagnoses


CTPA in children with clinically suspected PE (N = 123)

Normal CTPA (N=39) 32%

Alternative Diagnosis (N=57) 48%

Non-Diagnostic CTPA (N=6)

PE (N=21) 17%

Alternative Diagnoses (N = 57)

- Pneumonia
- Atelectasis
- Malignancy
- Cardiac disease
- Pulmonary hypertension
- Pleural effusion
- Pulmonary nodules
- Rib fractures
- Right atrial thrombus
- Fat embolism
Pneumonia

15-year-old girl with SOB and left sided pleuritic chest pain
Atelectasis

3-year-old girl with SOB / increased oxygen requirement status post left hemispherectomy for refractory seizure disorder
Lung CA

14-year-old girl with SOB and de-saturation
Right Atrial Thrombosis

18-year-old girl with factor V Leiden mutation with de-saturation and chest pain
Overutilization of CTPA in Children?

- Recent studies showed increasing use of CTPA in children suspected of having PE

- But, the rate of positive studies is relatively low, suggesting overutilization of this test

- Thromboembolic risk factor assessment was shown to be useful for directing when to perform CTPA in a recent study in adult patients

Thromboembolic Risk Factors & Implications for Appropriate Use

- To evaluate thromboembolic risk factors for PE detected by using CTPA in children
- To determine whether such information may guide more appropriate use of CTPA
The investigators systematically reviewed:

- **Patient demographics**
  - Age, gender, in/out patient status

- **7 thromboembolic risk factors**
  - Immobilization, malignancy, hypercoagulable state, excess estrogen state, indwelling CVL, underlying cardiac disease & prior history of PE and/or DVT

- **D-dimer assessment**

- **Clinical outcome**
  - Length of follow-up & any complications related to PE

## Comparison in Pts with & without PE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients with PE ($n = 36$)</th>
<th>Patients without PE ($n = 191$)</th>
<th>$P$ Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>13.6 ± 5.4</td>
<td>14.1 ± 4.0</td>
<td>.529</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>.623</td>
</tr>
<tr>
<td>Male</td>
<td>18 (50)</td>
<td>87 (46)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>18 (50)</td>
<td>104 (54)</td>
<td></td>
</tr>
<tr>
<td><strong>Clinical signs and symptoms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tachycardia</td>
<td>22 (61)</td>
<td>101 (53)</td>
<td>.466</td>
</tr>
<tr>
<td>Pleuritic chest pain</td>
<td>15 (42)</td>
<td>104 (54)</td>
<td>.203</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>17 (47)</td>
<td>96 (50)</td>
<td>.856</td>
</tr>
<tr>
<td>Increased oxygen requirement</td>
<td>9 (25)</td>
<td>48 (25)</td>
<td>.987</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>7 (19)</td>
<td>7 (4)</td>
<td>.999</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>0</td>
<td>3 (2)</td>
<td>.999</td>
</tr>
<tr>
<td><strong>Referral setting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient</td>
<td>33 (92)</td>
<td>43 (23)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Outpatient</td>
<td>3 (30)</td>
<td>98 (50)</td>
<td></td>
</tr>
<tr>
<td>Emergency Department</td>
<td>1 (3)</td>
<td>80 (42)</td>
<td></td>
</tr>
<tr>
<td>Multidetector CT scanner</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Detector row</td>
<td>7 (19)</td>
<td>42 (22)</td>
<td>.457</td>
</tr>
<tr>
<td>32 Detector row</td>
<td>7 (19)</td>
<td>53 (28)</td>
<td></td>
</tr>
<tr>
<td>64 Detector row</td>
<td>22 (62)</td>
<td>96 (50)</td>
<td></td>
</tr>
<tr>
<td><strong>Risk factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immobilization</td>
<td>27 (75)</td>
<td>10 (5)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Indwelling CVL</td>
<td>20 (56)</td>
<td>24 (13)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Prior PE and/or DVT</td>
<td>16 (44)</td>
<td>22 (12)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Hypercoagulable state</td>
<td>8 (22)</td>
<td>13 (7)</td>
<td>.003</td>
</tr>
<tr>
<td>Excess estrogen state</td>
<td>8 (22)</td>
<td>12 (6)</td>
<td>.002</td>
</tr>
<tr>
<td>Malignancy</td>
<td>9 (23)</td>
<td>52 (17)</td>
<td>.249</td>
</tr>
<tr>
<td>Cardiac disease</td>
<td>3 (8)</td>
<td>18 (9)</td>
<td>.998</td>
</tr>
</tbody>
</table>
Comparison of Five Statistically Significant Risk Factors b/n Pts with & without PE

- Immobilization: 75% in PE, 5% in No PE
- Indwelling CVL: 56% in PE vs. 13% in No PE
- Prior PE and/or DVT: 44% in PE vs. 12% in No PE
- Hypercoagulable State: 22% in PE vs. 7% in No PE
- Excess Estrogen State: 22% in PE vs. 6% in No PE
Number of Risk Factors in Patients with & without PE

Percentage of Patients

- PE (N = 36)
  - None: 5%
  - Any 1: 5%
  - Any 2: 56%
  - 3 or More: 34%

- No PE (N = 191)
  - None: 31%
  - Any 1: 6%
  - Any 2: 0%

Number of Risk Factors

- None
- Any 1
- Any 2
- 3 or More
ROC Curve for Differentiating Pts with PE from Those without PE

Sensitivity = 89%
Specificity = 94%
### Simplified Algorithm of Number of Risk Factors & Probability of PE

<table>
<thead>
<tr>
<th>No. of Risk Factors*</th>
<th>Probability of PE (%)</th>
<th>95% CI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0.5</td>
<td>0.1, 2</td>
</tr>
<tr>
<td>Any one</td>
<td>8</td>
<td>5, 15</td>
</tr>
<tr>
<td>Any two</td>
<td>62</td>
<td>46, 76</td>
</tr>
<tr>
<td>Any three or more</td>
<td>89</td>
<td>87, 99</td>
</tr>
</tbody>
</table>

Risk Factor Assessment for PE: Older Children & Young Adult

TABLE 2: Comparison of Patients With and Without Pulmonary Embolism (PE)

<table>
<thead>
<tr>
<th>Variable</th>
<th>With PE ($n=16$)</th>
<th>Without PE ($n=100$)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y), mean ± SD</td>
<td>20.4 ± 1.5</td>
<td>20.8 ± 1.9</td>
<td>0.40</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>0.56</td>
</tr>
<tr>
<td>Male</td>
<td>6 (38)</td>
<td>28 (28)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>10 (62)</td>
<td>72 (72)</td>
<td></td>
</tr>
<tr>
<td>MDCT scanner</td>
<td></td>
<td></td>
<td>0.66</td>
</tr>
<tr>
<td>16</td>
<td>5 (31)</td>
<td>24 (24)</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>3 (19)</td>
<td>27 (27)</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>8 (50)</td>
<td>49 (49)</td>
<td></td>
</tr>
<tr>
<td>Immobilization</td>
<td>13 (81)</td>
<td>14 (14)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>History of PE or deep venous thrombosis</td>
<td>8 (50)</td>
<td>22 (22)</td>
<td>0.029*</td>
</tr>
<tr>
<td>Cardiac disease</td>
<td>6 (38)</td>
<td>7 (7)</td>
<td>0.003*</td>
</tr>
<tr>
<td>Malignancy</td>
<td>4 (25)</td>
<td>14 (14)</td>
<td>0.27</td>
</tr>
<tr>
<td>Hypercoagulable state</td>
<td>3 (19)</td>
<td>5 (5)</td>
<td>0.08</td>
</tr>
<tr>
<td>Excess estrogen state</td>
<td>2 (13)</td>
<td>20 (20)</td>
<td>0.73</td>
</tr>
<tr>
<td>Central venous line placement</td>
<td>2 (13)</td>
<td>2 (2)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Lee EY, et al. PE Detected by CTPA in Older Children & Young Adults: Risk Factor Assessment. AJR. 2012
Take Home Points

• Diagnosis of PE is not easily done clinically, even with the help of biochemical tests

• Failure to be diagnosed in the greatest threat to patients with PE

• Utilization of CTPA are helpful in diagnosis
  – Presence of PE
  – Associated lung findings
  – Alternative diagnoses
Take Home Points

• Important to know **proper CTPA techniques**
  - Contrast optimization
  - Radiation dose reduction techniques

• **Use of MPR MDCT images significantly increases** confidence level & interobserver agreement among radiologists

• **Use of risk factor assessment** as a first-line triage tool has the potential to guide more appropriate use of CTPA in children
  - Reductions in radiation exposure & costs