Background: Chest computed tomographic angiograms (CTAs) are frequently ordered for evaluation of suspected pulmonary embolism (PE) in the emergency department, but non-PE findings are often noted. Our objective was to determine the prevalence and management implications of incidental findings on chest CTAs ordered to assess for PE.

Methods: In a cross-sectional study, we reviewed 589 pulmonary CTAs that were ordered in the emergency department of a tertiary care hospital. We measured the prevalence of PE and placed other findings into the following 3 categories: (1) findings that provided potential alternative explanations for acute symptoms, (2) incidental findings that required clinical or radiologic follow-up, and (3) other findings that required less urgent or no follow-up. We reviewed all newly diagnosed pulmonary nodules and significant thoracic adenopathy and determined standard recommended clinical follow-up.

Results: Pulmonary embolism was found in 55 of 589 CTAs (9%). A total of 195 CTAs (33%) had findings that supported alternative diagnoses. A total of 141 patients (24%) had a new incidental finding that required diagnostic follow-up, including 73 patients (13%) with a new pulmonary nodule and 51 patients (9%) with new adenopathy. Using current clinical guidelines, follow-up computed tomography or another procedure would be recommended for 96% of patients with new incidental pulmonary nodules.

Conclusions: The CTAs that are ordered in the emergency department are more than twice as likely to find an incidental pulmonary nodule or adenopathy than a PE. Systematic approaches should be developed to help primary care physicians contend with a growing number of clinically relevant incidental radiologic findings.
STUDY SETTING AND PATIENT POPULATION

The study was performed at an academic tertiary care center of a major university with an annual ED patient census of 50,000. The study population consisted of all patients for whom a CTA was ordered in the tertiary care center during their ED evaluation. Patients were identified through a computerized radiologic database that registers all radiologic studies performed by the department of radiology. The CTAs that were obtained at outside hospitals and submitted for interpretation were not included in the database. Patients were enrolled during 2 different periods: July 2, 2002, to December 9, 2003, and January 11, 2005, to July 13, 2005. The CTAs were obtained with a Siemens Somatom Plus 4 scanner (Siemens Medical Systems Inc, Iselin, New Jersey) during the first period and with a Siemens Sensation 16 scanner during the second period.

DATA COLLECTION

Medical records and images were located in a Web-based server. We collected most data by reviewing electronic medical records. For consecutive CTAs ordered in the ED during the study periods, we documented all findings noted in the final radiology reports that were entered into the medical record and signed by an attending radiologist. The CTA was read as positive for PE if filling defects were noted in the pulmonary arterial tree.

POTENTIAL ALTERNATIVE DIAGNOSES

Findings that provided an alternative explanation for acute chest pain, shortness of breath, hypoxemia, or tachycardia included infiltrates (any lesion read as infiltrate, further categorized as lobar or multifocal); pleural effusion (noted on the report as pleural effusion or pleural fluid); significant atelectasis (atelectasis involving 3 or more pulmonary segments as defined by Tsai et al.); pericardial effusion (read as pericardial effusion or pericardial fluid on the report); aneurysm (any lesion read as aortic aneurysm or dilated aortic root [the largest diameter was recorded]); and hiatal hernia (any process described as a hiatal hernia).

RELEVANT INCIDENTAL FINDINGS

Previously unknown findings that required clinical or radiologic follow-up included pulmonary nodule (any lesion described as a mass or nodule measuring <3 cm located in or arising from the pulmonary parenchyma); pulmonary mass (any lesion described as a mass or nodule measuring >3 cm and located inside the lung parenchyma or, based on appearance, thought to arise from the pulmonary parenchyma); mediastinal mass (any lesion described as a mass in the mediastinum); paratracheal adenopathy (any lymph node >1 cm described as paratracheal in origin); mediastinal adenopathy (any lymph node >1 cm located in the mediastinum); hilar adenopathy (any lymph node >1 cm located in the pulmonary hilum); and, mass, other organ (any lesion described as a mass located in an organ other than the lungs, including the liver, spleen, kidneys, bone, thyroid gland, pancreas, adrenal glands, and stomach). We recorded the size of nodules and masses in centimeters of greatest diameter as well as the diameter of the largest lymph node in each segment.

A pulmonary mass or nodule was defined as a new finding if no mass or nodule was evident on previous imaging reports or if no history of malignancy, mass, or nodule was noted in the patient's local medical record, including all history and physical reports, clinical progress notes, and discharge summaries. Adenopathy was considered significant if follow-up was required. Adenopathy that required follow-up included (1) any lymph node larger than 1 cm in diameter and not associated with an infiltrate; (2) any lymph node larger than 3 cm in diameter; or (3) presence of multiple mediastinal or hilar lymph nodes.

OTHER FINDINGS

Findings that required less urgent or no follow-up included emphysema (changes described as emphysematous or consistent with emphysema or chronic obstructive pulmonary disease); mild atelectasis (read as atelectasis, collapse, or volume loss described as dependent or involving fewer than 3 pulmonary segments); cardiomegaly (read as cardiomegaly or cardiac enlargement); bone findings (degenerative changes and other nonmalignant anomalies in skeletal structures); other pulmonary process (any other pulmonary process not already recorded, such as scarring or calcifications); and atherosclerotic changes (any atherosclerotic process other than coronary artery calcification). Coronary artery calcification was noted separately.

We classified PE location based on the largest pulmonary vessel that was found to obtain opacification (either main pulmonary, segmental, or subsegmental pulmonary arteries). For all patients who received a CTA, we documented whether a D-dimer assay was ordered and the results. A D-dimer level greater than 0.50 µg fibrinogen equivalent units per milliliter or 230 ng/mL on a malondialdehyde assay was considered a positive result.

To determine whether incidental findings of a pulmonary mass or nodule were evident on a chest radiograph, a chest radiologist (L.A.P.) reviewed the chest radiographs that were obtained within 24 hours of the CTA scan for all patients whose CTA scans revealed a mass or nodule. The radiologist also reviewed a random sample of chest radiographs for patients who had findings other than a pulmonary mass or nodule. The radiologist was blinded to the purpose of the study. We compared readings of chest radiographs and CTAs to determine the proportion of masses, nodules, infiltrates, pleural effusions, and significant atelectasis that were evident on both chest radiographs and CTAs.

To characterize the degree of initial clinical or radiologic testing that could result from incidental findings of pulmonary nodules on CTA, 2 pulmonologists (S.G.T. and M.P.R.) reviewed the CT scans of all patients for whom a new pulmonary nodule was noted in the final radiology reports. They characterized nodules by number, size, and appearance. Using the criteria of MacMahon et al.6 they recommended initial management according to the findings on the CTA. The entire electronic medical records of patients whose nodules were smaller than 4 mm were reviewed for smoking status. Documentation of more than 10 pack-years was determined to be a positive smoking history. The pulmonologists were blinded to actual patient follow-up at the time of CTA review. Both pulmonologists read the initial 20% of the CTAs with pulmonary nodules. They compared their recommendations and agreed on resolution of any differences. After agreeing on a consistent approach, the remaining CTAs were evaluated by either one of the reviewers.

STATISTICAL ANALYSIS

Descriptive statistics were performed for all variables. Results for continuous variables are expressed as mean (SD) or median (interquartile range). Categorical variables are expressed as number (percentage). The analysis was performed using Stata version 8.0 (Stata Corp, College Station, Texas).

RESULTS

A total of 589 CTAs were reviewed. The mean (SD) age of patients at the time of CTA was 53 (19) years, and 63%
were female. A D-dimer assay was ordered for 122 of the patients who underwent CTA, and the results were negative in 24 cases (20%). None of the 24 patients who had a negative D-dimer test result had findings consistent with PE. Findings of PE and radiographic findings supporting potential alternative diagnoses are shown in Table 1. Fifty-five of the CTAs (9%) were positive for PE. Four hundred seventy-eight patients (81%) had findings other than PE. Pathologic findings supporting alternative diagnoses for symptoms were noted in 195 patients (33%), the most common of which were infiltrates (66 patients) and pleural effusion (113 patients). Thirty-five percent of the infiltrates and 67% of the pleural effusions were evident on chest radiographs compared with only 5% of pulmonary nodules and adenopathy. In fact, the like-

Table 1. Prevalence of Pulmonary Embolus and Radiographic Findings Supporting Alternative Diagnoses for Shortness of Breath, Hypoxemia, or Tachycardia on 589 Computed Tomographic Angiograms

<table>
<thead>
<tr>
<th>Finding</th>
<th>No. (%) of Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary embolus</td>
<td>55 (9)</td>
</tr>
<tr>
<td>Main pulmonary artery</td>
<td>26 (4)</td>
</tr>
<tr>
<td>Segmental</td>
<td>19 (3)</td>
</tr>
<tr>
<td>Subsegmental</td>
<td>6 (1)</td>
</tr>
<tr>
<td>Radiographic findings supporting alternative diagnoses</td>
<td></td>
</tr>
<tr>
<td>Infiltrates</td>
<td>Lobar 29 (5)</td>
</tr>
<tr>
<td></td>
<td>Multilobar 37 (6)</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion 113 (19)</td>
</tr>
<tr>
<td></td>
<td>Significant atelectasis 17 (3)</td>
</tr>
<tr>
<td></td>
<td>Pericardial effusion 30 (5)</td>
</tr>
<tr>
<td></td>
<td>Aortic root &gt;3 cm 5 (&lt;1)</td>
</tr>
<tr>
<td></td>
<td>Hiatal hernia 16 (3)</td>
</tr>
</tbody>
</table>

Table 2. Incidental Findings Requiring Clinical or Radiographic Follow-up on 589 Computed Tomographic Angiograms

<table>
<thead>
<tr>
<th>Finding</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary nodule</td>
<td>127 (22)</td>
</tr>
<tr>
<td>Pulmonary mass</td>
<td>24 (4)</td>
</tr>
<tr>
<td>Mediastinal mass</td>
<td>21 (4)</td>
</tr>
<tr>
<td>Adenopathy</td>
<td>220 (37)</td>
</tr>
<tr>
<td>Mediastinal</td>
<td>84 (14)</td>
</tr>
<tr>
<td>Hilar</td>
<td>67 (11)</td>
</tr>
<tr>
<td>Paratracheal</td>
<td>69 (12)</td>
</tr>
<tr>
<td>Mass, other organ</td>
<td>42 (7)</td>
</tr>
<tr>
<td>Liver</td>
<td>19 (3)</td>
</tr>
<tr>
<td>Spleen</td>
<td>1 (&lt;1)</td>
</tr>
<tr>
<td>Kidney</td>
<td>1 (&lt;1)</td>
</tr>
<tr>
<td>Bone</td>
<td>16 (3)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (&lt;1)</td>
</tr>
</tbody>
</table>

*New incidental findings requiring follow-up are defined as nodules, masses, or adenopathy on computed tomographic angiograms not previously noted on other radiologic studies or commented on in medical record and no history of malignancy. Adenopathy requiring follow-up was defined as (1) any lymph node larger than 1 cm in diameter and not associated with an infiltrate, (2) any lymph node larger than 3 cm in diameter; or (3) presence of multiple mediastinal or hilar lymph nodes.

Table 3. Other Incidental Findings Requiring Less Urgent or No Follow-up on 589 Computed Tomographic Angiograms

<table>
<thead>
<tr>
<th>Finding</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emphysema</td>
<td>69 (12)</td>
</tr>
<tr>
<td>Mild atelectasis in dependent regions</td>
<td>137 (23)</td>
</tr>
<tr>
<td>Other pulmonary process</td>
<td>39 (7)</td>
</tr>
<tr>
<td>Cardiomegaly</td>
<td>37 (6)</td>
</tr>
<tr>
<td>Coronary artery calcification</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>45 (8)</td>
</tr>
<tr>
<td>Bone finding, excluding malignancy</td>
<td>144 (24)</td>
</tr>
<tr>
<td>Degenerative changes</td>
<td>197 (18)</td>
</tr>
<tr>
<td>Other</td>
<td>24 (4)</td>
</tr>
</tbody>
</table>

Of 1.9 (1.4) nodules per patient and an average diameter of 6.8 mm. Of these, 56% were smooth, 39% were ill-defined, 4% were calcified, and 1% were lobulated. Mediastinal and hilar lymphadenopathy (nodes >1 cm) were present in 29% and 7% of patients, respectively. After pulmonology review, 78% of the scans met criteria for follow-up with CT; 2%, with PET scan; 2%, with bronchoscopy; 2%, with mediastinoscopy; and 8%, with other procedures (such as thoracentesis). Only 4 patients (8%) required no follow-up because they were nonsmokers and their nodules were smaller than 4 mm in diameter.

Among our sample of CTAs that were ordered to rule out PE in the ED, 24% had incidental findings that required radiographic or clinical follow-up; most of the findings were pulmonary nodules and adenopathy. In fact, the like-
lhood of finding a new incidental nodule or adenopat-
y was twice that of finding a PE.

The prevalence of pulmonary nodules in our popula-
ton of patients who underwent CTA is within the range
that is found in populations of high-risk patients who un-
dergo low-dose CT screening for lung cancer.7,8 The pro-
portion of nodules that are actually malignant in these
studies is between 1% and 10%, but low-dose screening
CT has not yet been shown to decrease the rate of de-
tection of advanced cancer or to affect mortality result-
ing from lung cancer.9 Additional data from the Na-
tional Lung Screening Trial are not yet available. The
prevalence of incidental nodules in our population is also
similar to that found with cardiac CT when screening for
coronary artery disease.10,11 One study included 2-year
observational follow-up within health plan databases.11
Of 459 patients who underwent cardiac CT, 81 had pul-
monary nodules, but none of them developed lung can-
cer. Sixty-three of the participants had follow-up CT
scans. The original lesion was not identified in 35%, the
lesion had decreased or remained stable in 62%, and there
was interval growth in 3%. The low likelihood of actual
benefit in following up incidental nodules found on cardiac
CT scans has generated lively debate about whether ra-
diologists should even look for lung nodules.12,13

The risks associated with follow-up of incidental find-
ings of pulmonary nodules are not inconsequential. Co-
che et al14 estimated that radiation exposure from a single
CTA was 18.2 to 21.5 mGy (to convert to rads, divide by
10), similar to that from cardiac CT.15 Data from atomic
bomb survivors show that exposure even at these levels
increases radiation-induced cancer risk.16 Repeated ex-
posure to intravenous contrast presents additional risk.17
The psychosocial stress of being informed about a CT find-
ing that “can be consistent with a malignancy” can be an
extreme emotional burden for patients.18 A considerable
amount of clinician time is required to educate patients
about the implications of these incidental findings and the
recommendations for follow-up. As the review of inciden-
tal nodules in our population revealed, nearly all of the
incidental nodules met criteria requiring clinical and ra-
diologic follow-up according to existing guidelines.9 This
clinician time, added to the actual cost of follow-up stud-
ies and subsequent complications, has substantial finan-
cial implications.

Incidental nodules found on CTAs have been re-
ported in 2 smaller European studies.19,20 A relatively high
PE rate (28.3%-30%) in these studies likely reflects more
careful selection of higher-risk patients. The lower preva-
ience of incidental nodules (5%-6%) compared with our
study is difficult to interpret, but it may be related to dif-
fences in CTA protocols or tendencies of radiologists
to report very small nodules in different medical legal
environments.

Adenopathy that should receive follow-up was a com-
mon finding on CTAs in our cohort. We defined clinici-
significantly adenopathy as the presence of (1) any
lymph node larger than 1 cm in diameter and not associ-
ated with an infiltrate; (2) any lymph node larger than 3
cm in diameter; or (3) presence of multiple mediastinal
or hilar lymph nodes. Formal guidelines for this defini-
tion do not exist and may need to be established, because
significant adenopathy is often not followed up. Inciden-
tal masses are a more important finding on CTAs; how-
ever, they were relatively uncommon in our cohort. Of
the pulmonary masses found on CTAs, 75% were also evi-
dent on chest x-ray films and would not have been missed
if a CTA had not been performed. It should be noted that
findings such as an infiltrate or pleural effusion in high-
risk patients could increase prior suspicion of PE and still
lead to a CTA.

Our positive PE rate of 9% on CTAs is similar to rates
reported in observational studies at other North Ameri-
can centers.21,22 However, it is much lower than that found
in the PIOPED II trial (23%).23 The PIOPED II trial in-
volved a highly selected population, enrolling only 824 of
7284 patients who had suspected PE. Our observational
study included all patients who received a CTA. Notably,
however, the PIOPED II trial highlighted the importance
of using a systematic clinical evaluation to enhance the posi-
tive predictive value of a CTA (96% for high or interme-
diate probability by clinical assessment vs 58% for low clini-
ical probability using the Wells Score).24 A D-dimer assay,
another method to help gauge prior probability,25 was or-
dered in only 20% of patients in this cohort. Most of the
D-dimer levels were elevated; however, none of the pa-
patients with a negative D-dimer test result had a CTA that
was positive for PE.

Some clinicians argue that CTA is a useful test even when
clinical suspicion of PE is low, because alternative expla-
nations for symptoms may be revealed.19,20 Radiographic
findings supporting potential alternative diagnoses, espe-
cially infiltrates and pleural effusions, were found in up to 31%
of our cohort. However, a substantial number of inflit-
rates that were not evident on chest x-ray films may be of
limited clinical significance. Forty-five percent of the chest
x-ray films obtained in the ED were portable anteroposte-
rior films. Our radiologist investigator, who was blinded
to the purpose of the study, noted their generally poor qual-
ity. Obtaining higher-quality chest radiograph images may
improve the sensitivity of chest x-ray films for subtle infl-
itrates in ED patients and obviate the need for CTA to as-
sess symptoms when clinical suspicion for PE is low. Lom-
bard et al21 also described potential alternative diagno-
ses and significant incidental findings in 62 patients who un-
derwent CTA at a tertiary care hospital in Canada. Their
PE rate (11%) was similar to our findings. Fifty-seven per-
cent of the patients in their study had findings categorized
as “alternative diagnoses or significant additional find-
ings.” This rate is similar to that of our study if categories
of potential alternative diagnoses and relevant incidental
findings are combined. Our significantly larger sample size
allowed more detailed categorization of non-PE findings
and a greater focus on the important problem of inci-
dental pulmonary nodules. We did not classify emphy-
sematous changes as an alternative diagnosis for acute
symptoms because the physical findings in acute excer-
bations of COPD are distinct and do not lead to CTA
unless a PE is suspected as the cause of the acute change
in status. In that latter instance, COPD is usually diag-
nosed before the CTA is ordered. Similarly, we did not
classify coronary artery calcification as an alternative di-
gnosis because this finding is not specific for an acute
coronary syndrome.
The primary limitation of this study is that it was conducted at a single tertiary care referral center, and results may not be generalizable to other settings. However, the prevalence of PE was similar to that of other observational studies in North America, and it is likely that the rate of incidental findings would be comparable if similar CTA protocols and equipment were used. There may be significant variability between radiologists’ skill and inclination for finding and commenting on incidental findings such as small nodules when the study was ordered to rule out a PE. The retrospective study design could have introduced bias in patient selection; however, the administrative database that was used to identify patients captures all studies that are ordered, and our electronic medical record was very complete in regard to reports of radiographic interpretations. We used a consecutive patient sampling strategy that minimized selection bias within our population, but exclusion of patients whose CTAs were obtained at outside centers and submitted for interpretation could have introduced a small amount of referral bias. Radiographic studies and medical records of patients at outside hospitals and clinics were not reviewed for previous documentation of lesions. However, our study design reflects the decision-making challenges regarding treatment and follow-up that are immediately faced by ED, admitting, and primary care physicians who must act on the results of these studies. A prospective study would be needed to determine the true resource implications of incidental findings on CTAs.

In conclusion, CTAs obtained in the ED are more than twice as likely to find a new incidental pulmonary nodule or significant thoracic adenopathy as they are to find a PE. Although CTA may identify other findings that could explain acute clinical symptoms, many of those findings would be evident on a good-quality chest radiograph. To avoid unnecessary, burdensome, and low-yield follow-up studies, systematic approaches to determining clinical risk and therefore higher yield indications for CTA are recommended during assessments of acute pulmonary symptoms in the ED. Primary care physicians should become familiar with recommended approaches for evaluation of pulmonary nodules, because increasing use of CTA in the acute setting will lead to the discovery of a large number of these lesions.

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