

The Prevalence of Clinically Relevant Incidental Findings on Chest Computed Tomographic Angiograms Ordered to Diagnose Pulmonary Embolism

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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.

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ACCURACY, SPEED OF TESTING, and, often, 24-hour availability make computed tomographic (CT) angiograms (CTAs) the preferred diagnostic study for pulmonary embolism (PE) in most emergency departments (EDs). Another advantage of CTAs is their ability to identify pathologic abnormalities that explain symptoms, such as pneumonia or pleural effusion.¹⁻³

See Invited Commentary at end of article

In addition to confirming PE or supporting alternative diagnoses, CTAs may reveal incidental findings, such as pulmonary nodules or lymphadenopathy. Small pulmonary nodules on chest CT scans could indicate bronchogenic carcinoma; however, these lesions are much more likely to be be-

nign.^{4,5} Incidental findings of pulmonary nodules can be a source of great anxiety for patients and often generate multiple follow-up radiographic studies and other diagnostic interventions. We reviewed the results of 589 CTAs that were ordered in the ED of a tertiary care medical center and compared the number of tests that were positive for PE with the number that had clinically relevant incidental findings requiring clinical or radiographic follow-up.

METHODS

We used a cross-sectional study design to characterize PE and non-PE findings on CTAs. The protocol entailed review of existing medical records with minimal risk to patients, so the requirement of informed written consent was waived after review by the institutional review board of the University of North Carolina at Chapel Hill.

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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 multilobar); 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 al²); 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 infil-

trate; (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 CT scan for all patients whose CT 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%

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

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

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 large enough to be evident on chest radiographs in the random sample of films reviewed by the radiologist.

Table 2 includes incidental findings that were unrelated to acute symptoms that would require clinical or radiographic follow-up. Pulmonary nodules, which were the most common incidental finding, were found in 127 cases (22%). Of these, 73 represented a new finding. New adenopathy requiring follow-up was found in 51 cases (9%). Thirteen (2%) had new findings of a pulmonary, mediastinal, or other organ mass, with an average diameter of 4.5 cm. Seventy-five percent of pulmonary masses were evident on chest radiographs compared with only 6% of pulmonary nodules. In all, 141 patients (24%) had incidental findings requiring clinical or radiologic follow-up. There were no differences in the rate of incidental findings related to the type of CT scanner used. There were 615 CTA findings that were unrelated to acute symptoms and required less urgent or no follow-up (**Table 3**). The most common were mild dependent atelectasis, degenerative changes in bone, and emphysema.

Of the 73 scans that revealed new incidental pulmonary nodules, 7 were unavailable for review, and 17 patients had a history of malignancy, which warranted individualized recommendations for follow-up. The remaining 49 CTAs with new incidental nodules were reviewed by the pulmonologists who participated in the study. There were a total of 79 nodules, with a mean (SD)

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

Finding	No. (%)	
	Total	New Findings Requiring Follow-up ^a
Pulmonary nodule	127 (22)	73 (13)
Pulmonary mass	24 (4)	4 (<1)
Mediastinal mass	21 (4)	3 (<1)
Adenopathy	220 (37)	51 (9)
Mediastinal	84 (14)	
Hilar	67 (11)	
Paratracheal	69 (12)	
Mass, other organ	42 (7)	5 (<1)
Liver	19 (3)	
Spleen	1 (<1)	
Kidney	1 (<1)	
Bone	16 (3)	
Other	5 (<1)	

^aNew 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

Finding	No. (%)
Emphysema	69 (12)
Mild atelectasis in dependent regions	137 (23)
Other pulmonary process	39 (7)
Cardiomegaly	37 (6)
Coronary artery calcification	13 (2)
Atherosclerosis	45 (8)
Bone finding, excluding malignancy	144 (24)
Degenerative changes	107 (18)
Other	24 (4)

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.

COMMENT

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-

likelihood of finding a new incidental nodule or adenopathy was twice that of finding a PE.

The prevalence of pulmonary nodules in our population of patients who underwent CTA is within the range that is found in populations of high-risk patients who undergo low-dose CT screening for lung cancer.^{7,8} The proportion 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 detection of advanced cancer or to affect mortality resulting from lung cancer.⁹ Additional data from the National 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 pulmonary nodules, but none of them developed lung cancer. 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 radiologists should even look for lung nodules.^{12,13}

The risks associated with follow-up of incidental findings of pulmonary nodules are not inconsequential. Coche 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 exposure to intravenous contrast presents additional risk.¹⁷ The psychosocial stress of being informed about a CT finding 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 incidental nodules in our population revealed, nearly all of the incidental nodules met criteria requiring clinical and radiologic follow-up according to existing guidelines.⁶ This clinician time, added to the actual cost of follow-up studies and subsequent complications, has substantial financial implications.

Incidental nodules found on CTAs have been reported 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 prevalence of incidental nodules (5%-6%) compared with our study is difficult to interpret, but it may be related to differences 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 common finding on CTAs in our cohort. We defined clinically significant adenopathy as the presence of (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. Formal guidelines for this definition do not exist and may need to be established, because

significant adenopathy is often not followed up. Incidental masses are a more important finding on CTAs; however, they were relatively uncommon in our cohort. Of the pulmonary masses found on CTAs, 75% were also evident 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 American centers.^{21,22} However, it is much lower than that found in the PLOPED II trial (23%).²³ The PLOPED II trial involved 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 PLOPED II trial highlighted the importance of using a systematic clinical evaluation to enhance the positive predictive value of a CTA (96% for high or intermediate probability by clinical assessment vs 58% for low clinical probability using the Wells Score).²⁴ A D-dimer assay, another method to help gauge prior probability,²⁵ was ordered in only 20% of patients in this cohort. Most of the D-dimer levels were elevated; however, none of the 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 explanations for symptoms may be revealed.¹⁻³ Radiographic findings supporting potential alternative diagnoses, especially infiltrates and pleural effusions, were found in up to 31% of our cohort. However, a substantial number of infiltrates 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 anteroposterior films. Our radiologist investigator, who was blinded to the purpose of the study, noted their generally poor quality. Obtaining higher-quality chest radiograph images may improve the sensitivity of chest x-ray films for subtle infiltrates in ED patients and obviate the need for CTA to assess symptoms when clinical suspicion for PE is low. Lombard et al²¹ also described potential alternative diagnoses and significant incidental findings in 62 patients who underwent CTA at a tertiary care hospital in Canada. Their PE rate (11%) was similar to our findings. Fifty-seven percent of the patients in their study had findings categorized as “alternative diagnoses or significant additional findings.” 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 incidental pulmonary nodules. We did not classify emphysematous changes as an alternative diagnosis for acute symptoms because the physical findings in acute exacerbations 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 diagnosed before the CTA is ordered. Similarly, we did not classify coronary artery calcification as an alternative diagnosis 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,^{21,22} 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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- van Strijen MJ, de Monyé W, Schiereck J, et al; Advances in New Technologies Evaluating the Localisation of Pulmonary Embolism Study Group. Single-detector helical computed tomography as the primary diagnostic test in suspected pulmonary embolism: a multicenter clinical management study of 510 patients. *Ann Intern Med.* 2003;138(4):307-314.
- Tsai KL, Gupta E, Haramati LB. Pulmonary atelectasis: a frequent alternative diagnosis in patients undergoing CT-PA for suspected pulmonary embolism. *Emerg Radiol.* 2004;10(5):282-286.
- Kim KI, Muller NL, Mayo JR. Clinically suspected pulmonary embolism: utility of spiral CT. *Radiology.* 1999;210(3):693-697.
- Kim YH, Lee KS, Primack SL, et al. Small pulmonary nodules on CT accompanying surgically resectable lung cancer: likelihood of malignancy. *J Thorac Imaging.* 2002;17(1):40-46.
- Benjamin MS, Drucker EA, McCloud TC, Shepard JA. Small pulmonary nodules: detection at chest CT and outcome. *Radiology.* 2003;226(2):489-493.
- MacMahon H, Austin JH, Gamsu G, et al; Fleischner Society. Guidelines for management of small pulmonary nodules detected on CT scans: a statement from the Fleischner Society. *Radiology.* 2005;237(2):395-400.
- Henschke CI, Yankelevitz DF, Libby DM, Pasmantier MW, Smith JP, Miettinen OS; International Early Lung Cancer Action Program Investigators. Survival of patients with stage I lung cancer detected on CT screening. *N Engl J Med.* 2006;355(17):1763-1771.
- Swensen SJ, Jett JR, Sloan JA, et al. Screening for lung cancer with low-dose spiral computed tomography. *Am J Respir Crit Care Med.* 2002;165(4):508-513.
- Bach PB, Jett JR, Pastorino U, Tockman MS, Swensen SJ, Begg CB. Computed tomography screening and lung cancer outcomes. *JAMA.* 2007;297(9):953-961.
- Lehman SJ, Abbara S, Cury RC, et al. Significance of cardiac computed tomography incidental findings in acute chest pain. *Am J Med.* 2009;122(6):543-549.
- Iribarren C, Hlatky MA, Chandra M, et al. Incidental pulmonary nodules on cardiac computed tomography: prognosis and use. *Am J Med.* 2008;121(11):989-996.
- Budoff MJ. Ethical issues related to lung nodules on cardiac CT. *AJR Am J Roentgenol.* 2009;192(3):W146.
- Colletti PM. Incidental findings on cardiac imaging. *AJR Am J Roentgenol.* 2008;191(3):882-884.
- Coche E, Vynckier S, Octave-Prignot M. Pulmonary embolism: radiation dose with multi-detector row CT and digital angiography for diagnosis. *Radiology.* 2006;240(3):690-697.
- Rixe J, Conradi G, Rolf A, et al. Radiation dose exposure of computed tomography coronary angiography: comparison of dual-source, 16-slice and 64-slice CT. *Heart.* 2009;95(16):1337-1342.
- Ghotbi N, Iwanaga M, Ohtsuru A, Ogawa Y, Yamashita S. Cancer screening with whole-body PET/CT for healthy asymptomatic people in Japan: re-evaluation of its test validity and radiation exposure. *Asian Pac J Cancer Prev.* 2007;8(1):93-97.
- Mitchell AM, Kline JA. Contrast nephropathy following computed tomography angiography of the chest for pulmonary embolism in the emergency department. *J Thromb Haemost.* 2007;5(1):50-54.
- Byrne MM, Weissfeld J, Roberts MS. Anxiety, fear of cancer, and perceived risk of cancer following lung cancer screening. *Med Decis Making.* 2008;28(6):917-925.
- Sohns C, Amarteifio E, Sossalla S, Heuser M, Obenaus S. 64-Multidetector-row spiral CT in pulmonary embolism with emphasis on incidental findings. *Clin Imaging.* 2008;32(5):335-341.
- Soye JA, Loughrey CB, Hanley PD. Computed tomography pulmonary angiography: a sample of experience at a district general hospital. *Ulster Med J.* 2008;77(3):175-180.
- Lombard J, Bhatia R, Sala E. Spiral computed tomographic pulmonary angiography for investigating suspected pulmonary embolism: clinical outcomes. *Can Assoc Radiol J.* 2003;54(3):147-151.
- Brown MD, Vance SJ, Kline JA. An emergency department guideline for the diagnosis of pulmonary embolism: an outcome study. *Acad Emerg Med.* 2005;12(1):20-25.
- Stein PD, Fowler SE, Goodman LR, et al; PLOPED II Investigators. Multidetector computed tomography for acute pulmonary embolism. *N Engl J Med.* 2006;354(22):2317-2327.
- Wells PS, Anderson DR, Rodger M, et al. Excluding pulmonary embolism at the bedside without diagnostic imaging: management of patients with suspected pulmonary embolism presenting to the emergency department by using a simple clinical model and D-dimer. *Ann Intern Med.* 2001;135(2):98-107.
- Kline JA, Nelson RD, Jackson RE, Courtney DM. Criteria for the safe use of D-dimer testing in emergency department patients with suspected pulmonary embolism: a multicenter US study. *Ann Emerg Med.* 2002;39(2):144-152.