Emergency Radiology (2002) 9: 55–59
DOI 10.1007/s10140-001-0192-5

ORIGINAL ARTICLE

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Comparing the interpretations of CT pulmonary angiograms by attending and resident radiologists: can residents identify life-threatening pulmonary emboli in hospitalized patients?

Published online: 20 February 2002

Abstract *Objective:* CT pulmonary angiography is now often the first-line investigation for pulmonary emboli. When these studies are performed after hours in teaching hospitals, they are often initially interpreted by trainees. It is of great significance whether the interpretations of trainees and certified radiologists with regard to the presence of pulmonary emboli on CT pulmonary angiograms correspond, because of the morbidity and mortality of both the condition and its treatment. *Material and methods:* Twenty-five consecutive CT pulmonary angiograms (CTPAs) of hospitalized patients were viewed at lung and soft tissue windows both on a workstation and on hard copies, at the observers' discretion. Each CTPA was divided into 28 arterial zones based on pulmonary anatomy (including the subsegmental arteries), giving a total of 700 arterial zones, and analyzed retrospectively and independently by two cross-sectional imaging specialists and four residents. Each arterial segment was rated with regard to pulmonary embolus as either high, intermediate, or low probability or not visualized. The kappa (K) test, which tests for interobserver agreement, was used for statistical analysis. *Results:* At the time of the scan all patients were hospitalized for underlying conditions. Of the 25 patients studied, 9 were referred from the ICU, 7 experienced severe acute shortness of breath and respiratory failure, 5 were post-partum women, 2 had had a recent stroke, 1 patient had antithrombin III deficiency, and 1 had a diagnosis of breast cancer. The incidence of pulmonary emboli was 44%. For the main pulmonary arteries interobserver agreement was good ($K = 0.61$) and for the segmental pulmonary arteries it was fair ($K = 0.26$). For the subsegmental arteries interobserver agreement was poor ($K = 0.16$). The zones where interobserver agreement was greatest ($K > 0.4$) were the left main, left lower lobe, and the right main pulmonary arteries. Interobserver agreement was poorest ($K < 0.05$) in the left interlobar, left lower lobe lateral basal segment, right lower lobe superior segment, and left lower lobe superior segment branches. None of the patients expired due to pulmonary emboli. *Conclusion:* Most life-threatening pulmonary emboli requiring urgent treatment are the more central emboli. This study demonstrates that trainees and certified radiologists can make similar conclusions regarding these central pulmonary emboli in hospitalized patients and that preliminary interpretations by trainees should not therefore adversely affect patient care.

Keywords CT angiography · Emboli · Pulmonary · Education

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Introduction

Pulmonary embolism accounts for up to 100,000 deaths per year in the United States [1, 2]. Traditionally pulmonary angiography has been the diagnostic and definitive study of choice for pulmonary emboli (PE). Even though empiric anticoagulation therapy carries a higher morbidity and mortality than pulmonary angiography [3], only 15% of patients ultimately proceed to formal angiography [4, 5] due to the definite although minimal risk and cost associated with it [6, 7]. Thus, the potential of CT as a noninvasive study in its ability to both screen for and detect particularly the acute, life-threatening PE has great promise.

There have been numerous studies of the sensitivity, specificity, and interobserver variability associated with CT pulmonary angiography (CTPA) for the detection of acute PE [3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20], but none of these studies addressed the reality that in many teaching hospitals, only radiologists-in-training (RITs) are present to provide an opinion after hours, with a review the following morning by a certified radiologist. Thus, RITs are regularly called to interpret a CTPA for the presence of an acute PE, and treatment

decisions are made on the basis of their interpretation. As the treatment of PE has its own morbidity and mortality [3], it is of great clinical significance that correct interpretations are made by anyone interpreting CTPAs for the presence of PE.

Materials and methods

Six observers at a single center participated in the study. Two are radiologists who have been certified by the American Board of Radiology for 30 and 6 years. The remaining observers were RITs, two of whom had 3 years of training, one of whom had 2 years of training, and one was in his first year of training. The reviewers examined the CTPAs of 25 consecutive patients retrospectively. Patients recruited were all in-patients (this included emergency room patients). All patients were under clinical suspicion of acute PE and were referred by the clinical service. The observers were aware of the age and sex of the patient but were unaware of the clinical findings.

An institutional protocol issued to all certified radiologists and RITs upon joining the department includes a standard CTPA for PE protocol. We did not provide any specific training or instruction over and above that given to all trainees in the interpretation of CTPAs. Prior to participating in the study observers were advised to perform a review of the vascular and lobar anatomy of the lung.

All scans were performed on a GE CTi scanner (General Electric Medical Systems, Milwaukee, Wis.). A non-contrast-enhanced spiral CT of the chest at a collimation of 5 mm for the mediastinum and 7 mm for the rest of the lung was performed first. A time–density curve was then acquired using enhancement of the right or left pulmonary arteries with 20 ml noniodinated contrast material at 2–3 ml per second via an automatic injector (Medrad, Pittsburgh, Pa.). CT angiography was then undertaken in a caudal-to-cranial direction at 3 mm collimation, a pitch of 1.6–2, 230–240 mA and 120 kV with 130 ml nonionic contrast material at an injection rate and delay determined by the time–density curve.

CTPAs were viewed at lung and soft tissue windows both on the CT console and on hard copies at the observers' discretion. Each CTPA was divided into 28 arterial zones based on pulmonary anatomy for analysis: right and left main pulmonary artery (PA), right and left upper lobe PA, segmental arteries of the right (anterior, posterior, superior) and left (anterior, apicoposterior) upper lobe PA, right and left interlobar PA, right middle lobe PA, lingular (considered a lobe) branch of left PA, segmental arteries of the lingula (superior, inferior) and right middle lobe (medial, lateral), right and left lower lobe PA, segmental arteries of the right (anterior, posterior, medial, lateral, superior) and left (posterior, lateral, superior, anteromedial) lower lobe PA. This format was based on several prior studies [3, 19].

Each arterial segment was rated for pulmonary embolus as either high, intermediate, or low probability or not visualized.

An additional correlative study was requested on each patient. This took the form of scintigraphy, calf venous ultrasound, or fluoroscopic angiography.

For statistical analysis the arterial zones were divided into three regions. Region 1 included the main pulmonary arteries, region 2 represented the lobar and interlobar arteries, and region 3 included the segmental arteries. The kappa test, which tests for interobserver agreement, was used for statistical analysis. As per Altman [21], interobserver agreement was considered maximal for $K = 1$. $K = 0$ denotes a result equivalent to a chance guess (50%). Statistical analysis was conducted by the Center for Scientific and Academic Computing at the State University of New York at Brooklyn.

Results

Twenty-seven patients were enrolled in the study, 2 of whom were excluded due to renal insufficiency and inability to remain motionless in the scanner. This yielded a final group of 25 studies. The age range was 23–81 years with a mean age of 53.04 years. In 18 cases a correlative study was performed where the overall rate of PE was 44%. In the remaining 7 cases no correlative study was performed, either because the referring physicians were confident of the diagnosis provided by CTPA or due to patient-related factors.

There was a wide variety of patients all of whom were either inpatients or emergency room patients. Nine of the studies were referred from the ICU (seven with underlying chronic obstructive pulmonary disease and two with end-stage renal disease). Seven patients were referred from the emergency room with severe acute shortness of breath and respiratory failure. From the floors, two patients had a recent stroke and were bed ridden, one had antithrombin III deficiency, and one had breast cancer. Five post-partum patients were referred from the gynecology department.

None of the patients died within four weeks of the completion of the study.

The results are represented in Table 1.

A total of 700 arterial zones were analyzed. In accordance with Altman [21], overall agreement was good for the main pulmonary arteries, fair for the lobar and interlobar arteries, and poor for the segmental arteries.

The zones where interobserver agreement was greatest ($K > 0.4$) were the left main, left lower lobe, and right main pulmonary arteries. Interobserver agreement was poorest ($K < 0.05$) in the left interlobar, left lower lobe lateral basal segment, right lower lobe superior segment, and left lower lobe superior segment branches.

Both certified radiologists and RITs reported similar percentages of nonanalyzable arteries (8.2% and 8.0% respectively). Segmental arteries were more likely to be considered nonanalyzable than lobar or interlobar arteries, which in turn were more likely to be nonanalyzable than the main pulmonary arteries.

There was also little difference in the number of intermediate probability zones between RITs (2.4%) and certified radiologists (2.6%).

Both residents (RITs) and attending (certified) radiologists cited flow artifacts and breathing as the greatest obstacle encountered when interpreting CTPAs. Both groups also noted confusion with respect to the evaluation of the left interlobar artery. In addition, residents also cited difficulties with some of the anatomical aspects of cross-sectional imaging of certain zones and differentiating lymph nodes from flow defects (Fig. 1).

Discussion

This study attempted to recreate the clinical environment where a certified radiologist's word is often final and confirmatory studies are requested on a minority of patients. Thus, in evaluating our results, importance was attached to the findings of the certified radiologist as compared with the trainee. Several studies have already

Table 1. Means and standard deviations of kappa by arterial region

Region	No.	Mean	Standard deviation	95% Confidence intervals		Interobserver agreement grade [21]
				Lower	Upper	
1	16	0.61	0.24	0.48	0.74	Good
2	64	0.26	0.25	0.19	0.32	Fair
3	144	0.16	0.24	0.12	0.20	Poor
Total	224	0.22	0.27	0.18	0.25	Fair

been undertaken on the detection rate of PE by CTPA as compared with a gold standard, providing specificities, sensitivities, and interobserver agreement for this technique [3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]. Our study does not aim to provide accuracy data for the use of CTPA in the detection of PE, but rather to fill a void in the literature not answered in earlier reports by addressing the real-world situation in regard to the trainee and to guide teaching institutions in the use of CTPA after hours.

A factor that reduced our overall kappa and the kappa for region 2 in particular was confusion regarding the left interlobar artery. There is widespread disagreement on whether the left lung (having two lobes) actually has a left interlobar artery or rather just a lower and upper lobe artery. This was noted by observers to have caused confusion, and the negative effect is further proved by the fact that the segments on either side of the left interlobar artery (the left main and left lower lobe pulmonary arteries) were the arteries with the highest kappa values.

Our study showed lower interobserver agreement than do other studies published in the literature. The only other study [19] comparing interobserver agreement for the detection of PE using CTPAs utilized six observers with an overall kappa of 0.56 on an arterial zone basis and a kappa of 0.47 for the segmental arteries (comparable to region 3 in the present study). All six observers in that study were certified radiologists with further fellowship training and there was no differentiation between outpatients and inpatients. Before the start of that study, all observers were given a refresher course on interpreting CTPAs. In our study we specifically did not provide a refresher course so as to approximate the clinical situation more closely. Furthermore, our kappa value was hurt by the relatively large proportion of ventilated and critically ill patients since many more scans are suboptimal in these patients, but they are the type of patients on whom scans are likely to be performed urgently after hours.

Several other studies also tested interobserver agreement for the detection of PE on CTPAs, but all used few observers or did not employ statistical methods to quantify interobserver agreement. Using two observers, Van Rossum et al. [3] obtained an overall kappa of 0.77 for the detection of acute PE on CTPAs but did not calculate a kappa for a zone to zone comparison or provide figures on the differences between regions. Another study by the same authors [22] yielded an overall

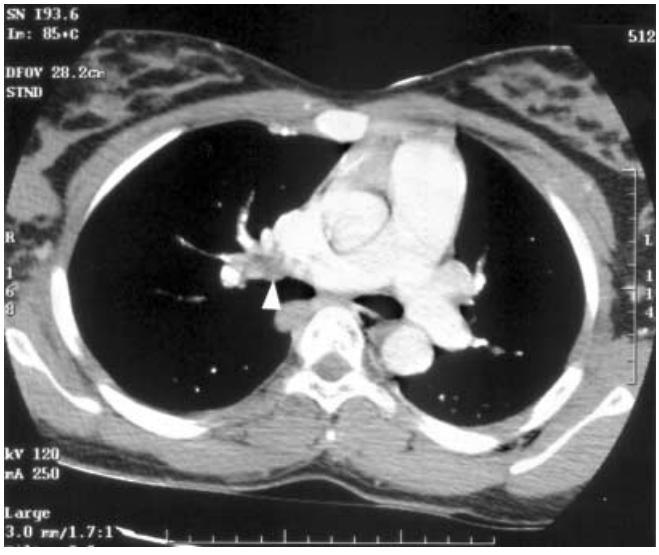

Fig. 1. Areas such as that marked by the *arrowhead* proved the downfall for residents who labeled this as an embolus. This patient went on to have a normal VQ scan

kappa of 0.85, while another study [11] resulted in a kappa of 0.61. Two more studies [23, 24], which appeared in abstract form only, provided overall kappas of 0.72 and 0.87 respectively for the detection of acute PE on CTPAs. Bergin et al. [18], in determining the sensitivity and specificity of chronic PE detection on CTPAs in a predominantly outpatient setting, found a kappa of 0.66 for central disease (comparable to region 1 in this study) and kappas of 0.31 and 0.34 for lobar (region 2) and segmental (region 3) emboli respectively with two observers.

Several studies in the past have shown that accuracy in detecting acute PE on CTPAs increases with experience. Van Rossum et al. [25] showed that accuracy of CTPA interpretation improves with the experience of the observer. This held true even amongst certified radiologists specializing in cross-sectional imaging [19].

We believe our interobserver agreement was weaker than in other studies as four of our six observers were RITs, some with as little as 1 year of postgraduate radiological experience. Nevertheless, we believe this to be a strength rather than a weakness as it approximates more closely the situation after hours in a teaching hospital. Our results should not be interpreted as showing that residents are as good as certified radiologists in the interpretations of CTPAs. Rather, residents

are adequate in providing preliminary interpretations until an attending radiologist arrives.

In interpreting our results, the clinical presentation of emboli to different levels of the pulmonary circulation is important. The immediately dangerous and imminently lethal emboli are the larger, more central emboli [8, 26], whereas emboli to the smaller arteries tend to cause chronic symptoms.

Previous studies on the ability of RITs to evaluate CT scans of the head for life threatening conditions noted that, while there were some discrepancies which occasionally involved major injury, overall patient care did not suffer [27, 28]. This was also the case in our study since none of the patients died when the CTPAs were originally interpreted by RITs in the course of their regular duties.

Our detection rate for PE was somewhat higher than those in recent multicenter trials [17]. We believe that this was due to our patient population, which was made up entirely of hospitalized patients of whom a significant number where in the ICU or were post-partum.

Even though our patient base was relatively small, because of the nature of the patient population we believe it to be large enough to provide an adequate number of positive cases. This population size also compares favorably to that in previous studies [26] which formed the basis of patient care decisions for several years.

Conclusions

As our study showed moderate to good interobserver agreement for the detection of central and lobar acute pulmonary emboli, and as these are the emboli which are more likely to cause immediate death, we believe that our study shows that radiologists-in-training can identify life-threatening pulmonary emboli on CT angiograms of hospitalized patients. However, our results do not show that residents are equal to attending radiologists in the interpretation of CTPAs, and therefore early attending review is essential.

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