



## Ultrasound Assessment of Pulmonary Embolism in Patients Receiving CT Pulmonary Angiography

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**Background:** CT pulmonary angiography (CTPA) is considered the gold standard for the diagnosis of pulmonary embolism (PE) and is frequently performed in patients with cardiopulmonary complaints. However, indiscriminate use of CTPA results in significant exposure to ionizing radiation and contrast. We studied the accuracy of a bedside ultrasound protocol to predict the need for CTPA.

**Methods:** This was an observational study performed by pulmonary/critical care physicians trained in critical care ultrasonography. Screening ultrasonography was performed when a CTPA was ordered to rule out PE. The ultrasound examination consisted of a limited ECG, thoracic ultrasonography, and lower extremity deep venous compression study. We predicted that CTPA would not be needed if either DVT was found or clear evidence of an alternative diagnosis was established. CTPA parenchymal and pleural findings, and, when available, formal DVT and ECG results, were compared with our screening ultrasound findings.

**Results:** Of 96 subjects who underwent CTPA, 12 subjects (12.5%) were positive for PE. All 96 subjects had an ultrasound study; two subjects (2.1%) were positive for lower extremity DVT, and 54 subjects (56.2%) had an alternative diagnosis suggested by ultrasonography, such as alveolar consolidation consistent with pneumonia or pulmonary edema, which correlated with CTPA findings. In no patient did the CTPA add an additional diagnosis over the screening ultrasound study.

**Conclusions:** We conclude that ultrasound examination indicated that CTPA was not needed in 56 of 96 patients (58.3%). A screening, point-of-care ultrasonography protocol may predict the need for CTPA. Furthermore, an alternative diagnosis can be established that correlates with CTPA. This study needs further verification, but it offers a possible approach to reduce the cost and radiation exposure that is associated with CTPA. *CHEST* 2014; 145(4):818–823

**Abbreviations:** CTPA = CT pulmonary angiography; PE = pulmonary embolism

The diagnosis of pulmonary embolism (PE) requires recognition of its variable presentation and the appropriate use of radiologic imaging in combination with estimation of pretest probability. CT pulmonary

angiography (CTPA) has high sensitivity and specificity for PE and is the reference standard for the diagnosis.<sup>1</sup> In addition to its use in making the diagnosis of PE, CTPA may provide the clinician with an alternative diagnosis to PE. The use of CTPA results in significant exposure to ionizing radiation, as well as a risk of contrast nephropathy, so the clinician has a responsibility to avoid its use whenever possible. Lower

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extremity compression ultrasonography offers an alternative means for diagnosis of VTE. However, not all patients with PE have DVT. Lower extremity compression ultrasonography cannot be used to exclude the diagnosis nor does it offer the clinician an alternative diagnosis, as does CTPA.<sup>2</sup> The use of validated prediction models for the diagnosis of PE, coupled with measurement of D-dimer levels, may reduce the use of CTPA.<sup>3</sup> Despite this, it has been shown that CTPA is often performed regardless of the pretest probability, and performance of lower extremity DVT study may be subject to delays in diagnosis.<sup>4,5</sup> The aim of this study was to examine whether point-of-care ultrasonography that includes thoracic ultrasonography, goal-directed ECG, and lower extremity DVT study might be useful to reduce the need for CTPA in patients with suspected PE.

## MATERIALS AND METHODS

### Study Site

This study was performed at Long Island Jewish Medical Center, which is an 888-bed teaching hospital of the Hofstra-North Shore Long Island Jewish Health System. The hospital institutional review board approved this study (IRB 09-134A), and all subjects gave signed informed consent to participate in the study.

### Subject Selection

To be eligible for the study, subjects had to be aged  $\geq 18$  years and have a CTPA ordered by an attending physician in the ED or inpatient medical service. Exclusion criteria included pregnancy, age  $< 18$  years, and lack of informed consent.

### Study Design

Subject enrollment and data collection were prospective from July 2010 through July 2011. During this period, patients in the ED or on the inpatient medical service were enrolled in the study by one of the investigators if they had a CTPA ordered by an attending physician between the hours of 8:00 AM and 6:00 PM (weekdays only). Enrollment was nonconsecutive and depended on whether one of the investigators was available; therefore, study subjects represent an observational, prospective convenience sample.

### Methods

All ultrasound scans were performed by one of three full-time, pulmonary/critical care faculty attending physicians or one of three third-year fellows, who had received comprehensive ultrasound training and had used ultrasonography throughout their fellowship. All ultrasonographers were fully trained in critical care ultrasonography as defined by a competence statement on the subject.<sup>6</sup> When a CTPA was ordered with the specific indication for diagnosis of PE, notification via pager was given to the investigators. One of the investigators then obtained consent from the patient and performed an ultrasound examination as described later in this article (Fig 1). The investigators were blinded to the history, formal physical examination of the study subject, any test

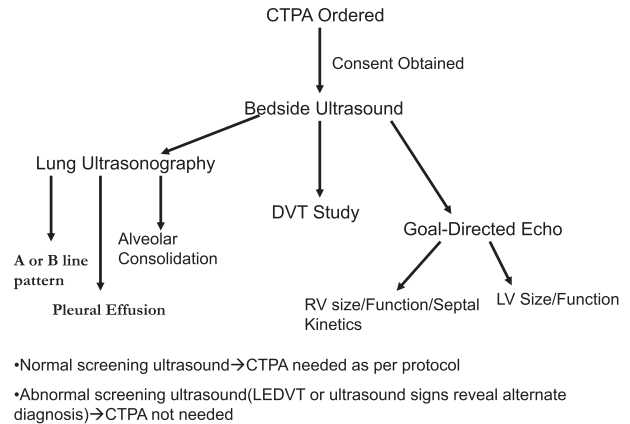


FIGURE 1. Flow diagram illustrating performance of ultrasound examination. CTPA = CT pulmonary angiography; LEDVT = lower extremity DVT; LV = left ventricle; RV = right ventricle.

results (including D-dimer level), and results of the CTPA, if already performed at the time of the ultrasound examination. All ultrasound examinations were performed either while the patients were waiting for or within 3 h after the performance of the CTPA. Based on the results of the ultrasound examination, the investigator then recorded on the data sheet whether a CTPA was, in their opinion, required to evaluate the patient for the possibility of a PE. The investigators were blinded to the results of the CTPA, and the results of the ultrasound examination were not shared with the clinical team that ordered the CTPA.

Ultrasound examination of the thorax, lower extremities, and the heart were performed using a Sonosite M-Turbo ultrasound machine (Fujifilm Sonosite Inc) equipped with a phased array (Sonosite P21 Transducer) and a linear ultrasound probe (Sonosite L38 Transducer). The primary ultrasonographer interpreted the images as they were acquired. Video clips of each part of the ultrasound study were recorded, and the entire study was reviewed offline by another investigator. If discrepancy occurred between the initial interpretation and the over read, the image set was reviewed by the two investigators to reach final consensus.

Thoracic ultrasonography was performed using a standard protocol. Presence or absence of sliding lung, anterior and lateral A or B line pattern, alveolar consolidation, and pleural effusion were evaluated at standard sites from each hemithorax<sup>7,8</sup> (Fig 2).

The cardiac examination consisted of standard goal-directed ECG views that included the parasternal long-axis view, the parasternal short-axis view, the apical four-chamber view, the subcostal long-axis view, and inferior vena cava longitudinal view.<sup>9</sup> Assessment of the left ventricle was graded as hyperdynamic, normal, mildly reduced, moderately reduced, or severely reduced. The size of the right ventricle was graded as normal, moderately enlarged, or severely enlarged by qualitative estimate; and right ventricle volume/pressure overload was indicated by the presence of septal dyskinesia or flattening.<sup>10</sup> The size of the inferior vena cava was determined in both inspiration and expiration.

A lower extremity venous compression study was performed on the proximal deep veins of both legs. Compression maneuvers were performed at the level of the proximal common femoral vein, the entrance of the greater saphenous vein into the common femoral vein, the bifurcation of the common femoral artery, the bifurcation of the common femoral vein into the superficial femoral vein and the deep femoral vein, the superficial femoral vein, and the popliteal vein. A compression maneuver was considered positive for lower extremity DVT if there was incomplete apposition of the anterior and posterior walls of the vein, if a visible clot

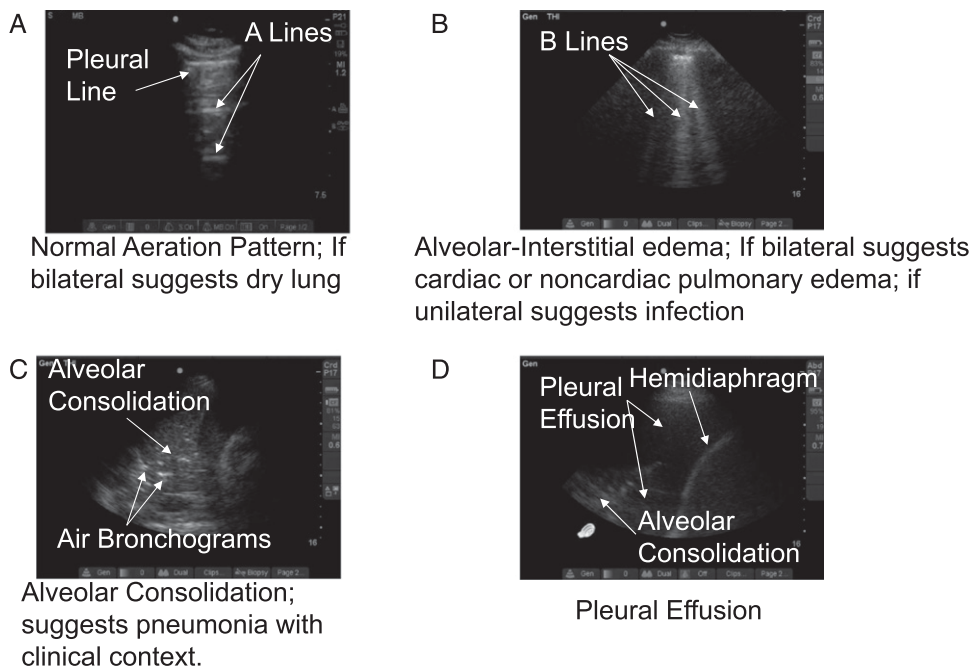


FIGURE 2. Ultrasound thoracic patterns. A, Normal aeration pattern. B, Alveolar-interstitial pattern. C, Alveolar consolidation pattern. D, Pleural effusion.

was seen within the lumen of the vein, or both. No Doppler measurements were made during the DVT study.<sup>5</sup> Basic demographic data were recorded from the patient chart.

In summary, the study used a passive observational design, the purpose being to determine to what extent ultrasonography might be useful in reducing the need for unnecessary CTPA. The ultrasonography investigator team functioned entirely independently of the clinical care team that was responsible for the decision to perform the CTPA. The results of the ultrasound examination were not communicated to the clinical care team nor were the results of the CTPA known to the ultrasonographers. Based solely on the results of the ultrasound examination, the sonographers determined if CTPA would be useful for diagnosis of PE in each individual patient. If the ultrasound examination yielded no abnormal findings, then a CTPA was considered necessary. This meant there was no indirect evidence of PE, such as lower extremity DVT, and that an obvious alternative diagnosis was not evident on point-of-care ultrasound. If the ultrasound examination showed either a lower extremity DVT or if it showed an abnormal finding supporting a diagnosis other than PE, then a CTPA was considered unnecessary. Examples of ultrasound examinations where the investigator would consider that CTPA was unnecessary would be an alveolar consolidation pattern consistent with pneumonia or atelectasis, evidence of interstitial syndrome, or a large pleural effusion on ultrasonography. Thoracic ultrasonography has been shown to have operational characteristics that are superior to standard chest radiography and comparable to chest CT scan for these applications.<sup>11-13</sup> On a later date, a different investigator reviewed results of the CTPA and determined if the ultrasonographers were correct in determining the need for CTPA.

On occasion, the clinical care team decided to order a cardiology-performed ECG or a radiology-performed lower extremity DVT study, in addition to the CTPA. The results of the CTPA, ECG, and lower extremity DVT studies done during the patient's hospital admission were compared with the results of the ultrasound examination done by the investigators.

## RESULTS

One hundred patients were prospectively enrolled in this study. No eligible patient declined to participate in the study. Of these subjects, four patients did not receive a CTPA. Two patients declined to receive the CTPA, and two CTPAs were cancelled by the clinical care team following enrollment but before the ultrasound examination was performed. The remaining 96 patients form the basis of this report. Baseline characteristics of these 96 subjects are presented in Table 1. The most common presenting complaints were dyspnea and chest pain. There were no patients

Table 1—Baseline Characteristics (N = 96)

Characteristic	Total
Age, mean ( $\pm$ SD), y	56 ( $\pm$ 20.5)
Male sex, %	41.4
Signs and symptoms at presentation	
Shortness of breath	52 (54)
Chest pain	36 (38)
Palpitations	5 (5)
Syncope	2 (2)
Dizziness	7 (7)
Hemoptysis	0
Lower extremity pain	7 (7)
Lower extremity edema or tenderness	4 (4)
Other	4 (4)
Hypoxemia	6 (6)
Hypotension	0

Data given as No. (%) unless otherwise indicated.

who were hypotensive (systolic BP < 90 mm Hg or mean arterial BP < 60 mm Hg) at the time of the CTPA request.

Based upon the ultrasound examination results alone, the investigators' opinion was that 56 of the 100 subjects (58%) did not need a CTPA (ie, the ultrasound examination revealed an abnormality of sufficient consequence that it established a convincing alternative diagnosis to PE or a DVT was identified). In none of these 56 cases did the CTPA identify a PE. The ultrasonography diagnoses for these 56 patients are presented in Table 2. The results of the goal-directed ECG examination were not useful in discriminating those patients who did not require a CTPA.

Based upon the ultrasound examination results alone, the investigators' opinion was that 40 subjects (42%) needed a CTPA (ie, the ultrasound examination was normal and did not reveal any abnormality that established an alternative diagnosis to PE). In 12 of these cases (30%), the CTPA identified a PE.

When comparing the findings of the ultrasound examination with those of the CTPA, in the 56 subjects where the ultrasound examination showed an alternative diagnosis, the abnormality correlated to the findings on the CT scan in 56 cases (100%). Two of the subjects had lower extremity DVTs and the CT scan showed PE for both of these subjects. The results of the goal-directed ECG examination were not useful in discriminating those patients who did not require a CTPA.

All study patients had adequate cardiac windows by judgment of the investigators. The cardiology service performed ECGs in 28 patients (29%); the study goal-directed ECGs agreed with official ECGs in 26 cases (93%). One of the discrepant examinations was rejected by the cardiology ECG service as having inadequate image quality, while the investigator read it as severely reduced left ventricular function. The other discrepant examination was read by the cardiology ECG service as showing severely reduced left ventricular function while the investigator read it as moderately reduced function. The radiology service performed a lower extremity DVT study with Doppler

in 18 study subjects (19%). The results of the radiology lower extremity DVT studies were 100% concordant with the investigator studies.

## DISCUSSION

The results of this study indicate that an ultrasound examination that includes thoracic ultrasonography, goal-directed ECG, and bilateral lower extremity DVT compression studies might have use in reducing the number of unnecessary CTPAs. When the investigators, who were blinded to the clinical presentation of the patient, found a relevant finding on ultrasound examination that suggested a diagnosis other than PE, no CTPA revealed a PE. However, when there was no relevant ultrasound examination that suggested an alternative diagnosis other than PE, 30% of patients were found to have a PE.

As performed by study investigators, the ultrasound examination had strong correlation with the findings of cardiology-performed ECG and radiology-performed lower extremity DVT studies, and it correlated well with CT scan results in the identification of alternative diagnosis. This indicates that the investigators were able to perform accurate ultrasound examinations. In this study, we used a well-described pleuro-pulmonary ultrasound examination protocol that was helpful in establishing alternative diagnosis to PE.<sup>8</sup> Compared with pleuro-pulmonary ultrasonography, goal-directed ECG was not useful in suggesting alternative diagnoses in the study population; however, it provided supportive evidence when left ventricular dysfunction was present with pulmonary edema. We note that none of the current patients had hypotension; ECG might have special application in this patient population in addition to pleuropulmonary ultrasound and DVT study. Although DVTs were uncommon in the current population, when found they eliminated the need for CTPA.

This study has limitations and should be considered only as a hypothesis-generating preliminary report. As an observational, though prospective, convenience sample, it is susceptible to patient-selection bias. In addition, the investigators, who were experienced bedside clinicians, were not blinded to some aspects of the patient's clinical presentation; that is, they were able to "eyeball" the patient during the ultrasound examination and were possibly aware of the patient's vital signs, including oximetry. To some extent, the ultrasound examination involved subjective judgment of the real-time image. The examiner could choose which images to save for later review and so may have identified minor abnormalities at the time of the examination that they arbitrarily did not include in video clips reviewed by the offline reader. Another problem

**Table 2—Performance of Ultrasound to Determine Need for CTPA**

Ultrasound Result	No. (%) (N = 96)
CTPA not needed	56 (58.3)
Because VTE found	2 (2.1) <sup>a</sup>
Because alternate diagnosis <sup>b</sup> found on ultrasound	54 (56.2)
CTPA needed	40 (41.7)

CTPA = CT pulmonary angiography.

<sup>a</sup>100% correlation of ultrasound results with CTPA.

<sup>b</sup>Alternative diagnoses were alveolar consolidation pattern, pleural effusion, and pulmonary edema.



relates to sample size. It is inadequate to make a definitive statement as to the utility of the ultrasonography, although no PE was missed using the ultrasound examination. We conclude that ultrasonography may have use in excluding the diagnosis of PE but not to make the diagnosis of PE. Another potential limitation of this study is that it does not address the possibility of a dual diagnosis such as PE with congestive heart failure or pneumonia. We are also aware that alveolar consolidation, alveolar interstitial pattern, and pleural effusion may be occasional ultrasound findings associated with PE. While we recognize this as a possibility, we had no such case. One possibility for this is that the examiners were not blinded to the patient's overall physical condition during the ultrasound examination, and were able to integrate the ultrasound findings into clinical and intuitive clinical assessment. Our data do not allow us to determine to what extent this happened.

The clinical implications of this study include the possibility that ultrasonography performed before CTPA might allow for reduction of the number of CTPAs performed to rule out PE. A typical CTPA results in 0.1 Sv of radiation exposure, which is the equivalent to approximately 400 standard chest radiographs.<sup>14</sup> There is serious concern that the excessive number of body CT scans performed in the United States will increase the overall rate of malignancies in coming years.<sup>15</sup> Every clinician has a responsibility to reduce the use of unnecessary CT scan studies, and we feel that ultrasonography might be useful in achieving this goal.

If the ultrasonographer was also the clinician managing the case, the utility of ultrasonography might be greater than what we have demonstrated in the present report. The study investigators were entirely independent of the clinical care team and were prohibited from using clinical data in making their judgment as to whether the subject needed a CTPA. One advantage of point-of-care ultrasonography is that the clinician in charge of the case can efficiently integrate the results of the ultrasound examination with clinical assessment at the patient's bedside. In this study, the investigators lacked this advantage. It is possible that complete clinical assessment by those performing the ultrasound examination might further improve the decision-making process regarding CTPA. Use of a formal scoring system to establish pretest probability for PE might also improve the utility of the ultrasound examination.

Mathis et al<sup>16</sup> have described findings on lung ultrasound examinations that are characteristic of PE. We used ultrasonography to rule out PE, whereas their work raises the possibility of using ultrasonography to rule in the diagnosis. The technique of lung ultrasonography used in the present study did not include

the methods used by these authors. It is possible that incorporating their advanced methods into the basic lung ultrasound examination would allow even greater reduction in the use of unnecessary CTPA. Pleural-based alveolar lesions are associated with small pulmonary emboli, so lung ultrasonography might have particular application to patients with nonsevere PE presentation, such as described in the present article.

## CONCLUSIONS

This preliminary report indicates that combining thoracic ultrasonography, limited ECG, and lower extremity DVT study might have use in reducing unnecessary CTPA ordered to rule out PE. It may be appropriate to examine the role of ultrasonography for the evaluation of PE with a controlled study that includes the use of additional lung ultrasonography findings and has the clinical care team perform the ultrasound examination.

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**Author contributions:** Dr Koenig had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

*Dr Koenig:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript and served as principal author.

*Dr Chandra:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript.

*Dr Alaverdian:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript.

*Dr Dibello:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript.

*Dr Mayo:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript.

*Dr Narasimhan:* contributed to the study design; acquisition, analysis, and interpretation of the data; and both the draft and final versions of the manuscript.

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