Acute Pulmonary Embolism

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Imaging plays a crucial role in the diagnosis of pulmonary embolism (PE) and deep venous thrombosis (DVT), a spectrum of the same disease entity. PE is the third most common cause of cardiovascular death in the United States, following ischemic heart disease and stroke, with an annual incidence of 300,000 to 600,000 per year.[1,2] Despite the high prevalence, PE is difficult to diagnose, with only 43 to 53 patients per 100,000 being accurately diagnosed, and up to 70% of clinically unsuspected PE diagnosed at autopsy.[1,3] In the past few decades, the incidence of PE has decreased by 45%, whereas that of DVT is unchanged.[4,5] Death occurs in up to 90% of patients with unrecognized PE, whereas in treated patients PE accounts for less than 10% of deaths.[6,7]

Rapid and timely diagnosis of this life-threatening disease is important to improve patient outcome as the signs and symptoms as well as ancillary tests are nonspecific. The recent rapid growth in CT technology over the past decade has seen the emergence of CT pulmonary angiography (CTPA) as the single first line test in the diagnosis of PE because of its high diagnostic accuracy and ability to provide alternate diagnosis for diseases of the lung parenchyma, pleura, pericardium, aorta, heart, thoracic lymph nodes, and mediastinum.

The widespread availability and use of CTPA has made the diagnosis of PE easier in most cases, but has raised the need for optimal use of this technique in the appropriate patient population, in order to minimize unnecessary medical radiation exposure.

Pretest risk stratification using Wells criteria, clinical probability scores, assessing premorbid conditions, past history, and a thorough clinical examination should precede an appropriate, timely ,and accurate diagnostic test.[8,9] In some common scenarios like pregnancy and in critically ill patients, the diagnosis of PE still remains challenging.

DIAGNOSIS OF ACUTE PULMONARY EMBOLISM

Ventilation-Perfusion Scintigraphy

Combined ventilation and perfusion (V/Q) scintigraphy had been the imaging technique of choice for decades. A V/Q scan with normal findings essentially excludes pulmonary embolism with an NPV (Negative Predictive Value) close to 100%, thereby precluding the use of anticoagulation, whereas a high-probability scan is highly specific for the diagnosis of PE, allowing definitive treatment. In the original PIOPED (Prospective Investigation of Pulmonary Embolism Diagnosis) study only 14% of patients had a normal V/Q scan and 13% a high-probability V/Q scan, rendering a definitive diagnosis in only a small group of patients; most (73%) had an indeterminate (nondiagnostic) or low-probability test result.[10] This high degree of uncertainty makes initiation of definitive anticoagulant therapy difficult because

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of risk of bleeding and necessitates additional tests to diagnose or exclude pulmonary embolism.

The criteria for reporting V/Q scans have improved significantly.[11] Recent use of V/Q scanning with SPECT allows 3-dimensional visualization of segments previously not identified on planar imaging, such as the medial basal segment of the right lower lobe. The lung segments are more clearly defined and can be viewed in any orthogonal plane, resulting in better detection and characterization of defects.[12] SPECT also improves image contrast, thus decreasing the rate of intermediate scan reports. Large-scale trials are needed to fully assess this modality and compare its performance with CTPA. Currently the definitive primary role of V/Q scanning is in patients where CTPA is contraindicated as in severe renal impairment or history of iodine or contrast allergy.

Catheter Pulmonary Angiography

Catheter pulmonary angiography has been considered as the reference test for the diagnosis of PE since the late 1960s. However, the invasive nature and expense of the study along with a small but definite risk in morbidity has contributed to its underutilization. Two studies, done 12 years apart in 1240 patients, showed that following an inconclusive V/Q scan result, catheter pulmonary angiography was performed in less than 15% of patients.[13,14] Many patients were treated with anticoagulants without a definitive result. Accurate diagnosis is important, as anticoagulants themselves account for significant morbidity (up to 6.5%), that increases with age and with comorbid conditions.[15,16]

With the newer generation of MDCT (multidetector CT) scanners, the role of catheter pulmonary angiography as the gold standard test has been questioned and is considered to be flawed, particularly at the subsegmental level.[17–19] The interobserver agreement at the subsegmental level on the original PIOPED study was reported to be only 66%.[10] In PIOPED II, in the 20 discordant cases, PE was missed at the lobar, segmental, and subsegmental levels in 13 patients; 8 of 13 were at the subsegmental level.[19] The current role of catheter pulmonary angiography is when CTPA is inconclusive, or when the clinical findings are discordant with CTPA results.

CT Pulmonary Angiography

Incidental detection of PE was first documented by Sinner in 1978.[20] The advent of single-detector helical CT in the early 1990s, made it possible to obtain volumetric datasets with good contrast in a single breath-hold, allowing diagnosis predominantly of central and segmental PE. With rapid evolvement of CT technology, the CT diagnosis of PE has been a subject of much research in the past couple of decades, and has resulted in CTPA becoming a first-line imaging test at many centers.[21] CTPA is a relatively safe, accurate, readily available and cost-effective noninvasive test that not only diagnoses PE, but also provides diagnosis of alternative pathologies in the thorax accounting for patient symptoms, particularly in the inpatient and emergency department settings.

Faster multidetector scanners have set the way for a potential new gold standard test. With newer 128 and higher slice scanners, the sensitivity and specificity is likely to increase albeit at a cost of increased radiation.

Advances in MDCT

MDCT has several advantages over SDCT (single detector CT) in the diagnosis of PE, which include improved z-axis resolution, shorter scan times, reduction in volume of contrast, and the ability to do a combined CTPA/CT venography (CTV) exam at the same setting with a single bolus of contrast.

Z-Axis Resolution

Advances in MDCT technology with improved gantry rotation speeds and increased detector width allow rapid acquisition of large volumetric datasets over a greater craniocaudal distance than with SDCT. While reduction in slice collimation with SDCT results in a longer breath hold and a likelihood of increased respiratory motion artifact, with MDCT reduction in slice thickness leads to better visualization of subsegmental pulmonary arteries, with 94% of fifth order and 74% of sixth order pulmonary arteries being visualized.[22–24] Reducing the reconstruction thickness decreases partial volume averaging and also results in better visualization of the obliquely oriented middle lobe and lingular arteries, in which an estimated 20% of emboli occur.[17] Reducing the slice thickness also improves the interobserver agreement for diagnosis of PE.[25]

Shorter Scan Acquisition Time

A shorter breath hold translates into decreased respiratory motion artifact which in turn results in less indeterminate studies and allows better visualization of the subsegmental pulmonary arteries. The scan range for SDCT typically ranges from 15 to 20 cm from the top of the aortic arch to the dome of the diaphragm, with a breath hold of 30 to 40 seconds or longer, whereas the entire chest can be scanned with 16-slice or higher generation