EDITORIAL

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Diagnostic Imaging Techniques for Pulmonary Embolism

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Imaging techniques, both invasive and noninvasive, are the primary tools used to diagnose pulmonary thromboembolism. Noninvasive techniques include ventilation—perfusion lung scintigraphy, spiral computed tomography (CT), CT angiography, pulmonary magnetic resonance angiography (MRA), and transthoracic echocardiography, which is useful in certain circumstances even though it only provides indirect signs of embolism. In 90% of cases, pulmonary embolism is caused by deep vein thrombosis (DVT) of the lower extremities; as a result, lower limb Doppler ultrasound—the most commonly used noninvasive method to detect DVT—is usually included in the diagnostic algorithm. Conventional pulmonary angiography, intravenous CT venography of the lower limbs, and currently digital intravenous angiographic subtraction (DIVAS) are considered the standard diagnostic tests for pulmonary embolism. We will briefly assess the current situation and the future prospects for each of these techniques and a few other new methods.

Ventilation-perfusion scintigraphy has been an excellent techique for diagnosing pulmonary embolism, especially since the PIOPED study,[1] which established the probability criteria for the diagnosis based on the combined results of radiology and lung scans. Because ventilation-perfusion scintigraphy has high negative predictive value, it is the first imaging technique in the diagnostic algorithm.[1] The technique has drawbacks, however, as evidenced by the finding from the PIOPED study that 30% of patients considered to have low or moderate probability of pulmonary embolism as determined by a lung scan were subsequently found to have an embolism on angiography. That study also found that among patients with angiographically confirmed embolism, only 41% were cases initially considered high probability based on ventilation-perfusion scans and 70% were considered to have moderate probability of pulmonary embolism.[1] In addition, in cases with low or moderate probability, interobserver variability was estimated to be approximately 30%.[1]

Another difficulty is that ventilation-perfusion scans are difficult to interpret in patients who have chronic obstructive pulmonary disease and suspected pulmonary embolism and in cases of recurrence (because, in a high percentage of cases, the perfusion abnormalities observed do not disappear completely[2]). The disadvantages of ventilation-perfusion scintigraphy, coupled with fact that such invasive tests are unavailable at most hospitals, have led to a search for alternative noninvasive methods to establish a definitive diagnosis of pulmonary embolism.

There has been a dramatic increase in the use of CT angiography in this clinical setting ever since the first report by Remy-Jardin[3] in 1992. Numerous studies have evaluated the sensitivity, specificity, and positive and negative predictive values of both single-detector and multidetector CT angiography—the second of which has a higher specificity in detecting subsegmental emboli.[3-6] In fact, one of these studies[5]—a multicenter, prospective study—found that the negative predictive value of single-detector CT angiography was high enough to allow that test to be used first to exclude pulmonary embolism. However, in a more recent study, this same group of researchers reported that the sensitivity offered by this type of CT angiography was not, in fact, acceptable for patients with a moderate or high clinical probability of pulmonary embolism.[7] This finding was recently confirmed by Jiménez et al[8] in their excellent study in the present issue of ARCHIVOS DE BRONCONEUMOLOGÍA. That retrospective study of 165 patients who underwent single-detector CT angiography for suspected pulmonary embolism found that this modality had a sensitivity of only 63% and, moreover, 35% of patients with a negative result later developed pulmonary embolism. However, these findings should be considered in the context of the study's limitations: relatively few patients, radiologists without specific expertise in pulmonary circulation, and no measurement of interobserver variability. The most important conclusion from the study is that a negative single-detector CT angiogram is not sufficient, by itself, to rule out pulmonary embolism in patients with moderate or high clinical probability. However, as has

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been observed in other series, this technique is sufficiently effective to rule out pulmonary embolism in low probability cases. Another interesting conclusion from the study by Jiménez and coworkers is that a negative CT angiogram is a predictor of recurrence. The development of multidetector CT angiography represents a significant advance in diagnosis because it has higher negative and positive predictive value compared to single-detector CT angiography, as shown in 2 recent meta-analyses and 1 study of cost-effectiveness[9-11]; compared to single-detector CT angiography, the multidetector modality is more effective in terms of excluding or confirming the presence of pulmonary embolism. These findings are consistent with those from the most recent study by van Strijen et al,[12] in which more than 500 patients were enrolled prospectively; those authors found that a diagnosis of pulmonary embolism could be ruled out in 80% of patients if CT angiography was negative. Multidetector CT angiography has additional advantages, including the ability to perform the DVT study during the same exploration, to differentiate thrombotic from fat emboli, and to distinguish between older and more recent thrombi.[13,14]

Gadolinium-enhanced MRA is an excellent noninvasive diagnostic technique for pulmonary embolism because its sensitivity and specificity are high, as confirmed by a review article and a meta-analysis, and it also allows simultaneous study of DVT.[15-18] An advantage of MRA over multidetector CT angiography is that images of ventilation can be obtained if noble gases, such as helium 3 or xenon 129, are used; in addition, it has no contraindications and is safe to use during pregnancy.[19,20] However, one disadvantage of MRA compared to CT angiography is that there are fewer studies available and, moreover, the ones published have enrolled only a limited number of patients. MRA is more sensitive than Doppler ultrasound in detecting pelvic DVT however.[21]

Transthoracic echocardiography is not part of the diagnostic algorithm for pulmonary embolism. Its sensitivity and specificity are not high but, if other diagnostic methods are unavailable or a massive pulmonary embolism is suspected, transthoracic echocardiography can nearly always provide indirect signs of the event so appropriate treatment can be initiated quickly.[22] Transthoracic echocardiography is currently included in the diagnostic algorithm for suspected massive pulmonary embolism.[23]

The sensitivity and specificity of lower limb Doppler ultrasound is high for symptomatic proximal DVT but lower for distal and/or asymptomatic DVT.[24-27] It is also less useful in recurrences of DVT because Doppler images become normal in only 55% of patients 1 year after a first episode.[28]

Conventional angiography, DIVAS, and CT venography are considered the gold standard tests for establishing a definitive diagnosis in both pulmonary embolism and DVT. These techniques are and have long been part of the traditional algorithm for pulmonary embolism, but they are invasive procedures with potential complications and are simply not available in many hospitals.[29] Moreover, with the emergence of multidetector CT angiography and considering that pulmonary embolism can be diagnosed by noninvasive methods in 94% of patients,[30] these standard tests are indicated only in a limited number of cases.

Currently, the main debate is whether multidetector CT angiography can replace both ventilation-perfusion scintigraphy and invasive methods. In my opinion, given the data presented here and considering that CT angiography requires the same amount of time and money to perform as the combination of ventilation-perfusion scintigraphy and lower limb Doppler ultrasound, it is more than probable that multidetector CT angiography will become the only imaging technique necessary in the near future for the diagnosis of pulmonary embolism in most patients, for both first episodes and recurrences. This is so especially because it is available in most hospitals. With multidetector CT angiography, pulmonary embolism can be ruled out, with an acceptable degree of certainty, in low probability cases; this does not contradict the results of Jiménez and colleagues[8] because their patients who developed pulmonary embolism had a moderate or high clinical probability; moreover, single-detector, rather than multidetector, CT angiography was used. Ventilation-perfusion scans would be indicated in patients with a low clinical probability of pulmonary embolism and a positive D-dimer assay, as well as to screen DVT patients for asymptomatic pulmonary embolism, which occurs in approximately 50% of cases.[31] Scintigraphy would also be indicated for patients who are allergic to iodine contrast medium. DIVAS would be indicated in cases with moderate to high clinical probability of pulmonary embolism and negative results on all noninvasive tests. Intravenous CT venography would be used when an inferior vena cava filter is necessary. Echocardiography would be the technique of choice to provoke fibrinolysis in the case of suspected unstable pulmonary embolism, although the best use of echocardiography is to establish prognosis, which depends on whether signs of right ventricular dysfunction are detected.[32] Likewise, CT angiography can replace Doppler ultrasound of the lower extremities in patients with suspected pulmonary embolism because the blood vessels of the lungs and lower limbs can both be evaluated in the same procedure. However, Doppler ultrasound, together with lung scintigraphy, is the first-line diagnostic technique in patients with DVT alone; CT angiography would only be necessary if the patient shows signs or symptoms of pulmonary embolism on follow-up.

Some new imaging techniques have a sensitivity and specificity similar to that of CT angiography. An example is single photon emission CT using anti-D-dimer, for which results have already been reported.[33] Others that may play roles within a few years are virtual CT angioscopy and intravascular pulmonary ultrasound. However, not only are these techniques invasive, but our collective experience with them is still limited.[34,35]

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