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Original Research

PULMONARY PROCEDURES

Accuracy of Point-of-Care Multiorgan Ultrasonography for the Diagnosis of Pulmonary Embolism

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Background: **Presenting signs and symptoms of pulmonary embolism (PE) are nonspecific, favoring a large use of second-line diagnostic tests such as multidetector CT pulmonary angiography (MCTPA), thus exposing patients to high-dose radiation and to potential serious complications. We investigated the diagnostic performance of multiorgan ultrasonography (lung, heart, and leg vein ultrasonography) and whether multiorgan ultrasonography combined to Wells score and D-dimer could safely reduce MCTPA tests.**

Methods: **Consecutive adult patients suspected of PE and with a Wells score > 4 or a positive D-dimer result were prospectively enrolled in three EDs. Final diagnosis was obtained with MCTPA. Multiorgan ultrasonography was performed before MCTPA and considered diagnostic for PE if one or more subpleural infarcts, right ventricular dilatation, or DVT was detected. If multiorgan ultrasonography was negative for PE, an alternative ultrasonography diagnosis was sought. Accuracies of each single-organ and multiorgan ultrasonography were calculated.**

Results: **PE was diagnosed in 110 of 357 enrolled patients (30.8%). Multiorgan ultrasonography yielded a sensitivity of 90% and a specificity of 86.2%, lung ultrasonography 60.9% and 95.9%, heart ultrasonography 32.7% and 90.9%, and vein ultrasonography 52.7% and 97.6%, respectively. Among the 132 patients (37%) with multiorgan ultrasonography negative for PE plus an alternative ultrasonographic diagnosis or plus a negative D-dimer result, no patients received PE as a final diagnosis.**

Conclusions: **Multiorgan ultrasonography is more sensitive than single-organ ultrasonography, increases the accuracy of clinical pretest probability estimation in patients with suspected PE, and may safely reduce the MCTPA burden.**

Trial registry: **ClinicalTrials.gov; No.: NCT01635257; URL: www.clinicaltrials.gov**

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Abbreviations: MCTPA = multidetector CT pulmonary angiography; PE = pulmonary embolism

Pulmonary embolism (PE) is a heterogeneous condition that should be always suspected in patients with dyspnea, chest pain, syncope, shock/hypotension, or cardiac arrest without an alternative obvious cause.[1] PE can be safely ruled out in patients with low pretest probability associated with a negative D-dimer test result.[2-5] Conversely, patients showing high pretest probability or high D-dimer level should undergo further diagnostic testing.

In recent years, multidetector CT pulmonary angiography (MCTPA) has become the standard of care for the detection of PE, and its use has shown a slight increase in the diagnosis of PE, but the number of patients tested without a PE has increased even more.[6,7] Wide use of MCTPA has several disadvantages, such as radiation exposure and contrast medium side effects.

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Moreover, MCTPA has high costs, is not feasible in unstable patients, is not available 24 h a day in all institutions, and should be used with caution in some patient groups, such as patients with renal failure and pregnant women.

Point-of-care ultrasonography can be rapidly performed at the bedside and is complementary to the physical examination; it should be considered as a focused diagnostic test that adds anatomic, functional, and physiologic information to the care of the emergent patient.[8] Many authors evaluated the diagnostic role of ultrasonography in patients with suspected PE, focusing on subpleural infarcts investigated by lung ultrasonography,[9,10] right ventricular dilatation by heart ultrasonography,[11-16] and DVT by leg vein ultrasonography.[17,18] However, due to the relatively low sensitivity, not one of these ultrasonographic methods can be safely used to rule out PE as a standalone test, while no previous studies have investigated the diagnostic accuracy of a combination of lung, heart, and leg vein ultrasonography for detecting PE. The aims of this study were to investigate the accuracy of multiorgan ultrasonography (lung, heart, and veins) in the diagnostic process of symptomatic patients with suspected PE and to evaluate whether a diagnostic model that integrates multiorgan ultrasonography to clinical assessment and to D-dimer level may be useful in reducing the number of patients who undergo MTCPA, while maintaining acceptable safety standards.

Materials and Methods

Design, Setting, Protocol, and Population

This was a multicenter prospective accuracy study, and the local ethic committees approved the study (No. 2012/20938 and 2012/5069). Written informed consent was obtained for inclusion in the study. The patients were recruited from June 2012 to November 2012 in the ED of three Italian hospitals: two university hospitals with an annual census of 120,000 and 50,000 visits, respectively, and one community hospital with an annual census of 50,000 visits.

Consecutive patients aged > 18 years, presenting to the EDs, and suspected of having a PE were considered for the study. The initial assessment included Wells score calculated by the attending physician and blood samplings for high sensitive D-dimer levels, in addition to all of the routine tests. D-dimer levels were assayed with automated latex agglutination tests (Hemosil D-Dimer HS; Instrumentation Laboratories spa, and Siemens AG). Patients with a Wells score ≤ 4 and a D-dimer value < 500 ng/mL, fibrinogen equivalent unit (negative D-dimer) were not considered for the study as no further tests are required to exclude PE according to international guidelines.[19] Patients with a Wells score > 4 or D-dimer value ≥ 500 ng/mL (positive D-dimer) who underwent MCTPA during ED evaluation were included.

Multiorgan ultrasonography was performed before and within 3 h from MCTPA by one of 13 sonographer investigators, including one emergency physician expert in lung ultrasound and chair of the scientific committee of the first international consensus conference on lung ultrasound, eight emergency medicine staff physicians with at least 5 years practicing point-of-care ultrasonography in emergency, and four resident physicians (two emergency medicine and two internal medicine) performing their training in emergency ultrasound with focus in cardiac, vein, and lung point-of-care examination. The following multiprobe machines were used: three MyLab30 Gold and one MyLab40 (Esaote S.p.A.), one Logiq3 (General Electric), and one HD7 (Koninklijke Philips N.V.). The investigators were blinded to clinical information other than the visible physical signs and symptoms of the patient's presentation.

Multiorgan Ultrasonography

Each ultrasonographic examination was performed by following a systematic and standardized sequence: lung, heart, and leg veins. Lung ultrasonography was performed by a 4- to 8-MHz linear probe or a 3.5- to 5-MHz curved array probe. The lung was examined by longitudinal and oblique scans both on anterior and posterior chest. The examination was performed with the patient in the supine position. The dorsal areas were scanned by turning the patient in the lateral decubitus on both sides or, when possible, in the sitting position. The examination was targeted to the detection of pulmonary subpleural infarcts, which consist of pleural-based, well-demarcated echo-poor triangular or rounded consolidations of at least 0.5 cm in size (e-Fig 1, Video 1).[10] The number and location of pulmonary subpleural infarcts were reported. Consolidations suggestive of pneumonia, pleural effusion, and diffuse interstitial syndrome were also noted according to international recommendations on point-of-care lung ultrasonography.[20]

Heart ultrasonography was performed with a 2- to 5-MHz phased-array probe. Right ventricular dilatation was diagnosed in the presence of at least one of the following criteria: right/left ventricular end-diastolic diameter ratio > 0.9 in the apical four chamber or in the subcostal view or right ventricular end-diastolic diameter > 30 mm in the parasternal view (e-Fig 2, Video 2).[15,21] Moreover, thrombi in the right cavities and signs of pericardial effusion and aortic dissection were recorded when detected.

Leg vein ultrasonography was performed by a 4- to 8-MHz linear probe and consisted of short-axis visualization and compression of the common and superficial femoral veins and of the popliteal veins. DVT was defined as absence of vein total collapse during compression (e-Fig 3, Video 3).[22,23]

Multiorgan ultrasonography was considered diagnostic of PE when lung ultrasonography visualized at least one pulmonary subpleural infarct, or heart ultrasonography detected right ventricular dilatation or thrombi in the right cavities, or leg vein ultrasonography detected DVT. In cases where multiorgan ultrasonography was negative for PE, the investigator was asked to specify whether an alternative ultrasonography diagnosis among pneumonia, pleural effusion, diffuse interstitial syndrome, pericardial effusion, or aortic dissection could justify the symptoms of presentation. Immediately after the completion of the exam, the investigators filled in a standardized form (e-Fig 4).

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