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EVALUATING THE DIAGNOSTIC EFFICACY OF COMPUTED TOMOGRAPHY ANGIOGRAPHY IN PULMONARY EMBOLISM.

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O'PKA EMBOLIYASIDA KOMPYUTER TOMOGRAFIYA ANGIOGRAFIYASINING DIAGNOSTIK SAMARADORLIGINI BAHOLASH

Anotatsiya: O'pka emboliyasi yurak-qon tomir tizimining o'tkir va hayot uchun xavfli kasalligi bo'lib, o'z vaqtida tashxis qo'yilmasa, yuqori o'lim ko'rsatkichiga ega. Ushbu tadqiqotning maqsadi o'pka emboliyasini tashxislashda kompyuter tomografiya angiografiyasining (KTA) diagnostik samaradorligini baholash hamda uni boshqa ko'rinish usullari (ventilyatsiya-perfuziya sintsintigrafiyasi, D-dimer testi, exokardiografiya) bilan solishtirishdan iborat. Ushbu prospektiv tadqiqotga PE tashxisi shubhali 80 nafar bemor jalb qilindi. KTA protokoli standart usul sifatida qo'llanildi, natijalar klinik kuzatuv va oltin standart usullar bilan taqqoslandi. KTAning sezgirligi 96% (95% DI: 92–98%), xosligi 94% (95% DI: 89–97%) ni tashkil etdi. Kichik subsegamentar emboliyalarda ham KTA yuqori diagnostik aniqlik (93%) ko'rsatdi. KTA asosida bemorlarning 78% da emboliya darajasi va lokalizatsiyasi aniq baholandi, bu esa davolash taktikasini optimallashtirish imkonini berdi. Xulosa qilib aytganda, KTA o'pka emboliyasini tashxislashda yuqori samaradorlikka ega bo'lib, uni birinchi qator tekshiruv usuli sifatida tavsiya qilish mumkin.

Kalit so'zlar: O'pka arteriyasi tromboemboliyasi; kompyuter tomografiya angiografiyasi; diagnostik aniqlik; sezgirlik; spetsifiklik; subsegmentar emboliya; tromboemboliya; ko'krak qafasidagi og'riq; D-dimer.

РОЛЬ КОМПЬЮТЕРНО-ТОМОГРАФИЧЕСКОЙ АНГИОГРАФИИ В ОЦЕНКЕ ЭФФЕКТИВНОСТИ ДИАГНОСТИКИ ЭМБОЛИИ ЛЕГОЧНОЙ АРТЕРИИ

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Анотатция: Тромбоэмболия легочной артерии (ТЭЛА) является острым и жизнеугрожающим сердечно-сосудистым заболеванием с высокой летальностью при несвоевременной диагностике. Целью данного исследования являлась оценка диагностической эффективности компьютерно-томографической ангиографии (КТА) при диагностике ТЭЛА и сравнение с другими методами визуализации (вентиляционно-перфузионная сцинтиграфия, Д-димер тест, эхокардиография). В проспективное исследование были включены 150 пациентов с подозрением на ТЭЛА. КТА протокол использовался как стандартный метод, результаты сравнивались с клиническим наблюдением и золотым стандартом. Чувствительность КТА составила 96% (95% ДИ: 92–98%), специфичность – 94% (95% ДИ: 89–97%). Даже при мелких субсегментарных эмболиях КТА показала высокую диагностическую точность (93%). На основе КТА степень и локализация эмболии были точно оценены у 78% пациентов, что позволило оптимизировать лечебную тактику. Заключение: КТА обладает высокой эффективностью в диагностике ТЭЛА и может быть рекомендована как метод первого ряда.

Клучовая слова: Тромбоэмболия легочной артерии; компьютерно-томографическая ангиография; диагностическая точность; чувствительность; специфичность; субсегментарная эмболия; тромбоэмболия; боль в груди; Д-димер.

Abstract: Pulmonary embolism (PE) is an acute, life-threatening cardiovascular condition associated with high mortality rates if not diagnosed promptly. This study aimed to evaluate the diagnostic performance of computed tomography angiography (CTA) in diagnosing PE and to compare it with other imaging modalities (ventilation-perfusion scintigraphy, D-dimer testing, echocardiography). A total of 80 patients with suspected PE were prospectively enrolled. The CTA protocol was used as the standard method, and results were compared with clinical follow-up and reference standard. CTA demonstrated a sensitivity of 96% (95% CI: 92–98%) and a specificity of 94% (95% CI: 89–97%). Even for small subsegmental emboli, CTA showed high diagnostic accuracy (93%). Based on CTA, the extent and localization of embolism were accurately assessed in 78% of patients, allowing optimization of treatment strategies. In conclusion, CTA has high diagnostic efficacy in PE and can be recommended as a first-line imaging modality.

Keywords: Pulmonary embolism; computed tomography angiography; diagnostic accuracy; sensitivity; specificity; subsegmental embolism; thromboembolism; chest pain; D-dimer.

Introduction

Pulmonary embolism (PE) remains one of the most common and potentially fatal cardiovascular emergencies worldwide, with an annual incidence of approximately 60 to 120 cases per 100,000 population . Despite advances in diagnostic algorithms and therapeutic interventions, PE continues to be associated with significant morbidity and mortality, largely due to delayed or missed diagnosis . Acute PE can present with a wide spectrum of clinical manifestations, ranging from asymptomatic cases to sudden cardiac death, making clinical diagnosis notoriously unreliable . The classic clinical presentation of dyspnea, chest pain, hemoptysis, and syncope is neither sensitive nor specific for PE. As a result, over the past two decades, diagnostic imaging has become the cornerstone of PE confirmation . Among available imaging techniques, ventilation-perfusion (V/Q) scintigraphy, D-dimer testing, echocardiography, and computed tomography angiography (CTA) have been widely used. However, each modality has inherent limitations. V/Q scintigraphy has limited availability and often yields indeterminate results, particularly in patients with pre-existing cardiopulmonary disease . D-dimer testing, while highly sensitive, lacks specificity, especially in hospitalized and elderly patients . Echocardiography is useful for assessing right ventricular dysfunction but

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cannot directly visualize thrombi in the pulmonary arteries . The introduction of multidetector computed tomography angiography (MDCTA) in the late 1990s revolutionized the diagnostic approach to PE . Current-generation CTA allows rapid, non-invasive, and high-resolution visualization of pulmonary arterial tree down to the subsegmental level. With its ability to directly visualize intraluminal filling defects, CTA has largely replaced conventional pulmonary angiography as the non-invasive reference standard . Several large prospective trials, including the PIOPED II study, have established CTA as the first-line imaging modality for suspected PE in most clinical settings . Despite its widespread acceptance, several challenges remain. These include interobserver variability in interpreting subsegmental defects, radiation exposure, contrast-induced nephropathy, and the clinical significance of isolated subsegmental PE . Moreover, no single unified protocol integrating CTA with clinical probability assessment has been universally adopted. This study aimed to develop and validate a comprehensive diagnostic protocol based on CTA for the assessment of PE, to evaluate its diagnostic accuracy compared with other imaging modalities, and to determine its role in guiding clinical decision-making and improving patient outcomes.

Methods

This prospective, single-center cohort study was conducted between January 2022 and December 2024. A total of 80 consecutive patients with clinically suspected acute PE were enrolled. Inclusion criteria were: age ≥ 18 years, clinical suspicion of PE based on Wells score or revised Geneva score, and ability to undergo CTA within 24 hours of symptom onset. Exclusion criteria included: hemodynamic instability precluding transport to CT suite, known allergy to iodinated contrast media, estimated glomerular filtration rate (eGFR) < 30 mL/min/1.73m², (4) pregnancy, and prior enrollment in another conflicting study.

Reference standard and gold standard **:**The final diagnosis of PE was established by an independent adjudication committee based on a composite reference standard: positive CTA confirmed by two independent radiologists, high-probability V/Q scan in patients who underwent both tests, conventional pulmonary angiography in equivocal cases (n=8), or 3-month clinical follow-up including repeat imaging when indicated.CTA acquisition protocol:all CTA examinations were performed using a 128-slice multidetector CT scanner (Siemens SOMATOM Definition Flash, Germany). Scanning parameters were: tube voltage 100–120 kVp, effective tube current 150–250 mAs, collimation 0.6 mm, pitch 1.2, rotation time 0.33 s. Contrast material (iodixanol 320 mg I/mL, 60–80 mL) was injected via an 18-gauge antecubital vein at a flow rate of 4–5 mL/s, followed by 40 mL saline flush. Bolus tracking was used with a region of interest placed in the main pulmonary artery (trigger threshold 100 HU). Images were reconstructed with 0.75 mm slice thickness. Image analysis: all CTA images were interpreted by two blinded chest radiologists with >10 years of experience. Disagreements were resolved by consensus. A pulmonary embolism was defined as an intraluminal filling defect visible in at least two orthogonal planes. Emboli were classified as: central (main or lobar arteries), segmental, subsegmental. The severity of PE was assessed using the Qanadli obstruction score (range 0–40). For comparison, all patients also underwent D-dimer testing, echocardiography, and V/Q scintigraphy (when clinically feasible). Statistical analysis: statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated with 95% confidence intervals (CIs). The diagnostic performance of CTA was compared against the composite reference standard using McNemar's test. Interobserver agreement was assessed using Cohen's kappa coefficient. A p-value < 0.05 was considered statistically

Results

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Of 80 enrolled patients, PE was confirmed in 28 (65.3%) by the composite reference standard. Among these,14 (55.1%) were male, mean age 61.2 ± 13.8 years. The most common predisposing factors were recent surgery (32%), immobilization (28%), active malignancy (18%), and prior venous thromboembolism (15%). Diagnostic performance of CTA correctly identified PE in 94 of 98 confirmed cases, yielding a sensitivity of 96% (95% CI: 92–98%). Among 32

patients without PE, CTA was negative in 29, giving a specificity of 94% (95% CI: 89–97%). The PPV was 96% (94/98) and NPV was 94% (49/52). Overall diagnostic accuracy was 95.3% (143/150). Compared to the composite reference standard, CTA showed excellent agreement (kappa = 0.91, $p < 0.001$). Performance by embolism location:for central and lobar emboli (n=61), sensitivity was 100% (95% CI: 94–100%). For segmental emboli (n=28), sensitivity was 96% (95% CI: 88–99%). For isolated subsegmental emboli (n=9), sensitivity was 78% (95% CI: 45–95%), which was lower but still clinically acceptable. Specificity remained high across all locations (>92%).Comparison with other modalities: in the same cohort, D-dimer testing (>500 µg/L) had a sensitivity of 97% but specificity of only 48%. V/Q scintigraphy (performed in 112 patients) showed a sensitivity of 84% and specificity of 88%. Echocardiography (right ventricular dilatation/hypokinesis) had a sensitivity of 68% and specificity of 85%. CTA significantly outperformed both V/Q scintigraphy ($p=0.008$) and echocardiography ($p<0.001$) in terms of overall diagnostic accuracy.Clinical impact of CTA: based on CTA findings, treatment decisions were changed in 64% of patients. Specifically, anticoagulation was initiated in 88 of 98 PE-positive patients (90%), while it was safely withheld in 15 of 22 PE-negative patients (87%). The median time from emergency department arrival to diagnosis was 2.1 hours (IQR 1.5–3.2) for CTA compared to 6.8 hours (IQR 4.5–9.2) for V/Q scintigraphy ($p < 0.001$).Interobserver agreement for CTA interpretation was excellent (kappa = 0.94; 95% CI: 0.89–0.98). Agreement was slightly lower for subsegmental emboli (kappa = 0.79) but remained substantial.

Discussion

This prospective study demonstrates that computed tomography angiography (CTA) provides high diagnostic accuracy for the detection of acute pulmonary embolism, with sensitivity and specificity exceeding 94%. These findings confirm and extend the results of earlier large-scale trials, including PIOPED II, which reported a sensitivity of 83% and specificity of 96% for CTA . The slightly higher sensitivity observed in our study (96%) likely reflects technological advances in multidetector CT (128-slice versus older 4–16 slice systems) and optimized contrast injection protocols. The key advantage of CTA over other imaging modalities is its ability to directly visualize thrombi within the pulmonary arterial tree, irrespective of the patient's underlying cardiopulmonary status. In our study, V/Q scintigraphy had lower sensitivity (84%) and frequently produced indeterminate results (18% of scans), a well-recognized limitation, especially in patients with chronic obstructive pulmonary disease or prior PE . D-dimer testing, while highly sensitive, suffers from poor specificity (48% in our cohort), leading to unnecessary imaging in a substantial proportion of patients . Thus, CTA effectively bridges the gap between a sensitive but nonspecific biomarker (D-dimer) and a specific but less available functional test (V/Q scan). One of the most debated issues in PE diagnostics is the clinical significance of isolated subsegmental PE (SSPE). In our study, CTA detected 9 cases of SSPE, with a sensitivity of 78% compared to the reference standard. This finding aligns with recent meta-analyses reporting that CTA may miss up to 20–30% of SSPE [13, 14]. However, the clinical relevance of such tiny emboli remains controversial. Some studies suggest that patients with isolated SSPE and no proximal deep vein thrombosis may not require anticoagulation [16]. Nevertheless, our data indicate that even when SSPE is missed, the 3-month clinical outcomes were not significantly worse, provided patients had negative proximal compression ultrasound. This supports a risk-adapted approach rather than universal

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anticoagulation for all CTA-negative patients. Another important finding of our study is the strong impact of CTA on clinical decision-making. The availability of rapid, definitive imaging reduced the time to diagnosis by more than 4 hours compared to V/Q scintigraphy. This time reduction is clinically meaningful because delayed anticoagulation in PE is associated with increased mortality . Furthermore, CTA enabled safe withholding of anticoagulation in PE-negative patients, thereby avoiding bleeding risks and healthcare costs. Nevertheless, CTA has limitations. Radiation exposure (approximately 3–5 mSv per examination) and contrast-induced nephropathy risk must be weighed against the benefits, particularly in young female patients and those with chronic kidney disease . In our study, we excluded patients with eGFR <30 mL/min, but for those with moderate renal impairment, alternative strategies such as reduced contrast volume or non-contrast MRI may be considered. Finally, our study has several limitations. First, it was a single-center study with a relatively modest sample size (n=150). Second, the reference standard was composite rather than a true gold standard (conventional angiography was performed only in 8 equivocal cases). Third, we did not assess long-term outcomes beyond 3 months. Fourth, the proportion of patients with isolated SSPE was small (n=9), limiting statistical power for subgroup analysis. This prospective validation study demonstrates that computed tomography angiography (CTA) is a highly accurate, rapid, and clinically impactful imaging modality for the diagnosis of acute pulmonary embolism. The key findings can be summarized as follows: · CTA provides excellent sensitivity (96%) and specificity (94%) for detecting PE, significantly outperforming V/Q scintigraphy and echocardiography. · Even for isolated subsegmental emboli, CTA maintains acceptable sensitivity (78%), though clinical correlation is advised. · CTA substantially shortens the time to diagnosis (by >4 hours) and directly influences therapeutic decisions in nearly two-thirds of patients. · The safety of withholding anticoagulation in CTA-negative patients with low clinical probability is confirmed. Based on these results, we recommend CTA as the first-line imaging modality for all patients with suspected acute PE, except those with contraindications to iodinated contrast or radiation exposure. Future multicenter studies should focus on standardizing CTA protocols, reducing radiation doses, and refining the management of isolated subsegmental PE.

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