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Diagnostic Yield of Computed Tomographic Pulmonary Angiography for Evaluation of Patients with Pulmonary Embolism

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A B S T R A C T

Introduction: The early diagnosis of pulmonary embolism (PE) is crucial in improving patient outcomes and reducing mortality rates. Computed tomographic pulmonary angiography (CTPA) is the gold standard method for the diagnosis of PE. Evaluating the effectiveness of CTPA in detecting PE is particularly significant, as a suboptimal CTPA procedure could lead to severe morbidity and mortality for undiagnosed or mismanaged PE patients. In this study, the diagnostic yield of CTPA for the diagnosis of PE was evaluated.

Materials & Methods: In this retrospective cross-sectional study, the electronic records of subjects suspected of having PE were surveyed from the years 2021 to 2023 at two tertiary care hospitals. Demographics, clinical manifestations, comorbidities, medical histories, and the confirmed diagnoses of the patients were retrieved. For each patient, the presence, site, and location of pulmonary embolism on CTPA scans were registered.

Results: The health records of 1,428 patients were reviewed, and after applying the exclusion criteria, 224 patients with PE were included in the study. One hundred and six of the patients (with a male sex ratio of 47.3%) were male, and their average age was 52.23±16.99 years. The results showed that the diagnostic yield of the CTPA approach was 35.71% (95% CI: 29.44% - 41.98%).

Conclusion: The results revealed that CTPA has a limited diagnostic yield, and planning to minimize errors and problems in the radiological data obtained from patients improves the diagnostic performance of this method. Continuous monitoring of CTPA performance, training healthcare professionals, and using clinical decision support tools could significantly impact the diagnosis of PE patients.

Keywords: Pulmonary embolism, Diagnostic yield, Computed tomographic pulmonary angiography, Computed tomography, Thoracic imaging, CTPA

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Introduction

Pulmonary embolism (PE) is a significant global health concern characterized by the obstruction of pulmonary arteries by a clump of material, most often a blood clot (1, 2). Globally, the estimated prevalence of PE varies widely, affecting approximately 1 to 2 cases per 1,000 individuals each year (3, 4). However, this figure can be significantly higher in certain populations, especially among those with risk factors such as older age, recent surgical procedures, or existing comorbidities like cancer and heart disease (5, 6). In Iran, recent studies have indicated a concerning prevalence of PE, particularly among hospitalized patients and those undergoing major surgeries. Factors such as a sedentary lifestyle, increasing obesity rates, and limited awareness of prevention measures contribute to the growing prevalence of PE in the country. Estimates suggest that the incidence rate is higher in high-risk populations (7-9). PE is frequently underdiagnosed due to its nonspecific symptoms, leading to a significant underrated burden of disease worldwide.

The early diagnosis of PE is crucial in improving patient outcomes and reducing mortality rates. When treated promptly, the mortality rate associated with PE can decrease significantly, from 30% in untreated cases to about 2-8% with timely intervention (1, 10). Therefore, early diagnosis of PE patients is essential for effective management and determining the optimal treatment strategies.

Computed tomographic pulmonary angiography (CTPA) is the reference imaging modality for the diagnosis of PE (11-13). The unique demographic and clinical characteristics of the Iranian population, including age distribution and prevalence of certain chronic conditions, necessitate the evaluation and optimization of localized diagnostic approaches for effective diagnosis and treatment. Hence, determining the local diagnostic yield of CTPA in the diagnosis of PE is essential for optimizing patient care and resource allocation in a healthcare setting. Evaluating the local diagnostic yield of CTPA enables assessing the quality of its implementation, benchmarking the modality, identifying practical challenges in its use, and ultimately optimizing this diagnostic procedure for a healthcare center. Evaluating the effectiveness of CTPA in diagnosing PE is of particular importance, as a suboptimal CTPA procedure can lead to severe complications and mortality in patients with undiagnosed or mismanaged PE (14).

Given the importance of the diagnostic performance of CTPA in determining the necessary therapeutic interventions for PE patients, this study evaluated the local diagnostic yield of CTPA for the diagnosis of PE in Ilam, western Iran.

Materials and methods

Study Design

This retrospective cross-sectional study was conducted on 248 patients with PE.

Setting and Participants

In this retrospective cross-sectional study, the diagnostic yield of the CTPA approach for patients with PE was evaluated in two tertiary care hospitals. The electronic records of subjects suspected to have PE were surveyed from the years 2021 to 2023. Of the 1,428 patient records reviewed, CTPA scans were requested for 248 individuals.

Demographics, clinical manifestations, comorbidities, medical histories, and the confirmed diagnoses of the patients were extracted from the hospital information system (HIS). During the diagnosis and treatment interventions for PE patients, the clinical signs and symptoms, radiological manifestations, and D-dimer levels were used to confirm embolism in patients.

Given the retrospective nature of this study and the use of recorded information and radiological data of the patients, there was no additional risks or therapeutic-diagnostic interventions for the patients.

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The patients under 18 years old, the patients without reportable CTPA data, and those without a definitive diagnosis of PE were excluded from the study.

Image Acquisition

Two medical CT units, the 16 MDCT Brilliance (Philips, Best, Netherlands) and the 16-slice Aquilion Lightning CT (Canon Medical Systems, Otawara, Japan), were used for scanning of the subjects. The scanning parameters used in these units are presented in the table below.

Table 1. The parameters used for scanning of PE patients.

Scanner	Tube voltage	mAs	Slice thickness	Space between slices
16 MDCT Brilliance	120 kV	Automatic tube current modulation (80–180 mAs)	1.5 mm	0.75 mm
16-slice Aquilion Lightning CT	100 kV	Automatic tube current modulation (80–200 mAs)	1 mm	1 mm

In the CTPA process, 80 mL of Visipaque (iodixanol) with an iodine concentration of 320 mg/mL was injected at a rate of 5 mL/s into the patients' antecubital vein, followed by a 20 mL normal saline flush at the same rate.

Image Analysis

The CTPA data were extracted from the picture archiving and communication system (PACS), and two radiologists reviewed these data. Any disagreements in evaluation of data were resolved through consultation. The definitive diagnosis of the patients was concealed from the radiologists. For each patient, the presence, site, and location of pulmonary embolism on CTPA scans were registered. The quality of CTPA data was determined as acceptable or non-reportable.

Statistical and Data Analysis

The statistical analysis was performed using SPSS (Ver. 16.0, IBM Corp., United States) software. Mean (± SD) and frequency were used to report continuous and categorical data, respectively. The diagnostic yield is defined as the number of patients identified by a specific approach. Therefore, the diagnostic yield of CTPA was determined using the following formula.

$$\text{Diagnostic yield (\%)}=\frac{Number\ of\ PE\ patients\ diagnosed\ by\ CTPA}{Number\ of\ PE\ patients\ scanned\ by\ CTPA}\times 100 \quad (1)$$

The following formula was used to determine the 95% confidence interval for diagnostic yield:

$$95\%CI=\text{Diagnostic yield}\pm 1.96\times\sqrt{\frac{\text{Diagnostic yield}\times(1-\text{Diagnostic yield})}{Number\ of\ PE\ patients\ scanned\ by\ CTPA}}$$

To investigate the effect of image quality on diagnostic yield of CTPA, a 2 × 2 contingency table analysis was used.

Results

The health records of 1,428 patients suspected of having PE were reviewed retrospectively. After applying the exclusion criteria, 224 patients with PE were included in the study. The flow diagram of the patient selection is shown in Figure 1. One hundred

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and six of the patients (with a male sex ratio of 47.3%) were male, and their average age was 52.23±16.99 years. Table 2 presents the descriptive data, comorbidities, and clinical manifestations of the participants included in the study.

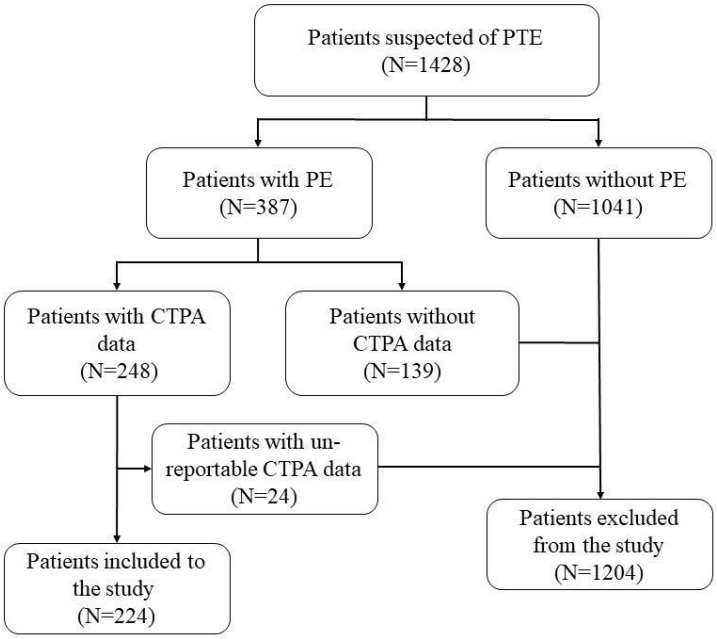


Figure 1. Flow diagram of the patient selection. There were 387 eligible participants, of which 224 were included.

Table 2. Demographic information, comorbidities, and clinical manifestations of the included patients with PE.

Parameter		Mean ± SD or frequency (%)
Age (Year)		52.23±16.99
Sex	Male	106(47.3)
	Female	118(52.7)
BMI>30	Yes	3(1.3)
	No	220(98.2)
Pregnancy	Yes	4(1.8)
	No	218(97.3)
Cough	Yes	49(21.9)
	No	174(77.7)
Hemoptysis	Yes	19(8.5)
	No	204(91.1)
Malignancy	Yes	8(3.6)
	No	215(96.0)
Hyperlipidemia	Yes	3(1.3)
	No	219(97.8)
Hypertension	Yes	64(28.6)
	No	158(70.5)
Heart palpitations	Yes	12(5.4)
	No	211(94.2)
HR>100	Yes	41(18.3)
	No	137(61.2)
Heart failure	Yes	10(4.5)

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	No	212(94.6)
Chronic obstructive pulmonary disease (COPD)	Yes	5(2.2)
	No	217(96.9)
History of Atrial Fibrillation	Yes	1(0.4)
	No	221(98.7)
History of cardiac thrombosis	Yes	11(4.9)
	No	211(94.2)
Stroke	Yes	5(2.2)
	No	217(96.9)
Heart valve disease	Yes	1(0.4)
	No	221(98.7)
Open heart surgery	Yes	1(0.4)
	No	221(98.7)
Shortness of breath	Yes	162(72.3)
	No	61(27.2)
Syncope	Yes	2(0.9)
	No	221(98.7)
tachypnea	Yes	7(3.1)
	No	216(96.4)
Symptom of DVT	Yes	13(5.8)
	No	210(93.8)
Chest pain	Yes	58(25.9)
	No	165(73.7)
Cardiac DVT	Yes	6(2.7)
	No	217(96.9)
Cardiac embolism	Yes	14(6.3)
	No	209(93.3)
Recent long air or land travel	Yes	2(0.9)
	No	221(98.7)
Immobilization for 3 or more consecutive days	Yes	29(12.9)
	No	194(86.6)
Surgery in the previous 4 weeks	Yes	27(12.1)
	No	196(87.5)

Figure 2 shows an exemplary CTPA image of a patient with partial filling defects in the right pulmonary artery and lobar and segmental pulmonary arteries on both sides, indicating acute pulmonary thromboembolism. The presence, side, and location of radiological manifestations of PE for patients are listed in Table 3.

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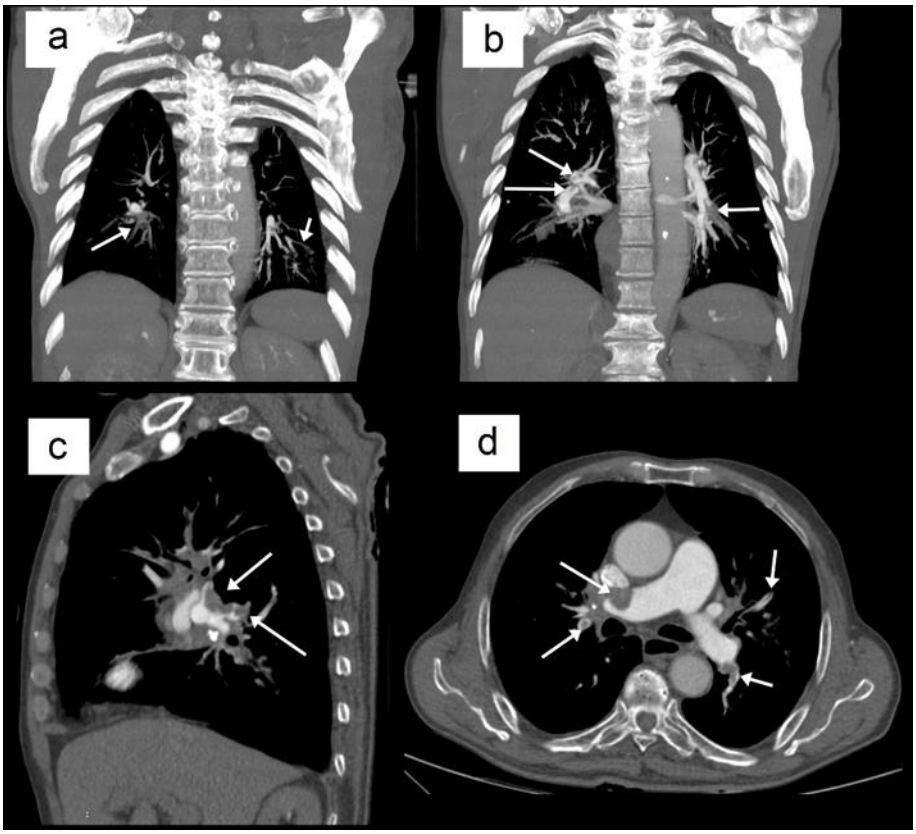


Figure 2. Coronal (a, b), sagittal (c), and axial (d) images from CTPA scan of a patient with pulmonary thromboembolism. In these images partial filling defect in the right pulmonary artery and lobar and segmental pulmonary arteries on both sides indicating acute pulmonary thromboembolism.

Table 3. Radiological manifestation of PE patients on CTPA data.

Parameters		Frequency (%)
Presence of radiological manifestations of PE	Yes	80(35.7)
	No	144(64.3)
Obstruction side	No	144(64.3)
	Right	12(5.4)
	Left	7(3.1)
	Bilateral	61(27.2)
Obstruction location	No	144(64.3)
	Pulmonary artery	19(8.5)
	Pulmonary trunk	28(12.5)
	Lobar/Interlobar	33(14.7)
CTPA data quality	Poor	34 (15.2)
	Acceptable	190 (84.8)

The achieved results showed that the diagnostic yield of the CTPA approach was 35.71% (95% CI: 29.44% - 41.98%). The results of the 2 × 2 contingency table analysis showed that image quality significantly affects the diagnostic yield of the CTPA modality (P = 0.0004). So that poor image quality reduces the diagnostic yield of CTPA from 40.53% to 8.82%.

Discussion

Timely and accurate diagnosis of PE patients is critical in reducing morbidity and mortality associated with this life-threatening condition. CTPA is a key tool in the diagnosis of PE that can enhance the accuracy and speed of diagnosis, enabling timely treatment decisions that can

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significantly influence patient outcomes. In this study, the diagnostic yield of CTPA for patients with PE was evaluated. The results showed that the diagnostic yield of CTPA was 35.71% in the hospitals surveyed. The diagnostic yield of CTPA refers to the proportion of examinations that result in a correct diagnosis of PE.

The diagnostic yield of CTPA was also evaluated in previous studies. In the study by Low CL et al. (15), the diagnostic yield of CTPA was evaluated for 351 patients with PE. In this study, patients who underwent CTPA at Hospital Tengku Ampuan Afzan (Kuantan, Malaysia) due to suspected acute PE were reviewed over a period of one year. The CTPA technique was able to diagnose 96 of these patients and had a diagnostic yield of 26.5%. In another study, the diagnostic yield of the CTPA approach was evaluated by Alshumrani G et al. (16). In this study, the medical records of 534 clinically suspected cases referred to a tertiary care hospital in the southern region of Saudi Arabia, who had a Wells score of ≥ 4.5, were reviewed retrospectively. The Wells score estimates the probability of PE using patient histories and clinical symptoms. Patients with a Wells score of less than 4 (indicating a low probability of PE), scores not available, and CTPA scans of poor quality were excluded from the study. Their results showed that PE was diagnosed in 177 out of 534 patients using CTPA data, and CTPA yielded a 33% diagnostic yield. In the study by Sun Z et al. (17), the diagnostic yield of the CTPA method was evaluated in a single medical center. This study examined patients who underwent CTPA to diagnose PE. Patients whose scans could not be completed due to allergic reactions to the contrast agent or renal failure, and patients whose CTPA diagnostic quality was poor, were excluded. Radiological records of 450 participants were reviewed retrospectively, and the results showed that the radiological manifestations of PE were observed in 30.7% of patients. The diagnostic yield obtained in our study is similar to that reported in these studies. The CTPA protocol and included patients were similar across all these studies. CTPA data were obtained during the pulmonary arterial phase using intravenous contrast administration. Differences in the manufacturer of the imaging system and its technical characteristics, such as the number of slices, do not affect the data obtained. Because in the quality control process, imaging protocols are adjusted to meet certain minimum diagnostic criteria such as contrast and spatial resolution for diagnosing various diseases.

These studies indicate that the CTPA method, despite a sensitivity between 60% and 100% and a specificity between 81% and 98% for the diagnosis of PE, has a diagnostic yield of approximately 30%, which is consistent with the results of our study (18). These results suggest that CTPA has a limited performance for diagnosing PA compared to other diagnostic indications and risk assessment systems (such as Wells and Geneva) and should not be used alone to diagnose these patients. However, given the radiological manifestations of PA on CTPA images, the use of this diagnostic method, along with the patient's history, clinical symptoms, and laboratory results, can be very helpful in diagnosing PA patients.

Evaluating the diagnostic yield of CTPA is crucial for several reasons. Firstly, understanding the diagnostic yield allows healthcare providers to assess the effectiveness of CTPA as a diagnostic tool in various patient populations. A higher yield indicates that the test successfully identifies significant cases of PE, justifying its use in clinical settings. Secondly, determining the diagnostic yield can help optimize resource allocation. In busy clinical environments, where multiple diagnostic modalities are available, knowing the yield helps prioritize the most effective tests for suspected PE. This optimization is particularly important in emergency situations, where quick and accurate diagnoses can save lives.

Additionally, determining the diagnostic yield of the CTPA approach in each medical institution enables

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healthcare facilities to benchmark their practices against national or international standards. This benchmarking process promotes accountability and fosters education and training for healthcare professionals. Understanding the factors influencing diagnostic yield can lead to more effective communication and collaboration among clinicians, radiologists, and technologists, enhancing the overall quality of care delivered to patients suspected of having PE.

In this study, motion artifacts were reported in CTPA data of 47 participants, and the CTPA data were unreportable for 24 cases. The main problems reported in the reviewed files included lack of CTPA data, scanning patients using conventional CT sequences, lack of high-resolution CTPA imaging, poor quality of CTPA data, use of aortic CT angiography instead of CTPA, problems related to the location and speed of contrast agent injection, and lack of saline chaser injection. The impact of these factors on the diagnostic yield of CTPA can be addressed by informing and training imaging technologists.

Continuous monitoring of the diagnostic yield of CTPA provides valuable insights into the performance of this imaging practice within a particular institution or region. This information can inform quality improvement initiatives aimed at enhancing service delivery, including adjustments in imaging techniques and contrast agent usage. Assessing the local diagnostic yield is instrumental in developing clinical protocols and guidelines tailored to the specific needs of a population.

Limitations and Strengths

This study has several limitations that should be acknowledged. First, there is no independent reference method for diagnosing PE. Patients are diagnosed based on history, clinical symptoms, laboratory results, and CTPA images. Second, due to the inability to scan healthy subjects using CTPA, it is not possible to perform further statistical analyses and determine the diagnostic performance of CTPA, in terms of sensitivity, specificity, etc. This study does not merely report the diagnostic yield of CTPA but rather provides local, multicenter, and real-world data with a clear focus on the quality of implementation and practical challenges of using CTPA in referral centers of a province. This work was designed to evaluate CTPA performance within a healthcare system, which is a major strength of the study. The main advantage of studies evaluating the yield of diagnostic methods is the ability to assess the performance of the diagnostic procedure in scenarios where the investigated method cannot be applied to healthy individuals in the community. In this study, the CTPA method cannot be performed on healthy individuals due to the radiation dose associated with this diagnostic method and the potential side effects of the contrast agent. Another strength of this study is its multicenter design, which enhances the generalizability of the results.

Conclusion

In this study, the diagnostic yield of the CTPA approach for patients with PE was evaluated in two tertiary care hospitals. The results indicated that CTPA has limited diagnostic yield, and planning to minimize errors and problems in the radiological data obtained from patients can improve the diagnostic performance of this method. Continuous monitoring of CTPA performance, training of healthcare professionals, and use of clinical decision support tools could significantly impact the diagnosis of PE patients. By accurately assessing the effectiveness of the CTPA modality, healthcare institutions can better manage PE, ultimately leading to enhanced patient outcomes and more effective healthcare delivery.

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CRediT authorship contribution statement

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Conceptualization, Methodology, Validation, Formal Analysis: SZ, SA, Investigation, Resources, Software, Data Curation, Writing–Original Draft Preparation, Writing–Review & Editing, Visualization, Supervision, Project Administration: SZ, AG, SA.

Declaration of Generative AI and AI-assisted technologies in the writing process

We did not use artificial intelligence programs in this article.

Conflict of interest

All authors declare that they have no conflict of interest.

Ethical considerations

This study is the result of a research project supported by Ilam University of Medical Sciences and all step and procedures of the study were supervised and approved by Institutional Ethics Committee of Ilam University of Medical Sciences (Approved Number IR.MEDILAM.REC.1403.249).

Data availability statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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