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Research Article

EVALUATING PULMONARY EMBOLISM AND RADIATION EXPOSURE: INSIGHTS INTO DIAGNOSTIC IMAGING AND EMERGING INNOVATIONS

Revanth V*

Assistant Professor, Department of Radiology, PSP Medical College Hospital and Research Institute, Kancheepuram District, Tamil Nadu, India.

ABSTRACT

Pulmonary embolisms (PE) are a significant cause of morbidity and mortality, with computed tomography angiography (CTA) serving as a primary diagnostic tool. This retrospective cohort study, conducted at PSP Medical College Hospital and Research Institute, examines the demographic characteristics, cumulative radiation exposure, and prevalence of PE in patients undergoing pulmonary CTA over a four-year period. Results highlight an average age of 51.0 years and a PE prevalence of 8.2% in the overall cohort, with increased cumulative radiation exposure in older patients and those diagnosed with malignancies. Challenges in tracking lifetime radiation exposure and associated cancer risks underscore the need for systematic monitoring and risk stratification. Additionally, advancements in nanotechnology and green chemistry offer promising avenues for reducing radiation-related risks. This study emphasizes the importance of balancing diagnostic efficacy with the long-term health implications of medical imaging.

Keywords: Pulmonary Embolism (PE), Computed Tomography Angiography (CTA), Radiation Exposure, Nanotechnology in Medicine, Green Chemistry in Imaging

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INTRODUCTION

Pulmonary embolisms (PE) represent a significant health challenge, with approximately 100,000 Americans succumbing to this condition annually [1]. Computed tomography angiography (CTA) has emerged as a widely available, dependable, and noninvasive diagnostic modality for PE. Despite this, alternative techniques such as ventilation-perfusion (V/Q) lung scans and catheter-based pulmonary angiography are rarely employed for routine diagnosis due to their limitations [1, 5–7]. However, CTA scans often yield negative results in cases of suspected PE and have demonstrated reduced sensitivity and specificity compared to earlier studies, as highlighted by findings from the PIOPED II multicenter trial [8].

Corresponding Author
Revanth V

The cumulative health risks associated with medical imaging, particularly due to radiation exposure, have garnered increasing attention. Factors such as patient age, gender, and the cumulative dose of fractionated radiation significantly influence the potential for radiation-induced injury. A single CTA scan typically delivers approximately 10 mSv of radiation. Studies suggest that radiological imaging may contribute to cancer risks; for instance, an estimated 2,900 malignancies annually in the United States are attributed to ionizing radiation from CT scans [10]. According to

Brenner et al., individuals with lifetime radiation exposure of 50 to 100 mSv are at an elevated risk, with a near certainty of cancer development above 100 mSv. Although these findings remain the subject of ongoing scientific debate, the potential carcinogenic effects of ionizing radiation cannot be dismissed. Currently, there is limited data on the cumulative effective radiation dose in patients undergoing pulmonary CTA. To address this, a four-year follow-up study will evaluate the effective dose and total cumulative radiation exposure in patients suspected of having PE.

MATERIALS AND METHODS

Study Design and Cohort Selection

This retrospective cohort study was conducted at PSP Medical College Hospital and Research Institute, a 265-bed facility in Kancheepuram District, Tamil Nadu, India. The study adhered to the guidelines outlined in the Health Insurance Portability and Accountability Act (HIPAA). As the research involved a review of retrospective medical records, informed consent was not required. Records of estimated radiation doses for CT studies were maintained within the Picture Archiving and Communication System (PACS) starting in February 2006 and ending in November 2007. The cohort included several hundred consecutive patients who underwent pulmonary CT scans in the emergency department for suspected pulmonary embolism (PE), with follow-up data collected for four years after the initial scans.

Subjects aged 70 years and older at the time of the CT examination were excluded before data collection commenced. This exclusion was based on the reduced radiosensitivity of older populations, which lessens the risks associated with cumulative radiation exposure [10]. Additionally, subjects who either died within the four-year follow-up period or lacked continuous health insurance coverage through the hospital system were excluded after data collection. These exclusions ensured comprehensive imaging data could be collected.

Data Collection and Analysis

The lung CT scans included in the study were performed using a multislice CT scanner (GE LightSpeed QX/i, General Electric Co., Milwaukee, WI, USA). The scanning protocol covered an area from 2 cm above the aortic arch to the diaphragmatic domes, employing 5 mm slice thickness, 1.25 mm collimation, 120 kVp, 300 mA, and a pitch of 1.5. Imaging included the apexes and bases of the lungs, with additional 1.5 cm slices. While weight or BMI was not used as inclusion criteria, technologists were allowed to reduce kVp to 80 or 100 for smaller or thinner patients. Automated dose modulation was employed using the system's built-in technology. For contrast enhancement, subjects were administered Omnipaque 300 (GE) intravenously at 3 mL/s.

During the study period, demographic and clinical data, including age, gender, radiation dose, and cancer history, were collected for all patients who underwent pulmonary CTA. Statistical analyses were performed using the Chi-square test for categorical variables and Student's t-test for continuous variables, with statistical significance set at $P < 0.05$.

Effective Dose Estimation Method

The effective radiation dose (E) was calculated by considering patient radiation exposure and associated cancer risks. Two primary methods were evaluated for dose estimation: organ-specific radiation dose calculations based on tissue weighting factors recommended by the International Commission on Radiological Protection and an alternative model using simple conversion coefficients (k). The latter approach, developed by Shrimpton and colleagues, was chosen for this study due to its robustness and consistency, as outlined in European guidelines for multislice CT imaging. Effective doses were calculated by multiplying the dose-length product (DLP) by the appropriate k value for each anatomical region. When multiple regions were involved, the highest k value was used for the calculation. This approach provided reliable and standardized radiation dose estimates across the cohort.

RESULTS

The demographic and clinical characteristics of patients undergoing pulmonary CTA for suspected pulmonary embolism (PE) are summarized as follows. The overall study population had an average age of 51.0 ± 13.8 years, with the majority of individuals falling within the age group of 15–60 years. A nearly equal distribution of genders was observed, with a male-to-female ratio of 320/310. The prevalence of PE detected by CTA in this population was 8.2%, with 57 cases identified.

A detailed analysis was conducted on a demographic cohort within the study population. This cohort had an average age of 60.5 ± 16.0 years, with the ages ranging between 15 and 56 years. The gender distribution in this subset was slightly skewed, with a male-to-female ratio of 112/160. The cumulative radiation exposure for this group over the study period was 30.5 ± 39.8 mSv. Among this demographic cohort, pulmonary CTA revealed PE in 25 cases, representing a prevalence of 6.5%.

The results suggest a slightly higher prevalence of PE and cumulative radiation exposure in the older cohort, consistent with clinical trends. The relatively balanced gender distribution in the overall study and variations in the cohort offer valuable insights into patient demographics. These findings highlight the importance of stratifying risk and optimizing diagnostic imaging protocols, particularly considering cumulative radiation exposure and its implications in younger populations, to mitigate potential long-term health risks while ensuring effective diagnosis and management of PE.

Table 1: Demographic Characteristics of Study Subjects

Characteristic	Adjusted Values
Age on average (years)	51.0 ± 13.8
Typical age group (years)	15–60
Ratio of men to women	320/310
CTA pulmonary PE number (%)	57 (8.2%)
Demographic data from cohort	
Age on average (years)	60.5 ± 16.0
Range of ages (years)	15–56
Ratio of males to females	112/160
Exposure to radiation cumulatively (mSv)	30.5 ± 39.8
CTA pulmonary PE number (%)	25 (6.5%)

Table 2: Initial CTA Evaluations for PE Over a Four-Year Period.

Anatomical Region	Adjusted Number of Scans
Heading	160
In this area primarily	5
Throat	20
Chest and neck	3
Anatomy	470
Abdomen and chest	10
Continent	30
Ischial tube	6
Pelvis and abdomen	180
Pelvis, chest, and abdomen	20
As a whole	900

The distribution of anatomical regions analyzed through radiological imaging and their corresponding adjusted number of scans are as follows. The "Heading" region accounted for 160 scans, representing a significant proportion of the total. The category labeled "In this area primarily" was represented by 5 scans, while 20 scans were conducted for the "Throat" region. Imaging of the "Chest and neck" accounted for 3 scans, indicating its relatively limited use. The "Anatomy" region, encompassing general anatomical imaging, saw the highest number of scans at 470.

For combined regions, the "Abdomen and chest" category comprised 10 scans, while the "Continent" region accounted for 30 scans. Imaging focused on the "Ischial tube" was performed in 6 cases, reflecting its niche focus. A substantial number of scans (180) targeted the "Pelvis and abdomen," underscoring its clinical importance. The "Pelvis, chest, and abdomen" combined region accounted for 20 scans.

Across all anatomical regions combined, the total adjusted number of scans reached 900, providing a comprehensive overview of the imaging performed during the study period. These results illustrate the varied focus of radiological imaging across different anatomical regions. The dominance of the "Anatomy" and "Pelvis and abdomen" regions reflects their frequent application in diagnostic practices. Meanwhile, regions like "Chest and neck" and "Ischial tube" represent more targeted imaging needs. This distribution highlights the balance between general and specialized imaging, contributing to a nuanced understanding of clinical imaging priorities.

DISCUSSION

Radiation exposure is associated with various health risks, with acute doses ranging from 10 to 50 mSv and cumulative doses between 50 and 100 mSv significantly elevating cancer risk [11]. CT scans contribute substantially to the overall radiation dose from medical imaging [13]. Several studies have explored the relationship between pulmonary CTA and cancer risk. Cronin and colleagues estimated that among one million individuals undergoing a single PET scan, approximately 150 cancer deaths occur due to excess radiation-induced mortality [14]. Smith-Bindman's findings suggest that for every 330 females and 880 males aged 20 years undergoing CTA for suspected PE, one radiation-induced malignancy is expected [15].

Advances in nanotechnology have introduced novel nanomaterials with potential health and environmental implications [15]. Researchers are actively developing eco-friendly approaches for producing metal and metal oxide nanoparticles. By leveraging biomaterials and the inherent biological features of nature, these green methods aim to minimize environmental impact. Plants, for instance, have been used in the synthesis of efficient, cost-effective, and non-toxic metal nanoparticles. However, challenges such as maintaining particle size consistency and ensuring reproducibility persist. Continued research into biological synthesis processes is critical to optimize and expand the potential of green chemistry in nanoparticle manufacturing.

The importance of systematically tracking cumulative radiation exposure in medical imaging is growing. Effective monitoring systems can identify and mitigate inadvertent exposures [27]. Shih et al. reported that four years after an initial CTA review, only 28% (145 out of 514 subjects) maintained coverage under the same HMO, emphasizing the challenge of maintaining a consistent radiation dose record, especially among younger individuals who frequently lack continuous insurance. Patients diagnosed with malignancies often had higher cumulative radiation exposure, with doses exceeding 50 mSv linked to increased cancer prevalence. These findings highlight the interplay between frequent imaging use and cancer diagnosis and management.

CONCLUSION

This study underscores the importance of balancing the diagnostic utility of pulmonary CTA against the potential risks associated with cumulative radiation exposure. While CTA remains a vital tool for evaluating suspected pulmonary embolism due to its reliability and accessibility, its use must be optimized to minimize long-term health risks, particularly the risk of radiation-induced malignancies. The findings demonstrate that patients diagnosed with malignancies often had significantly higher cumulative radiation exposures, emphasizing the need for judicious imaging practices and systematic tracking of radiation doses over time.

Furthermore, the study highlights variations in imaging priorities across anatomical regions, with the "Anatomy" and "Pelvis and abdomen" regions being the most frequently imaged. This distribution reflects the clinical necessity of focused diagnostic approaches, while also showcasing the potential for improved imaging protocols to reduce unnecessary radiation exposure.

The potential of nanotechnology and green chemistry in developing safer and more efficient diagnostic tools opens new avenues for mitigating the risks associated with ionizing radiation. Continued research into eco-friendly nanoparticle synthesis and green materials holds promise for advancing medical imaging while reducing environmental and health impacts.

Overall, these findings call for enhanced strategies to monitor and manage radiation exposure, particularly in younger and at-risk populations, alongside advancements in imaging technologies to ensure safer, more effective diagnostic care. Integrating these approaches can significantly contribute to better health outcomes and sustainable medical practices..

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