Radiography Open

ISSN: 2387-3345 Vol 9, No 1 (2023) https://doi.org/10.7577/radopen.5571

Evaluation of pulmonary computed tomography angiography protocols: A multicenter audit in Togo

P. Gbande[1,2*], M. Tchaou[1], M. Dagbe[3], M.B. Atcha[2], L. Sonhaye[2], L.K. Agoda-Koussema [4], K. Adjenou[2]

[1]Regional Hospital Center of Sokodé, Department of Radiology and Medical Imaging, Sokodé, Togo
[2]Campus University Hospital Center, Department of Radiology and Medical Imaging, Lomé, Togo
[3]Kara University Hospital Center, Department of Radiology and Medical Imaging, Kara, Togo
[4]Sylvanus Olympio University Hospital Center; Department of Radiology and Medical Imaging, Lomé, Togo
*Corresponding author e-mail address: gbandepihou@yahoo.fr

Keywords: Pulmonary CT angiography, Acquisition techniques, Iodinated contrast media, Iodine flow, Vascular enhancement

Abstract

Introduction: Pulmonary CT angiography is among the most challenging protocols to execute, with significant inter-center variability in image acquisition protocols and iodinated contrast media injection. This study aimed to ascertain whether the use of iodinated contrast media (ICM) and acquisition protocols are optimized during pulmonary CT angiography procedures.

Material and methods: This was a multicentric cross-sectional, descriptive and analytical study with prospective data collection conducted in three radiology departments in Togo. It encompassed all pulmonary CT angiography examinations carried out from March 1st to June 30th, 2023.

Results: In total, 89 patients, of which 52 were females (58.43%), were registered. The average age was 59.97±14.34 years. The average volume of injected ICM was 67.08±14.21 ml. The mean iodine dose was 0.31±0.07 gI/Kg. Catheters of 20 G (44.94%) and 18 G (43.82%) were most frequently used. The mean injection rate was 4.22±0.64 ml/s. The bolus test technique was the most employed (75.28%). The average acquisition delay was 17.77±12.26 seconds, while the average acquisition duration was 10.56±2.56 seconds. The average dose-length product (DLP) was 390.09±236.69 mGy.cm, and the average volumetric computed tomography dose index (CTDI_vol) was 12.31±11.69 mGy. Vascular enhancement was insufficient in 7.87% of cases. No statistically significant difference was found on the rate of insufficient enhancement and optimization factors. Similarly, there was no enhancement difference between bolus test and bolus tracking techniques.

Conclusion: The vast majority of examinations allowed for optimal opacification of the pulmonary arteries. However, the optimization measures for the use of iodinated contrast media are not consistently applied.

Introduction

Pulmonary embolism (PE) is the complete or partial occlusion of the pulmonary artery trunk or one of its branches by a circulating foreign body, most commonly fibrinocruoric material[1]. It is a prevalent condition in clinical practice. Indeed, in epidemiological studies, the annual incidence rates of PE range from 39 to 115 per 100,000 individuals[2–4]. Despite advances in medical technologies, its diagnosis remains challenging. Early diagnosis and intervention are crucial, as the majority of deaths due to acute PE occur within the first hours or days, with more than 70% of deaths occurring in the initial hour[5]. In Togo, a West African country, the prevalence of PE was 3.1% in 2017, with a significant increase in the number of diagnosed PE cases per year[6].

Computed tomography (CT) is highly effective in diagnosing PE and is currently the preferred imaging modality[7]. Typically, CT is employed to assess the pulmonary artery and is performed with a rapid contrast medium injection. It should yield enhancement of 250 HU or even 300 HU during the arterial phase at the level of the pulmonary artery trunk[8–10]. According to the literature, the iodine flow rate at 120 kV should range between 1.2 and 2 gI/s[11,12]. This represents one of the most challenging protocols to execute, as it is highly sensitive to heart rate and patient body size[9]. Consequently, considerable inter-center variability exists regarding image acquisition protocols and injection of iodinated contrast agents. In all cases, administering a fixed contrast agent dose for all examinations is no longer considered appropriate. The optimization of injection protocols must be tailored to each machine based on its technical characteristics.

To contribute to best practices in computed tomography within our facilities, we have undertaken this study, the overarching goal of which is to evaluate pulmonary CT angiography protocols. Specifically, our objectives are to determine the anthropometric characteristics of patients, assess vascular opacification protocols, and evaluate image acquisition protocols.

Materials and methods

This was a multicentric cross-sectional, descriptive and analytical study with prospective data collection spanning a four-month period (from March 1st to June 30th, 2023). It was carried out in three departments of radiology in Togo, namely: CHU Campus and Polyclinic le Cœur in Lomé, and Saint-Sauveur Clinic in Kara. The study received approval from the medical advisory board of these healthcare institutions and was carried out in accordance with the ethical standards set by the Helsinki Declaration.

We included in this study all patients who underwent pulmonary CT angiography for suspected pulmonary embolism during the study period. Thoracic CT scans requested for indications other than pulmonary embolism were not included.

The variables examined were:

- Patient anthropometric parameters: age, sex, weight, height, and body mass index (BMI),
- Vascular opacification protocols: catheter size and location, concentration, volume, contrast injection rate and duration, acquisition delay, iodine flow rate, and vascular enhancement,
- Acquisition protocols: type of machine, kilovoltage, tube current-time product, slice thickness, pitch, dose-length product (DLP), volumetric computed tomography dose index (CTDI_vol), and acquisition duration.

Based on the World Health Organization's international BMI classification[13], patients were categorized as underweight with a BMI less than 18.5 kg/m², of normal weight between 18.5 kg/m² and 25 kg/m², overweight between 25 kg/m² and 30 kg/m², and obese when exceeding 30 kg/m².

Vascular enhancement was measured by placing a region of interest (ROI) in the vessel. The ROI covered more than half the vessel's diameter (Figure 1).

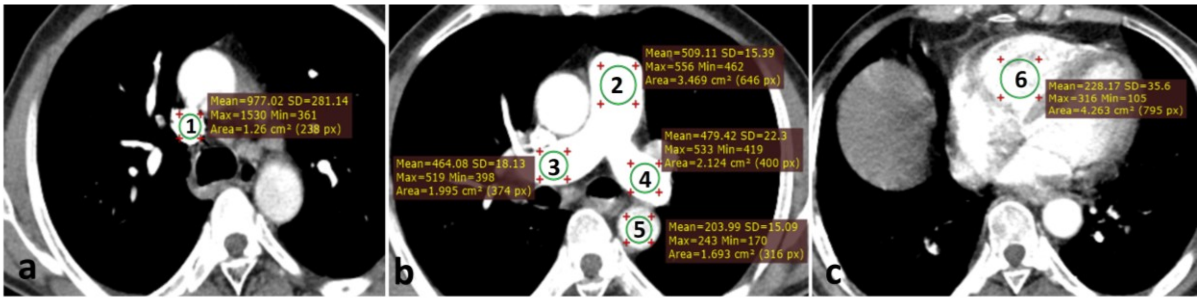

Figure 1. Images a, b and c correspond to the axial sections of a pulmonary CT angiogram passing respectively through the aorto-pulmonary window, the bifurcation of the pulmonary artery and the cardiac chambers and show the measurement of the enhancement of the structures. 1= Superior vena cava ; 2= trunk of the pulmonary artery; 3= right pulmonary artery; 4= left pulmonary artery; 5= descending thoracic aorta; 6= right ventricle.

Six vascular structures were analyzed: the pulmonary artery trunk (PAT), right pulmonary artery, left pulmonary artery, right ventricle, inferior vena cava, and descending thoracic aorta. PAT enhancement was considered optimal if it exceeded 250 HU and suboptimal if below this threshold[10,14] (Figure 2).

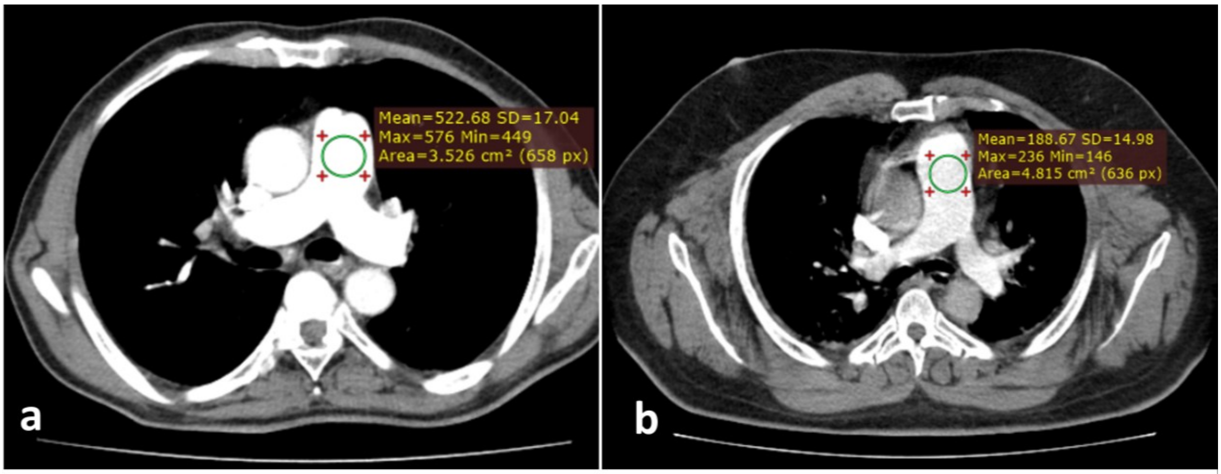

Figure 2. Axial pulmonary CT angiogram sections passing through the trunk of the pulmonary artery. Image a: optimal enhancement, average density of the trunk of the pulmonary artery measured at 522 HU. Image b: insufficient enhancement, average density of the trunk of the pulmonary artery is measured at 188 HU.

Data was processed using the EPI Info 7.1.3.3 software. Qualitative variables were presented as frequencies and percentages, while quantitative variables were expressed as mean ± standard deviation. Analysis of variance (ANOVA) was used to compare pitch and acquistion duration means according to the type of machine and the mean of iodine injection flow rate according to catheter gauge. The Kruskal-Wallis test was utilized to compare the mean iodine dose injected and the mean dosimetric parameters according to BMI groups. The exact Fisher test was used to compare proportions with respect to the optimality of TAP enhancement and various optimisation parameters. A significance level of 5% was set for statistical tests.

Results

General characteristics of the patients

During the study period, a total of 89 patients were recorded. Females accounted for 52 patients (58.43%) and males 37 patients (41.57%), with a sex ratio of 1.4. The patients' age ranged from 24 to 91 years, with an average of 59.97±14.34 years. The average weight was 74.29±18.18 kg (ranging from 46 to 136 kg). The average height was 1.67±0.08 m (ranging from 1.50 to 1.96 m). The average BMI was 26.51±6.26 kg/m² (ranging from 15.35 to 47.05 kg/m²). Most patients had a normal BMI (36 cases; 40.45%) (Table 1).

Table 1. Distribution of patients according to body mass index (BMI)

BMI	Frequency	Percentage
Underweight	6	6.74
Normal	36	40.45
Overweight	24	26.97
Obesity	23	25.84
Total	89	100.00

Protocols for iodinated contrast media injection

The pink catheter (20 G) was used in 40 cases (44.94%); the green catheter (18 G) in 39 cases (43.82%); and the blue catheter (22 G) in 10 cases (11.24%). The catheter was predominantly placed on the upper limb in 88 cases (98.88%) (table 2). It was primarily positioned at the elbow bend (n=58, 65.17%) (Table 2). The right side was used in 74 cases (83.15%) and the left in 15 cases (16.85%). The average injection rate was 4.22±0.64 ml/s. In 50 cases (56.18%), the contrast medium injection rate was less than 4 ml/s, compared to 39 cases (43.82%) where it exceeded 4 ml/s. The average flow rate was 3.52±0.21 ml/s with the blue catheter (22 G), 3.83±0.42 ml/s with the pink catheter (20 G), and 4.79±0.35 ml/s with the green catheter (18 G), with a statistically significant difference ($p<0.00001$). The contrast medium injection duration ranged between 9 and 30 seconds, averaging 16.05±4.89 seconds. It was less than 10 seconds in 9 cases (10.11%) and exceeded 10 seconds in 80 cases (89.89%). The iodine flow rate ranged between 1.02 and 1.75 gI/s, with an average of 1.47±0.23 gI/s. Saline flush was only administered in 21 cases (23.60%).

Table 2. Distribution of examinations according to the site and the caliber of the catheter

	Frequency	Percentage
Catheter seat		
Forearm	4	4.49
Internal jugular vein	1	1.12
Bend of the elbow	58	65.17
Wrist	25	29.21
Total	89	100.00
Catheter gauge		
Blue (22G)	10	11.24
Pink (20G)	40	44.94
Green (18G)	39	43.82
Total	89	100.00

Two types of concentration of iodinated contrast agents were employed. The 350 mgI/ml contrast agent was used in 78 cases (87.64%) and the 300 mgI/ml agent in 11 cases (12.36%). The average injected ICM volume was 67.08±14.21 ml (ranging from 45 to 120 ml). The average dose of iodine was 0.31±0.07 gI/Kg. There was a statistically significant relationship between the iodine dose injected and BMI groups, ranging from 0.37 gI/kg in underweight individuals to 0.27 gI/kg in obese patients (p<0.00001) (Figure 3).

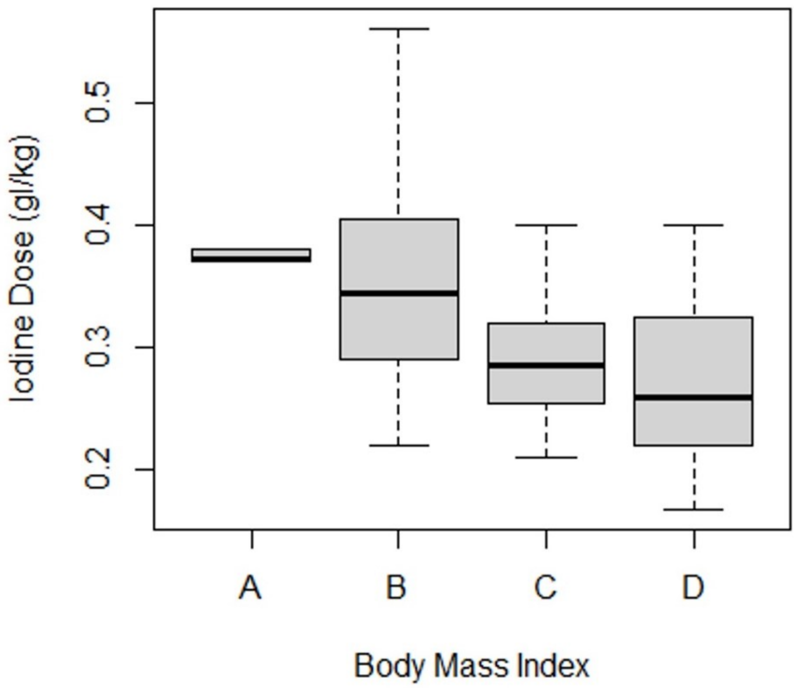

Figure 3. Iodine dose according to body mass index groups. A : underweight; B: normal weight; C: Overweight; D: Obese.

Image acquisition protocols

Forty-three examinations (48.31%) were performed on a 16-slice scanner, 32 examinations (33.71%) on a 32-slice scanner and 16 examinations (17.98%) on a 64-slice scanner. The 120 kV voltage setting was the most commonly used, applied in 65 cases (73.03%). The voltage of 130 kV was used more frequently in underweight patients (n=3 ; 50.0%). The voltage of 120 kV was the most commonly used in patients of normal weight (n=23, 63.89%), overweight patients (n=19 ; 79.27%), and obese patients (n=21 ; 91.30%) (Figure 4). The average tube current-time product was 159.15±109.27 mAs (ranging from 4.3 to 360 mAs).

The average dose-length product (DLP) was 390.09±236.69 mGy.cm (ranging from 49.70 to 997.05 mGy.cm). The average volumetric computed tomography dose index (CTDI_vol) was 12.31±11.69 mGy (ranging from 1.5 to 75.44 mGy). These dosimetry parameters did highly variable and were not correlate with the patient's weight (Table 3).

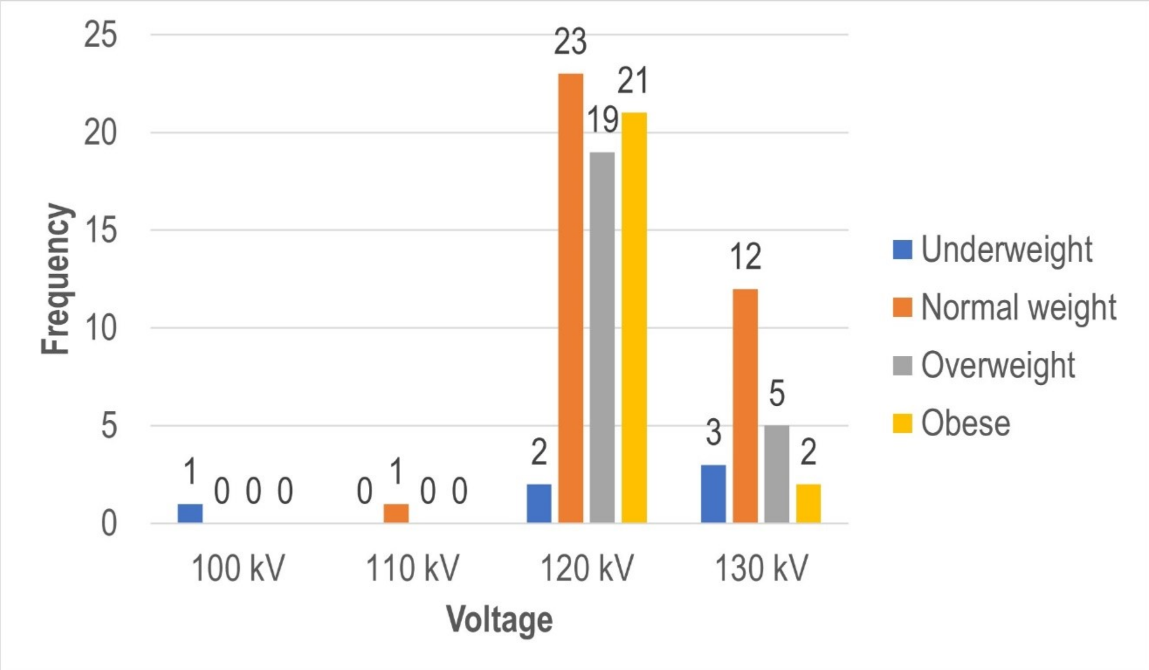

Figure 4. Different voltages used according to BMI groups.

Table 3. Dosimetric parameters according to body mass index groups

	DLP*	p value	CTDIvol**	p value
BMI***		0,66		0,42
Underweight	323.02±281.79		17.67±28.58	
Normal	382.04±261.80		12.62±14.27	
Overweight	393.85±234.85		10.95±4.04	
Obesity	416.26±193.06		11.84±3.24	

**DLP : dose-length product ; **CTDIvol : volumetric computed tomography dose index ; ***BMI : body mass index*

Two techniques were utilized to initiate acquisition. The bolus test technique was used in 67 cases (75.28%), and the automated bolus tracking technique was used in 22 cases (24.72%). The acquisition delay varied from 2 to 39 seconds, with an average of 17.77±12.26 seconds. It was less than 10 seconds in 34 cases (38.20%) and more than 10 seconds in 55 cases (61.80%).

The average acquisition duration was 10.56±2.56 seconds (ranging from 5 to 15 seconds). The duration varied slightly depending on the type of machine (p=0.07) (Table 4). The average pitch was 1.3±0.17 (ranging from 1 to 1.5) and varied based on the machine type (p<0.00001). The average slice thickness was 3.02±1.48 mm. Most examinations were conducted with a slice thickness greater than 2 mm (n=51, 57.30%).

Table 4. Acquisition duration and pitch according to the type of machine used

	Acquisition duration Mean ± Standard Deviation	p-value	Pitch Mean ± Standard Deviation	p-value
Machine type		0.07		<0.00001
16-slice (n=43)	10.90±3.23		1.16 ±0.06	
32-slice (n=30)	9.73±0.98		1.50 ±0.0	
64-slice (n=16)	11.18±2.25		1.33 ±0.18	

Vascular enhancement and optimization factors

The average enhancement of the PAT (pulmonary artery trunk) was 316.85±55.47 HU. The PAT enhancement was sufficient in 82 cases (92.13%) and insufficient in 7 cases (7.87%). In 8 cases (8.9%), aortic enhancement was greater than that of the PAT. The enhancement of different vascular structures is detailed in Table 5.

Table 5. Enhancement of different vascular structures (in HU)

Vascular structure	Mean ± Standard Deviation	Minimum	Maximum
Superior vena cava	473.90±403.41	39	2830
Right ventricle	281.22±141.16	110	1332
Pulmonary artery trunk	316.85±55.47	209	456
Right pulmonary artery	272.87±66.18	100	495
Left pulmonary artery	272.14±64.73	132	497
Thoracic aorta	161.95±71.09	33	461

PAT enhancement was sufficient in 94.59% of cases when the catheter was placed on the right versus 80% when placed on the left (p=0.09). Catheter size, injection rate, acquisition delay and injection duration dit not have significant influence on the rate of insufficient pulmonary artery enhancement. No statistically significant difference was found on the rate of insufficient enhancement when saline flush was used or not (p=0.66). There was also no statistically significant enhancement difference between the bolus test technique and the bolus tracking technique (Table 6).

Table 6. Optimization factors and quality of pulmonary artery trunk enhancement

	Insufficient enhancement (n=7)	**Sufficient enhancement (n=82)**	**p-value**
Catheter gauge			N / A
Blue (22G)	0	10 (100.0)	
Pink (20G)	2 (5.0)	38 (95.0)	
Green (18G)	5 (12.82)	34 (87.18)	
Catheter placement			0.09
Right side	4 (5.41)	70 (94.59)	
Left side	3 (20.0)	12 (80.0)	
Injection rate			0.23
< 4ml/s	2 (4.0)	48 (96.0)	
>4ml/s	5 (12.82)	34 (87.18)	
Acquisition delay			0.1
< 10s	5 (14.71)	29 (85.29)	
>10s	2 (3.64)	53 (96.36)	
Injection duration			0.14
< 10s	2 (22.22)	7 (77.78)	
>10s	5 (6.25)	75 (93.75)	
Saline injection			0.66
No	5 (7.35)	63 (92.65)	
Yes	2 (9.52)	19 (90.48)	
Acquisition technique			1
Test bolus	2 (9.09)	20 (90.91)	
Bolus tracking	5 (7.46)	62 (92.54)	

N/A : Not applicable

Discussion

The success of a thoracic angio-CT scan is evaluated retrospectively by clinicians by assessing vascular enhancement. The factors that influence the quality of pulmonary arterial enhancement are numerous and fall into three categories : factors related to the patient, factors related to the iodinated contrast medium injection protocol, and factors related to the image acquisition protocol[15].

In this study, 20 G and 18 G catheters were the most used, accounting for 44.95% and 43.82% respectively. Catheters were almost exclusively placed in the right upper limb, and in 65.17% of cases at the elbow crease. Basson et al.[16] made a similar observation, but preferred the forearm (in 33.9% of cases) followed by the hand (in 32.3%). They also noted that the 20 G catheter was the most used (66.1%). In our study, the injection rate was strongly correlated with catheter size, but these rates still exceeded the theoretical maximum values[17,18]. Indeed, the theoretical maximum flow rates for 22 G, 20 G, 18 G, and 16 G catheters are 35 ml/min, 65 ml/min, 105 ml/min, and 195 ml/min respectively[19]. Knowing these rates helps prevent exceeding the catheter's physical limits, potentially causing it to detach and migrate into the patient's venous system. It also reduces the risk of extravasation of contrast media[20]. For these reasons, 18 G and 16 G catheters are recommended for contrast media injection[21]. For Sum et al.[22], the 20 G diameter seems to be a good compromise for patients with impaired venous capital when placing an 18 G is impossible.

The choice of an appropriate injection rate is vital for obtaining consistent enhancement and adequate vessel opacification. If the volume and concentration of the ICM remain constant, vascular enhancement intensity is directly related to the injection rate and inversely related to both bolus arrival time and peak enhancement duration[15]. For vascular protocols, the iodine flow rate is the key factor to optimize. In this study, the average injection rate was 4.22±0.64 ml with an average iodine flow rate of 1.47±0.23 gI/s (ranging from 1.02 to 1.75 gI/s). Our result aligns with the recommendations of the literature which fall between 1.2 and 1.6 gI/s [8,23–25].

The appropriate duration of injection is determined by the exam conditions and the clinical objectives of the study. According to the Interdisciplinary Committee for Research and Work on Imaging Contrast Agents (CIRTACI), a group from the French Radiology Society dedicated to contrast agents, there is no need to continue injecting contrast media after the vessel of interest has been opacified[8]. Since the contrast media takes about 10 seconds to reach the pulmonary artery trunk, the injection will therefore be made for a maximum of 10 seconds[8]. In our study, more than 4/5 of the exams had an injection duration that exceeded 10 seconds. With a fixed injection rate, the duration of injection varies with the volume of ICM to be injected. The average volume of ICM injected in this study was 67.08±14.21 ml (ranging from 45 to 120 ml). The average iodine dose was 0.31±0.07 gI/Kg. Basson et al. found an average volume of 85.12 ml[16]. The trend today is to reduce ICM doses and injection volumes in vascular applications to between 20 and 40 ml[26–28].

In the present study, 120 kV was the most commonly used (73.03% of cases) for examinations and was not correlate with the patient's weight. In some previous studies, the voltage of 120 kV was also the most commonly used[29.30]. However, recent studies recommend 100 kV and even 80 kV for pulmonary angiography in non-obese patients[31-33]. The voltage influences the penetration of the X-ray beam into the patient. It represents the flow of X photons, directly influencing the dose administered to the patient, as well as the signal-to-noise ratio[34]. The voltage must be adapted to the thickness of the examined body. For radioprotection reasons, it is necessary to reduce the voltage as much as possible (for children and thin individuals). Reducing the voltage allows one to reduce the necessary dose of iodine and radiation dose[29,35–37]. Other parameters are also used to reduce radiation, such as reducing the scan length, utilizing automatic tube current modulation, employing iterative reconstruction and sometimes artificial intelligence[38]. In our study, the dose-length product (DLP) and the volumetric computed tomography dose index (CTDIvol) showed significant variability and had no relationship with the patient's body size, with averages exceeding international recommendations [39–41]. Therefore, it is essential to implement a system to significantly reduce radiation doses in CT scans while maintaining good image quality.

This study found that the rate of exams with insufficient enhancement was 7.87%. This result is lower than those of Basson et al.[16] and Marshall et al.[42], which found 20.8% and 11.2%, respectively. This result is encouraging. The enhancement of the pulmonary artery was more satisfactory when the catheter was placed on the right compared to when it was placed on the left, with a difference tending towards significance. Marshall et al. [42] did not find a statistically significant difference between the proportion of unsatisfactory exams and the location or size of intravenous catheters. The same was true in the study by Basson et al.[16]. In a study, Kim et al. reported that when ICM is administered through the leg veins, there is a higher proportion of insufficient enhancement of the PAT compared to cases where contrast medium is injected through an upper limb vein[10]. Thus, it is preferable to use the upper limb veins for ICM injections.

Although some studies have shown a correlation between injection rate, acquisition delay, injection duration, and enhancement of the pulmonary artery[15], our study did not find a significant influence between these factors and the rate of insufficient enhancement. This may be due to the small proportion of exams that had insufficient enhancement. There was also no enhancement difference between the bolus test technique and the automated bolus detection technique. A lingering debate is whether bolus test techniques offer real advantages over automated bolus follow-up techniques in terms of optimal vascular attenuation. Some researchers did not find this distinction[43,44]. However, others have reported the benefits of the bolus test technique over automated bolus tracking [45]. Given that the necessary contrast medium volume is slightly higher for the bolus test technique, it is preferable to use the bolus monitoring method.

Limitations

The main limitation of this study is the small sample size, which may impact the interpretation of the results. Additionally, this study did not take into account several patient-related factors.

Conclusion

This study demonstrated that the vast majority of examinations achieved optimal opacification of the pulmonary arteries, although optimization measures for the use of iodinated contrast media were not always applied. Reducing the kilovoltage, shortening the injection duration and acquisition delay, and using appropriate venous catheters will result in higher-quality examinations with as low an iodine dose as possible. This would also reduce radiation doses. Therefore, it becomes imperative to implement a management system for iodinated contrast media for efficient management and standardization of pulmonary angio-CT scan protocols, while also adapting them to patients' body sizes.

Statements and Declarations

Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this article.

Source of founding

The authors received no financial support for the research, writing, and/or publication of this article.

References

1. Cohen A. Cardiologie et pathologie vasculaire. Paris: Ed. ESTEM; 1997.

2. Wendelboe AM, Raskob GE. Global burden of thrombosis: epidemiologic aspects. Circ Res. 2016;118(9):1340-7. http://dx.doi.org/10.1161/CIRCRESAHA.115.306841

3. Konstantinides SV, Meyer G, Becattini C, Bueno H, Geersing GJ, Harjola VP, et al. 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS): The Task Force for the diagnosis and management of acute pulmonary embolism of the European Society of Cardiology (ESC). Eur Respir J. sept 2019;54(3):1901647. doi: 10.1183/13993003.01647-2019.

4. Keller K, Hobohm L, Ebner M, Kresoja KP, Münzel T, Konstantinides SV, et al. Trends in thrombolytic treatment and outcomes of acute pulmonary embolism in Germany. Eur Heart J. 2020;41(4):522-9. doi: 10.1093/eurheartj/ehz236.

5. Martinez Licha CR, McCurdy CM, Maldonado SM, Lee LS. Current Management of Acute Pulmonary Embolism. Ann Thorac Cardiovasc Surg. 2020;26(2):65-71. doi: 10.5761/atcs.ra.19-00158.

6. Pessinaba S, Molba YD, Baragou S, Pio M, Afassinou Y, Kpélafia M, et al. L’embolie pulmonaire au centre hospitalier universitaire Campus de Lomé (Togo): étude rétrospective à propos de 51 cas. Pan Afr Med J [Internet]. 2017 [cité 21 janv 2023];27(129). Disponible sur: http://www.panafrican-med-journal.com/content/article/27/129/full/.

7. Stein PD, Gottschalk A, Sostman HD, Chenevert TL, Fowler SE, Goodman LR, et al. Methods of Prospective Investigation of Pulmonary Embolism Diagnosis III (PIOPED III). Semin Nucl Med. 2008;38(6):462-70. doi: 10.1053/j.semnuclmed.2008.06.003

8. Gaultier AL, Mandry D, Pontana F, Morel B, Blondiaux E, Kuchcinski G, et al. Recommandations du CIRTACI sur l'optimisation de l'injection des produits de contraste iodés en tomodensitométrie – Applications oncologiques. J Imag Diagn Interv. 2020;3(3):145-50. doi: 10.1016/j.jidi.2020.03.002

9. Faggioni L, Neri E, Sbragia P, Pascale R, D'Errico L, Caramella D, et al. 80-kV Pulmonary CT Angiography With 40 mL of Iodinated Contrast Material in Lean Patients: Comparison of Vascular Enhancement With Iodixanol (320 mg I/mL)and Iomeprol (400 mg I/mL). Am J Roentgenol. 2012;199(6):1220-5. doi: 10.2214/AJR.11.8122

10. Kim C, Lee CW, Hong GS, Kim G, Lee KY, Kim SS. Assessment of pulmonary arterial enhancement on CT pulmonary angiography using a leg vein for contrast media administration. Medicine (Baltimore). 2017;96(49):e9099. doi: 10.2214/AJR.11.8122

11. Bae KT. Intravenous contrast medium administration and scan timing at CT: considerations and approaches. Radiology. 2010;256(1):32-61. doi: 10.1148/radiol.10090908

12. Jia C fu, Zhong J, Meng X yi, Sun X xia, Yang Z qiang, Zou Y jie, et al. Image quality and diagnostic value of ultra low-voltage, ultra low-contrast coronary CT angiography. Eur Radiol. 2019;29(7):3678-85. doi: 10.1007/s00330-019-06111-0

13. WHO. Obesity and overweight [Internet]. 2016. Disponible sur: : http://www.who.int/en/ news-room/fact-sheets/detail/obesity-and-overweight

14. Chen M, Mattar G, Abdulkarim JA. Computed tomography pulmonary angiography using a 20% reduction in contrast medium dose delivered in a multiphasic injection. World J Radiol. 2017;9(3):143. doi: 10.4329/wjr.v9.i3.143

15. Weininger M, Barraza JM, Kemper CA, Kalafut JF, Costello P, Schoepf UJ. Cardiothoracic CT angiography: current contrast medium delivery strategies. Am J Roentgenol. 2011;196(3):W260-72. doi: 10.2214/AJR.10.5814

16. Basson DJ, Moodley H. An audit of the adequacy of contrast enhancement in CT pulmonary angiograms in a South African tertiary academic hospital setting. South Afr J Radiol. 2022;26(1):a2350. doi: 10.4102/sajr.v26i1.2350

17. Djian C, Nicolas C, Janoly-Dumenil A, Plauchu MM. Régulateur de débit : mise en évidence du mésusage par une enquête de pratiques et propositions d'actions correctives. 2008;27(2):65-72.

18. Calesse A, Charbonnel JF. Perfusion des médicaments en milieu hospitalier : problématique des perfusions complexes. Pharm Hosp Clin. 2018;53(4):342-53. doi: 10.1016/j.phclin.2018.08.004

19. B. Braun Medical. Les cathéters veineusx périphériques B. Braun: À chaque patient son cathéter sécurisé [Internet]. [cité 19 août 2023]. Disponible sur: https://www.free-med.com/cache/documents/product/brochure-catheter301624p-533.pdf

20. Ding S, Meystre NR, Campeanu C, Gullo G. Contrast media extravasations in patients undergoing computerized tomography scanning: a systematic review and meta-analysis of risk factors and interventions. JBI Database Syst Rev Implement Rep. 2018;16(1):87-116. doi: 10.11124/JBISRIR-2017-003348

21. Schwab SA, Kuefner MA, Anders K, Adamietz B, Heinrich MC, Baigger JF, et al. Peripheral intravenous power injection of iodinated contrast media: the impact of temperature on maximum injection pressures at different cannula sizes. Acad Radiol. 2009;16(12):1502-8. doi: 10.1016/j.acra.2009.07.026

22. Sum W, Ridley LJ. Recognition and management of contrast media extravasation. Australas Radiol. déc 2006;50(6):549-52. doi: 10.1111/j.1440-1673.2006.01626.x

23. Wang Y, Di AH, Zhang Y. [Feasibility analysis on reducing iodine delivery rate of coronary CT angiography with 100 kVp to 60% of 120 kVp standard]. Zhonghua Yi Xue Za Zhi. 2022;102(43):3457-62. doi: 10.3760/cma.j.cn112137-20220729-01649

24. Yuan W, Qu T ting, Wang H juan, Wang M yu, Qu Y, Niu G, et al. Coronary CT angiography using low iodine delivery rate and tube voltage determined by body mass index: superiority in clinical practice. Curr Med Sci. oct 2019;39(5):825-30. doi: 10.1007/s11596-019-2112-5

25. Rengo M, Dharampal A, Lubbers M, Kock M, Wildberger JE, Das M, et al. Impact of iodine concentration and iodine delivery rate on contrast enhancement in coronary CT angiography: a randomized multicenter trial (CT-CON). Eur Radiol. 2019;29(11):6109-18. doi: 10.1007/s00330-019-06196-7

26. Silva M, Milanese G, Cobelli R, Manna C, Rasciti E, Poggesi S, et al. CT angiography for pulmonary embolism in the emergency department: investigation of a protocol by 20 ml of high-concentration contrast medium. Radiol Med (Torino). 2020;125(2):137-44. doi: 10.1007/s11547-019-01098-6

27. Kapoor A, Mahajan G, Kapoor A. Evaluation of low-kVp low-volume iodinated contrast protocol for coronary CT angiography using retrospective ECG gating. Indian J Radiol Imaging. 2021;31(4):910-6. doi: 10.1055/s-0041-1741102

28. Goble EW, Abdulkarim JA. CT pulmonary angiography using a reduced volume of high-concentration iodinated contrast medium and multiphasic injection to achieve dose reduction. Clin Radiol. 2014;69(1):36-40. doi: 10.1016/j.crad.2013.07.023

29. Knollmann F, Chu L, Lang JA. CT Angiography for the detection of pulmonary embolism: role of tube voltage and contrast injection rate on diagnostic confidence. Acad Radiol. 2022;29 Suppl 2:S91-7. doi: 10.1016/j.acra.2021.01.020

30. Szucs-Farkas Z, Schaller C, Bensler S, Patak MA, Vock P, Schindera ST. Detection of pulmonary emboli with CT angiography at reduced radiation exposure and contrast material volume: comparison of 80 kVp and 120 kVp protocols in a matched cohort. Invest Radiol. 2009;44(12):793-9. doi: 10.1097/RLI.0b013e3181bfe230

31. Çetin M. Diagnostic quality of CT pulmonary angiography in pulmonary thromboembolism: A comparison of three different kV values. Med Sci Monit. 2013;19:908-15. doi: 10.12659/MSM.889578

32. Rusandu A, Ødegård A, Engh GC, Olerud HM. The use of 80 kV versus 100 kV in pulmonary CT angiography: An evaluation of the impact on radiation dose and image quality on two CT scanners. Radiography. 2019;25(1):58-64. doi: 10.1016/j.radi.2018.10.004

33. Viteri-Ramírez G, García-Lallana A, Simón-Yarza I, Broncano J, Ferreira M, Pueyo JC, et al. Low radiation and low-contrast dose pulmonary CT angiography: Comparison of 80 kVp/60 ml and 100 kVp/80 ml protocols. Clin Radiol. 2012;67(9):833-9. doi: 10.1016/j.crad.2011.11.016

34. Dillenseger JP, Moerschel É, Zorn C. Guide des technologies de l'imagerie médicale et de la radiothérapie: quand la théorie éclaire la pratique. 2e éd. Issy-les-Moulineaux: Elsevier Masson; 2016.

35. Hu X, Ma L, Zhang J, Li Z, Shen Y, Hu D. Use of pulmonary CT angiography with low tube voltage and low-iodine-concentration contrast agent to diagnose pulmonary embolism. Sci Rep. 16 oct 2017;7(1):12741. doi: 10.1038/s41598-017-13077-w

36. Mourits MM, Nijhof WH, Van Leuken MH, Jager GJ, Rutten MJCM. Reducing contrast medium volume and tube voltage in CT angiography of the pulmonary artery. Clin Radiol. 2016;71(6):615.e7-615.e13. doi: 10.1016/j.crad.2016.03.005

37. Marin D, Nelson RC, Schindera ST, Richard S, Youngblood RS, Yoshizumi TT, et al. Low-tube-voltage, high-tube current multidetector abdominal CT: improved image quality and decreased radiation dose with adaptive statistical iterative reconstruction algorithm—initial clinical experience. Radiology. 2010;254(1):145-53. doi: 10.1148/radiol.09090094

38. Nagayama Y, Oda S, Nakaura T, Tsuji A, Urata J, Furusawa M, et al. Radiation dose reduction at pediatric CT: use of low tube voltage and iterative reconstruction. RadioGraphics. 2018;38(5):1421-40. doi: 10.1148/rg.2018180041

39. Foley SJ, McEntee MF, Rainford LA. Establishment of CT diagnostic reference levels in Ireland. Br J Radiol. 2012;85(1018):1390-7. doi: 10.1259/bjr/15839549

40. Aberle C, Ryckx N, Treier R, Schindera S. Update of national diagnostic reference levels for adult CT in Switzerland and assessment of radiation dose reduction since 2010. Eur Radiol. 2020;30(3):1690-700. doi: 10.1007/s00330-019-06485-1

41. Jafari S, Ghazikhanlu Sani K, Karimi M, Khosravi H, Goodarzi R, Pourkaveh M. Establishment of diagnostic reference levels for computed tomography scanning in Hamadan. J Biomed Phys Eng. 2020;10(6):792-800. doi: 10.31661/jbpe.v0i0.2004-1099

42. Marshall T, Chen N, Nguyen E, Slattery D, Zitek T. Rethinking intravenous catheter size and location for computed tomography pulmonary angiography. West J Emerg Med. 2019;20(2):244-9. doi: 10.5811/westjem.2018.11.40930

43. Kerl JM, Lehnert T, Schell B, Bodelle B, Beeres M, Jacobi V, et al. Intravenous contrast material administration at high-pitch dual-source CT pulmonary angiography: test bolus versus bolus-tracking technique. Eur J Radiol. 2012;81(10):2887-91. doi: 10.1016/j.ejrad.2011.09.018

44. Sun K, Liu GR, Li YC, Han RJ, Cui LF, Ma LJ, et al. Intravenous contrast material administration at high-pitch dual-source CT coronary angiography: bolus-tracking technique with shortened time of respiratory instruction versus test bolus technique. Chin Med Sci J Chung-Kuo Hsueh Ko Hsueh Tsa Chih. 2013;27(4):225-31. doi: 10.1016/s1001-9294(13)60006-1

45. Rodrigues JCL, Mathias H, Negus IS, Manghat NE, Hamilton MCK. Intravenous contrast medium administration at 128 multidetector row CT pulmonary angiography: Bolus tracking versus test bolus and the implications for diagnostic quality and effective dose. Clin Radiol. 2012;67(11):1053-60. doi : 10.1016/j.crad.2012.02.010