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CTPA in Patients with Pulmonary Embolism: Compare Test Bolus and Bolus Tracking Methods

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Abstract

Background: Computed tomography pulmonary angiography (CTPA) is a non-invasive imaging method that can quickly diagnose pulmonary embolism. This study aimed to compare test bolus and bolus track contrast enhancement protocols to determine the optimal technique for CTPA in the diagnosis of pulmonary embolism.

Methods and Results: This retrospective study was conducted at the King Abdul-Aziz Specialist Hospital (KASH) in Taif city from September 2022 to March 2023. Ninety-eight patients with suspected PE were included in the study: underwent CTPA using the test bolus (TB) approach, and 49 patients underwent CTPA using the bolus tracking (BT) approach. The examination was performed using a 128-slice CT scanner. Densities of pulmonary arteries were measured based on the Hounsfield unit (HU) and compared between two groups (TB and BT) based on gender and age. The mean HU of the pulmonary arteries was significantly higher in the TB group than that of the BT group (392.06±110.77 HU and 298.9±93.098 HU, respectively, *P*=0.001). There was no statistically significant difference in the mean HU between females of the two groups (P=0.062). In contrast, men in the TB group had a substantially greater density (384.7±116 HU) than men in the BT group (273.0±88.0 HU) (*P*=0.001). There were no statistically significant differences between the two groups based on age except for the age subgroup 46-55 years; the TB group exhibited considerably higher density (421.54±138.148 HU) than the BT group (255.2±82.155 HU) (*P*=0.003). The ANOVA test showed no statistically significant correlation between the effects of tracking systems, gender, and age on tracking intensity (*P*=0.640).

Conclusion: Both TB and BT procedures are accurate for diagnosing pulmonary embolism. A TB protocol results in significantly better opacification of the pulmonary arteries in men aged 46 to 55 than the BT protocol. **(International Journal of Biomedicine. 2024;14(3):464-468.)**

Keywords: pulmonary embolism • CTPA • test bolus • bolus tracking

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Abbreviations

BT, bolus tracking; **CTPA**, computed tomography pulmonary angiography; **HU,** Hounsfield units; **MDCT**, multi-detector CT; **MPA**, main pulmonary artery; **PA**, pulmonary artery; **PE**, pulmonary embolism; **ROI**, region of interest: **TB**, test bolus.

Introduction

Pulmonary embolism (PE) is a life-threatening illness characterized by chest pain, shortness of breath, and a weak pulse.[1] It necessitates rapid emergency care. Despite breakthroughs in diagnosis and therapy, morbidity and death remain significant.[2] Pulmonary embolism occurs when a thrombus from another place affects blood flow in the pulmonary artery or its branches. Deep vein thrombosis mainly affects the large veins in the lower leg and thigh, but can occur in other deep veins, such as the arms and pelvis. Deep vein thrombosis causes PE when clots break off, travel to the lungs, and get stuck in the arteries, creating a blockage. Pulmonary embolism can occasionally develop from the embolization of various materials into the pulmonary circulation, such as air, fat, or tumor cells.[3]

Computed tomography pulmonary angiography (CTPA) became the preferred imaging modality for diagnosing PE. With advancements in spatial resolution in modern CT scanners, the diagnosis of PE has improved significantly, particularly in the detection of segmental and sub-segmental PE.[4] However, methods can make a difference in terms of image and diagnostic quality from several perspectives. Contrast agents can be used in CT examinations to investigate tumor and organ perfusion, as well as vascular architecture and angiography.[5,6] CTPA is a non-invasive imaging method that can quickly diagnose PE.[3,7] There are two techniques for determining scan timing: bolus monitoring and timing bolus. Bolus tracking (BT) commences the scan after the radiodensity of the pulmonary trunk reaches 100 HU. Timing bolus employed a TB to determine the time required for maximum enhancement in the pulmonary trunk. Imaging PE depends on the model of CT and techniques, as well as radiologic technologists, which causes different opacification, which leads to poor or excellent diagnosis. So, optimal opacification is crucial.

Few studies focus on finding the optimal timing while scanning, as smart prep protocol or some other protocols do a test scan before the actual scan to achieve optimal opacification.[8] With current technology and evidence, the main pulmonary artery (MPA) opacification should be at least 210 HU to achieve acceptable contrast enhancement in peripheral vessels.[9]

Most previous investigations began the scan with a BT system (HU of the region of interest [ROI] located within the MPA) or a TB system.[8,9] The use of multi-detector CT (MDCT) results in complex and challenging scan techniques. Suckling et al.[8] performed a retrospective study comparing the smart prep protocol with the TB protocol, which comprised 160 patients receiving CTPA, and found that the TB protocol had a greater success rate in obtaining optimum opacification than the smart prep protocol. In the same year, another innovative study published by Dhamanaskar et al.[10] indicated that TB protocol achieves superior results than scanning as smart prep for pulmonary diagnosis.

This study aimed to compare test bolus and bolus track contrast enhancement protocols to determine the optimal technique for CTPA in the diagnosis of PE.

Materials and Methods

This retrospective study was conducted at the King Abdul-Aziz Specialist Hospital (KASH) in Taif city from September 2022 to March 2023. Ninety-eight patients with suspected PE were included in the study: underwent CTPA using the test bolus (TB) approach, and 49 patients underwent CTPA using the bolus tracking (BT) approach.

Two expert radiologists with 10 years of experience reported images to confirm the accuracy of findings and prevent any uncertainty from diagnostic reports.

Examination Protocol

The examination was performed using a 128-slice CT scanner, while patients were positioned supine and scanned in a caudal to cranial on suspended inspiration. Intravenous contrast was injected using an automatic injection device; the volumes of contrast material and injection rate were for smart BT, with contrast volume depending on the patient's weight. So basically, the equation is patient weight multiplied by 1.5, with an injection rate of 4-4.5 mL/sec. While contrast media was injected, the threshold was put on the MPA or superior vena cava. Whenever threshold levels reached 100 or 120, image acquisition was initiated, usually delayed sit on 3 sec.

In the TB protocol, contrast volume depends mainly on when the contrast reaches its peak, usually between 8-10 sec multiplied by the flow rate, which is 5-6 mL/sec. A standard 25-40 mL test bolus of contrast was injected, and sequential low-dose axial slices at the set ROI in the pulmonary trunk were acquired. The time of peak contrast enhancement was displayed in the form of an 'attenuation versus time' graph, which was viewed by the radiographer.

The parameters applied for diagnostic image acquisition were 120kVp and auto mA for both protocols. For the TB protocol, the rotation time was 0.3 sec, a pitch of 1.2, the slice thickness was 3, and the scan time was 2-3 sec. For the smart BT protocol, the rotation time was 0.5 sec, a pitch of 0.891, the slice thickness was 2, and the scan time was 5-6 sec. The iodinated contrast media used was Omnipaque, which was administered by automated injectors using an 18- or 20-gauge cannula.

The study hypothesized that for comparison of the theoretical mean for BT (μBT) with that of the theoretical mean for TB (μTB) concerning exposure factors, duration of the study, and the volume of contrast agent used, the null hypothesis is equal for BT and TB. The data was collected using a data collection sheet containing all the variables. Then, densities of pulmonary arteries were measured based on the Hounsfield unit (HU) and compared between two groups (TB and BT) based on gender and age.

Statistical analysis was performed using the statistical software package SPSS version 20.0 (SPSS Inc, Armonk, NY: IBM Corp). Baseline characteristics were summarized as frequencies and percentages for categorical variables and mean ± standard deviation (SD) for continuous variables. The Mann-Whitney U Test was used to compare the differences between the two independent groups. A three-way ANOVA was done to see the effect of the tracking system, gender, and age on tracking density. A probability value of $P<0.05$ was considered statistically significant.

Results

The result shows that the bilateral lobe is the most common site for PE during the TB protocol for 20 patients, representing 40.8%, while the right lower lobe is the most common site for PE during the BT protocol for 15(30.6%) patients (Table 1). The mean HU of the pulmonary arteries was significantly higher in the TB group than that of the BT group (392.06±110.77 HU and 298.9±93.098 HU, respectively, P=0.001) (Table 2 and Figure 1) There was no statistically significant difference in the mean HU between females of the two groups [P=0.062]. In contrast, men in the TB group had a substantially greater density (384.7±116 HU) than men in the BT group (273.0±88.0 HU) (P=0.001) (Table 3). There were no statistically significant differences between the two groups based on age except for the age subgroup 46-55 years; the TB group exhibited considerably higher density (421.54±138.148 HU) than the BT group (255.2±82.155 HU) (P=0.003) (Table 4). The ANOVA test showed no statistically significant correlation between the effects of tracking systems, gender, and age on tracking intensity (P=0.640) (Table 5).

Table 1.
Sites of pulmonary embolism identified with TB and BT protocols.

		Frequency	Percent
TB protocol	Bilateral subsegmental arteries	6	12.2
	Bilateral upper lobes	20	40.8
	Bilateral lobe segmental arteries	2	4.1
	Bilateral lower lobes	2	4.1
	Both main PAs	2	4.1
	Lower lobe segmental arteries	1	2
	Left lower lobe	1	2
	Left PA	1	2
	Left lower segmental artery	1	2
	Left upper lobe	2	4.1
	Right main branch	1	2
	Right main segmental branch	1	2
	Right and left lower segmental arteries	1	2
	Right and left upper lobe	1	2
	Right lower lob	1	2
	Right lower lobe – Left upper lobe	1	2
	Right lower segmental and subsegmental arteries	1	2
	Right main PA	2	4.1
	Right PA branch	1	2
	Right segmental artery	1	2
	Total	49	100
BT protocol	Both main PAs	4	8.2
	Left lower lobe	5	10.2
	Left main PA	1	2
	Left subsegmental artery	1	2
	Left upper lobe	10	20.4
	Right lower lope	15	30.6
	Right – left lower lobes	1	2
	Right main PA	2	4.1
	Right middle lobe	1	2
	Right subsegmental artery	1	2
	Right upper lobe	8	16.3
	Total	49	100

Table 2.
Comparison the mean HU between TB and BT groups.

Group	N	Mean	SD	
TB	49	392.06	110.77	P <0.001
BT	49	298.9	93.098	

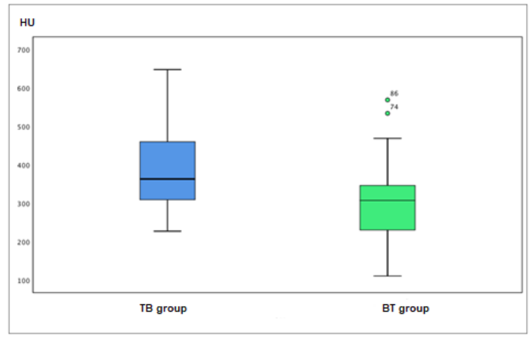

Fig. 1. *Comparison between the TB and BT groups.*

Table 3.
Comparison of the mean HU between two groups based on gender.

Gender	Group	N	Mean	SD	P-value
Female	TB	30	396.7	108.7	0.062
	BT	19	339.8	88.0	
Male	TB	19	384.7	116.6	<0.001
	BT	30	273.0	88.0	

Table 4.
Comparison of the mean HU between two groups based on age.

Age	Group	N	Mean	SD	P-value
<=25 years	TB	1	363	.	-
	BT	2	297.5	28.991	
26-35 years	TB	5	386	137.535	0.090
	BT	12	295.5	71.481	
36-45 years	TB	7	307	48.518	0.786
	BT	9	296	95.356	
46-55 years	TB	13	421.54	138.148	0.003
	BT	10	255.2	82.155	
56-65 years	TB	11	401.09	80.138	0.135
	BT	7	324.14	128.384	
≥66 years	TB	12	406.42	112.649	0.161
	BT	9	335.56	106.495	

Table 5.
Factorial ANOVA model.

Dependent Variable: HU						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	429964.239a	21	20474.488	1.976	0.017	0.353
Intercept	6464710.875	1	6464710.875	623.766	0.000	0.891
Age	56071.728	5	11214.346	1.082	0.377	0.066
Gender	3445.135	1	3445.135	0.332	0.566	0.004
Group	141249.817	1	141249.817	13.629	0.000	0.152
Age * Gender	72842.193	4	18210.548	1.757	0.146	0.085
Age * group	38797.15	4	9699.287	0.936	0.448	0.047
Gender * group	32905.906	1	32905.906	3.175	0.079	0.040
Age* Gender * group	26277.285	4	6569.321	0.634	0.640	0.032
Error	787664.22	76	10364.003			
Total	12914531	98				
Corrected Total	1217628.459	97				
R Squared = 0.353 (Adjusted R Squared = 0.174)						

Discussion

Pulmonary embolism, as a critical life-threatening condition, must be diagnosed and managed rapidly. Multi-slice computed tomographic angiography (MSCTA) is the first line and imaging modality of choice in PE diagnosis. MSCT is based mainly on the timing of contrast injection and image accusation at the proper time. This result shows that the average HU of the pulmonary arteries was significantly higher in the TB group than that of the BT group (392.06±110.77 HU and 298.9±93.098 HU, respectively, P=0.001). Johnson et al.[11] and Henzler et al.[12] found no significant difference between BT and TB protocols. Indeed, the Henzler et al. study found a slightly greater mean opacification of the pulmonary trunk using a BT protocol, which is the opposite of the findings of this study. Also, Bassoon et al.,[9] Wells et al.,[13] and Ramos et al.[14] assessed the effect of TB and BT, which showed higher opacification in TB protocol compared to BT in the pulmonary trunk, which is in line with this study. Another study by Cademartiri et al.[15] showed no significant visual differences between the TB and BT protocols, except that BT yielded more homogeneous enhancement than the TB protocol. However, Kavita et al. suggested that the TB protocol gave a higher contrast opacification than the BT protocol, which is the same as the study result.

Our study shows that the bilateral lobe is the most common site for PE during the TB protocol for 20(40.8%) patients, while the right lower lobe is the most common site for PE during the BT protocol for 15(30.6%) patients.

Based on the individuals' genders, a sample of 30 TB and 19 BT in female groups; additionally, male groups consisted of 19 TB and 30 BT. The tracking density shows a relatively small difference in the density of the BT female group compared to the TB female group without statistical significance. On the other hand, the TB male group showed a significantly higher density than the BT male group (P=0.001). A study by Dhamanaskar et al.[10] found no significant difference between males and females regarding the two methods.

Another study by Murphy et al.[16] showed no statistically significant difference in age between both groups. Both the TB and BT groups had a male majority. The study's tracking density was based on the subjects' age. The results showed no statistically significant differences between the two groups based on different age groups, except for the 46-55-year age group. In this age group, the TB group showed a significantly higher density (421.54±138.148 HU) than the BT group (255.2±82.155 HU), P=0.003.

This suggests that the TB protocol was more effective at enhancing contrast in this age group, possibly due to differences in the vascular anatomy or physiology of the patients in this age range. However, it's important to note that this was just one subgroup analysis, and the study's overall results should be interpreted in the context of other factors such as the sample size, study design, and other demographic characteristics of the subjects.

A three-way ANOVA performed to observe all the factors that could potentially affect opacification, including the tracking systems used, gender, and age, showed no statistically significant interaction between the effects of tracking systems, gender, and age on the tracking intensity (P=0.640). This suggests that neither gender nor age significantly impacted the effectiveness of the tracking systems used in the study.

This study had several limitations. First, the number of subjects was relatively small. Second, the data collected lacked variables like weight and exposure factors. Thus, it is necessary to conduct further studies, considering these limitations.

In conclusion, both TB and BT procedures are accurate for diagnosing PE. A TB protocol results in significantly better opacification of the pulmonary arteries in men aged 46 to 55 than the BT protocol. Subjectively, PE could be adequately assessed using the two methods.

Ethical Considerations

The study was approved by the Research Ethics Committee District as a quality assurance project No HAP-02-T-067-782.

Competing Interests

The authors declare that they have no competing interests.

References

1. Kiely DG, Kennedy NS, Pirzada O, Batchelor SA, Struthers AD, Lipworth BJ. Elevated levels of natriuretic peptides in patients with pulmonary thromboembolism. Respir Med. 2005 Oct;99(10):1286-91. doi: 10.1016/j.rmed.2005.02.029. PMID: 16099151.
2. Margoushy NM, Al-Suwat RW, Al-Otaibi WA. Incidence of Pulmonary Embolism in CCU at King Faisal Hospital, Taif, Saudi Arabia. The Egyptian Journal of Hospital Medicine. 2017;68(1):865–877. Doi: 10.12816/0038185
3. Rodrigues JC, Mathias H, Negus IS, Manghat NE, Hamilton MC. 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 Nov;67(11):1053-60. doi: 10.1016/j.crad.2012.02.010. Epub 2012 Apr 19. PMID: 22520034.
4. Aldosari S, Jansen S, Sun Z. Optimization of computed tomography pulmonary angiography protocols using 3D printed model with simulation of pulmonary embolism. Quant Imaging Med Surg. 2019 Jan;9(1):53-62. doi: 10.21037/qims.2018.09.15. PMID: 30788246; PMCID: PMC6351811.
5. Callahan MJ, Taylor GA. CT of the pediatric esophagus. AJR Am J Roentgenol. 2003 Nov;181(5):1391-6. doi: 10.2214/ajr.181.5.1811391. PMID: 14573443.
6. Kumamaru KK, Hoppel BE, Mather RT, Rybicki FJ. CT angiography: current technology and clinical use. Radiol Clin North Am. 2010 Mar;48(2):213-35, vii. doi: 10.1016/j.rcl.2010.02.006. PMID: 20609871; PMCID: PMC2901244.
7. Moore AJE, Wachsmann J, Chamarthy MR, Panjikaran L, Tanabe Y, Rajiah P. Imaging of acute pulmonary embolism: an update. Cardiovasc Diagn Ther. 2018 Jun;8(3):225-243. doi: 10.21037/cdt.2017.12.01. PMID: 30057872; PMCID: PMC6039809.
8. Suckling T, Smith T, Reed W. A retrospective comparison of smart prep and test bolus multi-detector CT pulmonary angiography protocols. J Med Radiat Sci. 2013 Jun;60(2):53-7. doi: 10.1002/jmrs.17. Epub 2013 Jun 7. PMID: 26229608; PMCID: PMC4175799.
9. Basson DJ, Moodley H. An audit of the adequacy of contrast enhancement in CT pulmonary angiograms in a South African tertiary academic hospital setting. SA J Radiol. 2022 Mar 24;26(1):2350. doi: 10.4102/sajr.v26i1.2350. PMID: 35402010; PMCID: PMC8991051.
10. Dhamanaskar KP, Figueira KS, Jerome SC, Yemen BL. Test bolus technique for detection of pulmonary emboli at 64-slice multidetector computed tomography angiography. Can Assoc Radiol J. 2013 Aug;64(3):226-8. doi: 10.1016/j.carj.2012.05.001. Epub 2012 Dec 12. PMID: 23245295.
11. Johnson TR, Nikolaou K, Wintersperger BJ, Knez A, Boekstegers P, Reiser MF, Becker CR. ECG-gated 64-MDCT angiography in the differential diagnosis of acute chest pain. AJR Am J Roentgenol. 2007 Jan;188(1):76-82. doi: 10.2214/AJR.05.1153. PMID: 17179348.
12. Henzler T, Meyer M, Reichert M, Krissak R, Nance JW Jr, Haneder S, Schoenberg SO, Fink C. Dual-energy CT angiography of the lungs: comparison of test bolus and bolus tracking techniques for the determination of scan delay. Eur J Radiol. 2012 Jan;81(1):132-8. doi: 10.1016/j.ejrad.2010.06.023. Epub 2010 Jul 10. PMID: 20621430.
13. Wells PS, Anderson DR, Rodger M, Stiell I, Dreyer JF, Barnes D, Forgie M, Kovacs G, Ward J, Kovacs MJ. Excluding pulmonary embolism at the bedside without diagnostic imaging: management of patients with suspected pulmonary embolism presenting to the emergency department by using a simple clinical model and d-dimer. Ann Intern Med. 2001 Jul 17;135(2):98-107. doi: 10.7326/0003-4819-135-2-200107170-00010. PMID: 11453709.
14. Ramos-Duran LR, Kalafut JF, Hanley M, Schoepf UJ. Current contrast media delivery strategies for cardiac and pulmonary multidetector-row computed tomography angiography. J Thorac Imaging. 2010 Nov;25(4):270-7. doi: 10.1097/RTI.0b013e3181efe8b0. PMID: 21042065.
15. Cademartiri F, Mollet NR, van der Lugt A, McFadden EP, Stijnen T, de Feyter PJ, Krestin GP. Intravenous contrast material administration at helical 16-detector row CT coronary angiography: effect of iodine concentration on vascular attenuation. Radiology. 2005 Aug;236(2):661-5. doi: 10.1148/radiol.2362040468. PMID: 16040923.
16. Murphy A, White H. A comparison of bolus track and test bolus computed tomography pulmonary angiography and the implications on pulmonary and aortic vessel enhancement, effective dose and suboptimal scan rate. J Med Radiat Sci. 2024 Mar;71(1):44-50. doi: 10.1002/jmrs.724. Epub 2023 Sep 7. PMID: 37675768; PMCID: PMC10920937.

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