Original Article

Comparison of helical and axial mode indirect computed tomographic venography in patients with pulmonary thromboembolism

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ABSTRACT

Objective: To compare the helical and axial modes of indirect computed tomographic (CT) venography (CTV) for accuracy for diagnosing deep venous thrombosis (DVT) of the lower extremities as well as for their radiation burden in patients proven to have pulmonary thromboembolism (PTE) on CT pulmonary angiography (CTPA). **Subjects and Methods:** Of patients evaluated with CTPA for suspected acute PE, 20 of patients who were found to have PTE underwent both indirect CTV of the lower extremities and color Doppler examination. For indirect CTV, patients were randomly assigned to helical and axial modes. The CTV and Doppler findings were interpreted by two experienced radiologists who were blinded to the results of each other. **Results:** Out of total of 260 venous segments analyzed (130 venous segments each by helical or axial CTV), thrombi were seen in 43 venous segments (15 and 28 each by helical or axial CTV respectively). On comparison with Doppler, helical CTV had 82.35% sensitivity and 99.11% specificity, whereas axial CTV had 96.6% sensitivity and 100% specificity. The mean radiation dose was significantly higher for helical (1153.57 mgy.cm) as compared to axial mode CTV (806.28 mgy.cm) with *P* value of <0.0001. **Conclusion:** Axial CTV results in decreased radiation dose without significant change in the accuracy, as compared to helical CTV in the evaluation of DVT.

KEY WORDS: Pulmonary embolism, CT, venography, deep venous thrombosis

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INTRODUCTION

Venous thromboembolism (VTE) is a multisite disorder which includes pulmonary thromboembolism (PTE) and deep venous thrombosis (DVT). It is a major health problem and has a wide spectrum of clinical presentations and consequences, ranging from no symptoms to a lethal outcome. Usually, a thrombus is formed in the deep venous system of the lower extremity, gets detached and lodges into the pulmonary vasculature. As most emboli originate in veins of the lower limbs, any diagnostic algorithm for PTE should include imaging for DVT and potentially clinically important site of embolism elsewhere for which lower limb is the most common site.[1,2]

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The clinical assessment of DVT of the lower limb is notoriously unreliable as two thirds of patients with venous thrombi are asymptomatic and thrombi are present in only half of patients with signs and symptoms of DVT.[2] It may be confused with other conditions such as cellulitis, leg edema, and chronic venous insufficiency. The deep veins of the lower limb can be evaluated with conventional venography, impedance plethysmography, compression sonography, Doppler sonography, CT venography, and MR venography. Each diagnostic modality has its own advantages and disadvantages. Doppler and compression sonography are widely used for the diagnosis of the DVT and has replaced contrast venography as the new reference standard due to contrast venography's invasive nature, costs, and failure rate. Color doppler has become the imaging modality of choice for the diagnosis as it has high diagnostic accuracy, ready accessibility, and has low cost.[3,4] Its disadvantages include operator dependence, less accuracy in asymptomatic individuals, limited evaluation in obese or post-operative and debilitated patients, potential pain induced by compression, and substantial limitations for the pelvic and calf veins. MR venography (MRV) provides one-stop examination for both pulmonary angiography and DVT; however, it is expensive, time-consuming, and difficult in critically ill patients.[5]

CT venography (CTV) following CT pulmonary angiography (CTPA) provides direct evidence of thrombosis in the deep veins without using additional contrast. It has advantage of being one-stop imaging procedure for VTE with reported sensitivity and specificity of 100% as compared with sonography.[6-8] It shows thrombus in the pelvic veins and IVC, which may not be evaluated with sonography. It can also be done in obese or post-operative and debilitated patients. In addition, complex venous anatomy can be surveyed and additional or alternative findings in the abdomen, pelvis, and legs can be diagnosed. Hence, the combined use of CTPA and indirect CTV is becoming the imaging protocol of choice for most patients as it has increased sensitivity for VTE detection.[6-17] This combination has the major disadvantage of increased radiation dose. Also, to our knowledge there are no standard guidelines for performing CTV and whether it should be done in discontinuous (axial) or continuous helical mode. There are only a few published studies which to our knowledge have compared axial and helical modes of indirect CTV.[6,9,12,16] They concluded that axial images have near equal sensitivity to helical images in detection of DVT and also substantially reduced the radiation dose. Our study was conducted to compare the diagnostic utility of helical and axial indirect CT venography for diagnosing DVT of the lower extremities in patients proven to have PTE on CTPA and to compare the radiation doses with each method.

SUBJECTS AND METHODS

In this prospective study, patients who were clinically suspected to have PTE underwent CT pulmonary angiography. The study was approved by the institutional review board. The axial images were reviewed during acquisition by an experienced radiologist on the console and 20 of these patients who were found to have PTE underwent indirect CT venography of the lower extremities. Doppler sonography of the abdomen and lower extremities (from inferior vena cava to popliteal veins) was performed using ATL HDI 5000 (Philips) immediately after CT pulmonary angiography. The CTV and doppler findings were interpreted by two experienced radiologists who were blinded to results of each other and were unaware of the clinical information of the patients. In the case of discordance between the observers, the final diagnosis of DVT was made by consensus and considered as hypothetical reference standard. As in all the recent studies in the literature, conventional venography was not done due to its invasive nature and known side effects.

CT pulmonary angiographies were performed using multidetector (4-slice) helical CT scanner (Qxi, Light Speed, GE Medical system, Milwaukee, Wisconsin) after taking informed consent for performing CTPA and CTV. Scanogram was taken from chest apices to lower extremities (upper third of legs were included). 150 ml of nonionic contrast material (Iohexol) was administered intravenously through antecubital vein (18 G Venflon) with the help of power injector at a rate of 4 ml/s. Scan was initiated using bolus tracking (Smart Prep protocol) by placing region of interest at main pulmonary artery and scanning was done from diaphragm to aortic arch in the caudocranial direction. Indirect CTV was done 180 s after the start of the contrast injection from the midcalf to subdiaphragmatic region (that is scanning of lower extremities and abdomen) in the caudocranial direction with patients randomly assigned to helical or axial modes (10 patients for each mode). Scan parameters were as follows: Collimation of 5 mm and interval 15 mm (for axial mode) or collimation of 5/2.5 mm (for helical mode) with table feed of 15 mm per rotation and pitch of 1.5:1. The tube current was 250-300 mAs and the peak voltage was 120 kV. CT venograms were graded into excellent, good, fair, and poor depending on the enhancement of the veins in comparison to adjacent artery and muscle. Detailed evaluation of thrombi distribution in various venous segments was also done. Radiation dose was calculated by using commercially available software on the CT scanner based on the dose on the CT dosimetery index (CTDI).

RESULTS

In 20 patients having PTE on CTPA, indirect CTV and doppler sonography was performed. Out of these, 14 (70%) were males and 6 (30%) were females. The mean age of the study group was 42.2 years and the age range was 17-70 years. Maximum patients (8) were seen in the age group of 41-50 years. The common predisposing factors in our study were prolonged immobility (8), cancer/paraneoplastic (4), cardiac diseases (2), factor V Leiden deficiency (1), and there were no identifiable predisposing factor in five patients.

Indirect CTV showed deep vein thrombosis in 13(65%) patients and doppler showed thrombosis in 12(60%) patients [Figures 1-3]. Out of the 13 cases which were positive on CTV, 10 had unilateral involvement [Figure 1] and 3 had bilateral involvement. One case with duplicated popliteal vein, with one limb containing thrombosis was not detected on doppler sonography [Figure 2]. CTV had 100% sensitivity and specificity, while Doppler had sensitivity of 92.3% and specificity of 100%, for diagnosing DVT on patient basis. CTV showed excellent/good venous opacification for thrombosis interpretation except in one patient which showed poor opacification. Of the total 260 venous segments (130 each for helical and axial mode) studied [Table 1], 43 segments showed deep venous thrombosis on CTV and 40 on doppler. DVT was seen to involve popliteal and superficial femoral veins most frequently on both CTV and doppler. Pelvic veins and IVC were the least common segments involved.

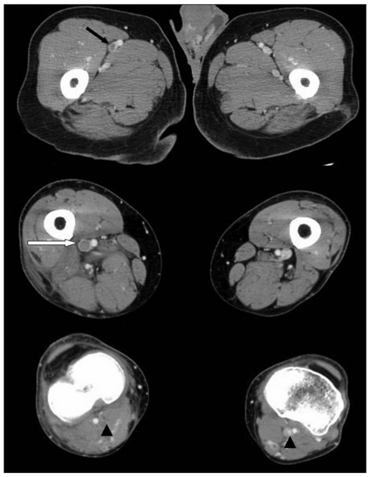

Figure 1a: 60-year-old man with left upper lobe bronchogenic carcinoma and pulmonary venous thromboembolism. CTV axial sections at level of right upper and mid thigh, and popliteal fossa showing acute thrombus involving right superficial femoral vein (black arrow), popliteal vein (white arrow) and bilateral short saphenous veins (arrowheads)

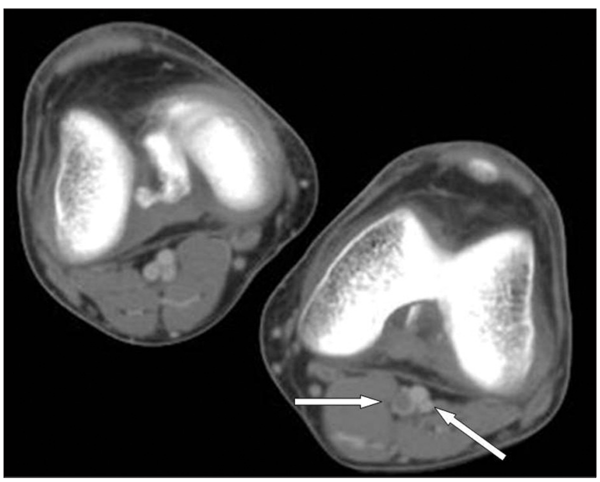

Figure 2a: 25-year-old male patient with encephalitis and prolonged immobilization. CTV axial sections at level of popliteal fossa shows bilateral duplicated popliteal veins. Medial limb of duplicated left popliteal vein shows acute thrombus (arrow). Right popliteal vein was normal

Helical and axial mode CT venography were compared to doppler sonography [Tables 2 and 3]. Helical and axial CTV showed thrombi in 15 and 28 venous segments respectively out of 130 venous segment analyzed by each mode. On comparison with doppler, helical CTV showed one false positive and three false negative results, whereas axial CTV showed only one false negative result. Helical CTV was found to have sensitivity of 82.35% and specificity of 99.11%. False positive rate and false negative rate were 6.67% and 2.68%, respectively. Axial CTV was found to have sensitivity of 96.6% and specificity of 100%. False positive rate and false negative rate were 0% and 0.98%, respectively. The difference in results of helical and axial CTV was not statistically significant. Radiation dose was calculated for helical and axial modes using commercially available software on the CT [Table 4]. The mean radiation dose for helical mode CTV was 1153.57 mgy.cm and for axial mode CTV was 806.28 mgy.cm. The "*t*" value obtained after applying "*t*" test was 12.779 which corresponds to "*P*" value of <0.0001, which indicates a significant difference in radiation dose of the two groups.

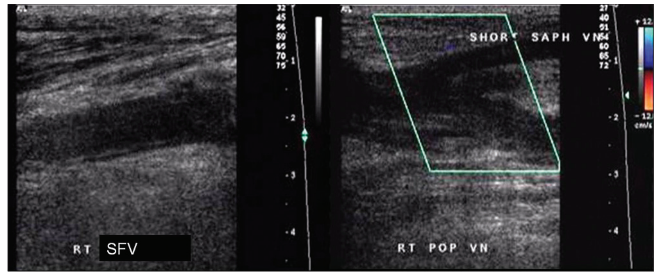

Figure 1b: Doppler USG of same patient at level of right mid thigh and popliteal fossa showing echogenic thrombus filling right SFV, popliteal vein and short saphenous vein with absence of color filling

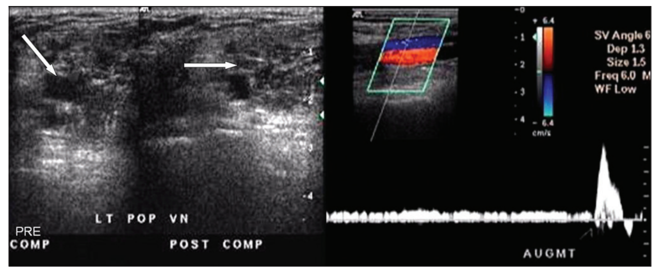

Figure 2b: Compression and Doppler USG of same patient in left popliteal fossa showing only normal popliteal vein which is compressible, has normal monophasic spectral waveform and normal response to augmentation

Table 1: Deep venous thrombi distribution in various venous segments

Venous segment studied	Venous segments affected on CTV (%)	Venous segments affected on doppler (%)
Popliteal (40)		
Isolated	3 (6.9)	1 (2.5)
Overall	12 (27.9)	11 (27.5)
Superficial femoral (40)		
Isolated	1 (2.3)	0
Overall	11 (25.6)	11 (27.5)
Deep femoral (40)		
Isolated	0	0
Overall	3 (6.9)	1 (2.5)
Common femoral (40)		
Isolated	1 (2.3)	1 (2.5)
Overall	8 (18.6)	8 (20)
External iliac (40)		
Isolated	0	0
Overall	6 (13.9)	7 (17.5)
Common iliac (40)		
Isolated	0	0
Overall	1 (2.3)	0
Inferior vena cava (20)		
Isolated	0	0
Overall	2 (4.6)	2 (5)
Total segments (260)		
Overall	43	40

CTV: CT venography

Figure 3a: 40-year-old man with acute thrombus in right pulmonary artery. CTV axial sections at level of upper thigh, mid thigh and popliteal fossa showing thrombus involving left common femoral vein, superficial femoral vein and popliteal vein (white arrows). In addition, thrombus is also seen in left popliteal artery (black arrow)

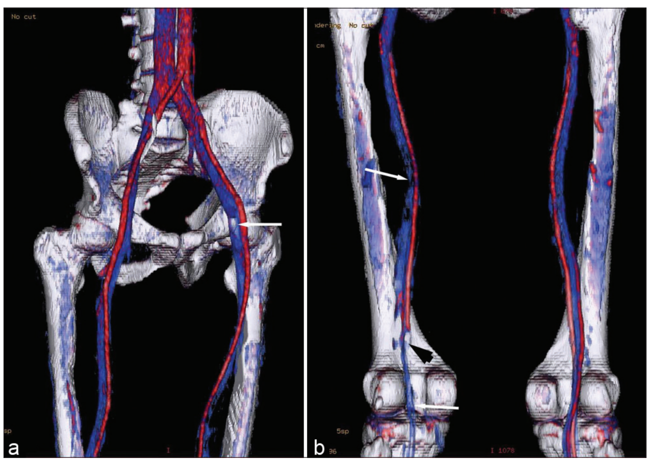

Figure 3b: Volume rendered images in anterior and posterior view in the same patient showing filling defect in the region of left common femoral vein, superficial femoral vein, popliteal vein (white arrows) and left popliteal artery (black arrow)

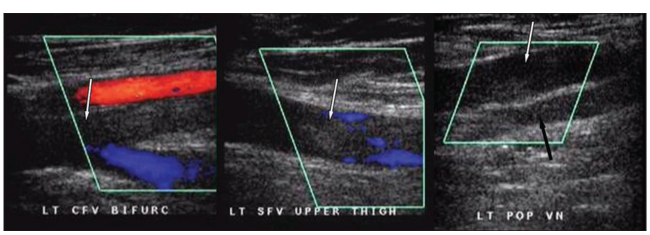

Figure 3c: Doppler USG of same patient at level left upper and mid thigh, and popliteal fossa showing thrombus filling left SFV and popliteal vein with absence of color filling. Left popliteal artery (black arrow) also showed no color fill in (thrombus)

DISCUSSION

Extension of CTPA to include leg veins in the same study serves the dual purpose of demonstrating PTE as well as DVT, which could provide the most useful way to prove or exclude PTE and predict its future risk by determining the potential source of thrombi in lower limbs.[6-12] Such a combination would be very useful to clinicians for deciding the need for an IVC filter to stop further progression of thrombi and PTE. There are many studies for venous thromboembolism (VTE) using a combined approach of CTPA and indirect CTV. However, there is no standard protocol for scanning the deep venous thrombi in the lower limbs and it is not clear whether axial or helical mode of CTV should be used. Hence, our main objective was to compare the helical and axial modes of indirect CTV for accuracy and radiation burden.

In our study, false positive and false negative helical CTV results were likely because of suboptimal opacification of the venous system due to incorrect timing of acquisition related to poor cardiac status of the patient. One false positive case on helical CTV was of a female with dilated cardiomyopathy. CTV opacification was graded as fair in this case with an equivocal thrombus in the left popliteal vein, which on Doppler was shown to be normal. False positive finding in this case can be explained due to suboptimal opacification of veins likely to be caused by

Table 2: Comparison of Doppler sonography with helical and axial mode CT venography

	CTV (helical) Total segments assessed (*n*=130)		CTV (axial) Total segments assessed (*n*=130)	
	Positive	Negative	Positive	Negative
True positive	14	3	28	1
True negative	1	112	0	101

CTV: CT venography

Table 3: Comparison of helical and axial mode CT venography

Mode of scanning	Sensitivity (%)	Specificity (%)	False positive rate (%)	False negative rate (%)
Helical CTV	82.4	99.1	6.7	2.7
Axial CTV	96.6	100	0	0.98

CTV: CT venography, CT: Computed tomographic

Table 4: Radiation dose of helical and axial mode CT venography

	Radiation dose (CTDI in mgy.cm)	
	Helical mode	Axial mode
	1247.63	799.98
	1045.31	881.61
	1268.93	771.41
	1091.46	814.27
	1183.74	757.13
	1169.54	828.55
	1091.46	785.70
	1197.94	828.55
	1109.20	842.84
	1130.50	728.55
Mean	1153.57	806.28
SD	72.4382	46.2450

CT: Computed tomographic

the patient's cardiac problem. False negative results seen in three patients were likely due to poor cardiac status of the patient, recanalization of the chronic thrombus, and progression of the thrombosis during the lag period between CTV and Doppler, respectively.

The only false negative case seen in axial CTV was a young patient with factor V Leiden deficiency. CTV opacification was rated as good in this case and convincingly showed normal right popliteal vein but Doppler done after 18 h showed thrombus in this vein. The length of the thrombus was more than 1.5 cm. Hence, the 1.5 cm section interval in axial CTV cannot be put forth as an explanation for the discordance. CTV opacification was good in this case and showed venous thrombi in other segments concordant with the Doppler findings. The only feasible explanation in this case is the new development of the thrombus during the lag period between CTV and doppler.

Loud *et al*.[6,12] evaluating the DVT with CTV concluded that as the venous thrombi are usually several centimeters long, the discontinuous axial images have almost equal accuracy to continuous helical images but with significantly reduced radiation dose. Similarly, Cham *et al*.[13] and Garg *et al*.[9] found that as most of the thrombi are more than 2 cm long, discontinuous axial images have comparable diagnostic yield but have advantage of reduced radiation burden. Begemann *et al*.[18] in their prospective study evaluating the ability of multidetector CTV concluded that using same ranges but by increasing the collimation and table feed there was statistically significant reduction of effective radiation dose without any difference in interpretation. However, in contrast, Das *et al*.[19] suggested that indirect CTV should be performed in helical scanning mode, to avoid false negative diagnosis and mistreatment. In our study, the mean radiation dose for helical mode CTV (1153.57 mgy.cm) was significantly higher as compared to axial mode CTV (806.28 mgy.cm), whereas the diagnostic results were comparable.

Our study has few limitations. Most importantly, the axial and helical images were not studied and compared in the same patient group in view of increased radiation burden. The difference in results of helical and axial CTV was not statistically significant. However, the better results with axial CTV were likely due to patient selection rather than due to technical factors. The small group (10 patients each with helical and axial modes) studied for comparison was another limitation of the study.

In all the four false negative cases on CTV, thrombi were present and detected by CTV in other venous segments; thus the overall patient management would not have been changed, had Doppler not been performed. In view of increased radiation exposure involved, CTV should be reserved for special circumstances in which Doppler sonography is difficult to perform such as obese and post-operative patients or non-diagnostic examinations.

To conclude, multidetector helical CTV does not offer any significant advantage over axial CTV and radiation dose of helical CTV with CTPA is significantly more than that of axial CTV with CTPA. Hence when indicated CTV should be performed in axial mode.

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