Diagnosis of Pulmonary Embolism By 64-Detector MDCT Combined with Doppler Ultrasonography and Indirect CTV of The Leg: A Different Protocol

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ABSTRACT

The aim of our study was to investigate the contribution of CT angiography in cases with a presumptive PTE diagnosis, evaluating lower extremity veins with CT venography and color Doppler ultrasonography (CDU) and the role of these methods at diagnosis of DVT. 46 patients with presumptive diagnosis of PTE which was confirmed with a positive CT angiography (CTA) were included in the study. Lower extremities between the iliac crest and head of femur and the popliteal region were scanned having 17-18 slices from each area, without administring extra contrast medium with a 0.8 mm slice gap. The patients underwent lower extremity CDU on the same day. Four out of 46 patients were shown to have thrombus by CDU while their CTV were normal. Two of them had an appearance of thrombus on CTV while their CDU were normal. When we consider CDU as the gold standard method, the sensitivity of CTV is calculated as 81.8% and the specificity as 91.6%. Kappa value between two modalities was calculated as 0.738 and a consistency of 87% is found. Mean radiation dose was calculated as 2.43 mSv for CTA and 0.457 mSv for CTV. With the imaging technique so-called combined CTA-indirect CTV method, DVT can be determined with moderate sensitivity and high specificity with application of low dose extra radiation.

Key words: *Pulmonary Thromboembolism, MDCT, pulmonary CT angiography, indirect CT venography, color doppler ultrasonography*

64-Detektör MDBT ile Birlikte Dopler Ultrasonografi ve İndirekt BTV'nin Pulmoner Emboli Tanısı

ÖZET

Pulmoner tromboemboli (PTE) sık görülmekle birlikte tanısındaki gecikme nedeniyle mortalitesi yüksek bir hastalıktır. PTE ve alt ekstremite derin ven trombozu (DVT) aynı patolojik sürecin iki parçası olmakla birlikte PTE' nin %90 nedenini alt ekstremite DVT oluşturmaktadır. Bu çalışmanın amacı pulmoner BT anjiografide (BTA) PTE tespit edilen olgularda, alt ekstremite derin venlerinin indirekt BT venografi (BTV) ve RDUS ile değerlendirilmesi ve son iki incelemenin DVT tanısındaki yerini araştırmaktır. Prospektif olarak, Haziran 2009 ve mayıs 2010 tarihleri arasında, ön tanısında PTE olan ve pulmoner BTA' de PTE tespit edilen 46 hasta çalışmaya dahil edildi. Pulmoner BTA sonrasında indirekt BTV incelemesi ayrı iki bölge (iliak krestler-femur başı arası ve popliteal bölge) alınarak, ek kontrast madde verilmeden yapıldı. Hastalar aynı gün içinde alt ekstremite venlerine yönelik renkli doppler ultrasonografi (RDUS) ile değerlendirildi. Hastaların aldığı radyasyon dozları hesaplandı. Çalışma dahilindeki 22 erkek (ortalama yaş: 48,7) ve 24 kadın (ortalama yaş: 63,4) toplam 46 hastanın tümünde PTE vardı. 46 hastanın 22' sinde RDUS' de DVT saptanmış olup 4 hastada RDUS' de trombüs varken BTV normaldi. 2 hastada da RDUS normal iken BTV' de trombüs görünümü vardı. RDUS altın standart kabul edildiğinde indirekt BTV'nin duyarlılığı: %81.8 seçiciliği: %91.6 olarak hesaplandı. İki tetkik arasında Kappa değeri: 0.738 olarak hesaplandı ve %87 tutarlılık olduğu saptandı. BTA çekimi için hastanın aldığı ortalama radyasyon dozu 2.43 mSv, indirekt BTV için verilen ek radyasyon dozu ise 0.457 mSv olarak hesaplandı. Kombine BTA-indirekt BTV yöntemi olarak adlandırılan inceleme tekniğinde çok yüksek duyarlılıkta olmasa bile yüksek seçicilik oranında, düşük dozda ek radyasyon verilerek DVT saptanabilmektedir.

Anahtar kelimeler: *Pulmoner tromboembolizm, MDBT, pulmoner BT anjiografi, indirekt BT venografi, renkli dopler ultrasonografi*

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INTRODUCTION

Pulmonary tromboembolism (PTE) and venous thromboembolism (VTE) are common disorders which can be fatal and require urgent treatment (1). It is the most frequently encountered emergency condition observed following surgical intervention, delivery, long bed rest and trauma (2). Mortality rate for patients not receiving treatment is 25-30%, while it is 5-8% for patients receiving treatment. Pulmonery embolism can present with myriad manifestations. In many of the cases, diagnosis is made in autopsy. Clinical prediction rules and laboratory tests are employed to assess the possibility of pulmoner embolism. Definitive diagnosis is often made via imaging methods (3). Ninenty percent of the PTE cases results from deep ven trombosis (DVT) (4).

Different diagnostic methods are used for PTE and DVT, which are two different components of the thromboembolic disease.Today, among these methods BTA for the diagnosis of PTE and RDUS for DVT have been established as the initial and baseline imaging methods (5, 6). However, during application of these two different methods there may be some problems such as the need for separate space and extra time, difficulties in patient transfer, delay in the diagnosis and failure to use RDUS effectively in some patients. Recently, in patients undergoing CTA for PTE, venous structures below the level of diaphragm have been assessed with CT venography sections obtained after waiting for some time based on the supposition that adequate opacification would be attained without administration of additional contrast medium. Thrombi in the deep venous system that could lead to PTE can be investigated with so-called indirect CTV method just after pulmonary CTA without a need for extra contrast medium (6,7).

The aim of this study was to investigate the contribution of CTA in the diagnosis in cases with a presumptive PTE diagnosis. In addition we aimed to assess lower limb deep veins via indirect venography and RDUS and find out the role of these two investigations in the diagnosis of DVT.

MATERIALS AND METHODS

Forty-six patients including 22 male (average age: 48,7) and 24 female (mean age: 63,4) who were referred to the CT Unit at Radiology Department of our hospital with a presumptive PTE diagnosis between June 2009 and May 2010 and were diagnosed with embolism in pulmonary artery and its branches, were included in the study. CTA and CTV were performed with 64 detector multislice CT (Sensation 64, Siemens Medical Solutions, Erlangen, Germany). Before the procedure a vascular access was attained on antecubital vein with a 18-20 G catheter. Patients were appropriately positioned to be able to examine lower extremities as well. 100 mL nonionic contrast medium was infused by means of an automated injector at a rate of 4 mL/second from the antecubital vein. Sections were started to be taken just after contrast density reached 180 HU at pulmonary truncus. Twently mililiter and 40 mL isotonic saline were injected via automatic injector before and after contrast medium injection, respectively. The patients were asked to hold their breath during the examination. Investigation was performed at supine position with hands over head levvel to preclude artefacts. CT imaging parameters from the level of diaphragm to the lung apex: 100 kv, 135 mAs, 64X0,6 colimation, pitch value 0.9 and start delay 5 seconds. Then reconstruction images were created as 1 and 5 mm section thicknesses. Vascular structures were evaluated from the images with 1 mm section thickness. Pulmonary paranchymal structures were evaluated from images with 5 mm section thickness. Indirect CTV was performed as to range from iliac crests to the level of femoral heads and from popliteal fossa up to 10 cm proximal of it. This procedure was started 3 minutes after contrast administration and extra contrast was not used for indirect CTV. CTV images were acquired at cranio-caudal direction with the following imaging parameters: 120 kv, 100 mAs, 64x0.6 colimation, section interval 0.8 mm and section thickness 2 mm. Pulmonay CTA and CTV images were evaluated in terms of PTE and DVT, respectively. Whether venous opacification degree is optimal was checked via density measurement in the main femoral vein. Whereas the minimum and maximum values measured from main femoral vein were 75 and 140 Hounsfield Units (HU), respectively, the mean value was determined as 95 HU. In 3 patients, values <70 HU was measured, hence these patients were excluded due to insufficient contrast density. After CTA procedure in patients who were referred with symptoms suggestive of pulmonary embolism such as shortness of breath, chest pain and hemopthysis CT images were evaluated rapidly within 1-2 minutes. Confirmation of pulmonary embolus during this procedure was deemed as a necessary inclusion criterion in this study. In all 46 patients included in the final analysis

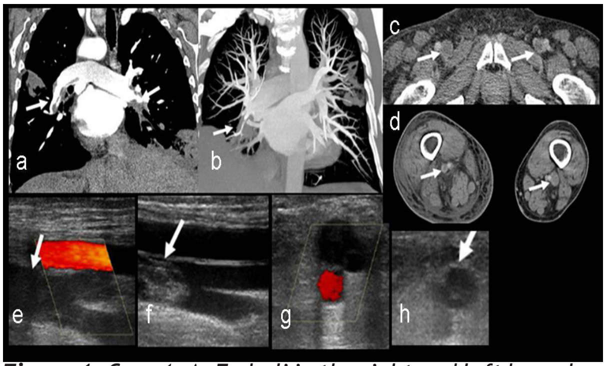

Figure 1*. Case 1. A. Emboli in the right and left branches of pulmonary artery (arrows) in the coronal curved MIP reformatted images B. Embolus in the right descending branch of pulmonary artery in coronal MIP reformatted images C. Filling defects in bilateral main femoral veins (arrows) in indirect CTV and popliteal veins D. (arrows) E. Absence of flow in the right femoral vein in Doppler (arrow) F. Echogenic thrombus in the left main femoral vein (arrow) G. While flow can be seen in right popliteal artery, hypoechogenic thrombi are evident in right popliteal vein G. and left popliteal vein H. lumens.*

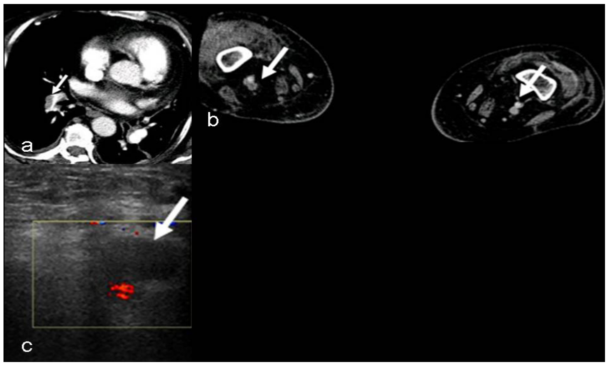

Figure 2*. Case 2. A. Filling defect in the descending segmentary branch of the right pulmonary artery (arrow) in pulmonary CTA B. Hypodense filling defect in the right popliteal vein in indirect CTV. Left popliteal vein is normal C. Thrombus in the right popliteal vein in Doppler Ultrasound.*

pulmonary embolism was documented with CTA. An experienced radiologist made a detailed examination beginning from main pulmonary arteries to subsegmentary branches with regards to presence of emboli which was confirmed with a filling defect. All of the cases which were deemed to have pulmonary emboli were confirmed after detailed examination as well. During this thorough examination, lung paranchyma in the imaging area and extravascular structures in the CTV sections were also assessed. Indirekt CTV sections were assessed by the radiologist who was blided to doppler ultrasound results. On the same day of indirect CTV, all patients underwent renal doppler ultrasound examination comprising an aria starting from vena cava inferior distal part to

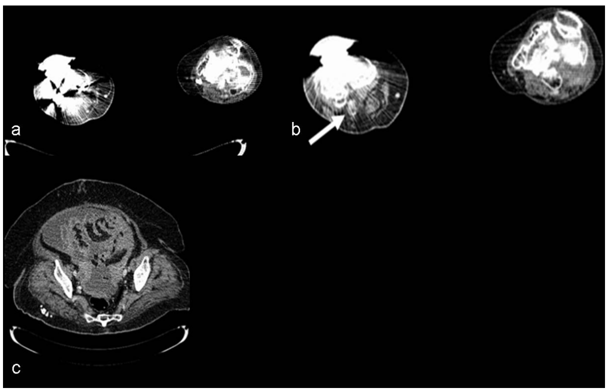

Figure 3*. Case 3. A. Indirect CTV showing an artefact due to bilateral knee implant, B. Thrombus in the right popliteal vein (arrow), C. Intraabdominal free fluid in the same patient.*

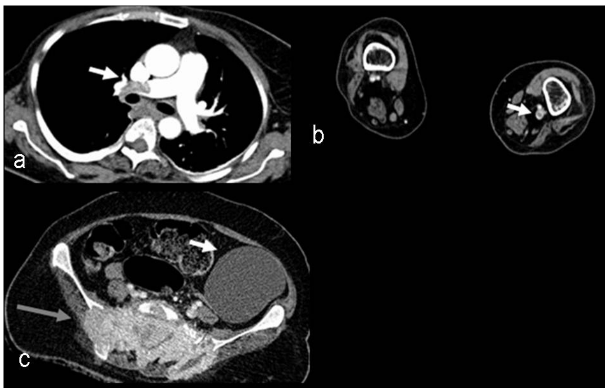

Figure 4*. Case 4. In sections of indirect CTV A. Filling defect in right main pulmonary artery, B. Thrombus in the left popliteal vein (arrow) C. Note sacral mass (gray arrow) and intraabdominal cyst in lower left quadrant (white arrow).*

***Table 1.** PTE localizations in study patients*

PTE localizations in study patients	n (%)
Main pulmonary artery and distal branches	16 (34.8)
Segmental branches and distal branches	25 (54.3)
Isolated subsegmental	5 (10.9)
Total	46

***Table 2.** DVT localizations in study patients*

DVT localizations	n (%)
Iliac vein, femoral ven, popliteal and crural vein	3 (13.6)
Femoral, popliteal vein and crural vein	7 (31.8)
Femoral and popliteal vein	4 (18.2)
Femoral vein	1 (4.54)
Popliteal and crural vein	2 (9.09)
Popliteal vein	4 (18.2)
Crural vein	1 (4.54)
Total	22

the popliteal vein trifurcation. RDUS procedure was carried out with the color doppler device, "GE Logiq S6". The venous structures from the main femoral vein to the level of popliteal vein trifurcation were evaluated with linear probe (10 MHz), while the distal segment of the inferior vena cava and iliac veins were evaluated with a convex probe (3,5 MHz). First, grey scale images and the diameter of veins, the changes in diameters with respiration, response to compression, the structure of the vessel wall and the lumen were evaluated. Later, it was documented whether there was flow in the lumen via color doppler investigation, and if there was any, the form of the flow was analysed and reported. The presence of thrombus in the lumen, the degree of vessel response to the compression (decrease or disappeareance), absence of flow in the doppler or various other findings (recanalised flow, collaterals, etc.) were deemed as the criteria for the diagnosis of DVT. After all these findings were documented, indirect CTV results were compared with USG results. The sensitivity and specificity of CTV in the diagnosis of DTV were investigated.

RESULTS

Forty-six patients included in the study underwent CTA and indirect CTV carried out with a 64-detector multislice CT. Since one patient died before doppler investigation and the another one had extreme edema in the lower extremity, they could not undergo doppler investigation and they were excluded from the study. In total, there were 47 patients who underwent doppler examination. PTE localizations according to the number of patients and DVT localizations are shown in Tables 1 and 2, respectively (Figures 1-4). At least 70 HU of contrast density in measurements of femoral vein with indirect CTV was stipulated as a prerequisite. The mean value for our patients was found to be 95 HU. As three of the patients had a contrast density level below 70 HU, they were not included in the study. In the evaluation of CTV, additional pathologic findings identified except from DVT (Figures 3,4) (Table 3) were also recorded. The data for two patients were excluded, as they did not take doppler investigation, and the total number of excluded patients was three. All of the 46 patients included in the study had PTE.

In the present study, D-dimer test was performed in 14 patients, and all of them had positive results. As there wasn't available kit in our hospital at that time, the rest of the patients did not undergo the test. Indirect CTV versus Doppler (Table 4): Sensitivity , specificity, positive predictive value and negative predictive value were calculated as 81.8%, 91.6%, 90% and 84.6%, respectively. Indirect CTV and Doppler USG were found to be consistent (kappa value: 0.738). SPSS package program was used for statistical analysis. The mean radiation dose received by the patients for pulmonary CTA, inguinal CTV and popliteal CTV were found as 2,43 mSv, 0,45 mSv, and 0,0072 mSv, respectively. The mean total dose was calculated as 2,89 mSv.

DISCUSSION

PTE is still among the three most common reasons for mortality. Annual incidence is between 0.5 and 1 for every 1000 people (8). In addition to being considered as one of the inexplicable reasons of death among the hospitalized patients, it is the subject of many malpractice suits (9). Mortality rates in patients who have been diagnosed with the disease and received treatment in time, are reported as 3-8%. If the diagnosis is missed,

Table 3. Pathologic findings other than DVT in indirect CTV

Pathologic findings other than DVT in indirect CTV	n
Pelvic free fluid	6
Sacral mass	1
Intraabdominal cyst	1
Popliteal Cyst	2
Hematoma in the popliteal region	1
Inguinal lymphadenopathy	1
Fat tissue herniation into bilateral inguinal canal	1

Table 4. Patient numbers, Indirect CTV versus Doppler

	Doppler		
	Positive	negative	total
CTV			
Positive	18	2	20
Negative	4	22	26
Total	22	24	46

mortality rate increases by 3-4 folds (10, 11). Although the clinical picture of PTE can be dramatic sometimes, patients are often found with obscure clinical manifestations or they can be completely asymptomatic. Nonspecific symptoms such as hemoptysis, chest pain and dyspnea can also be found, and this triad can be observed in 20% of the patients (12).

VTE trombophlebitis is an entity secondary to DVT and PTE, and it consitutes one of the major reasons for moratlity and morbidity. Majority of pulmonary emboli originate from iliac, deep femoral and popliteal veins. Moreover, some studies report that 90% PTE originate from thrombi in the lower extremity veins (13). Spiral BT is becoming a widely accepted investigation method for PTE diagnosis in proximal pulmonary arteries. It is a fast, and nonivasive technique which can be employed in many hospitals. However, isolated subsegmental emboli and veins horizontal to the CT axis cannot be visualized in spiral CT and lynph nodes can be interpreted as PTE by mistake. Sensitivity and specificity values for spiral BT at subsegmenter level emboli can decrease to 60-70% (14). MDCT is faster than CT, and is more senstive in terms of the evaluation of the subsegmenter branches. Stein et al. found that the specificity of CTPA in diagnosing embolus has been found as 83%, while the sensitivity value has been found to be 96% with MDCT (15). It is reported that the primary risk factor in repeated pulmoner embolism is presence of residual proximal venous thrombosis (16). This indicates the importance of evaluating lower extremity veins in terms of DVT in cases of PTE. Thus, in a number of studies lower extremities of the patients suspected of PTE have been assessed with invasive and noninvasive diagnostic methods regarding the presence of DVT (17). It has become a necessity that the search for PTE and DVT are performed with a single investigation since approximately 90% of PTE arise from thrombus in deep veins of the lower extremities and patients with PTE are usually critically ill with severe dyspnea.

The so-called "combined CTA-indirect CTV" technique in which use of pulmonary CTA is coupled with indirect CTV to screen leg veins, is the most commonly used method for this purpose (7, 18-19). Novadays this investigation can be rapidly performed by means of MDCT whose use is ever becoming more common. Despite ongoing studies in this field, there is not an investigation method upon which a consensus is made. The rationale behind combined CTA-indirect CTV is evaluation of leg veins after pulmonary CTA without a need for extra contrast medium use. The procedure consists of, though studies differ, screening of venous structures from diaphragm to popliteal region with a 1-5 mm slice gap and 5-10 mm slice thickness after a delay of application of pulmonary CTA (7, 18). Although various approaches exist as to duration of delay following pulmonary CTA to start CTV procedure, a delay time of 3-5 minutes is generally accepted.

Goodman and colleagues utilized a 3 minutes delay time in their study (20). We also used 3 minutes delay time considering our study generally had older patients. After determining the delay time, the criterion employed to decide whether the examination is diagnostic or not is the HU value of opacification in venos structures. Balt et al has reported that an HU value of 60 and above is adequate for venos evaluation. Goodman et al, on the other hand, stated that according to the measurements taken from main femoral vein, HU values below 70 were not diagnostic (20,21). We accepted 70 HU as the threshold for our study. There is no agreement on investigation of which regions of venous structures are necessary and sufficient in combined CTA-indirect CTV method. The regions investigated differ in the literature. In addition to the studies investigating the region between diaphragm and popliteal fossa, there are studies screening the region between iliac crest and popliteal fossa (7,8). We examined the region between iliac crests, femoral head and the popliteal fossa. Another factor with different applications in studies is the section thickness and interval. In the literature, it is possible to find studies carried out with spiral CT most frequently, and it is observed that in these studies the section thickness and interval were chosen as 5-10 mm and 2-5 cm, respectively (7,18). However, there is no research on the efficiency and reliability of the utilization of these parameters in the diagnosis of DVT by CTV.

We aimed at keeping the radiation dose received by the patient at a low level as carrying out our investiagtion in two short segments. To this end, we took one segment from the iliac crests to head of femur, and another segment from the popliteal region level at 0.8 mm section intervals. One patient was diagnosed with thrombus in distal part of superficial femoral vein by RDUS, but since this region was not within the limits of investigation thrombus could not be visualized in CTV.

One additional difference of our study with the previous literature is that the performance of indirect CTV in only cases with pulmonary embolism diagnosis. A quick glance at the literature reveals that in various studies using the combined CTA-indirect CTV method RDUS was accepted as the gold standart technique and very different sensitivity and specificity values were reported for indirect CTV. The values for sensitivity and specificity range from 71% to 100% and 93% to 100% , respectively (20-23). In the present study, the sensitivity value was calculated as 81.8%, while the specificity value was found to be 91.6%. The reasons for why our values are lower compared to the values in the previous studies can be explained in the following way: There were patients in the literature who couldn't be evaluated with RDUS due to the plaster in their legs, but underwent CTV (6). We did not have such cases in our study. As we restricted our investigation to the pelvic and popliteal regions, one patient had thrombus in distal part of the superficial femoral vein, and this region could not be seen in CT since it was outside the borders of the imaging region. Some patients who have leg edema cannot be evaluated with RDUS in terms of DVT, and alternatively they can be evaluated with CTV. One of our patients could not undergo RDUS due to extreme leg edema, however, due to the circulation problem of the patient adequate opasification could not be obtained in the veins in indirect CTV either.

What makes our study different from other studies in the literature is that only the patients who were diagnosed with PTE underwent indirect CTV. With an aim to keep the radiation level received by the patient at minimum levels, incremental scanning method was employed in our research and rather than scanning the whole leg, sections were taken from the popliteal region in two parts. The average amount of dose taken by the patient was calculated. According to this, the dose taken by the patient for pulmonary CTA, the popliteal region and the inguinal region were found to be 2.43 mSv, 0.0072 mSv and 0.45 mSv, respectively. When the indirect CTV is added to the average dose of 2.43 mSv given for CTA, the amount of additional dose given is found to be 0.457 mSv. Looking at these results, it is possible to conclude that the additional dose given to the patients is not too high. In the literature it is observed that in some of the studies CTA-CTV is applied on a routine basis in patients with suspected PTE (6,21,22), but in some of the recent studies (24) it is seen that for patients with PTE clinic and a high level of risk (patients with malignity, VTE history or surgical intervention in the preceding 4 weeks, patients with cardiovascular disease), CTA and CTV are applied together in order to avoid extra cost and unnnecessary radiation. In a study carried out with a 4 detector MDCT comparing CTV and RDUS the total amount of dose given to the patients has been calculated.

The amount of dose given to women is found as 2.31 mSv when only CTA is applied, but the dose has been found to increase to 8.31 mSv when CTA and CTV were combined. In the present study, CTV protocol was determined as 4X2.5 mm colimation, and the table speed was decided as 12.5 mm. Similar findings were found for the men. It was found that when the protocol colimation and table speed are incresaed to 4X5 and 25 mm, respectively, the dose of radiation received by the patient decresases by 11%. We also prefered to apply CTV investigation in patients diagnosed with PTE by CTA only instead of examining all patients. It is possible to find out some other pathologies in addition to DVT in the indirect BTV investigation carried out to investigate the DVTs in the lower extremities. In our study, in addition to venous thrombosis other pathologies such as pelvic free fluid (n=6), sacral mass (n=1), intraabdominal cyst (n=1), popliteal cyst (n=2), hematoma in the politeal region (n=1), inguinal lymphadenopathy (n=1) and fat tissue herniation into bilateral inguinal canal were also identified. Although combined CTA-indirect CTV method is a quick study to detect PTE and DVT, the two different components of VTE, in a single session BT investigation, it has still some limitations and drawbacks. The missing point is that although there is research carried out in this field, there are various applications for the investigation protocol and there is not any consensus. Section thickness and interval, scanning method (incremental or helical) are applied in different values in different protocols. It is known that joint prosthesis and metalic artefacts can influence/hinder the evaluation. One of our patients also had metalic artefacts caused by the prosthesis in the popliteal region. However, these artefacts did not preclude DVT evaluation.

In conclusion, the investigation technique called as combined CTA-indirect CTV can help to identify DTV at a high level of sensitivity, although the specificity level is not too high. Moreover, the additional dose of radiation given for indirect CTV is quite low in this protocol. Especially, when it is taken into consideration that the patients with PTE are old with dyspnea, and that early diagnosis is crucial to VTE, this method can be used as an alternative to RDUS. However, additional studies with larger sample sizes are needed to define the most appropriate protocol for the combined CTA-indirect CTV method.

REFERENCES

1. *Stein PD, Woodard PK, Weg JG, et al. Diagnostic pathways in acute pulmonary embolism: recommendations of the PIOPED II investigators. Radiology 2007; 242:15-21.*
2. *Yankelevitz DF, Gamsu G, Shah A, et al. Optimization of combined CT pulmonary angiography with lower extremity CT Venography AJR 2000; 174:67-9*
3. *Kalva SP, Jagannathan JP, Hahn PF, Wicky TS. Venous Thromboembolism: indirect CT Venography during CT Pulmonary Angiography—Should the Pelvis Be Imaged? Radiology 2008; 246:605-11.*
4. *Taffoni MJ, Ravenel JG, Ackerman SJ. Prospective comparison of indirect CT venography versus venous sonography in ICU patients. AJR 2005;185:457-62*
5. *Loud PA, Katz DS, Klippenstein DL, Shah Grossman ZD. Combined CT venography pulmonary angiography in suspected thromboembolic disease: diagnostic accuracy for venous evaluation. AJR 2000;174:61-5.*
6. *Torbicki A, Perrier A, Konstantinides S, et al. Guidelines on diagnosis and management of acute pulmonary embolism. Eur Heart J 2000; 21:1301-36.*
7. *Nazaroğlu H, Ozmen CA, Akay HO, Kilinç I, Bilici A. 64-MDCT pulmonary angiography and CT venography in the diagnosis of thromboembolic disease. AJR 2009;192:654-61.*
8. *Gillum RF. Pulmonary embolism in the United States, 1970-1985. Am Heart J 1987; 113:1262-4.*
9. *Tapson VF. Prophylaxis strategies for patients with acute venous thromboembolism. Am J Manag Care 2001;7:524-34.*
10. *Rodger M, Wells PS. Diagnosis of pulmonary embolism. Thromb Res 2001;103:225-38.*
11. *Carson JL, Kelley MA, Duff A, et al. The clinical course of pulmonary embolism. N Engl J Med 1992; 326:1240-5.*
12. *Miniati M, Prediletto R, Formichi B, et al. Accuracy of clinical assessment in the diagnosis of pulmonary embolism. Am J Respir Crit Care Med 1999;159: 864-71.*
13. *Catheline JM, Turner R, Gaillard JL, Rizk N, Champault G. Thromboembolism in laparoscopic surgery: risk factors and preventive measures. Surg Laparosc Endosc Percutan Tech 1999;9:135-9.*
14. *Virginia WK Au, Walsh G, Fon G. Computed tomography pulmonary angiography with pelvic venography in the evaluation of thrombo-embolic disease Australasian Radiology 2001;45:141-5.*
15. *Stein PD, Hull RD. Multidetector computed tomography for the diagnosis of acute pulmonary embolism. Curr Opin Pulm Med 2007;13:384-8.*
16. *Prandoni P, Lensing AW, Prins MH, et al. Residual venous thrombosis as a predictive of recurrent venous thromboembolism. Ann Intern Med 2002; 137:955-60.*
17. *Beecham RP, Dorfman GS, Cronan JJ, Spearman MP, Murphy TP, Scola FH. Is bilateral lower extremity compression sonography useful and cost-effective in the evaluation of suspected pulmonary embolism? AJR 1993; 161:1289-92.*
18. *Duwe KM, Shiau M, Budorick NE, Austin JHM, Berkmen YM. Evaluation of the lower extremity veins in patients with suspected pulmonary embolism: a retrospective comparison of helical CT venography and sonography. AJR 2000; 175:1525-31.*
19. *Loud PA, Grossman ZD, Klippenstein DL, Ray CE. Combined CT venography and pulmonary angiography: a new diagnostic technique for suspected thromboembolic disease. AJR 1998; 170:951-4.*
20. *Goodman LR, Stein PD, Matta F, et al. CT venography and compression sonography are diagnostically equivalent: data from PIOPED II. AJR 2007; 189:1071-6.*
21. *Baldt MM, Zontsich T, Stümpflen A, et al. Deep venous thrombosis of the lower extremity: efficacy of spiral CT venography compared with conventional venography in diagnosis. Radiology 1996; 200:423-8.*
22. *Loud PA, Katz DS, Bruce DA, Klippenstein DL, Grossman ZD. Deep venous thrombosis with suspected pulmonary embolism: detection with combined CT venography and pulmonary angiography. Radiology 2001; 219:498-502.*