COMPARISON OFDUAL ENERGY CT LUNG PERFUSION VERSUS LUNG VENTILATION/PERFUSION SCINTIGRAPHY IN PULMONARY EMBOLISM

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ABSTRACT:

Background: *Pulmonary Embolism PE is a potentially fatal disorder and the third most common acute cardiovascular disease, after myocardial infarction and stroke. In current clinical practice Lung Ventilation / Perfusion Scintigraphy is mainly used to exclude PE andComputed Tomography Pulmonary Angiography CTPA has now been widely accepted as the standard test for the diagnosis of acute pulmonary emboli.*

Aim of work: *to compare the performance of dual energy computed tomography lung perfusion and ventilation/perfusion scintigraphy in the detection of pulmonary embolism.*

Patients and Methods: *Twenty-six patients with suspected acute pulmonary thromboembolism underwent both DECT and SPECT V/Q scanning. Nine of these patients were females and 17 were males. Average age of the patients was 55.2 years. The diagnostic value of DECT lung perfusion imaging was assessed regarding V/Q SPECT as standard of reference. Diagnostic accuracy was calculated per patient and per segment using standard contingency tables. Chi-square test and Receiver operating characteristic curve were to assess sensitivity, specificity, positive predictive value, negative predictive value and accuracy taking SPECT as a gold standard.*

Results: *acute PE was diagnosed in 19 patients based on DECT findings and in 16 patients based on nuclear medicine findings. Concordant positive diagnoses were made in 16 patients. Two patients had segmental and subsegmental perfusion defect in both imaging modalities. Due to a correlative ventilation defect (matched V/Q SPECT), this finding was rated as being consistent with prior PE in nuclear medicine imaging. However, CTPA findings suggested acute PE due to an intraluminal filling defect in the supplying segmental artery that showed a typical configuration of a recently developed embolus.One patient result was false negative with homogeneous perfusion in both DE iodine mapping and SPECT, there was non-occlusive embolus at the segmental level outlined by contrast material. Seven cases showed negative diagnoses, i.e. no evidence of PE. Sensitivity/specificity for the detection of perfusion defects were thus 82.9% and 100% by DECT iodine perfusion mapping per segment and combined DE-CTPA had a sensitivity/specificity of 100%/100% for detection of acute PE per patient.*

Conclusion: *DECT is the test of choice for the evaluation of suspected PE due to its availability, speed, high accuracy, and ability to identify alternative diagnoses.*

Key word: *Lung Perfusion, Scintigraphy, Ventilation, Pulmonary Embolism.*

INTRODUCTION:

Pulmonary Embolism is a potentially fatal disorder and the third most common acute cardiovascular disease, after myocardial infarction and stroke. Computed Tomography Pulmonary Angiography (CTPA) has now been widely accepted as the standard test for the diagnosis of acute pulmonary emboli.

Unfortunately, CTPA only provides morphological information and its ability to assess subsegmental pulmonary arteries is variable (1&2).

With the development of modern diagnostic methods, the role of Lung Ventilation/Perfusion Scintigraphy (V/Q Scan) in the work up of patients with suspected PE has also changed. In current clinical practice Lung Ventilation/ Perfusion Scintigraphy is mainly used to exclude PE(3).

The concept of Dual Energy Computed Tomography (DECT) originated in the 1970s. It was only recently that advances in CT scanner technology, including both dual-source and single-source configuration made DECT feasible for routine clinical use.

Dual energy CT Pulmonary Perfusion offers a functional aspect to CTPA when iodine map from DECT is used and the detectability of small endoluminal clots in segmental and subsegmental pulmonary arteries is expected to improve. DECT refers to the CT that uses two photon energy spectra (one high and one low) and can differentiate iodine from the normally present air, blood and lung parenchyma differentiation is based upon specific shifts in attenuation differences at high and low x-ray energies(4,5,6).

In this study DECT Lung Perfusion and Lung Ventilation/Perfusion Scintigraphy are directly compared to evaluate feasibility of the simultaneous detection performance of DECT Lung Perfusion and Pulmonary Angiography.

PATIENTS AND METHODS:

Study population: this prospective study was performed with local institutional review board approval and individual informed consentin Al-Adan Hospital, Kuwait.Over a period of 6 months (June 2019 to December 2019), 26 patients with suspected acute pulmonary thromboembolism underwent both DECT and SPECT V/Q scanning. The diagnosis of acute pulmonary thrombo-embolism PTE was made using clinical presentation and imaging tests. Mean time interval between DECT and SPECT-CT V/Q scanning was 3 days. Nine of these patients were females and 17 were males. Average age of the patient was 55.2 years. Exclusion criteria included contraindications to contrast administration and pregnant females.

Study Procedures:

(1) DECT examination: Dual-energy CT angiography was performed using a single source 64-slice CT scan, Discovery 750HD (General Electric Healthcare, Milwaukee, WI, USA) after injection of 60 ml iodinated contrast agent (Iodixanol, GE Medical Diagnostics, Amersham, UK) a flow rate of 4 mL/s, triggered in the pulmonary trunk. DECT scan settings were 140/80 kVp, 64 × 0.625 mm, rotation time 0.7 s, average tube current 275 mA, pitch 1.38 and CTDI vol 7.6 mGy. Material decomposition (iodine versus water) was used to reconstruct iodine perfusion maps. In the evaluation, the reader took the iodine map and lung anatomy into account to differentiate artifacts from true segmental or subsegmental perfusion defects.

(2) V/Q SPECT scan examination: V/Q imaging was performed in the nuclear medicine department as a perfusion SPECT examination and a planar inhalation scintigram. V/Q SPECT acquisition were done with a dual head gamma camera (GE Millennium VG5 SPECT scanner). Perfusion studies were acquired first after intravenous administration and activity of 170 MBq Tc99m labelled macro aggregates of albumin in supine position with their arms raised behind the head using a dual-head camera at tidal breathing. Eight standard projections were obtained for both scans, i.e. anterior, posterior, right posterior oblique, left posterior oblique, right anterior oblique, left anterior oblique and left and right lateral. Emission (180◦ SPECT acquisition, high-resolution low-energy collimators, matrix size of 128×128, 3◦ angle steps, 15s per frame) and transmission data were acquired sequentially at tidal breathing and fused with a dedicated workstation (Hybrid Viewer version 1.1; Hermes Medical Solutions, Stockholm, Sweden). After the perfusion examination, patients underwent planar ventilation imaging following inhaling of 1700MBq of aerosolized 99m Tc-Technegas (Cyclomedia Germany GmbH, Salzgitter, Germany) until three times as much counts/s had reached the lungs as had been measured in the perfusion examination. All patients carefully maintained their supine positions during acquisition time. SPECT ventilation projections were acquired in matching eight views (anterior, posterior, right posterior oblique, left posterior oblique, right anterior oblique, left anterior oblique and left and right lateral; 750.000 counts/view; zoom factor 1.45).

Parameters for acquisition: 32 stops over 180◦/head, with 10s/stop for Q and 20 s/stop for V, 64 × 64 matrix; iterative image reconstruction (OS- EM). Corresponding V and Q reconstructed images were displayed in orthogonal planes and scored visually.

Perfusion and ventilation scintigrams were assessed by an experienced nuclear medicine physician blinded to the findings of DECT perfusion or CTA. The diagnosis of pulmonary embolism was based on a mismatch between perfusion and ventilation following the PIOPED classification.

Finally, the diagnostic value of DECT lung perfusion imaging was assessed regarding V/Q SPECT as standard of reference. Diagnostic accuracy was calculated per patient and per segment using standard contingency tables.

Statistical Methods:

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. Relation between DECT and SPECT was done by using Chi-square test and Receiver operating characteristic curve was done in the form of qualitative data to assess sensitivity, specificity, positive predictive value, negative predictive value and accuracy taking SPECT as a gold standard. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant at $p < 0.05$.

RESULTS:

All examined 26 patients were symptomatic (table 1), 17 out of 26 patients were previously healthy and 9 patients had known underlying disease (table 2).

In 26 patients, a total of 468 lung segments (18 segments per patient) were analyzed for the presence or absence of perfusion defects or of acute PE. Comprehensive reading of V/Q SPECT on the one hand and with CTPA and DE iodine perfusion maps on the other hand led to the diagnosis of acute PE in 19 patients based on DECT findings and in 16 patients based on nuclear medicine findings. Concordant positive diagnoses were made in 16 patients.

Two patients had segmental and subsegmental perfusion defect in both imaging modalities. Due to correlative ventilation defect (matched V/Q SPECT), this finding was rated as being consistent with prior PE in nuclear medicine imaging. However, CTPA findings suggested acute PE due to an intraluminal filling defect in the supplying segmental artery that showed a typical configuration of a recently developed embolus. One patient result was false negative with homogeneous perfusion in both DE iodine mapping and SPECT; there was non-occlusive embolus at the segmental level outlined by contrast material. Seven cases showed negative diagnoses, i.e. no evidence of PE; with perfusion patterns were concordantly rated as being homogeneous or slightly patchy.

Circumscribed perfusion defects were found in patients with PE and corresponded well with locations of embolic vessel occlusion in CTPA. DECT iodine mapping depicted 63 out of 76 segments with perfusion defects in SPECT. Concordance for detection of perfusion defects -per segment- by DECT iodine map to V/Q SPECT was 18/18 in 5 patients, 17/18 in 4 patients and 16/18 in 3 patients (table 3).

In DECT, 63 defects were detected in 18 patients. There was an agreement between both modalities in the diagnosis of perfusion defects per patient in 17 cases. Altogether, a good correlation of the perfusion patterns was found between DE iodine mapping and perfusion SPECT. With the SPECT findings as standard of reference, sensitivity/specificity for the detection of perfusion defects were thus 82.9% and 100% by DECT iodine perfusion mapping per segment (table 4&5) and combined DE-CTPA had a sensitivity/specificity of 100%/100% for detection of acute PE per patient (table 6&7).

Table (1):Symptoms distribution of the patients.

Symptoms	Total no. = 26
Shortness of breath	17(65.4%)
Chest pain	12(46.2%)
Cough	14 (53.8%)
Hemoptysis	3 (11.5%)
Leg pain	8 (30.8%)
Arrhythmias	2 (7.7%)
Syncope	2 (7.7%)
Collapse	1 (3.8%)

Table (2): Distribution of the previous condition of the patients.

Patient condition	Total no. = 26
Previously healthy	*17 (65.4%)*
Underlying disease	*9 (34.6%)*
Lung fibrosis	1 (11.1%)
Pulmonary edema	2 (22.2%)
Emphysema	1 (11.1%)
Breast cancer	2 (22.2%)
Pulmonary arterial hypertension	2 (22.2%)
Prostate cancer	1 (11.1%)

Table (3): Shows V/Q findings, concordance of DECT iodine mapping to SPECT, time delay and final diagnosis of acute pulmonary embolism

		Total no. = 26
V/Q scan findings	Match	10 (38.5%)
	Dismatch	16 (61.5%)
Concordant findings (number of segments) DECT iodine mapping to SPECT images	16/18	5 (19.2%)
	17/18	3 (11.5%)
	18/18	18 (69.2%)
Time delay (days) between DECT & V/Q	Mean ± SD	1.96 ± 0.82
	Range	1 – 3
Final diagnosis of acute PE	No	7 (26.9%)
	Yes	19 (73.1%)

Table (4): Shows the accuracy of DECT for the detection of perfusion defects in comparison to V/Q SPECT as a gold standard.

		SPECT perfusion		Test value*	P-value	Sig.
		Normal	Defect			
		No. = 392	No. = 76			
DECT perfusion	Normal	392 (100.0%)	13 (17.1%)	375.495	<0.001	HS
	Defect	0 (0.0%)	63 (82.9%)			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
*: Chi-square test

Table (5): Receiver operating characteristics curve for sensitivity, specificity, positive predictive value and accuracy of DECT to the gold standard V/Q SPECT per segment.

	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
DECT perfusion	63	392	0	13	82.9%	100.0%	100.0%	96.8%	92.2%

Table (6): Shows the accuracy of DE-CTPA for the detection of acute pulmonary embolism in comparison to SPECT as a gold standard per patient.

Final diagnosis of PE DE-CTPA	V/Q Match		V/Q Dismatch		Test value*	P-value	Sig.
	No.	%	No.	%			
No	7	70.0%	0	0.0%	15.326	<0.001	HS
Yes	3	30.0%	16	100.0%			

Table (7): Receiver operating characteristics curve for sensitivity, specificity, positive predictive value and accuracy of DE-CTPA to the gold standard V/Q SPECT per patient.

	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
DE-CTPA	16	7	3	0	100.0%	70.0%	82.21%	100.0%	88.46%

DISCUSSION:

Suspected acute pulmonary embolism (PE) is a common cause for acute hospital attendance and admission. Because of evasive and nonspecific diagnostic symptoms and signs, pulmonary embolism is one of the most common causes of unexpected death. The presenting symptoms are varying from chest pain, shortness of breath, cough and hemoptysis, to syncope and cardiac arrest. Although PE can be lethal, it is manageable if it is diagnosed and treated in a timely fashion. Hence, prompt diagnosis is essential.

The diagnosis of pulmonary embolism in the emergency department is challenging and based on the following: the clinical pre-test probability; the D-dimer level; and imaging findings. Imaging plays a pivotal role in the diagnosis and management of these patients. However, regarding the sensitivity in the detection of peripherally located perfusion defects related to PE, perfusion SPECT imaging using Tc-99m-macroaggregated albumin (MAA) particles that cause microembolism in the pulmonary microvasculature still seems to be superior to CTPA, although the latter method has shown a higher specificity for PE [(7).]

In recent years, the introduction of multidetector CT systems capable of dual energy CT (DECT) has led to a practical implementation of the imaging potential that was first proposed and investigated at the inception of CT more than 30 years ago, but a lack of appropriate technology did not allow clinical implementation [(8).]

Dual Energy CT (DECT) imaging of the pulmonary iodine distribution after intravenous contrast administration in pulmonary CT angiography (CTPA) has shown its potential to visualize perfusion defects related to embolic pulmonary arterial vessel occlusion. Furthermore, low-energy virtual monochromatic images (≤ 60 KVp) are acquired with DECT to ensure high attenuation in pulmonary vessels, even to the level of subsegmental vessels. To date there have been limited studies assessing the correlation between pulmonary embolism related perfusion defects seen at DECT and those seen at V/Q SPECT [(7).]

Thieme et al:[(9)] reported limited diagnostic accuracy for Iodine perfusion maps, with 75% sensitivity and 80% specificity for pulmonary embolism in a per-patient analysis, but these increased to 83% and 99% in a per-segment analysis in 13 patients. DECT perfusion defects related to SPECT imaging had a sensitivity of 77% and a specificity of 98% in a follow-up study by the same group [(7)] in 15 patients. Using a similar approach, we assessed the feasibility of this technique in a larger patient population. In this study, 26 consecutive patients with suspected PE were examined with DECT to assess the parenchymal perfusion in the generated iodine perfusion maps and to correlate perfusion defects to the CTPA and V/Q SPECT findings.

In this study setting, CTPA images and iodine distribution maps were evaluated separately, the imaging findings (embolic clots/perfusion defects) were correlated. The consistency of diagnosis for PE between CT pulmonary artery angiography and pulmonary perfusion imaging using iodine perfusion maps is good in our results, similar to [(10)]and[(11)], who reported consistency of diagnosis for PE between pulmonary artery angiography and pulmonary perfusion imaging by iodine perfusion maps, which is consistent with our results (figure:1).As well as, the diagnostic value of combined DECT perfusion iodine mapping with pulmonary CT angiography in the assessment of pulmonary perfusion patterns is evaluated, by analyzing DECT iodine perfusion maps of the 26 patients and correlated the findings with those of the well-established V/Q SPECT imaging method. We analyzed the data and found that, for occlusive PE, DECT iodine perfusion mapping could better show the perfusion changes of the corresponding region, while the diagnostic accuracy of DECT iodine perfusion mapping for nonocclusive PE was less in our study one patient result was false negative with homogeneous perfusion in both DE iodine mapping and SPECT, there was non-occlusive embolus at the segmental level outlined by contrast material. This is similar to results of Thieme et al.[(9)], who reported one patient with homogeneous perfusion, and there were multiple non-occlusive emboli at the segmental level outlined by contrast material. Furthermore,[(12)] found that diagnostic accuracy of iodine perfusion maps for incomplete PE is less than diagnostic accuracy for complete PE. This may be because the embolus did not completely block the blood vessels and enough blood could flow through so that a decline in perfusion was not significant (figure:2).

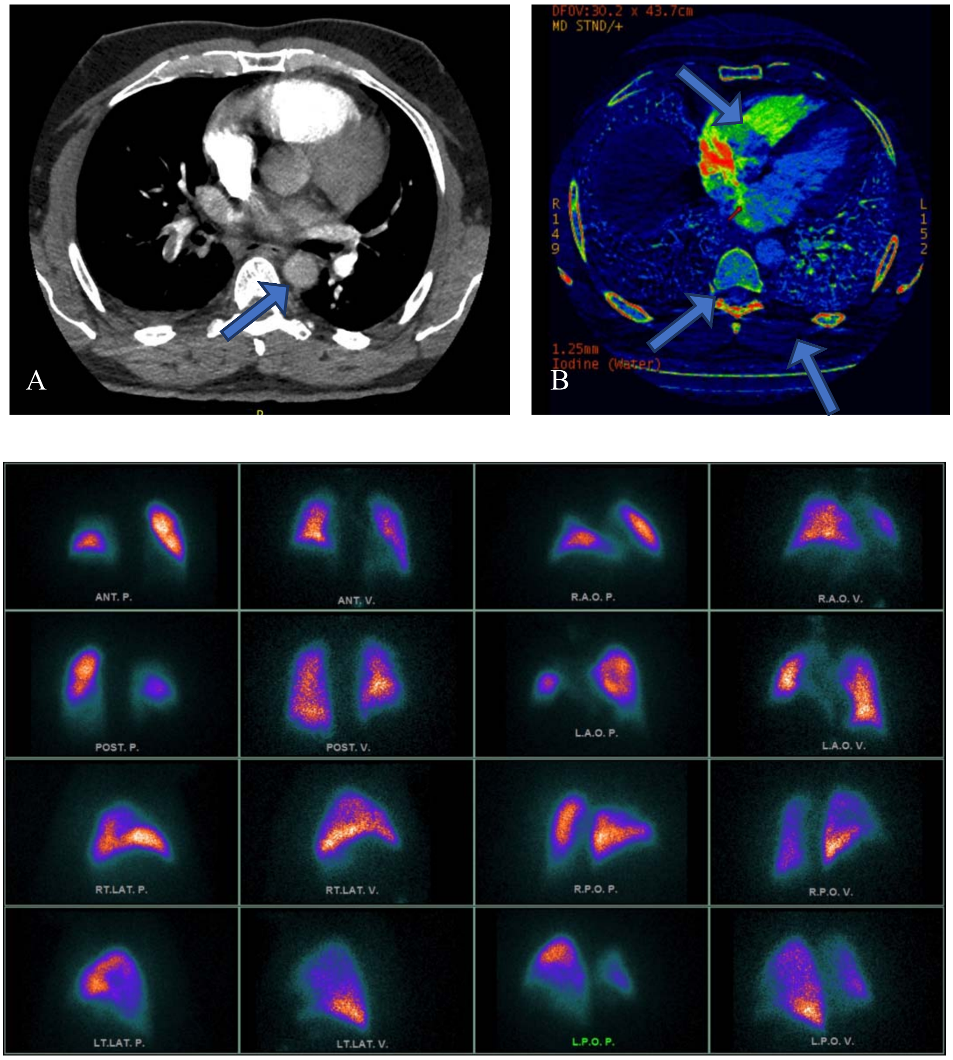
Presence of occlusive PE correlates well with segmental/subsegmental perfusion defects on iodine maps and V/Q SPECT. Therefore, absence of perfusion defects confers a high negative predictive value in excluding occlusive emboli. As the perfusion information is available with the DECT pulmonary angiogram, it may be able to increase the sensitivity of CTA for tiny peripheral occlusive emboli, which can be of great functional importance if many segments are affected as in chronic thrombembolic pulmonary hypertension(figure:3). On the other hand, the functional relevance of subsegmental and non-occlusive PE has been a matter of repeated discussion. Non-occlusive emboli in central, lobar and segmental pulmonary arteries can sometimes have very little effect on the corresponding regional perfusion, as partial occlusion of pulmonary arteries may not lead to changes in blood supply and may be of minor relevance. In the present study we found that the detection rate by DE-CTPA monochromatic images for segmental and subsegmental pulmonary embolism was significantly higher than that of conventional CTPA, which is consistent with the literature[13], in a retrospective analysis of 51 DECT pulmonary angiograms, the image quality derived from the 80- and 140-kV datasets was systematically compared in third-, fourth- and fifth-order pulmonary arteries. The mean level of vascular enhancement was found to be significantly greater in the 80-kV images. Furthermore, despite a higher noise level, signal-to-noise ratio and contrast-to-noise ratio were found to be significantly higher at 80 kV. The authors concluded that 80-kV protocols significantly improve the image quality of peripheral pulmonary arteries. Similarly, in our study we found a superiority of peripheral pulmonary artery image quality on low kV images during interpretation of the DE CTPA images, although this aspect of the diagnostic performance of DECT, was not subject to our present study. However, the higher vascular attenuation at lower kV settings could lead to an increase in sensitivity in the detection of peripheral PE. Also low-energy mono-chromatic imaging was used to enhance image contrast in suboptimally enhanced vascular studies, whereas high-energy monochromatic images could be used to decrease the artifacts in our study.

Our results of the comparison of DECT and SPECT perfusion imaging show a very good correlation of the findings of both modalities in the visualization of perfusion patterns (figure 4) and emphasized the diagnostic potential of DE iodine mapping and further support the use of the term “perfusion imaging”. A complete concordance between defects seen at DECT perfusion iodine map and scintigraphy is unlikely. Not only are these measures not precisely physiologically equivalent, but V/Q scintigraphy is performed during shallow respiration, whereas DECT iodine perfusion maps reflect full inspiration. The degree of agreement between DECT iodine mapping and scintigraphic images is encouraging, particularly on a clinically significant per-segment basis[14].Thus, DE CTPA with perfusion imaging can be considered as an alternative to SPECT perfusion imaging as it seems to offer a comparable mapping of the parenchymal perfusion and, beyond that, a delineation of vascular and mediastinal structures as well as a high-resolution depiction of the pulmonary parenchyma and may also support the diagnostic workup of chronic lung disease. Similarly, perfusion information can give an impression of the severity and functional relevance of parenchymal changes.

The study limitation was the time delay between the time points of the two examinations. In patients with the diagnosis of acute PE, an anticoagulant therapy between DECT and nuclear medicine imaging might have caused resolution of embolic material and reperfusion of lung areas with initially reduced perfusion. On the other hand, PE could also have been worsened during this time period by embolization of additional thrombus material from the deep venous system. Similarly to previous studies[8&15], some streak artifacts in the DECT iodine perfusion maps caused by dense contrast material in the superior vena cava and the right heart could be identified by their typical configuration and thus were not mistaken for perfusion defects.

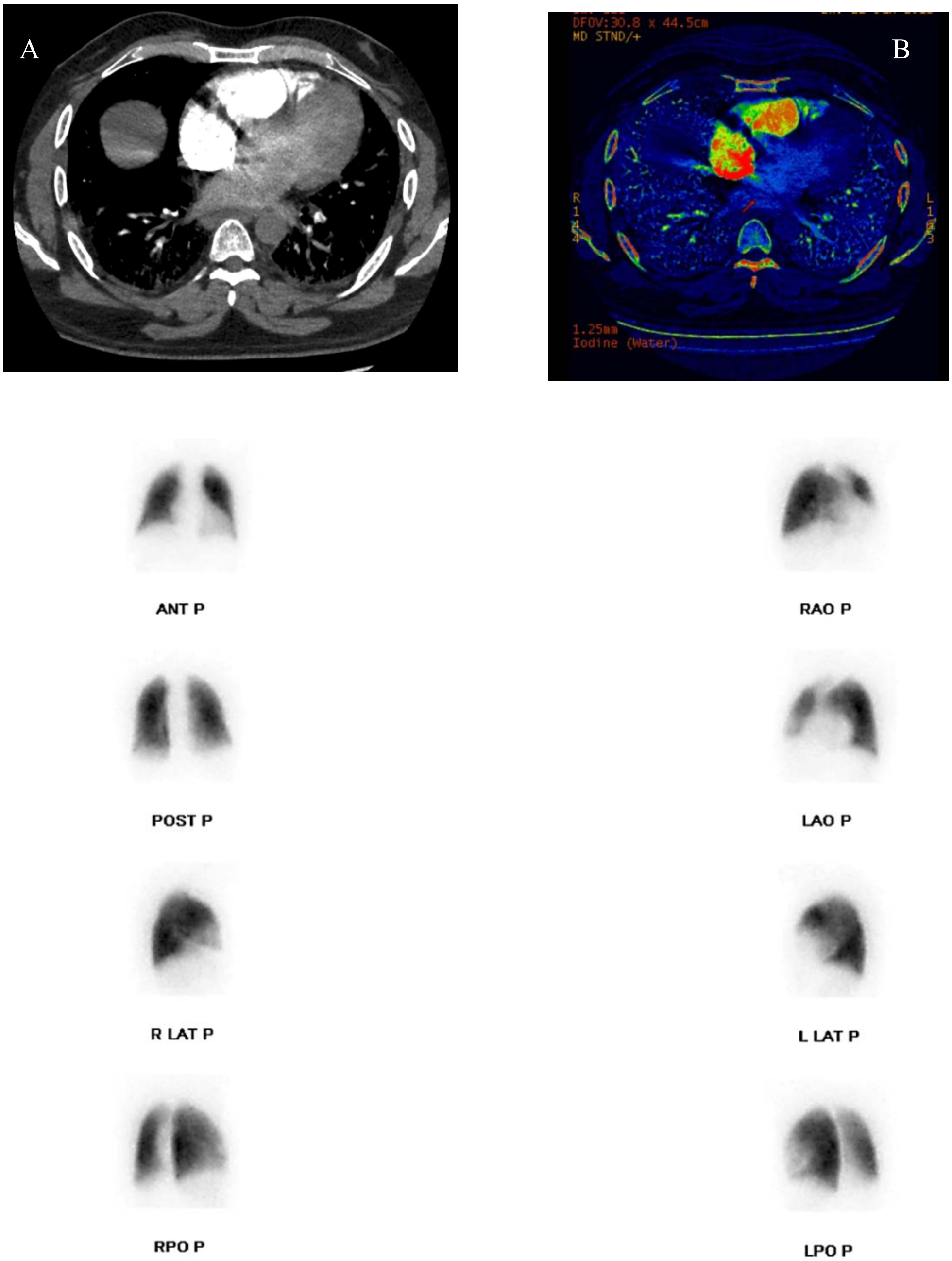
In conclusion:

Dual energy CT perfusion imaging is able to display pulmonary perfusion defects with good agreement to scintigraphic findings. Combining CTPA with iodine mapping perform equally well as V/Q SPECT to detect pulmonary embolism.This study indicates that both perfusion and angiography derived from DECT acquisitions are highly sensitive and specific at diagnosing pulmonary embolism. DECT is the test of choice for the evaluation of suspected PE due to its availability, speed, high accuracy, and ability to identify alternative diagnoses. Certainly the use of V/Q scanning is an important alternative for selected patients, such as pregnancy and impaired renal function.



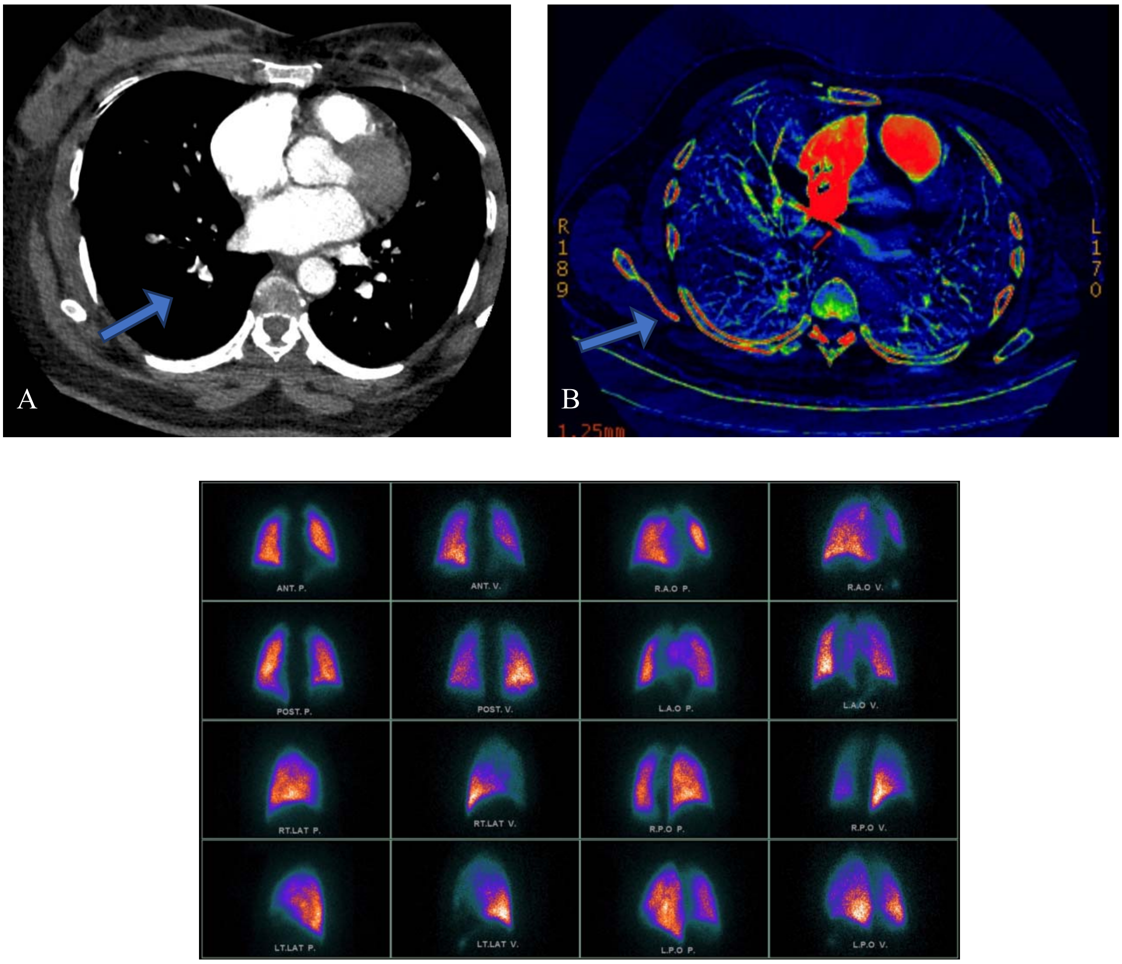
(C)

Figure (1): (A) DE-CTPA revealed right lower lobar pulmonary arteries filling defects (B) DECT iodine perfusion map revealed perfusion defects in the right lower lobe anterior, posterior and lateral basal segments (C) V/Q scan revealed multiple mismatched perfusion defects in right upper lobe apical segment, right lower lobe anterior, posterior and lateral basal segments and left upper lobe anterior segment.Concordant number of segments with perfusion defects of DECT iodine perfusion maps to V/Q scan is 16/18.



C

Figure (2): (A) DE-CTPA revealed left lower lobar pulmonary artery filling defect (B) DECT iodine perfusion map revealed no perfusion defect (C) V/Q perfusion scan revealed normal study



(C)

Figure (3): (A) DE-CTPA revealed right lower lobar artery lateral basal segment filling defect (B) DECT iodine perfusion map revealed perfusion defect in the right lower lobe lateral basal segment (C) V/Q scan revealed mismatched perfusion defect in right lower lobe lateral basal segment

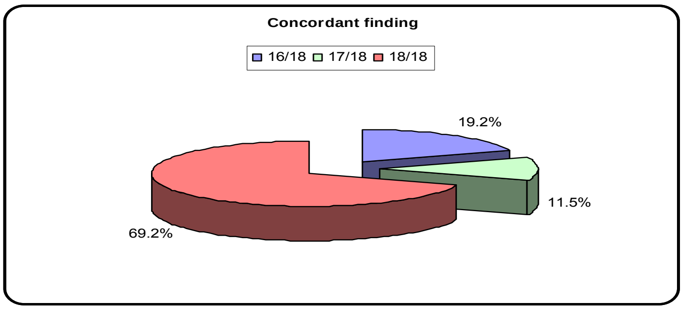


Diagram: Shows distribution of concordance of perfusion defect detection of DECT iodine mapping to SPECT images per segment.

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الملخــص العربــى

المقدمة: تعتبر الجلطة الرئويةمن الأمراضالمسببة للوفاة وتعد ثالث أمراض القلب والأوعية الدموية الأكثر شيوعا، بعد احتشاء عضلة القلب والسكتة الدماغي؛ وقد تماعتماد تصوير الأشعة المقطعية بالصبغةللأوعية الدموية الرئوية،على نطاق واسع كاختبار معياري لتشخيص الجلطة الرئوية الحادة كما تغير دورفحص الإنسكاب الدموي الرئوي وتهوية الرئتين عن طريق النظائر المشعةوأصبح استخدامه حاليا قاصرا على استبعاد الجلطة الرئوية.

هدف الدراسة: تقييم إمكانية استخدام التصوير بالأشعة المقطعية المزدوج للطاقة في تشخيص الجلطة الرئوية مقارنة بالنظائر المشعة لفحص الإنسكاب الدموي الرئوي و تهوية الرئتين.

المرضى والوسائل: شمل البحث القيام بفحص ٢٦ مريضا مشتبها بالجلطة الرئوية بالأشعة المقطعية المزدوج للطاقة متضمنة كلا من، التصوير بالصبغةللأوعية الدموية الرئوية وخريطة اليود للإنسكاب الدموي الرئوي من جهة؛ وبالنظائر المشعة لفحص الإنسكاب الدموي الرئوي و تهوية الرئتين من جهة أخرى.

النتائج: بمقارنة نتائج التصوير بالأشعة المقطعية المزدوج للطاقة بشقيها إلى فحص النظائر المشعة، أظهر التصوير بخريطة اليود بالأشعة المقطعية المزدوج للطاقة حساسية وخصوصية للفحص ٨٢,٩% و ١٠٠٪ على التوالي في تشخيص نقص الإنسكاب الدموي الرئوي الدال على انسداد الشريان الرئوي بالجلطة الدموية، وأظهر دمج كلا من تصوير الأشعة المقطعية المزدوج للطاقة بالصبغةللأوعية الدموية الرئوية و خريطة اليود للإنسكاب الدموي الرئوي حساسية وخصوصية للفحص ١٠٠% و ١٠٠٪ على التوالي في تشخيص الجلطة الرئوية

الإستنتاج: يعد التصوير بالأشعة المقطعية المزدوج للطاقة متضمنة كلا من، التصوير بالصبغةللأوعية الدموية الرئوية و خريطة اليود للإنسكاب الدموي الرئوي بديلا ناجحا للفحص بالنظائر المشعة لفحص الإنسكاب الدموي الرئوي و تهوية الرئتين في تشخيص الجلطة الرئوية بإمكانية الحصول على كلا من الصفات التشريحيةالمتمثلة في الكشف عن وجود انسداد الشريان الرئوي بالجلطة الدموية وكذلك الصفات الوظيفية للرئتين بالكشف عن نقص الإنسكاب الدموي الرئوي الدال على انسداد الشريان الرئوي بالجلطة الدموية