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A Review Dual-Energy CT Clinical Applications in Pulmonary Diseases

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Abstract: **The dual-energy computed tomographic (CT) technique allows the differentiation of materials with large atomic numbers such as iodine and xenon. The basic principle of dual-energy CT is material decomposition based on attenuation differences at different energy levels. By using dual-energy CT angiography for the evaluation of perfusion defects in cases of pulmonary embolism, and using xenon CT for the evaluation of ventilation defect.(1)**

Keywords: **Dual-energy CT, Pulmonary Diseases.**

1. INTRODUCTION

THEORY:

Like conventional radiography, computed tomography utilizes x-rays generated from a rotating anode to expose a digital detector after passing through an attenuating object. The signal detected reflects the intensity of the x-ray after attenuation through the patient. Attenuation is dependent not only on the energy spectrum of the x-ray beam, but the material and length of the attenuating object. A typical CT unit would consist of a rotating tube with a stationary ring of detectors. Helical CT uses slip ring technology which allows the tube to continuously rotate while the patient may be passed through the bore of the unit on a moving table. This produces a spiral scanning effect along the length of the patient.

As the tube rotates around the patient, projection images are acquired by the detectors for an angle of rotation which is dependent on the sampling frequency. The resulting projections can be processed before or after they are subjected to a particular reconstruction algorithm which assembles the final image. Processing methods are applied to the image in either the spatial or frequency domain, and can reduce noise as well as smooth the image through the use of filtering algorithms. In angiography, the image may be subtracted from another image acquired using similar parameters. The second image is acquired when a contrast agent has been injected in the patient. The contrast agent displays different attenuation effects revealing the locations of blood vessels and arteries (2) .The maximum and minimum voltage that can be applied across the tube is 140 kVp and 80 kVp. Thus the largest energy difference between the two tubes would be 60 kVp. However, since the x-ray beam consists of a continuum of energies which include the characteristic x-rays of the anode material, the average energies of the two spectrums are 76 keV and 56 keV, thus a smaller average energy difference(3). Additionally, a tin filter may be placed in the path of the beam to remove the low energy x-rays from the spectrum, increasing the overall average energy to 92 keV. This process of removing lower energy x-rays by including a tin filter in the path of the beam is known as beam hardening (4) . In the lung, as an example of the three-component system, consisting of air, soft tissue, and iodine, the algorithm assigns a ratio of air and soft tissue to the voxel; at the same time, the CT numbers at both energy levels are used to derive the additional iodine content. X-ray attenuations are caused by photoelectric absorption and Compton scattering and vary according to the specific material and energy levels. In low atomic number materials such as fat and muscle, increase of photon energy results in a small degree of reduction in the Hounsfield unit (1)

2. OBJECTIVES

To evaluate feasibility and added value of dual-energy computed tomography (CT) in diagnosis of pulmonary diseases.

Thorax applications:

The major advantages of DECT in thoracic applications are a lack of misregistration and visualization of the lung perfusion and ventilation Misregistration is avoided due to the simultaneous acquisition of 80 and 140 kVp images. In patients with pulmonary thromboembolism, DECT may allow the detection of subtle emboli by revealing perfusion defects. Several articles have assessed the role of DECT in the diagnosis of pulmonary thromboembolism . Krisska et al. (5) obtained a high negative predictive value by using perfusion images. Chae et al. (6) proposed a perfusion defect score that demonstrated a good correlation to the right ventricle/left ventricle diameter ratio and the CTA obstruction score. In addition, an assessment of the lung perfusion can allow the visualization of pathologies that have been previously unknown particularly in patients with interstitial lung disease, emphysema, asthma, or chronic thromboembolic disease and in patients with tumors (7). Recently, the introduction of Xenon DECT enabled the collection of ventilation-perfusion CT acquisitions, and in the future, it may replace ventilationperfusion scintigraphy. Ferda et al. (8) have reported the use of perfusion and minimum intensity projection (minIP) images for the assessment of iodine and air distributions. The superior registration of DECT may demonstrate the presence or lack of enhancement of sub-centimeter and solitary lung nodules have reported that dual-energy methods for the thorax are feasible without the additional radiation dose provided by dual-source CT. A change of the collimation from 0.6 to 1.2 mm is required to achieve dose neutrality for the 140/80-kVp combi(8) Acute pulmonary embolism (PE) detection (9)

Initial clinical experience—Since 2007, pulmonary MDCTA has been accepted as the reference standard for the diagnosis of acute PE . However, conventional pulmonary MDCTA provides only morphologic information and does not allow the direct assessment of the effects of thromboembolic clots on lung perfusion. The latter aspect, however, remains of considerable import because of its implications for patient management, risk stratification, and prognostication. The ability of DECT-based pulmonary MDCTA to simultaneously provide functional and morphologic information enables the comprehensive “one-stop-shop” evaluation of PE. Compared with previously developed perfusion CT techniques and with conventional CT techniques for lung imaging, DECT eliminates registration problems and allows selective visualization of contrast medium distribution with high spatial resolution and no additional radiation exposure to the patient

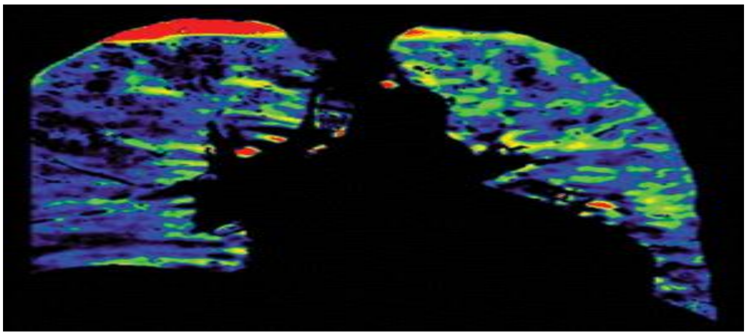

Fig. 1A—Blood pool defect on dual-source CT–based dual-energy CT blood pool study of lungs caused by emphysema in 67-year-old man.

A, Coronal (**A**) and right sagittal (**B**) blood flow images show heterogeneously decreased distribution of pulmonary blood pool in both lungs due to emphysematous changes.

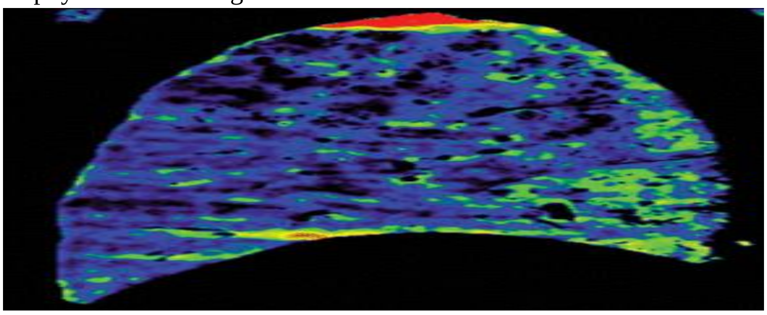

Fig. 1B—Blood pool defect on dual-source CT–based dual-energy CT blood pool study of lungs caused by emphysema in 67-year-old man.

B, Coronal (**A**) and right sagittal (**B**) blood flow images show heterogeneously decreased distribution of pulmonary blood pool in both lungs due to emphysematous changes

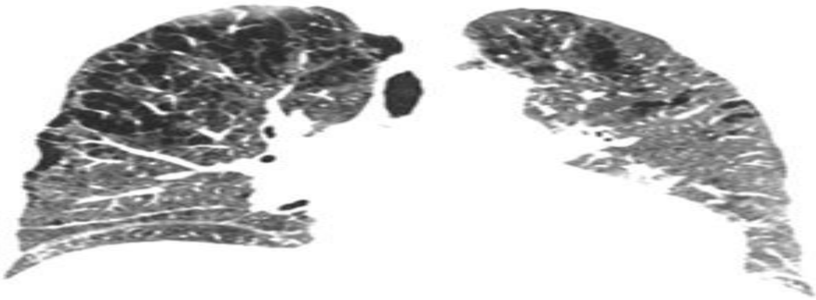

Fig. 1C—Blood pool defect on dual-source CT–based dual-energy CT blood pool study of lungs caused by emphysema in 67-year-old man.

C, Findings shown in **A** and **B** are readily seen on coronal multiplanar reformation displayed in lung window.

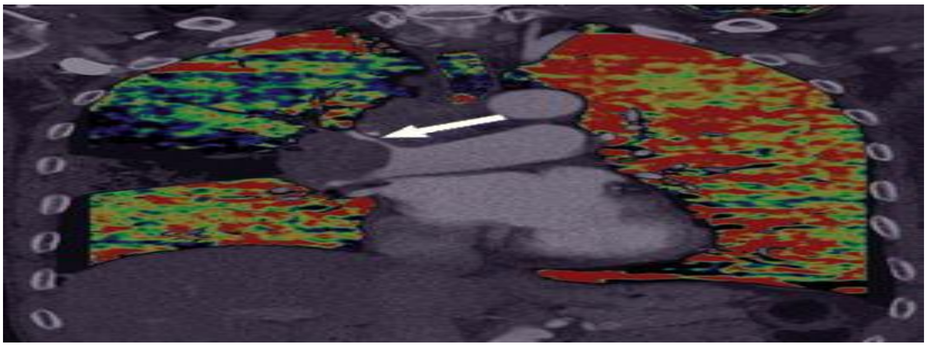

Fig. 2A—Blood pool defect in pulmonary blood volume map caused by lung carcinoma in 71-year-old man. Images were derived from dual-source CT–based dual-energy CT blood pool study of lungs.

A, Coronal fused image (**A**) and corresponding coronal blood flow image fused with CT angiogram (**B**) show right lung carcinoma (*arrow*, **A**) invading hilar vasculature, resulting in diffuse decreased blood distribution within right lung.

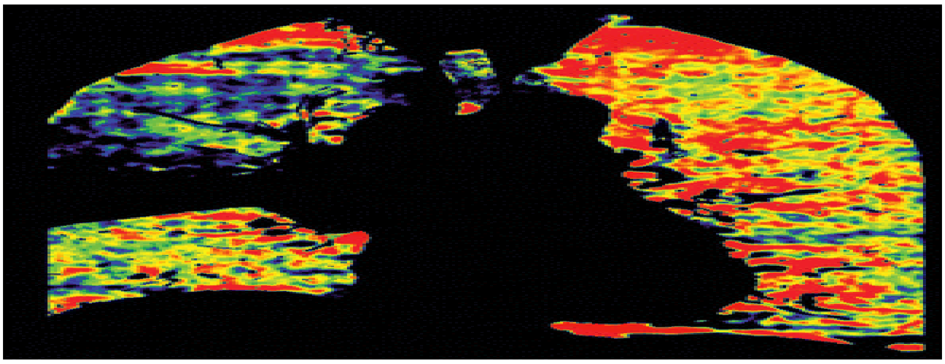

Fig. 2B—Blood pool defect in pulmonary blood volume map caused by lung carcinoma in 71-year-old man. Images were derived from dual-source CT–based dual-energy CT blood pool study of lungs.

B, Coronal fused image (**A**) and corresponding coronal blood flow image fused with CT angiogram (**B**) show right lung carcinoma (*arrow*, **A**) invading hilar vasculature, resulting in diffuse decreased blood distribution within right lung

3. PERFUSION DEFECTS DUE TO PARENCHYMAL DISEASES

Areas of emphysema, atelectasis, or consolidation and lung masses are demonstrated as perfusion defects. In the case of emphysema, the cause of perfusion defects is a true decrease in pulmonary circulation secondary to lung destruction; in the area of emphysema, alveolar surface reduction is accompanied by an equal reduction in capillary volume. Pansini et al reported that the degree of decreased perfusion was correlated with the severity of emphysema. In the case of atelectasis, consolidation, and lung masses, the cause of perfusion defects is considered to be technical failure. In PBV application mode, to generate an iodine perfusion map, material decomposition could be performed only in the range between −960 HU and −600 HU. Any areas with attenuation out of this range are displayed as perfusion defects (10).

Evaluation of Pulmonary nodules:

By using dual-energy CT, solitary pulmonary nodules can be characterized. To distinguish malignant pulmonary nodules from benign lesions, the degree of contrast enhancement is important. Because the attenuation value of pulmonary nodules on true nonenhanced images is similar to that on virtual nonenhanced images, the degree of enhancement of pulmonary nodules can be correctly measured with dualenergy CT. With single-energy CT, dual acquisition of nonenhanced and enhanced scans is required to (11) differentiate calcification from enhancing tissue. However, with dual-energy CT, the differentiation of calcification from enhancing tissue in solitary pulmonary nodules is made with a single contrast-enhanced CT acquisition and virtual nonenhanced image reconstruction (12).

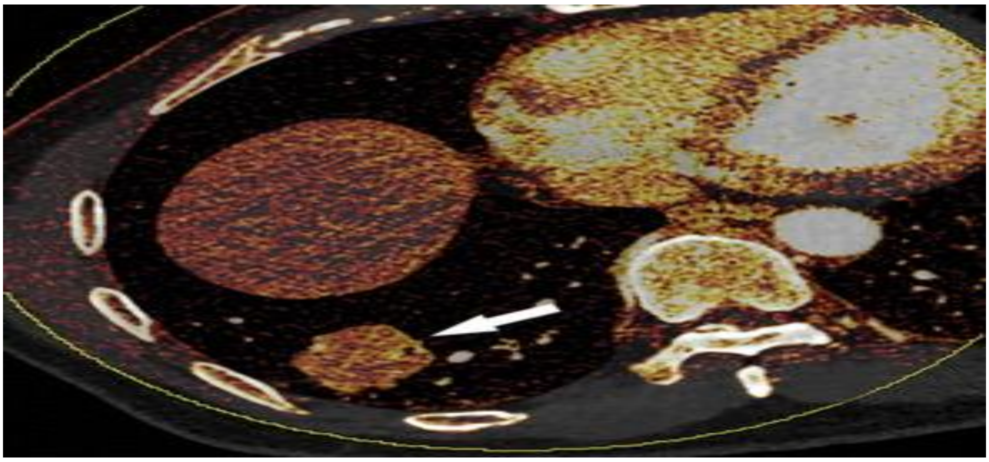

Fig. 2C—Blood pool defect in pulmonary blood volume map caused by lung carcinoma in 71-year-old man. Images were derived from dual-source CT–based dual-energy CT blood pool study of lung middle lobe.

Dual-energy CT (DECT) study of 45-year-old man with lung adenocarcinoma in right lower lobe. Images were derived from dual-source CT–based DECT study of lungs.

Advantages and Limitations of Dual-Energy CT of the Lung:

DECT has many important advantages over conventional CT for imaging of the lung. DECT is the only technique that allows direct comparison of CT angiograms acquired at different energies in the same patient at the same time point after the administration of contrast medium and within strictly similar hemodynamic conditions. It simultaneously obtains functional information on perfusion and ventilation along with high-resolution anatomic information to allow comprehensive evaluation for lung disease [13]

The limitations of DECT include false-negative or false-positive findings of perfusion or ventilation defects because of artifacts from motion or high-concentration contrast medium. The analysis of DECT-based studies requires somewhat more time and expertise to process image data and for interpretation, although this time investment should decrease with increasing experience and ongoing technical evolution. Also, larger image datasets require increased data storage capabilities. Additionally, as with all imaging, the use of DECT is limited in morbidly obese patients because high image noise often interferes with structural and functional image analyses. Last, potentially unwanted effects of more novel contrast agents used with DECT applications, such as inhaled gases, require further study [13]

4. CONCLUSIONS

Conventional radiography's progression has arrived at Dual Energy CT along with the technological development of a Dual Source CT unit. While performing at or above the standards set by standard CT units regarding imaging quality, tissue differentiation and therefore bone removal in angiography becomes a possibility. The ability to differentiate between two tissues is dependent upon the Dual Energy spectrum attenuation in the object. The spectral properties of the tissue are important because the atomic material which makes up a selected volume can be determined. This allows for image processing which can remove bone for angiograms and visualize plaque distributions in determining atherosclerosis. Dual Energy CT also has the ability to quantify ventilation and perfusion images with the use of a contrast agent such as iodine or xenon gas. The ability to distinguish between tissue types and enhance contrast will certainly lead to new discoveries in the diagnostic imaging.

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