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Perfusion defects in pulmonary perfusion iodine maps: Causes and semiology☆,☆☆

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KEYWORDS
Pulmonary embolism;
Dual energy;
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Abstract
Objective: To describe the usefulness of dual-energy CT for obtaining pulmonary perfusion maps to provide morphological and functional information in patients with pulmonary embolisms. To review the semiology of perfusion defects due to pulmonary embolism so they can be differentiated from perfusion defects due to other causes: alterations outside the range used in the iodine map caused by other diseases of the lung parenchyma or artifacts.
Conclusion: CT angiography of the pulmonary arteries is the technique of choice for the diagnosis of pulmonary embolisms. New dual-energy CT scanners are useful for detecting perfusion defects secondary to complete or partial obstruction of pulmonary arteries and is most useful for detecting pulmonary embolisms in subsegmental branches.

PALABRAS CLAVE
Tromboembolismo pulmonar;
Energía dual;
Perfusión pulmonar;
Mapa de iodo

Defectos de perfusión en el mapa de iodo pulmonar: causas y semiología

Resumen
Objetivo: Describir la utilidad de la tomografía computarizada con energía dual (TCED) en la obtención de mapas de perfusión pulmonar para aportar información morfológica y funcional en el tromboembolismo pulmonar (TEP). Revisar la semiología de los defectos de perfusión debidos a TEP y diferenciarlos de los defectos no debidos a TEP que son alteraciones que quedan fuera del rango utilizado en el mapa de iodo y están causados por otras enfermedades del parénquima pulmonar o por artefactos.

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Conclusión: La angiografía por TC de las arterias pulmonares es la técnica de elección en el diagnóstico de TEP. Las nuevas TC con energía dual son útiles para detectar defectos de perfusión secundarios a obstrucción completa o parcial de las arterias pulmonares, y tiene su mayor utilidad en la detección de TEP en ramas subsegmentarias.

Introduction

The dual-energy computed tomography (DECT) allows us to characterize and differentiate chemical elements using different attenuation spectrums of X-rays based on kilovoltage (kV) in order to detect functional alterations in the presence of subtle morphological or densitometrical alterations. Some of the applications of dual energy are obtaining studies ''without virtual contrast''; characterizing cystinic lithiasis; and assessing urate deposit in diseases such as gout. When it comes to the thorax, the computed tomography angiography (CTA) is the modality of choice for the diagnosis of acute pulmonary thromboembolisms (PTEs). Ever since the dual energy technique was first introduced, we have had the opportunity to obtain angiographic images of pulmonary arteries and perfusion maps of the pulmonary parenchyma[1,2] simultaneously, in such a way that now it is possible to obtain a higher diagnostic accuracy and more precise information on the severity of PTEs.

The goal of this paper is to describe the utility of pulmonary perfusion maps in order to give functional information on the PTEs and make correct differentiations of perfusion defects that are not due to PTEs.

Technique and post-processing of dual energy pulmonary CTA

Dual energy is based on the principle that certain materials have different attenuation when using different kilovoltages (kV). Air, water, and fat have the same attenuation coefficient when using different kVs, and cannot be distinguished using dual energy, unlike iodine, calcium, and uric acid, xenon, and gadolinium that are materials that can be characterized.[3,4] Every material has a specific attenuation coefficient between two energies, which is known such as the ''dual-energy index'' (DEI). Some substances may have similar attenuation coefficients when using a certain kVs, such as calcium and iodine, but different DEIs when using different kVs, meaning that we can differentiate them when using two (2) different spectrums of energy.

With the actual CT machines, we can conduct dual energy studies using three (3) different techniques: dual source CT scan, fast kV commutation, and multilayer ''sandwich'' detectors.[1,4,7]

The dual source CT scan uses two (2) X-ray tubes with their respective detector panels placed perpendicularly to the gantry and operates, at the same time, with different kVs, in such a way that we can obtain a series of high-energy images at 140 kV, and another series of low-energy images at 80 kV.[5,6]

We should remember that the DECT allows us to characterize and differentiate materials using the different attenuation coefficients of X-rays of every material based on the kV used.

The post-processing of the data obtained using the dual energy CT scan is based on the theory of ''material decomposition'', that allows us to obtain images defined by voxels that only contain the material we are interested in.[5] When it comes to the lung, contrast-only images are consistent to what we call iodine map or pulmonary perfusion map and provide information of the pulmonary parenchyma vascularization.[8] It is important to say that this information speaks about the concentration of iodine in the pulmonary parenchyma, and not about true perfusion, for whose detection we would need dynamic studies.

At our center, we conduct DECT studies when on suspicion of PTE. We use a dual source CT machine (Somaton Definition Flash, Siemens Medical Solutions, Forchheim, Germany) integrated by two X-ray tubes working with different energies: tube B (80 kV at 252 mAs) and tube A (140 kV at 126 mAs). Post-processing takes place in a working station (Syngo Multimodality, Siemens Healthcare) using the ''lung PBV'' (lung pulmonary blood volume) software. One hundred (100) ml of iopromide (300 mg/ml) are administered at a flow rate of 5 ml/s followed by an injection of 20 ml of saline solution at the same flow rate. Delay time is estimated using the bolus tracking technique by placing the region of interest (ROI) in the ascending aorta; the CT acquisition starts at densities of 100 HU, which is how we can obtain the adequate contrast staining of the pulmonary parenchyma while keeping the adequate staining of the pulmonary arteries for the detection of thrombi. At other centers, the ROI is placed in the pulmonary artery followed by a 7 s-delay in order to achieve a correct opacification of the pulmonary parenchyma. Acquisition takes place in the caudal-to-cranial direction in order to avoid artifacts due to the high concentration of contrast in the subclavian vein, or the superior vena cava.

Images are post-processed in the working station and one iodine map of the pulmonary parenchyma is obtained using attenuation thresholds between −950 and −600 HU, in such a way that tissues with densities outside this range such as pulmonary arteries, atelectasis, and tumors are excluded even though they have iodine. The iodine map is represented with a color scale that can be normalized with respect to any iodine structure; to this end, one ROI is placed in the left