Pulmonary Perfusion Imaging Techniques

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Introduction

• Pulmonary circulation is a complex system;
• Likewise liver, lungs have a dual blood supply with bronchial and pulmonary arterial sources;
• Many different causes can disarrange pulmonary circulation including diseases of the heart (congenital and acquired), diseases of pulmonary arteries or veins and diseases of lung parenchyma or airways.
• Even positional changes may affect lungs blood distribution;
• Lungs ventilation and perfusion are in constant balance to minimize “dead space”.
Introduction

• Perfusion imaging is an established technique for evaluation of myocardial and central nervous system diseases, especially for ischemic conditions.

• Vascular physiology is less complex in these organs and hypoperfused segments usually means an occluded or severely stenosed arterial supply.

• Lung perfusion analysis is not so straightforward as hypoperfused segments do not always mean arterial occlusion or stenosis.
Myocardium scintigraphy is well established as a perfusion imaging test for ischemic heart disease.
MRI is another imaging technique with capability to perform perfusion evaluation and already used in clinical practice. Above is an example of a left atrium mixoma. Note dynamic enhancement of lung parenchyma.
Pulmonary Perfusion Imaging Techniques

- The next slides will show pulmonary perfusion using nuclear medicine, Dual-Energy CT and MRI in cases based approach.

**Learning Objectives:** To become familiar with lung perfusion imaging techniques.

**Outcomes:** To demonstrate the main lung perfusion imaging techniques, including dual source CT, MRI and nuclear medicine studies.
Nuclear Medicine

- Scintigraphy is the most common modality used for lung perfusion analysis;
- For a long time it was considered gold standard for diagnosing pulmonary embolism;
- Advances in technology made CT replace scintigraphy in clinical practice for acute PE diagnosis;
- Chronic PE diagnosis, newer criteria for acute PE and modern technologies (SPECT vs planar scans) made lung scintigraphy reemerge as an important modality for diagnosis of both acute and chronic PE.
• Lung scintigraphy is a diagnostic imaging procedure that uses radiopharmaceuticals to evaluate ventilation and/or perfusion;

• $^{99}$ Tc-DTPA (aerosol) is most commonly used for ventilation scans and $^{99}$TC-MAA (EV) for perfusion imaging;

• Most common indications are:
  1- diagnosis of acute and chronic PE and;
  2- to quantify pulmonary function before surgery.

• A normal scan must show a homogenous distribution of radiopharmaceuticals in both ventilation and perfusion images.

Radiol Oncol 2014; 48:113-19
Eur J Radiol 2015; 84: 1392-400
There are different diagnostic criteria for V:Q scans interpretation when PE is suspected;

Most of them are derived from PIOPED study;

The goal is to search for mismatched (V:Q) defects;

Inconclusive studies, low spatial resolution and a limited capability of differential diagnosis are some of the weakness of lung scintigraphy.
One single, large, non-segmental perfusion defect as shown is not common in PE (low likelihood for PE);

Definite diagnosis of pulmonary veins stenosis was made only after CT;

Lung scintigraphy fails to make alternative diagnosis.
Dual Energy CT

- Pulmonary perfusion imaging using CT is not new;
- Many attempts using old generations scanners have been made;
- Area of coverage and radiation dose were some of the limitations encountered to apply this technique in clinical practice;
- Dual energy technology made pulmonary perfusion possible;
- Perfusion using dual energy CT is based in the difference of iodine attenuation when using different tube kilovoltages.
Dual Energy CT

- Color perfusion maps are a subproduct of a chest dual energy CT;
- Color perfusion maps can be obtained with no extra time, radiation dose or contrast media, while maintaining CT capabilities to evaluate chest wall, mediastinum, lung parenchyma, airways and an angiographic view.
Dual energy CT color perfusion maps and angiographic capabilities. One-stop-shop for pulmonary vasculature imaging evaluation?
Chronic thromboembolic pulmonary hypertension occurs in 1-4% of cases after an acute PE episode.

Scintigraphy remains as modality of choice for detecting perfusion defects and a positive scan triggers further investigation.

CT is the gold standard for diagnosing acute PE, it may also confirm CTEPH and helps in treatment choice (surgical vs non-surgical).

Dual energy CT can provide at the same time the angiographic and perfusion information needed for CTEPH diagnosis.

Images above shows multiple perfusion defects in a patient with CTEPH.

Images on the left, after pulmonary endarterectomy, shows a significant improvement in lung perfusion.
3D angiographic view from the same dataset of previous slide. Pre (left) and post endarterectomy (right) confirming improvement in patency of pulmonary arterial bed.

Angiographic and perfusion capabilities of Dual-Energy CT may overcome the need for multiple exams in patients with CTEPH.
Pulmonary artery sarcoma

Sarcoma is the most common primary malignancy of pulmonary artery;

Differentiation from thrombus is difficult, unless extension outside pulmonary artery or metastases are evident;

Scintigraphy (not available) would probably show a large perfusion defect;

Dual-energy CT can depict the perfusion defect and at the same time shows a huge mass arising and extending outside left pulmonary artery.
Magnetic Resonance Imaging

- Although not new, chest MRI is still the 3rd line modality for chest imaging;
- Low proton density and susceptibility artefacts at air-tissues interfaces are the most common problems for MRI lung imaging;
- On the other hand, for mediastinal evaluation (cystic / solid lesions), chest wall (tumoral invasion) and vascular studies, MRI is already established and in current clinical use;
- MRI has the ability to perform morphologic and functional studies which is already well done in heart and central nervous system studies;
- Lack of ionising radiation makes MRI a good choice for patients who need repeated examinations.

Insights Imaging 2012; 3:355-71
Insights Imaging 2012; 3:61-71
AJR 2007; 188:48-56
J Magn Reson Imaging 2010; 32:12-87-1301
Magnetic Resonance Imaging

- There are different MRI techniques available for evaluation of vessels and lung perfusion disorders using contrast-enhanced or non-contrast-enhanced scans;
- T1 weighted contrast-enhanced 3D gradient echo MR angiography is a powerful technique, but insufficient image quality due to timing of contrast material injection is a common problem;
- Dynamic contrast enhanced MR (4D MRI) may overcome this problem and it seems to have a good sensitivity for PE diagnosis.
4D MRI. Extremely short acquisition times allows dynamic evaluation of pulmonary circulation and lung perfusion. Time resolution is excellent with reasonable spatial resolution. Like Dual- energy CT, MRI can depict angiographic and perfusion information.
Gradient echo perfusion imaging in a health volunteer.
Chronic thromboembolic pulmonary hypertension. 4D MRI showing peripheral thrombus in right pulmonary artery and right lower lobe oligaemia in good agreement with CT.
Suggested Readings


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