Dual Energy CT Imaging for Suspected Pulmonary Embolism Using a Lower Dose of Contrast Agent

- CT is the preferred imaging modality to diagnose pulmonary embolism
- Evaluation of pulmonary embolism with dual energy CT (DECT) retains diagnostic accuracy using less contrast material than standard CT
- Virtual monochromatic images, derived from DECT data, show contrast material at greater intensity than standard CT
- Iodine images show the distribution of contrast material and can be used to assess perfusion deficits in the lungs
- Reduced contrast volume DECT is an option for patients with suspected pulmonary embolism and impaired kidney function

CT pulmonary angiography (CTPA) is the first-line diagnostic imaging technique for patients who present with symptoms consistent with pulmonary embolism. On traditional CT scanners, CTPA is performed at a single kV (generally 120 kV) to maintain satisfactory image quality with low image noise. However, at such kV, iodine-based contrast material is often low in brightness (i.e., attenuation, measured in Hounsfield units or HU, is low). Thus relatively high contrast concentrations are required to obtain diagnostic information for pulmonary embolism.

Figure 1(A,B,C). A 72-year-old man (weight 175 lbs) underwent DE CTPA for suspected pulmonary embolism using 35 cc of 370 mg% iodine contrast. Axial DECT virtual monochromatic images demonstrate A) suboptimal enhancement and low noise at 100 keV; B) optimal enhancement with moderate noise at 60 keV; and C) excellent enhancement with high noise at 40 keV.
Modern CT scanners that enable dual-energy CT (DECT) simultaneously use two separate kV (e.g., 80/140 kV or 100/140 kV) and substantially increase brightness of iodine-based contrast material. As a result, DECT has become the method of choice for all CTPA examinations performed at Mass General on DECT-capable scanners. For patients with normal kidney functions, the injected contrast material volume for DECT is identical to single energy CT. However, in patients whose kidney functions is compromised, the tremendous contrast-enhancing capabilities of DECT allows a lower contrast dose.

Data from DECT techniques can be used to create special images such as virtual monochromatic and iodine images. The virtual monochromatic images, generally between 40 and 60 kilo-electron volts (keV) (Figure 1) for a vascular CT, appear much like standard CT images except for the increased intensity or attenuation (HU) from contrast material compared to traditional single kV images at 120-140 kV. They produce diagnostic-quality studies with a fraction of the iodine-based contrast typically used for a CT. A recent prospective trial comparing standard CTPA with DECT pulmonary angiography using a 50% reduction in contrast media demonstrated that the rate of non-diagnostic studies was similar between the two groups.

Low dose iodine DECT imaging may also be useful in cases when patients who have a had a contrast-enhanced CT examination within the past 24 hours have incidental findings of pulmonary embolism (Figure 2) or present with new symptoms that suggest pulmonary embolism.

Figure 2(A,B). A 63-year-old woman (weight 145 lbs) with incidental finding of pulmonary embolism in right lower lobe on abdominal CT (with 80 cc of 370 mg% iodine contrast) underwent DECT pulmonary angiography with 35 cc of 370 mg% iodine contrast 30 minutes after the abdominal CT scan to evaluate the entire pulmonary vasculature. A) Axial virtual monochromatic image at 40 keV demonstrates excellent enhancement in pulmonary arteries and a filling defect in segmental right lower lobe artery (arrow) that extends to sub-segmental level, left side atelectasis, and bilateral pleural effusions. B) Pulmonary blood volume image demonstrates filling defect in right lower lobe (arrow), area of low-iodine distribution in the same region most likely representing infarction (curved arrows) and high iodine distribution in left side atelectasis (arrow head).

Figure 3(A,B). A 67-year-old woman (weight 186 lbs) with impaired renal function (eGFR=41 mL/min/1.73 m²) and three-day history of progressive dyspnea underwent DE CTPA with 35 cc of 370 mg% iodine contrast. A) Virtual monochromatic axial DECT images at 40keV demonstrate bilateral filling defects in sub-segmental right and left lower lobes arteries (arrows). B) Pulmonary blood volume (iodine distribution) image at same axial level demonstrates filling defects in sub-segmental right and left lower lobe arteries (arrows) without any evidence of infarction.
Iodine images (Figure 2 and 3) derived from DECT, which can be gray scale or colored, show the distribution of iodine and allow assessment of contrast perfusion. Therefore, iodine images can help assess for the sequela of pulmonary embolism including perfusion defects and pulmonary infarcts in the lungs. Initial studies have shown that perfusion deficits due to pulmonary embolism can be detected with a sensitivity ranging from 75% to 100% and a specificity ranging from 80% to 100% in a per patient analysis.

The ability to lower contrast dose while maintaining diagnostic confidence is particularly important for patients with suspected pulmonary embolism because many of these patients have co-morbidities, including renal impairment, and may be at risk for contrast-induced nephropathy. The extent of this problem was illustrated in the PIOPED II trial that established the effectiveness of CTPA in which 18.5% of patients were rejected from the trial because of impaired renal function.

**Indications for Reduced Contrast Dose DECT for Suspected Pulmonary Embolism**

DECT can be performed in any patient but reduced contrast dose DECT for pulmonary embolism is most suitable for patients who meet the following criteria:

- Body weight less than 200 lbs
- Impaired kidney functions (eGFR < 60 mL/min/1.73 m²)
- Higher risk for contrast-induced nephropathy including pre-existing renal impairment, renal transplant, diabetes mellitus, age >70 years, anemia, congestive heart failure, hypotension, hypovolemia, taking nephrotoxic drugs, multiple myeloma

The typical volume of contrast material injected with reduced contrast dose DECT is 20-30 cc (370 mg% iodine) compared to the standard 80-110 cc used for traditional single energy CT or DECT for pulmonary embolism.

Before contrast is administered, the Mass General Emergency Department checks available creatinine/estimated glomerular filtration rate (eGFR) lab results for these patients. Patients with an estimated eGFR of < 60 mL/min/1.73 m² are considered at risk of contrast-induced nephropathy. According to the American College of Radiology (ACR) contrast manual, reduced contrast dose (< 30 ml) may decrease risks associated with contrast material. When these patients receive contrast, they should also receive IV hydration to minimize the risk of developing contrast-induced nephropathy.

Patients without impaired kidney function should be scanned with standard contrast dose CT.

In heavier patients (typically those greater than 200 lbs and BMI > 35 kg/m²), reduced contrast dose DECT may not provide sufficient diagnostic information. These patients may need a relatively high amount of contrast compared to than those under 200 lbs.

**Relative Contraindications**

CT pulmonary angiography may not be optimal in patients with metallic implants in the scanning field, an inability to hold their breath, or a history of stenosis or occlusion of the subclavian vein, brachiocephalic vein, or superior vena cava. In such cases, special modifications of injection and scan protocols may be necessary in consultation with sub-specialized radiologists.

**Radiation Dose**

The radiation dose from DECT for pulmonary embolism protocol at Mass General is in the range of 4–4.6 mSv, which is lower than that from standard single energy CT for pulmonary embolism.

**Scheduling**

Three CT scanners on the Mass General main campus are capable of DECT. Two of these scanners are located in Blake 2, and one is in the Emergency Radiology suite. Referring physicians may request DECT with reduced contrast volume by specifying it in the comments section associated with the scan request. Appointments can be made through ROE (inside Partners network) or ROE Portal (outside Partners network) or by calling 617-724-XRAY (9729).
Further Information
For further information on imaging for suspected pulmonary embolism, please contact Shaunagh McDermott, MD, Thoracic Imaging, Department of Radiology, Massachusetts General Hospital, at 617-724-2275.

We would like to thank Shaunagh McDermott, MD, Alexi Otrakji, MD and Mannudeep K. Kalra, MD, Division of Thoracic Imaging, Department of Radiology, Massachusetts General Hospital, and Ali Raja, MD, Emergency Medicine, Massachusetts General Hospital, for their assistance and advice on this issue.

References


