Dual-energy CT for the preoperative evaluation of lung function: correlation with $^{99m}$Tc-MAA SPECT

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Purpose

Dual source computed tomography (DSCT) can obtain dual energy images in the same phase of contrast enhancement by using different tube voltages. Dual energy CT (DECT) pulmonary angiography using DSCT allows selective visualization of the distribution of iodine contrast media in the lung parenchyma in addition to a standard pulmonary CT angiogram with high resolution morphology without additional dose. Therefore, DECT pulmonary angiography was expected to improve the diagnosis accuracy in pulmonary CT examination and to replace other functional imaging such as lung scintigraphy. Several studies of DECT iodine mapping were reported about its clinical efficacy for diagnosis [1-4]. For evaluating acute pulmonary embolism, DECT iodine mapping is able to display pulmonary perfusion defects with good agreement with scintigraphic findings using technetium-99m labeled macroaggregated albumin ($^{99m}$Tc-MAA) [5, 6]. However, DECT iodine mapping was evaluated only based on the visual presence or absence of perfusion defects by observers. To the best of our knowledge, there were few studies about objective evaluation of iodine mapping [7, 8]. Preoperative quantification of regional lung function prior to lung resection or transplantation is an indication for single photon emission computed tomography (SPECT) using $^{99m}$Tc-MAA. The purpose of this study was to assess the feasibility of DECT pulmonary angiography for the preoperative evaluation of lung function by comparing it with SPECT using $^{99m}$Tc-MAA.
Methods and Materials

We made a retrospective review of 25 patients (men-women, 17:8; mean age, 69.1 years; age range, 45-83 years) underwent DECT pulmonary angiography and $^{99m}$Tc-MAA SPECT during November 2008 and February 2010. The mean time between examinations was 2.6 days (range, 0-20). The study had been approved by the university’s ethics committee prior to patient recruitment.

All CT examinations were performed with a 64 slice DSCT (Somatom, Definition, Siemens Healthcare) in dual energy mode. Tube voltages were set to 140 kV (tube A) and 80 kV (tube B). To compensate for the lower photon output of tube B the reference tube current was set to 210 mA for tube B and 30 mA for tube A. Automatic tube current modulation (CARE Dose 4D) was used in all cases. The detector collimation was set to 0.6 × 64 mm. For DECT pulmonary angiography, 100ml medium-concentration iodine-based contrast media (Omnipaque 300; Daiichi-Sankyo) was administered at a flow rate of 3.0 ml/s followed by a 30 ml saline chaser bolus at the same injection rate. Scan delay time was set to 25 s. A caudocranial scan direction was chosen in order to avoid beam hardening artifacts due to high concentrations of iodine in the area of the subclavian vein or superior vena cava [9]. Images were reconstructed with 1.0 mm slice thickness and 1.0 mm reconstruction increment using a soft tissue kernel (D40). DECT iodine distribution maps were generated based on the spectral behavior of iodine.

The SPECT data acquisition (360 degrees, 128×128 matrix, 60view-projections, 20 s/rotation, 12 time rotations) was performed after an intravenous injection of 185 MBq of $^{99m}$Tc-MAA by using the dual head #-camera (E.CAM, Siemens HealthCare) using the low-energy high-resolution, parallel hole collimator. SPECT data reconstruction was achieved by filtered back projection using the Butterworth filter with a cut-off frequency of 0.53 mm$^{-1}$ and order 8.0.

To estimate the potential of DECT iodine mapping for objective analysis, left to total ratio (LTR) was applied for simulating pulmonary reserve after unilateral lung resection [10]. LTR was calculated by the following equation.

\[
\text{LTR} = \frac{\#S_L}{\#(S_L + S_R)} \quad (1)
\]

Where $S_L$ and $S_R$ are pixel values of the left lobe and the right lobe, respectively.

Pixel values of the left and right lungs obtained from both the DECT iodine maps and $^{99m}$Tc-MAA SPECT were separately summed and LTR was calculated, respectively. Then, we evaluated the correlation between the ratios.
Results

Fig. 1 on page 5 shows the linear regression analysis of the LTRs obtained with DECT iodine mapping vs. $^{99m}$Tc-MAA SPECT. The LTRs of DECT iodine map and $^{99m}$Tc-MAA SPECT showed a strong positive correlation ($r = 0.95; p < 0.001$). The gradient of fitted curve was 0.75 and it was under 1.0. It shows that differences between right lung and left lung were underestimated in DECT iodine map compared with $^{99m}$Tc-MAA SPECT (Fig. 2 on page 5). We assume that these differences depend on pharmacokinetic difference and it is inevitable. In this study, we applied the $^{99m}$Tc-MAA SPECT as a reference; however, we think there needs to be more consideration whether any current method of measuring lung perfusion is adequate for a correct diagnosis.

Although we used the a 30 ml saline chaser bolus after contrast media injection and selected a caudocranial scan direction to avoid beam hardening artifacts due to high concentrations of iodine in the area of the subclavian vein or superior vena cava, some non-applicable sections were found in the DECT iodine maps because of artifacts from concentrated contrast enhanced material. Recently, the studies about optimization of injection protocol were reported [11, 12]. Non-applicable sections can be diminished by using optimal protocol of contrast media injection.
Fig. 0: Figure 1: Scatter plots show correlations between LTR of DECT iodine mapping and LTR of 99mTc-MAA SPECT. The LTRs of DECT iodine map and 99mTc-MAA SPECT showed a strong positive correlation ($r = 0.95; p < 0.001$).

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**Fig. 0:** Figure 2: Axial image of $^{99m}$Tc-MAA SPECT (a) shows significant bilateral difference of pixel value. The differences between right lung and left lung were underestimated in DECT iodine map (b) compared with $^{99m}$Tc-MAA SPECT.

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Conclusion

There is a strong correlation between DECT iodine mapping and $^{99m}$Tc-MAA SPECT. Our results showed the possibility of DECT pulmonary angiography providing pulmonary functional information for the preoperative evaluation of lung reserve. It can be used in addition to a standard pulmonary CT angiogram with high resolution morphology without additional dose.
References


Personal Information

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