Pulmonary CT angiography: optimization of contrast enhancement technique

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Purpose

Background With multi-row detector CT applied clinically, CT pulmonary angiography (CTPA) has been considered the most important imaging method for pulmonary artery embolism diagnosis. With the rotation speed of the scanner becoming faster, the acquisition time of CTPA shortened markedly. But the contrast injection program changes little, with contrast injection often not finished even at the end of CT scanning, resulting in not only in over dose of contrast media to the patient but also in apparent hard beam artifact from the superior vena cava (SVC) and inefficiency of following injection of saline. We believe that with the development of the CT technique, the exact dose of contrast injected should be critical for CTPA study.

Purpose: To derive and evaluate a formula with which to calculate the exact dosage of contrast media used during CTPA study with small dose injection contrast test (SDCT) technique.
Methods and Materials

Formula derivation:

Method

Taking the vein from forearm to the main pulmonary artery (PA) as a single vessel proximately, the time for saline reaching the caudle end of superior vena cava (CEV) from injection point should take a portion of delay time (DT, from starting injection of contrast to scan beginning), so DT minus this portion time and plus the scan time from starting level of CTPA scan (near the lung base, scan direction-caudle to cranial) to the level of CEV, should be the contrast injection time which can ensure the injected saline reaches the caudle end of the SVC when scanning at the same level (fig. 1). Collected randomly the data of time-density curves of SDCT of 27 patients taking CTPA study, getting the enhancing peak times of CEV and right main pulmonary (MPA) from start of contrast injection, and calculating their ratio (fig. 2), and the ratio between the scan time to CEV and the whole scan time shown on the scan planning screen (fig. 3), derived the formula for calculating dosage of contrast to be used in CTPA.

Result: The enhancing peak time of CEV in the 27 patients was 7.29 s ±1.52 s and that of MPA was 11.33s±2.33s, the ratio was 0.65±0.09 (about 2/3) and the ratio of scan time to CEV to whole scan time was about 1/2, so that the formula for contrast dosage calculating was derived as (DTs/3+STs/2) FR ml/s (ST-scan time giving by the CT system after scan planting on the scout view, FR-injection flow rate of contrast), when needed saline can be delivered to the caudal end of SVC when scanning to the same level from the base of the lung.

Evaluation of the efficacy of the formula:

Method: 68 patients with clinically suspected pulmonary embolism (PE) and no PE found with CTPA (SIEMENS Sencation 16, collimate0.75mm×16, rotation time 0.5 s, pitch 1, scan direction from caudle to cranial) were divided randomly into group A- CTPA with conventional bolus tracing technique (n=26), and group B- CTPA with SDCT technique and contrast dosage calculated with the derived formula (n=42). Measure and calculate the CT value of right main pulmonary artery (RMPA), pulmonary vein of right upper lobe (RUPV), pulmonary artery and vein of right lower lobe (RLPA and RLPV) and ascending aota (AA), differences between RMPA and RMPV, RLPA and RLPV, RMPA and AA, calculate DT, total dosage of the contrast injected, calculation of the degree of the hard beam artifact produced by the contrast in the SVC by two senior radiologists with no knowledge of the method of enhancement the patient used in a three scale system: good, no artifact can be recognized and the density of SVC lower than contiguous
RMPA; acceptable, little artifact from SVC but not observation of RMPA interfered and poor, the artifact obviously interfering with RMPA observation. Statistically analysed the significance of differences in those data between the two groups.
Fig. 1: Drawing illustrating the contrast and saline injected flow. The whole time from injection start to CT scan from basis of the lung to the caudle end of the superior vena cava (CNS) should be delay time (from injection point to main pulmonary artery, MPA) plus the scan time. So the contrast injection time should be the whole time minus the saline injection time plus that scan time. All we should know is the ratio of segment from CNS to MPA. In the drawing: blue,-saline flow, orange-contrast flow, arrow-first half of scan.

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**Fig. 2:** Time-density curves of test CT scan with small dose of contrast injection. Put the ROI on the superior vena cava (curve 3), right main pulmonary artery (curve 1) and aorta (curve 2). From the time to peak of curve, we can calculate the ratio of SVC enhance time (should be saline injection time) to the delay time (MPA enhance time).

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Fig. 3: The screen of CT scan plan. With put the end line of scan field at the CEV temporally, scan time (arrow) can be get easily.

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Results

The difference in CT values of pulmonary arteries between the two groups was not significant (table 1) but the difference in the paired PA and PV's CT value differences was significant ($P=0.044$~$P=0.001$) (table 2) (fig 4). Contrast artifact of the SVC of the group B was significantly less than Group A ($P=0.002$) (table 3) (fig. 5, 6), dosage of contrast injected of group A was 87.6±7.3 ml, and that of group B was 40.±5.42ml ($P<0.001$).

Tab 1. Comparison of the CT value of RMPA, RUPV, RLPA, RLPV and AA between group A and group B

<table>
<thead>
<tr>
<th></th>
<th>RMPA</th>
<th>RUPV</th>
<th>RLPA</th>
<th>RLPV</th>
<th>AA</th>
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<tbody>
<tr>
<td>group A</td>
<td>301±117</td>
<td>247±88</td>
<td>329±122</td>
<td>240±103</td>
<td>194±78</td>
</tr>
<tr>
<td>group B</td>
<td>283±95</td>
<td>125±62</td>
<td>277±98</td>
<td>112±57</td>
<td>111±58</td>
</tr>
<tr>
<td>$t$</td>
<td>1.060</td>
<td>6.652</td>
<td>2.056</td>
<td>6.341</td>
<td>4.972</td>
</tr>
<tr>
<td>$P$</td>
<td>0.292</td>
<td>0.0001</td>
<td>0.044</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Tab 2. Comparison the CT value differences of RMPA and RUPV, RLPA and RLPV, RLPA and AA between group A and B

<table>
<thead>
<tr>
<th></th>
<th>RMPA-RUPV</th>
<th>RLPA-RLPV</th>
<th>RMPA-AA</th>
</tr>
</thead>
<tbody>
<tr>
<td>group A</td>
<td>54±118</td>
<td>89±123</td>
<td>108±156</td>
</tr>
<tr>
<td>group B</td>
<td>158±121</td>
<td>165±105</td>
<td>171±120</td>
</tr>
<tr>
<td>$t$</td>
<td>-3.346</td>
<td>-2.700</td>
<td>-1.697</td>
</tr>
<tr>
<td>$P$</td>
<td>&lt; 0.05</td>
<td>&lt; 0.05</td>
<td>&lt; 0.05</td>
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</table>

Tab 3. Comparison artifact of the SVC between group A and B

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Acceptable</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>group A</td>
<td>11#42#</td>
<td>10#39#</td>
<td>5#19)</td>
</tr>
<tr>
<td>group B</td>
<td>34#81#</td>
<td>7#17#</td>
<td>1#2#</td>
</tr>
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</table>

$\chi^2 = 10.714 \quad P=0.002#0.05$
**Fig. 4:** CTPA coronal multiple planes reformation (MPR) image with SDCT method, the density (enhancement) of left lower pulmonary vein (arrow head) is lower than that of left lower pulmonary artery (arrow).

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**Fig. 5:** CTPA at the level of main pulmonary artery with SDCT method, no artifact observed from SVC (arrow)

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Fig. 6: CTPA at the level of main pulmonary artery with conventional bolus tracing technique, show the hard beam artifact from high concentrated contrast in the SVC (arrow), interfering observation of right main pulmonary artery.

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Conclusion

**Conclusion:** Compared with conventional bolus tracing technique, the image quality and the PA enhancement of CTPA with SDCT technique and contrast dosage calculating with the derived formula were identical, but the density of PV was much lower, facilitating identification of pulmonary artery from pulmonary vein, the interference of contrast artifact in the SVC to right PA observation. The contrast dosage used with CTPA study also reduced significantly.
References


