Dynamic MR Perfusion Imaging vs. Time-Resolved MR Angiography vs. MDCT: Disease Extent Assessment and Outcome Prediction for Patients with Acute Pulmonary Thromboembolism

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Introduction: Acute pulmonary thromboembolism (APTE) is a common, potentially life threatening cardiopulmonary illness that has only recently attracted the attention of general public. Currently, multidetector-row CT (MDCT) pulmonary angiography can be used to identify clot within distal pulmonary arteries (PAs) with high sensitivities and specificities, and can demonstrate alternative diagnoses and underlying lung diseases. In addition, some investigators have evaluated the accuracy of CT scoring systems for PA clot assessment as well as right ventlicular (RV) failure assessment by using several parameters. Therefore, MDCT has become the first imaging examination in suspected APTE patients (1-3). As well as technical advances of CT, technical advances of magnetic resonance (MR) imaging make it possible to obtain time-resolved or four-dimensional (4D) contrast-enhanced MR angiography or perfusion MR imaging (perfusion MRI) in APTE patients (4-6). However, no one reported the potential of quantitative pulmonary perfusion parameters from perfusion MRI for disease extent assessment and utility as a predictor of acute PE (APTE) patients. We hypothesized that quantitatively assessed pulmonary perfusion parameters from contrast-enhanced perfusion MRI have potential for disease extent assessment and have predictive capability of patient outcome in APTE patients. The aim of our study was therefore to directly compare the capability for disease severity assessment and patient outcome prediction of MDCT and MR techniques in APTE patients.

Materials and Methods: Fifty consecutive APTE patients (22 men and 28 women; age range, 27-81 years; mean age, 61years) underwent contrast-enhanced MDCT, time-resolved MR angiography and perfusion MRI, and were treated in accordance with the established guideline (7). All MR studies were performed on two 1.5 T MR systems using a phased-array coil. From the signal intensity-time curves, pulmonary blood flow (PBF), pulmonary blood volume (PBV) and mean transit time (MTT) maps were generated on a pixel-by-pixel basis. From all perfusion parameter maps, each segmental perfusion parameter was determined by ROI measurement. To determine the most accurate pulmonary perfusion parameter for determination of pulmonary segment affected by PE and its feasible threshold value, diagnostic capability of each parameter was compared by receiver operating characteristic (ROC) analysis, and the feasible threshold value was also determined. For assessing the disease severity in APTE patients, the APTE index for perfusion MRI ($PE_{Perfusion\ MRI}$ index) was calculated as the ratio between total lung volume and lung volume affected by PE for evaluation of disease severity in each subject, when the determined feasible threshold value was adapted. On contrast-enhanced MDCT and time-resolved MR angiography, RV/LV diameter ratio and the APTE index for CT (PE_{CT} index) and time-resolved MR angiography (PE_{MRA} index) were also evaluated according to the past literatures (1-3). Then, ROC analyses were performed to determine the feasible threshold values for differentiation of mortality group from survival group. This was followed by comparison of sensitivities, specificities and accuracies of all parameters with each other by means of McNemar's test. Finally, logistic regression analyses were performed to determine whether a parameter was a significant predictor of patient outcome, which was either survival or death. A p value less than 0.05 was considered significant for all statistical analyses.

Results: Area under the curve of PBF (Az=0.98) was significantly larger than that of PBV (Az=0.82, $p<0.05$), and larger than that of MTT (Az=0.91, $p>0.05$). When the feasible threshold value of each parameter was used, sensitivity, specificity and accuracy of mean PBF and MTT were significantly better than those of mean PBV ($p<0.05$). In addition, sensitivity, specificity and accuracy of mean PBF were significantly better than those of mean MTT ($p<0.05$). On results of ROC analyses for distinguishing the mortality APTE patient group from the survival group and the diagnostic results for all parameter, Az, specificity and accuracy of the RV/LV diameter ratio (AZ=0.96, specificity=97.6, accuracy=92.0) and $PE_{Perfusion\ MRI}$ index (AZ=0.96, specificity=97.6, accuracy=92.0) were significantly better than those of the PE_{CT} index (AZ=0.86, $p<0.05$; specificity=83.36, $p<0.05$; accuracy=80.0, $p<0.05$) and PE_{MRA} index (AZ=0.86, $p<0.05$; specificity=83.36, $p<0.05$; accuracy=80.0, $p<0.05$). Results of logistic regression tests are shown in Table 2. Every logistic regression analysis demonstrated that each index was a significant predictor ($p<0.05$) with odds ratios ranging from 1.10 to 1.21. Representative

Conclusion: Quantitative assessment of perfusion MRI can be effective for disease extent assessment and outcome prediction for APTE patients. In addition, quantitative perfusion MRI can more accurately assess disease severity and predicted patient outcome than can pulmonary embolic burden observed on MDCT and time-resolved MR angiography, and should therefore be considered at least as valid as right ventricular dysfunction assessment with MDCT.

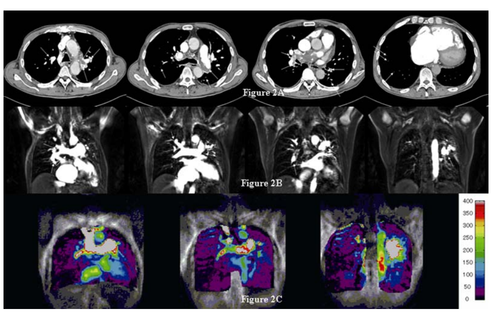

Figure 1. 66-year-old male with acute pulmonary embolism.
A: Contrast-enhanced MDCT (L to R: cranial to caudal) demonstrates thrombi (arrows) in bilateral main, interlobar, segmental and subsegmental pulmonary arteries. PECT index was 60 %, but RV/LV diameter ratio was 70 %. B: Source images of time-resolved contrast-enhanced MR angiography (L to R: ventral to dorsal) demonstrates thrombi (arrows) in bilateral main, interlobar, segmental and subsegmental pulmonary arteries, and heterogeneously reduced pulmonary parenchymal perfusion in both lungs. PEMRA index was 67.5 %. C: Quantitative PBF maps (L to R: ventral to dorsal) demonstrate heterogeneously and markedly reduced PBF in both lungs. PEPerfusio MRI index was 85.0 %.

Table 1. Feasible threshold values based on ROC analysis and diagnostic capability of pulmonary perfusion parameters for differentiation of APTE from non-APTE segments

	RV/LV diameter ratio	PE_{CT} index	PE_{MRA} index	$PE_{Perfusion\ MRI}$ index
Az	0.96	0.86*, **	0.86*, **	0.96
Feasible threshold value	60 %≤	60% ≤	60% ≤	60% ≤
Sensitivity (%)	62.5 (5/8)	62.5 (5/8)	62.5 (5/8)	62.5 (5/8)
Specificity (%)	97.6 (41/42)	83.3*, ** (35/42)	83.3*, ** (35/42)	97.6 (41/42)
Positive Predictive Value (%)	83.3 (5/6)	41.6 (5/12)	41.6 (5/12)	83.3 (5/6)
Negative Predictive Value (%)	93.2 (41/44)	87.5 (35/40)	87.5 (40/45)	93.2 (41/44)
Accuracy (%)	92.0 (46/50)	80.0 (40/50)*, **	80.0 (40/50)*,**	92.0 (46/50)

AZ: Area under the curve
RV: right ventricle; LV: left ventricle

Table 2. Results of logistic regression analysis for each index as predictor of patient outcome in APTE patients.

	Odds ratio*	95% CI	p value
RV/LV diameter ratio	1.17	1.05-1.31	0.004
PE_{CT} index	1.10	1.03-1.18	0.004
PE_{MRA} index	1.16	1.05-1.27	0.004
$PE_{Perfusion\ MRI}$ index	1.21	1.06-1.37	0.004

*: For increments of 10 % in an index.

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