Quantitative Assessment of Dynamic MR Perfusion Imaging: Utility for Prediction of Patient Outcome in Acute Pulmonary Embolism

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Synopsis: Pulmonary embolism (PE) presents with a wide clinical spectrum, from asymptomatic small PE to life threatening major PE. However, many previous CT and MR studies have focused on the diagnostic capability, and under-investigated the capability for prediction of patient outcome. Currently, some investigators have reported the capability of dynamic MR imaging for assessment of regional perfusion abnormalities (1, 2). Therefore, we hypothesized dynamic MR perfusion imaging had the potential for quantitative assessment of pulmonary perfusion abnormalities and predict patient outcome in acute PE patients. The purpose of our study is to evaluate the utility of dynamic MR perfusion imaging for prediction of patient outcome in acute PE patients.

Materials and Methods: Twenty-five consecutive acute PE patients (14 men, 11 women, age ranged 22-78) underwent contrast-enhanced MDCT, dynamic MR perfusion imaging, lung scan, angiography, treatment and follow-up examination. All MR studies were performed on a 1.5 T superconducting magnet (Gyroscan Intera; Philips Medical systems, Best, The Netherlands) using a phased-array coil. Dynamic MR images (TR 2.7 ms/ TE 0.6 ms/ flip angle 40°) were acquired with a 3D radiofrequency spoiled GRE sequence. 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 by ROC-based positive test. To assess the disease severity in acute PE patients, PE 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. Then, mean PE indexes were compared between death (n=5) and survival (n=20) groups by Student's t-test. Finally, logistic regression analyses were performed to determine the significant predictor for patient outcome (death or survival) among age, sex, PE index with adaptation of determined threshold value, anticoagulation therapy, thrombolytic therapy, preexisting cardiac conditions and risk factor of DVT. Risk ratio of significant predictor was also calculated. A p value less than 0.05 was considered significant in all statistical analyses.

Results: All 3D dynamic MR perfusion imaging examinations were successfully completed. PBF, PBV and MTT maps of representative case are shown in Figure 1. The result of ROC analysis of each pulmonary perfusion parameter is shown in Figure 2. Area under the curve (AZ) of PBF (Az=0.98, p<0.05) was significantly higher than that of MTT (Az=0.88) and PBV (Az=0.81). The results of ROC-based positive test is shown in Figure 3. To maximize the diagnostic accuracy, the threshold value of PBF was determined as 80ml/100ml/min. When 80ml/100ml/min was adapted as threshold value, mean PE index of death group (67.4±4.0 %, Mean±Standard error) was significantly higher than that of survival group (29.6±7.1%, p=0.0003). The results of logistic regression analyses and risk ratios of significant predictor to determine the patient outcome are shown in Table 1. PE index was a significant predictor of patient outcome (p=0.04; odds ratio, 2.66 for 10 % increase in PE index; 95% confidence interval: 1.05, 6.61).

Conclusion: Quantitatively assessed dynamic MR imaging is useful for prediction of patient outcome in acute PE patients.

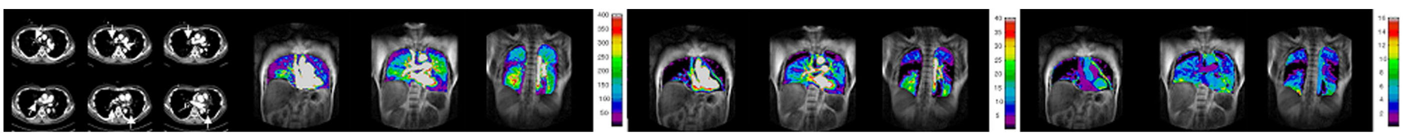

Fig. 1a **Fig. 1b** **Fig. 1c** **Fig. 1d**

Figure 1. 49-year old male acute pulmonary embolism patient.

a: Contrast-enhanced CT demonstrate thrombi in the right main, trunks anterior and interlobar pulmonary arteries, and left descending trunk of pulmonary artery (arrows). b: Quantitative PBF maps (L to R: anterior to posterior) demonstrated heterogeneous and decreased PBF in the both lungs. c: Quantitative PBV maps (L to R: anterior to posterior) demonstrated heterogeneous and decreased PBV in the both lungs. d: MTT maps (L to R: anterior to posterior) demonstrated heterogeneous MTT in the both lungs.

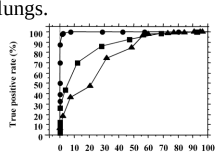

Fig. 2

Figure 2. ROC curves of PBF (●), PBV (▲) and MTT (■).

Area under the curve (AZ) of PBF (Az=0.98, p<0.05) was significantly higher than that of MTT (Az=0.88) and PBV (Az=0.81).

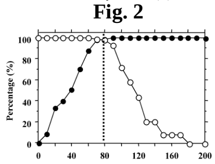

Fig. 3

Figure 3. The results of ROC-based positive test of PBF.

To maximize the diagnostic accuracy, the threshold value of PBF was determined as 80ml/100ml/min. When 80ml/100ml/min was adapted, sensitivity, specificity, positive predictive value, negative predictive value and accuracy for distinguishing pulmonary segment with PE from that without PE were 98.7 (160/162) %, 97.9 (282/288) %, 96.4 (160/166)%, 99.3 (282/284) % and 98.2 (442/450) %, respectively.

Table 1. Results of logistic regression analysis and odds ratio of significant predictor.

Predictors	p value	Odds ratio♣	95% CI
Age	0.96	N/A	N/A
Sex	0.90	N/A	N/A
PE index*	0.04	2.66	1.05 6.61
Thrombolic therapy	0.99	N/A	N/A
Cardiac condition	0.99	N/A	N/A
Risk of DVT	0.90	N/A	N/A

♣: For increments of 10 % in PE index.
95% CI: 95% confidence interval of odds ratio for increments of 10 % in PE index
N/A: Not applicable
*: Significant predictor to patient outcome (p<0.05).

References.

1. Levin DL, et al. Magn Reson Med 2001; 46: 166-171.
2. Ohno Y, et al. J Magn Reson Imaging. 2004; 20: 353-365.