Comparative Analysis of Predictive Capability of 3D Non-Contrast-Enhanced Perfusion MRI, 3D Contrast-Enhanced Perfusion MRI, Quantitatively Assessed Thin-Section CT, and Perfusion Scan for Postoperative Lung Function in Non-Small Cell Lung Cancer Patients

Yoshiharu Ohno[1], Shinichiro Seki[2], Mizuho Nishio[1], Hisanobu Koyama[2], Takeshi Yoshikawa[1], Sumiaki Matsumoto[1], Nobukazu Aoyama[3], Yoshimori Kassai[4], Masao Yui[4], Hideaki Kawamitsu[3], and Kazuro Sugimura[2]

[1]Advanced Biomedical Imaging Research Center, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [2]Radiology, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan, [3]Center for Radiology and Radiation Oncology, Kobe University Hospital, Kobe, Hyogo, Japan, [4]MRI Systems Development Department, Toshiba Medical Systems Corporation, Otawara, Tochigi, Japan

Introduction: Despite advances in radiation therapy and chemotherapy, surgical resection remains the treatment of choice for resectable non-small cell lung cancer. In current medical practice, perfusion scan combined with spirometry are the most widely utilized radiological examination for evaluation of patients whose pulmonary function, on the basis of spirometry findings alone, may not be sufficient to tolerate resection (1). As another alternative approach for evaluating surgical risk in lung cancer patients, quantitative or qualitative evaluation by CT based on lung attenuation or anatomy has been proposed (1, 2). In the last decade, 3D dynamic contrast-enhanced perfusion MR imaging (CE-perfusion MRI) at 1.5 T scanner is tested and demonstrates the similar capability for prediction of postoperative lung function, when compared with quantitatively assessed CT and perfusion SPECT or SPECT/CT (3-5). However, there are several technical problems on dynamic CE-perfusion MRI at 3T system, and non-CE-perfusion MRI has suggested as having the advantages. In this situation, no one evaluate its' capability for regional perfusion assessment, and compare its' potential for prediction of postoperative lung function than other modalities in NSCLC patients.

We hypothesize that Non CE-perfusion MRI based on fresh blood imaging (FBI) technique at 3T system can accurately assess regional perfusion difference, and predict postoperative lung function in NSCLC patients, when compared with perfusion scan (Q scan), thin-section MDCT and dynamic CE-perfusion MRI. The purpose of this study was to prospectively and directly compare capabilities of regional perfusion assessment and prediction of postoperative lung function in NSCLC patients among Q scan, thin-section CT, dynamic CE-perfusion MRI and non-CE-perfusion MRI.

Materials and Methods: 35 consecutive pathologically proven and operable NSCLC patients (19 males, 16 females; mean age: 72 years) underwent non-CE-perfusion MRI, dynamic CE-perfusion MRI, multi-slice CT, Q scan, and FEV_1% measurements before and after lung resection. Non-CE- and dynamic CE-perfusion MRIs were acquired at a 3T scanner. On non-CE- and dynamic CE-perfusion MRIs and Q scan, each regional perfusion rate in the resected lobe was determined as signal intensity or radioisotope uptake ratio between resected lobe and total lung. Then, postoperative FEV_1% ($poFEV_1$%) was predicted from non-CE-perfusion MRI ($poFEV_1\%_{\text{Non-CE-perfusion MRI}}$), dynamic CE- perfusion MRI ($poFEV_1\%_{\text{CE-Perfusion MRI}}$) and Q scan ($poFEV_1\%_{\text{Q scan}}$) were assessed from regional perfusion rate within total and resected lungs. Quantitatively assessed CT was used to predict $poFEV_1$% from the functional lung volumes by means of commercially available software ($poFEV_1\%_{\text{Quantitative CT}}$). To determine the capability of non-CE-perfusion MRI for regional perfusion assessment, regional perfusion rate of non-CE-perfusion MRI was statistically correlated with that of dynamic CE-perfusion MRI and Q scan. To determine the capability for prediction of postoperative lung function among four methods, each predicted poFEV1% was correlated with actual $poFEV_1$%. Finally, the limits of agreement (mean±1.96×standard deviation) between actual and each predicted $poFEV_1$% was also evaluated by Bland-Altman analysis. A p value less than 0.05was considered as significant in each statistical analysis.

Results: Representative case is shown in Figure 1. Regional perfusion rate of non-CE-perfusion MRI had significant and good correlations with that of dynamic CE-perfusion MRI ($r=0.77$, $p<0.0001$) and Q scan ($r=0.70$, $p<0.0001$). The limits of agreements between non-CE-perfusion MRI and dynamic CE-perfusion MRI(1.3 ± 11.4%) and that between non-CE-perfusion MRI and Q scan (2.2 ± 12.3%) were small enough for clinical purpose. Correlation and the limits of agreement between each $poFEV_1$% and actual $poFEV_1$% are shown in Table 1. There are significant and excellent correlations between actual poFEV1% and each $poFEV_1$% ($0.89 \le r \le 0.95$, $p<0.0001$). The limits of agreement of non-CE-perfusion MRI (1.6±11.6 %) were smaller than that of Q scan (3.2±13.2 %), and almost equal to that of thin-section CT (1.9±10.8%) and dynamic CE-perfusion MRI (2.7±11.8%).

Conclusion: Non-CE-perfusion MRI by means of 3D FBI sequence is considered at least as valuable as dynamic CE-perfusion MRI and Q scan for regional perfusion assessment in NSCLC patients. In addition, non-CE-perfusion MRI has similar or slightly better capability for prediction of postoperative lung function in NSCLC patients, when compared with thin-section CT, Q scan and dynamic CE-perfusion MRI.

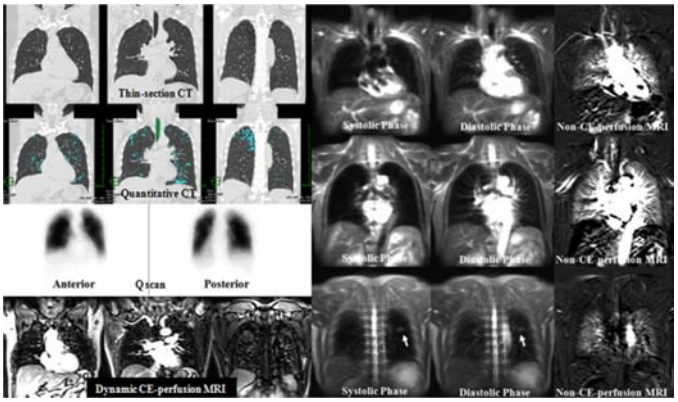

Figure 1. 63-year-old male subject with squamous cell carcinomoa in the left lower lobe.

A: Thin-section MPR image and quantitatively assessed CT show low attenuation areas in both lungs and lung cancer as a nodule with cavity in the left lower lobe. The low attenuation areas, whose CT values were less than -950HU, were expressed as sky blue. B: Q scan demonstrates heterogeneous perfusion within the lung. C: Dynamic CE-perfusion MRI shows heterogeneously enhanced lung parenchyma except lung cancer. D: Non-CE-perfusion MRI (L to R: systolic phase image, diastolic phase image, and non-CE-perfusion image obtained by subtraction between two phase images). Non-CE-perfusion MRI clearly demonstrate lung perfusion except lung cancer (black arrow).

Table 1. Correlation and the limits of agreement between each $poFEV_1$% and actual $poFEV_1$%.

	Correlation		The limits of agreement
	Correlation coefficient	p value	Mean±1.96×Standard deviation
Thin-section CT	0.95	p<0.0001	1.9±10.8
Q scan	0.89	p<0.0001	3.2±13.2
Dynamic CE-perfusion MRI	0.93	p<0.0001	2.7±11.8
Non-CE-perfusion MRI	0.94	p<0.0001	1.6±11.6

References:

1. Wyser C, et al. Am J Respir Crit Care Med 1999; 159: 1450-1456
2. Bolliger CT, et al. Respiration 2002; 69: 482-489
3. Ohno Y, et al. AJR Am J Roentgenol 2004;182:73-78
4. Ohno Y, et al. AJR Am J Roentgenol. 2007; 189: 400-408.
5. Ohno Y, et al. Eur J Radiol. 2011; 77: 97-104