Oxygen-enhanced MR Imaging: Utility of Prediction of Postoperative Lung Function in Lung Cancer Patients

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Synopsis: Most lung cancer patients have a history of cigarette smoking and chronic obstructive lung disease, which bring potential risks for operation. Currently, CT and/or perfusion scintigraphy are utilized for evaluation of the patient whose pulmonary function may not be adequate to tolerate resection on the basis of spirometry alone (1). Recently, oxygen-enhanced MR imaging offers an alternative approach for imaging regional ventilation and oxygen diffusion (2-4). We hypothesized oxygen-enhanced MR imaging may have potential for prediction of postoperative lung function in lung cancer patients. The purpose of this study is to demonstrate the capability of oxygen-enhanced MR imaging for prediction of postoperative lung function in lung cancer patients.

Methods and Materials: Thirty consecutive patients (16 men, 14 women; aged 44 to 81 years; mean age 65 years) considered candidates for lung resection underwent oxygen-enhanced MR imaging, contrast-enhanced CT, perfusion scintigraphy, and measurement of forced expiratory volume in 1 second (FEV1). A respiratory-synchronized inversion recovery half-Fourier single shot turbo spin echo sequence (TR 3200-5000 ms; TE 4 ms; TI 900 ms; ETS 4ms) was used for data acquisition. In order to visualize the relative enhancement map of oxygen-enhanced MR imaging, oxygen-enhanced MR images were expressed as the percentage change between the oxygen-enhanced and baseline images on a pixel-by-pixel basis. On oxygen-enhanced MR imaging, the predicted postoperative FEV1 ($poFEV1_{MR}$) was estimated by preoperative FEV1 and averaged relative enhancement ratios of resected lobe and all lobes in both lungs (total 6 lobes). On contrast-enhanced CT, postoperative FEV1s were predicted by quantitative and qualitative methods. As quantitative method (quantitative CT), commercially available density-masked CT software was utilized for prediction of postoperative FEV1 ($poFEV1_{Quantitative\ CT}$). The $poFEV1_{Quantitative\ CT}$ was estimated by preoperative FEV1 and functional lung volumes of resected lobe and all lobes. As qualitative method (qualitative CT), the predicted postoperative FEV1 ($poFEV1_{Qualitative\ CT}$) was estimated by preoperative FEV1, the number of bronchopulmonary segments removed by lung resection and total numbers of bronchopulmonary segments in both lungs (total 19 segments). On perfusion scintigraphy, the predicted postoperative FEV1 ($poFEV1_{Perfusion\ scintigraphy}$) was estimated by preoperative FEV1 and regional perfusion ratios of resected lobe and all lobes.

To compare the capability of oxygen-enhanced MR imaging for prediction of postoperative lung function with other method, the correlation and the limits of agreement between actual and each predicted postoperative FEV1 were statistically evaluated. The limits of agreement between actual and each predicted postoperative FEV1 was analyzed by Bland-Altman analysis. A p value less than 0.05 was considered to be significant in all statistical analyses. The basic theory and application of the limits of agreement have been documented in the literature (5).

Results: All 30 oxygen-enhanced MR imaging examinations were completed successfully. Representative case is shown in Figure 1.

Comparison of correlation between each actual and predicted postoperative FEV1 was shown in Table. 1. The $poFEV1_{MR}$ ($r=0.90$. $r^2=0.81$, $p<0.0001$) and the $poFEV1_{Quantitative\ CT}$ ($r=0.90$. $r^2=0.81$, $p<0.0001$) had excellent correlation with actual postoperative FEV1 (percentage predicted). Correlation coefficient of $poFEV1_{MR}$ was higher than that of $poFEV1_{Qualitative\ CT}$ ($r=0.87$. $r^2=0.76$, $p<0.0001$) and $poFEV1_{Perfusion\ scintigraphy}$ ($r=0.88$. $r^2=0.77$, $p<0.0001$).

The limits of agreement between actual and each predicted postoperative FEV1 are shown in Table 2. The limits of agreement between $poFEV1_{MR}$ and actual postoperative FEV1 was between -9.9% and 10.9%, smaller than those between actual and predicted postoperative FEV1 by using qualitative CT method and perfusion scintigraphy, and equal to that between $poFEV1_{Quantitative\ CT}$ and actual postoperative FEV1.

Conclusion: Oxygen-enhanced MR imaging has the potential to predict postoperative lung function similar to quantitative assessment of CT in lung cancer patients.

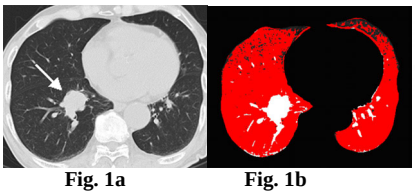

Fig. 1a Fig. 1b

Fig. 1c

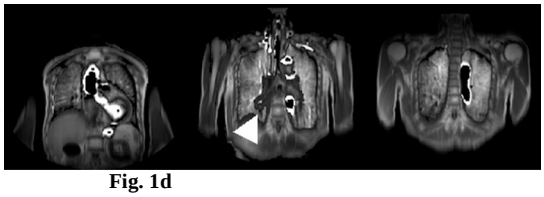

Fig. 1d

Figure 1. 69-year-old subject with adenocarcinoma in the right lower lobe with subtle pulmonary emphysema.

a: Routine transverse CT reveals no low attenuation areas in both lungs; the mass is seen (arrow). b: On quantitative CT, functional lung is expressed as red, pulmonary emphysema is expressed as gray, and lung cancer and fibrosis are expressed as white. c: Perfusion scintigraphy (anterior and posterior views) demonstrates heterogeneous uptake excluding lung cancer (arrow). d: Oxygen-enhanced MR images (L to R, from anterior to posterior) show heterogeneous oxygen-enhancement in both lungs excluding lung cancer (arrowhead).

Table 1. Comparison of correlation between each actual and predicted postoperative FEV1.

Predicted postoperative FEV1	r	r^2	p value
$poFEV1_{MR}$	0.90	0.81	<0.0001
$poFEV1_{Quantitative\ CT}$	0.90	0.81	<0.0001
$poFEV1_{Qualitative\ CT}$	0.87	0.76	<0.0001
$poFEV1_{Perfusion\ scintigraphy}$	0.88	0.77	<0.0001

Table 2. The limits of agreement between each actual and predicted postoperative FEV1.

Predicted postoperative FEV1	The limits of agreement (%)
$poFEV1_{MR}$	0.5±10.4
$poFEV1_{Quantitative\ CT}$	0.7±11.0
$poFEV1_{Qualitative\ CT}$	1.1±11.8
$poFEV1_{Perfusion\ scintigraphy}$	-0.5±11.4

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