Oxygen-enhanced MRI vs. Quantitative CT vs. Perfusion SPECT/CT: Quantitative and Qualitative Capability to Predict Therapeutic Effect for Lung Volume Reduction Surgery Candidates

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Introduction: During the last decade, evaluation for lung volume reduction surgery (LVRS) of most patients have involved preoperative radiologic examinations including chest radiography, quantitatively and qualitatively assessed CT, and perfusion scintigraphy or single-photon emission tomography (SPECT) for assessment of disease extent, severity and distribution (1-3). From 1996 onward, various investigators have suggested that hyperpolarized noble gas MRI and oxygen-enhanced MR imaging (O_2-enhanced MRI) can be useful for assessment of regional morphological and functional changes in pulmonary diseases. In addition, it has been proposed that O_2-enhanced MRI can assess regional ventilation and alveolocapillary gas transfer of molecular oxygen (4, 5). However, none of these studies have examined the quantitative and qualitative capabilities of O_2-enhanced MRI for evaluation of candidates for LVRS, and compared with that of evaluation by means of thin-section MDCT and perfusion SPECT/CT. We hypothesized that O_2-enhanced MRI has the potential to quantitatively and qualitatively predict therapeutic effect for candidates for LVRS, and that results obtained with O_2-enhanced MRI can be considered at least as valid as those obtained with thin-section MDCT or perfusion SPECT/CT. The purpose of the study was thus to prospectively and directly compare the quantitative and qualitative capabilities of O_2-enhanced MRI, thin-section MDCT and perfusion SPECT/CT to predict therapeutic outcomes for LVRS candidates.

Materials and Methods: 24 consecutive candidates for LVRS (20 men and five women, age range 45-76 years) underwent thin-section MDCT, O_2-enhanced MRI at three 1.5 T scanners and perfusion SPECT/CT before and after LVRS. Clinical outcomes for each candidate were evaluated in terms of differences between pre- and postoperative %FEV_1, PaO_2 6-minute walking distance (6MWD), and the transition dyspnea index (TDI). Quantitatively assessed upper-lower lung ratios (U/L ratios) on O_2-enhanced MRI, thin-section MDCT and SPECT/CT before LVRS were calculated from regional relative enhancement ratios (RERs), functional lung volumes and radioisotope uptakes between upper and lower lung field. Qualitatively assessed U/L ratios on O_2-enhanced MRI, MDCT and SPECT/CT before LVRS were estimated by using visual scoring systems. To evaluate the correlation between each of the U/L ratios and clinical outcomes, every preoperative U/L was statistically correlated with changes in the pre- and postoperative status of FEV_1, PaO_2, 6MWD and TDI assessed 6 months after LVRS. To determine the capability of visualization of O_2-enhanced MRI to assess therapeutic effect after LVRS, improvement of MRER was correlated with changes in the pre- and postoperative status of %FEV_1, PaO_2, and 6MWD and TDI. A p value less than 0.05 was considered to be significant for all statistical analyses.

Results: Representative case is shown in Figure 1. Results of correlation between quantitative and qualitative U/Ls assessed for each modality and for clinical outcomes are shown in Table 1. Quantitatively assessed U/Ls for each of the methods showed moderate or negative correlations, both statistically significant, with clinical outcomes except TDI ($-0.63 \leq r \leq -0.47$; $p<0.05$). Qualitatively assessed U/Ls for each method showed moderate or positive correlations, both statistically significant, with clinical outcomes except TDI ($0.41 \leq r \leq 0.57$; $p<0.05$). Improved MRER showed moderate, good, or positive correlations, all statistically significant, with clinical outcomes (%FEV_1: $r=0.71$, $p<0.0001$; PaO_2: $r=0.64$, $p<0.0001$; 6MWD: $r=0.45$, $p=0.02$; TDI: $r=-0.44$, $p=0.03$).

Conclusion: O_2-enhanced MRI shows potential for more accurate prediction of postoperative clinical outcome for LVRS candidates than is possible with perfusion SPECT/CT, and can be considered at least as reliable as thin-section MDCT. In addition, O_2-enhanced MRI may play a complementary role in the management of candidates for LVRS, and can directly visualize therapeutic effect as regional pulmonary respiration improvement for use in routine clinical practice.

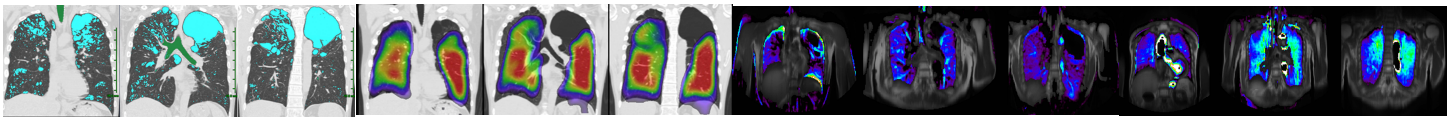

Fig. 1A **Fig. 1B** **Fig. 1C** **Fig. 1D**

Figure 1. 42-year-old male candidate for lung volume reduction surgery

A: Quantitatively assessed thin-section MDCT on coronal planes (L to R: ventral to dorsal) show giant bulla and emphysema in both lungs in blue. $U/L_{Quantitative\ CT}$ was 0.23 and $U/L_{Qualitative\ CT}$ was 8. B: SPECT/CT on coronal planes (L to R: ventral to dorsal) show perfusion defects or diminished perfusion due to giant bulla and emphysema in both lungs. $U/L_{Quantitative\ SPECT/CT}$ was assessed as 0.3 and $U/L_{Qualitative\ SPECT/CT}$ as 7. C: Preoperative O_2-enhanced MRI on coronal planes (L to R: ventral to dorsal) shows heterogeneously and markedly reduced oxygen enhancement due to giant bulla and emphysema in both lungs. Relative enhancement is expressed as a color-coded map showing pixels with 0 to 0.5 enhancement progressing from dark blue to red. $U/L_{Quantitative\ O2\text{-}enhanced\ MRI}$ was 0.25 and $U/L_{Qualitative\ O2\text{-}enhanced\ MRI}$ was 7. D: Postperative O_2-enhanced MRI on coronal planes (L to R: ventral to dorsal) shows markedly improved oxygen enhancement in both lungs. Relative enhancement is expressed as a color-coded map showing pixels with 0 to 0.5 enhancement progressing from dark blue to red.

Table 1. Correlations between U/Ls and parameters of postoperative outcomes.

	Clinical outcomes (Differences between post- and pre-operative status)							
	%FEV_1		PaO_2		6MWD		TDI	
	r	p value	r	p value	r	p value	r	p value
$U/L_{Quantitative\ CT}$	-0.62	<0.001	-0.59	0.001	-0.54	0.006	0.30	0.17
$U/L_{Quantitative\ O2\text{-}enhanced\ MRI}$	-0.63	<0.001	-0.59	0.001	-0.55	0.006	0.29	0.18
$U/L_{Quantitative\ SPECT/CT}$	-0.56	0.003	-0.55	0.006	-0.47	0.02	0.29	0.18
$U/L_{Qualitative\ CT}$	0.42	0.04	0.48	0.01	0.57	0.004	-0.27	0.20
$U/L_{Qualitative\ O2\text{-}enhanced\ MRI}$	0.42	0.04	0.48	0.01	0.57	0.004	-0.27	0.20
$U/L_{Qualitative\ SPECT/CT}$	0.41	0.04	0.47	0.02	0.41	0.04	-0.27	0.20

U/L: Ratio of upper versus middle and lower lobes or lower zones, % FEV_1: Percentage of predicted forced expiratory volume in one second, PaO_2: Partial pressure of arterial oxygen, 6MWD: 6-minute walking distance, TDI: Transition dyspnea index

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