Comparison of Assessment of Preoperative Pulmonary Vasculature in NSCLC Patients by Non-Contrast-Enhanced and 4D Contrast-Enhanced MR Angiography at 3T and by Contrast-Enhanced MDCT Using a 64-Detector Row System

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Introduction: Branching patterns of pulmonary vasculature reportedly show many variations, so that pulmonary vasculature assessment is considered important for surgical procedures for non-small cell lung cancer (NSCLC) patients. In this context, a few investigators have suggested that non- or contrast-enhanced (CE-) multi-detector row CT (MDCT) may be useful for assessment of pulmonary vasculature and tumor extent because it uses thin-section axial images, multiplanar reformatted (MPR) images and three-dimensional (3D) CT images (9-11). In addition, CE-magnetic resonance (MR) angiography and time-resolved or four-dimensional (4D) CE-MR angiography (CE-MRA) at 1.5 T MR systems have been proposed as new techniques for assessment of vasculature in patients with lung cancer as well as other pulmonary diseases (2). However, it has been suggested that administration of gadolinium contrast media carries a risk for patients with low renal function or renal dysfunction due to nephrogenic systemic fibrosis (NSF) or patients with asthma or allergic reaction to gadolinium contrast media. Since the early days of use of MR imaging in the clinical setting, non-CE-MRA using two-dimensional (2D) or 3D time of flight (TOF), 2D or 3D phase contrast (PC) MR imaging and 2D or 3D balanced steady-state free-precession (bSSFP) imaging have been introduced for pulmonary disease assessment. In addition, during the past decade or so, several novel procedures have been introduced as a new version of non-CE-MRA angiography using 2D or 3D fresh blood imaging (FBI) obtained with an ECG-gated 3D half-Fourier fast spin-echo (FSE) sequence, and 2D or 3D time spatial labeling inversion pulse (time-SLIP) techniques, which are performed as arterial spin labeling technique (3). However, to the best of our knowledge, no direct comparison has been made of assessment of pulmonary vasculature in candidates for thoracic surgery by non-CE-MRA, 4D CE-MRA at 3T, and thin-section CE-MDCT. We hypothesized that non-CE-MRA at 3T could assess pulmonary vasculatures as effectively as 4D CE-MRA at 3T and thin-section CE-MDCT using a 64-detector row system, and be used as a substitute for these techniques for thoracic surgery in NSCLC patients. The purpose of this study was thus to prospectively and directly compare assessment of pulmonary vasculature in NSCLC patients before surgical treatment by non-CE-MRA, 4D CE-MRA and thin-section CE-MDCT.

Materials and Methods: 77 consecutive pathologically proven NSCLC patients (41 males, 36 females; mean age: 71 years) who were clinically assessed as stage I underwent thin-section CE-MDCT, non-CE-MRA and 4D CE-MRA, and surgical treatment. Postoperatively, two board-certified thoracic surgeons with more than 20 years' experience were instructed to complete detailed surgical forms to ensure standardized surgical quality control, and also to record information about pulmonary vasculatures affecting surgical resection. All MRA procedures were performed with a 3T MR system (Vantage Titan 3T; Toshiba Medical Systems, Ohtawara, Tochigi, Japan) using an eight-element phased-array body surface coil and receiver channels combined with parallel imaging capability (SPEEDER, Toshiba Medical Systems). Five sequences performed for non-CE-MRA and 4D CE-MRA examinations of each patient. The SPEEDER factor for each sequence was similar to the sensitivity encoding (SENSE) factor or reduction factor used for parallel imaging. 2D ECG-gated cine-MRI with a steady-state free precession (SSFP), ECG-gated 3D time-spatial labeling inversion pulse (time-SLIP) technique combined with half-Fourier FSE, ECG-gated 3D FBI and 4D CE-MRA sequences obtained in the coronal plane for assessment of pulmonary veins. Then, visualization and variation of pulmonary vasculature affecting surgical resection were assessed by 5-point visual scoring systems in each patient. To compare visualization by the three methods of pulmonary vasculature relevant for segmentectomy and lobectomy, visualization scores were statistically compared by means of Fisher's least significant difference test. To compare assessment by the three methods of variations in overall pulmonary vasculature assessment relevant for surgical treatment, ROC analyses were performed on a per-patient basis. Finally, sensitivity, specificity and accuracy of the three methods for the detection of anomalies were directly compared by means of McNemar's test.

Results: Representative case is shown in Figure 1. For pulmonary artery and vein assessment for segmentectomy, there were no significant difference of the visual score among thin-section CE-MDCT, 4D CE-MRA and non-CE-MRA ($p>0.05$). Results of ROC analysis and diagnostic performance of pulmonary vasculature assessment are shown in Table 1. There were also no significant difference of area under the curve and diagnostic performance of pulmonary vasculature assessment among three methods ($p>0.05$).

Conclusion: Pulmonary vascular assessment by non-CE-MR angiography can be considered to be equally valid as that by 4D CE-MR angiography and thin-section CE-MDCT for NSCLC patients before surgical treatment.

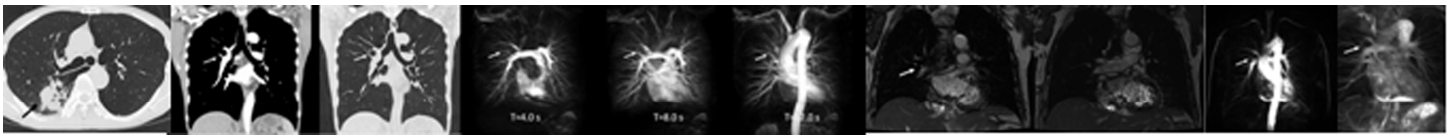

Figure 1A **Figure 1B** **Figure 1C** **Figure 1D** **Figure 1E** **Figure 1F**

Figure 1. 50-year-old man with adenocarcinoma

A: Thin-section CT shows lung cancer (black arrow) in the right posterior segment. B: Thin-section MPR images clearly show that the posterior segmental artery (arrow) branches directly from the pulmonary arterial trunk. Visualization score: 5, variation probability score: 5. C: 4D CE-MR angiography clearly shows that the posterior segmental artery (arrow) branches directly from the pulmonary arterial trunk. Visualization score: 5, variation probability score: 5. D: Cine MRI shows that the posterior segmental artery (arrow) branches directly from the pulmonary arterial trunk. Visualization score: 4, variation probability score: 5. E: FBI clearly shows that the posterior segmental artery (arrow) branches directly from the pulmonary arterial trunk. Visualization score: 5, variation probability score: 5. F: Time-SLIP image clearly shows that the posterior segmental artery (arrow) branches directly from the pulmonary arterial trunk. Visualization score: 5, variation probability score: 5.

Table 1. Comparison of assessment of pulmonary vascular anomalies by non-CE-MR angiography, 4D CE-MR angiography and thin-section CE-MDCT.

		Area under the curve	Threshold value	SE (%)	SP (%)	PPV (%)	NPV (%)	AC (%)
Overall pulmonary arteries	Non CE-MRA	0.94	4	77.1 (27/35)	97.4 (37/38)	96.4 (27/28)	82.2 (37/45)	87.7 (64/73)
	4D CE-MRA	0.94	4	77.1 (27/35)	97.4 (37/38)	96.4 (27/28)	82.2 (37/45)	87.7 (64/73)
	Thin-section CE-MDCT	0.96	3	91.4 (32/35)	89.5 (34/38)	88.9 (32/36)	91.9 (34/37)	90.4 (66/73)
Overall pulmonary veins	Non CE-MRA	0.85	4	50 (4/8)	98.5 (64/65)	80 (4/5)	94.1 (64/68)	93.2 (68/73)
	4D CE-MRA	0.87	4	62.5 (5/8)	100 (65/65)	100 (5/5)	95.6 (65/68)	95.9 (70/73)
	Thin-section CE-MDCT	0.88	4	62.5 (5/8)	100 (65/65)	100 (5/5)	95.6 (65/68)	95.9 (70/73)

SE: sensitivity, SP: specificity, PPV: positive predictive value,
NPV: negative predictive value, AC: accuracy
*: Significant difference with non CE-MRA ($p<0.05$).

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