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Comparison of the utility of whole-body MRI with and without contrast-enhanced Quick 3D and double RF fat suppression techniques, conventional whole-body MRI, PET/CT and conventional examination for assessment of recurrence in NSCLC patients

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ABSTRACT

Purpose: The purpose of this study was to compare diagnostic capabilities for assessment of recurrence in non-small cell lung cancer (NSCLC) patients by contrast-enhanced whole-body MRI (CE-WB-MRI) with and without CE-Quick 3D and double RF fat suppression technique (DFS), FDG-PET/CT and conventional radiological examinations.
Materials and methods: A total of 134 pathologically proven and completely resected NSCLC patients (78 males, 56 females; mean age: 72 years) underwent FDG-PET/CT, CE-WB-MRI with and without Quick 3D and DFS at 3 T as well as conventional radiological examinations. The probability of recurrence was assessed with a 5-point scoring system on a per-patient basis, and final diagnosis was made by consensus between two readers. The capability for overall recurrence assessment by all the methods was compared by means of ROC analysis and their sensitivity, specificity and accuracy by means of McNemar's test.
Results: Although areas under the curve did not show any significant differences, specificity (100%) and accuracy (95.5%) of CE-WB-MRI with CE-Quick 3D and DFS were significantly higher than those of FDG-PET/CT (specificity: 93.6%, $p = 0.02$; accuracy: 89.6%, $p = 0.01$) and conventional radiological examinations (specificity: 92.7%, $p = 0.01$; accuracy: 91.0%, $p = 0.03$). In addition, specificity of CE-WB-MRI without CE-Quick 3D and DFS (100%) was significantly higher than that of FDG-PET/CT ($p = 0.02$) and conventional radiological examinations ($p = 0.01$).
Conclusion: Specificity and accuracy of CE-WB-MRI with CE-Quick 3D and DFS for assessment of recurrence in NSCLC patients are at least as high as, or higher than those of others.

1. Introduction

Despite many advances in the diagnosis, staging and treatment of non-small cell lung cancer (NSCLC), reported recurrence rates after complete resection range from 30% to 75% [1,2], depending on the final pathologic stage. Recurrence of NSCLC is classified in routine clinical practice as local recurrence or distant metastasis [3]. Local recurrence is located within the treated hemithorax and usually presents with nodules involving the resection staple line or in the area that was treated with radiotherapy or radiofrequency ablation (RFA), as well as in the bronchial stump, pleura, chest wall and lymph nodes. Moreover, distant metastases as well as multiple organ metastases are frequently detected, including metachronous pulmonary nodules [3,4].

For several decades, detection of recurrent disease using standard methods such as chest radiograph and/or computed tomography (CT) was sometimes made difficult, and positron emission tomography with [18F] fluoro-2-D-glucose (FDG-PET) as well as FDG-PET fused with CT (FDG-PET/CT) has been found more

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effective than standard methods for diagnosis of tumor recurrence and may well lead to major changes in management of patients with suspected recurrence [5–7]. In addition, it has been suggested that magnetic resonance imaging (MRI) is at least as accurate as, or more so, as a diagnostic tool for TNM staging in NSCLC patients, although it could not frequently be used in routine clinical practice because repeated examinations required repositioning of the patients and the use of different surface coils for different body parts.

State-of-the-art non-contrast-enhanced and contrast-enhanced whole-body MR imaging (non-CE and CE-WB-MRI) has been introduced as one single examination method that uses either a moving table platform in combination with a body coil or a specially designed rolling table platform with a single body phased-array coil [8–14]. Promising results have been reported for staging of malignant tumors or metastasis detection in comparison to those obtained with FDG-PET or FDG-PET/CT or multi-detector row (MD) CT [8–14]. In addition, it has been proposed that CE-WB-MRI with and without diffusion-weighted MR imaging (DWI) can perform a complementary role in FDG-PET or PET/CT for NSCLC staging at 1.5 tesla (T) [11,12]. All previous studies for lung cancer staging have used a body coil for CE-WB-MRI without any enhancement of spatial resolution [8–14].

Under these circumstances, a newly developed fast and segmented 3D T1-weighted spoiled gradient echo sequence (Quick 3D, Toshiba Medical Systems, Ohtawara, Japan) and a double fat suppression RF pulse technique for enhancing fat-free capability (DES) has proven to be effective in clinical use for improving the diagnostic capability of contrast-enhanced MR imaging in routine clinical practice [15]. Moreover, multiple phased-array surface coils and receiver channels combined with the capability of parallel imaging, which provides complete head-to-toe coverage with high spatial resolution and can be used for a single examination and a within a reasonable time frame, has also become available for routine clinical practice. However, no direct comparison of diagnostic capability for assessment of distant metastasis and/or recurrence in NSCLC patients has been made of CE-WB-MRI with a conventional protocol using a contrast-enhanced in-phase T1W-GRE (CE-T1W-GRE) sequence, CE-Quick 3D and DFS technique, and integrated FDG-PET/CT.

We hypothesized that CE-Quick 3D and DFS could improve the diagnostic performance of CE-WB-MRI using a 3 T MR system for assessment of both local and overall recurrence compared with that of a previously reported conventional protocol [9–12], and might be at least as effective as FDG-PET/CT and conventional radiological examinations. The purpose of this study was thus to directly and prospectively compare diagnostic capabilities for assessment of recurrence of CE-WB-MRI at 3 T with those of a conventional protocol using the CE-T1W-GRE sequence, CE-Quick 3D and DFS, integrated FDG-PET/CT and conventional radiological examinations.

2. Materials and methods

2.1. Subjects

This prospective study was approved by the institutional review board of Kobe University Hospital and written informed consent was obtained from all patients. This study was financially and/or technically supported by Toshiba Medical Systems and Eizai Co. Ltd. The authors who were not employees of Toshiba Medical Systems had full control over the data for the entire duration of this study.

Between January 2010 and March 2012, 134 consecutive pathologically proven and completely resected NSCLC patients (78 males, 56 females; mean age: 72 years) underwent whole-body integrated FDG-PET/CT, CE-WB-MRI with and without Quick 3D and DFS at 3 T and conventional radiological examinations after treatment. All radiological studies were completed in random order every three or six months, and all follow-up examinations for post-therapeutic patients were conducted more than six months after treatment. All radiological examinations of one patient were performed within one month (mean: 15 days; range: 1–45 days). The cases enrolled in this study comprised 120 adenocarcinomas, eleven squamous cell carcinomas, and three large cell carcinomas. Based on the results of preoperative radiologic and postoperative pathological examinations, 86 of the patients were diagnosed with stage IA, 19 with stage IB, 13 with stage IIA, nine with stage IIB, and seven with stage IIIA diseases. All recurrent patients underwent chemotherapy either with or without radiotherapy.

2.2. Whole-body MRI protocol

All WB-MRIs were performed with a 3 T MR system (Vantage Titan 3 T; Toshiba Medical Systems), which uses a moving table system and multiple phased-array surface coils and receiver channels combined with parallel imaging capability (Atlas SPEEDER, Toshiba Medical Systems), and generates a longitudinal field of view (FOV) of 2050 mm and a transverse FOV of 500 mm. For every examination, whole-body MR images were obtained in the coronal and sagittal planes with an Atlas SPEEDER coil and a moving table. Five sequences were used for WB-MR imaging.

The first was the in-phase T1-gradient echo (T1-field echo: T1-FE) sequence (TR 210 ms/TE 2.5 ms/flip angle 50°; 256 × 184 matrix, 512 × 368 reconstruction matrix; number of excitations [NEX]: 1) without administration of contrast-media. The second was the opposed-phase T1-FE sequence (TR 210 ms/TE 1.3 ms/flip angle 50°; 256 × 184 matrix, 512 × 368 reconstruction matrix; NEX: 1) without contrast media. The third was the sequentially reordered half-Fourier multi-shot short inversion time (TI) inversion recovery fast advanced spin-echo (STIR-FASE) sequence (TR 7800 ms/TE 80 ms/TI 250 ms/ETL 40; 256 × 192 matrix, 512 × 384 reconstruction matrix; NEX: 2). The fourth was the CE-T1W-GRE sequence applying first sequence. The fifth was a newly developed CE-Quick 3D and DFS sequence (TR 3.7 ms/TE 1.3 ms/TI 230 ms/flip angle 9°; 320 × 160 matrix, 640 × 320 reconstruction matrix; NEX: 1). Coronal and sagittal WB-MRI scans were performed at five or six contiguous stations with 35–66 consecutive 6.0–8.0 mm slices acquired at each station. The 21 s breath holding was used for obtaining dual-phase T1-FE, STIR-FASE and CE-Quick 3D and DFS sequences for the chest and abdominal imaging.

For the CE-WB-MRI examination, a standard dose (0.1 mmol/kg BW) of contrast material (gadoteridol, Gd-HP-DO3A or PuroHance; Eizai Co., Ltd., Tokyo, Japan) was administered intravenously via an antecubital vein with an automatic infusion system (Sonic shot, Nemoto Kyorindo, Tokyo, Japan) at a rate of 2 mL/s. All CE-WB-MRIs were performed within less than 90 min (mean, 75.8 min; range, 60–90 min). The examination times and receiver coil channels for every sequences at each anatomical station were stated in Table 1. Twenty-one second breath-holding per acquisition was required to obtain in- and opposed phase T1-FE, STIR and Quick 3D with DFS images at chest, abdominal or chest and abdominal stations. Images acquired in matching positions were automatically aligned to generate a seamless whole-body coronal and sagittal image on an MR scanner.

2.3. Integrated FDG-PET/CT examination

After at least 6 h fasting, 3.3 MBq/kg BW of FDG (range: 132–300 MBq; <3.5 to >8.2 mCi) was intravenously given to all patients and images were obtained from the skull to the mid-thigh 60 min after completion of the injection. The mean glucose level for all patients was 93.8 ± 17.3 mg/dl (mean ± standard deviation;