Metastatic vs non-metastatic lymph nodes in non-small cell lung cancer patients: compared diagnostic capability among 3.0 T-STIR turbo SE imaging, 1.5 T-STIR turbo SE imaging, and FDG-PET/CT

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Purpose

Accurate tumor staging is essential for choosing the appropriate treatment strategy for non-small-lung cancer (NSCLC) patients.Computed tomography (CT) provides excellent morphologic information on staging of NSCLC, but has limitation of capability to differentiate between benign and malignant lymph nodes. \(^1\) Integrated positron emission tomography with 2-[fluorine-18] fluoro-2-deoxy-D-glucose (FDG-PET)/CT has higher diagnostic capability to detect lymph node metastasis of NSCLC patients which simultaneously assess glucose metabolism with FDG-PET and precise lesion of NSCLC with CT.\(^2\) As for MR imaging, it has been suggested that short inversion time (TI) inversion-recovery (STIR) imaging may be useful for the detection of metastatic lymph nodes NSCLC, \(^3,4\) and it has high diagnostic capability similar to FDG-PET.\(^5\)

Recently, approved clinical WB-MRI scanners with a field strength of 3 T have become commercially available.\(^6\) The high field strength of 3 T provides the increased SNR within shorter acquisition time, which can further ameliorate diagnosis of pathologies in complex anatomic structures. However, there is no examination comparing the diagnostic capability of N-stage of NSCLC patients among integrated FDG-PET/CT, STIR on 1.5 T and 3T MR scanner directly. The purpose of this study was to compare diagnostic capabilities of lymph node metastasis among short inversion time inversion recovery (STIR) imaging on 1.5 T and 3.0 T MR scanners, and PET-CT in non-small cell lung cancer (NSCLC) patients.
Methods and Materials

Thirty consecutive NSCLC patients (19 men and 11 women) with a mean age of 69 years (range, 48 to 83) evaluated as T1 and T2 stages on chest radiograph or plain CT underwent contrast-enhanced multi-detector raw CT, whole-body integrated FDG-PET-CT, and STIR on 1.5T and 3T MR imaging before thoracotomy or resection of primary lesion in conjunction with hilar and mediastinal sampling and/or more than one-year follow up. The final diagnosis of lung cancer and N-stage was based on pathological findings of resected specimens or follow up study, which showed that 20 patients had adenocarcinoma, six had squamous cell carcinoma, two had large-cell carcinoma, and two had non-small cell carcinoma. The lymph node stages of the patients were N0 for 13, N1 for one, and N2 for 13 cases.

All integrated FDG-PET/CT examinations were performed with a commercially available PET/CT scanner (Discovery ST; GE Health Care, Milwaukee, WI). After at least six hour fasting, 3.3 MBq/kg BW of FDG was intravenously administered to all patients and images were obtained from the skull to the mid-thigh 60 min after completion of the injection. The scans were performed during quiet tidal breathing. PET images were displayed in a 128×128 matrix. The resulting PET and CT scans were co-registered on hardware. All integrated PET/CT examinations were performed within 60 min without iodinated contrast media. The CT data were resized from a 512×512 to a 128×128 matrix to match the PET data so that the scans could be fused and CT-based transmission maps could be generated.

MR imaging on 1.5T scanner was performed with a 1.5 T superconducting magnet (Gyroscan Achieva; Phillips Medical Systems, Best, The Netherlands) using a four-channel sensitivity encoding (SENSE) body coil. Axial and coronal STIR turbo SE images were obtained by using a centrically-reordered multishot blackblood STIR turbo SE sequence with SENSE (TR = 2-3 <R-R>msec, TEff = 8 msec, TI = 150 msec, echo train length = 8, number of excitations = 2, slice thickness = 5 mm, slice gap = 5 mm, 20-24 slices, matrix size = 256 × 192, reconstruction matrix size = 512 × 384, field of view = 450 mm, reduction factor = 4).

MR imaging on 3T scanner was performed with a 3 T superconducting magnet (Gyroscan Achieva 3T; Phillips Medical Systems, Best, The Netherlands) using a 16-channel SENSE body coil. Axial and coronal STIR turbo SE images were obtained by using a centrically-reordered multishot blackblood STIR turbo SE sequence with SENSE (TR = 2 <R-R> msec, TEff = 9.8 msec, TI = 200 msec, echo train length = 12, number of excitations = 1, slice thickness = 5 mm, slice gap = 5 mm, 20-24 slices, matrix size = 256 × 192, reconstruction matrix size = 512 × 384, field of view = 450 mm, reduction factor = 2).

On STIR turbo SE images, regions of interest (ROIs) were drawn over mediastinal and hilar lymph nodes and over the saline phantom for measurement of signal intensity (SI).
For quantitative evaluation of the SI of the lymph nodes, the SI was normalized by that of 0.9% saline phantoms to produce the LSR (lymph node saline ratio). \(^{3,4}\)

\[
\text{LSR} = \frac{\text{SI of lymph node}}{\text{SI of saline phantom}} \quad [1]
\]

For quantitative assessment of lymph node metastases on integrated FDG-PET/CT, all maximal standardized uptake value (SUVmax) measurements were obtained from ROIs drawn over the mediastinal and hilar lymph nodes on integrated FDG-PET/CT.

Statistical Analysis

To assess the relationship between SUVmax and LSRs on 1.5T and 3T MR scanners on a per node basis, differences in SUV and LSRs between metastatic and nonmetastatic lymph nodes were determined by means of Student's t-test. To evaluate the diagnostic capability of integrated FDG-PET/CT and quantitatively analyzed STIR turbo SE imaging on a per node basis, the feasible thresholds of SUVmax and LSRs were determined with a receiver operating characteristic (ROC) based positive test. Finally, diagnostic capabilities of all indexes were compared by using McNemar's test on a per node and patient basis.
Results

For the 30 patients, 33 of the 86 lymph nodes were diagnosed as metastatic lymph nodes, and 53 as nonmetastatic lymph nodes. The mean, LSR_{1.5} (0.74 ± 0.12) on 1.5 T MR scanner LSR_{3.0} (0.62 ± 0.22) on 3 T MR scanner of metastatic lymph nodes, and SUV_{max} (4.3 ± 3.2) were significantly higher than those of nonmetastatic lymph nodes (p<0.001; Fig.1).

According to the ROC based positive test, the feasible threshold values of LSRs on 1.5 and 3.0 T systems and SUV_{max} were determined as follows: 0.65, 0.4 and 2.0, respectively (Fig. 2).

When each feasible threshold value was adapted, on a per node basis, the sensitivity, specificity and accuracy by using the threshold LSR of 0.65 on 1.5 T MR scanner were 81.8% (27/33), 64.2% (34/53) and, 70.9% (61/86), respectively. The sensitivity, specificity and accuracy by using the threshold LSR of 0.40 on 3 T MR scanner were 84.8% (28/33), 60.4% (32/53) and, 69.8% (60/86), respectively. The sensitivity, specificity and accuracy by using the threshold SUV_{max} of 2.0 were 75.8% (25/33), 66.0% (35/53) and, 69.8% (60/86), respectively (Fig. 3). On a per patient basis, the sensitivity, specificity and accuracy by using the threshold LSR of 0.65 on 1.5 T MR scanner were 100% (14/14), 25.0% (4/16) and, 60.0% (18/30), respectively. The sensitivity, specificity and accuracy by using the threshold LSR of 0.40 on 3 T MR scanner were 100% (14/14), 43.8% (7/16) and, 70.0% (21/30), respectively. The sensitivity, specificity and accuracy by using the threshold SUV_{max} of 2.0 were 78.6% (11/14), 50.0% (8/16) and, 63.3% (19/30), respectively (Fig. 4). There were no significant differences of sensitivity, specificity and accuracy among all three indexes on both a per node basis and a patient basis (p>0.05).

Representative cases are shown in Fig. 5, 6.
This is the results of Student's t-test of the comparison of LSR_{1.5} on 1.5 T MR scanner, LSR_{3.0} on 3 T MR scanner and SUV_{max} between metastatic and nonmetastatic lymph nodes. The mean LSR_{1.5} (0.74 ± 0.12; mean ± standard deviation) of metastatic nodes were significantly higher than that (0.61 ± 0.02) of nonmetastatic nodes. The mean LSR_{3.0} (0.62 ± 0.22) of metastatic nodes were significantly higher than that (0.38 ± 0.02) of nonmetastatic nodes. The mean SUV_{max} (4.3 ± 3.2) of metastatic nodes were significantly higher than that (2.1 ± 1.7) of nonmetastatic lymph nodes (p<0.001).

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Fig. 2: This is the result of ROC-based positive test to determine the feasible threshold value. According to the results of ROC-based positive test, the feasible threshold values of LSR_{1.5}, LSR_{3.0} and SUV_{max} were determined as 0.65, 0.40 and 2.0, respectively.

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Fig. 3: This is the result of diagnostic capability on a per node basis. McNemar’s test revealed no significant difference of diagnostic capability among STIR on 1.5 T-MR scanner, STIR on 3 T-MR scanner and FDG-PET-CT. (p > 0.05)

<table>
<thead>
<tr>
<th></th>
<th>Index</th>
<th>Threshold Value</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>STIR on 1.5 T MR scanner</td>
<td>LSR_{1.5}</td>
<td>0.65</td>
<td>.818 (27/33)</td>
<td>.642 (34/53)</td>
<td>.709 (61/86)</td>
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<tr>
<td>STIR on 3 T MR scanner</td>
<td>LSR_{3.0}</td>
<td>0.40</td>
<td>.848 (28/33)</td>
<td>.604 (32/53)</td>
<td>.698 (60/86)</td>
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<tr>
<td>FDG-PET-CT</td>
<td>SUV_{max}</td>
<td>2.0</td>
<td>.758 (25/33)</td>
<td>.660 (35/53)</td>
<td>.698 (60/86)</td>
</tr>
</tbody>
</table>

*Department of Radiology, Kobe Graduate School of Medicine / Japan 2011*

Fig. 0: Fig. 3: This is the result of diagnostic capability on a per node basis. McNemar’s test revealed no significant difference of diagnostic capability among STIR on 1.5 T-MR scanner, STIR on 3 T-MR scanner and FDG-PET-CT. (p > 0.05)

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Fig. 4: This is the result of diagnostic capability on a per patient basis. Mc Nemar’s test revealed no significant difference of diagnostic capability among STIR on 1.5 T-MR scanner, STIR on 3 T-MR scanner and FDG-PET-CT. (p > 0.05)

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<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>STIR on 1.5 T MR scanner</td>
<td>LSR$_{1.5}$</td>
<td>0.65</td>
<td>1.00 (14/14)</td>
<td>.250 (4/16)</td>
<td>.600 (18/30)</td>
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<tr>
<td>STIR on 3 T MR scanner</td>
<td>LSR$_{3.0}$</td>
<td>0.40</td>
<td>1.00 (14/14)</td>
<td>.438 (7/16)</td>
<td>.700 (21/30)</td>
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<tr>
<td>FDG-PET-CT</td>
<td>SUV$_{max}$</td>
<td>2.0</td>
<td>.786 (11/14)</td>
<td>.500 (8/16)</td>
<td>.633 (19/30)</td>
</tr>
</tbody>
</table>

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Fig. 5: 79 y.o. male patient with adenocarcinoma in right upper lobe. There was pretracheal lymph node metastasis. (a) Contrast enhanced CT shows pretracheal lymphadenopathy. (b) FDG-PET-CT shows high uptake (SUV$_{\text{max}} = 5.5$) of pretracheal lymph node. (c) STIR imaging on 1.5 T-MR scanner shows high signal intensity (LSR$_{1.5} = 0.74$) of tracheal lymph node. (d) STIR imaging on 3 T MR scanner shows high signal intensity (LSR$_{3.0} = 0.55$) of pretracheal node. This is true positive case of all indexes.

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Fig. 0: Fig. 5: 79 y.o. male patient with adenocarcinoma in right upper lobe. There was pretracheal lymph node metastasis. (a) Contrast enhanced CT shows pretracheal lymphadenopathy. (b) FDG-PET-CT shows high uptake (SUV$_{\text{max}} = 5.5$) of pretracheal lymph node. (c) STIR imaging on 1.5 T-MR scanner shows high signal intensity (LSR$_{1.5} = 0.74$) of tracheal lymph node. (d) STIR imaging on 3 T MR scanner shows high signal intensity (LSR$_{3.0} = 0.55$) of pretracheal node. This is true positive case of all indexes.

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Fig. 6: 61 y.o. male patient with adenocarcinoma in left upper lobe. There was subaortic lymph node metastasis. (a) Contrast enhanced CT shows subaortic lymphadenopathy. (b) FDG-PET-CT shows high uptake (SUVmax = 1.5) of subaortic lymph node. (c) STIR imaging on 1.5 T MR scanner shows high signal intensity (LSR1.5 = 0.96) of subaortic node. (d) STIR imaging on 3 T MR scanner shows high signal intensity (LSR3.0 = 0.60) of subaortic node. This is true positive case of 1.5T-STIR and 3T-STIR and false negative case of FDG-PET-CT.

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Conclusion

The quantitative analysis of STIR turbo SE imaging on 3.0 T MR scanner enable differentiating metastatic lymph nodes from without as well as those of STIR turbo SE imaging on 1.5 T MR scanner and FDG-PET/CT. STIR turbo SE imaging on 3.0 T system is considered at least as valuable as STIR turbo SE imaging on 1.5 T system and FDG-PET/CT for differentiation of metastatic from non-metastatic lymph nodes in non-small cell lung cancer patients.
References


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