Supplemental value of diffusion weighted whole body imaging with background body signal suppression (DWIBS) technique to whole body magnetic resonance imaging in detection of bone metastases from thyroid cancer.

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Purpose

Background

Differentiated thyroid carcinoma ([DTC]; papillary and follicular) is characterized by good prognosis in comparison to carcinomas in other organs. The 10-y survival rate of DTC is about 80%. However, metastases of thyroid carcinoma develop in 7-23% of patients and the overall survival rate 10 years after the distant metastasis drops to about 40%. Patients with bone metastasis tend to do worse than those with lung metastasis. And the poor prognosis of patient with bone metastasis is linked to the bulkiness of the lesions because the response rates of [131I] therapy get lower when they are visible on radiographs. Therefore, it is very important to detect bone metastasis in earlier stage in DTC patients.

Skeletal imaging by [18F] fluoro-2-D-glucose positron emission tomography with computed tomography (FDG-PET/CT) and whole body magnetic resonance imaging (WBMRI) are useful for the detection of bone metastases from carcinomas of various organs including thyroid.

Recently it has been suggested that diffusion weighted body imaging with background body signal suppression (DWIBS), introduced by Takahara et al., can improve the detectability of bone metastasis.

3.0-Tesla MR scanners provide a higher signal-to-noise-ratio (SNR) and greater spatial resolution than 1.5-Tesla scanners. At 3.0-Tesla, only a few studies have been reported with respect to DWIBS. No direct comparison has been made between the efficacy of WBMRI with DWIBS on 3.0-Tesla MRI systems and that of integrated FDG-PET/CT for bone metastases assessment of DTC patients.

Purpose

The purpose of this study was to compare WBMRI with and without DWIBS using 3.0-Tesla MRI and FDG-PET/CT in the detection of bone metastases of DTC.
Methods and Materials

Subjects

#23 patient suspected to have bone metastasis among 84 patients with DTC and had gone through [131I] therapy at Nagoya University hospital from May, 2007 to December, 2009

#All patients underwent both

• WBMRI with DWIBS
• whole-body FDG-PET/CT

to detect bone metastases prior to radioiodine therapy.

The interval between WBMRI and whole-body FDG-PET/CT was a median 15 days (range, 3-60 days).

#At the start of the study, 15 (65%) of the 23 patients had received previous [131I] therapy, and 7 (30%) patients had undergone radiation for bone metastasis.

#All subjects had received post-treated whole body scans; TxWBS.

#Seventeen (74%) of the 23 patients had follicular carcinoma and six (26%) patients had papillary carcinomas.

MRI protocol

#MRI was performed with a 3.0-Tesla MRI scanner

: MAGNETOM Trio A Tim System; Siemens AG, Erlangen, Germany

#Three pulse sequences were used for WBMRI;

• Coronal T1 weighted spin echo sequence
• Coronal Short inversion time inversion recovery (STIR) turbo spin-echo sequence
• DWIBS
The parameters of each sequence are in Table 1 on page 7.

DWIBS images were obtained in the axial plane with a spin-echo single-shot EPI with STIR incorporating the modified sensitivity encoding (mSENSE) algorithm for parallel acquisition. Motion probing gradient pulses were applied along the superior-inferior axis with b values of 800 sec/mm$^2$. STIR was used for fat suppression. The slice-selection gradient reversal (SSGR) method of fat suppression was not implemented. Axial whole-body MR scans were performed at seven contiguous stations with 18 interleaved 6 mm slices acquired at each station. Total acquisition time for DWIBS was about 330 seconds.

Three-dimensional maximum intensity projection images (3D-MIP) were reconstructed from the axial DWIBS images.

**FDG-PET/CT Examination**

All FDG-PET/CT examinations were performed with a commercially available PET/CT scanner: Biograph 16; Siemens AG, Erlangen, Germany.

Patients fasted for at least 6 hours prior to intravenous administration of [18F]-FDG at a dose of 3.7 MBq/kg bodyweight (BW) (for BW ≤ 60kg) or 4.07 MBq/kg BW (BW > 60kg), and images were obtained from the skull to the mid-thigh 50 minutes following FDG injection. CT was performed from the skull to mid-thigh. Patients maintained normal shallow respiration during the acquisition of CT scans and no iodinated contrast media was administered. Immediately after the unenhanced CT, PET was performed in the identical transverse field of view. The resulting PET and CT scans were coregistered automatically on the workstation.

**Gold standard**

The presence of bone metastases was assessed in 13 bone segments (Table 2 on page 7).

At least 2 experienced radiologists diagnosed bone metastases using

- TxWBS
- WBMRI (T1 weighted image and STIR image)
- FDG PET
The presence of bone metastases was verified if the positive findings for bone metastases were obtained in a minimum of 2 imaging modalities.

Among the total of 299 bone segments examined, 9 segments (3.0%) were excluded; 8 segments: a positive finding for metastases in only one modality and 1 segments: the metastasis was shown in the skull but was out of the scan in integrated FDG-PET/CT.

Twenty (83%) of the 23 study patients were diagnosed with bone metastases, and 78 bone segments were confirmed to have at least one metastatic lesion according to the definitions of this study. The distribution of metastases in the examined bone segments is given in Table 2 on page 7. No metastases were found in upper and lower extremities except the thigh bone.

Image interpretation

First, WBMRI without DWIBS (T1 weighted images and STIR images) were analyzed independently and separately by two radiologists with 16 and 9 years experience, respectively.

Over a month later, adding DWIBS (axial plane and 3D-MIP image), WBMRI were analyzed again.

The readers were blind to the results of the other imaging technique and clinical information. Based on morphology and signal intensity, the readers were asked to assign bone segments as having metastasis or not. A final consensus reading was performed between both readers if the decision was not identical.

Whole-body FDG-PET/CT fusion images were analyzed in coronal, sagittal and axial planes separately and under blinded conditions by two nuclear medicine physicians with 11 and 5 years experience, respectively. The bone segments were assigned as having metastasis or not. No quantitative measurements were considered.

Statistical Analysis
McNemar’s test was used to compare the sensitivity, specificity, and accuracy of WBMRI with and without DWI and integrated FDG-PET/CT on a per segment basis.

We also compare the sensitivity of WBMRI with and without DWI and integrated FDG-PET/CT in each segment.

A P-value less than 0.05 was considered statistically significant for all statistical analyses.

Statistical analyses were performed using the program Excel 2003 (Microsoft co.) with the statistical add-in software for Microsoft excel "Statcel" (The publisher OMS Ltd., Tokyo, Japan, 2004).
Table 1: The parameters of each MRI sequence.

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<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR/TE (msec)</th>
<th>TE (msec)</th>
<th>FOV (mm)</th>
<th>matrix</th>
<th>Slice thickness /Gap (mm)</th>
<th>TA (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1WI</td>
<td>500/11</td>
<td></td>
<td>500</td>
<td>384</td>
<td>5/1</td>
<td>169</td>
</tr>
<tr>
<td>STIR</td>
<td>6170/105</td>
<td>200</td>
<td>500</td>
<td>276</td>
<td></td>
<td>174</td>
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<tr>
<td>DWIBS</td>
<td>4000/78</td>
<td>250</td>
<td>440</td>
<td>128</td>
<td>6/0 interleave</td>
<td>46</td>
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<tr>
<td>Bone segment</td>
<td>Number of metastases</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>--------------------------------------------</td>
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<tr>
<td>Cervical spines</td>
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<td>Thoracic spines</td>
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<tr>
<td>Lumbar spines</td>
<td>7</td>
<td></td>
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<tr>
<td>Sacrum with coccyx</td>
<td>6</td>
<td></td>
<td></td>
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<tr>
<td>Right pelvis</td>
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<td></td>
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<tr>
<td>Left pelvis</td>
<td>12</td>
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<tr>
<td>Sternum</td>
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<td>Right scapulae with clavicles</td>
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</tr>
<tr>
<td>Left scapulae with clavicles</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>Right ribs</td>
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<tr>
<td>Left ribs</td>
<td>5</td>
<td></td>
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<tr>
<td>Skull</td>
<td>2</td>
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<tr>
<td>Upper and lower extremities</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>78</strong></td>
<td></td>
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</tr>
</tbody>
</table>

**Table 2:** Number of the metastases of each bone segment

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Results

#In Fig. 1 on page 12, all the lesions in spines, sacrum, Right and left pelvis, and left thigh bone are visible in both DWIBS 3D-MIP image and FDG-PET 3D-MIP image.

#In Fig. 2 on page 12, lesions in pelvis and sacrum (arrows) are clearly demonstrated in both WBMRI with DWIBS and FDG-PET/CT.

<table>
<thead>
<tr>
<th></th>
<th>WBMRI without DWIBS</th>
<th>WBMRI with DWIBS</th>
<th>FDG-PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity(%)</td>
<td>50/78(64.1)***</td>
<td>64/78(82.0)</td>
<td>62/78(79.5)</td>
</tr>
<tr>
<td>Specificity</td>
<td>211/212(99.5)</td>
<td>209/212(98.6)</td>
<td>210/212(99.1)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>261/290(90.3)*</td>
<td>273/290(94.5)</td>
<td>272/290(93.1)</td>
</tr>
</tbody>
</table>

*, ***significant difference between WBMRI without DWIBS and WBMRI with DWIBS

Table 3: Comparison of diagnostic capability of WBMRI with and without DWIBS and FDG-PET/CT

References: Nagoya University Hospital - Nagoya City/JP

#As indicated in Table 3 on page 13, 50 (64.1%) of the 78 metastases were detected by WBMRI without DWIBS, and 64 (82.0%) of the 78 metastases were detected by WBMRI with DWIBS. The difference between these values was statistically significant (P=0.015).
Sixty-two (79.5%) of the 78 metastases were detected by integrated FDG-PET/CT; the difference in the sensitivity between WBMRI with DWIBS and integrated FDG-PET/CT was not statistically significant (P=1).

The overall accuracy of WBMRI with DWIBS (273/290, 94.5%) was also higher than that of WBMRI without DWIBS (261/290, 90.3%); the difference between these values was statistically significant (P=0.003).

The overall accuracy between WBMRI with DWIBS (273/290, 94.5%) and integrated FDG-PET/CT (272/290, 93.1%) was not statistically significant.

There were only 1-3 false positive segments of the 212 bone segments that were confirmed to have no bone metastases, and the difference among specificities were not statistically significant in these modalities.

**Location of detected bone metastasis (n=78)**

![Anatomical distribution of 77 bone metastases detected by WBMRI with and without DWIBS and FDG-PET/CT](image)

**Fig. 3:** Anatomical distribution of 77 bone metastases detected by WBMRI with and without DWIBS and FDG-PET/CT
### Table 4: Sensitivities of each segment of WBMRI with and without DWIBS and FDG-PET/CT

**References:** Nagoya University Hospital - Nagoya City/JP

#The numbers of lesions detected in each bone segments by three modalities and Gold Standard are shown in Fig. 3 on page 14. Sensitivities of those three modalities in each segment are shown in Table 4 on page 15.

#The difference between the sensitivities of MRI with and without DWIBS in the segment "spine" was statistically significant (P=0.04). In other segments, the values were not statistically significant.
**Fig. 1:** A 62-year-old woman with bone metastasis in spines, sacrum, right and left pelvis, and left thigh bone (yellow arrow head). All the lesions were visible in both DWIBS 3D-MIP image and FDG-PET 3D-MIP image. The lesions also showed increased uptake patterns in TxWBS and can be specifically diagnosed as metastases from DTC. In TxWBS, a hot spot in neck was considered to be the uptake in thyroid bed (red arrow).

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**Fig. 2:** A 62-year-old woman with bone metastasis of right and left pelvis, sacrum and left thigh bone. Lesions in pelvis and sacrum (arrows) are clearly demonstrated in all the following modalities. 

a: DWIBS MIP image  
b: DWIBS axial image  
c: STIR coronal images  
d: T1 weighted images  
e: FDG-PET/CT fusion axial image  
f: FDG-PET/CT fusion coronal images.

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<table>
<thead>
<tr>
<th></th>
<th>WBMRI without DWIBS</th>
<th>WBMRI with DWIBS</th>
<th>FDG-PET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity(%)</strong></td>
<td>50/78 (64.1)***</td>
<td>64/78 (82.0)</td>
<td>62/78 (79.5)</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>211/212 (99.5)</td>
<td>209/212 (98.6)</td>
<td>210/212 (99.1)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>261/290 (90.3)*</td>
<td>273/290 (94.5)</td>
<td>272/290 (93.1)</td>
</tr>
</tbody>
</table>

*, ***significant difference between WBMRI without DWIBS and WBMRI with DWIBS

**Table 3:** Comparison of diagnostic capability of WBMRI with and without DWIBS and FDG-PET/CT

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Fig. 3: Anatomical distribution of 77 bone metastases detected by WBMRI with and without DWIBS and FDG-PET/CT

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<table>
<thead>
<tr>
<th>Segment</th>
<th>WBMRI without DWIBS (%)</th>
<th>WBMRI with DWIBS (%)</th>
<th>FDG-PET/CT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spines</td>
<td>13/22 (59.1)*</td>
<td>19/22 (86.4)*</td>
<td>16/22 (72.7)</td>
</tr>
<tr>
<td>Sacrum with coccyx</td>
<td>5/6 (83.3)</td>
<td>5/6 (83.3)</td>
<td>6/6 (100)</td>
</tr>
<tr>
<td>Right and left pelvis</td>
<td>14/19 (73.7)</td>
<td>19/19 (100)</td>
<td>18/19 (94.7)</td>
</tr>
<tr>
<td>Sternum</td>
<td>2/5 (40)</td>
<td>4/5 (80)</td>
<td>4/5 (80)</td>
</tr>
<tr>
<td>Right and left scapulae with clavicles</td>
<td>4/7 (57.1)</td>
<td>4/7 (57.1)</td>
<td>3/7 (42.9)</td>
</tr>
<tr>
<td>Right and left ribs</td>
<td>7/12 (58.3)</td>
<td>10/12 (83.3)</td>
<td>12/12 (100)</td>
</tr>
<tr>
<td>Skull</td>
<td>0/2 (0)</td>
<td>0/2 (0)</td>
<td>0/2 (0)</td>
</tr>
<tr>
<td>Upper and lower extremities</td>
<td>5/5 (100)</td>
<td>3/5 (60)</td>
<td>3/5 (60)</td>
</tr>
</tbody>
</table>

*significant difference between WBMRI without DWIBS and WBMRI with DWIBS (P-value=0.04)

**Table 4:** Sensitivities of each segment of WBMRI with and without DWIBS and FDG-PET/CT

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Conclusion

#WBMRI with DWIBS acquired on 3.0-Tesla MRI systems and used for bone metastasis assessment of DTC patients was found to be as sensitive and accurate as integrated FDG-PET/CT.

In addition, when whole-body DWIBS was used as an adjunct for WBMRI without whole-body DWIBS, the sensitivity and accuracy of whole-body MR examination can be improved.
References


