Whole body diffusion-weighted and ADC mapping, and STIR MRI versus PET/CT in relapsing lymphoma

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Purpose

The aim of this study is to compare the performance of whole body MR studies including: the diffusion-weighted (DWIBS) and ADC mapping and STIR imaging, and whole body positron emission tomography with an integrated computed tomography scanner in patients diagnosed to have relapsing lymphoma.
Methods and Materials

Patient population:

Between October 2008 and December 2009, 19 cases (14 males, and 8 females) with a median age of 66.5 (26-81 y) diagnosed to have recurrent lymphoma (9 HD, and 13 NHL) were referred to our department to undergo whole body MR imaging to evaluate the tumor load and for staging. PET/CT study was done for all patients within the same week of the MR examinations that was used as the reference whole-body modality to which whole-body diffusion and STIR studies were compared.

PET/CT study:

All studies were acquired using a Gemini (Philips Medical Systems, Cleveland, OH, USA). Patients were informed of the procedure and were provided with a written informed consent. They were also instructed to fast for at least 6h before the study and presented a blood glucose level <200 mg/dl before injection of the tracer. Sixty minutes after intravenous injection of FDG (dose range 210-350 MBq), whole-body emission scans, 8-9 bed positions were acquired. A CT bidimensional projection scout view of the patient, from the base of skull to the proximal femur, was first done to define the body axial extension necessary to acquire the CT and PET data. The CT scan had a voltage 120kV, and tube current 80mA and lasted for approximately 1 min. It achieved anatomical localization, and attenuation correction of PET data. Then, the bed position was translated into the PET field of view (FOV) at which whole-body distribution of the tracer was acquired in 3D mode. PET data acquisition was done in 25 min. Data sets in the coronal, axial, and transverse planes were reconstructed using dedicated software named Syntegra.

Magnetic resonance imaging:

Whole-body MR imaging was performed on 1.5T body system (Signa Horizon LX Echospeed GE Medical Systems, Milwaukee, W1) using the body coil. Patients acquired the supine position with their arms to their sides. At first, a localizing sequence was obtained followed by entire body coverage with 3-6 stations. FSE STIR sequences were taken with the following parameters: TR, 3,500-5,700 ms; Te, 20-33 ms; inversion time, 150-165 ms; echo train length, 4-16; NEX, 1; FOV, 320-480 mm; matrix,256x128-512x256; slice thickness, 5-10 mm; interslice gap, 0-2 mm. We obtained 15-32 slices per station depending upon the anatomical location and the chosen slice thickness. Also, coronal FSE STIR sequences were taken. Next, DWIBS sequences were acquired without respiratory triggering while the patient was breathing freely using a single-shot echo-planar imaging sequence with diffusion-module and fat-suppression pulse. Water diffusion was measured with a 3-scan-trace technique and b-value of 0, 400,
and 1000s/mm² at selected suspicious areas of interest (measurements were based upon 3D maximum intensity projections), and automated generated ADC-maps (taking into account all 3-b values for ADC calculation) were generated. Whole-body MR studies were completed in 30-35 min.

Detected lesions at regions of interest were documented and compared at all whole-body imaging modalities.

**Statistical methods**

PET-CT was considered the gold standard. Concordance between DWIBS or STIR and PET-CT as regards the number of lesions detected was expressed as a percentage (number of lesions detected with DWIBS or STIR/number of lesions detected by PET-CT %). Concordance percentage was expressed as mean (SD) and differences between groups was compared parametrically using the independent samples t-test.

Concordance between DWIBS or STIR and PET-CT as regards the lymphoma stage was expressed as number [%] of patients in whom the two techniques yielded concordant or non-concordant results, and differences between groups were compared using the Pearson's $\chi^2$-test with application of Fisher's exact test when appropriate.

Correlations among variables were tested non-parametrically using Spearman's correlation analysis. A correlation coefficient of 0.7-1.0 was taken as denoting strong correlation, 0.4-0.7 as denoting moderate correlation, 0.2-0.4 as denoting mild correlation, and <0.2 as denoting no correlation. P < 0.05 was considered statistically significant.
Results

Whole-body DWIBS MR sequences provided high diagnostic quality images comparable to PET images (figure 1). There has been image distortion in abdomen and peritoneal reflections due to high susceptibility difference in these regions. In one patient DWIBS revealed possible para-aortic and mesenteric adenopathies that showed no activity on PET scans consistent with absence of involvement of the disease process (figure 2). This resulted in over-staging of tumor load by DWIBS where STIR was inconclusive. In agreement with previous authors (21), we observed that at b=1000, metastasis had higher measurements that normal tissues with the exception of spleen. Consequently, lymphomatous involvement of spleen could not be assessed by diffusion studies. ADC mapping were useful in delineating lesions of less serious nature as inflammation. Figure (1) reveals right lung parenchymatous infection of intermediate value b=400, that was not apparent on PET images. Yet, ADC mapping were variable and sometimes were not conclusive regarding differentiating between benign and malignant tissues. DWIBS showed multiple nodal involvement that were not confirmed by molecular uptake of FDG on PET studies. These nodes were likely small <1 cm3 to morphologically categorize them as metastasis. Also, the reverse may be true, as we had a patient with multiple nodal involvement with disclosed vertebral metastasis only on PET/CT study not revealed by either DWIBS or STIR MR sequences (figure 2).

Regarding STIR sequence, it revealed more skeletal deposits and metastatic sites that did DWIBS achieving a higher concordance with tracer uptake on PET scans regarding the detected number of lesions and thus lymphoma staging.

The median (interquartile range) number of lesions detected by DWIBS, STIR and PET/CT was 4 (2-6), 4.5 (3-7), and 5 (3.0-7.5) lesions, respectively. On the other hand, the median (interquartile range) stage of lymphoma as determined by DWIBS, STIR and PET/CT was 2 (2.0-3.25), 2.5 (2.0-5.0), and 3.5 (2.0-5.25), respectively (Table 1).

DWIBS had 81.2% (22.5%) concordance with PET/CT as regards the number of lesions detected, while the concordance of STIR with PET/CT was 95.0% (8.8%) (P < 0.05). The concordance between DWIBS and PET/CT as regards the stage of lymphoma was 45.5%, whereas the concordance between STIR and PET/CT was 81.8% (P < 0.05) (Table 2).

There was a strong correlation between DWIBS and PET/CT (correlation coefficient = 0.935, P < 0.001), and between STIR and PET/CT (correlation coefficient = 0.984, P <
0.001) as regards the number of lesions detected (table 3). Likewise, there was a strong correlation between DWIBS and PET/CT (correlation coefficient = 0.804, P < 0.001), and between STIR and PET/CT (correlation coefficient = 0.871, P < 0.001) as regards the staging of lymphoma (Tables 4).

Table (1) Number of lesions and lymphoma stage as determined by the three radiologic techniques.

<table>
<thead>
<tr>
<th>Variable</th>
<th>number of lesions by DWIBS</th>
<th>number of lesions by STIR</th>
<th>number of lesions by PET/CT</th>
<th>stage by DWIBS</th>
<th>stage by STIR</th>
<th>stage by PET/CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>4.00</td>
<td>4.50</td>
<td>5.00</td>
<td>2.00</td>
<td>2.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Percentile 50th</td>
<td>2.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Percentile 50th</td>
<td>4.00</td>
<td>4.50</td>
<td>5.00</td>
<td>2.00</td>
<td>2.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Percentile 75th</td>
<td>6.00</td>
<td>7.00</td>
<td>7.25</td>
<td>3.25</td>
<td>5.00</td>
<td>5.25</td>
</tr>
</tbody>
</table>

Data are median (interquartile range).

Table (2) Concordance between DWIBS or STIR and PET-CT as regards number of lesions and stage of lymphoma

<table>
<thead>
<tr>
<th>Variable</th>
<th>DWIBS</th>
<th>STIR</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concordance with PET-CT as regards number of lesions detected (%)</td>
<td>81.15 (22.5)</td>
<td>94.97 (8.81)</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Concordance with PET-CT as regards stage of lymphoma</td>
<td></td>
<td></td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Concordant</td>
<td>10 [45.5%]</td>
<td>18 [81.8%]</td>
<td></td>
</tr>
<tr>
<td>Non-concordant</td>
<td>12 [54.5%]</td>
<td>4 [18.2%]</td>
<td></td>
</tr>
</tbody>
</table>

Data are mean (SD) or number [%].

Table (3) Correlation between number of lesions detected by DWIBS or STIR and number of lesions detected by PET-CT
<table>
<thead>
<tr>
<th>number of lesions by PET/CT</th>
<th>Correlation Coefficient</th>
<th>number of lesions by DWIBS</th>
<th>number of lesions by STIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.935</td>
<td>0.984</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table (4) Correlation between stage of lymphoma as determined by DWIBS or STIR and stage of lymphoma as determined by PET-CT

<table>
<thead>
<tr>
<th>stage by PET/CT</th>
<th>Correlation Coefficient</th>
<th>stage by DWIBS</th>
<th>Stage by STIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.804</td>
<td>0.871</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
Fig. 0: Figure (1): 35-years old male diagnosed to have HL. (a-d) MR DWIBS and ADC mapping showing mediastinal (a,c), bilateral axillary (b), mesenteric (d) lymphadenopathy. Right parenchymal infiltration* of b-value = 400 denoting benign nature. (e, f) axial & coronal PET images showing only the concordant hilar adenopathy.

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Figure 0: (a,b and c,d) MR DWIBS and STIR showing cervical, inguinal adenopathies. (e,f) PET/CT confirming the findings. (g) PET/CT disclosing dorsal deposits.

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Conclusion

Noninvasive whole-body MR imaging provides a valuable tool in disclosing tumor load and staging of lymphoma. Whole body DWIBS and fat-suppressed STIR T2W MRI studies are feasible, relatively quick, not involving ionizing radiation techniques. Thus, they are inevitable screening tools and should be implemented in routine imaging of recurrent lymphoma.
References

References:

1. Schmidt G, Reiser M, Baur-Melnyk A. Whole-body MRI for the staging and follow-up of patients with metastasis. EJR. 2009; 70:393-400.


