Can whole body diffusion-weighted MRI replace $^{18}$FDG-PET/CT in lymphoma staging? On the road to a new gold standard

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Aims and objectives

Lymphomas are the most common primary hematopoietic malignancies and include approximately 5-6% of all malignancies. Once histopathological diagnosis has been established, accurate staging is crucial for treatment planning and determining prognosis. Clinical staging for both Hodgkin and non-Hodgkin lymphomas is based on Ann Arbor classification, which includes the number of sites involved, the type of involvement (nodal or extra-nodal) and the distribution of disease [1; 2].

Currently, ¹⁸F-fluoro-2-deoxy-D-glucose positron-emission tomography (¹⁸F-FDG-PET) co-registered with computed tomography (¹⁸F-FDG-PET/CT) and computed tomography (CT) represent the reference standard for lymphoma staging as they enable anatomical and functional information [1; 3]. In addition, these imaging techniques are crucial for response assessment and patients' monitoring and nowadays they represent a cornerstone in lymphoma management [3].

Main concerns related to the repeated use of CT and PET/CT in follow-up of these patients are the considerable dose of ionizing radiation and the subsequent increased cancer risk [4; 5]. Thus, effective radiation-free alternatives are needed in order to reduce the extensive use of CT and PET/CT.

Whole body diffusion-weighted magnetic resonance imaging (WB-DW-MRI) is a novel and feasible imaging technique that provides both anatomical and functional information in the same examination. This technique could be considered as an alternative tool in staging lymphoma without using ionizing radiations and, eventually, even without intravenous contrast media administration [6; 7]. Furthermore, the implementation of whole body DWI with background body signal suppression (DWIBS) in MRI protocol may be a further advantage; indeed, because of its high lesion-to-background contrast, DWIBS allows "at-a-glance" detection of lesions providing high quality PET-like whole body images [8; 9].

Purpose of this prospective study was to evaluate the agreement between WB-DW-MRI and ¹⁸F-FDG-PET/CT in the assessment of disease burden and patient stage in newly diagnosed lymphoma. We also aimed to evaluate WB-DW-MRI sensitivity and specificity using PET/CT as the standard of reference. The other goal of this study was to analyze interobserver agreement in reading WB-DW-MRI in accordance with standardized reporting criteria.
Methods and materials

Patients

Twelve patients with newly diagnosed lymphoma followed at the Institute of Hematology "L. e A. Seràgnoli" (Sant'Orsola-Malpighi Hospital, University of Bologna) were prospectively enrolled from June 2016 to July 2017. Inclusion criteria were: adult patients (age at or over 18 years) with histologically documented lymphoma requiring pre-treatment staging, absence of general contraindications to MRI examination (i.e. claustrophobia, implanted pacemakers or neurostimulators), absence of previous malignancies and performance status with values from 0 to 2 according to ECOG scale [10].

The Ethics Committee of our Hospital approved the study and all patients provided a written informed consent to the diagnostic procedures.

All patients received a histological diagnosis in accordance with the World Health Organization (WHO) recommendations [11]. Disease staging was based on the Ann Arbor classification [2] with physical examination, total body contrast-enhanced CT, $^{18}$F-FDG-PET/CT and iliac crest bone marrow biopsy. During the inclusion period, all eligible patients underwent WB-DW-MRI a short time away from $^{18}$F-FDG-PET/CT (time interval, 16.1 ± 14.5 days) prior to any treatment.

Characteristics of the studied population are summarized in TABLE 1.

Imaging techniques

All MRI examinations were performed on a 1.5-T MRI scanner using a rolling table platform with the patient in supine position with posterior coil, head and neck coil and two anterior coils. After a scouting sequence, coronal turbo spin-echo T1-weighted and fat-suppressed T2-weighted short tau inversion recovery (STIR) were acquired separately for head and neck, chest and superior abdomen, inferior abdomen and pelvis, femurs, tibias and feet and then merged in order to obtain seamless coronal images of the whole body. In the same stations, axial single-shot spin-echo echo-planar DWI with background body signal suppression (DWIBS) were acquired with b = 1.000 s/mm². After that, DWIBS images were reformatted on the coronal plane and then merged to create seamless coronal DWIBS images of the whole body. In addition, radial DWIBS maximum intensity projections (MIP) in the coronal plane were created. The applied MRI protocol allowed a full body coverage from vertex to feet in all patients. In order to obtain apparent diffusion coefficient (ADC) maps, additional targeted single-shot spin-echo echo-planar
DWI were performed with \( b = 0 \) and 1.000 s/mm\(^2\) on the axial plane for every hyperintense finding depicted on DWIBS images. Diffusion gradients of DWIBS and targeted DWI were applied in three orthogonal directions. No intravenous contrast agent was administered. On average, the total scan time was approximately 67 minutes. MRI technical parameters are shown in TABLE 2. An example of our MRI protocol in a 20-year-old patient affected by Hodgkin lymphoma is shown in FIG. 1.

All \(^{18}\)F-FDG PET-CT examinations were performed on a PET-CT system according to the standard body technique. After a six-hours fasting period, patients were injected with 3.7 MBq/kg body weight of \(^{18}\)F-FDG 60 minutes before performing PET scan. A non-contrast CT scan was acquired with 120 kV and 80 mA before PET scan.

**Image analysis and interpretation**

WB-DW-MRI and PET-CT data were interpreted by two independent radiologists, respectively blinded, and nuclear medicine specialists. All images were systematically reviewed for per-lesion and per-patient evaluation. Per-lesion analysis was based on the assessment of disease in each of the following 19 nodal stations: right and left laterocervical, right and left infraclavicular, right and left axillary, mediastinal, right and left pulmonary hilar, para-aortic, mesenteric, right and left iliac, right and left inguinal/femoral, right and left epitrochlear, right and left popliteal (FIG. 2). In addition, per-lesion assessment included the evaluation of the following 19 extra-nodal regions: Waldeyer's ring, lungs, pleura, pericardium, liver, spleen, kidneys, adrenal glands, major salivary glands, stomach, bowel, pancreas, gonads, prostate (uterus in female patients), brain, thyroid, breasts, bone marrow and other soft tissues not otherwise classified.

Reconstructed coronal and radial DWIBS of the whole body were reviewed both with native grayscale and with a black-white inverse grayscale in order to obtain a qualitative optical visualization directly comparable to PET/CT. All DWIBS and DWI images were qualitatively interpreted in association with ADC maps, but ADC measurements were not used for tissue characterization because there are still no validated criteria for this purpose [12]. The observers systematically assessed as positive or negative for disease every nodal and extra-nodal region using standardized scoring forms. Lymph nodes were considered positive for lymphomatous involvement according to the following criteria: 1) size and morphology: short axis diameter greater than 10 mm (15 mm in axillary and inguinal/femoral stations) on coronal T1-weighted and axial DWI b0 images, except those with a thin cortex and a fatty hilum on T1-weighted and STIR images; 2) signal intensity greater than the spinal cord on DWIBS images with signal lower than muscle on ADC maps; 3) signal heterogeneity due to the presence of necrosis within the evaluated site, regardless of size. In extra-nodal sites, every area of diffusion signal abnormality relative to the surrounding tissue was considered positive for lymphomatous involvement. On tissues with normally impeded diffusion (including brain, salivary glands, tonsils, spleen,
gallbladder, adrenal glands, prostate, testes, penis, endometrium, ovaries, spinal cord, peripheral nerves and bone marrow [8; 9]) any focally increased signal intensity was considered positive for disease involvement. Splenomegaly (longest diameter more than 13 cm [3]) without liver cirrhosis was considered positive for diffuse splenic involvement.

On $^{18}$F-FDG-PET/CT images, any area of visually elevated tracer uptake relative to the background, not located in areas of physiologically increased uptake, was regarded as positive for lymphomatous involvement. In sites with physiologic tracer uptake (e.g. spleen and liver), focal or inhomogeneous uptake patterns were considered to be indicative of disease involvement [1].

Per-patient evaluation relied on the assignment of a disease stage using Ann Arbor classification according to MRI and PET/CT findings.

**Statistical analysis**

Collected data were analyzed on a per-lesion and per-patient basis. Kappa (#) coefficients were calculated according to Cohen's analysis to estimate MRI-PET/CT agreement and interobserver agreement in reading MRI examinations. Agreement was considered poor at a value of 0, weak at 0.01-0.20, fair at 0.21-0.40, moderate at 0.41-0.60, good at 0.61-0.80 and very good at 0.81-1. MRI sensitivity and specificity were obtained using PET/CT as the standard of reference, with 95% confidence interval (CI). Finally, the impact of MRI and PET/CT on disease staging was analyzed according to Ann Arbor staging system. In order to compare MRI to PET/CT and to assign to each patient a disease stage, disagreements between the two radiologists were resolved by consensus.
**Table 1:** Characteristics of the 12 patients included in the study. The Ann Arbor stage is based on physical examination, contrast-enhanced CT, integrated FDG-PET/CT and bone marrow biopsy.

Table 1: Characteristics of the 12 patients included in the study. The Ann Arbor stage is based on physical examination, contrast-enhanced CT, integrated FDG-PET/CT and bone marrow biopsy.

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### TABLE 2.a
Whole-body MRI technical parameters

<table>
<thead>
<tr>
<th>Imaging</th>
<th>Breathing</th>
<th>Acquisition plane</th>
<th>RT (ms)</th>
<th>ET (ms)</th>
<th>IT (ms)</th>
<th>b-value (s/mm²)</th>
<th>FOV (FH x RL x AP)</th>
<th>Matrix</th>
<th>Section thickness / gap (mm)</th>
<th>SENSE factor</th>
<th>NSA</th>
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<td>DWBS head neck</td>
<td>Free</td>
<td>Axial</td>
<td>6225</td>
<td>69</td>
<td>180</td>
<td>1.00</td>
<td>285x500x402</td>
<td>100x78</td>
<td>6/0.2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>DWBS neck chest</td>
<td>Free</td>
<td>Axial</td>
<td>6225</td>
<td>69</td>
<td>180</td>
<td>1.00</td>
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<td>6/0.2</td>
<td>2</td>
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</tr>
<tr>
<td>DWBS chest sup abdomen</td>
<td>Free</td>
<td>Axial</td>
<td>6225</td>
<td>69</td>
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<td>1.00</td>
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<td>100x78</td>
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<td>280x367</td>
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### TABLE 2.b
Targeted DWI technical parameters

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<th>Imaging</th>
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<th>RT (ms)</th>
<th>ET (ms)</th>
<th>Fat suppression</th>
<th>b-value (s/mm²)</th>
<th>FOV (FH x RL x AP)</th>
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<th>Section thickness / gap (mm)</th>
<th>SENSE factor</th>
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**Table 2:** Technical parameters of whole body diffusion-weighted MR examination used in our Institute (BH = Breath hold, RT = Repetition time, ET = Echo time, IT = Inversion time, FOV = Field of view, NSA = Number of signals averaged).

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Fig. 1: Our WB-DW-MRI protocol in a 20-year-old patient with Hodgkin lymphoma with supradiaphragmatic disease. DWIBS reformatted and merged on the coronal plane with inverted (A) and native (B) grayscale, coronal T1 (C) and coronal STIR (D) of the whole body.

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Fig. 2: Nodal localizations taken into account in our study.

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Results

Per-lesion and per-patient analysis

Overall, 456 body areas in 12 patients (228 nodal and 228 extra-nodal regions) were systematically evaluated. MRI and PET/CT overlapped in 218/228 (95.6%) lymph node regions, showing a very good (k = 0.855; standard error SE: 0.045) agreement. MRI sensitivity compared to PET/CT was 100% (95% confidence interval [CI]: 97.9-100%) and specificity was 94.8% (95% [CI]: 90.8-97.1%).

Among the 228 extra-nodal areas analyzed (19 regions per patient), MRI and PET/CT findings overlapped in 223 regions (97.8%), with a good (k = 0.772; SE: 0.098) agreement between the two procedures. MRI sensitivity compared to PET/CT was 100% (95% [CI]: 97.9-100%) and specificity was 97.7% (95% [CI]: 94.6%-99.1%).

The overall agreement between MRI and PET/CT was very good (k = 0.842; SE: 0.040). Using PET/CT as the standard of reference, MRI overall sensibility and specificity were respectively 100% (95% [CI]: 99.0-100%) and 96.3% (95% [CI]: 94.1-97.8%). Per-lesion based comparison between the two procedures and results from Cohen’s analysis are reported in TABLE 3 and TABLE 4.

All body regions considered positive for disease involvement on PET/CT were reported as positive also on MRI examinations. Discrepancies between the imaging procedures were related to the higher number of lesions reported on MRI (in particular, 10 nodal and 5 extra-nodal localizations). Among nodal stations, disagreement occurred mostly in right pelvic and right inguinal/femoral sites (k = 0.625, SE: 0.267), while spleen represented the site with the worst agreement (k = 0.428, SE: 0.236) among extra-nodal areas. In particular, splenic involvement was reported in 3/12 patients on MRI and in 1/12 on PET/CT; in inconsistent cases, MRI reported as positive for lymphomatous involvement a splenomegaly without liver cirrhosis and a single millimetric splenic lesion.

Despite the discrepancies between the two imaging techniques, per-patient evaluation showed that Ann Arbor stages based on MRI and those based on PET/CT matched in 10/12 (83.3%) patients. As underlined in TABLE 5, in one patient MRI detected a diffuse splenic involvement not reported on PET/CT while in the other discordant case MRI underlined an additional mediastinal localization in a patient with a main sub-diaphragmatic disease extent. In both cases, MRI over-staged the disease.

FIG. 3 - 4 - 5 - 6 illustrate some cases of this study.

Interobserver agreement
The two blinded and independent observers reported the same conclusion on the status of disease involvement in 445/456 body areas (97.5%) (TABLE 6), showing a very good (k = 0.887; SE: 0.033) overall agreement. In particular, the agreement was very good both in nodal (k = 0.839; SE: 0.047) and extra-nodal (k = 1.000; SE: 0.000) regions, with excellent overlap in latter areas. Disagreements occurred only in some nodal regions, with major discrepancies observed in axillary and inguinal/femoral lymph node stations (k = 0.000). Results from Cohen’s analysis are summarized in TABLE 7.
Table 3: Per-lesion based comparison between PET-CT and WB-MRI in nodal (3.a) and extra-nodal (3.b) regions.

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Table 4: Cohen's Kappa (#) values for whole-body MRI-PET/CT agreement.

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Table 5: Per-patient based comparison between PET-CT and WB-MRI using the Ann Arbor staging system; the main causes of discrepancies are underlined.

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Fig. 3: 51-year-old patient affected by Hodgkin disease with a large mediastinal involvement and multiple bone localizations. Coronal T1 (A), coronal STIR (B), DWIBS reformatted and merged on the coronal plane with inverted grayscale (C) and related PET/CT image (D).
Fig. 4: Mediastinal bulk disease in a 27-year-old patient affected by primary mediastinal large B-cell lymphoma. The lesion showed hyperintensity on DWIBS (A) with restricted diffusivity on ADC maps (B) and pathological tracer uptake on PET/CT (C). Note the large necrotic area within the lesion (white arrow).
Fig. 5: 45-year-old patient affected by follicular lymphoma. DWIBS (A - B) showed a nodal localization in posterior mediastinum (yellow arrow) not detected on PET/CT (C - D; red circle). In this patient, MRI over-staged the disease using Ann Arbor classification.

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**Fig. 6:** Coronal images focus on discrepancies between MRI and PET/CT on splenic involvement. In the first case, MRI showed a small splenic lesion (A; blue arrow) not detected on PET/CT (B) in a 51-year-old patient affected by Hodgkin disease. In the other case, splenomegaly without liver cirrhosis was considered positive for diffuse involvement on MRI (C; blue arrow) in a 26-year-old patient affected by Hodgkin disease; PET/CT was negative for disease involvement instead (D). In this patient, MRI over-staged the disease using Ann Arbor classification.

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### Table 6.1

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### Table 6.2

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<td>Observer 2 positive</td>
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<tr>
<td>Observer 2 negative</td>
<td>214</td>
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</table>

**Table 6:** Per-lesion based interobserver agreement both in nodal (4.a) and extra-nodal (4.b) regions analyzed on WB-MRI studies.

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Table 7: Cohen’s Kappa (#) values for interobserver agreement.

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Conclusion

This prospective study showed a very good agreement between WB-DW-MRI and PET/CT in pre-therapeutic assessment and staging of newly diagnosed lymphoma. In addition, MRI overall sensibility and specificity were respectively 100% and 96.3% using PET/CT as the standard of reference.

Our results are in line with current literature; in fact, other recent studies have already investigated the reliability of DW-MRI in lymphoma staging [13 - 17], underlining its high accuracy when compared to PET/CT. As emphasized in some of these studies, we remark that PET/CT and DW-MRI should be considered as complementary techniques in the evaluation of cancer patients, because they provide information about completely different tissue properties (metabolic activity versus cellular density) [6].

Another interesting finding was the very good interobserver agreement in accordance to standardized reporting criteria previously fixed by consensus. However, these data need further validation in larger cohorts of patients because of the known potential difficulties with MRI in the evaluation of some nodal (e.g. hilar lymph nodes) and extra-nodal (e.g. lungs and spleen) regions [6; 15].

The lack of validated quantitative measurements (i.e. ADC values) to support discrimination between healthy and pathological sites [6; 12] is one of the major drawbacks of DWI when compared to PET/CT, especially in small sized lymph node characterization [18]. In our opinion, the absence of a quantitative parameter for a better tissue characterization could have determined most of the discrepancies found in our study between the two observers as well as between the two imaging modalities. Nevertheless, WB-DW-MRI staging matched PET/CT staging in the majority of our patients.

To conclude, according to our results, whole body diffusion-weighted MRI represents a reliable tool in staging lymphoma without radiation exposure and could be considered a valid alternative to PET/CT if repeated radiation exposure should be avoided, especially in young adults. However, additional studies on larger populations are needed in order to prove the strength of this tool in both staging and assessment of treatment response.
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References


