Whole body MRI – How I do it and what it tells you

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The idea of whole body MRI (WB-MRI), acquiring multiple image stacks across the entire body is not new. Since the 1990s, conventional T1 and short-tau inversion recovery (STIR) techniques have been investigated as methods for tumor detection [1-3]. These initial studies did demonstrate relatively high sensitivity, specificity and diagnostic accuracy for malignant lesion detection in a variety of tumor types [1, 2, 4-8]. However, whole body MRI did not gain widespread acceptance despite its promise of being as accurate as FDG-PET for malignant lesion detection in the bones [9-13]. Important negating factors to clinical deployment include the need to use multiple sequences in multiple imaging planes before and after contrast medium. Whole body MRI protocols have to be tailored by tumor type and were time consuming to acquire, view, analyze and report [14, 15].

However, substantial improvements have been made in MR hardware and software innovations, which allow multi-part MR examinations to be performed with a relative easy workflow [15, 16]. The advent of continuous moving table technology allows even more efficient scanning [7, 16-19]. Dedicated software enables the imaging data acquired at different anatomical stations and in different imaging planes to be quickly stitched and fused together to facilitate analysis and reporting. Today, most modern state-of-the-art MR scanners, can perform whole-body MRI from the vertex to the mid-thighs with T1-weighted, fat-suppressed T2-weighted or STIR, and diffusion weighted imaging sequences supplemented T1-weighted and T2W-weighted spinal images in less than 60 minutes, thus making WB-MRI a viable clinical tool. A key recent development has been the addition of whole body diffusion weighted (DW) sequences which makes it possible to do away with the need to use IV contrast medium for routine WB-MRI examinations [20, 21]. WB-DWI is now considered to be an integral component of WB-MRI examination that improves reading performance [22]. This is because WB-DWI it enables “at a glance” assessments, immediately drawing attention to potential abnormal regions and thus helping to reduce image interpretation times of anatomical WB-MRI [20].

Working whole body MRI protocol without using IV contrast medium

Patients are best imaged on a 1.5T system equipped with multiple surface coils. Our imaging studies are done in the following sequence order, after obtaining appropriate whole body scout images. We do not use IV contrast medium injections although the literature suggests that it use may be beneficial for the detection of bone, lungs, liver and brain metastases – see below [23-25].

1. Whole spine: T1-weighted, turbo spin-echo sagittal images. Images are acquired in two stations (cervico-dorsal spine and lower dorsal with lumbo-sacral region) and composed into single images for display purposes. TR=180ms, TE=10ms, bandwidth=195Hz/pixel, 11 slices, 4mm slice thickness, 0.8mm gap, echo-train length =3, refocusing flip angle=180°, field of view=342x380cm, matrix 177x256. Total imaging time for both stations= 2:12 minutes.

2. Whole spine: T2-weighted, turbo spin-echo sagittal images with spectral fat suppression. Images are acquired in two stations (cervico-dorsal spine and lower dorsal
with lumbo-sacral region) and composed into single images. TR=4500ms, TE=101ms, bandwidth=252Hz/pixel, acceleration factor=2, 11 slices, 5mm slice thickness, echo-train length=29, refocusing flip angle=150⁰, field of view=342x380cm, matrix 256x256. Total imaging time for both stations = 2:36 minutes.

3. Whole body: T1-weighted, gradient-echo axial images from vertex to upper mid thighs. TR=130ms, TE=4.8/2.4ms, bandwidth=470Hz/pixel, acceleration factor=2, 5mm slice thickness, flip angle=70⁰, field of view=336x430cm, matrix 175x320. Continuous table movement (5.9 mm/s) are used during data acquisition, employing multiple breath-holds for the neck, chest and abdomen and shallow breathing for the pelvis and thighs. Total imaging time = 3:00 minutes.

4. Whole body: T2-weighted, short-tau inversion recovery (STIR) axial images with half-fourier single shot turbo spin echo (HASTE) readouts of the data from vertex to upper mid thighs. TR=1000ms, TE=75ms, Inversion time=170ms, bandwidth=501Hz/pixel, acceleration factor=2, 5mm slice thickness, echo-train length =208, flip angle=150⁰, field of view=350x430cm, matrix 208x256. Continuous table movement (5 mm/s) are used during data acquisition, employing breath-holds for the neck, chest and abdomen and shallow breathing for the pelvis and thighs. Total imaging time = 4:00 minutes.

5. Multi-station WB-DWI for 1.5T using the machine parameters given in the table below in 4 stations.

<table>
<thead>
<tr>
<th>Machine parameters for WB-DWI at 1.5T</th>
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<tbody>
<tr>
<td>Imaging sequence</td>
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<td>Repetition time</td>
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<td>Echo time</td>
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<td>No of slices</td>
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<td>Field of View</td>
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<td>Matrix</td>
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<td>Number of signal averages</td>
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<td>Fat suppression scheme</td>
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<td>Diffusion encoding</td>
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<td>Parallel imaging factor</td>
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<td>Section thickness/gap</td>
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<tr>
<td>b-values (s/mm²)</td>
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<td>Receiver bandwidth</td>
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<td>Acquisition time/station</td>
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6. Diffusion weighted b900 images from all 4 diffusion imaging stations are grouped and reconstructed as axial and coronal 5mm slices. Whole body 3D-maximum intensity projection of b900 images are displayed as rotating images (every 3 degrees=120 images) using an inverted grey-scale.

7. The ADC for all slices is calculated using the two b-values obtained monoexponential fitting of log signal intensity (SI) versus b values: \( S_{900} = S_{50} \times \exp (- b \times \text{ADC}) \), where \( S_{900} \) is the signal intensity at \( b \) of 900 s/mm\(^2\) and \( S_{50} \) is the signal intensity at \( b \) of 50 s/mm\(^2\) (the ADC represents the slope of the curve).

Lesion detection with whole body MRI with WB-DWI – a brief review of the literature

The ability of WB-MRI to detect lesions is highly dependent on tumor histological type and grade as well as an anatomic location. Thus, in our experience detection ability is good for breast cancers, myeloma and lymphoma and for tumors with highly packed small cancer cells such as neuroendocrine tumors, small cell cancers and many childhood tumors [26-30]. Metastatic diseases from these tumor types generally appear bright on high b-value DW images. In contradistinction, primary tumors and metastases from renal cancers are sometimes less well seen, with clear cell metastases appearing relatively less conspicuous compared to other renal cancer histological subtypes; this may be related to the relatively greater water diffusivity in the clear cell cancers [31-34]. Furthermore, it has been noted that well-differentiated or low-grade masses are less well seen probably because they often have a more normal appearing histomorphologic structure [33, 35-39]. The latter point is not a hard and fast rule because many cytological features aside from cellular density determine tumor grade.

There are several anatomic “blind spots” where lesion detection is impaired (leading to false negative results) including the mediastinum, at the pulmonary hila and in the most cranial aspect of the left hepatic lobe just beneath the heart. At these sites, complex incoherent motion contributes to signal losses on high b-value DW images. Motion-related signal intensity losses may explain why metastatic lesions in the bone marrow of the anterior chest wall are sometimes relatively less conspicuous than lesions found in the spine & paraspinal regions. Lastly, small lung metastases are poorly shown on WB-DWI although a sensitivity analysis by lesion size has not been done. The ability to detect lung metastases appears to improve by the use of contrast medium but not to the detection level of CT [40, 41]. The literature suggests that contrast enhancement may also be beneficial for the detection of bone, liver and brain metastases [23-25, 41].

On the other hand, FDG-PET and MRI have been found to be comparable at lesion detection in the bone marrow and both significantly more accurate than CT and BS for the diagnosis of bone metastases [9, 27, 42, 43] in a variety of cancers including lung cancer. MRI performance exceeds FDG-PET in detecting bony metastases in breast cancer patients [44]. For example, a recent meta-analysis demonstrated a high pooled sensitivity of 0.899 (95% CI, 0.845-0.939) and high specificity of 0.918 (95% CI, 0.882-0.946) [8]. A sub-group analysis found that addition of DWI decreased the specificity of WB-MRI in bone metastases detection; the subgroup of WB-MRI without DWI had higher pooled specificity (0.961, 95% CI 0.922–0.984) than the subgroup of WB-MRI without DWI (0.861, 95% CI 0.792–0.914) (P < 0.05) [8].

Causes of false positive increases in bone marrow signal intensity on DWI images include bone marrow edema caused by fractures, degenerative diseases, bone infarction, infection and hemangiomas. Other causes of false positive focal increases in signal intensity on DWI include
isolated red bone marrow islands within yellow marrow and treated, but inactive lesions (T2-shine through). Many of these false positive increases in signal intensity on high b-value images can overcome by performing image interpretations with ADC maps and conventional images. Causes of false negative results in the bone marrow tumor detection include low levels of tumor infiltration, skull vault and skull base metastases (due to the adjacent high signal intensity of the brain) and when metastases develop within hypercellular bone marrow. As a general rule, lytic bony metastases are better seen than pure sclerotic metastases because of lower water and cellular content of sclerotic and treated lesions [23, 27, 45].

References


