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Review

Whole-body diffusion-weighted magnetic resonance imaging: Current evidence in oncology and potential role in colorectal cancer staging

Doenja M.J. Lambregts ^{a,b}, Monique Maas ^{a,b}, Vincent C. Cappendijk ^a,
 Leonne M. Prompers ^c, Felix M. Mottaghy ^{c,d}, Geerard L. Beets ^b, Regina G.H. Beets-Tan ^{a,*}

^a Department of Radiology, Maastricht University Medical Centre, P.O. Box 5800, 6202 AZ Maastricht, The Netherlands

^b Department of Surgery, Maastricht University Medical Centre, P.O. Box 5800, 6202 AZ Maastricht, The Netherlands

^c Department of Nuclear Medicine, Maastricht University Medical Centre, P.O. Box 5800, 6202 AZ Maastricht, The Netherlands

^d Department of Nuclear Medicine, University Hospital Aachen, Pauwelsstraße 30, 52074 Aachen, Germany

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ABSTRACT

Tumour staging in cancer patients generally entails a multimodality imaging approach. Whole-body (WB) imaging techniques may, however, be more time- and cost-effective than a multimodality approach. 2-Fluorine-18-fluoro-2-deoxy-D-glucose positron emission tomography (¹⁸FDG-PET), computed tomography (CT) and hybrid positron emission tomography and computed tomography (PET/CT) are the most established WB modalities, although new techniques, amongst which diffusion-weighted magnetic resonance imaging (DWI), are emerging. This review aims to evaluate the current evidence for WB-DWI in oncology, to discuss its potential for the WB staging of (colo)rectal cancer and to relate it to the established WB techniques.

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1. Introduction

When patients are diagnosed with a malignant tumour, imaging plays a key role in tumour staging and generally entails an evaluation of the primary tumour site, as well as the most likely sites for distant metastases. In patients with colorectal cancer, detection of synchronous distant metastases during primary staging is specifically relevant, since early treatment (chemotherapy and/or surgery) can improve survival.¹ In these patients, staging consists of a combination of a chest X-ray (or chest computed tomography (CT)) plus a CT, Magnetic resonance imaging (MRI) or ultrasound of the liver and abdomen.^{2–4} Recently, whole-body (WB) imaging techniques

are being suggested as a potentially more time- and cost-effective alternative to such a multimodality approach. The most established whole-body staging techniques are CT, 2-Fluorine-18-fluoro-2-deoxy-D-glucose positron emission tomography (¹⁸FDG-PET) and hybrid positron emission tomography and computed tomography (PET/CT). There are, however, some shortcomings to these techniques, amongst which are patient's exposure to ionising radiation and limitations in spatial and contrast resolution.^{5,6} Considering these drawbacks, MRI could potentially be beneficial, although its role for whole-body staging has so far not frequently been explored. This is mainly due to the long image acquisition times required when the whole-body needs to be covered with MRI.

* Corresponding author: Tel.: +31 (0)43 387 69 10; fax: +31 (0)43 387 69 09.

E-mail address: r.beets.tan@mumc.nl (R.G.H. Beets-Tan).

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The development of time-efficient whole-body magnetic resonance (MR) imaging techniques is now in evolution, one of the most promising being diffusion-weighted MR imaging (DWI). DWI has shown great potential for the detection of various malignancies throughout the body and can also be used as a one-stop-shop imaging tool for whole-body tumour staging.^{7,8} Furthermore, DWI is a non-invasive technique that does not require the use of ionising radiation or contrast agents and can easily be added to a standard clinical MRI protocol. Because MRI – in many countries – is part of the standard staging work-up for rectal cancer patients, the use of MRI + DWI as a one-stop-shop imaging tool could be of particular interest for this specific patient group.

This article aims to review the current evidence for whole-body diffusion-weighted MR imaging in oncology, to discuss its potential for the staging of (colo)rectal cancer and relate it to the established whole-body imaging techniques: CT, ¹⁸F-FDG-PET and PET/CT.

2. Diffusion-weighted MR imaging

An in-depth discussion of the physics of diffusion-weighted MRI is beyond the scope of this article. For a more extensive overview we, therefore, refer the reader to related articles.^{7,9,10} In summary, the signal in DWI is derived from differences in random water proton movement within tissues, which is mainly dependent on tissue cellularity, the integrity of cell membranes and viscosity of fluids. In tissues with a normal or low cellularity, water protons can diffuse relatively freely which can be detected as an attenuation of the signal intensity on DWI. Conversely, malignant tumours are generally hypercellular and contain many intact cell membranes, which results in restricted water diffusion and a remaining high signal on DWI. The sensitivity to diffusion is obtained by applying two bipolar diffusion-sensitising gradients to a standard T2-weighted spin echo sequence. The diffusion-sensitivity can be varied by adjusting the 'b-factor', which is a combination of the gradient duration, gradient amplitude and the time interval between the two gradients. The higher the b-value, the greater the signal attenuation from moving water protons. By visually analysing the relative signal attenuation between images obtained at different b-factors, differences in water diffusion can be used for tissue characterisation and identification of pathologic lesions. DWI images obtained with high b-values make the signal of malignant tumours stand out compared to the suppressed background signal and have been shown useful for a better visual detection of (small) malignant tumours, for example in the liver and prostate.^{11–13} In addition to visual DWI evaluation, the diffusion characteristics of tissues can also be measured quantitatively as the 'apparent diffusion coefficient' (ADC). ADC is measured by plotting the logarithmic signal attenuation against the applied b-factors. The slope of this plotted line can be used as a quantitative measurement of water diffusion; the ADC. The use of ADC has been exploited for lesion characterisation. Malignant lesions, for example in the liver, prostate, breast and head & neck region, can be distinguished because of differences in ADC values compared to benign lesions.^{14–17} In addition to lesion characterisation,

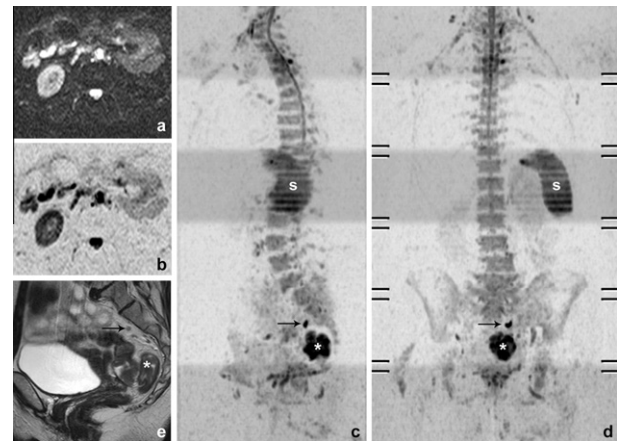


Fig. 1 – Image display of whole-body diffusion-weighted images (WB-DWI). Whole-body diffusion-weighted images are generally obtained by acquiring several separate DWI stacks [a] covering different parts of the thoraco-abdominal region. The image greyscale is inverted [b] and the images are combined as maximum intensity projection (MIP) reconstructions for 3D display. This example shows the sagittal [c] and coronal [d] WB-DWI reconstructions of a female patient with a large tumour in the rectum (*) and a metastatic lymph node located just proximal from the tumour (arrow). Because the spleen (s) is an organ with a relatively high cellular density, it generally shows high signal on WB-DWI. For anatomical reference, the DWI images are evaluated together with an anatomical T2-weighted magnetic resonance imaging [e].

studies in rectal cancer, colorectal hepatic metastases and brain tumours have suggested that tumour ADC measurements can also be used as a biomarker for treatment response and may predict the response to treatment at an earlier stage than morphological changes occur.^{18–25} Compared to other functional imaging techniques, DWI is advantageous in that it does not require the use of ionising radiation or MR contrast agents and it can easily be implemented into a standard MRI protocol. In 2004, Takahara et al. introduced an interesting new concept of DWI, called DWIBS (diffusion-weighted whole-body imaging with background body signal suppression), which made it possible to obtain high quality 3D diffusion images of the whole-body during free breathing. These whole-body images can be displayed in an inverse greyscale to resemble the image display of PET (Fig. 1).²⁶

3. Pitfalls in DWI image interpretation

3.1. Qualitative (visual) image interpretation

An important limitation in the visual evaluation of DWI is the fact that not only malignant tumours, but also several benign lesions (e.g. abscesses) and normal anatomical structures, such as the spinal cord, spleen, prostate and lymph nodes may show high signal on DWI and may erroneously be interpreted as malignant tumour (Figs. 1 and 2).²⁷ Furthermore, since DWI sequences are typically based on T2-weighted

imaging, high signal on DWI is not necessarily caused by restricted water diffusion, but may also be due to prolonged T2-relaxation times (e.g. fluid showing high signal on T2 W-MRI), a phenomenon known as 'T2 shine through'. Hence, knowledge of the normal anatomy and morphology is crucial when analysing DWI and diffusion images will need to be interpreted in combination with anatomical imaging. Different studies have suggested that combined assessment of DWI together with anatomical T2-weighted and/or T1-weighted images can be beneficial to diminish interpretation errors of DWI, for example in the evaluation of cystic liver lesions and skeletal metastases.^{28,29}

The evaluation of lymph nodes on DWI is particularly challenging. Due to the high cellularity (and thus restricted diffusion) of lymphoid tissue, DWI is a very sensitive technique for the detection of lymph nodes. However, benign and malignant nodes may show equally high signal on DWI, making it difficult to stage the visualised nodes (Fig. 2). For visual evaluation of nodes on DWI, we will thus have to rely on the same criteria as applied on morphological images, mainly being size and homogeneity of signal.

3.2. Quantitative (ADC) image interpretation

Studies, mainly in head and neck and gynaecological tumours, have shown more promising results for quantitative evaluation of ADC in the discrimination between benign and malignant lymph nodes.^{17,30} However, other studies focussing mainly on ADC for pelvic lymph node evaluation reported no additional benefit for ADC.^{31,32} A general limitation of quantitative (ADC) evaluation for lesion characterisation is that benign and malignant lesions can show overlapping ADC

values, which may restrict the use of ADC for the discrimination of malignancies in daily clinical practise.^{14,33} ADC values are also dependant on variations in MR equipment and DWI sequence parameters. Efforts are, therefore, being made to standardise DW imaging protocols in order to minimise these effects. Presently, ADC quantification is not widely applied in whole-body studies, because it is fairly time consuming and image quality may be reduced to compensate for the relatively long scan times needed to image the whole body.

4. Current evidence for whole-body DWI in oncology

4.1. Search strategy and selection criteria

The Pubmed and Medline databases were searched for all English, Dutch and German language original articles published between 1990 and November 2010, using the following search terms: 'whole-body', 'diffusion-weighted imaging', 'cancer', 'tumour', 'detection' and 'staging'. Studies were selected when the following inclusion criteria were met: (1) a DWI sequence covering the body was applied, (2) the main study question was the detection/staging of malignant tumour using WB-DWI, (3) a clear description of the applied standard reference was provided, and (4) sensitivity and/or specificity was provided or could otherwise be extracted from the study data. One reviewer (DMJL) checked the titles and abstracts of the identified studies in order to select studies potentially meeting the inclusion criteria. Additional studies were traced by checking the reference list of the selected studies. The reviewer then studied full text copies of the selected studies to decide which studies finally met the inclusion criteria.

4.2. Results

Twenty-seven eligible studies were identified, of which 11 were excluded for the following reasons: full text copies of the articles could not be retrieved,^{34–39} no English/Dutch/German language,⁴⁰ the study focus was technical DWI improvement rather than tumour detection,^{41,42} sensitivity and/or specificity could not be extracted,⁴³ the study focused on the detection of tumour within a specific organ instead of whole-body tumour detection.⁴⁴

The vast majority of the included WB-DWI studies focused on a visual evaluation of DWI for malignant tumour detection. The main findings of these studies are provided in Table 1. Several authors focussed on WB-DWI for the detection of bone metastases, mostly originating from prostate and breast cancers.^{45–48} All of these authors reported a high sensitivity, ranging between 82% and 96%. Nakanishi et al. reported as an additional benefit of WB-DWI that both osseous and extra-osseous tumour lesions (i.e. lymph nodes) could be evaluated within one single examination. Nevertheless, results were limited, as sensitivity for detection of metastatic lymph nodes was only 46%.⁴⁶ Because tumour detection was the main focus in most studies, specificity has been scarcely reported and results are conflicting. Whereas Gutzeit et al. reported a high specificity of 99%, Heusner et al. found an overall specificity of 67% for M-staging in breast cancer. Moreover, specific-

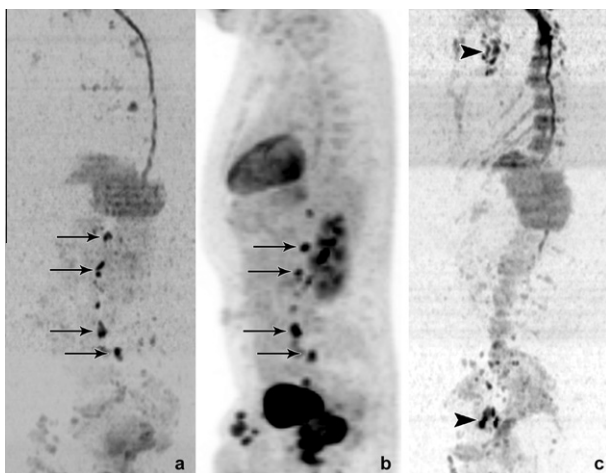


Fig. 2 – Lymph node imaging on WB-DWI. Sagittal WB-DWI [a] and ¹⁸F-FDG-PET [b] images of a 62 year old male patient with massive metastatic nodal spread along the abdominal aorta (arrows). For comparison, the sagittal WB-DWI in [c] shows an example of a 26 year old healthy female volunteer in whom pronounced lymph nodes are also visible in the pelvic and axillary region (arrowheads). Since healthy lymph nodes have a high cellular density they will show high signal on DWI, similar to metastatic nodes and may thus harbour a risk for false positive findings.

Table 1 – Overview of studies analysing the diagnostic performance of visual evaluation of whole-body diffusion-weighted imaging (WB-DWI) with or without additional standard MRI sequences for primary whole-body tumour staging. When studies included multiple independent observers, mean scores are given. All results are per lesion results, except for the studies by Ohno and Fischer, for which the per patient results are given.

Author	Year	N	No readers	Aim	Reference standard	MRI only		DWI only		MRI + DWI	
						Sens	Spec	Sens	Spec	Sens	Spec
Chen et al. ⁵⁵	2010	56	2 (C)	M-staging in NSCLC	Histology and/or ≥ 6 months imaging FU	–	–	91	92	–	–
Fischer et al. ⁵¹	2010	64	2 (C)	Detection of various malignant tumours	¹⁸ FDG-PET/CT	85	81	88	69	96	75
Goudarzi et al. ⁴⁷	2009	29	2 (C)	Detection of bone mets from various primaries	MRI, CT and/or ≥ 3 months FU	–	–	–	–	89	–
Gutzeit et al. ⁴⁵	2010	36	2 (I)	Detection of bone mets from prostate and breast ca.	Two reader consensus from scintigraphy, CT, MRI, PET, PET/CT, conventional radiography and/or ultrasound	–	–	82	99	–	–
Heusner et al. ⁴⁸	2010	20	2 (C)	M-staging in breast cancer	Histology, concordant DWI and ¹⁸ FDG-PET findings, MRI, CT and scintigraphy	–	–	–	–	86	67
Komori et al. ³³	2007	16	2 (C)	Detection of various malignant tumours	Histology and/or ≥ 6 months clinical and imaging FU	–	–	–	–	93	–
Lin et al. ⁷⁸	2010	15	2 (C)	Staging of large B-Cell lymphoma	¹⁸ FDG-PET/CT	–	–	81	100	–	–
Lambregts et al. ⁷⁷	2010	15	2 (C)	M-staging in rectal cancer	Histology, ¹⁸ FDG-PET/CT, and/or ≥ 6 months clinical and imaging FU	–	–	81	–	–	–
Laurent et al. ⁵⁶	2009	35	2 (C)	M-staging in malignant melanoma	Histology, ¹⁸ FDG-PET/CT, MRI and/or tumour markers	–	–	–	–	83	98
Nakanishi et al. ⁴⁶	2007	30	2 (I)	Detection of bone mets from various primaries	≥ 6 months FU with MRI, CT, radiography and/or scintigraphy	88	–	–	–	96	–
Ohno et al. ⁵⁴	2008	203	2 (I)	M-staging in NSCLC	Biopsy, radiography, MRI, ¹⁸ FDG-PET/CT and ≥ 12 months clinical FU	60	92	58	88*	70	92**
Stecco et al. ⁴⁹	2009	29	2 (I)	Detection of various malignant tumours	¹⁸ FDG-PET/CT	–	–	88	99	–	–
Takenaka et al. ⁵³	2009	115	2 (I)	Detection of bone mets from NSCLC	Biopsy and/or ≥ 12 months FU with MRI, ¹⁸ FDG-PET/CT and scintigraphy	73	96	96*	94*	96*	96**

Abbreviations: NSCLC = Non-small cell lung cancer; M-staging = metastases staging; mets = metastases; FU = Follow-up; (I) = independent; (C) = in consensus; Sens = sensitivity; Spec = specificity; ¹⁸FDG-PET = 2-Fluorine-18-fluoro-2-deoxy-D-glucose positron emission tomography; CT = Computed Tomography; MRI = Magnetic Resonance Imaging; DWI = Diffusion-weighted Imaging.

* Indicates a significant difference compared with MRI only.

** Indicates a significant difference compared with DWI only.

ity was only 8% when analysing DWI exclusively for the evaluation of bone metastases.^{45,48} Goudarzi et al. confirmed in their study that many benign bone lesions and normal structures demonstrated high signal intensity on DWI, again suggesting a limited specificity.⁴⁷

Some authors did not focus on a homogeneous study population as described above, but included patients with a variety of primary malignancies.^{33,49–51} Most of these studies used ¹⁸FDG-PET/CT as the reference standard. A high concordance between WB-DWI and PET/CT for detection of lesions was generally reported,^{33,49} although Lichy et al. found that PET/CT was able to identify several mediastinal lymph node metastases, which were missed with WB-DWI.⁵⁰ Furthermore, Fischer et al. showed a low sensitivity of only 19% for WB-DWI, when looking specifically at the detection of lung metastases. Moreover, when they compared WB-DWI with standard WB-MRI, relatively many false positives were encountered with WB-DWI, resulting in a lower overall PPV for WB-DWI (84%) than for standard MRI (93%).⁵¹

Different studies have shown that a combination of DWI and anatomical MR imaging (WB-MRI/DWI) provides higher accuracy than the use of WB-MRI or WB-DWI as stand alone techniques. Tsushima showed in a study of 110 abdominal examinations that DWI as a stand alone technique resulted in a sensitivity and specificity of only 72% and 59%, respectively, for detection of malignant lesions. When the anatomical MR images and DWI were combined, results improved to 90% and 82%. The combination of MRI + DWI was also significantly better than the use of standard MRI only (sensitivity 80%, specificity 69%).⁵² This finding was confirmed by three other groups who all reported a superior diagnostic performance for the combined WB-MRI/DWI as compared to each on its own.^{51,53,54}

The role of whole-body DWI for ADC quantification has rarely been studied. Feuerlein et al. applied WB-DWI to measure ADC in a group of 230 patients with a variety of benign and malignant abdominal lesions.²⁷ They observed lower ADC values for the malignant tumours, but there was an overlap in ADC with the benign lesions and the difference was not statistically significant ($P = 0.72$). This finding can probably partly be attributed to the fact that the study included a very heterogeneous group of lesions (including liver, pancreas, colorectal and gynaecological lesions), for which sub analyses were not provided.

4.3. WB-DWI versus ¹⁸FDG-PET

DWI and PET are both functional imaging techniques, but their mechanisms of action differ considerably. Whereas PET uses differences in the glucose metabolism between benign and malignant tissues, DWI analyses differences in tissue cellular structure. Therefore, reasons for false positivity and false negativity will differ between the two techniques. PET is mainly hampered by its limited spatial resolution and problems in interpreting areas of inflammation. DWI on the other hand, mainly suffers from false positivity in high-cellular organs or lesions.

Few studies have systematically compared WB-DWI with ¹⁸FDG-PET. The key findings of these reports are summarised in Table 2. The main methodological problem is the lack of a

true gold standard, since generally not all lesions can be histologically confirmed. In most studies, the reference standard consists of a combination of clinical and imaging examinations and long-term follow-up. Three studies compared whole-body DWI and ¹⁸FDG-PET/CT for M-staging in patients with non-small cell lung cancer (NSCLC).^{53–55} All reported equal results for WB-DWI and PET/CT, with sensitivities and specificities for both techniques ranging between 63–97% and 92–98%, respectively. Laurent et al. found superior sensitivity for WB-DWI compared to PET/CT for M-staging in patients with malignant melanoma.⁵⁶ Komori et al. analysed a group with a variety of primary malignancies and reported a sensitivity of 93% for WB-DWI for malignant tumour detection versus 82% for PET/CT. In addition to visual evaluation, they also compared quantitative measurements of ¹⁸FDG-PET and DWI: whereas the standardised uptake value (SUV) of PET showed significant differences between malignant lesions and reference organs, ADC was not able to discriminate between normal and malignant tissue.³³ Heusner et al. compared WB-DWI to PET/CT for whole-body staging in 20 patients with breast cancer.⁴⁸ Sensitivity was equally high for both modalities, but specificity and PPV were significantly better for PET/CT. The main reasons for false positivity on DWI were benign lymph nodes and bone lesions.

5. WB-imaging for colorectal cancer staging

Because MRI plays an important role in the local staging of colorectal cancer, it is interesting to explore whether MRI (and/or DWI) can also be used for whole-body tumour staging in this patient group. At present, the role of MRI is, however, not yet established, whereas the roles of CT and ¹⁸FDG-PET are much more consolidated. ¹⁸FDG-PET has proven to be more sensitive than CT for both local and distant tumour detection. Reported sensitivities and specificities for ¹⁸FDG-PET range from 78–100% and 50–100%, respectively,^{57,58} whereas for CT these range between 32–100% and 58–98%.^{57,59,60} Since its launch in clinical practice about a decade ago, hybrid ¹⁸FDG-PET/CT has increasingly been shown to be superior in performance compared to either CT or ¹⁸FDG-PET as a stand alone modality, with sensitivities and specificities ranging from 80–100% and 67–100%, respectively.^{61,62} Nevertheless PET/CT is not incorporated in the guidelines as a primary staging modality of first choice and CT is still the recommended modality. The use of PET/CT is, however, justified and proven more beneficial than CT for the detection of extrahepatic metastases when curative liver surgery is considered in patients with liver metastases. As such, PET/CT can reduce the number of unnecessary laparotomies and limit the high treatment costs.^{63–65} The main role of PET/CT in patients with colorectal cancer at present consists of (1) excluding the presence of extrahepatic metastases in patients who are potential candidates for curative resection of isolated liver metastasis, (2) characterising equivocal findings on CT and (3) detecting recurrent tumour in patients with a clinical suspicion and rising carcino-embryonic antigen (CEA) levels during follow-up after rectal cancer surgery.^{66,67} In the latter setting, ¹⁸FDG-PET has a sensitivity of nearly 100% and a specificity of 71%.⁶⁷

Table 2 – Overview of studies comparing WB-MRI + DWI and ¹⁸FDG-PET/CT for whole body tumour staging. All results are per lesion results, except for the study by Ohno, for which the per patient results are given.

Authors	Year	N	Aim	WB-MRI + DWI				PET/CT				Statistical Significance		
				Sens	Spec	PPV	NPV	Acc	Sens	Spec	PPV		NPV	Acc
Chen et al. ⁵⁵	2010	56	M-staging in NSCLC	91	92	96	81	91	97	98	99	93	97	Accuracy for lymph nodes better for PET/CT (<i>P</i> = 0.031), other results n.s.
Heusner et al. ⁴⁸	2010	20	M-staging in breast cancer	86	67	71	95	76	95	99	95	99	98	Specificity, PPV and accuracy significantly better for PET/CT
Komori et al. ³³	2007	16	Detection of various malignant tumours	93	-	-	-	-	82	-	-	-	-	Not reported
Laurent et al. ⁵⁶	2009	35	M-staging in malignant melanoma	83	98	98	77	-	73	93	94	67	-	Not reported
Ohno et al. ⁵⁴	2008	203	M-staging in NSCLC	70	92	68	93	88	63	95	74	91	88	n.s.
Takenaka et al. ⁵³	2009	115	Detection of bone mets from NSCLC	96	96	63	100	96	97	95	60	100	96	<i>P</i> < 0.05 for specificity and overall accuracy (in favour of WB-DWI)
Abbreviations: NSCLC = Non-small cell lung cancer; M-staging = metastases staging; n.s. = not significant; Sens = sensitivity; Spec = specificity; PPV = positive predictive value; NPV = negative predictive value; Acc = Accuracy; WB-MRI = Whole-body Magnetic Resonance Imaging; DWI = Diffusion-weighted Imaging; ¹⁸ FDG-PET = 2-Fluorine-18-fluoro-2-deoxy-D-glucose positron emission tomography; CT = Computed Tomography.														

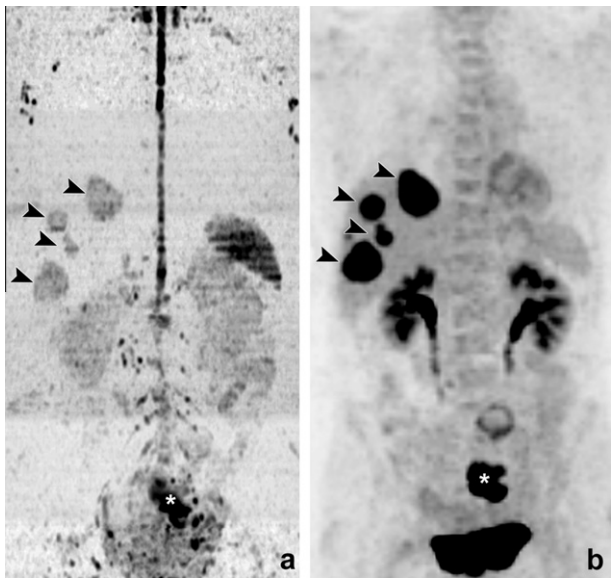


Fig. 3 – WB-DWI for the detection of metastatic liver lesions. WB-DWI [a] and ¹⁸FDG-PET images [b] of a 65 year old female patient with a tumour in the rectum (*) and several hepatic metastases (arrowheads). Both the primary tumour and the metastases are clearly visible on WB-DWI.

5.1. Whole-body DWI for colorectal cancer

So far, there is no evidence for the combined use of MRI/DWI as a whole-body primary staging modality in colorectal cancer. Two studies have investigated the use of conventional WB-MRI without DWI, but both focussed on the detection of recurrent tumour during follow-up and not on primary staging.^{61,68} Some studies exist that used DWI in a dedicated protocol for either local or distant staging in colorectal cancer patients and have shown promise for DWI in the primary detection of colorectal tumours,^{69–71} the detection of colorectal hepatic metastases,^{72,73} for lymph node staging^{32,74,75} and for the evaluation of tumour response after neoadjuvant chemo- or chemoradiation treatment.^{18–21,23–25,76} However, no reports exist on the use of DWI as a single whole-body staging modality in colorectal cancer. In a feasibility study, we performed WB-DWI in a group of 15 patients with known colorectal cancer and suspected distant metastases using a combination of histology, ¹⁸FDG-PET/CT and/or follow-up imaging as the reference standard.⁷⁷ Additionally, we included a control group of 6 healthy volunteers. The WB-DWI protocol was performed at a 1.5T MR unit (Intera; Philips Medical Systems, Best, The Netherlands) using the built-in quadrature body coil. A DWIBS-sequence was acquired in 6 stacks (b-values 0,800 s/mm², TR/TE 3717/70 ms, EPI factor 95, 8 NSA, 2.93 × 2.96 × 5.00 acquisition voxel size, 26 slices per stack, 2.06 min acquisition time per stack), that were aligned as 3D maximum intensity projections (MIP) for image evaluation (Fig. 1). Overall sensitivity of WB-DWI as a single modality for detection of malignant lesions was 81%; all primary colorectal tumours were detected, 77% of the liver metastases (Fig. 3), 72% of the distant nodal metastases (Fig. 2) and 75%

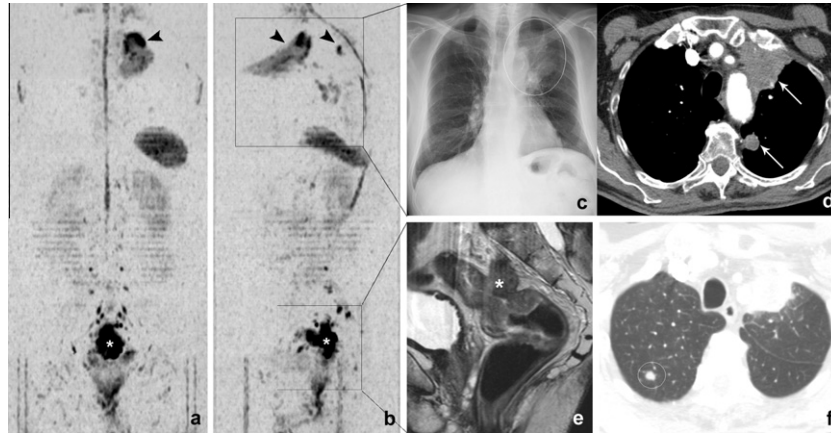


Fig. 4 – WB-DWI for the evaluation of metastatic lung disease. Coronal [a] and sagittal [b] WB-DWI reconstruction of a 88 year old male patient with pulmonary metastases originating from a primary tumour in the rectum (*), which corresponds with a rectal tumour as seen on T2-weighted MRI [e]. In the thorax there are two high signal intensity lesions, suggestive for lung metastases (arrowheads), which correspond with a suspicious area visible adjacent to the aorta (circle) on the chest X-ray [c]. On the chest CT [d] it was confirmed that the high signal intensity lesions on DWI corresponded with two metastases in the left lung (arrows). There was another small metastasis visible in the right lung [f] that could not be visualised with DWI. Such small nodular metastases may be beyond the detection level of WB-DWI.

of the lung metastases (Fig. 4). In the group of healthy volunteers several pronounced lymph nodes were also seen on DWI, mainly in the axillary and inguinal regions (Fig. 2). This indicates that DWI visualises benign and malignant nodes with similar high signal, resulting in limited specificity. All together, the lesion detection of WB-DWI was already promising (81%), using nowadays MR equipment and available software. With advancing MR technology it is, however, expected that DWI techniques will improve. Furthermore, protocol optimisation and the combined use of functional WB-DWI and anatomical MR imaging may contribute to a further improvement in diagnostic performance.

6. Conclusions

Whole-body tumour staging using CT, ^{18}F FDG-PET and hybrid PET/CT is already widespread incorporated in daily practice. Newer techniques, like whole-body MRI – and in particular diffusion-weighted MRI – are, however, emerging. Results from various cancer studies, as well as our preliminary results in colorectal cancer are encouraging: sensitivity of WB-DWI for malignant lesion detection is promisingly high. Encouraging specificities have also been reported, although false positives are known to occur, particularly in the evaluation of lymph nodes and bone lesions. Especially for patients with rectal cancer, in whom local staging with MRI is recommended and in many countries even mandatory, the availability of a cost-effective single modality tool for both local and distant staging justifies further investigation on DWI.

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Conflict of interest statement

None declared.

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