Whole-body Diffusion-weighted MRI: The Time has Come for a Change

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Abstract

The two functional tools available for detecting and staging cancer are PET/CT and WB-DWMRI [1]. PET/CT has been the established modality for the last two decades. Improvements in MRI technology, however, mean that it is now possible to perform whole-body functional and anatomical imaging without ionizing radiation [2]. In this study, we share our experiences of the first 50 patients with cancer who underwent whole-body imaging. We determined patient compliance, practicality of performing the study, final results, and cost effectiveness. We also performed a review of studies conducted between 2009 and 2016 to compare WB-DWMRI with PET/CT for imaging cancer patients.

NRCL	Score
No discomfort	1
Mild discomfort	2
Moderate discomfort – bearable	3
Severe discomfort – bearable	4
Unbearable – sedative required	5

Table 1: Table to determine nurse-reported comfort levels (NRCL).

PCS	No discomfort	Mild	Severe
Preparation	0	1	2
Sedation	0	1	2
IV use	0	1	2
Radiation dose (mSv)	0	1	2
Examination time			
< 1 hour	0		
1–2 hours		1	
> 2 hours			2
Reading time	Same day	Next day	> 2 days
Time (hours)	0	1	2
Ambient noise, temperature	0	1	2

Table 2: Table to determine patient comfort score (PCS).

Methods

We analyzed data from 50 consecutive cancer patients who underwent whole-body diffusion-weighted MRI (WB-DWMRI) at our institute. We recorded nurse-reported comfort level (NRCL) and patient comfort score (PCS). All patients had previously undergone a PET/CT and were on follow-up treatment for cancer. We provided questions to establish NRCL and PCS (Tables 1 and 2). We also conducted a review of the literature on WB-DWMRI, and determined mean sensitivity and specificity from 19 articles published between 2009 and 2016. Finally, we calculated the incremental cost-effectiveness ratio (ICER) for both WB-DWMRI and PET/CT.

Technique

WB-DWMRI was performed on a 1.5T MAGNETOM Amira system (Siemens Shenzhen Magnetic Resonance Ltd. (SSMR), China) in four stations, using local coils and without contrast medium.Images were taken from the head to the mid-tibia level, and were acquired axially under free breathing. Diffusion gradients were applied in the X, Y, and Z axes before and after a 180-degree inversion pulse in order to have fat-saturated images and diffusion sensitivity b-values of 0, 400, and 800 mm^2/sec. The data obtained underwent multiplanar reformatting to produce whole-body images in the coronal plane, and were inverted to provide grayscale images (Fig. 1A, B) for analysis. Apparent diffusion coefficient (ADC) values for regions of interest (ROI) were determined in order to estimate tumor cellularity, and were expressed in units of 10^{-3} mm^2/s. Another parameter, the lesion-to-spinal-cord ratio, was determined on a high b-value image using the ROI technique. T2w HASTE whole-body coronal images and T1w sagittal images of the spine were also obtained. The complete study lasted a total of 16 minutes.

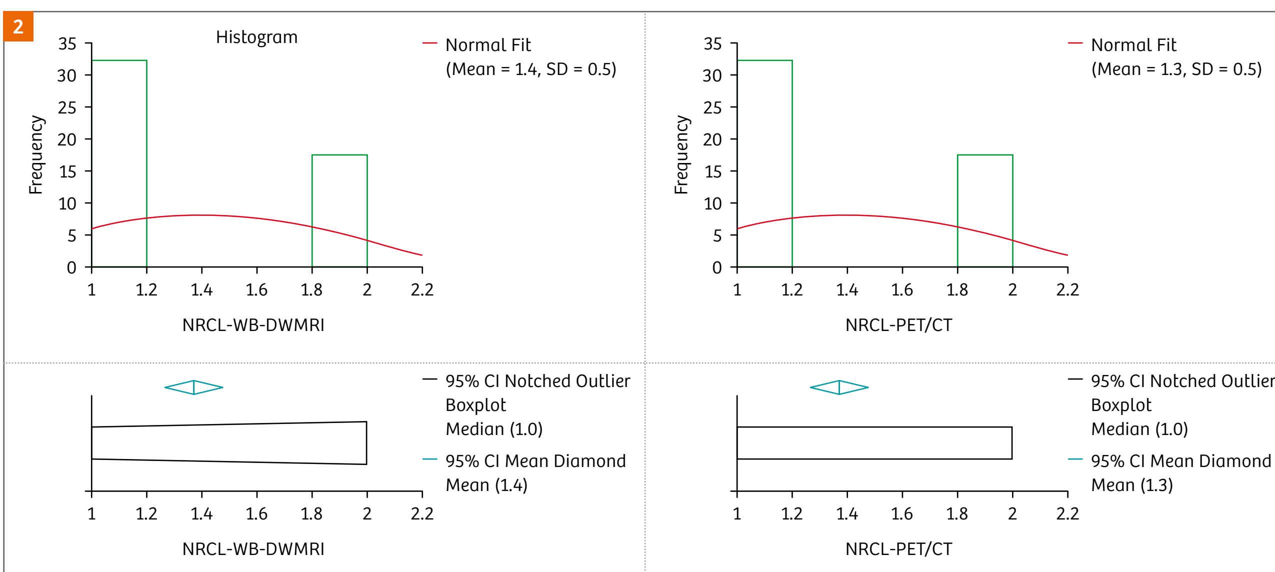
Results

The analysis of the data obtained from the responses to Tables 1 and 2 revealed that the mean NRCL score for patients in both groups (WB-DWMRI and PET/CT) was quite similar: 1.3 and 1.4 respectively (1.2–1.5: 95% CI) (Fig. 2). The PCS was 1.4 (1.2–1.5: 95% CI) in the WB-DWMRI group, and 6.3 (6.0–6.7: 95% CI) for the PET/CT group (Fig. 3). The Kruskal-Wallis test was performed for the above results. It showed no statistical difference in the NRCL results between the two groups ($p = 0.8$), and a statistically significant difference in the PCS of the two groups ($p = 0.02$) (Fig. 4).

The literature review of the articles listed in Table 3 found that all the studies showed that WB-DWMRI can be used to diagnose and stage malignancy, and to assess treatment response in cancer patients by quantifying changes in ADC. Almost all the studies suggested that the two modalities were comparable in terms of sensitivity and specificity when it came to detecting metastasis. PET/CT had a slight edge in diagnosing small lung metastasis and subcentimeter nodal metastasis, while WB-DWMRI had a slight edge in detecting liver, brain, and bony metastasis. Pooled sensitivity of WB-DWMRI was 97% for bony metastatic detection and 89% for lymph node detection. Overall sensitivity for WB-DWMRI was 93%, while overall pooled sensitivity for PET/CT was 91%. The calculated incremental cost-effectiveness ratio (ICER) was 150.53 for WB-DWMRI, and 263.73 for PET/CT. In India, WB-DWMRI costs 14,000 rupees, and PET/CT costs 24,000 rupees.

Figure 1:
(1A) WB-DWMRI image showing multiple bony metastases.

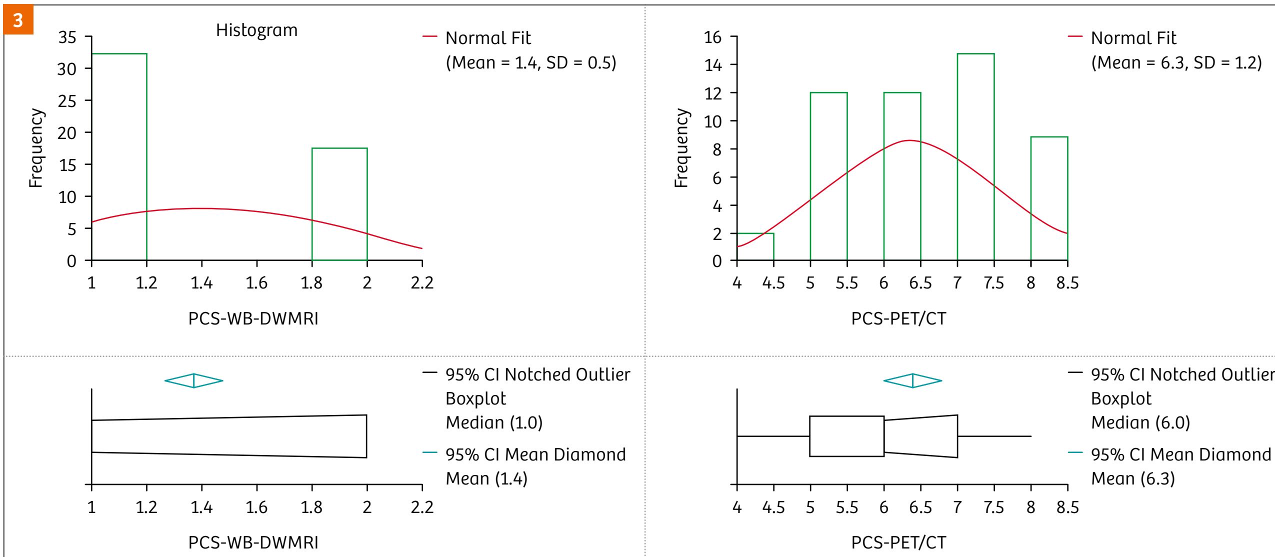
(1B) WB-DWMRI image showing multiple abdominal metastases in a patient with prostate carcinoma.



	NRCL-WB-DWMRI			NRCL-PET/CT			
n	50 (cases excluded: 1 due to missing values)			n	50 (cases excluded: 1 due to missing values)		
Mean	1.4	Median	1.0	Median	1.3	Median	1.0
95% CI	1.2 to 1.5	95.7% CI	1.0 to 2.0	95% CI	1.2 to 1.5	95.7% CI	1.0 to 1.0
SE	0.07			SE	0.07		

Figure 2: Histogram of NRCL scores in the WB-DWMRI and PET/CT groups.

3



	PCS-WB-DWMRI			PCS-PET/CT		
n	50 (cases excluded: 1 due to missing values)			50 (cases excluded: 1 due to missing values)		
Mean	1.4	Median	1.0	6.3	Median	6.0
95% CI	1.2 to 1.5	95.7% CI	1.0 to 2.0	6.0 to 6.7	95.7% CI	6.0 to 7.0
SE	0.07			0.16		

Figure 3: Histogram of PCS scores in the WB-DWMRI and PET/CT groups.

4

n | 50

WB-DWMRI by PET/CT	n	Rank sum	Mean rank
4	2	33.0	16.50
5	12	248.0	20.67
6	12	248.0	20.67
7	15	497.5	33.17
8	9	248.5	27.61

Kruskal-Wallis' statistic	11.19
X^2 statistic	11.19
DF	4
p	0.0245 (chisqr approximation, corrected for ties)

n | 100

NRCL	n	Rank sum	Mean rank
WB-DWMRI	50	2550.0	51.00
PET/CT	50	2550.0	50.00

Kruskal-Wallis' statistic	0.04
X^2 statistic	0.04
DF	1
p	0.8348 (chisqr approximation, corrected for ties)

Figure 4: Kruskal-Wallis test charts comparing NRCL and PCS in the WB-DWMRI and PET/CT groups.

Discussion

Our study shows that WB-DWMRI is a more viable solution for imaging patients with known cancer. The many reasons for this are related to higher patient comfort scores, lower incremental cost-effectiveness ratios, and matching sensitivity and specificity for cancer detection. Although the NRCL scores are the same in both groups, the PCS data show a statistically significant lower score for the WB-DWMRI group (p = 0.02). This difference was mainly due to faster imaging time, to the lack of radiation, patient preparation, and intravenous contrast and isotope use, and to significantly less radiologist reporting time. These factors had a greater impact on patient comfort and resulted in improved patient compliance. The lower ICER of WB-DWMRI is another argument for using this newer imaging modality, as it means it is more cost effective than PET/CT. With cost-effectiveness currently one of the most robust parameters in deciding between two modalities, a lower ICER certainly tilts the scale toward more frequent use of WB-DWMRI for following up on and managing cancer patients.

No.	Study	Year	No. of Patients	Organ	WB-DWMRI		PET/CT		Conclusions
					Sensitivity (in %)	Specificity (in %)	Sensitivity (in %)	Specificity (in %)	
1	Mori et al. [3]	2008	104	Lung	72	97	70	79	WB-DWMRI better
2	Ohbaet al. [4]	2009	110	Lung	73	96	72	82	Similar
3	Takenakaet al. [5]	2009	115	Lung	75	93.7	73	95.4	Similar
4	Gong et al. [6]	2015	28	Colorectal	81.1	99.1	95.1	99.8	Similar
5	Ono et al. [7]	2009	25	Colorectal	80	76.9	30	100	WB-DWMRI better for nodal detection
6	Schmidt et al. [8]	2004	33	Breast	90	86	91	90	Similar
7	Heusneret al. [9]	2010	20	Breast	91	72	94	99	Similar
8	Pawlynet al. [10]	2016	17	Myeloma	WB-DWI Better than PET/CT				
9	Shen et al. [11]	2014	27	Meta-analysis, Prostate Ca	97	95	91	99	WB-DWMRI better
10	Barchettiet al. [12]	2016	154	Prostate Ca	99	98	99	-	Similar
11	Eschmann et al. [13]	2007	42	Prostate Ca	76	94	96	74	Similar
12	Lin et al. [14]	2010	15	Lymphoma	81	100	90	94	Similar
13	Steccoet al. [15]	2015	17	Lymphoma	100	96	96	100	Similar
14	Gutzeitet al. [16]	2010	36	Any metastasis	97	99	(Scinti-graphy) 91	87	WB-DWMRI better
15	Fischer et al. [17]	2011	68	Any metastasis	72	89	74	91	Similar
16	Li et al. [18]	2013	1067	Any metastasis	89	95	89	97	Similar
17	Steccoet al. [19]	2009	29	Any metastasis	89.1	98.5	100	-	Similar
18	Choi et al. [20]	2009	236	Uterine cervical Ca	86	80	100	-	Similar
19	Hassan et al. [21]	2014	6	Meta-analysis, Head-neck Ca	100	71	68	84	WB-DWMRI better

Table 3: List of studies comparing WB-DWMRI and PET/CT for staging cancer.

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