

Whole-Body Dot Engine: First Clinical Experience with Automated Chest, Abdomen and Pelvis Examinations

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Introduction

Time and cost efficiency are among the major challenges in clinical magnetic resonance imaging (MRI), mainly driven by the funding cuts in most health care systems [1]. At the same time, there is an increasing overall demand for a higher quality of MRI exams with regard to comparability, i.e. important for primary and/or follow-up studies in oncologic patients. To address these challenges, several vendors and researchers are developing automated scanner workflows for clinical MRI systems. The hypothesis is that these workflows allow a standardized and time-efficient use and provide a robust image quality at only little user

interaction. The Whole-Body Dot Engine was developed to meet these needs for multi-station MRI exams of chest, abdomen, pelvis, and even the whole body. Potential indications of multi-station body MRI exams are oncologic staging or follow-up, rheumatic disease and evaluation of myopathies.

MRI technique

The Whole-Body Dot Engine automatically detects landmarks like lung apex, lung recesses, diaphragm, liver apex, iliac bone on a fast low-resolution whole-body scout, which is acquired during moving table. Based on this scout the body regions selected for scanning, namely chest,

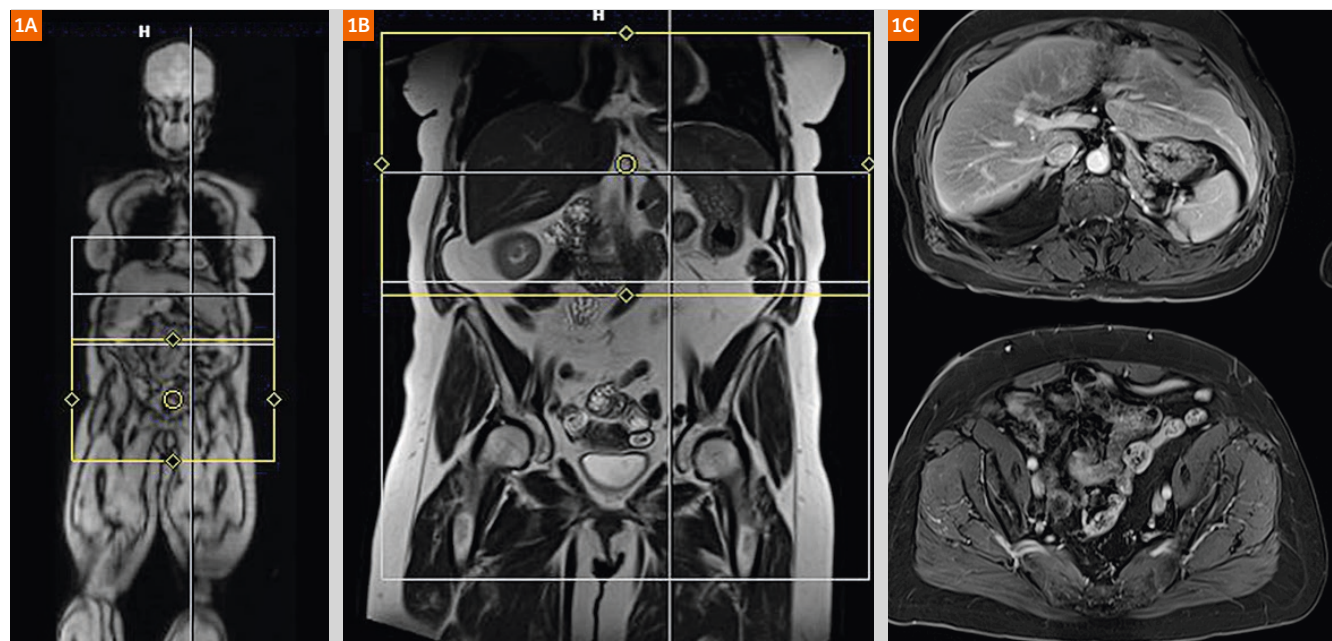


Figure 1: (1A) Fast low resolution whole-body scout with automatically segmented abdomen and pelvis for multi-station scanning. (1B) Coronal T2 single-shot turbo-spin-echo images with automatically segmented abdomen and pelvis split into two blocks for the transverse T1-weighted sequence (1C) with an acquisition time of 15 s for each lying within the preset 20-second breath-hold capacity. The cranio-caudal coverage per block is set to 400 mm with a fixed overlap of 2 cm between blocks and is adjusted to patient size and breath-hold capacity.

Table 1: MRI protocol	T2w HASTE	T2w HASTE	iShim ¹ EPI DWI	T1w VIBE Dixon without and with contrast	T1w VIBE Dixon with contrast
Scan plane	coronal	transverse	transverse	transverse	coronal
Repetition time / Echo time (ms)	1230/92	1000/60	6100/56	4.27/1.28	3.93/1.23
Flip angle (°)	160	160	90	12	12
Slice thickness (mm)	6	5	6	3	1,5
Spacing (mm)	1	1	1	0	0
Acquisition matrix	256 x 256	256 x 109	128 x 84	320 x 180	192 x 162
Acceleration, factor	GRAPPA, 3	GRAPPA, 3	GRAPPA, 2	CAIPIRINHA, 2	CAIPIRINHA, 6
Number of excitations	1	1	6 and 15	1	1
b-values (s/mm ²)	na	na	50, 800	na	na

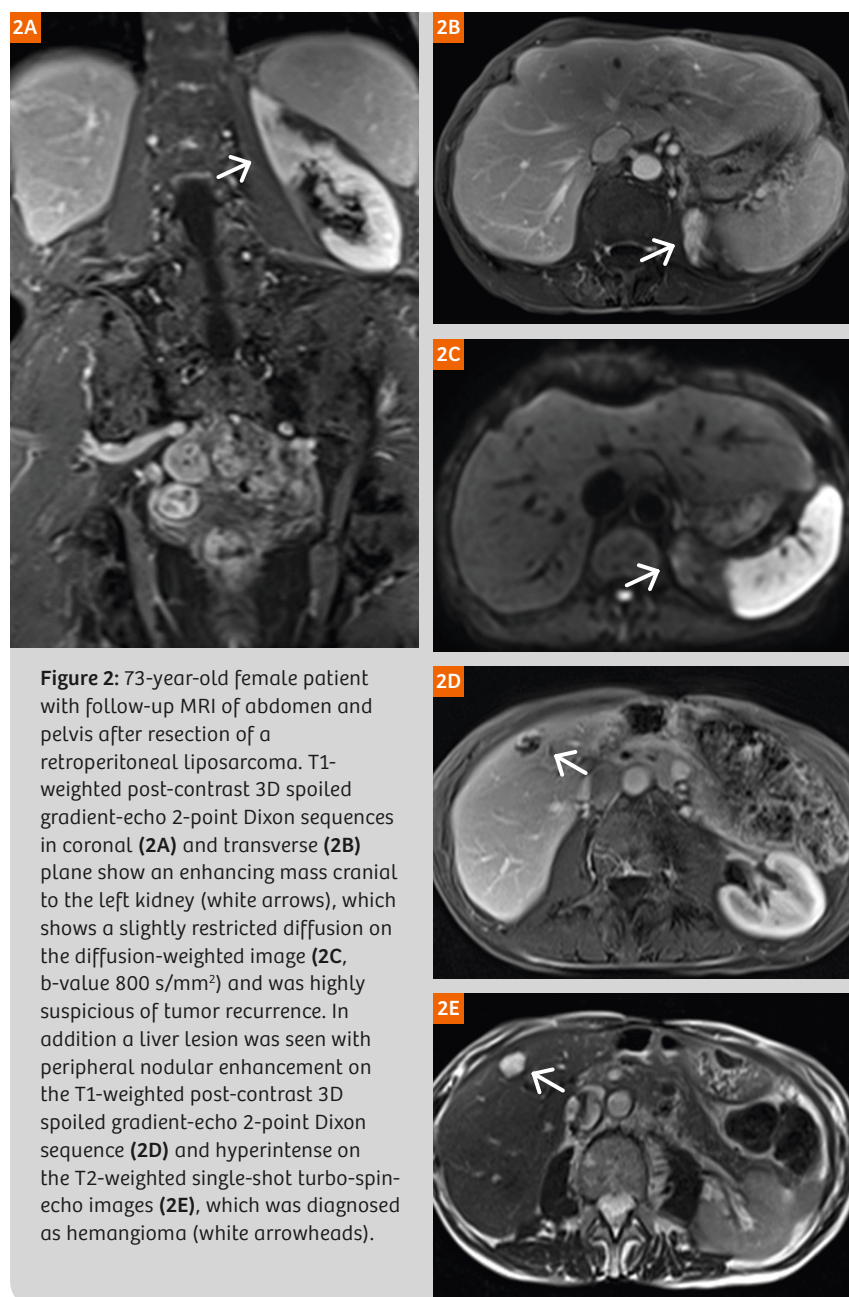


Figure 2: 73-year-old female patient with follow-up MRI of abdomen and pelvis after resection of a retroperitoneal liposarcoma. T1-weighted post-contrast 3D spoiled gradient-echo 2-point Dixon sequences in coronal (2A) and transverse (2B) plane show an enhancing mass cranial to the left kidney (white arrows), which shows a slightly restricted diffusion on the diffusion-weighted image (2C, b-value 800 s/mm²) and was highly suspicious of tumor recurrence. In addition a liver lesion was seen with peripheral nodular enhancement on the T1-weighted post-contrast 3D spoiled gradient-echo 2-point Dixon sequence (2D) and hyperintense on the T2-weighted single-shot turbo-spin-echo images (2E), which was diagnosed as hemangioma (white arrowheads).

abdomen and/or pelvis are automatically segmented

(Fig. 1). With the information of the segmentation the sequence parameters (field-of-view [FOV] and number of slices) are automatically adjusted in order to ensure proper coverage of the body regions of interest. Additionally, the Whole-Body Dot Engine uses an anticipated patient's breath-hold capacity to automatically adjust the imaging protocols in body regions where breath-hold is required to generate optimal image quality. The user can configure which parameters shall be adjusted for each protocol individually. In our protocol, base resolution was used for this purpose in 3D sequences, and number of concatenations was used in 2D sequences. We set the breath-hold capacity to 20 seconds. The protocol included a coronal and transverse T2-weighted single-shot turbo-spin-echo sequence (HASTE) acquired in breath-hold technique, transverse single-shot diffusion-weighted echo-planar imaging with slice-specific shim optimization (EPI-DWI, iShim¹ [2]) in free-breathing, and a transverse T1-weighted pre- and post-contrast 3D spoiled gradient-echo 2-point Dixon (VIBE) sequence acquired in breath-hold technique pre- and post-contrast (delay: chest 35 s, abdomen 70 s, pelvis 90 s after injection of 0.1 mmol/kg bodyweight gadoterate meglumine, Dotarem, Guerbet) (Table). Imaging after contrast-injection was timed by using automated bolus detection. The cranio-caudal coverage per block was adjusted to 400 mm. We chose a rather short scan protocol without

¹ The product is still under development and not commercially available yet. Its future availability cannot be ensured.

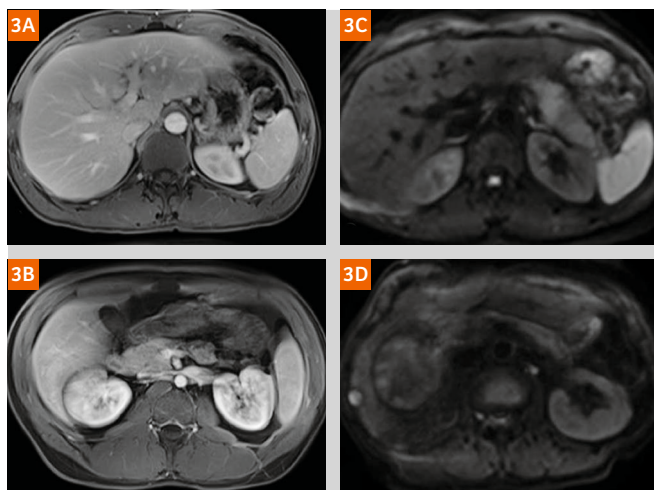


Figure 3: T1-weighted post-contrast 3D spoiled gradient-echo 2-point Dixon sequences with excellent image quality (3A) and with mild respiratory motion artifacts (3B). Single-shot diffusion-weighted echo-planar imaging sequence with slice-specific shim optimization with excellent image quality (3C) and with mild motion artifacts (3D).

dynamic acquisitions in a focus region (e.g. liver), because we wanted a fast and straightforward protocol for general oncologic imaging comparable to computed tomography. We used this scan protocol for oncologic follow-up imaging of abdomen and pelvis or chest, abdomen, and pelvis.

Patients

20 patients (9 females, 11 males; mean age 52 years, range 21–79 years) were examined on a 3T MRI scanner (MAGNETOM Skyra, Siemens Healthcare) using the Whole-Body Dot Engine. Multi-station exams were performed on 11 patients for oncologic follow-up, in 2 for primary staging, and in 7 for tumor screening. The clinical diagnosis of these patients was: genitourinary malignancy (n=8), sarcoma (n=3), gastrointestinal malignancy (n=1), poly-posis syndromes (n=2), and chronic abdominal pain (n=6). In 18 patients abdomen and pelvis were scanned and in 2 patients chest, abdomen and pelvis. An image example is given in Figure 2. To validate whether our straightforward protocol results in an acceptable duration of this multi-station MRI,

patients scored their satisfaction with exam duration on a visual analogue scale from 0 (not acceptable, too long) to 10 (ideal exam duration).

Image quality

The scans were evaluated for overall image quality (IQ) (5 = excellent, 4 = good, 3 = moderate, 2 = poor, 1 = non-diagnostic) and artifacts (5 = no artifacts, 4 = mild artifacts, 3 = moderate artifacts, 2 = severe artifacts, 1 = non-diagnostic) on a 5-point scale by a board-certified abdominal radiologist with 8 years of experience. The image acquisition time was noted, as well as whether the coverage of the targeted body region was complete.

In all but one patient (19 of 20, 95%), the selected body regions were covered completely by the automated algorithm. An exception was the DWI, which showed markedly reduced signal in the sub-diaphragmatic part of the right liver in four patients (4 of 20, 20%), which impaired diagnostic ability of DWI in these liver parts.

The mean score for overall IQ was 4.7 ± 0.47 standard deviation (SD) and for artifacts overall was 4.4 ± 0.5 SD. Mild to moderate respiratory motion artifacts were seen in three patients (3 of 20, 15%) on T1-weighted post-contrast images with a mean IQ score of 4.8 ± 0.52 (Fig. 3). Mild motion artifacts were observed in four patients (5 of 20, 25%) on DWI with a mean IQ score of 4.75 ± 0.44 . The mean examination time was 27.4 ± 6.5 min for chest, abdomen and pelvis and 21.0 ± 6.9 min for abdomen and pelvis. The mean score of patient satisfaction regarding exam duration was 6.45 ± 2.19 (median, 6) and did not correlate with scan duration.

Conclusion

MR scanning with the automated Whole-Body Dot Engine results in good to excellent image quality within a reasonable total examination time with only small patient-dependent variations. An almost 'single-button protocol' for standardized fast, reproducible, and automated workflow of chest, abdomen, and pelvis could open up new possibilities in the diagnostic process. However, further comparison studies with traditional manual scan modes need to be performed to support our preliminary experience.

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