Whole-body DCE MR Imaging for Evaluation of Bone Marrow Enhancement in Multiple Myeloma

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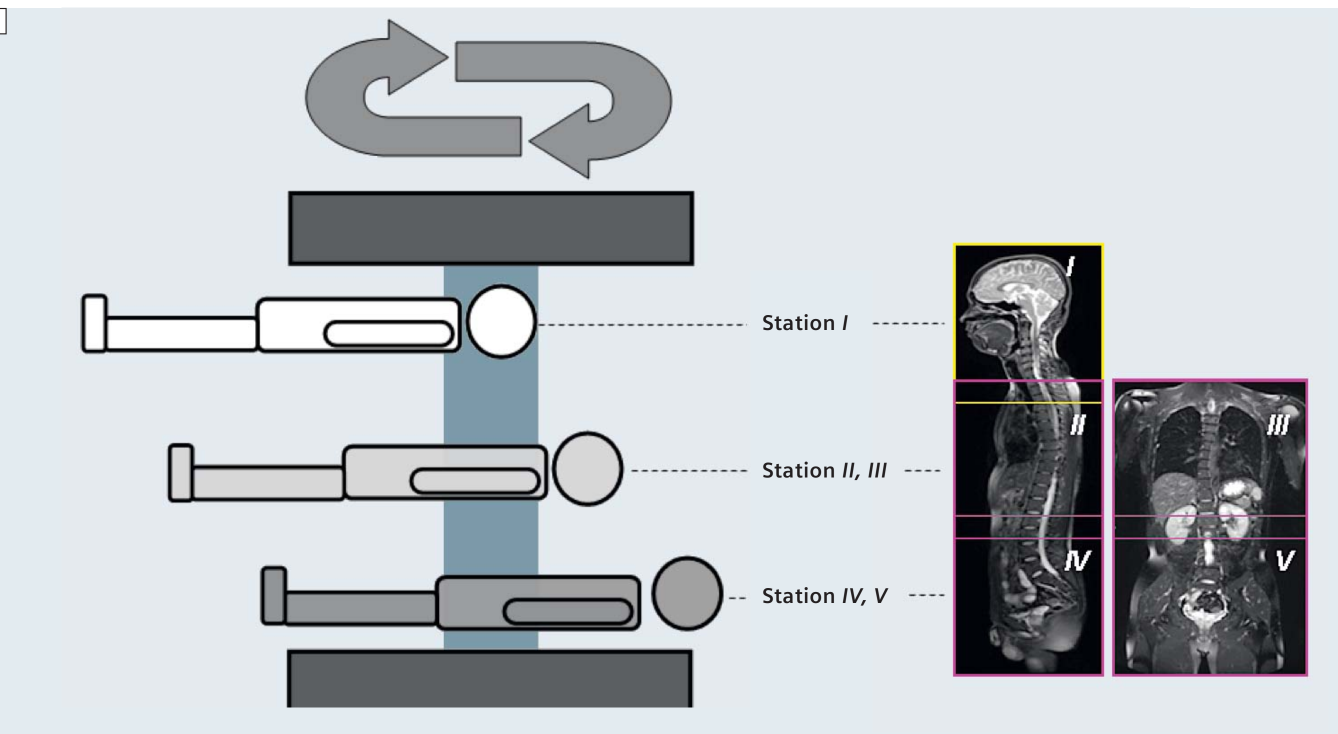
Patient history

A 55-year-old patient with newly diagnosed multiple myeloma (MM) underwent high-dose therapy followed by autologous stem cell transplantation (ASCT). After completion of ASCT, serum immunoglobulin G level decreased from 50 g/L at baseline to 3 g/L. However, despite a good clinical response, whole-body dynamic contrast-enhanced (DCE) MR imaging depicted persistent early-enhancing focal lesions over the rib and the pelvic bone (outside the usually imaged spine MR examination in MM). The patient had confirmed disease progression two months later.



1 Overview of the applied MR Protocol: T1 SE and T2 FS TSE sequences in sagittal (I, II, and IV) and coronal (III and V) planes. DCE studies were performed using a 3D VIBE sequence, which was acquired sequentially at five stations (I-II-III-IV-V) and repeated seven times.

Sequence details

After institutional approval, in Henri Mondor University Hospital (Creteil, France) patients suspected with MM or during their MM chemotherapy follow-up, undergo a newly published dynamic whole-body MR examination [1, 2].
It has been demonstrated that micro-circulation parameters of dynamic MR examination, such as the maximal enhancement (Emax), correlate well with histologic infiltration grade, micro-vessel density (MVD) and serum markers of disease activity [3–7]. A reduction in these parameters has been observed in patients who respond to treatment [3, 4, 5]. These parameters could potentially serve as non-invasive surrogate biomarkers for response assessment. However, in the past, these parameters could only be obtained on acquisition protocols in which the maximal field-of-view (FOV) was limited to 400 mm, whereas myeloma can involve bone marrow throughout the body and even tissue outside the bone marrow space [8].
A rolling table platform with combined multichannel phased array-surface coils which cover the head, neck, trunk and proximal extremities along with parallel imaging has made it feasible to perform whole-body dynamic MR imaging without compromising spatial and temporal resolutions.
The protocol is articulated as described in figure 1. All sequence parameters are detailed in tables 1 and 2. Acquisition was done on a 1.5T Siemens MAGNETOM Avanto 76x18 SQ. Standard T1-weighted Spin Echo (SE) and T2-weighted Fat Saturated (FS) Turbo Spin Echo (TSE) sequences were acquired both in sagittal and coronal planes before contrast agent injection over the whole FOV to assess fat and bone marrow repartition [9].
A cyclic contrast media was administrated during an ultra-fast dynamic T1-weighted FS 3D VIBE (Volume Interpolated Breath-hold Examination), Gradient

Table 1: Parameters for whole-body T1- and T2-weighted sequences.

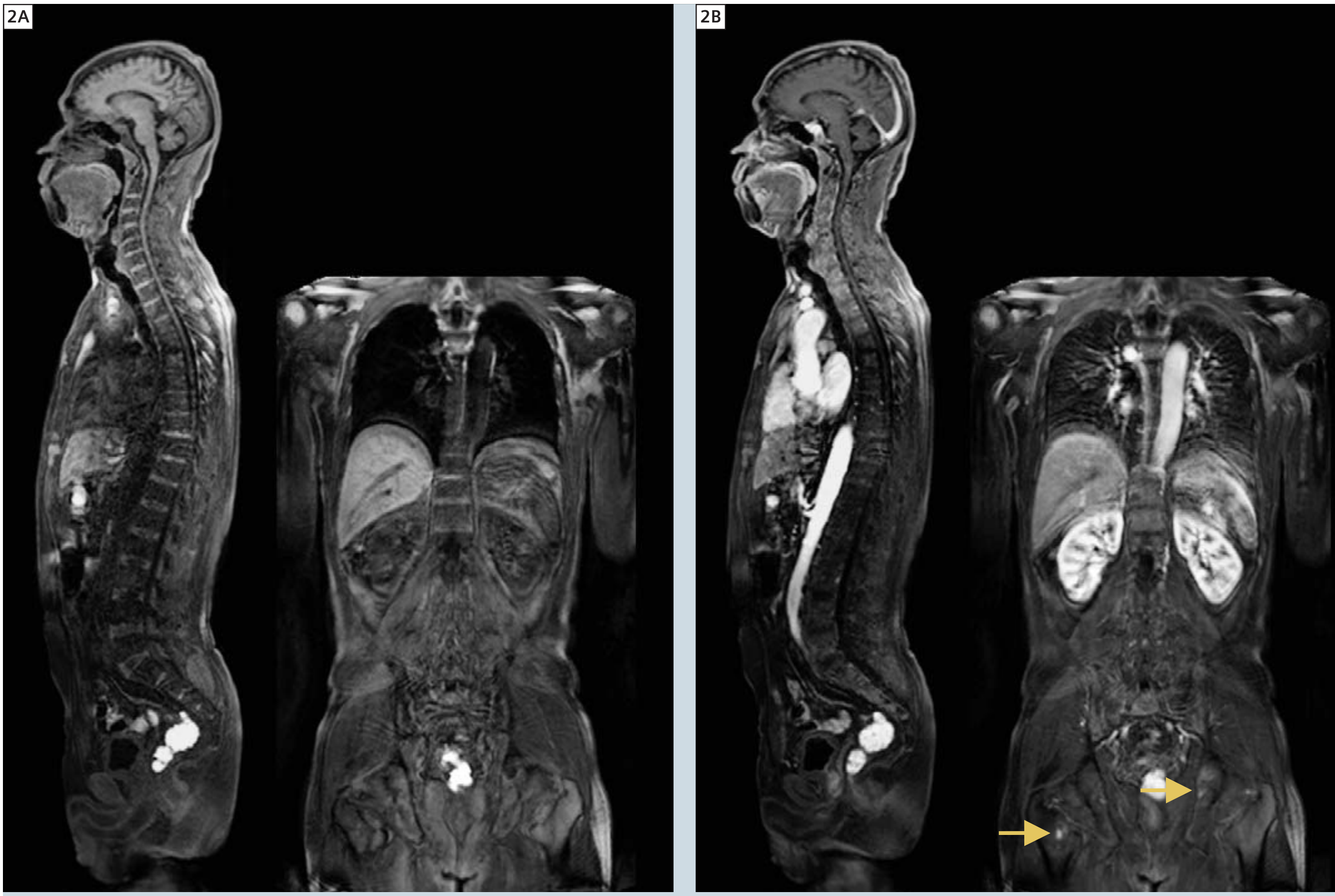
Parameters	T1 SE	T2 FS TSE
Stations imaged	*I, II, IV, V*	*I–V*
TR/TE (msec)	400/10	4200/70
Turbo Factor	1	21
FOV (mm²)	500 x 500	500 x 500
Matrix	448 x 358	448 x 358
Averaging	1	2 for stations *I, II, IV* 1 for stations *III* and *V*
Slice thickness/Gap (mm)	4/0 sagittal 4/1.2 coronal	
Number of slices	20 for stations *I, II, IV* 50 for station *V*	20 for stations *I, II, IV* 50 for stations *III* and *V*
syngo GRAPPA acceleration factor	2 for stations *I, II, IV* 3 for station *V*	2 for stations *I, II, IV* 3 for stations *III* and *V*
TA (sec)	112 for stations *I, II,* and *IV*; 186 for station V	93 for stations *I, II,* and *IV*; 84 for stations *III* and *V*

Stations' FOV and orientations are described in figure 1. Coronal T2-weighted fat-saturated (FS) turbo spin echo (TSE) imaging was performed by using a respiratory-triggering belt.

Table 2: Parameters for whole-body 3D VIBE five-station DCE MR imaging.

Parameter	Stations *I, II,* and *IV* (sagittal)	Stations *III* and *V* (coronal)
TR/TE (msec)	3.6/1.3	3.3/1.3
Flip angle (°)	20	20
Bandwidth (Hz/pixel)	490	490
FOV (mm³)	500 x 500x 72	500 x 500 x 200
Matrix	256 x 192 x 24	256 x 192 x 40
Acquired voxel size (mm³)	2.0 x 2.6 x 3.0	2.0 x 2.6 x 5.0
syngo GRAPPA acceleration factor	2	2
TA (sec)	7	9

Stations' FOV and orientations are described in figure 1.



2 Composing of the 3 sagittal stations (left) and the 2 coronal stations (right) with ultra fast 3D VIBE sequence both before **(A)** gadolinium injection and right after **(B)** the injection. This patient had a good clinical response after treatment. Nevertheless persistent enhancing focal lesions over pelvic bone and right femur are visible on selected images after gadolinium injection (white arrows).

Recalled Echo (GRE)-like, sequence applied over the whole FOV in 3 sagittal and 2 coronal stations. The acquisition time of each station was set under 10 seconds. The time to complete acquisition of the 5 stations was 60 s including three table movements. The total duration of whole-body DCE study was set at 7 minutes.

Imaging findings

This patient has been monitored using our MR protocol right after completion of therapy. He had a good clinical response. Fig. 2 shows whole-body five-station dynamic MR images obtained before and immediately after contrast agent administration in this patient. The bone marrow enhancement is within normal range but tiny early-enhancing focal lesions are depicted. Another 8 cm left rib mass was also noted (image not shown). Two months later the patient complained of back pain and underwent the same MR examination (Fig. 3). Numerous early-enhancing focal lesions were seen, confirming previous MR findings and the relapse of the disease.

Discussion

Preliminary findings using this method gave time-signal intensity curves for both bone marrow indicating the degree of diffuse infiltration and focal lesions on a whole-body scale. They allowed the differentiation between normal and infiltrated bone marrow and to assess the disease activity of each imaged focal lesion. Whole-body DCE MR imaging might be proven useful in treatment response assessment in MM patients. Further investigations have been conducted successfully to evaluate this potential and will be soon published [2].

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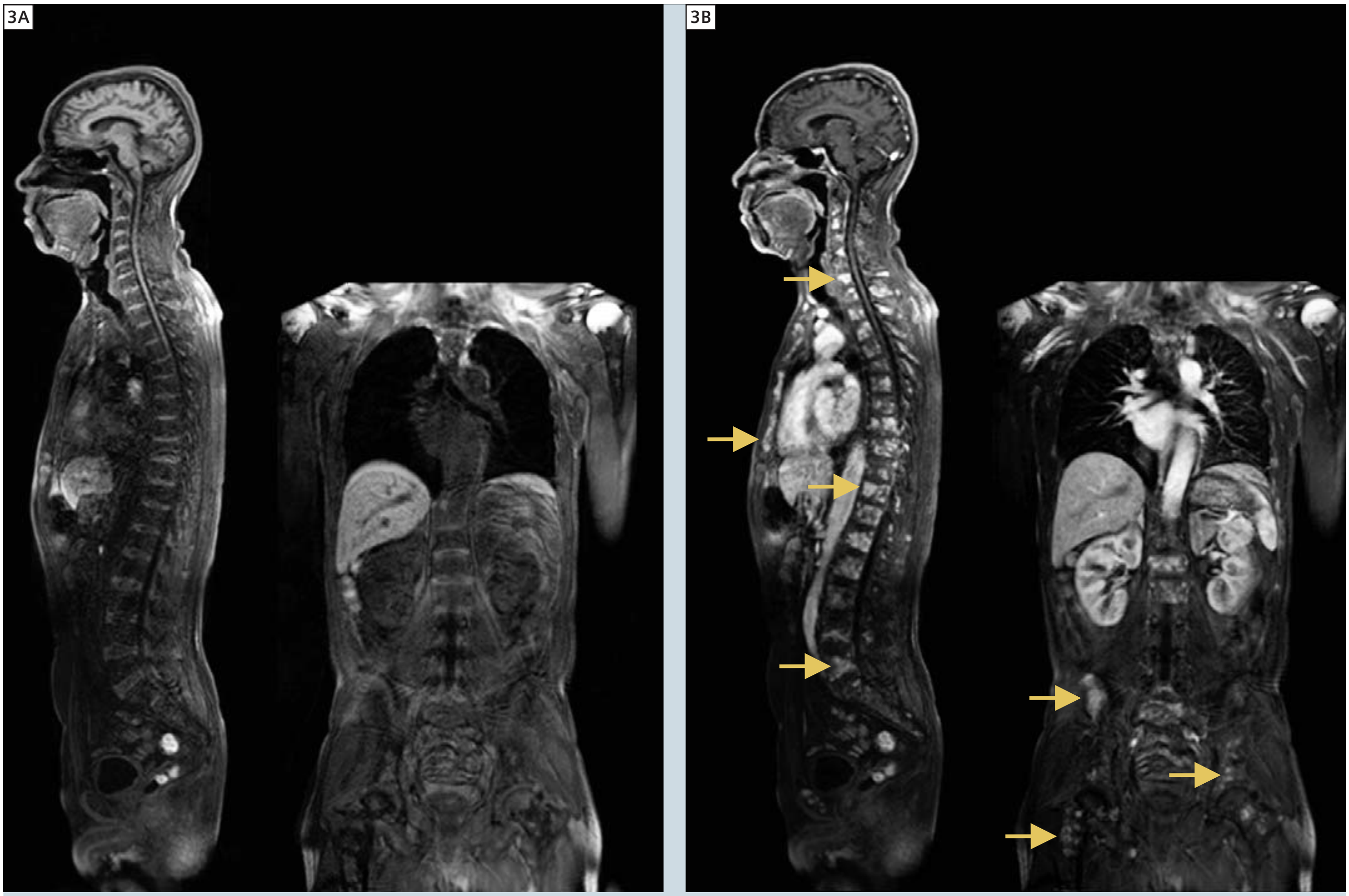

3 Whole-body DCE MR examination of the same patient as in Fig. 2 two months later, before **(A)** and right after **(B)** gadolinium injection. Numerous new focal lesions had appeared and were visible (white arrows) on the post-contrast images.

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