REVIEW / Pediatric imaging

Whole body MRI in paediatric oncology

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Abstract Whole body MRI provides excellent contrast resolution imaging and is an interesting alternative to nuclear medicine examinations in paediatric oncology because it does not involve exposure to radiation. This technique, now feasible in clinical practice, helps to evaluate metastatic spread and response to treatment, which are of great prognostic interest. Numerous studies have demonstrated the non-inferiority of this technique when compared to nuclear medicine examinations. However, there is still a need to standardize indications in each type of cancer and at every stage of it. This article first discusses the technical principles of whole body MRI, then reviews current clinical applications for the modality in children, and finally, discusses future useful developments for paediatric oncology.

Whole body imaging is essential in oncology. It enables the assessment of the initial metastatic spread and the response to treatment, which are of great prognostic value in the care of patients. Whole body imaging is currently used in routine clinical practice more than any nuclear medicine procedure: scintigraphy, positron emission tomography with fluorodesoxyglucose (PET-FDG) and PET-computed tomography (PET-CT). These procedures involve exposure to ionizing radiation, suspected of increasing the long-term risk of cancer [1]. Until recently, magnetic resonance imaging (MRI) was restricted to localized zones. With the technological progress in MRI, it is now possible to cover the whole human body in a reasonable lapse of time. The first studies concerning the feasibility of the technique on adult subjects were published about fifteen years ago [2]. The feasibility and assessment of this procedure in paediatric oncology have been reported in the literature over the last ten years [3,4]. Along with a continued increase in the rate of survival of the child with malignant tumours (80% of the patients reach adulthood), the long-term consequences of ionizing radiation are increasing and need to be taken into account [5]. Therefore,
due to its excellent contrast resolution imaging and the fact that it does not involve exposure to radiation, WB-MRI is an especially attractive alternative in paediatric oncology.

We will first discuss the technical principles of WB-MRI, then, in light of an exhaustive review of the literature, we will describe the current clinical applications for the procedure, and finally discuss future useful developments in paediatric oncology.

Technical aspects of whole body MRI (WB-MRI)

Principles

WB-MRI involves the acquisition of whole body images, from the top of the head to the tip of the toes, in one or several planes using one or several image weightings. Initial attempts at WB-MRI required the successive imaging of each zone of the body while repositioning the patient several times in order to cover the entire body [6]. This procedure was very long. A certain number of innovations now allow WB-MR imaging to be performed in a more reasonable time frame. The first of these innovations was the use of a rolling table platform, allowing the patient to be moved in stages through the magnetic bore [7,8]. The second innovation was the availability on the market of multiple-phased array coils that improve the resolution of the image [9,10]. The use of this type of coil has the advantage that local imaging of the tumour with a good resolution can be combined with an assessment of the whole body as recommended by certain authors [11]. The idea of a double examination, both local and metastatic, is of interest in paediatrics since it can be carried out in the same session of sedation or general anaesthesia [12], although the time of examination is considerably increased. Finally, the time of examination has been shortened by the new parallel imaging techniques [13].

The current WB-MRI procedure consists of acquiring series of images in slices by successive stations. The number is a function of the field of view and the size of the patient. These series are then merged cranio-caudally using post-processing software (Fig. 1). It is therefore possible to, in turn, analyze each station for the diagnosis and obtain a global coronal view as in nuclear medicine examinations. A complementary sagittal plane is often recommended for the analysis of the spine due to the physiological curves. The recommended thickness of the slice ranges from 4 to 8 mm in contiguous sections. MR imaging of the thorax and abdomen present specific problems due to the movements caused by the respiration and intestinal peristaltism. Certain authors recommend using respiratory gating in the acquisition on the trunk in order to reduce movement artifacts, and the prior injection of intestinal anti-peristaltics.

Sequences

STIR

Due to the great variability in the technical parameters between the different manufacturers of MRI and the still recent nature of WB-MRI, a consensus still has not been reached about which combination of sequences provides the highest diagnostic accuracy while maintaining reasonable time efficiency. Most initial studies in paediatric oncology used coronal slices in Short Tau Inversion Recuperation (STIR) sequences [3,4,13].

STIR sequences are highly sensitive to bone and soft tissue anomalies due to a short inversion time (TI) that eliminates the fat signal, and double T1- and T2-weighting [14]. Most pathological tissue is rich in protons, thereby, lengthening T1 and reducing T2. This creates an intense hypersignal with STIR sequences. The signal of other substances with a short T1 relaxation time is also reduced (blood, liquid protein, melanin and gadolinium) [3], accounting for the fact that a STIR sequence is never carried out after the injection of gadolinium. The suppression of the fat signal in STIR images is more robust and homogenous than a T2 with fat saturation. Certain organs have a physiological STIR hypersignal, as is the case of the lymph organs (spleen, thymus, Waldeyer’s ring) and the kidneys. In case of nodular infiltration of one of these organs, the lesions are visible in relative hypersignal.

In the lymphadenopathies, size remains a discriminating criterion, as is the case with other standard diagnostic methods of imaging. The signal of the liver and the pancreas is relatively low, equal that of muscle. The lesions appear in hypersignal.

The study of the pulmonary parenchyma is difficult with MRI and is still less efficient than with CT-scan in the detection of pulmonary metastases. The difficulties in the MRI technique in this environment is due to the low signal/noise ratio of the lung because of its low concentration in protons, a very short T2 and T2* relaxation times due to the diffusion of water molecules within the gradients induced by the air–tissue interfaces and finally, by the physiological movements of the heart and respiration. Nevertheless, the presence of pulmonary infiltrates induces a local increase in the signal from the lung (due to an increase in the proton concentration and a reduction in the magnetic susceptibility effects) and the peri- or supra-centimetric metastases are therefore, easy to identify in hypersignal on the STIR sequence.

The STIR sequence is interesting in the detection of osteomedullary metastases in the child. Classically, in the adult, the T1 sequence is most useful to identify metastases of the bone marrow. They are revealed by areas of medullary tissue replacement in labeled hyposignal within a fat medullary environment in hypersignal. In the child, when zones of hypercellular red marrow persist (T1 hyposignal), the STIR sequence is of use in detecting tumour infiltration. Good knowledge of the physiological modifications in the signal from the bone marrow as a function of age is required to distinguish the areas of haematopoiesis from bone lesions [15]. Nevertheless, care is required in the analysis of the bone marrow signal in STIR sequences since although the hypersignal of the red marrow is theoretically less distinct than that of the tumours, there is a lack of sequence specificity, in particular, in post- or intra-therapeutic situation. In the child, medullary infiltration may be focal or diffuse, as is the case of the rhabdomyosarcomas, neuroblastomas, leukaemias, medullary hyperplasia in anaemia or treatments by haematopoietic growth factors. One disadvantage of the sequence is that osteoblastic metastases may be overlooked [10].
The acquisition time of a coronal STIR sequence ranges from 2 to 4 min by station, depending on the machine and the parameters used. The number of stations varies according to the size of the patient, generally from 4 to 6. An acquisition only with STIR sequences may be considered in a WB-MRI protocol, although the ideal solution to analyse the whole skeleton (in particular, the sternum, ribs and scapula, and skull), and to detect lymphadenopathies, would then be to acquire the sequence in 2D.

T1
T1-weighted (Spin Echo) sequences are used to search for bone lesions. They have the merit of having a good spatial resolution and a short time of acquisition. In 2001, Daldrup-Link et al. exclusively used T1 with good reliability, except for short bones and small bones, in the diagnosis of bone metastasis [16]. The use of in-phase and out-of-phase gradient-echo sequences has the advantage that it is faster but less sensitive than spin echo. Coronal T1-weighted fast spin echo sequences are particularly useful in the assessment of fat involvements of the marrow after radiotherapy and medullary tissue replacements of metastatic origin [17]. The use of a gadolinium chelate improves the sensitivity and diagnostic specificity in the identification of lesions since pathological tissue, in particular, tumoral tissue, is strongly enhanced, especially if the fat signal is eliminated [6]. However, a systematic contrast enhanced T1-weighted sequence in the whole body MRI protocol is currently not recommended. An examination protocol comprising both non-enhanced coronal T1 sequences and STIR provide greater specificity in the detection of marrow anomalies [18].

Diffusion
Diffusion imaging distinguishes tissues according to the mobility of water molecules at the microscopic scale that directly depend on the cellularity of the tissue. Cell proliferation in a malignant zone reduces the diffusion, visible in the form of a hypointense and measurable by the reduction in the apparent diffusion coefficient (ADC). As a result, this sequence provides a functional approach to the imaged tissues. Diffusion sequences are obtained in axial sections. The parameters recommended for this sequence are contiguous sections 5 to 8 mm thick, a b = 0 and a b = 400 at 1000/mm², a 2 NEX for the b = 0 and 5 to 6 NEX for the b max and coding in the 3 directions so as to be able to calculate the ADC. The addition of successive anatomic stations contiguous acquired in the axial plane provides continuous visualization in the axial sections of the whole body (autobinding and a coronal reconstruction) [19]. Diffusion sequences are of value in the screening of multiple lesions, in particular, bone metastases [20]. The image obtained calls to mind scintigraphic images when the greyscale is inverted (Fig. 2). It is now possible to merge the images obtained in diffusion with STIR sequences to obtain both anatomic and functional information and approach the techniques merging diagnostic and nuclear imaging: PET-CT, scintigraphy-CT [21]. For correct analysis of the diffusion imaging, it is important to
be familiar with the normal anatomic structures that present a physiological hypersignal: the brain and the marrow, salivary glands, Waldeyer’s ring, thymus, spleen, gallbladder, adrenal glands, prostate, penis, endometrium, ovaries, testicles, red marrow and lymph nodes. Yellow marrow appears dark in diffusion imaging because the suppression of fat and red marrow in children is hyperintense due to the restriction in diffusion caused by the hypercellularity. The interpretation of marrow anomalies may be especially difficult in children. In a recent study, normal zones of limited diffusion in the marrow, asymmetrically distributed and independent of any pathological process, were observed in 48% of all healthy children [22]. The difference between benign and malignant lymphadenopathies based on apparent diffusion coefficients (ADC) is still inadequate, since the series of ADC values of normal lymph nodes overlaps those of metastatic lymph nodes44. It is therefore important to remember that diffusion sequences are very sensitive but lack enough specificity to be able to reliably conclude on the basis of signal analysis, in particular, in the above-mentioned situations.

Others
Other sequences, such as magnetization transfer contrast imaging, or steady state free precession (SSFB), have been tested on small patient samples without demonstrating a major interest or superiority in the field of oncology [23,24].

Current clinical applications of WB-MRI in paediatric oncology
The most important clinical application of WB-MRI in children, as in adults, is the screening of the metastatic spread of cancer. In most of the series published, MRI discovers more lesions than the so-called conventional techniques, and in particular, more than the examinations in nuclear medicine with which they are in direct competition [25–27].

Lymphoma
Lymphoma is the third most common malignancy in the child, after leukaemia and brain tumours. Accurate staging is required to determine the most appropriate method of management, and CT remains the mainstay imaging modality for this purpose. Recently, PET-CT has come into use for staging and evaluation of treatment response. A great many studies have reported the non-inferiority or even superiority of WB-MRI over conventional imaging (nuclear medicine techniques included) in the staging of lymphomas in the adult and child as regards to the detection of supra-centimetric lymphadenopathies and bone marrow infiltration [4,28–30] (Fig. 3). Different studies carried out in patients with lymphoma have shown that the sensitivity of WB-MRI ranges from 92% to 100% in the detection of lymph nodes 10 to 12 mm in diameter, compared to a sensitivity of 67% for lymph nodes 6 to 12 mm in diameter and 11% for lymph nodes 1 to 6 mm in diameter [28,30]. However, certain studies have reported that WB-MRI was inferior to PET-CT, in particular, in the detection of pulmonary and hepatic metastases [31], although the MRI protocol did not include the diffusion sequence, which is, today, subject to criticism.

Diagnostic hesitation about osteomedullary involvement (moderate hyperfixation in FDG-PET and negative medullary samples) is a good indication for WB-MRI. Nevertheless, outside of stages 1 and 2, in which the discovery of medullary involvement that has not been diagnosed by another method

Figure 2. A 17-year-old girl with lymphoma. Coronal whole body T1-W (a), STIR (b) and greyscale inverted DWI (c) show extensive (bilateral) cervical, axillary, paraaortic, mesenteric, and pelvic lymph node involvement (continuous arrows). Note the relatively high signal intensity of the bone marrow [e.g. in both femoral diaphyses (dashed arrows), indicating bone marrow hyperplasia (reconversion)]. Also note insufficiently suppressed fat in the right flank and buttock (arrowheads). Images from: “Whole body diffusion-weighted imaging for staging malignant lymphoma in children”. Kwee, T. C. et al. Pediatr Radiol 2010. Reproduced by kind permission of Springer.
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Figure 3. Lymphoma in a 12-year-old boy. Coronal STIR MR images (a–c) show lymphadenopathy in the neck, axillae, mediastinum, lungs, and left inguinal region (arrowheads). Lymphomatous infiltrates are seen in the marrow of the pelvic bones and the right knee (arrows). Coronal PET image (d) clearly depicts all these lesions (arrows). Images from: “Whole body MRI imaging in children: principles, technique, current applications, and future directions”. Chavhan, G. B. and Babyn, P. S. Radiographics 2011. Reproduced by kind permission of the Radiological Society of North America.

Solid tumours

In the adult, certain studies demonstrate the superiority of WB-MRI over other imaging procedures in the detection of hepatic, skeletal and central nervous system metastases in solid tumours [34]. In particular, in the detection of bone metastases, the sensitivity of WB-MRI is similar or superior to that of bone scintigraphy with technetium 99m. Most authors report a sensitivity of over 97% for WB-MRI in this indication [11]. In the child, series on small cell tumours are more limited and heterogeneous [35]. In a first study, where the authors only used a T1-weighted sequence, the sensitivity of the PET-CT was higher (90%) than the sensitivity of WB-MRI (82%) in the assessment of the spread of different malignant tumours in the child [16]. The results of subsequent studies, in which the STIR sequence was used in addition to the T1-weighted sequence, have shown that the sensitivity of WB-MRI becomes similar to that of the PET-CT [36,37]. In 2010, Goo et al. published an article on the value of WB-MRI in initial monitoring (local and metastatic) and the monitoring of neuroblastomas (Fig. 4) [17]. He emphasized the promising aspect of the technique as well as the need to assess it on larger prospective cohorts with the systematic use of diffusion sequences. He also noted the limits of the technique: the assessment of lymph node involvement, the differentiation between viable and residual non-viable tumour, and the detection of calcified lesions. Finally, the author emphasized the potential complementarity between WB-MRI and metabolic methods of imaging to improve the diagnostic specificity in these difficult situations.

Results of the ACRIN study

The American College of Radiology Imaging Network (ACRIN) protocol [31] is a multicentric prospective study (20 centers) carried out in North America between November 2004 and June 2007. The main goal of this study was to establish the non-inferiority of WB-MRI over conventional imaging in the detection of metastases in the initial assessment of current paediatric tumours. WB-MRI was carried out with coronal STIR sequences and the conventional imaging procedures were those currently used in everyday practice for initial
assessments: CT-scan of the thorax, scintigraphies (bone, MIBG, gallium) and PET-FDG. The tumours studied were lymphomas, neuroblastomas and sarcomas of soft tissue. Sixty-six patients under the age of 21 were analyzed (mean age: 10 years). The study was not able to establish that the diagnostic precision by WB-MRI was not inferior to that of conventional imaging in the detection of remote metastases in the patient selected. However, it shows that the detection of metastases by WB-MRI is more precise in paediatric patients with solid tumours than in those with lymphomas (mean area under ROC curve 0.92 vs 0.72, respectively, \( P = 0.006 \)). It also shows that WB-MRI helps, on the average, detect more skeletal lesions than conventional imaging (\( P = 0.03 \)) but does not improve the detection of pulmonary metastases (mean sensitivity, 0.53 vs 0.83, respectively, \( P = 0.001 \)). These results support past studies that show that STIR sequences were better than scintigraphy in the detection of bone metastases. Whole body MRI is less efficient in the detection of extra-skeletal disease. Most of the lesions missed in this study were under 1 cm in diameter and all were located in the lungs or liver. The under-diagnosis of lung disease with WB-MRI is not surprising as it has been demonstrated by other authors [7, 38]. The advantage of this study is that all of the participants used a single STIR technique. One of the weaknesses is that the diffusion was not assessed as this seems promising in improving the detection of lesions [39, 40].

Pre-clinical screening of children with a cancer predisposition syndrome

WB-MRI may be of use in the pre-clinical screening of cancers in patients presenting a genetic predisposition to cancer (retinoblastoma, Von Hippel–Lindau disease, familial adenomatous polyposis, neurofibromatosis, Beckwith–Wiedmann disease, Li–Fraumeni syndrome, etc.) [41]. The Li–Fraumeni syndrome is a rare autosomal dominant hereditary disease, caused by a germ-like mutation of the tumour suppressor gene p53. Children with this syndrome are predisposed to develop certain malignant tumours, including breast cancer, brain tumours (carcinoma of the choroid plexus, etc.), acute leukaemia, soft tissue sarcoma, and corticosurrenalomas. A pilot study carried out at Dana Farber Institute has shown that the use of the PET-scan may enable the detection of asymptomatic tumours in these patients [42]. However, these patients are particularly sensitive to ionizing radiation. A North-American study on 49 persons from 8 Li–Fraumeni families, reported the incidence and mortality by cancer in these subjects whether monitored \((n=16)\) or not \((n=38)\) by imaging, including a whole body MRI. After 38 months, 6 monitored individuals developed a total of 9 cancers (brain tumours) and were alive, whereas 22/33 non-monitored individuals died [43]. This study tends to demonstrate the usefulness of tumour screening in this population. Our institution is the main

Figure 4. Seven year-old girl with stage 4 neuroblastoma. a: coronal whole body STIR MR image shows heterogeneously hyperintense bone marrow the lumbar spines, the pelvis, both femora, and the left tibia (arrowhead). The primary tumour (arrows) is also seen in the left lower abdomen and the whole body diffusion-weighted image reveals extensive bone marrow metastases (arrows), conspicuously because of the excellent suppression of body and fat signal. Images from: ’Whole body MRI of neuroblastoma’. Goo, H. W. Eur J Radiol 2010. Reproduced by kind permission of Elsevier.
investigator in a national multicentric randomized study that began at the end of 2011 to assess the value of whole body MRI with diffusion sequences in the pre-clinical detection of cancer in carriers of constitutional mutation P53 (Lifescience study, subjects 5 to 71-years-old), the clinical criterion of judgement being the incidence of cancer after 3 years.

Future prospects for the development of WB-MRI in paediatric oncology

Diffusion imaging

The inclusion of diffusion data improves the specificity of WB-MRI by providing information about tumoral cellularity and necrosis [44]. In the past, diffusion imaging with free breathing was considered impossible. For this reason, the sequences were obtained with apnea or gating, thereby, deteriorating the signal/noise ratio due to the great section thickness or prolongation of the acquisition time. In 2004, Takahara et al. [45] demonstrated that the breathing movement occurring during the application of the diffusion gradient is a coherent intravoxel movement that does not affect the diffusion weighting, even if it provokes a certain blur in the images. He developed a new free breathing diffusion imaging technique with 3D maximum intensity projection (MIP) reconstructions, allowing for the acquisition of thin sections within a reasonable time frame. The technique is called diffusion-weighted imaging background body signal suppression (DWIBBS). In addition to free breathing, this technique is characterised by the high diffusion weighting ($b = 1000–1500 \text{s/mm}^2$) and fat suppression obtained by inversion recovery as in the STIR sequence [46]. With the suppression of the background noise (normal anatomic structures), only the structures and lesions restricting the diffusion are represented. The resulting images are in general displayed in an inverted greyscale and resemble PET images. For a better analysis, it is often necessary to refer to the underlying anatomy. Image fusion software now can be used to calibrate the diffusion on a STIR or T1 sequence. In 2009, Kwee et al. described that the addition of weighted diffusion sequences in the whole body MRI protocol provided a more exact staging of lymphomas by correctly readjusting the stage upwards in 4 of the 28 patients analyzed [47].

Lesions in diffusion hypersignal (black on the image in inverted greyscale), with a high value of $b$ do not always indicate the presence of limited diffusion. This is why the concomitant quantitative analysis of ADC measurements on colour mapping is required [39]. This technique does not require the administration of contrast agent and does not use ionising radiation. It is especially advantageous in repeated follow-ups, in particular, in monitoring under chemotherapy [48]. ADC measurement within a large organ is relatively uniform and fairly precise with free breathing although it seems to be less reliable for small focal lesions due to the contamination of the signal by the adjacent tissue [49]. The optimisation of ADC measurements is the main direction of future on the diffusion sequence. The final goal is to obtain a reliable functional biomarker, like SUV measurements in PET-CT [19].

![Figure 5](image-url)

Figure 5. Whole body DW imaging versus FDG-PET for monitoring therapy response in a 23-year-old man with Hodgkin lymphoma. Inverted greyscale DW images obtained before (a) and 5 months after treatment (b) show supradiaphragmatic distribution of nodal disease. Splenic signal intensity is considered to be within normal limits. Bone marrow signal is hyperintense but normal for the age. After therapy, a hypointense signal is not seen at sites of nodal disease, consistent with the therapy response. Note interval development of bone marrow hypointensity (both pre- and post-therapy DW images are normalized to right kidney signal intensity). Whole body FDG-PET-scans obtained before (c) and after therapy (d) show complete response to therapy. FDG-PET-scan shows splenic deposit before therapy (arrow), which is not visible on diffusion. Images from: “Whole body diffusion-weighted MR imaging in cancer: current status and research directions”. Padhani, A. R., Koh, D.-M., Collins, D. J. Radiology 2011. Reproduced by kind permission of the Radiological Society of North America.
A great many studies compare diffusion imaging and PET-FDG in adults and show similar results with both procedures (Fig. 5). A study has still not been carried out to compare whole body diffusion MRI and PET-FDG in children.

3 Tesla MRI

The WB-MRI technique on 3 Tesla (3 T) machines is currently difficult to use on a routine basis since it still requires adjustments to reduce the signal non-homogeneities and the susceptibility to artifacts. A great many related artifacts are in fact increased with a high field. This is the case of the non-homogeneity of b0 and b1, motion and magnetic susceptibility artefacts and difficulties in the suppression of the fat signal. Several teams have worked on ways to improve 3 T diffusion sequences. This work, in particular, involves the use of dual-source radiofrequency transmission technology to reduce field non-homogeneities [50], and the suppression of fat by slice selection gradient reversal (SSGR), which is more robust at 3 T [51]. The prime interest in the use of 3 T promoted by the manufacturers is the theoretical possibility of reducing the overall acquisition time for whole body imaging and thereby, improving the paediatric patient comfort.

PET/MRI

The simultaneous acquisition of morphological and functional data by hybrid PET-MRI technology is a new, rapidly growing, diagnostic and lesion characterization method [52–54]. The joint study of the metabolism of glucose and the cellularity within tumour tissue enables more sophisticated characterization. For example, PET improves the detection of abnormal metabolic activity in lymph nodes that, in the MRI, would not have been noticed due to their normal size and their hypersignal in physiological diffusion. Diffusion imaging may, in turn, effectively complement PET in the evaluation of urinary tract disease that naturally excretes the radionucleotide. The first clinical research carried out in this field was published in 2008 [55,56]. However, this technique is complex and involves new problems and challenges, including the reduction of artefacts and the optimisation of the examination procedure beyond the simple merger of 2 sets of image data. Certain teams are working on the optimisation of this new technology in order to propose an efficient clinical tool that can be used on a routine basis [54,57] (Fig. 6).

Conclusion

Whole body MRI is a technique that can now be used on a routine basis and is promising in paediatric oncology. Its role with respect to nuclear medicine examination still has not been clearly determined, although the number of studies demonstrating the similar efficacy of these two methods is constantly increasing. This exhaustive review of the literature concludes that WB-MRI is superior to scintigraphy and PET-CT in the detection of bone, brain and liver lesions but remains inferior for the detection of small lymphadenopathies and pulmonary lesions. The major value of this technique in paediatrics is that it is radiation free. The main limitations are the length of the examination, the lack of spatial resolution in the detection of small lesions and the lack of specificity for the evolution under treatment, in particular, for bone marrow lesions. The current optimisation of diffusion sequences and PET-MRI are innovative techniques that may eventually improve the last shortcoming. In conclusion, a standardised whole body paediatric protocol within a context of metastatic screening for diagnostic purposes may be suggested: coronal STIR sequences and axial diffusion on the whole body, more or less completed with sagittal STIR sequences on the spine. This protocol is a compromise between the detection sensitivity of skeletal and visceral metastases and a reasonable acquisition time for the paediatric population. It does not pretend to provide a fine
analysis of the primary tumour at the same time. Targeted and homogenous studies are still required to specify the role of WB-MRI in each type of paediatric tumour, at the time of the diagnosis or during the follow-up. In this way, the technical parameters may be optimised and standardised for each indication.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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