Whole-Body MRI

- Whole-body MRI is a noninvasive screening technique that acquires images of the entire body in the coronal plane only using fast magnetic resonance pulse sequences.
- Whole-body MRI is a promising method for screening pediatric patients with small round blue cell tumors for metastases, including lymphoma and neuroblastoma.
- Whole-body MRI is also useful for assessing tumor burden in patients with neurofibromatosis and potential detection of malignant transformation.
- Whole-body MRI is particularly beneficial for children because there is no exposure to ionizing radiation, making it an ideal imaging modality for serial imaging surveillance.

Appropriate therapeutic management of patients with malignant disease requires accurate tumor staging, which most often is performed by imaging. In children with small round blue cell tumors (e.g., neuroblastoma, Ewing sarcoma, lymphoma, rhabdomyosarcoma), imaging examinations typically include CT to evaluate the extent of the primary tumor and detect lymphatic and distant organ metastasis, as well as 99mTc bone scintigraphy in the case of neuroblastoma and sarcomas to detect bone metastases. More recently, PET and PET/CT have been used for initial tumor staging and evaluation of treatment response based on tumor metabolic activity, with PET/CT currently regarded as the gold standard imaging modality for lymphoma. All of these imaging modalities involve ionizing radiation exposure to patients. In some cases, such as Hodgkin’s lymphoma which has a high cure rate, the number of surveillance imaging studies is low. However, in many cases there is either incomplete response to treatment or a significant risk of disease recurrence, both of which necessitate a longer active surveillance period and an increased number of imaging studies. With increasing concern about the potential long-term effects of radiation exposure, especially for pediatric patients, there is a growing interest in alternative imaging techniques that do not involve exposure to ionizing radiation.

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Whole-body MRI is now a practical technique that may fulfill this role, thanks to recent advances in imaging techniques and software development. Whole-body MRI uses a limited number of sequences intended to highlight lesions throughout the body in a single examination. Images are obtained in the coronal plane only, which minimizes the number of image acquisitions and enables fast coverage of larger regions of the body. This plane also has an advantage in that coronal images are also comparable to those from other whole-body imaging modalities. Using these techniques, it is now possible to complete whole-body MRI studies in most cases within a time period that is comparable to that for focused MRI studies.
It should be noted that whole-body MRI is intended primarily for screening purposes and that it differs from focused regional MRI, which produces more detailed anatomic definition by utilizing multiple sequences in several planes and may include the use of an intravenous contrast agent. Nor is whole-body MRI ready to become a replacement for CT, due to issues concerning speed, resolution, contrast, and availability. However, whole-body MRI has theoretical benefits in that it has the potential to be a single examination that could replace two or more imaging examinations for patients with small round blue cell tumors. In addition, it would avoid multiple exposures to ionizing radiation in those who require repeated imaging over a prolonged period of time.

Because whole-body MRI can reliably detect tumor spread to bone and bone marrow as well as extra-skeletal tissues, it is well-suited to the evaluation of pediatric patients with small round blue cell neoplasms, such as neuroblastoma, Ewing sarcoma family of tumors, rhabdomyosarcoma, and lymphoma. Several recent studies have shown that whole-body MRI is a sensitive screening technique for these purposes and is, therefore, suitable for initial staging and for follow-up studies. One potential advantage of whole-body MRI over conventional imaging is the ability to detect osseous (both cortical and medullary) and extraosseous disease in a single imaging examination.

Patients with neurofibromatosis (NF1 and NF2), a genetic disorder characterized by the development of innumerable tumors derived from nerve tissue, are also likely to benefit from whole-body MRI. In these cases, whole-body MRI may be useful to identify neurofibromas causing symptoms that would be amenable to surgical excision. Additionally, these patients are at risk of the neurofibromas undergoing malignant degeneration and early detection of malignant nerve tumors would improve patient prognosis. Whole-body MRI in this population can be used to monitor tumor burden, including the number, distribution, type (discrete or plexiform), and size, and to calculate how that changes over time. This information is important for the assessment of tumor growth and response to treatment. It should be noted that, because nerve sheath tumors can be highly irregular in shape, the tumor burden cannot be accurately assessed by traditional linear measurements. Instead, three-dimensional computerized segmentation techniques have been developed for the accurate assessment of tumor burden.

**The Examination Procedure**

At Mass General Hospital, whole body MRI is performed on scanners that have radiofrequency coils embedded in the patient table, which makes it possible to complete the entire scan without moving the patient. Images are acquired at multiple stations to scan the entire body, except for patients with lymphomas because this condition is less commonly associated with bone metastases and scanning the lower extremity station is not generally necessary. Because of their smaller size, pediatric patients can often be imaged in fewer stations, which shortens the total scan time.

The imaging sequences for patients with small round blue cell tumors include T2 imaging for anatomic detail, short tau inversion-recovery (STIR)(Figure 1), and a T1 out-of-phase sequence. The STIR sequence has a mix of proton density, T1, and T2 contrast with inherent fat suppression. Because most pathological tissues have high proton density and prolonged T1 relaxation and T2 decay, STIR images show lesions as regions of high signal intensity. The T1 out-of-phase sequence is intended to suppress the signal from fat, which aids in the detection of bone marrow lesions because most neoplasms replace bone, fat, and hematopoietic elements in bone marrow. In some cases, a diffusion-weighted (DWI) sequence is included in the whole-body protocol. Most metastatic lesions have higher cellular density and lower diffusion rates than normal tissue and DWI images are particularly helpful for detecting lymph node metastases. Total imaging time is about 45 minutes. Pediatric patients under the age of six are not usually able to remain still during this time and will require sedation.

STIR sequences alone are sufficient for evaluation of tumor burden in patients with neurofibromatosis. Therefore, total imaging time for the five imaging stations necessary for adult imaging is only 15 minutes.
Sensitivity and Specificity
Whole-body MRI is more sensitive than scintigraphy in the detection of bone metastases. This is partly due to the lower spatial resolution of scintigraphic images but also reflects that scintigraphy detects bone remodeling, whereas MRI detects structural alterations in bone marrow. Several small studies have reported sensitivities and specificities of the different imaging techniques. Reports of sensitivity of whole body MRI range from 97.5-100%, compared to 26-71% for 99mTc scintigraphy. Although CT has a high sensitivity for soft-tissue metastases, the sensitivity for the detection of bone metastases has been reported to be 10%.

It should be noted that whole-body MRI using STIR sequences is not specific for malignancy. Inflammatory, infectious, or traumatic lesions also appear hyperintense, as do benign lesions such as cysts or vascular lesions. In addition, some lesions can be missed, such as small (<0.6 cm) lung nodules or small lymph node metastases. However, out-of-phase imaging can help differentiate between benign and malignant tissue. An ongoing multi-center study is currently gathering more data to compare the effectiveness of these MRI sequences for the detection of metastases in small round blue cell tumor patients with other imaging modalities including CT, scintigraphy, and in some cases, PET imaging.

Scheduling
At this time whole-body MRI remains an emerging technique that is not yet routinely available clinically. Therefore, it cannot be ordered online but must be arranged through Dr. Michael Gee for pediatric patients with small round blue cell tumors or through Dr. Miriam Bredella for patients with neurofibromatosis. Whole-body MRI is only performed at the main MGH campus.

Further Information
For further questions about whole body MRI for patients with small cell tumors, please contact Michael S. Gee, MD, PhD, Pediatric Radiology, at 617-726-8360. For patients with neurofibromatosis, please contact Miriam Bredella, MD, Musculoskeletal Imaging, at 617-726-7717.

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