Whole-Body MRI in Oncology: From Morphology to Functional Tumor Assessment

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Whole-body MRI (WB-MRI) has evolved from a technically demanding research examination into an increasingly practical tool for oncologic imaging. Improvements in multichannel coils, parallel imaging, table movement, Dixon techniques and diffusion-weighted imaging (DWI) now allow evaluation of the entire body within a clinically acceptable examination time. Its major advantages are the absence of ionizing radiation, excellent bone marrow and soft-tissue contrast, and the possibility of combining anatomical imaging with functional information from DWI. WB-MRI should not simply be regarded as “many regional MRIs performed at once.” Its real value lies in providing a global map of tumor distribution and biological behavior.

For the radiologist, three questions dominate: Where is the disease? What is the total tumor burden? And how has that burden changed following treatment?

The basic protocol: keep it simple

A successful WB-MRI examination does not require an exhaustive collection of sequences. The objective is to obtain robust, reproducible whole-body coverage within a reasonable acquisition time. A typical oncologic protocol combines anatomical T1-weighted imaging—often using Dixon techniques—with fluid-sensitive sequences and whole-body DWI. Dixon imaging is particularly useful because it simultaneously provides water-only and fat-only images. This improves assessment of bone marrow replacement and allows visualization of soft-tissue lesions.

DWI is acquired with multiple b-values and reconstructed at high b-values. Maximum-intensity-projection images can provide a PET-like overview of disease distribution. However, the MIP should be regarded as a navigation image rather than a diagnostic image. Every suspected lesion must be confirmed on source diffusion images, ADC maps and anatomical sequences.

DWI: the functional core of WB-MRI

Diffusion-weighted imaging has transformed whole-body MRI. Many malignant tumors demonstrate high signal on high-b-value DWI because of restricted water diffusion associated with increased cellularity. The ADC map provides complementary quantitative information. This allows WB-MRI to detect disease that may be inconspicuous on purely morphological sequences and provides a potential biomarker for treatment response.

High signal on DWI does not equal malignancy.

Normal lymphoid tissue, spleen, bone marrow, spinal cord, peripheral nerves and several benign lesions may demonstrate high diffusion signal. T2 shine-through can also mimic restriction. DWI must therefore always be interpreted together with the ADC map and anatomical images.

Bone marrow: one of the major strengths of WB-MRI

Perhaps the greatest strength of WB-MRI in oncology is assessment of the bone marrow. CT detects bone metastases primarily through secondary changes in mineralized bone. MRI directly depicts replacement of normal marrow by tumor. Consequently, MRI may identify metastatic marrow infiltration before cortical destruction or reactive sclerosis becomes visible on CT. This is particularly important in cancers with predominantly marrow-based disease.

WB-MRI can demonstrate focal, multifocal and diffuse infiltration patterns and can simultaneously assess complications such as pathological fracture, epidural extension and spinal cord compression.

Multiple myeloma: a major indication

Multiple myeloma represents one of the strongest clinical applications of WB-MRI. The disease is fundamentally a bone marrow malignancy, making MRI particularly well suited to its assessment. WB-MRI can demonstrate focal lesions as well as diffuse, variegated and mixed patterns of marrow infiltration. The total burden and distribution of disease can be assessed without radiation exposure, which is particularly attractive in patients requiring repeated imaging. DWI also provides information regarding disease activity and treatment response.

An important pitfall is the interpretation of diffuse marrow signal abnormalities. Age, anemia, hematopoietic stimulation, treatment and marrow reconversion can all modify normal

marrow signal. Knowledge of normal and treatment-related marrow patterns is therefore essential.

Metastatic bone disease

WB-MRI is highly sensitive for skeletal metastases, particularly marrow-replacing lesions. Prostate and breast cancer are obvious applications because skeletal disease may dominate the metastatic burden. The MRI appearance of metastases varies according to the underlying tumor, treatment status and degree of sclerosis. Sclerotic metastases may demonstrate relatively low signal on both anatomical and diffusion sequences, particularly following successful treatment. Therefore, absence of high DWI signal does not necessarily mean absence of metastatic disease. Comparison with CT can be highly complementary: MRI evaluates marrow viability and cellularity, while CT depicts mineralization and sclerosis.

Lymphoma: a natural whole-body application

Lymphoma is another attractive indication because disease frequently involves multiple nodal and extranodal sites. WB-MRI can demonstrate enlarged lymph nodes, splenic lesions, marrow infiltration and extranodal disease. DWI is particularly useful because lymphoma generally demonstrates marked diffusion restriction. However, physiological lymphoid tissue can also show high DWI signal, particularly in younger patients.

PET/CT remains extremely important for many lymphoma subtypes because metabolic information has established prognostic and response-assessment roles. WB-MRI should therefore be regarded as a complementary or alternative technique in selected situations rather than a universal replacement for PET/CT.

Prostate cancer: increasing importance

Whole-body MRI is particularly useful for evaluating advanced prostate cancer, where bone metastases represent a major component of disease burden. DWI facilitates detection of marrow metastases and allows a global assessment of skeletal tumor load. Response evaluation can be challenging because successful therapy may produce complex changes in marrow signal and diffusion.

The development of standardized approaches such as MET-RADS-P has helped structure acquisition, interpretation and reporting in advanced prostate cancer. This

standardization is important because WB-MRI produces an enormous amount of imaging information. Without a systematic approach, subtle progression or mixed response can easily be missed.

Treatment response: size is not enough

One of the most promising applications of WB-MRI is treatment-response assessment. Traditional response criteria rely heavily on changes in lesion size. This approach has obvious limitations in bone metastases, which may not substantially decrease in size despite effective therapy. DWI provides additional biological information.

Successful treatment often produces reduced cellularity and increased extracellular water mobility, potentially resulting in increased ADC values and reduced high-b-value DWI signal. However, response is not always straightforward. Early treatment effects may transiently increase diffusion abnormalities. Bone marrow reconversion can complicate interpretation. Sclerotic healing may alter lesion morphology without directly reflecting viable tumor. ADC should therefore not be interpreted as a simple binary biomarker. The most reliable assessment integrates morphology, diffusion behavior, ADC change and lesion distribution over time.

WB-MRI versus PET/CT: complementary rather than competing

The question “Is WB-MRI better than PET/CT?” is generally too simplistic. The two techniques measure different biological properties. PET evaluates the distribution of a specific radiotracer and therefore provides molecular or metabolic information. MRI evaluates anatomy, marrow composition, tissue water and diffusion. Their relative performance depends strongly on tumor type, tracer and clinical question.

PET/CT may be superior for certain metabolically active tumors and provides highly standardized quantitative information. WB-MRI has particular advantages for marrow disease, soft tissues and repeated examinations without ionizing radiation. The correct question is therefore: Which technique best answers the biological and clinical question in this particular cancer?

Important pitfalls: normal structures can look malignant

Whole-body DWI creates striking images, but it also generates numerous potential false positives. The brain, spinal cord, spleen, kidneys, testes, endometrium, lymphoid tissues and peripheral nerves may demonstrate physiological high signal. Brown fat, muscle activity and inflammatory lesions can also produce abnormalities.

Benign bone lesions, fractures, degenerative changes and inflammatory disease may mimic metastases. Conversely, some tumors may demonstrate relatively little diffusion restriction. A lesion should therefore never be diagnosed as malignant solely because it is bright on a high-b-value image. A useful rule is: DWI detects abnormal water behavior; it does not detect cancer specifically.

Fractures: a particularly important trap

Cancer patients frequently have vertebral compression fractures. WB-MRI may detect them easily, but distinguishing benign osteoporotic fractures from pathological fractures can remain difficult. Marrow replacement, posterior element involvement, convex posterior vertebral contour and epidural or paravertebral tumor favor malignant fracture. However, acute benign fractures can show intense edema and diffusion abnormalities. Morphology remains essential. This illustrates why whole-body oncology imaging cannot be reduced to functional imaging alone.

Incidental findings: the price of looking everywhere

Whole-body imaging inevitably reveals incidental abnormalities. Thyroid nodules, renal lesions, ovarian abnormalities, degenerative musculoskeletal disease and benign bone lesions are frequently encountered. Over-investigation of incidental findings can generate anxiety, additional radiation exposure and unnecessary procedures. Radiologists therefore need a disciplined approach to incidental findings, emphasizing abnormalities with a realistic potential to alter management. The ability to see more creates a responsibility **not to overdiagnose more**.

Reporting WB-MRI: structure is essential

Whole-body examinations generate too much information for an unstructured narrative report. A systematic approach should evaluate major anatomical compartments: skeleton, lymph nodes, viscera and soft tissues.

The report should distinguish known disease, new lesions, treatment response and complications. Particular attention should be paid to lesions that alter staging or management rather than documenting every visible abnormality. Comparison with previous WB-MRI, CT or PET examinations is fundamental. Ideally, response should be described globally while also identifying discordant sites.

Conclusion: from staging examination to whole-body biomarker

Whole-body MRI has evolved into a powerful oncologic imaging technique combining anatomical and functional information without ionizing radiation. Its particular strengths include assessment of bone marrow disease, multiple myeloma, skeletal metastases and selected applications in lymphoma and advanced solid tumors. DWI has dramatically increased its sensitivity and has opened the possibility of functional treatment-response assessment. Yet diffusion must be interpreted carefully because restricted diffusion is not synonymous with malignancy.

Three principles are particularly useful:

Do not read whole-body DWI without anatomical correlation.

Do not evaluate bone metastases solely by changes in lesion size.

Do not think only lesion by lesion—consider the total tumor burden and its evolution.

The future of WB-MRI in oncology is therefore unlikely to be simply as a radiation-free substitute for CT or PET/CT. Its greater potential is to become a whole-body biomarker, simultaneously depicting where cancer is located, how extensively it involves the patient and how its biological behavior changes under treatment. For radiologists, this requires a shift from merely detecting metastases toward mapping disease as a dynamic whole-body process.