INTERNATIONAL MULTI DISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
eISSN 2394-6334 Impact factor: 8.854 Volume 13, issue 03 (2026)

RADIOLOGICAL FEATURES OF BRAIN METASTASES ON MRI

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Abstract: Brain metastases are the most common intracranial tumors in adults, accounting for approximately 20–40% of all brain neoplasms. Magnetic Resonance Imaging (MRI) plays a central role in the detection, characterization, and monitoring of metastatic brain lesions due to its superior soft tissue contrast and multiplanar capability. This article reviews the key radiological features of brain metastases on MRI, including conventional sequences and advanced imaging techniques. Emphasis is placed on lesion morphology, enhancement patterns, surrounding edema, and differential diagnostic considerations. Current literature and statistical data are also analyzed to highlight the diagnostic accuracy of MRI in clinical practice.

Keywords: brain metastases, MRI, radiology, contrast enhancement, neuroimaging

Introduction

Brain metastases represent a significant clinical problem, occurring in up to 30% of adult cancer patients. The most common primary tumors include lung cancer (40–50%), breast cancer (15–25%), melanoma (5–20%), renal cell carcinoma, and colorectal cancer.

According to studies by Patchell RA, early detection and accurate imaging significantly improve patient outcomes and guide treatment strategies such as surgery, radiotherapy, or stereotactic radiosurgery.

MRI is considered the gold standard imaging modality for detecting brain metastases due to its high sensitivity compared to CT, especially for small lesions and lesions located in the posterior fossa.

Materials and Methods

This article is based on a review of published scientific literature, clinical radiology guidelines, and retrospective imaging studies. Key sources include works by Suh CH and Smirniotopoulos JG, focusing on MRI characteristics of metastatic brain lesions.

MRI protocols analyzed typically include:

- T1-weighted imaging (T1WI)
- T2-weighted imaging (T2WI)
- Fluid-attenuated inversion recovery (FLAIR)

- Diffusion-weighted imaging (DWI)
- Post-contrast T1-weighted imaging
- Advanced techniques: perfusion MRI and MR spectroscopy

Results

1. Lesion Localization and Distribution

Brain metastases are most commonly located at the gray-white matter junction due to hematogenous spread. Approximately 80% occur in the cerebral hemispheres, 15% in the cerebellum, and 5% in the brainstem.

Multiple lesions are observed in about 70–80% of patients, although solitary metastasis can occur in 20–30% of cases.

2. Signal Characteristics on MRI

- **T1WI:** lesions are typically hypointense or isointense
- **T2WI/FLAIR:** hyperintense lesions with extensive surrounding vasogenic edema
- **DWI:** usually show no significant restriction (helps differentiate from abscess)

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3. Contrast Enhancement Patterns

One of the hallmark features of brain metastases is **ring or nodular contrast enhancement**.

Common patterns:

- Ring-enhancing lesions with central necrosis
- Homogeneous enhancement in smaller lesions
- Heterogeneous enhancement in larger lesions

Studies show that contrast-enhanced MRI increases detection sensitivity by up to 95%.

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4. Peritumoral Edema

Metastases are associated with **vasogenic edema**, which appears hyperintense on T2/FLAIR sequences.

Important characteristics:

- Disproportionately large edema compared to lesion size
- No diffusion restriction

- Mass effect (midline shift in severe cases)

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5. Advanced MRI Techniques

Perfusion MRI

Metastases typically show:

- Increased relative cerebral blood volume (rCBV) in the tumor periphery
- Lower perfusion in necrotic center

MR Spectroscopy

Findings include:

- Elevated choline (tumor marker)
- Reduced N-acetylaspartate (NAA)
- Presence of lipid/lactate peaks in necrotic lesions

According to research by Law M, perfusion MRI helps differentiate metastases from high-grade gliomas.

Discussion

MRI provides high diagnostic accuracy in detecting brain metastases and distinguishing them from other intracranial lesions such as gliomas, abscesses, and demyelinating diseases.

Key differential points:

- **Glioblastoma:** infiltrative growth, irregular margins
- **Abscess:** diffusion restriction (high signal on DWI)
- **Metastases:** well-circumscribed lesions with vasogenic edema

A meta-analysis by Suh CH reported MRI sensitivity of 90–95% and specificity of approximately 85–90% for detecting brain metastases.

Early and accurate diagnosis is critical for treatment planning, including stereotactic radiosurgery and systemic therapy.

Conclusion

MRI is the most effective imaging modality for evaluating brain metastases. Typical radiological features include:

- Multiple lesions at the gray-white junction
- Ring or nodular contrast enhancement
- Extensive vasogenic edema
- Characteristic findings on advanced MRI techniques

Integration of conventional and advanced MRI sequences significantly improves diagnostic confidence and patient management.

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