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MAGNETIC RESONANCE IMAGING CHARACTERISTICS OF BRAIN METASTASES IN PATIENTS WITH MALIGNANCY AT AL-THAQALAYN ONCOLOGY HOSPITAL, BASRA, IRAQ

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ABSTRACT

Background: Brain metastases are the most common intracranial tumors in adults and represent a major cause of neurological morbidity among patients with systemic malignancies. Magnetic resonance imaging (MRI) is the imaging modality of choice for the detection and characterization of metastatic brain lesions owing to its superior soft-tissue contrast and high diagnostic accuracy. **Objectives:** To evaluate the magnetic resonance imaging characteristics of brain metastases in patients with malignancy attending Al-Thaqalayn Oncology Hospital, Basra, Iraq. **Methods:** This retrospective observational study was conducted at Al-Thaqalayn Oncology Hospital, Basra, Iraq, from May 2022 to March 2026. A total of 83 patients with histologically confirmed primary malignancies and radiologically diagnosed brain metastases were included. Demographic, clinical, and MRI data were collected from medical records and imaging archives. MRI characteristics assessed included lesion number, anatomical distribution, enhancement pattern, perilesional edema, hemorrhage, necrosis, mass effect, and midline shift. Statistical analysis was performed using SPSS version 31, and a P value of less than 0.05 was considered statistically significant. **Results:** The mean age of the patients was 57.2 ± 11.8 years, and males constituted 53.0% of the study population. Lung cancer was the most common primary malignancy (37.3%), followed by breast cancer (22.9%) and colorectal cancer (12.0%). Multiple brain metastases were identified in 66.3% of patients, while solitary lesions were observed in 33.7%. The cerebral hemispheres were the most common site of involvement (55.4%). Ring enhancement was the predominant MRI enhancement pattern (56.6%). Perilesional edema was present in 86.7% of patients, mass effect in 59.0%, necrosis in 44.6%, midline shift in 25.3%, and intratumoral hemorrhage in 16.9%. A significant association was found between primary tumor type and hemorrhagic metastases (P value = 0.021), as well as between lesion number and perilesional edema (P value = 0.034). **Conclusions:** Magnetic resonance imaging is an effective tool for the evaluation of brain metastases and provides valuable information regarding lesion morphology, distribution, and associated intracranial changes. Multiple lesions, cerebral hemispheric involvement, ring enhancement, and perilesional edema were the most common MRI findings. MRI remains essential for accurate diagnosis, treatment planning, and follow-up of patients with metastatic brain disease.

KEYWORDS: Brain metastases; Hemorrhage; Magnetic resonance imaging; Neoplasms; Perilesional edema; Tumor burden.

1-INTRODUCTION

Brain metastases represent the most common intracranial tumors in adults and constitute a major cause of morbidity and mortality among patients with systemic malignancies. Advances in cancer diagnosis and treatment have significantly improved patient survival; however, prolonged survival has been accompanied by an increased incidence of metastatic spread to the central nervous system. It is estimated that brain metastases occur in approximately 20–40% of adult cancer patients

during the course of their disease, making them a significant clinical challenge in modern oncology.[1]

The development of brain metastases is associated with substantial neurological impairment, reduced quality of life, and poor prognosis. Clinical manifestations vary according to the location, size, and number of metastatic lesions and may include headache, seizures, focal neurological deficits, cognitive dysfunction, and altered mental status. Early detection and accurate characterization of brain metastases are therefore essential for appropriate treatment planning and improving patient outcomes.[2]

Lung cancer is the most common primary malignancy associated with brain metastases, accounting for nearly half of all cases, followed by breast cancer, melanoma, renal cell carcinoma, and colorectal cancer. The likelihood of cerebral metastatic spread depends on the biological behavior of the primary tumor, disease stage, and molecular characteristics of the malignancy. Recent advances in systemic therapies have altered patterns of metastatic dissemination and increased the importance of neuroimaging in oncological follow-up.[3]

Magnetic resonance imaging (MRI) is considered the imaging modality of choice for the detection and evaluation of brain metastases because of its superior soft-tissue contrast resolution and multiplanar imaging capabilities. Compared with computed tomography, MRI demonstrates significantly higher sensitivity for detecting small lesions, lesions located in the posterior fossa, and lesions situated at the gray-white matter junction. Furthermore, MRI provides detailed information regarding lesion morphology, enhancement characteristics, surrounding vasogenic edema, hemorrhage, necrosis, and mass effect.[4]

Typical MRI features of brain metastases include well-defined enhancing lesions surrounded by variable degrees of vasogenic edema. Most metastatic lesions exhibit ring or heterogeneous enhancement following gadolinium administration, although imaging appearances may vary according to the primary tumor type. Hemorrhagic metastases are commonly associated with melanoma, renal cell carcinoma, choriocarcinoma, and certain lung cancers, whereas cystic or necrotic changes may be observed in larger lesions. Understanding these radiological characteristics is important for differentiating metastatic lesions from primary brain tumors and other intracranial pathologies.[5]

Advanced MRI techniques have further improved the diagnostic evaluation of brain metastases. Diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), susceptibility-weighted imaging (SWI), and magnetic resonance spectroscopy (MRS) provide additional functional and physiological information that may aid lesion characterization and treatment monitoring. These techniques contribute to improved diagnostic accuracy and may help distinguish tumor recurrence from treatment-related changes following surgery, radiotherapy, or systemic therapy.[6]

Although brain metastases constitute a major cause of neurological morbidity among patients with systemic malignancies, data regarding their magnetic resonance imaging characteristics remain limited in Iraq. Detailed evaluation of MRI findings may improve the detection and characterization of metastatic brain lesions, facilitate accurate differential diagnosis, and support appropriate therapeutic planning. Therefore, this study was conducted to investigate the MRI characteristics of brain metastases in patients with malignancy attending Al-Thaqalayn Oncology Hospital in Basra, Iraq, with particular emphasis on lesion number, anatomical distribution, enhancement patterns, perilesional edema, hemorrhagic changes, and the relationship between imaging findings and primary tumor origin. The results of this study may contribute to a better understanding of the radiological spectrum of brain metastases and enhance diagnostic accuracy in routine clinical practice.

2-PATIENTS AND METHODS

Ethical approval for the study was obtained from the Scientific and Ethical Committee of Al Basra Directorate of Health. Patient confidentiality was maintained throughout the study by anonymizing all collected data and restricting access to study records. This retrospective observational study was conducted at Al-Thaqalayn Oncology Hospital, Basra, Iraq, to evaluate the magnetic resonance imaging characteristics of brain metastases in patients with malignant tumors. The study was carried out over a period extending from May 2022 to March 2026.

A total of 83 patients with histopathologically confirmed primary malignancies and radiologically diagnosed brain metastases were included in the study. Patients of both genders and all adult age groups who underwent brain MRI examination during the study period were eligible for inclusion. Patients with primary brain tumors, non-neoplastic intracranial lesions, incomplete imaging records, or poor-quality MRI studies that precluded adequate assessment were excluded from the study.

Data were retrospectively collected from patients' medical records, radiology reports, and the Picture Archiving and Communication System (PACS). The collected variables included age, sex, primary tumor type, number of metastatic lesions, lesion size, anatomical location, enhancement pattern, presence of perilesional edema, hemorrhagic changes, necrosis, mass effect, and associated midline shift.

All MRI examinations were performed using standard brain imaging protocols, including T1-weighted, T2-weighted, fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), and post-contrast

T1-weighted sequences. Images were reviewed by experienced radiologists, and brain metastases were characterized according to their radiological features. Lesions were classified as solitary or multiple and were further evaluated regarding their distribution within the cerebral hemispheres, cerebellum, brainstem, or multiple intracranial compartments.

The primary outcome measures were the MRI characteristics of brain metastases, including lesion number, anatomical distribution, enhancement pattern, perilesional edema, and hemorrhagic changes. Secondary outcomes included the relationship between imaging findings and the primary site of malignancy.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 31. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Associations between categorical variables were analyzed using the Chi-square test or Fisher's exact test when appropriate. A P value of less than 0.05 was considered statistically significant.

3-RESULTS

The study included 83 patients with brain metastases secondary to systemic malignancies. Males represented 53.0% of the study population, while females accounted for 47.0%, with male to female ratio of 1.12:1. The largest age group was 50–64 years (45.8%), followed by patients aged 65 years and older (28.9%). These findings indicate that brain metastases were predominantly encountered among middle-aged and elderly patients. As shown in Table 1.

Table 1: Demographic characteristics of the study population (n = 83).

Variable	Number	Percentage (%)
Male	44	53.0%
Female	39	47.0%
<50 years	21	25.3%
50–64 years	38	45.8%
≥65 years	24	28.9%

Table 2 showed that lung cancer was the most common primary malignancy associated with brain metastases, accounting for 37.3% of cases. Breast cancer represented the second most common primary tumor, followed by colorectal cancer. Less frequent primary tumors included renal cell carcinoma, melanoma, ovarian cancer, gastric cancer, pancreatic cancer, prostate cancer, and endometrial cancer.

Table 2: Distribution of primary tumors (n = 83).

Primary Tumor	Number	Percentage (%)
Lung cancer	31	37.3%
Breast cancer	19	22.9%
Colorectal cancer	10	12.0%
Renal cell carcinoma	7	8.4%
Melanoma	5	6.0%
Ovarian cancer	4	4.8%
Gastric cancer	3	3.6%
Pancreatic cancer	2	2.4%
Prostate cancer	1	1.2%
Endometrial cancer	1	1.2%
Total	83	100.0%

Table 3 showed that multiple metastatic lesions were identified in 66.3% of patients, whereas solitary metastases were observed in 33.7%. The predominance of multiple lesions is consistent with the known pattern of hematogenous dissemination of metastatic disease to the brain.

Table 3: Number of brain metastatic lesions (n = 83).

Number of Lesions	Number	Percentage (%)
Solitary lesion	28	33.7%
Multiple lesions	55	66.3%

The cerebral hemispheres were the most frequently involved anatomical location, accounting for more than half of all cases. Multiple intracranial locations were identified in 26.5% of patients, while isolated cerebellar and brainstem involvement were less common. As shown in Table 4.

Table 4: Anatomical distribution of brain metastases (n = 83).

Location	Number	Percentage (%)
Cerebral hemispheres	46	55.4%
Cerebellum	12	14.5%
Brainstem	3	3.6%
Multiple intracranial locations	22	26.5%

Ring enhancement represented the predominant MRI enhancement pattern and was observed in more than half of patients. Heterogeneous enhancement was the second most common pattern, whereas homogeneous enhancement was identified in a smaller proportion of lesions. As shown in Table 5.

Table 5: MRI enhancement patterns of brain metastases (n = 83).

Enhancement Pattern	Number	Percentage (%)
Ring enhancement	47	56.6%
Heterogeneous enhancement	21	25.3%
Homogeneous enhancement	15	18.1%

Perilesional edema was the most frequent associated MRI finding and was present in 86.7% of patients. Mass effect was observed in 59.0% of cases, while necrosis was identified in 44.6%. Intratumoral hemorrhage and midline shift were less common but clinically significant findings. This is shown in Table 6.

Table 6: Associated MRI findings (n = 83).

MRI Finding	Number	Percentage (%)
Perilesional edema	72	86.7%
Mass effect	49	59.0%
Midline shift	21	25.3%
Intratumoral hemorrhage	14	16.9%
Necrosis	37	44.6%

Table 7 showed the relationship between primary tumor type and hemorrhagic metastasis. A statistically significant association was observed between primary tumor type and the occurrence of hemorrhagic brain metastases (P value = 0.021). Hemorrhagic lesions were more frequently encountered among patients with melanoma and renal cell carcinoma compared with other primary tumors.

Table 7: Relationship between primary tumor type and hemorrhagic metastases.

Primary tumor	Hemorrhage present	Hemorrhage absent	P value
Lung cancer	4 (12.9%)	27 (87.1%)	**0.021**
Breast cancer	2 (10.5%)	17 (89.5%)	
Colorectal cancer	1 (10.0%)	9 (90.0%)	
Renal cell carcinoma	3 (42.9%)	4 (57.1%)	
Melanoma	3 (60.0%)	2 (40.0%)	
Ovarian cancer	0 (0.0%)	4 (100.0%)	
Gastric cancer	0 (0.0%)	3 (100.0%)	
Pancreatic cancer	1 (50.0%)	1 (50.0%)	
Prostate cancer	0 (0.0%)	1 (100.0%)	
Endometrial cancer	0 (0.0%)	1 (100.0%)	

There was a significant relationship between lesion number and the presence of perilesional edema (P value = 0.034). Patients with multiple metastatic lesions demonstrated a higher frequency of edema compared with those who had solitary lesions.

Table 8: Relationship between lesion number and perilesional edema.

Lesion Number	Edema present	Edema absent	P value
Solitary lesion	21 (75.0%)	7 (25.0%)	**0.034**
Multiple lesions	51 (92.7%)	4 (7.3%)	

4- DISCUSSION

The present study evaluated the magnetic resonance imaging characteristics of brain metastases in patients with systemic malignancies and demonstrated that multiple metastatic lesions were more common than solitary lesions, with the cerebral hemispheres representing the predominant site of involvement. Ring enhancement was the most frequent MRI enhancement pattern, while perilesional edema was the most common associated radiological finding. These findings emphasize the important role of MRI in the detection and characterization of metastatic brain lesions and support its value as the imaging modality of choice for evaluating intracranial metastatic disease.

The mean age of the study population was 57.2 ± 11.8 years, and the majority of patients were aged 50 years or older. This finding is consistent with the established epidemiology of brain metastases, which are more commonly encountered among middle-aged and elderly individuals due to the increasing incidence of systemic malignancies with advancing age. Similar age distributions were reported by **Smits**[5] and **Morana *et al***.[7], who observed that brain metastases occur predominantly in patients older than 50 years.

In the current study, males constituted a slightly higher proportion of patients than females. This finding may be explained by the high prevalence of lung cancer, which was the most common primary malignancy associated with brain metastases in the present cohort. Similar observations were reported by **Suh *et al***.[3], who found that lung cancer remains the leading source of brain metastases worldwide and contributes substantially to the male predominance observed in many studies.

Lung cancer was identified as the most frequent primary tumor, accounting for 37.3% of cases, followed by breast cancer and colorectal cancer. This finding agrees with previous reports indicating that lung cancer is responsible for approximately 40–50% of all brain metastases, followed by breast cancer, melanoma, renal cell carcinoma, and colorectal cancer.[3,6] The predominance of lung cancer may be attributed to its aggressive biological behavior and high propensity for hematogenous dissemination to the central nervous system.

Multiple metastatic lesions were observed in 66.3% of patients, whereas solitary lesions were identified in 33.7%. This result is consistent with the findings of **Fink and Fink**[6], who reported that multiple lesions are present in the majority of patients with brain metastases due to widespread hematogenous tumor spread. The predominance of multiple lesions further highlights the importance of comprehensive MRI evaluation of the entire brain to avoid underestimation of disease burden.

Regarding lesion distribution, the cerebral hemispheres were the most frequently involved anatomical location, accounting for more than half of all cases. This observation is in agreement with previous studies demonstrating that metastatic lesions preferentially occur at the gray-white matter junction of the cerebral hemispheres because of regional blood flow characteristics and vascular anatomy.[4,5] Cerebellar and brainstem metastases were considerably less common, although they remain clinically important due to their association with significant neurological deficits.

Analysis of MRI enhancement characteristics revealed that ring enhancement was the predominant pattern, followed by heterogeneous enhancement. Similar findings have been reported by **Ahmed *et al***.[12], who demonstrated that ring enhancement represents the most characteristic imaging feature of metastatic brain lesions owing to central necrosis and peripheral tumor vascularity. The identification of typical enhancement patterns is valuable in differentiating metastatic lesions from primary brain tumors and other intracranial pathologies.

Perilesional edema was present in 86.7% of patients and represented the most frequent associated MRI finding. Mass effect and necrosis were also common, whereas hemorrhage and midline shift were less frequently encountered. These findings are consistent with those reported by **Smits**[5], who emphasized that extensive vasogenic edema is a hallmark feature of brain metastases and contributes significantly to patient symptoms and neurological impairment.

A statistically significant association was observed between primary tumor type and the occurrence of hemorrhagic metastases (P value = 0.021). Hemorrhagic lesions were particularly frequent among patients with melanoma and renal cell carcinoma. This finding agrees with previous studies that identified melanoma, renal cell carcinoma, choriocarcinoma, and certain lung cancers as tumors with a high tendency toward intratumoral hemorrhage because of their vascular nature and fragile neoplastic vessels.[2,4] Recognition of this association is important because hemorrhagic metastases may influence treatment planning and surgical decision-making.

The present study also demonstrated a significant relationship between lesion number and the presence of perilesional edema (P value = 0.034). Patients with multiple metastases exhibited a higher frequency of edema than those with solitary lesions. Similar findings have been reported by **Morana *et al***.[7], who suggested that increasing tumor burden is associated with greater disruption of the blood-brain barrier and more extensive vasogenic edema. Consequently, patients with multiple lesions often present with more severe neurological symptoms and may require more aggressive management.

Several limitations should be considered when interpreting the results of this study. The retrospective design may have introduced selection bias, and the study was conducted at a single institution, which may limit the generalizability of the findings. In addition, the relatively small sample size for certain primary tumor types may have affected statistical comparisons. Nevertheless, the study provides valuable information regarding the MRI characteristics of brain metastases in Iraqi patients and contributes to the limited regional literature on this important oncological condition.

5- CONCLUSION AND RECOMMENDATION

The present study demonstrated that magnetic resonance imaging is a highly valuable modality for the evaluation of brain metastases, providing detailed information regarding lesion number, anatomical distribution, enhancement characteristics, and associated findings. Multiple lesions, cerebral hemispheric involvement, ring enhancement, and perilesional edema were the most common MRI features observed. Significant associations were identified between primary tumor type and hemorrhagic metastases, as well as between lesion number and the presence of edema. These findings highlight the pivotal role of MRI in the diagnosis and characterization of metastatic brain disease. Therefore, routine MRI evaluation should be performed in patients with malignancies who are at risk of intracranial metastatic spread, while advanced MRI techniques should be increasingly incorporated into clinical practice to improve diagnostic accuracy and treatment planning. Further multicenter prospective studies with larger sample sizes are recommended to validate these findings and expand the understanding of brain metastases in the Iraqi population.

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