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Brain metastasis mimicking brain abscess: illustrative case and systematic review

Anoop S. Chinthala, BS,[1] Barnabas Obeng-Gyasi, MD,[2] Kenneth L. Virgin, BS,[1] Macy Deckert, BS,[1] and Gordon Mao, MD[1]

[1]Department of Neurological Surgery, Indiana University School of Medicine, Indianapolis, Indiana; and [2]Department of Neurological Surgery, Allegheny Health Network, Pittsburgh, Pennsylvania

BACKGROUND Diffusion-weighted imaging (DWI) is a valuable tool in distinguishing brain abscesses from neoplastic lesions, with restricted diffusion often interpreted as indicative of infection. However, some metastatic brain lesions can mimic abscesses both radiologically and clinically, presenting a diagnostic challenge.

OBSERVATIONS A 58-year-old woman presented with confusion and was found to have multiple ring-enhancing brain lesions with uniform restricted diffusion on DWI. Initial imaging raised concern for pyogenic abscesses, and empiric antibiotics were initiated. However, systemic imaging revealed a left upper lobe lung mass, and stereotactic biopsy confirmed metastatic adenocarcinoma. The authors performed a systematic review and identified 28 studies describing metastatic lesions with restricted diffusion, most involving solitary lesions with partial restriction. Only a few described multiple lesions with partial restricted diffusion. Lung adenocarcinoma was the most common primary source.

LESSONS This case illustrates that metastatic disease can mimic abscesses on DWI, particularly when lesions are ring enhancing and diffusion restricting. In the absence of clear infectious signs, a broader differential should be considered. Clinical context, systemic imaging, and early biopsy may help clarify the diagnosis and guide appropriate management.

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KEYWORDS brain metastasis; diffusion-weighted imaging; restricted diffusion; ring-enhancing lesion

Ring-enhancing brain lesions on MRI represent a broad differential diagnosis, including both infectious and neoplastic etiologies.[1] Among these, pyogenic brain abscesses and necrotic or cystic brain metastases often present similarly on conventional MRI, frequently complicating timely and accurate diagnosis. While clinical signs of infection may be absent or nonspecific in patients with cerebral abscesses, advanced MRI techniques, particularly diffusion-weighted imaging (DWI), have emerged as valuable tools in distinguishing these entities.[2–4]

Pyogenic abscesses are typically characterized by restricted diffusion within the lesion core, often accompanied by the "dual-rim sign" on susceptibility-weighted imaging.[2,3] This imaging feature reflects a well-formed capsule. Conversely, most metastatic brain lesions, particularly necrotic or cystic metastases, exhibit central areas of unrestricted diffusion on the apparent diffusion coefficient (ADC) view.[2]

Although several studies have described the utility of DWI and ADC calculations in differentiating cerebral abscesses from tumors, the notion that restricted diffusion within ring-enhancing lesion is pathognomonic for infection has been questioned.[5,6] This overlap poses a diagnostic dilemma, particularly in immunocompromised or patients with a high risk of cancer. We present a rare case of a patient with multiple metastatic brain lesions that are fully ring enhancing with restricted diffusion. To our knowledge, no systematic review has been conducted specifically evaluating the incidence, imaging characteristics, and underlying pathology of brain metastases presenting with restricted diffusion. Therefore, the objective of this review is to synthesize the available literature on the clinical and radiological features of metastatic brain lesions that mimic abscesses on DWI, with particular attention to lesion morphology, primary tumor origin, and patterns of diffusion restriction.

Illustrative Case

A 58-year-old female with a past medical history significant for hypertension, tobacco use (1 pack per day), and emphysema was transferred from an outside hospital for multiple brain lesions. She initially developed flu-like symptoms about a month prior. The patient

ABBREVIATIONS ADC = apparent diffusion coefficient; DWI = diffusion-weighted imaging; MRS = MR spectroscopy.
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also experienced a 10-pound unintentional weight loss. The patient had been admitted to an outside hospital 3 weeks prior for confusion. She tested negative for the flu, and her laboratory results were unremarkable. A subsequent visit to her primary care physician led to an emergency department referral for further workup.

Initial CT imaging of the head at the outside hospital suggested a new brain mass (Fig. 1), and a chest radiograph raised concern for a new lung mass. CT imaging of the chest confirmed a left upper lobe lung mass measuring 2.4 × 1.6 cm with scattered pulmonary nodules, left hilar and subcarinal lymphadenopathy, and pulmonary fibrosis. Brain MRI showed multiple peripherally enhancing lesions with internal diffusion restriction in the posterior fossa, right parieto-occipital lobes, and right temporal lobe, concerning for abscesses (Fig. 2A–L). Notably, all lesions demonstrated significant cerebral edema with high-intensity T2 FLAIR signal changes in the surrounding white matter. The lesions showed intense restriction with markedly elevated DWI signal intensity and correspondingly low ADC values.

On examination, the patient was alert and oriented (Glasgow Coma Scale score 15), with no focal deficits. Her physical examination was otherwise unremarkable. Her white blood cell count was elevated at 13,000 but she was afebrile. She was started on vancomycin, cefepime, and metronidazole for broad-spectrum antibiotic therapy. The neurosurgery team was consulted for evaluation of the brain lesions, and Keppra was started for seizure prophylaxis. Brain MRI was ordered to further evaluate intracranial lesions. Brain MRI showed numerous small 1- to 2-cm rim-enhancing lesions associated with vasogenic edema, including a 2.2-cm right parieto-occipital lesion abutting the right atrium ventricular wall. There was no hydrocephalus. All lesions showing restriction on DWI are concerning for possible abscess versus metastasis. Given the possibility of abscess with ventricular rupture, performing small emergency right-sided stereotactic abscess draining of the periventricular lesion was discussed with the patient, to avoid the high mortality risks associated with ventriculitis.

The patient underwent a stereotactic biopsy of the left parietal lobe abscess, where 3–5 ml of purulent fluid was aspirated and sent for pathological analysis. Initial findings suggested a brain abscess. Postoperatively, the patient was slightly confused but oriented to self and date. Her inflammatory markers (C-reactive protein 0.7 mg/L, erythrocyte sedimentation rate 17 mm/hr) were stable, and she remained afebrile. Her neurological examination was otherwise stable. However, overnight, the patient developed new-onset incontinence and worsening leg weakness, with nondermatomal numbness in the bilateral feet. MRI of the lumbar spine revealed extensive enhancement of the cauda equina nerve roots, suggesting infectious myelitis or leptomeningeal carcinomatosis (Fig. 3). The patient's condition was further complicated by worsening weakness in her right plantar flexion and dorsiflexion. A head CT revealed increased vasogenic edema and midline shift. By postoperative day 3, the patient continued to show signs of confusion, but no new seizures were noted.

On postoperative day 4, the pathology report of the brain biopsy confirmed metastatic adenocarcinoma with lung origin. The patient was transferred to the floor on postoperative day 5, and neurosurgery determined that further surgical intervention was unnecessary due to the number of lesions. The radiation oncology department was consulted for palliative radiation therapy to address both brain and spinal lesions. The patient began radiation therapy, which included 3D conformal radiation therapy to the whole brain and palliative radiation treatment to the lumbosacral spine. She received 10 radiation treatments in total. Prior to discharge to home with 24-hour assistance on postoperative day 19, the patient had a port placed for chemotherapy.

Informed Consent

The necessary informed consent was obtained in this study.

Discussion

Observations

We conducted a systematic search of the PubMed, Embase, and Cochrane Library databases for studies published in the English language from database inception through April 2025. The search strategy, developed with assistance from a medical librarian, combined MeSH terms and keywords related to brain metastasis, brain abscess, restricted diffusion, and DWI. Two reviewers independently screened all titles and abstracts. Relevant studies were imported into Covidence and reviewed in full by three investigators to determine final inclusion.

Studies were eligible if they examined patients with brain metastases that demonstrated restricted diffusion on DWI. We excluded studies that did not involve brain metastases, did not mention restricted diffusion, or lacked quantitative data on how many patients exhibited restricted diffusion. Studies involving metastases with superimposed

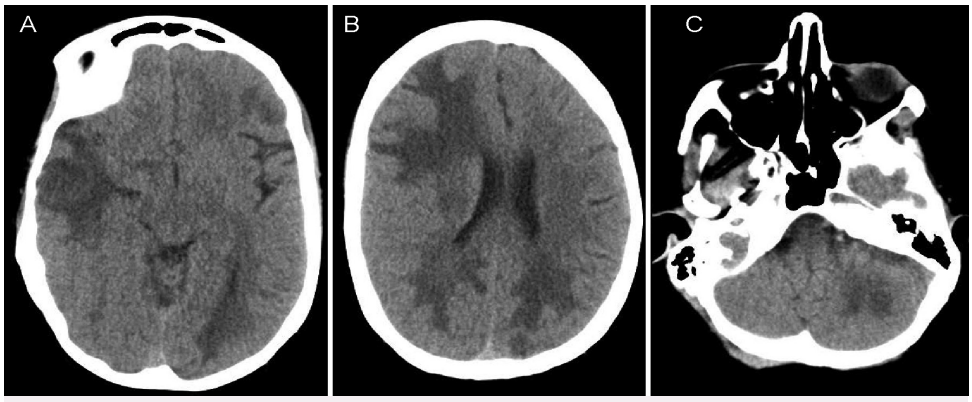

FIG. 1. Noncontrast axial CT scans of the head obtained at admission, showing a right-sided hypodense lesion in the frontoparietal lobe (**A**), diffuse edema (**B**), and a left-sided hypodense lesion in the occipital lobe (**C**).

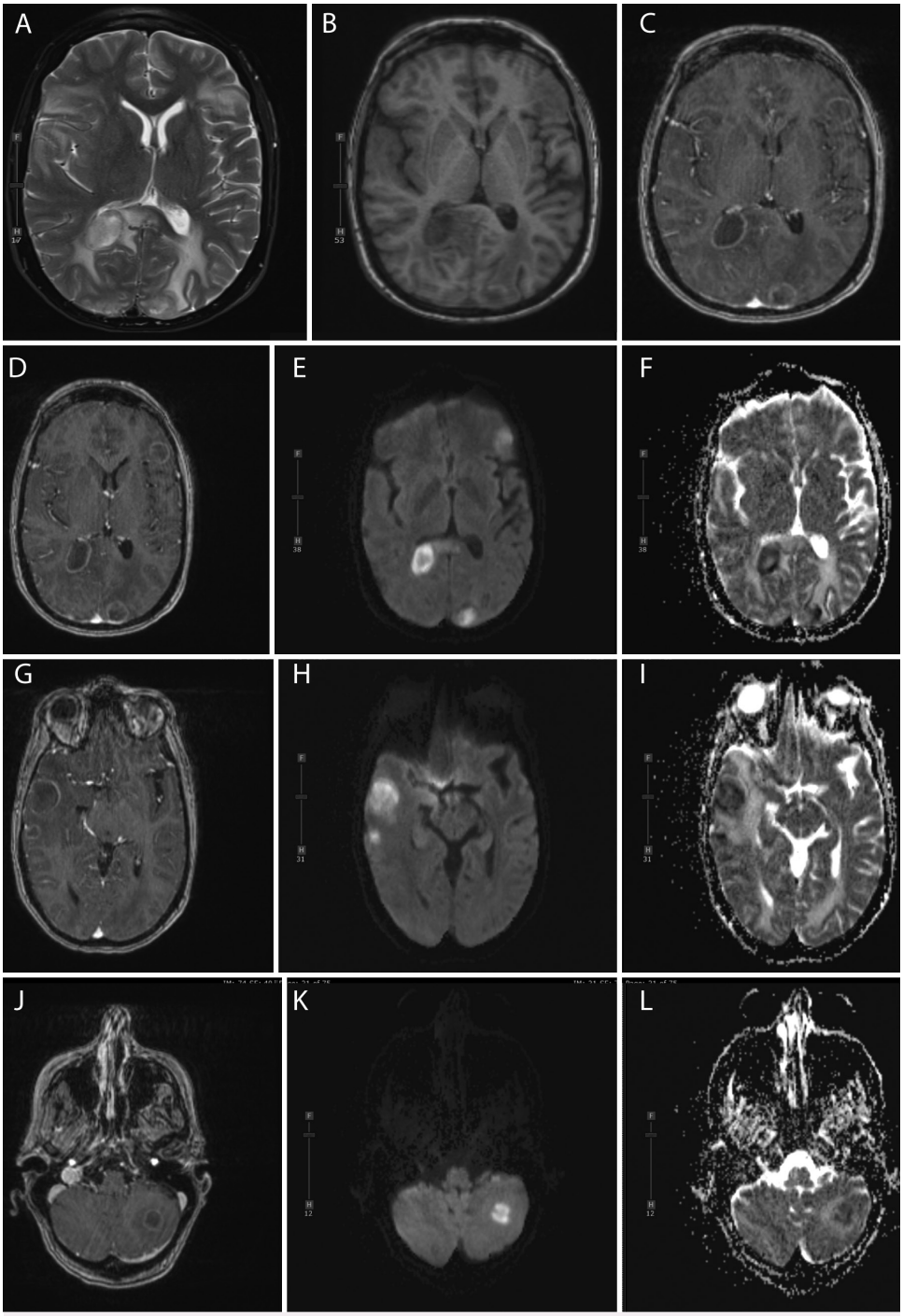

FIG. 2. Preoperative axial MR images of the brain showing a moderate T2 hyperintense lesion in the right parieto-occipital periventricular lesion with associated edema (**A**), a T1 hypointense circumferential lesion (**B**), and multiple ring-enhancing lesions (**C and D**). Diffusion-weighted image showing hyperintense, ring-enhancing lesions (**E**) with restricted diffusion confirmed on the ADC view (**F**). Right temporal ring-enhancing lesion (**G**). Diffusion-weighted image showing lesions (**H**) with restricted diffusion confirmed on the ADC view (**I**). Left-sided, hypointense, rim, fully ring-enhancing lesion in the occipital lobe (**J**). Diffusion-weighted image showing hyperintense lesions (**K**) but with hypointensity on the ADC view (**L**), confirming diffusion restriction.

abscesses were also excluded. Eligible study designs included case reports, case series, observational studies, retrospective cohort studies, and cross-sectional studies.

Three reviewers independently extracted data using a standardized form. Data collected included the number of patients with brain metastases, number with restricted diffusion, type of restriction (partial

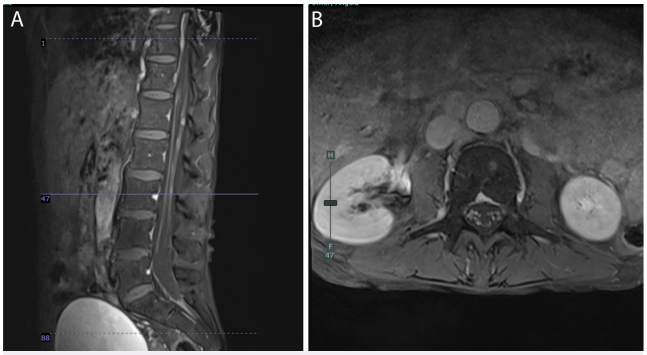

FIG. 3. Postoperative sagittal (**A**) and axial (**B**) lumbar MR images with contrast, showing leptomeningeal metastasis.

vs full), lesion multiplicity (single vs multiple), primary tumor origin, and final pathological diagnosis. Discrepancies were resolved by consensus or consultation with a fourth reviewer. The study selection process is detailed in Fig. 4.

We provide a descriptive and narrative synthesis of the findings, highlighting common patterns and variations across studies. This review adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and has been registered in PROSPERO (registration no. CRD420251025717).

This case highlights a rare but clinically significant imaging pattern in metastatic brain lesions: multiple ring-enhancing lesions with uniform restricted diffusion on DWI (Fig. 2A–L). This radiographic constellation is traditionally associated with pyogenic brain abscesses and may mislead clinicians, particularly in the absence of overt infectious symptoms. In our patient, the presence of restricted diffusion across all lesions initially suggested a diagnosis of cerebral abscesses. However, biopsy revealed metastatic adenocarcinoma of pulmonary origin.

One particularly important observation in this case is the complete radiological mimicry of brain abscesses by metastatic lesions in both imaging morphology and diffusion characteristics. All lesions demonstrated not only ring enhancement but also complete and well-defined uniform restricted diffusion—features that are strongly associated with bacterial abscesses. This led to the initial assumption of an infectious etiology, initiation of broad-spectrum antibiotics, and biopsy. However, the patient's clinical presentation, including absence of fever and normal inflammatory markers, was discordant with a typical abscess course.

Additionally, the detection of a left upper lobe mass on chest imaging, along with widespread pulmonary nodules and lymphadenopathy, offered an important systemic clue to the underlying diagnosis. The early decision to perform a stereotactic biopsy was critical and enabled timely redirection of treatment from empiric antibiotics to oncological management. The development of spinal symptoms and subsequent MRI revealing leptomeningeal spread further supported a metastatic process and emphasized the aggressiveness of the underlying malignancy.

Our systematic review of 28 studies encompassing 551 patients revealed several key trends (Table 1). First, the vast majority of brain metastases with restricted diffusion were solitary lesions, and only a small minority of cases described multiple enhancing lesions with diffusion restriction. Of those, most showed only partial restriction. Our case was unusual in that it demonstrated multiple, uniformly diffusion-restricting, and completely ring-enhancing lesions. Second, lung cancer was the predominant primary tumor type, accounting for more than two-thirds of reported cases with restricted diffusion. Within lung primaries, adenocarcinoma and small cell carcinoma were the most frequently identified histologies. Other primary sources included breast, prostate, gastrointestinal tract, and hematological malignancies, but these were much less commonly associated with restricted diffusion.

Among the 551 patients reported, 22% were identified to have restricted diffusion. Many had restricting metastases originated from the lung, with adenocarcinoma being the most common subtype. Of the 28 studies, only 3 reported multiple lesions with full or near-complete restricted diffusion, but none matched the uniformity and number of lesions seen in our case. Furthermore, 14 of the included reports were case reports, often lacking granular detail on imaging parameters, lesion morphology, or follow-up outcomes. This limited the ability to perform meta-analysis but supported the rarity of this presentation.

Additionally, our review highlighted that while DWI is a sensitive tool for detecting abscesses, the specific pattern of complete ring enhancement with restricted diffusion is not pathognomonic. Instead, it may be seen in hypercellular metastatic tumors, hemorrhagic lesions, or necrotic neoplasms. The literature suggests a spectrum of diffusion characteristics among metastases, with some displaying heterogeneous or rim-like restriction due to central necrosis and peripheral tumor viability. In contrast, uniform restriction across all lesions, as in this case, remains exceedingly rare. The frequent overlap in imaging characteristics between abscesses and metastases, particularly when using DWI alone, emphasizes the necessity of interpreting imaging findings in the context of comprehensive clinical and laboratory data.

Limitations

This study is limited by the inherent constraints of a systematic review consisting largely of case reports and retrospective studies, which may introduce selection and reporting bias. Many included studies lacked uniform imaging protocols or detailed descriptions of DWI findings, making direct comparisons challenging. Additionally, data on clinical outcomes and long-term follow-up were inconsistently reported. As a single-institution case report, the generalizability of our findings is also limited. Further prospective studies with standardized imaging interpretation are needed to better characterize the radiographic spectrum of brain metastases with restricted diffusion.

Lessons

Clinicians should exercise caution when interpreting DWI findings in ring-enhancing brain lesions, particularly in patients without clinical or laboratory evidence of infection. The presence of multiple, uniformly ring-enhancing lesions with restricted diffusion does not exclude a neoplastic etiology. Our literature review demonstrates that although restricted diffusion is a hallmark of brain abscesses, it is not exclusive to infectious etiologies. Most prior reports describe only partial restriction or incomplete enhancement, making our case of multiple uniformly restricted lesions particularly unique. Several authors have highlighted cases of misdiagnosed metastasis, often delayed due to reliance on imaging features alone.[7,8] This highlights the importance of integrating clinical history, imaging, and pathology for accurate diagnosis.

The diagnostic overlap between abscess and metastasis poses both therapeutic and prognostic implications. Misclassification can lead to inappropriate use of broad-spectrum antibiotics, delays in initiating oncological therapy, and unnecessary surgical interventions. In contrast, prompt identification of metastatic disease allows for timely

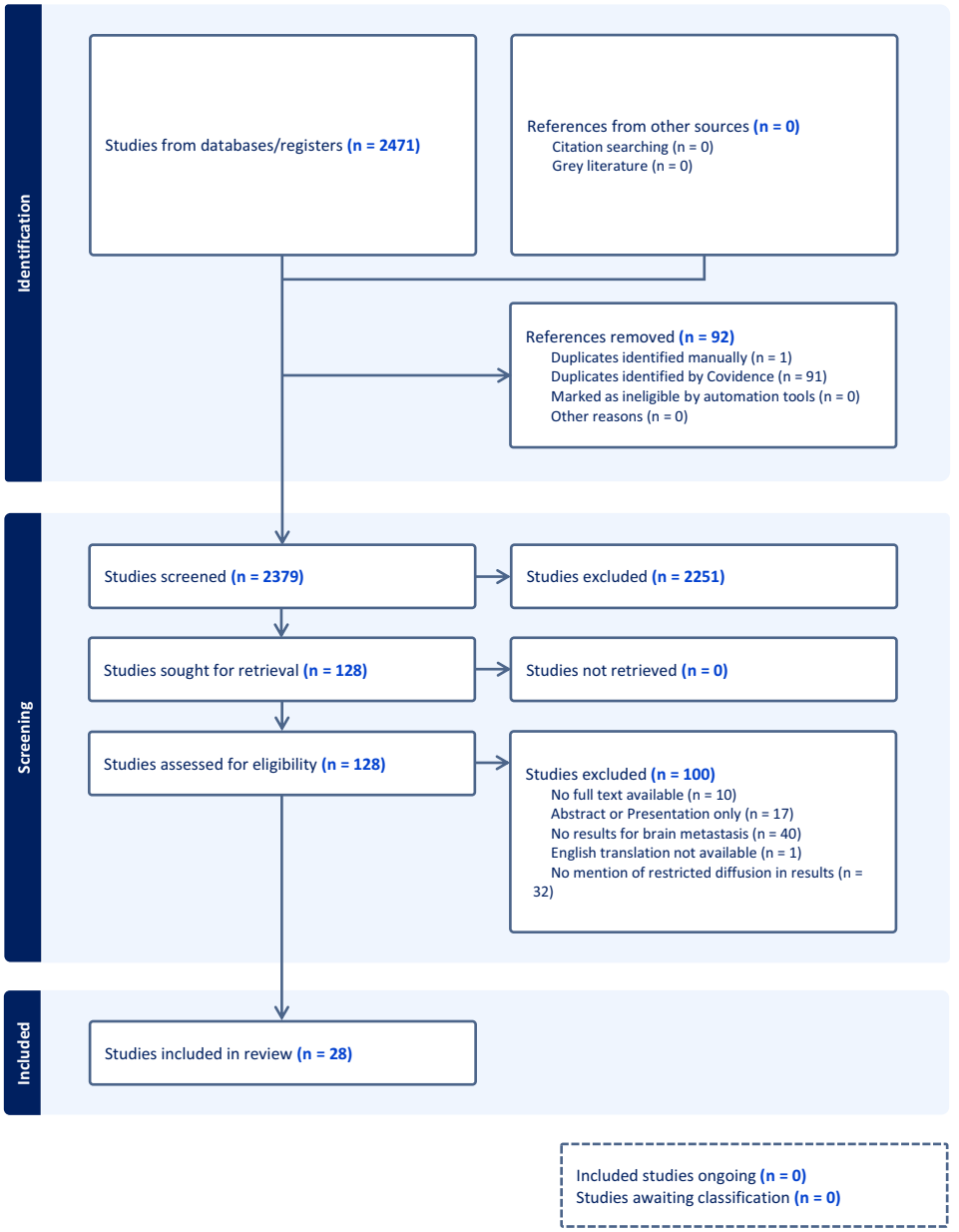

FIG. 4. PRISMA flow diagram. Data added to the PRISMA template (from Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71) under the terms of the Creative Commons Attribution (CC BY 4.0) License (https://creativecommons.org/licenses/by/4.0/).

staging and multidisciplinary planning for palliative or disease-directed treatment. Given the consequences of misdiagnosis, a structured diagnostic algorithm that includes early tissue sampling in ambiguous cases may be warranted, especially in patients with risk factors for malignancy and without systemic signs of infection.

The clinical implications of misdiagnosis extend beyond delayed appropriate therapy. Empirical treatment with broad-spectrum intravenous antibiotics, while potentially lifesaving in true infectious cases, can significantly delay initiation of systemic chemotherapy and other oncological interventions when the underlying etiology is metastatic disease. Furthermore, prolonged antibiotic therapy introduces unnecessary risks, including *Clostridioides difficile*–associated colitis, allergic reactions, and central line–associated bloodstream infections in patients requiring vascular access for presumed brain abscess treatment. These iatrogenic complications can further compromise already vulnerable cancer patients and delay definitive oncological care.

TABLE 1. Summary of key findings from literature review

Authors & Year	Study Design	No. of Pts w/ Metastasis	No. of Metastases w/ Restricted Diffusion	Partial or Full Restricted Diffusion	Single or Multiple Lesions (n)	Primary Origin (n)	Pathology (n)
Tung et al., 2001[13]	Retro cohort	5	2	—	Single	Lung	Squamous cell carcinoma
Li et al., 2022[14]	Case report	1	1	Partial	Single	Lung	Adenocarcinoma
Park et al., 2000[15]	Retro cohort	39	2	—	Single	Lung (1), bladder (1)	Adenocarcinoma (1), transitional cell carcinoma (1)
Hartmann et al., 2001[5]	Retro cohort	17	1	Partial	Single	Lung	Adenocarcinoma
Duygulu et al., 2010[11]	Retro cohort	87	15	—	—	Lung (10), breast (3), colon (1), testicle (1)	Small cell carcinoma (5), non–small cell carcinoma (5), breast carcinoma (3), colon adenoma carcinoma (1), teratocarcinoma (1)
Holtås et al., 2000[7]	Case report	1	1	Full	Multiple	Lung	Adenocarcinoma
Sakatani et al., 2019[8]	Case report	1	1	Partial	Single	Lung	Non–small cell carcinoma
Besada et al., 2010[16]	Case report	1	1	Partial	Single	Lung	Adenocarcinoma
De Keersmaecker et al., 2024[1]	Case report	1	1	Partial	Multiple	Lung	Small cell carcinoma
Taydas et al., 2020[17]	Case report	1	1	Full	Single	Blood	Acute lymphocytic leukemia
Bilgin et al., 2023[18]	Retro cohort	292	58	—	—	—	—
Schneck et al., 2005[19]	Case series	4	3	—	Multiple (3)	Lung (3)	Small cell carcinoma (2), poorly differentiated carcinoma (1)
Abou Zeid et al., 2012[20]	Retro cohort	8	1	Partial	Single	—	—
Taj-Aldean, 2017[21]	Prospective cohort	19	5	—	—	—	—
Erdogan et al., 2005[22]	Retro cohort	7	1	—	—	Lung	Adenocarcinoma
Sharma et al., 2023[23]	Retro cohort	1	1	—	—	—	—
Pérez-Riverola et al., 2023[24]	Case report	1	1	Full	Single	Lung	Adenocarcinoma
Guruprasad et al., 2004[9]	Case report	1	1	Partial	Single	Lung	Adenocarcinoma
Ishihara et al., 2011[25]	Case report	1	1	Partial	Multiple	Blood	Natural killer/T-cell lymphoma
Mortimer et al., 2010[26]	Case report	1	1	Partial	Single	Lung	Squamous cell carcinoma
Mori et al., 2002[27]	Case report	1	1	Partial	Single	Lung	Carcinoma (unspecified)
Yousef et al., 2014[28]	Retro cohort	10	2	—	—	—	—
Hatzoglou et al., 2014[29]	Retro cohort	21	4	—	—	Prostate	Adenocarcinoma
Saito et al., 2015[12]	Case report	1	1	Partial	Single	Lung	Mucoepidermoid carcinoma
Zacharzewska-Gondek et al., 2017[30]	Case report	1	1	Partial	Multiple	Lung	Small cell carcinoma
Greco Crasto et al., 2007[31]	Retro cohort	20	8	—	Multiple	Lung	—
Nabavizadeh et al., 2014[32]	Retro cohort	7	2	—	Single & multiple	—	Neuroblastoma
Dziadziuszko et al., 2014[33]	Case report	1	1	Partial	Multiple	Lung	Adenocarcinoma

Pts = patients; retro = retrospective; — = not available.

A systematic review was conducted according to PRISMA guidelines to identify the prevalence and radiological characteristics of brain metastases presenting with restricted diffusion. Studies were included if they discussed restricted diffusion in patients with cerebral metastases. Studies were excluded if the lesions lacked diffusion restriction, included intratumoral abscesses, or did not specify the number of lesions per patient. Databases searched included PubMed, Embase, and Cochrane Library.

Therefore, early tissue diagnosis becomes even more critical to avoid both therapeutic delays and unnecessary treatment-related morbidity.

Our systematic review revealed that this specific radiographic pattern—multiple metastases with uniform restricted diffusion—is exceedingly rare. Most prior reports have described solitary lesions with partial restriction or incomplete ring enhancement. Importantly, our review demonstrates that DWI findings must be interpreted within the clinical context, as reliance on this modality in isolation may lead to diagnostic error. Although DWI is a powerful tool for identifying restricted diffusion, it lacks specificity in distinguishing between infectious and neoplastic etiologies. Several of the reviewed cases demonstrated that metastases, particularly those from lung primaries, can exhibit restricted diffusion due to high tumor cellularity, central necrosis, or hemorrhagic transformation.

In addition, the absence of classic radiographic features seen in abscesses, such as the characteristic rim of low signal on DWI or central T2 hypointensity, may provide subtle but critical diagnostic clues, which was notably absent in our case. As the radiological overlap continues to expand with improved imaging resolution, clinicians should become familiar with such nuances. Anchoring bias may contribute

significantly to diagnostic delay in such cases. The recognition of ring-enhancing lesions with restricted diffusion often prompts a reflexive diagnosis of abscess, which may lead clinicians to overlook discordant clinical information. Our findings reinforce that ring enhancement with restricted diffusion is not pathognomonic for abscess and that diagnostic anchoring on this pattern can obscure consideration of neoplastic etiologies. A broader differential should always be maintained, particularly in patients without overt infectious signs or with known malignancy risk factors.

The overlap in imaging features between abscess and metastasis illustrates the limitations of relying on DWI alone. Advanced imaging techniques such as MR spectroscopy (MRS) may provide additional diagnostic utility in distinguishing metastatic lesions from abscesses,[9,10] although this modality is not readily available or feasible at most non-tertiary hospitals. MRS typically demonstrates elevated choline peaks in neoplastic lesions, including brain metastases, reflecting increased cellular proliferation and membrane turnover. Conversely, brain abscesses more commonly show elevated lactate peaks, indicating anaerobic metabolism within the infected tissue. However, these spectroscopic findings are not definitively diagnostic, as overlap can occur between infectious and neoplastic processes. The limited availability of MRS at many institutions further restricts its practical application in acute diagnostic scenarios.

Our case and review of the literature support a critical take-home point: intracranial lesions that demonstrate ring enhancement with restricted diffusion on DWI, in the absence of definitive infectious symptoms or laboratory evidence of infection, should prompt strong consideration of a neoplastic etiology, particularly metastatic disease. Providers should maintain a high index of suspicion and pursue early imaging of the chest, as lung cancer remains the most common primary malignancy associated with this radiographic pattern.[11,12] DWI is a powerful imaging tool, but it should be interpreted in the broader clinical context. Clinical history, examination findings, laboratory studies, and, when needed, histopathological confirmation are essential to avoid diagnostic error and ensure timely, appropriate management.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Mao, Chinthala, Obeng-Gyasi. Acquisition of data: all authors. Analysis and interpretation of data: Mao, Chinthala, Obeng-Gyasi, Virgin. Drafting the article: Mao, Chinthala, Obeng-Gyasi. Critically revising the article: Mao, Chinthala, Obeng-Gyasi, Virgin. Reviewed submitted version of manuscript: Mao, Chinthala, Obeng-Gyasi, Virgin. Approved the final version of the manuscript on behalf of all authors: Mao. Statistical analysis: Chinthala, Obeng-Gyasi. Administrative/technical/material support: Obeng-Gyasi. Study supervision: Mao.

Correspondence

Gordon Mao: Indiana University Health Neuroscience Center, Indianapolis, IN. gomao@iu.edu.