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Review Article

Comparison of PET/CT and PET/MRI in central nervous system tumors, a narrative review

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Abstract: Background: PET/CT and PET/MRI are two useful imaging modalities in neuro-oncology. Our aim was to review the existing literature on the benefits and drawbacks of using PET/CT and PET/MRI in the diagnosis of central nervous system (CNS) tumors. Methods: A literature search was conducted using valid databases, limited to English-language articles published between 2010 and 2023, and independently reviewed by two reviewers. A standard data extraction form was used to extract data from the included papers. The results were condensed and narratively presented, accompanied by supporting data from the included investigations. Results: The study analyzed 28 articles, mostly from Europe. The results varied, with some studies comparing PET/CT and PET/MRI, examining specific types of brain tumors, pediatric tumors, or focusing on specific PET/CT or PET/MRI modalities. The synthesis aimed to provide a comprehensive overview of PET/CT and PET/MRI use in CNS malignancies. Conclusions: PET/MRI offers promising advantages in neuro-oncology diagnosis and follow-up imaging, but its use should be prioritized in appropriate situations.

Keywords: PET/MRI, PET/CT, neuro-oncology, CNS tumors

Introduction

Primary central nervous system tumors have one of the highest incidence rates of cancer across all age groups. In 2023, it is estimated that 24,810 individuals will be diagnosed with primary malignancies of the brain and spinal cord [1]. Positron emission tomography/computed tomography (PET/CT) and positron emission tomography/magnetic resonance imaging (PET/MRI) are two key methods used to diagnose and monitor tumors of the central nervous system (CNS) [2]. PET/CT and PET/MRI are both imaging techniques that combine positron emission tomography (PET) with either computed tomography (CT) or magnetic resonance imaging (MRI). PET/CT is widely used for cancer detection, staging, and monitoring because CT provides detailed anatomical information and PET highlights metabolic activity. PET/MRI, on the other hand, offers superior soft tissue contrast, making it more suitable for neurological, musculoskeletal, and certain abdominal imaging. Additionally, MRI avoids radiation exposure, which is a consideration in pediatric and frequent imaging scenarios. The choice between the two depends on the clinical focus, with PET/CT favored for oncology and PET/MRI for soft tissue and brain studies [1]. Physicians can assess the stage of a tumor and whether it has migrated to other parts of the body by using information from PET/CT and PET/MRI scans regarding the metabolic activity of the tumor. These imaging modalities can also be utilized to track the progress of a patient's treatment and identify any tumor recurrence [3].

PET is a valuable tool that complements MRI by addressing unresolved issues related to lesion grading, tumor extent definition, and treatment

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response evaluation. While MRI remains the predominant imaging technique for brain cancers, the advent of hybrid PET/MRI technology allows for the acquisition of structural, functional, and molecular information on brain tumors in a single scan, effectively combining the strengths of both imaging modalities [4].

It is crucial to compare the features of PET/CT and PET/MRI to understand the advantages and disadvantages of each imaging modality and determine which is best suited for a given clinical situation [5]. By carefully evaluating the pros and cons of PET/CT and PET/MRI, clinicians can select the most appropriate imaging modality for a specific patient, leading to more accurate diagnoses and more targeted treatments. Given the lack of consistency in findings from previous studies, the purpose of this study is to review the literature on the use of PET/CT and PET/MRI in CNS tumors and to assess the advantages and disadvantages of each.

Methods

We conducted a thorough literature search using PubMed, Embase, Web of Science, and the Cochrane Library databases. The search was limited to English-language articles published between 2010 and 2023, using the terms "PET/CT", "PET/MRI", and "central nervous system tumor". To identify additional relevant studies, we also manually reviewed the reference lists of the selected articles.

Two reviewers independently assessed the titles and abstracts of the selected publications to ensure their relevance. If an article met the inclusion criteria, its full text was retrieved for further evaluation. The inclusion criteria were: (1) the article had to be original; (2) it had to be published in English; and (3) it had to be published between 2010 and 2023. Any disagreements between the reviewers were resolved through consensus and discussion. Reviews, letters to the editor, and case-report articles were excluded.

Data extraction from the selected papers was conducted using a standard data collection form. The extracted information included the author, publication year, methodology, number of participants, intervention or exposure, outcome measures, and findings. The quality of the included studies was assessed using the Cochrane Risk of Bias tool for randomized controlled trials and the ROBINS-I tool for non-randomized studies.

A narrative technique was used to synthesize the gathered data. The results were condensed and narratively presented, accompanied by supporting data from the included investigations. In this study, we compared several key parameters between PET/CT and PET/MRI for the assessment of CNS tumors. These parameters included sensitivity and specificity in tumor detection, the ability to accurately characterize and differentiate between tumor recurrence and treatment-related changes, and the overall diagnostic performance. Additionally, we evaluated the radiation dose associated with each modality, noting that PET/MRI provides a lower radiation dose compared to PET/CT, which is particularly advantageous in pediatric and frequent imaging contexts.

We also assessed the cost and accessibility of both modalities, recognizing that PET/MRI, despite its clinical benefits, is more expensive and less widely available than PET/CT. The clinical utility of each modality was further explored in terms of their roles in diagnosis, treatment planning, and follow-up, with PET/MRI showing particular promise in specific scenarios, though its advantages over PET/CT were not universally consistent across all studies.

Results

A total of twenty-eight articles met our inclusion criteria (**Figure 1**). The majority of these studies were conducted in Europe (n=18), followed by Asia (n=5), the United States (n=4), and Australia (n=1). The studies exhibited a diverse range of research trends, with mixed results. Some focused on the advantages and disadvantages of PET/CT alone, PET/MRI alone, or even PET alone, while others compared these modalities. Certain studies concentrated on specific types of brain tumors, including pediatric tumors, while others investigated particular types of PET/CT or PET/MRI, such as 18F-FDG-PET/CT or 18F-FET PET/MRI. Our synthesis of the literature aimed to provide a comprehensive overview of the use of PET/CT and PET/MRI in central nervous system malignancies, taking into account all relevant aspects.

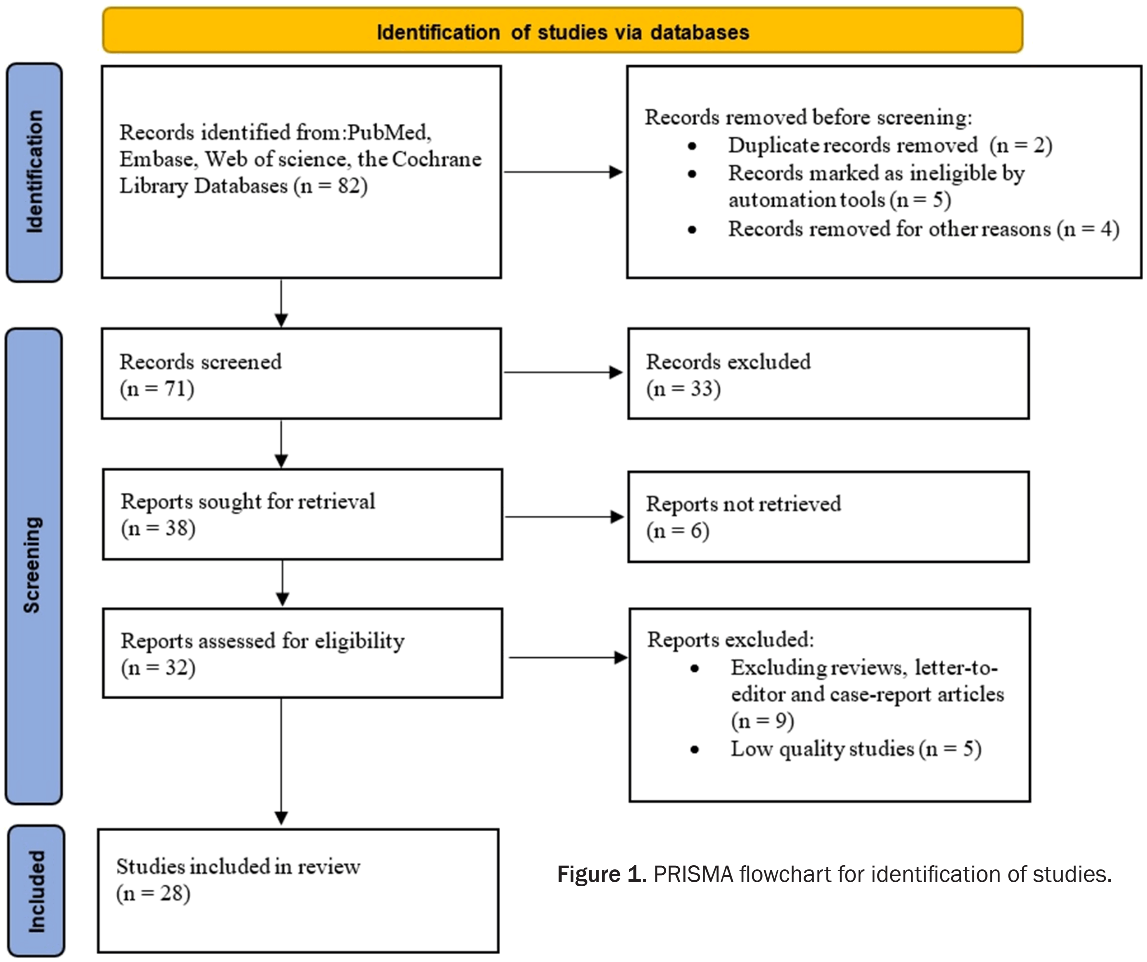

Figure 1. PRISMA flowchart for identification of studies.

Discussion

The goal of this narrative review was to provide a comprehensive overview of the applications of PET/CT and PET/MRI in the detection and management of CNS cancers. We identified 28 papers that met our inclusion criteria, which reflected a wide range of study trends. The inconsistent findings across these studies highlight the need for further investigation in this area. Recent research has shown that PET is particularly useful in guiding clinical management and determining the therapeutic outlook for patients [6, 7]. One of the key strengths of PET is its ability to precisely characterize functional aspects of tumors, aiding in the selection of targeted and quantifiable treatment options [8]. PET is crucial in identifying malignant tissue, assessing tumor dimensions for further evaluation and therapeutic decisions (such as biopsy or resection) [9], evaluating the response to specific cancer treatments [10], and distinguishing between treatment-related changes (like pseudoprogression and radiation necrosis) and actual tumor progression in follow-up studies [11]. Moreover, molecular PET has been suggested as a non-invasive tool that opens new avenues for the diagnosis of CNS tumors and the detection of malignant changes [8] (**Table 1**).

The study highlighted several key differences, advantages, and disadvantages between PET/CT and PET/MRI in the diagnosis of central nervous system tumors. PET/CT is widely available, faster, and generally more cost-effective, making it a practical choice in many clinical settings. It also offers superior attenuation correction and spatial resolution, providing detailed anatomical information. In contrast, PET/MRI excels in soft tissue contrast, making it particularly valuable for brain imaging, and exposes patients to less radiation, which is crucial for pediatric patients and those needing multiple

Table 1. Comparing advantages and disadvantages of PET/CT with PET/MRI

Imaging modality	PET/CT	PET/MRI
Advantages	1. Compared to PET/MRI, PET/CT is less expensive and more readily available [23]. 2. Compared to MRI, PET/CT is more sensitive in identifying tiny lesions [24]. 3. MRI is not as effective as PET/CT in identifying bone metastases [24]. 4. Compared to MRI, PET/CT has a higher spatial resolution [24].	1. In most cancer cases, PET/MRI offers sensitivity and specificity that are either similar to or better than PET/CT and MRI [25]. 2. One benefit of PET/MRI is that it may be obtained in a single session, which can save imaging time and costs [23, 25]. 3. Compared to PET/CT, PET/MRI offers superior soft tissue contrast [25].
Disadvantages	1. Patients are exposed to ionizing radiation during PET/CT scans [24].	1. Compared to PET/CT and MRI, PET/MRI is more costly and not yet generally accessible [23]. 2. For the detection of bone metastases, PET/MRI is not as effective as PET/CT [25].

scans. PET/MRI also benefits from multi-parametric imaging, integrating functional and anatomical data in a single scan, which is useful for monitoring tumor progression and treatment response. However, PET/MRI is more expensive, less accessible, and requires longer scan times, limiting its widespread use. Ultimately, the choice between PET/CT and PET/MRI depends on the specific clinical scenario, balancing the need for detailed imaging against practical considerations like cost, availability, and patient safety.

PET/CT and related imaging modalities are well-established, offering several benefits such as cost-effectiveness, speed, familiarity, and ease of use [12]. They are highly accurate for differential diagnosis in neuro-oncology, providing valuable information.

However, the question remains whether PET/CT or PET/MRI is the ideal choice. In the early days of PET/MRI, studies comparing it to PET/CT often concluded that PET/MRI could not easily replace PET/CT [13]. Over time, opinions have increasingly favored PET/MRI, particularly due to its advantages such as a lower radiation dose [14], improved motion correction, and the practicality of an integrated scan [12]. The addition of PET to MRI has enhanced the ability to precisely assess the metabolism and function of CNS tumors, significantly increasing the value of PET/MRI. This capability has proven especially beneficial in monitoring malignancy progression and differentiating between tumor recurrence and benign changes after treatment, often more effectively than PET/CT [3].

PET/MRI is advantageous in diagnosis, treatment, and follow-up [11]. It provides valuable benefits, such as determining tumor extent for further diagnostic evaluation, assessing tumor response to treatment, and supporting radiotherapy or chemotherapy. Additionally, PET/MRI is effective in differentiating between tumor progression and regression during follow-up. Previous studies have concluded that PET/MRI has significant potential to improve patient outcomes [6, 11, 15]. Furthermore, research has demonstrated that PET/MRI offers comparable or even superior sensitivity and specificity to both PET/CT and MRI in most cancer cases, while also being performed in a single visit. These findings support the theoretical benefits of PET/MRI in clinical practice [16].

On the other hand, PET/MRI has two main drawbacks: its higher cost and limited accessibility compared to more widely available imaging techniques. Additionally, some studies suggest that PET/MRI does not offer significant advantages over PET/CT for new diagnoses and that its benefits may be marginal. It has been argued that MRI alone can be as valuable as PET/MRI for early diagnosis [17]. Future research should focus on comparing the outcomes of MRI alone, PET/CT, and PET/MRI across a large number of patients during both initial diagnosis and follow-up periods. Such studies could provide clearer insights into where PET/MRI offers the most benefit to patients.

The majority of experts agree that PET/MRI excels in multi-parametric imaging and soft tissue contrast compared to PET/CT. Conversely, PET/CT provides superior attenuation correction and spatial resolution [3]. Some studies have suggested specific imaging modalities for particular types of brain tumors, as shown in **Table 2**.

Table 2. Summary of some studies with suggestion of specific imaging modalities

Year of publication	Authors	Brain tumors	Recommended modality
2017	Yaru Zou et al. [26]	Primary CNS lymphoma	18F-FDG PET and PET/CT
2019	Domenico Albano et al. [27]	Glioma/Glioblastoma	18F-FACBC PET/CT or PET/MRI
2020	Francesco Bertagna et al. [28]	Glioma/Glioblastoma	Radiolabled PSMA PET
2022	Chong Hyun Suh et al. [29]	Primary CNS lymphoma	PET/CT
2022	Guisheng Zhang et al. [30]	Primary CNS lymphoma/High-grade gliomas	18F-FDG-PET/CT

Recent investigations have shown growing interest in FET PET, which uses the radioactive tracer 18F-fluoro-ethyl-tyrosine (18F-FET) to identify and diagnose primary brain cancers [18]. FET PET has demonstrated good diagnostic performance for primary brain tumors, with a pooled sensitivity of 0.82 and specificity of 0.76 [19]. It has also proven useful in detecting glioma progression [20], identifying patients who respond to adjuvant temozolomide chemotherapy [21], and predicting overall and progression-free survival [22]. However, studies on this imaging method remain limited, and further research is needed to fully understand its potential.

Our narrative review has certain limitations. Firstly, the authors' choices for sampling and analysis may have influenced the synthesis and rigor of the review, as is common in any review process. Secondly, there is a possibility that some relevant research was overlooked, which could have impacted our conclusions. This study was conducted as a literature review rather than a meta-analysis, and as such, our results section does not include the extensive quantitative analysis often associated with meta-analyses. Instead, we aimed to synthesize and summarize existing research on PET/CT and PET/MRI in the diagnosis of central nervous system tumors based on the available literature. This approach limits the depth of the results compared to a meta-analysis, which would provide pooled data and statistical insights. The variability in study designs, methodologies, and outcomes among the included studies may also affect the generalizability of our findings. Future research should consider conducting meta-analyses to offer quantitative comparisons between PET/CT and PET/MRI, incorporating data from a larger number of studies to enhance statistical power. Longitudinal studies investigating the clinical outcomes of each imaging modality in different patient populations and tumor types, as well as research on the cost-effectiveness and accessibility of PET/MRI compared to PET/CT, would provide valuable insights. Additionally, exploring advancements in imaging technologies to address current limitations could contribute to more effective diagnostic approaches in neuro-oncology.

Conclusions

This narrative review concluded that PET/MRI offers promising advantages over PET/CT for both new diagnoses and follow-up imaging in neuro-oncology. However, due to the higher cost and lower availability of PET/MRI, its use should be prioritized for specific situations where its benefits are most significant. Despite the advantages of PET/MRI, PET/CT remains an important tool in the imaging of CNS tumors. Gaining a deeper understanding of the advantages and disadvantages of both PET/MRI and PET/CT will help make more informed clinical decisions. Future research should involve larger sample sizes and more diverse populations to enhance the generalizability of the findings. Additionally, exploring the impact of different sampling and analysis methods on the rigor and synthesis of reviews could provide valuable insights.

Disclosure of conflict of interest

None.

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