Journal Innovation, Social, and Environment

Volume 2, Number 2, 2026
Open Access: https://journisen.com/journisen

Early Neurological Manifestations of Brain Tumors and the Role of Public Health Systems: A Literature Review

Romel Ciptoadi Wijaya[1], Arya Satya Rajanagara[2,3*],

[1]Faculty of Medicine, Universitas Islam Malang, Malang, Indonesia

[2]China Medical University, Taichung, Taiwan

[3]Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia

Correspondence: arya.rajanagara01@gmail.com

Article Info

Article history:
Received May 24th, 2026
Revised Jun 10th, 2026
Accepted Jun 18th, 2026

Keyword:

Brain tumors, Neurological symptoms, Diagnostic delay, Public health systems, Primary care

ABSTRACT

Brain tumors remain a major global neurological health challenge associated with substantial morbidity and mortality. Early diagnosis is critical for improving patient outcomes; however, diagnostic delays remain common in both high-income and low and middle-income countries (LMICs). Early symptoms are often nonspecific and may resemble common conditions such as migraine, epilepsy, or stress-related disorders, making timely recognition difficult. This review summarizes the early neurological manifestations of brain tumors, the major factors contributing to diagnostic delay, and the role of public health systems in accelerating diagnosis. Delays may occur at the patient, physician, and healthcare system levels, including limited symptom awareness, misdiagnosis, inadequate clinical suspicion, poor access to neuroimaging, and inefficient referral systems. Addressing these barriers requires a coordinated public health approach involving improved physician training, public awareness campaigns, optimized referral pathways, and expanded access to neuroimaging, particularly in resource-limited settings.

INTRODUCTION

Brain tumors pose a serious neurological challenge with far-reaching implications for global health. The World Health Organization (WHO) estimates that approximately 308,000 new cases of primary brain and central nervous system tumors are diagnosed each year, with considerable variation in incidence across regions and countries.[1] Beyond their impact on mortality, brain tumors cause substantial disability and morbidity, affecting cognitive function, motor performance, and quality of life even among those who survive. The burden extends well beyond the individual patient, imposing high economic costs on healthcare systems and families particularly in resource-constrained settings.[2]

A fundamental challenge in brain tumor management is diagnostic delay, the interval between the onset of symptoms and a definitive diagnosis. This gap has a significant impact on clinical staging, treatment options, and overall prognosis. When a tumor is detected early, less invasive surgical techniques become viable, radiation planning is more effective, and overall survival improves. By contrast, a delayed diagnosis often means the disease has already reached an advanced stage, narrowing the therapeutic options available and diminishing the prospect of cure.[3]

The early manifestations of brain tumors are frequently non-specific neurological symptoms that overlap with those of many common conditions. Headaches, seizures, cognitive changes, and focal neurological deficits represent the most frequent early signs, yet they are often attributed to primary headache disorders, seizure disorders, psychiatric conditions, or stress-related phenomena. This diagnostic ambiguity creates a real risk of misdiagnosis and delayed recognition, particularly in primary care settings where clinical suspicion for brain pathology tends to be low.

The public health implications are especially pronounced in LMICs, where diagnostic delays are more severe due to multiple compounding factors: limited access to advanced neuroimaging, inadequate training among primary care providers in recognizing red flag symptoms, fragmented referral systems, and low public awareness of early warning signs. Understanding the interplay between clinical symptoms, physician-level diagnostic processes, patient behavior, and health system characteristics is essential for designing effective, targeted interventions. This review examines the early neurological manifestations of brain tumors, the multifactorial nature of diagnostic delay, and the pivotal role of public health systems in accelerating diagnosis. We synthesize evidence on symptom recognition, diagnostic algorithms, system-level barriers, and evidence-based interventions to improve outcomes across diverse healthcare settings.

EARLY NEUROLOGICAL MANIFESTATIONS OF BRAIN TUMORS

The clinical presentation of a brain tumor is influenced by several factors, including the anatomical location of the lesion, the rate of tumor growth, and the degree of intracranial pressure elevation. In the early stages, some tumors may remain asymptomatic and are occasionally discovered incidentally during imaging performed for unrelated reasons. When symptoms become apparent, they generally fall into four major categories: headaches, seizures, focal neurological deficits, and cognitive or behavioral disturbances.[4]

Headache

Headache is among the most common presenting symptoms of brain tumors, occurring in approximately 30-50% of patients at diagnosis and in up to 70% during the course of the disease.[5] Although headache is highly prevalent in the general population, certain red flag characteristics may suggest an underlying intracranial lesion. These include: (1) progressively worsening headache in frequency or severity; (2) a change in headache pattern in patients with a prior history of migraine or tension-type headache; (3) headaches that are worse in the morning or awaken the patient from sleep; (4) headache accompanied by vomiting, particularly when unexplained or associated with other neurological symptoms; (5) headache occurring together with focal neurological signs or papilledema; and (6) headache in patients with known systemic malignancy or immunosuppression, raising concern for metastatic or opportunistic intracranial disease.[6]

Several mechanisms contribute to tumor-associated headache, including increased intracranial pressure from mass effect, traction on pain-sensitive intracranial structures such as meninges and blood vessels, obstruction of cerebrospinal fluid circulation, and peritumoral edema.[7] Nevertheless, many brain tumor-related headaches may resemble primary headache disorders, particularly migraine, which can contribute to delayed diagnosis. Neuroimaging should therefore be considered in patients with new or progressive headaches when accompanied by red flag features, abnormal neurological findings, or systemic symptoms suggestive of intracranial pathology.

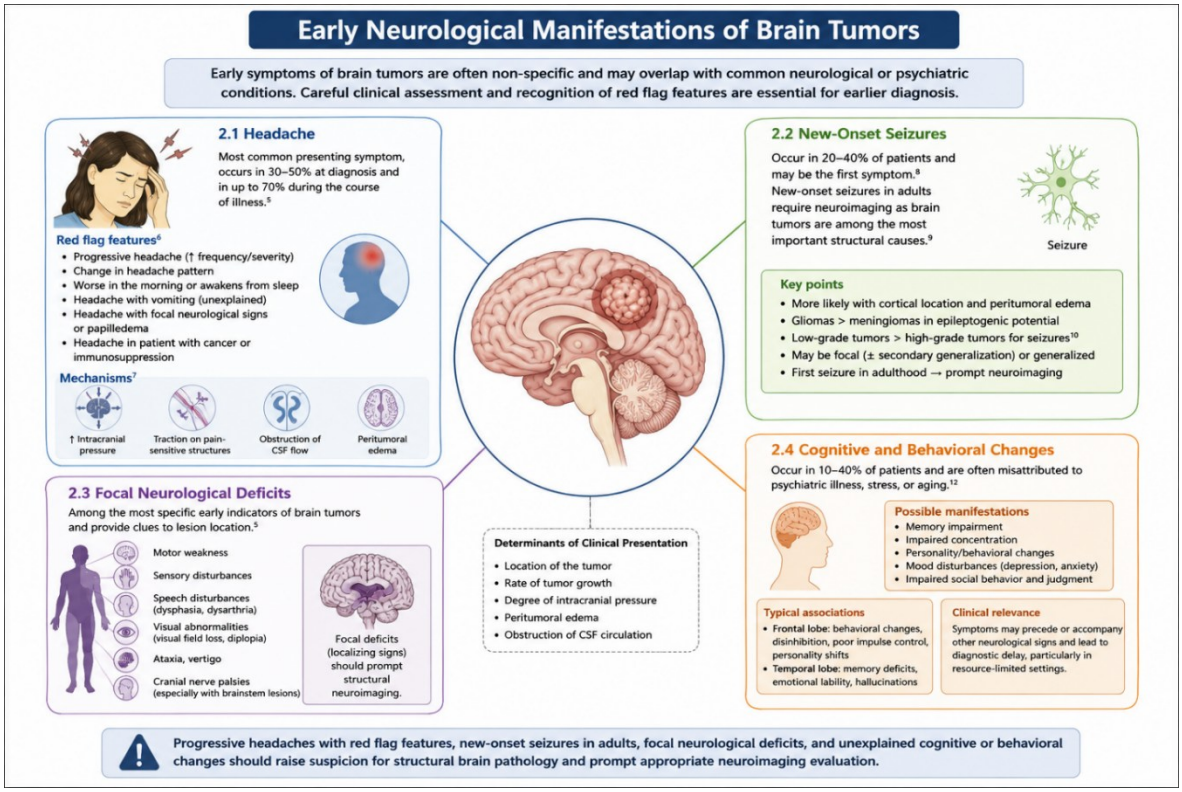

Figure 1. The Major Early Neurological Manifestations Associated with Brain Tumors

New-Onset Seizures

Seizures occur in approximately 20-40% of patients with brain tumors and may represent the first clinical manifestation of the disease.[8] New-onset seizures in adulthood, particularly in individuals over 20 years of age without a prior seizure history, warrant careful evaluation because structural intracranial lesions are an important underlying cause. Brain tumors are among the most clinically significant etiologies identified in this setting.[9] Current clinical guidelines recommend neuroimaging as an essential component of evaluation for adults presenting with first-onset seizures.

Tumors located within the cerebral cortex, especially in functionally eloquent regions, are more likely to provoke seizures, particularly when associated with surrounding edema. Gliomas generally demonstrate greater epileptogenic potential than meningiomas, and low-grade gliomas are more commonly associated with seizures than high-grade tumors.[10] Seizures may present as focal events with or without secondary generalization, or less commonly as generalized seizures. Regardless of seizure type, the occurrence of a first seizure in adulthood should raise suspicion for structural brain pathology and prompt appropriate neuroimaging evaluation.

Focal Neurological Deficits

Focal neurological deficits are considered among the most specific clinical indicators of structural brain lesions and may provide important clues regarding tumor localization. Depending on the affected region, manifestations may include motor weakness, sensory disturbances, speech impairment, visual deficits, ataxia, or vertigo.[5]

Speech disturbances such as dysphasia, dysarthria, or broader language impairment commonly arise from lesions involving the dominant cerebral hemisphere. Cerebellar tumors may present with ataxia, dysmetria, impaired coordination, and vertigo, whereas brainstem lesions frequently produce cranial nerve abnormalities accompanied by motor or sensory deficits. Importantly, objective focal neurological findings substantially increase clinical suspicion for structural intracranial pathology and should prompt timely neuroimaging assessment.

Cognitive and Behavioral Changes

Cognitive and behavioral disturbances are relatively common manifestations of brain tumors, occurring in approximately 10-40% of patients depending on tumor location and assessment methods.[12] These symptoms may be particularly difficult to recognize in the early stages because they are often misattributed to psychiatric disorders, psychological stress, or normal aging processes. Patients may present with memory impairment, decreased concentration, personality changes, mood disturbances such as depression or anxiety, or impaired social judgment and behavior. Tumors involving the frontal lobes are especially associated with behavioral and personality changes, including disinhibition, impaired impulse control, apathy, and altered social conduct. Temporal lobe tumors may instead manifest with memory dysfunction, emotional instability, or hallucinations. Importantly, cognitive and behavioral symptoms may precede other neurological manifestations, and their gradual onset can contribute substantially to diagnostic delay. In resource-limited settings, these presentations may be even more likely to be interpreted as primarily psychological or psychosocial in origin, further delaying appropriate investigation and diagnosis.

Overall, early manifestations of brain tumors are frequently nonspecific and may overlap considerably with common neurological and psychiatric conditions. Progressive headaches with red flag features, new-onset seizures in adults, focal neurological deficits, and unexplained cognitive or behavioral changes should each raise suspicion for structural intracranial pathology. However, because many of these symptoms are also common in benign conditions, determining which patients require neuroimaging remains a significant diagnostic challenge. Careful clinical assessment, detailed history-taking, and recognition of red flag features therefore remain essential for facilitating earlier diagnosis.

DIAGNOSTIC DELAY IN BRAIN TUMORS

Diagnostic delay defined as the interval between the onset of symptoms and a definitive diagnosis is a well-documented phenomenon in brain tumor patients that significantly affects clinical outcomes. Studies consistently show that delays of 2–6 months are common, and in some cases patients wait more than a year before receiving a diagnosis.[13] The causes of diagnostic delay are multifactorial, operating across three distinct levels: the patient, the physician, and the healthcare system.

Patient-Level Delays

Patient-level delays refer to the period between the onset of symptoms and the patient's decision to seek medical care. Multiple factors may contribute to this delay, including: (1) limited awareness or poor health literacy regarding neurological warning signs; (2) attributing symptoms to non-serious causes such as stress, fatigue, or lifestyle-related factors; (3) self-medication using over-the-counter analgesics or alternative therapies; (4) the expectation that symptoms will improve spontaneously; and (5) fear, stigma, or reluctance to undergo medical evaluation in certain cultural or social settings.[14]

In low-resource environments, additional barriers such as financial constraints, transportation difficulties, and long distances to healthcare facilities can further prolong the interval before initial medical consultation.

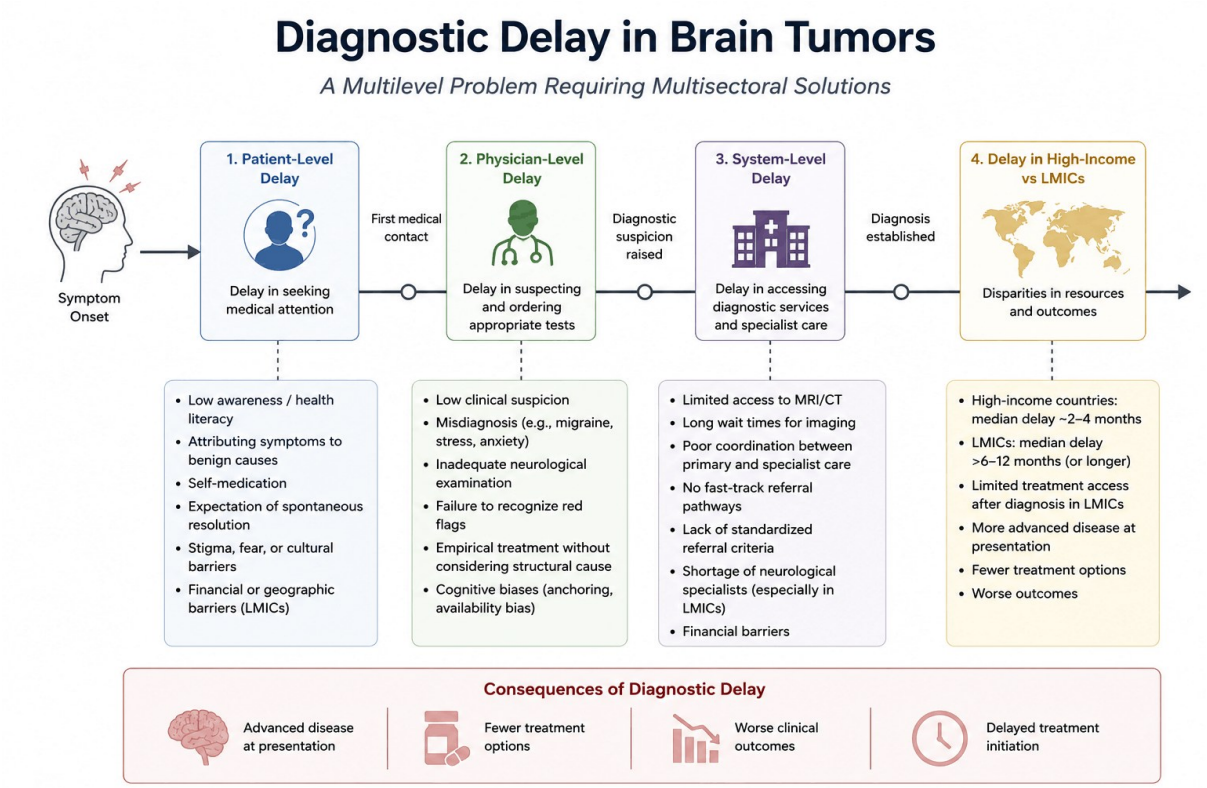

Figure 2. Diagnostic Delays in Brain Tumors

Physician-Level Delays

Physician-level delays describe the time between a patient's first interaction with the healthcare system and the establishment of a definitive diagnosis. These delays contribute substantially to overall diagnostic latency and may arise from several causes, including: (1) low clinical suspicion for brain tumors in primary care settings, where benign conditions are far more common; (2) misclassification of symptoms as migraine, tension-type headache, anxiety disorders, or other functional conditions; (3) incomplete neurological examination or failure to identify red flag symptoms; (4) limited familiarity with diagnostic pathways among frontline healthcare providers; and (5) empirical treatment of presumed benign disorders without adequate consideration of structural intracranial disease.[15] In addition, cognitive biases may contribute to diagnostic error. Anchoring bias may cause clinicians to remain fixed on an initial benign diagnosis despite evolving symptoms, while availability bias may lead physicians to overestimate the likelihood of more commonly encountered conditions. Together, these factors can delay recognition of serious neurological pathology and postpone appropriate neuroimaging or specialist referral.

System-Level Delays

System-level delays arise from structural limitations within healthcare systems that impede timely diagnosis, even after clinical suspicion has been established. Major contributing factors include: (1) inadequate access to advanced neuroimaging modalities such as MRI and CT, particularly in rural

and underserved regions; (2) prolonged waiting times for imaging studies; (3) poor coordination between primary care and specialist services; (4) absence of fast-track referral systems for suspected neurological pathology; (5) lack of standardized referral guidelines; and (6) shortages of neurologists and neurospecialists, especially in low- and middle-income countries (LMICs).[16]

Global disparities in healthcare infrastructure are particularly evident in access to neuroimaging. High-income countries commonly have approximately 10–20 MRI scanners per million population, whereas many LMICs possess fewer than one scanner per million inhabitants.[17] Financial barriers including high out-of-pocket imaging costs, limited insurance coverage, and socioeconomic hardship further restrict access to timely diagnosis in resource-constrained settings. Consequently, patients in LMICs frequently experience prolonged diagnostic delays and are more likely to present with advanced-stage disease.

LMICs versus High-Income Countries

The duration of diagnostic delay differs substantially between high-income countries and LMICs. In higher-resource settings, median diagnostic intervals are generally reported to range from 2-4 months, whereas delays in LMICs often exceed 6-12 months or longer.[18] These disparities largely reflect differences in healthcare infrastructure, neuroimaging availability, specialist expertise, and referral system efficiency.

Importantly, delays in LMICs often continue even after diagnosis has been established. Limited access to surgery, radiotherapy, chemotherapy, and specialist oncology services may postpone treatment initiation for additional months. As a result, patients in resource-limited settings are more likely to present with advanced disease, have fewer therapeutic options available, and experience poorer clinical outcomes compared with patients in wealthier healthcare systems.

THE ROLE OF PUBLIC HEALTH SYSTEMS IN ACCELERATING DIAGNOSIS

Public health systems play a critical role in reducing diagnostic delays through coordinated interventions targeting patient-level, physician-level, and system-level barriers simultaneously. Effective strategies should focus on strengthening primary healthcare services, optimizing referral pathways, improving access to neuroimaging, and increasing public awareness regarding early neurological warning signs.

Primary Care Improvement and Physician Training

Primary care providers often serve as the first point of contact for patients with early neurological symptoms, particularly in resource-limited settings where access to specialists is restricted. Enhancing the diagnostic capacity of primary care physicians through structured education and training programs is therefore essential. Key components include: (1) education regarding red flag symptoms of brain tumors, such as progressive headaches accompanied by neurological signs, new-onset adult seizures, focal neurological deficits, and cognitive or behavioral changes; (2) training on appropriate diagnostic algorithms and indications for neuroimaging; (3) instruction in focused neurological examination techniques; and (4) clear guidance regarding referral pathways and urgency criteria.[19]

Evidence-based clinical decision-support tools and symptom-screening algorithms may further assist frontline healthcare providers in identifying patients at increased risk of serious intracranial pathology. Red flag–based assessment frameworks can help standardize clinical decision-making and

reduce variability in diagnostic practice. In addition, effective communication channels between primary care providers and neurology specialists can facilitate earlier consultation and shorten the time to specialist evaluation.

Referral System Optimization

Many healthcare systems lack standardized referral pathways and efficient fast-track systems for suspected neurological emergencies. The implementation of structured referral protocols with clearly defined criteria for urgent neurological assessment may substantially reduce delays in diagnosis. Fast-track referral systems prioritize patients presenting with red flag symptoms such as new-onset seizures, progressive focal neurological deficits, or rapidly worsening headaches for expedited specialist evaluation, often within one to two weeks.[20] Electronic referral platforms may further improve communication efficiency and reduce administrative delays.

In resource-limited settings, telemedicine and remote specialist consultation provide practical approaches for extending neurological expertise beyond urban tertiary centers. Telephone consultations, video-based assessments, and remote imaging review may support clinical decision-making and facilitate timely referral even in regions with limited local specialist availability. However, these systems require adequate technological infrastructure and provider training to ensure effective implementation.

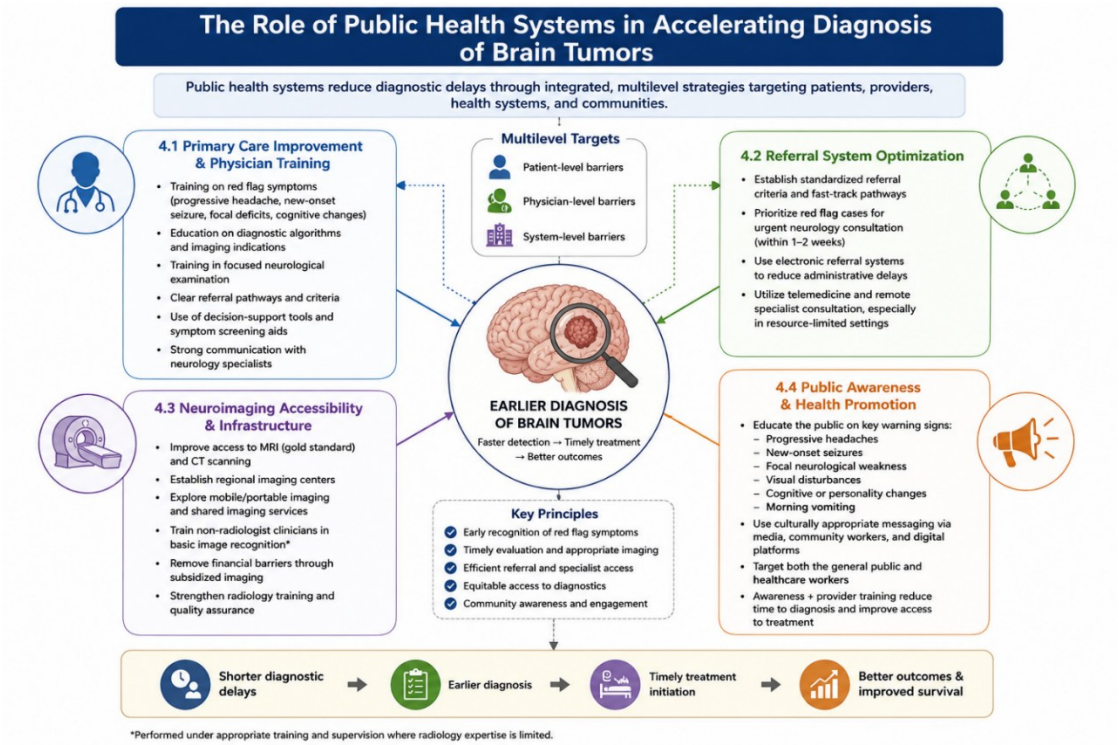

Figure 3. The Role of Public Health Systems in Accelerating Brain Tumor Diagnosis.

Neuroimaging Accessibility and Infrastructure

Access to neuroimaging remains a cornerstone of brain tumor diagnosis. MRI is considered the diagnostic gold standard because of its superior soft-tissue resolution and absence of ionizing radiation

exposure. However, MRI systems are expensive and require substantial technical and operational resources. CT imaging is more widely available and generally less costly, although it provides lower soft-tissue contrast and involves radiation exposure. In LMICs, healthcare systems must balance the diagnostic advantages of advanced imaging modalities against limitations in cost, infrastructure, and accessibility.[21]

Potential strategies to improve imaging accessibility include: (1) establishing regional imaging centers serving wider geographic populations; (2) exploring portable or point-of-care imaging technologies for remote settings; (3) implementing mobile or shared imaging services; (4) training non-radiologist clinicians in basic neuroimaging interpretation; and (5) reducing financial barriers through subsidized imaging programs for patients with suspected serious neurological disease. Expanding radiology training and strengthening quality assurance systems are also essential for maintaining diagnostic accuracy and reliability.

Public Awareness And Health Promotion

Public awareness campaigns aimed at improving recognition of early brain tumor symptoms may encourage individuals to seek medical attention sooner. Educational initiatives should emphasize major neurological red flag symptoms, including progressive headaches, adult-onset seizures, focal neurological weakness, persistent visual disturbances, cognitive or personality changes, and unexplained morning vomiting. Campaign messaging should be culturally appropriate and disseminated through accessible communication channels such as television, radio, digital media, and community healthcare outreach programs. Importantly, awareness initiatives should target both the general population and community-level healthcare workers. Existing evidence suggests that public education campaigns combined with provider training programs may reduce diagnostic delays and improve access to timely treatment.[17]

CLINICAL IMPACT OF DELAYED DIAGNOSIS

Delayed diagnosis of brain tumors carries significant clinical consequences and is strongly associated with poorer patient outcomes. Patients who experience prolonged diagnostic intervals frequently present with more advanced disease, including larger tumor burden, increased peritumoral edema, and more severe neurological impairment at the time of diagnosis.[23] Larger and more advanced tumors are often technically more difficult to resect completely, may invade eloquent brain regions, and can sometimes become only partially resectable or entirely inoperable. These factors may also reduce the effectiveness of adjuvant therapies such as radiotherapy and chemotherapy.

Survival outcomes are closely linked to tumor stage at diagnosis and the extent of surgical resection achieved. In high-grade gliomas, prolonged diagnostic delay has been associated with reduced overall survival, with several studies suggesting that survival outcomes decline progressively as delays increase. In low-grade gliomas, delayed recognition may increase the risk of malignant transformation over time. Similarly, in patients with brain metastases, late diagnosis and treatment are associated with shorter survival duration and reduced quality of life.

Beyond survival, delayed diagnosis contributes substantially to long-term neurological morbidity. Patients may develop permanent neurological deficits, including motor weakness, speech and language impairment, visual disturbances, cognitive dysfunction, and seizure-related complications that might have been minimized through earlier intervention. These impairments often result in chronic disability, loss of independence, and diminished quality of life. Furthermore, delayed diagnosis may

reduce opportunities for optimal multimodal treatment strategies involving surgery, radiation therapy, and chemotherapy.

The economic burden associated with delayed diagnosis is also considerable. Advanced-stage disease typically requires more complex and prolonged treatment, extended hospitalization, intensive supportive care, and long-term rehabilitation. In addition to direct medical expenses, indirect costs related to productivity loss, caregiver burden, and disability management may impose substantial financial strain on patients and families. In many low- and middle-income countries (LMICs), the cost of managing advanced brain tumors may exceed household financial capacity, leading to catastrophic out-of-pocket expenditures and worsening socioeconomic hardship.

CONCLUSION

Brain tumor diagnosis remains a major clinical and public health challenge because early neurological manifestations are often nonspecific and easily mistaken for benign conditions. Symptoms such as progressive headaches, new-onset seizures in adults, focal neurological deficits, and cognitive or behavioral changes frequently contribute to delayed recognition and diagnosis. Diagnostic delay is a multifactorial problem involving patient-level, physician-level, and healthcare system–level barriers. Limited public awareness, misdiagnosis in primary care, insufficient neurological assessment, restricted access to neuroimaging, and fragmented referral systems all contribute to delayed diagnosis, particularly in resource-limited settings and LMICs. The consequences of delayed diagnosis are substantial, including advanced disease presentation, irreversible neurological deficits, reduced treatment opportunities, poorer survival outcomes, and increased economic burden. Reducing these delays requires a coordinated public health approach focused on strengthening primary care training, improving referral pathways, expanding access to neuroimaging, and increasing public awareness of neurological red flag symptoms. Ultimately, improving early detection and timely intervention is essential for enhancing neurological outcomes, treatment effectiveness, and quality of life for patients with brain tumors worldwide.

CONFLICT OF INTEREST

The authors declared there is no conflict of interest.

FIGURE DECLARATION

The figures included in this manuscript were generated with the assistance of ChatGPT (OpenAI) for scientific visualization purposes only. The generated figures did not alter, influence, or modify the scientific content, interpretation, results, or conclusions of the study.

AUTHORS' CONTRIBUTION

Conceptualization of the framework: RCW & ASR. Data analysis, synthesis of the findings, and drafting of the manuscript: ASR. All authors contributed and approved the final version of the manuscript.

REFERENCES

1. Ferlay J, Ervik M, Lam F, et al. *Global Cancer Observatory: Cancer Today*. Lyon, France: International Agency for Research on Cancer; 2024. Available at: https://gco.iarc.fr/today
2. Ostrom QT, Gittleman H, Truitt G, et al. CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2011–2015. *Neuro Oncol*. 2018;20(Suppl 4):iv1–iv86.
3. Dubey A, Kataria S. Role of early diagnosis in improving prognosis of brain tumors. *J Neurosci Rural Pract*. 2016;7(2):342–349.
4. Forsyth PA, Posner JB. Headaches in patients with brain tumors: a study of 111 patients. *Neurology*. 1993;43(9):1678–1683.
5. Rees JH, Smits M. Neuroimaging of brain tumors. *Semin Neurol*. 2016;36(4):379–390.
6. Schwedt TJ, Dodick DW. Secondary headaches: diagnostic clues and best treatment options. *Neurology*. 2015;84(5):e39–e45.
7. Chozick BS. Clinical characteristics of headache caused by brain tumors. *Postgrad Med*. 1991;89(2):91–99.
8. Lote K, Stenwig AE, Skullerud K, Hirschberg H. Prevalence, predictive factors and prognosis of seizures in patients with glioma. *Acta Neurochir (Wien)*. 1998;140(9):882–888.
9. Pallud J, Audureau E, Blonski M, et al. Epileptic seizures in diffuse low-grade gliomas in adults. *Brain*. 2014;137(Pt 2):449–462.
10. Komnos F, Potagas C, Kasselimis D, et al. Seizures in brain tumors: clinical and pathological correlations. *Epileptic Disord*. 2012;14(4):375–387.
11. Klein M, Heimans JJ, Aaronson NK, et al. Neurocognitive dysfunction in adult high-grade glioma patients. *Cancer*. 2003;97(6):1382–1392.
12. Müller K, Henkel A, Diete U, et al. Diagnostic delay in high-grade gliomas—a retrospective analysis of 142 patients. *Nervenarzt*. 2003;74(3):213–218.
13. Darnall RA, Czaban M, Heng Y, et al. Characterizing diagnostic delays in pediatric brain tumors. *Pediatr Blood Cancer*. 2018;65(1):e26809.
14. Brasme JF, Grill J, Doz F, et al. Delays in diagnosis of pediatric brain tumors in France. *Pediatrics*. 2012;130(5):e1013–e1021.
15. Neal RD, Tharmanathan P, France B, et al. Is increased time to diagnosis and treatment in symptomatic cancer associated with poorer outcomes? Systematic review. *Br J Cancer*. 2015;112(Suppl 1):S92–S107.
16. Jaffray DA. Global radiation oncology infrastructure challenges and opportunities. *Front Oncol*. 2020;10:570370.
17. Farmer P, Frenk J, Knaul FM, et al. Expansion of cancer care and control in countries of low and middle income: a call to action. *Lancet*. 2010;376(9747):1186–1193.
18. Starfield B, Shi L, Macinko J. Contribution of primary care to health systems and health. *Milbank Q*. 2005;83(3):457–502.
19. Hjertner L, Barth EH, Ali Z, et al. Prompt referral of patients with clinically diagnosed glioblastoma: impact on diagnosis, treatment, and outcome in a tertiary referral center. *J Neurosurg*. 2016;124(6):1715–1721.

20. World Health Organization. *WHO Global Atlas of Medical Devices*. Geneva: World Health Organization; 2017.
21. Walter FM, Rubin G, Bankhead C, et al. Symptoms and other factors associated with time to diagnosis and stage of lung cancer: a prospective cohort study. *Br J Cancer*. 2015;112(Suppl 1):S6–S13.
22. Ziegler CM, Pressler H, Ziegler JC. Meta-analysis of outcomes for glioblastoma patients who undergo gross total vs subtotal resection. *J Neurosurg Sci*. 2018;62(3):294–301.
23. Stupp R, Mason WP, van den Bent MJ, et al. Radiotherapy plus concomitant and adjuvant temozolomide for glioblastoma. *N Engl J Med*. 2005;352(10):987–996.