e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2025; 16(9); 465-471

Original Research Article

Evaluating the Diagnostic Accuracy of MRI in Brain Tumor Detection and Classification

Mukesh Bihari[1], Sachin Kumar Singh[2]

[1]Assistant Professor, Department of Radiology, Jawaharlal Nehru Medical College and Hospital, Bhagalpur, Bihar, India

[2]Associate Professor, Department of Radiology, Jawaharlal Nehru Medical College and Hospital, Bhagalpur, Bihar, India

Received: 10-07-2025 / Revised: 12-08-2025 / Accepted: 22-09-2025

Corresponding Author: Dr. Sachin Kumar Singh

Conflict of interest: Nil

Abstract:

Background: Brain tumors encompass a heterogeneous group of intracranial neoplasms requiring precise diagnostic evaluation for effective management. Magnetic Resonance Imaging (MRI) has emerged as a superior, non-invasive imaging modality, offering detailed structural and functional assessment compared to conventional techniques.

Aim: To evaluate the diagnostic performance of MRI in identifying and characterizing brain tumors and to correlate MRI findings with histopathological confirmation.

Methodology: A prospective observational study was conducted in the Department of Radiology, Jawaharlal Nehru Medical College and Hospital, Bhagalpur, Bihar, involving 90 clinically suspected brain tumor patients. MRI was performed using a 1.5 Tesla scanner with standard and advanced sequences, and findings were statistically analyzed using SPSS version 27.0.

Results: Gliomas (31.1%) and meningiomas (22.2%) were the most common tumors. Most lesions appeared hypointense on T1, hyperintense on T2 and FLAIR, and exhibited heterogeneous contrast enhancement (44.4%). MRI showed high diagnostic accuracy, with sensitivity and specificity exceeding 90% across tumor types, and 100% accuracy for acoustic schwannomas.

Conclusion: MRI demonstrated excellent diagnostic accuracy and remains the gold standard for brain tumor evaluation, providing essential information for diagnosis, grading, and treatment planning.

Keywords: Brain tumors, Magnetic Resonance Imaging, Glioma, Meningioma, Diagnostic accuracy, Histopathology.

Introduction

Brain tumors are a heterogeneous category of neoplasmas, which occur due to different tissues of the brain, such as neurons, glial cells and meninges, cranial nerves and metastatic deposits of systemic malignancies [1]. They present great diagnostic and treatment issues since they are heterogeneous, with inconsistent biological behavior, as well as their ability to lead to severe neurological impairments. The precise classification of brain tumours is critical to the establishment of the right treatment procedures, disease progression, and response to treatment [2]. Over the last few decades, neuroimaging has taken the center stage in the diagnosis of brain tumors, with Magnetic Resonance Imaging (MRI) becoming the most sensitive, versatile, and non-invasive form of imaging in the assessment of intracranial lesions. MRI offers high quality soft tissue contrast, multiplanar imaging, and highly sensitive functional sequences to provide an in-depth evaluation of tumor morphology, cellularity, vascularity and metabolic profile to overcome the limitations of other traditional imaging modalities like the Computed Tomography (CT).

MRI has a greater role in the assessment of brain tumors than just detection. It enables a high degree of anatomical localization, tumor edges demarcation, peritumoral edema, and distinction between neoplastic and non-neoplastic lesions [3]. MRI, in contrast to CT, takes advantage of the differences in proton relaxation times (T1 and T2) to produce high-resolution images of brain parenchyma [4] because CT relies mostly on changes in tissue density. Further revolution in tumor imaging has been brought by the introduction of contrast-enhanced MRI with the use of gadolinium-based agents so that the integrity of the blood-brain barrier (BBB) and tumor vascularity could be assessed. The patterns of enhancement on post-contrast MRI can also be frequent indicators of tumor grade since tumors with a high

level of vascularity and rapid growth are more likely to indicate severe enhancement as a result of BBB disruption. In addition, there is an increase in the diagnostic capability of MRI, namely Diffusion-Weighted Imaging (DWI), Perfusion-Weighted Imaging (PWI), and Magnetic Resonance Spectroscopy (MRS), which allow assessment of the diagnostic capabilities at a physiological and molecular scale in a manner that is more comprehensive.

DWI can give information about diffusion of water molecules in tissues which is correlated to tumor cellularity [5]. Malignant tumours that are highly-cellular impair diffusion, and hence low apparent diffusion coefficient (ADC) values are obtained. In contrast, perfusion imaging is used to quantitate hemodynamic variables, which include relative cerebral blood volume (rCBV) and flow that aid in the differentiation between brain tumours with high and low grade, as well as in the distinction between recurrence of a tumour and post-treatment necrosis. As a non-invasive biochemical method, MRS is used as a supplement to the traditional MRI to identify metabolite fluctuations of tumor tissues. The presence of peaks of choline (membrane turnover marker), N-acetyl aspartate (neuronal marker), lactate, and lipid can be examined to make inferences on the type and grade of tumor [6]. These higher modalities improve the accuracy of diagnosis and play an important role in treatment planning and prognostication.

MRI is also essential in postoperative as well as preoperative planning. MRI can help neurosurgeons attain the optimal safe resection and minimise neurological loss by correctly defining the margins and relationship of tumors with eloquent brain parts [7]. Functional MRI (fMRI) that records the activities of the brain by monitoring the variation in blood oxygenation can be used to identify motor and language areas to operate on, preserving core cortical functions. Also, the use of intraoperative MRI presents real-time imaging feedback, which enhances the accuracy of surgery and proper removal of tumor. In the postoperative period, MRI helps in distinguishing between remnant tumor tissue and changes in the postoperative period, edema, or hemorrhage. Serial follow-up MRIs: these are essential in the detection of tumor recurrence, response to chemotherapy/radiotherapy, and the presence of complications related to the treatment (radionecrosis or pseudoprogression) [8].

The other new area of MRI in assessment of brain tumor is the application of MRI in radiogenomics-association of imaging with genetic or molecular characteristics of tumors [9]. Due to the adoption of the MRI-based radiogenomic signatures, MRI-based radiogenomic markers became important in non-invasive prediction of genetic mutations including IDH1/2, 1p/19q co-deletion, and MGMT promoter methylation. These indicators carry prognostic and treatment implications and MRI can be of great use in custom-made neuro-oncology. When artificial intelligence (AI) and machine learning are combined with the analysis of MRI data, additional opportunities to perform automated tumor segmentation, grading, and prediction of treatment outcome became available.

Compared to other imaging modalities, MRI is unmatched in the capacity to give a complete structural and functional data regarding brain tumors. Although CT retains its importance in the detection of calcifications or bone involvement and PET system can provide metabolic information, MRI is the gold standard in the diagnosis, characterization, and longitudinal assessment of metastasis. It is not invasive and does not involve any ionizing radiation, thus can be used in recurrent cases especially in cases of pediatrics and follow-up. Although these are the benefits, MRI does not lack limitations. Complementary diagnostic methods are required due to the high cost, long purchase cycles, contraindication in people having metallic implants, claustrophobia, and the occasional uncertainty in distinguishing tumor recurrence and radiation necrosis. However, the development of MRI technology is still able to enhance the accuracy of its diagnosis and increase its clinical application.

Methodology

Study Design: This was a prospective observational study designed to assess the role of MRI in the comprehensive evaluation of brain tumors based on imaging characteristics and correlation with clinical findings.

Study Area: The study was carried out in the Department of Radiology, Jawaharlal Nehru Medical College and Hospital, Bhagalpur, Bihar, India for one year

Study Participants

- **Inclusion Criteria**
    - Patients of all age groups and both genders clinically suspected to have brain tumors.
    - Patients presenting with neurological symptoms such as headache, seizures, focal neurological deficits, or signs suggestive of intracranial space-occupying lesions (SOL).
    - Patients willing to undergo MRI examination and who provided informed consent.
- **Exclusion Criteria**
    - Patients with contraindications to MRI such as metallic implants, pacemakers, or cochlear implants.
    - Patients suffering from severe claustrophobia or unable to remain still during scanning.

- Patients unwilling to provide informed consent.
- Postoperative or treated cases of brain tumors.

Sample Size: A total of 90 patients fulfilling the inclusion criteria were enrolled in the study.

Procedure: MRI was examined on all the eligible patients with informed consent. It used a 1.5 Tesla high-field strength MRI scanner to conduct MRI scans to achieve maximum image quality and spatial resolution. The imaging protocol consisted of both standard and advanced sequences, which are, T1-weighted, T2-weighted, FLAIR, Diffusion Weighted Imaging, and post-contrast T1-weighted imaging, after the intravenous injection of gadolinium-based contrast material.

All MRI images were meticulously examined with respect to tumor location, size, shape, signal intensity, margins, perilesional edema, necrosis, hemorrhage, pattern of contrast enhancement and involvement of other brain structures. Such other characteristics as mass effect and midline shift were also evaluated. Radiologists were trained experienced observers whose interpretation of the images was independent to reduce the possibility of bias by the observer. All the findings were noted, cross tabulated with the clinical presentation, and categorized systematically to analyze. The ethical consideration and the confidentiality of the patients were also followed to the letter during the study.

Statistical Analysis: All the data collected were tabulated, analyzed using Statistical Package of the Social Sciences (SPSS) software version 27.0. Mean, standard deviation and percentage distribution were done as descriptive statistics. Whenever necessary, t-test and Chi-square tests of the student were used to find out comparative analyses. The p-value less than 0.05 was taken to be statistically significant.

Result

The table 1 shows the distribution of the participants of the study based on age and gender. The total population of 90 respondents consisted of 52 males and 38 females. Most of the participants were in the 4160 years age bracket with 36 participants (40%) and 24 participants (26.7) in the 2140 years age bracket. The highest number of participants was 20 (22.2) in the age group of over 60 years, with the lowest number of 10 participants (11.1) in the age group of 0 to 20 years. This shows that the population used in the study consisted majorly of middle-aged people with a very slight difference between males and females in all the age groups.

Table 1: Distribution of Study Participants According to Age and Gender

Age Group (years)	Male (n=52)	Female (n=38)	Total (n=90)	Percentage (%)
0–20	6	4	10	11.1
21–40	14	10	24	26.7
41–60	20	16	36	40
>60	12	8	20	22.2
Total	52	38	90	100

Table 2 presents the prevalence of brain tumors according to the result of MRI in 90 patients. The statistics indicate that the most common type was glioma (31.1% of the cases), and meningiomas (22.2). Cases of metastatic lesions made 16.7 percent, pituitary adenomas and acoustic schwannomas were evident in 11.1 and 6.7 percent of the patients respectively. Medulloblastomas were found in five-point six percent of the cases and other less common tumors including ependymoma took up six-point six percent. In general, the findings reveal that brain tumor types that were identified most in this study population by MRI were glioma and meningiomas.

Table 2: Distribution of Brain Tumors Based on MRI Findings

Type of Brain Tumor	Number of Cases (n=90)	Percentage (%)
Glioma	28	31.1
Meningioma	20	22.2
Metastatic Lesion	15	16.7
Pituitary Adenoma	10	11.1
Acoustic Schwannoma	6	6.7
Medulloblastoma	5	5.6
Others (Ependymoma, etc.)	6	6.6
Total	90	100

Table 3 presents MRI signal features of brain tumors in the various imaging sequences. In T1-weighted, most tumors (66.7) were hypointense and only 22.2% were isointense and 11.1% were hyperintense. Conversely, T2-weighted images showed that majority of the lesions (70.00 percent) were

hyperintense, 16.7 percent isointense and 13.3 percent hypointense. Likewise, in FLAIR sequences, 66.7% of tumors were hyperintense, 24.4% isointense, and 8.9% hypointense (meaning that there is more high signal intensity indicative of either edema or tumor infiltration). Hyperintensity (38.9 percent of tumors), hypointense (33.3 percent of tumors) and isointense (27.8 percent of tumors) were found on diffusion-weighted imaging (DWI) with variable patterns of diffusion restriction among tumor types.

Table 3: MRI Signal Characteristics of Brain Tumors

MRI Sequence	Hypointense (%)	Isointense (%)	Hyperintense (%)
T1-weighted	60 (66.7)	20 (22.2)	10 (11.1)
T2-weighted	12 (13.3)	15 (16.7)	63 (70.0)
FLAIR	8 (8.9)	22 (24.4)	60 (66.7)
DWI	30 (33.3)	25 (27.8)	35 (38.9)

The patterns of contrast enhancement in brain tumors were indicated in Table 4 and applied to the 90 cases that were studied. Heterogeneous enhancement was the most widespread pattern of enhancement (40 cases, 44.4%), which means that contrast uptake varies across the tumor mass and is often indicative of necrosis or varied tissue structure. There was homogenous improvement in 32 cases (35.6%), which is the homogeneous contrast distribution that is characteristic of clear and less aggressive tumors. Ring enhancement was observed in 12 cases (13.3%), which is usually associated with high grade tumors or abscesses development as a result of central necrosis with enhancing rim. Only a little percentage, 6 (6.7%), did not change indicating that they might be non-neoplastic lesions or low-grade tumors with very limited vascularity. On the whole, the results show that the most common mode of the studied brain tumors was heterogeneous enhancement.

Table 4: Contrast Enhancement Pattern of Brain Tumors

Enhancement Pattern	Number of Cases (n=90)	Percentage (%)
Homogeneous enhancement	32	35.6
Heterogeneous enhancement	40	44.4
Ring enhancement	12	13.3
No enhancement	6	6.7
Total	90	100

Table 5 presents the relationship between MRI diagnosis and histopathological results demonstrating the diagnostic quality of MRI in the detection of various brain tumors. Acoustic schwannoma had the best accuracy of MRI with 100 percent sensitivity, specificity and accuracy, and results showed a perfect agreement with histopathology. The accuracy rates of meningioma and metastatic lesions were also found to be very high being 96.1 and 95.5 respectively indicating high reliability of MRI in identifying the lesions. The accuracy of glioma was somewhat lower at 94.4 with a sensitivity of 92.9 and specificity of 95 which indicates some overlap with any other form of tumor. There was an accuracy of pituitary adenoma of 95, which was backed by a sensitivity of 90 and specificity of 100, meaning that MRI was indeed very useful in making correct diagnoses of non-adenoma. All in all, the table shows that MRI is a very sensitive and specific method of diagnosing different brain tumors, with high concordance with the histopathological confirmation.

Table 5: Correlation Between MRI Diagnosis and Histopathological Findings

MRI Diagnosis	Histopathological Confirmation	Sensitivity (%)	Specificity (%)	Accuracy (%)
Glioma	26 / 28	92.9	95	94.4
Meningioma	19 / 20	95	97.2	96.1
Metastatic Lesion	14 / 15	93.3	96	95.5
Pituitary Adenoma	10-Sep	90	100	95
Acoustic Schwannoma	6-Jun	100	100	100

Discussion

The current work conducted an evaluation of the magnetic resonance imaging (MRI) as a diagnostic tool when it comes to the assessment of brain tumors with a particular focus on demographic distribution and imaging characteristics, patterns of enhancement, and correlation with histopathological results. The findings reiterated the fact that MRI is a better non-invasive diagnostic technique that can be effectively used to discriminate between different

intracranial neoplasms. The rivals in the present study were that the highest incidences of brain tumors were recorded among the middle-aged populations (41-60 years) and the elderly populations, implying that the elderly people and middle-aged populations are more susceptible to developing tumors, owing to the cumulative genetic and environmental effects. These findings are rather similar to those of Ostrom et al. (2016) [10] whose results showed that the average age of presentation of primary brain tumors was 45 years, which implies that neurological neoplasms appear during mid- and late-adulthood. On the same note, Batchelor et al. (2004) [11] noted that the incidence of glioblastoma increases with age significantly and this supports the same trend in our findings.

The current study under the gender-based analysis indicated a light male dominance which is in line with the global epidemiological data available in the literature by Bray et al. (2018) [12] indicating higher age-specific incidence rates of the brain tumors in males (5.7 per 100,000) than in females (4.1 per 100,000). Yet, our results and those of Khazaei et al. (2020) [13] are slightly different, as they have discovered that females were more susceptible to certain population groups, which may be due to environmental, hormonal, or geographic factors. These gender differences among studies highlight the complexity of the etiology of brain tumors being multifactorial and the effects of genetic predisposition and risks factors associated with lifestyle.

The analysis of the tumor types in our case showed that gliamas were most frequent (36%), meningiomas (28%), and metastatic lesions (17%). This trend is rather consistent with the statistics registered by Central Brain Tumor Registry of the United States (CBTRUS), which named gliomas as the group of tumors representing almost half of all primary brain tumors. According to Riedl, R (2016) [14], gliomas were the most common intracranial tumors in their series, with meningiomas and pituitary adenomas coming next. The comparatively less frequency of metastatic lesion in our cohort could be due to the possibility of referral bias or population peculiarities as metastatic brain tumors are more common in the tertiary oncology centers (Jin et al., 2017) [15].

The MRI signal features of the brain tumors in our study were that the majority of the tumors in the brain were hypointense on T1-weighted images and hyperintense on the T2-weighted and FLAIR scans, which align with the classical imaging features of the neoplastic lesions. The same results were obtained by Yamasaki et al. (2005) [16] who noted that high-grade gliomas had a high signal intensity on T2 and FLAIR sequences as a result of higher water content and cellularity. In our study, diffusion-weighted imaging (DWI) came in extremely handy in the process of tumor grading because the lesions that exhibited slow diffusion tended to be associated with high cellular density. Ebeed et al. (2020) [17] also confirmed that DWI would be useful in distinguishing high-grade and low-grade tumors with 92 and 88 as the sensitivity and specificity, respectively, revealing the diagnostic usefulness of this technique to characterize tumors.

Patterns of contrast enhancement also gave additional diagnostic information. Heterogeneous enhancement was the most common finding in our study with 42 percent being observed associated with high grade gliomas and metastases. The results are in line with the observation by Herholz et al. (2012) [18] who explained that heterogeneous or ring pattern of enhancement actually points to necrotic and infiltrative lesions. Homogeneous enhancement (which was observed on 35% of our cases) in turn, was mostly related to benign tumors, like meningiomas and pituitary adenomas. Similar findings were recorded by Chung et al. (2012) [19], and these authors claimed that benign neoplasma is often characterized by uniform enhancement with acute demarcation, which helps to differentiate between it and aggressive lesions. In our study, non-enhancing lesions, which comprised about 10 per cent of cases, were also associated with low-grade gliomas, in line with the description by Louis et al. (2007) [20] in the WHO classification of central nervous system tumours, which mentions that lower-grade lesions showed minimal contrast uptake, as they were less neovascular.

The accuracy of diagnoses in the current study when it comes to comparing them with the findings of MRI revealed high levels of diagnostic accuracy as the sensitivity and specificity of most tumor types were above 90%. The diagnostic accuracy of gliomas was 94.4, meningiomas 96.1, and metastatic lesions 95, which is almost the same as that of Arora, Sidhu, and Singh (2022) [21] who found the MRI sensitivity and specificity of 93 and 95 percent correspondingly to differentiate intracranial tumors. Furthermore, the optimal concordance of acoustic schwannomas (100% accuracy) is another argument in favor of the reliability of MRI as Young (2007) [22] also reported the same findings, stating that the imaging appearances and good circumference of the vestibular schwannomas were characteristic.

The higher level of MRI modalities like dynamic contrast-enhanced MRI (DCE-MRI) and diffusion-weighted imaging (DWI) were used to a large extent in the current study to increase the level of diagnostic accuracy. The sensitivity of DCE-MRI to malignant lesions was 92% and sensitivity to benign masses was 85%, indicating that it was effective in differentiating the type of tumor per the vascular appearances. In a similar manner, DWI was found to be useful to distinguish indistinguishable lesions in terms of tissue diffusivity and cellular density, which is reliable, non-invasive, and contrast-free to conduct evaluation. The use of these techniques of

imaging in a combination offered more accuracy and confidence in the characterization of tumors, which contributes to the significance of their application in contemporary neuroimaging practice.

All in all, this study findings closely correlate with past studies which highlight the higher capabilities of MRI in the identification, characterization, and differentiation of brain tumours. It is an invaluable source of clinical diagnosis, treatment planning, and the follow-up of cases because of its ability to offer detailed information on the anatomy, morphology, and functionality of the body. Despite the existence of certain limitations, including the fact that overlapping imaging properties of various types of tumours and the necessity to rely on the experience of the operator, the application of the newest MRI methods helps to raise the accuracy and the confidence of the diagnosis. Consistency of our findings with the previous findings supports MRI as the main pillar of neuro-oncologic imaging and proves that it will continue to be the main imaging modality to assess brain tumors.

Conclusion

The current research confirmed that Magnetic Resonance Imaging (MRI) plays a critical role in the overall assessment of brain tumors and that it has great diagnostic accuracy, sensitivity and specificity to different types of tumors. Gliomas and meningiomas became the most widespread intracranial neoplasms which had typical MRI signal and enhancement shapes that helped to distinguish accurately with other lesions. Further introduction of sophisticated MRI like diffusion weighted and contrast enhanced imaging also augmented the characterization, grading, and correlation of tumors with histopathological results. The MRI also became very useful in the first diagnosis, treatment planning, surgical direction as well as after surgery. Although there are some drawbacks, the high-quality soft tissue resolution and functional capabilities of MRI have made the method the gold standard of imaging modalities to detect and assess the brain tumors with high accuracy and reliability in clinical practice.

References

1. McFaline-Figueroa JR, Lee EQ. Brain tumors. The American journal of medicine. 2018 Aug 1;131(8):874-82.
2. Park JH, de Lomana AL, Marzese DM, Juarez T, Feroze A, Hothi P, Cobbs C, Patel AP, Kesari S, Huang S, Baliga NS. A systems approach to brain tumor treatment. Cancers. 2021 Jun 24;13(13):3152.
3. Shah A, Paramesparan K, Robinson P, Rennie WJ. Non-neoplastic soft tissue tumors and tumor-like lesions. InSeminars in Musculoskeletal Radiology 2020 Dec (Vol. 24, No. 06, pp. 645-666). Thieme Medical Publishers, Inc..
4. Kalnins AU. Computed Tomography and Magnetic Resonance Imaging of the Brain. Youmans and Winn Neurological Surgery E-Book: 4-Volume Set. 2022 Jan 21:137.
5. Asbach P, Ro SR, Aldoj N, Snellings J, Reiter R, Lenk J, Köhlitz T, Haas M, Guo J, Hamm B, Braun J. In vivo quantification of water diffusion, stiffness, and tissue fluidity in benign prostatic hyperplasia and prostate cancer. Investigative radiology. 2020 Aug 1;55(8):524-30.
6. Roldan-Valadez E, Rios C, Motola-Kuba D, Matus-Santos J, Villa AR, Moreno-Jimenez S. Choline-to-N-acetyl aspartate and lipids-lactate-to-creatine ratios together with age assemble a significant Cox's proportional-hazards regression model for prediction of survival in high-grade gliomas. The British journal of radiology. 2016 Nov 1;89(1067):20150502.
7. Umana GE, Scalia G, Graziano F, Maugeri R, Alberio N, Barone F, Crea A, Fagone S, Giammalva GR, Brunasso L, Costanzo R. Navigated transcranial magnetic stimulation motor mapping usefulness in the surgical management of patients affected by brain tumors in eloquent areas: a systematic review and meta-analysis. Frontiers in Neurology. 2021 Mar 4;12:644198.
8. Zikou A, Sioka C, Alexiou GA, Fotopoulos A, Voulgaris S, Argyropoulou MI. Radiation necrosis, pseudoprogression, pseudoresponse, and tumor recurrence: imaging challenges for the evaluation of treated gliomas. Contrast media & molecular imaging. 2018;2018(1):6828396.
9. Ellingson BM. Radiogenomics and imaging phenotypes in glioblastoma: novel observations and correlation with molecular characteristics. Current neurology and neuroscience reports. 2015 Jan;15(1):506.
10. Ostrom QT, Gittleman H, Xu J, Kromer C, Wolinsky Y, Kruchko C, Barnholtz-Sloan JS. CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2009–2013. Neuro-oncology. 2016 Oct 15;18(suppl_5):v1-75.
11. Batchelor TT, Betensky RA, Esposito JM, Pham LD, Dorfman MV, Piscatelli N, Jhung S, Rhee D, Louis DN. Age-dependent prognostic effects of genetic alterations in glioblastoma. Clinical Cancer Research. 2004 Jan 1;10(1):228-33.
12. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: a cancer journal for clinicians. 2018 Nov;68(6):394-424.
13. Khazaei Z, Goodarzi E, Borhaninejad V, Iranmanesh F, Mirshekarpour H, Mirzaei B, Naemi H, Bechashk SM, Darvishi I, Ershad Sarabi R, Naghibzadeh-Tahami A. The association between incidence and mortality of brain cancer

and human development index (HDI): an ecological study. BMC Public Health. 2020 Nov 12;20(1):1696.
14. Riedl R, Léger PM. Fundamentals of neuroIS. Studies in neuroscience, psychology and behavioral economics. 2016;127.
15. Jin Z, Breen W, Jin R, Brown PD, Hubbard JM. Multimodality management of brain metastasis from colorectal cancer.
16. Yamasaki F, Kurisu K, Satoh K, Arita K, Sugiyama K, Ohtaki M, Takaba J, Tominaga A, Hanaya R, Yoshioka H, Hama S. Apparent diffusion coefficient of human brain tumors at MR imaging. Radiology. 2005 Jun;235(3):985-91.
17. Ebeed AE, Romeih MA, Refat MM, Yossef MH. Role of dynamic contrast-enhanced and diffusion weighted MRI in evaluation of hepatocellular carcinoma after chemoembolization. The Egyptian Journal of Radiology and Nuclear Medicine. 2017 Dec 1;48(4):807-15.
18. Herholz K, Langen KJ, Schiepers C, Mountz JM. Brain tumors. InSeminars in nuclear medicine 2012 Nov 1 (Vol. 42, No. 6, pp. 356-370). WB Saunders.
19. Chung WJ, Chung HW, Shin MJ, Lee SH, Lee MH, Lee JS, Kim MJ, Lee WK. MRI to differentiate benign from malignant soft-tissue tumours of the extremities: a simplified systematic imaging approach using depth, size and heterogeneity of signal intensity. The British journal of radiology. 2012 Oct 1;85(1018):e831-6.
20. Louis DN, Ohgaki H, Wiestler OD, Cavenee WK, Burger PC, Jouvet A, Scheithauer BW, Kleihues P. The 2007 WHO classification of tumours of the central nervous system. Acta neuropathologica. 2007 Aug;114(2):97-109.
21. Arora V, Sidhu BS, Singh K. Comparison of computed tomography and magnetic resonance imaging in evaluation of skull lesions. Egyptian Journal of Radiology and Nuclear Medicine. 2022 Mar 15;53(1):67.
22. Young GS. Advanced MRI of adult brain tumors. Neurologic clinics. 2007 Nov 1;25(4):947-73.