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Magnetic Resonance Imaging Patterns of Intracranial Meningiomas in Erbil City

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Abstract

Background and objectives: Meningiomas are the most common non-glial tumors of the central nervous system representing around one fifth of primary intracranial tumors with annual incidence of six per 100,000 populations. This study aimed to address the diagnostic precision of magnetic resonance imaging as a brain investigation tool to evaluate meningioma diagnosis and tumor staging before performing the operation.

Methods: This study designed as a cross-sectional study and carried out between December 2019 and December 2020. A total number of 48 meningiomas resected and evaluated at three public hospitals in Erbil City. Pre-operative magnetic resonance imaging investigation and postoperative histopathological evaluation were done for all patients for their intracranial tumors and tissue sections.

Results: Majority of patients showed isointense pattern on T1 (87.5%) and T2 (85.4%) signal intensity, homogenous in consistency (81.3%), the vast majority of the meningiomas were typical (93.8%) and of meningothelial type (81.3%). In most of the cases, there was no bone involvement (77.1%), no invasion of dural venous sinuses (83.3%), no calcifications (83.3%), no cystic changes (97.9%) but positive cerebral spinal fluid cleft (66.7%) and homogenous enhancement pattern (83.3%). Five out of eleven imaging patterns and configurations including T1 signal intensity, T2 signal intensity, consistency, calcification and vascularity of the meningioma were valid and reliable by calculating their sensitivity, specificity and running kappa test.

Conclusions: Some magnetic resonance imaging patterns such as T1 signal intensity, T2 signal intensity, consistency, calcification, and vascularity of the meningioma are useful for predicting the stages of meningioma.

Key words: Erbil, Magnetic resonance imaging patterns, Meningioma, Screening, Validity.

Introduction

Meningiomas are regarded as the most common non-glial tumors of the central nervous system (CNS), representing around one fifth (20%) of primary intracranial tumors.[1-2] Meningiomas have an annual incidence of 6 per 100,000 people and are twice as common in the female as in the male population.[3] They are most common after the 5th decade of life and are often asymptomatic, with a 2–3 % prevalence in the elderly population.[3] Meningiomas are typically slow-growing tumours that arise from the meningothelial cells of the arachnoid.[4] Based on classification system of World Health Organization (WHO); majority of meningiomas (78%-90%) are of grade I.[2, 4, 5] The histological subtypes of grade I meningiomas include meningothelial, psammomatous, secretory, fibroblastic, angiomatous, lymphoplasmacyte-rich, transitional, metaplastic and microcystic. They differ from the more aggressive meningiomas.[4] Although grades II and III of meningioma are more aggressive, however they are less common (5–7 % and 1–3 % of cases respectively) than grade I.[4] They differ from grade I in their number of

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mitoses, cellularity, nuclear-to-cytoplasmic ratio, histological patterns and their relatively low risk of recurrence or aggressive growth pattern.[6] Five-year recurrence rates are 12% for benign meningiomas and 41% for atypical meningiomas.[2] Meningiomas can arise anywhere over or under the brain from the arachnoid cell rests, but have several sites of determination as: Convexity, parasagittal, tuberculum sellae, sphenoid ridge and pterion, cerebellopontine angle, sub frontal, cerebellar convexity, tentorium, intraventricular, and other well documented sites include the optic nerve sheath and olfactory groove, however they are rarely detected in extra-calvarial or ectopic locations.[7] Magnetic resonance imaging (MRI) is the modality of choice for the investigation of meningiomas, providing superior contrast differentiation and usually the ability to differentiate between intra- and extra-axial lesions.[3] Magnetic resonance imaging has the added value in providing more specific and important information such as, contrast material enhancement, peritumoral edema, distant tumor foci, hemorrhage, necrosis, mass effect and so on, which are all helpful in characterizing tumor aggressiveness and hence tumor grade.[8-9] In this context, by comparing MRI with the histopathological findings, this study addresses the diagnostic precision of MRI a brain investigation tool; identify the screening capabilities to evaluate meningioma diagnosis; and determine different characteristic patterns of intracranial meningiomas for the purpose of tumor staging prior to surgery.

Patients and methods

This study was designed as cross-sectional study and carried out between December 2019 and December 2020. A total number of 48 meningiomas were resected and evaluated at in three public hospitals (Rizgari teaching hospital, Hawler teaching Hospitala and Rozhawa Emergency Hospital) in Erbil city/Kurdistan region of Iraq. This sample has been taken by purposive sampling. All suspected cases of meningioma admitted to neurosurgical ward was considered as eligible and patients with incomplete data and information or those who refuse to participate was excluded from the study. A complete history was taken from the patient or his relative. All patients underwent pre-operative MR imaging study on a 1.5 (See Fig.1 and 2) T clinical scanner using (Siemens Medical Systems) with a standard head coil of 240x240-mm FOV suitable for head imaging. Conventional MR images consisted of sagittal and axial T2-weighted images (TR/TE=3000–5400/100–105 msec) and contrast-enhanced images sagittal and axial T1-weighted imaging (TR/TE=400-600 msec./12–20 msec.) after slow intravenous contrast injection (Gadolinium DTPA with a dose of (0.1) mmol/Kg body weight and it was given to all patients except 2 pregnant cases). Diffusion-weighted magnetic resonance (DW MR) imaging was acquired in the axial plane by using a single-shot, spin-echo echo-planar imaging sequence (TR/TE = 10,000/68.4 ms) with b-values of 0 and 1000 s/mm2 in 3 orthogonal directions. T2-FLAIR coronal, post-contrast T1-weighted images in axial, sagittal and coronal sections to demonstrate the enhancement pattern of the lesions, MRV examination was performed only in suspicious cases of meningiomas that are adjacent to a major dural venous sinus. The following features were analyzed: size, side and location of the lesion, signal intensity, consistency, mass effect, and presence of homogeneity or heterogeneity in all obtained sequences, presence of contrast enhancement, and presence of brain edema, foci of calcification (low signal on T2*-weighted gradient-echo images and correlation with CT), hemorrhage or cystic components in the tumors. The edema was classified as mild, moderate and marked according to the extension of the perifocal edema and intensity of the contrast enhancement.

Evidence of bone penetration and dural tail sign were also studied.

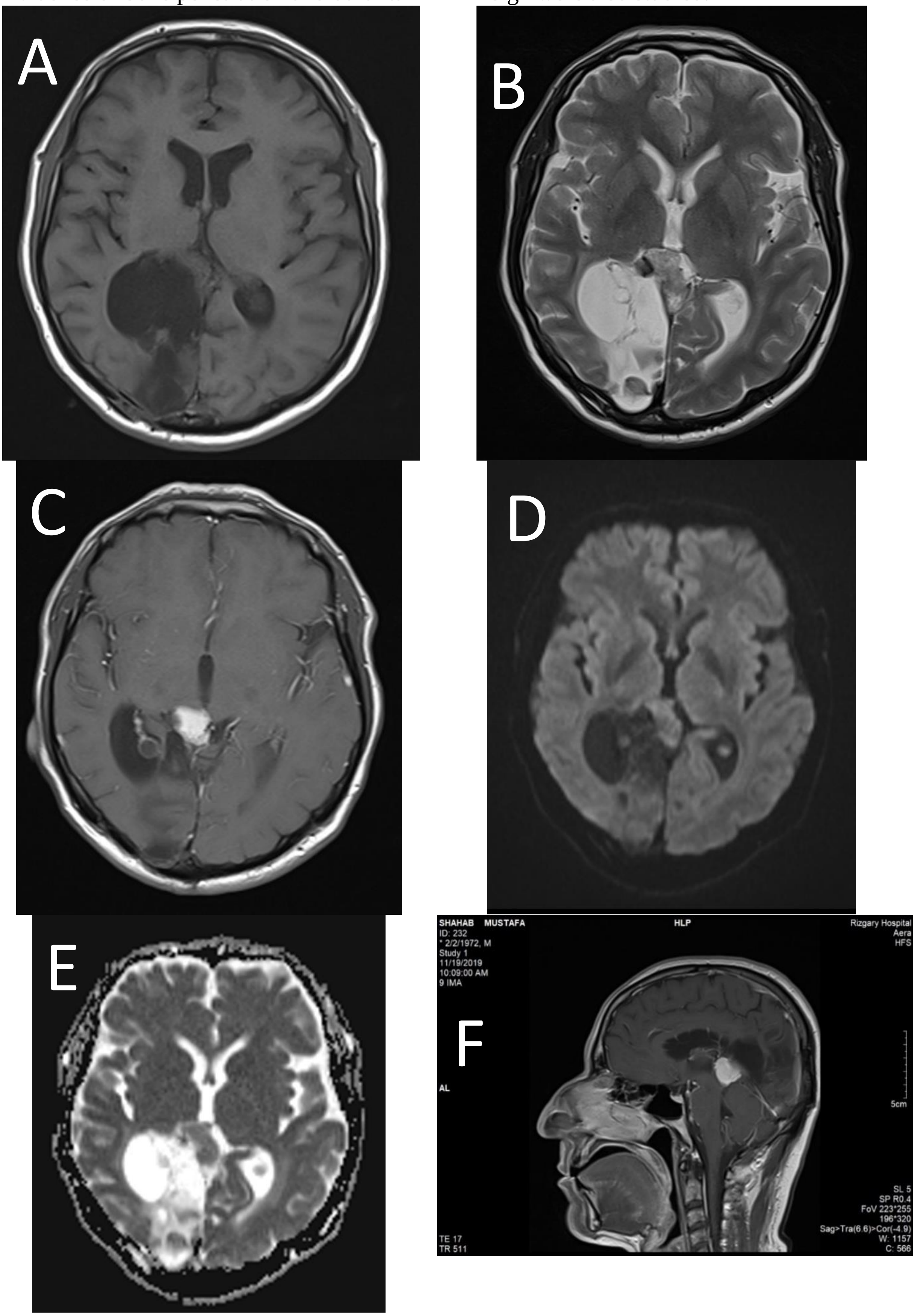

Figure (1): A 43 years old male with meningioma in the right quadrigeminal cistern with cerebromalacia seen in the right occipital lobe and evidence of occipital craniotomy, MRI shows isointense lesion in both T1-weighted (A) and T2-weighted images. (B) Post-contrast axial T1W image (C) shows homogeneous enhancement. Diffusion-weighted imaging (DWI) (D) shows diffusion restriction. (E) Sagittal T1W image shows avid post-contrast enhancement. (F) Biopsy showed typical transitional meningioma.

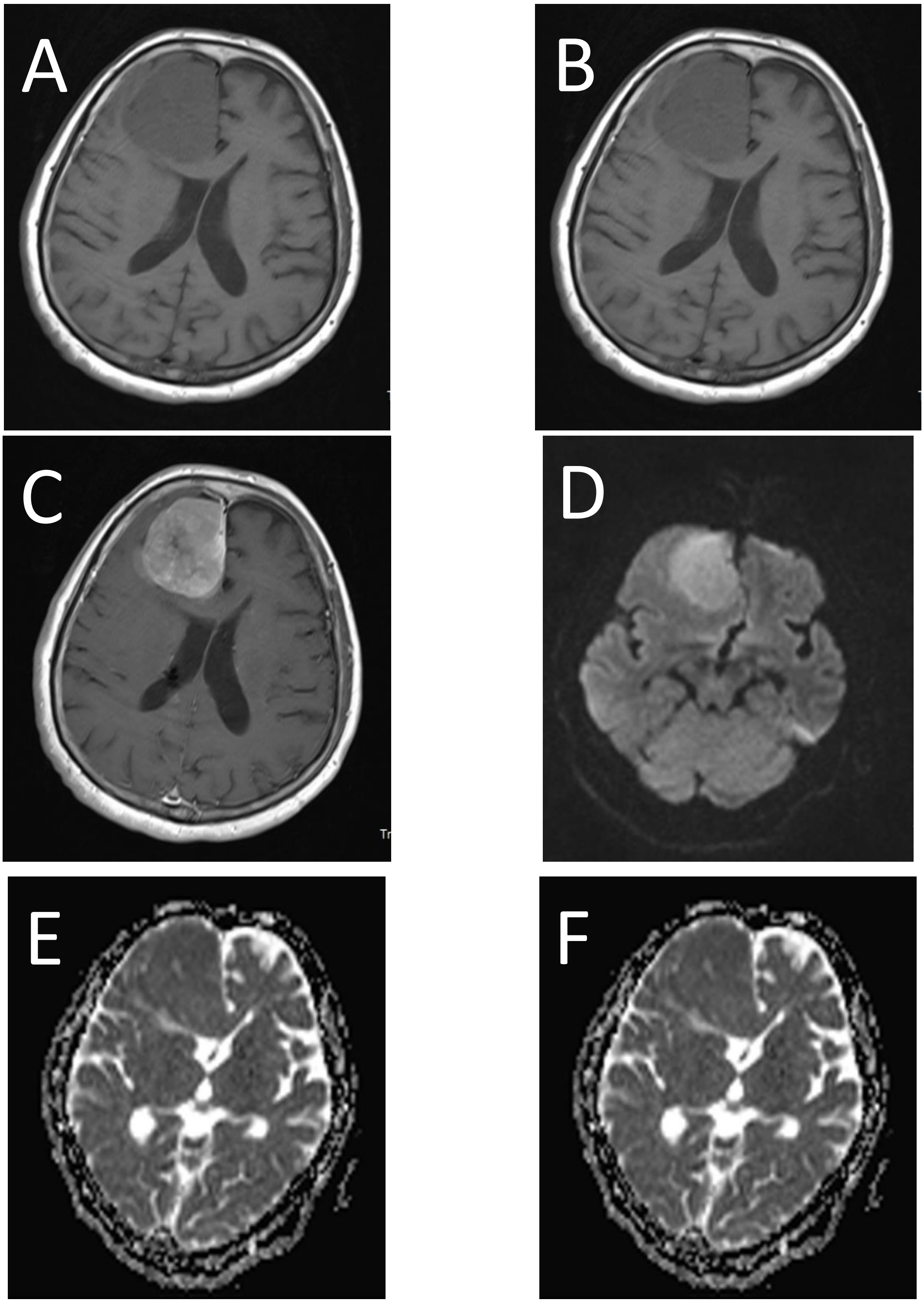

Figure (2): A 70 years old female patient with typical meningioma in the right frontal region. MRI shows isointense lesion in both T1-weighted (A) and T2-weighted images (B). Post-contrast axial T1W (C) shows relatively homogenous enhancement. Diffusion-weighted imaging (DWI) (D) shows diffusion restriction. The apparent diffusion coefficient (ADC) (E) shows hypointense signal. Sagittal T1W image shows avid post-contrast enhancement (F)

Histopathological diagnosis was done for all patients subsequently after surgery for their intracranial tumors and tissue sections from each case were viewed by pathologist and a detailed histopathological report was obtained. Sample size was calculated taking into consideration the prevalence of the disease among the population. The researcher explained in detail the procedures and steps of the study for each patient prior to the surgical operation and a written consent form was obtained from the patient or his/her companion in a local language. Magnetic resonance imaging films and reports of the patients from the Radiology departments of each hospital were accessed; this access was granted by the Directorate of Health of Erbil. Both the supervisor and trainee accessed these healthcare records. Statistical analysis was done using SPSS computer software (statistical package of social sciences). Frequency distribution for selected variables (age, sex, ...etc.) was done first and p- values of less than 0.05 level of significance was considered statistically significant. The sensitivity, specificity, positive and negative predictive values of MRI investigation was calculated and the possibility of using it as screening tool was assessed.

Results

A total of 48 patients with meningioma enrolled in the current study, most (66.7%) of them were female and the vast majorities were newly diagnosed by MRI of brain. The meningiomas distributed equally on the right, left and central sides of the brain. In most of the cases, the meningioma was located at parasagittal followed by lateral sphenoid wing, convexity then other different locations in the brain Table (1).

Table (1): Gender of participants, and criteria of meningiomas.

Variables	Categories	Frequency	Percent
Gender	Female	32	66.7
	Male	16	33.3
History	Newly diagnosed	46	95.8
	Recurrent	2	4.2
Side of meningioma	Right	17	35.4
	Left	16	33.3
	Central	15	31.3
Location of meningioma	Parasagittal	13	27.1
	Tuberculum sella	1	2.1
	Middle sphenoid wing	2	4.2
	Lateral sphenoid wing	6	12.5
	Convexity	6	12.5
	Tentorial	5	10.4
	Suprasellar	1	2.1
	Olfactory Groove	3	6.3
	Torcula	1	2.1
	Foramen Magnum	2	4.2
	Planum Sphenoidale	2	4.2
	Temporal	1	2.1
	CPA	1	2.1
	Frontal	1	2.1
	Parietal	1	2.1
	Paraflacine	1	2.1
	Flax	1	2.1
Total		48	100

All patients were screened using MRI to know the various patterns and configurations of the meningioma, majority of the patients showed isointense pattern on T1 (87.5%) and T2 (85.4%) signal intensity, homogenous in consistency (81.3%) Table (2). When FLAIR and DWI sequences were performed most of the meningiomas were isointense (58.3%) and (47.9%) consecutively. For majority of the patients there was no bone involvement (77.1%), no invasion of Dural venous sinuses (83.3%), no calcifications (83.3%), no cystic changes (97.9%) but positive CSF cleft (66.7%) and homogenous enhancement pattern (83.3%). Most of the meningiomas showed mass effect without hydrocephalous (89.6%) and they were avascular (91.7%).

Table (2): Radiological patterns of meningiomas.

Variables	Categories	Frequency	Percent
T1 signal intensity	Hypointense	6	12.5
	Isointense	42	87.5
T2 signal intensity	Hyperintense	7	14.6
	Isointense	41	85.4
Consistency	Heterogeneous	9	18.8
	Homogenous	39	81.3
FLAIR sequence	Hypointense	13	27.1
	Isointense	28	58.3
	Hyperintense	6	12.5
	heterogeneous	1	2.1
DWI sequence	restricted	23	47.9
	partial restriction	2	4.2
	not restricted	3	6.3
	not available	20	41.7
Bone involvement	positive	11	22.9
	negative	37	77.1
Invasion of Dural venous sinuses	Positive	8	16.7
	Negative	40	83.3
CSF cleft	Positive	32	66.7
	Negative	16	33.3
Calcification	Positive	8	16.7
	Negative	40	83.3
Cystic changes	Positive	1	2.1
	Negative	47	97.9
Enhancement pattern	Homogenous	40	83.3
	Heterogeneous	8	16.7
Mass effect	With hydrocephalous	5	10.4
	Without hydrocephalous	43	89.6
Vascularity	Vascular	4	8.3
	Avascular	44	91.7
Total		48	100

All the meningiomas were sent for complete histopathological processing and evaluation. The data revealed that majority of the cases were typical (93.8%) and of meningothelial type 81.3% Table (3).

Table (3): Histopathological results of meningiomas.

Variables	Categories	Frequency	Percent
Type histopathological appearances	Meningothelial	39	81.3
	Fibroblastic	2	4.2
	Transitional	7	14.6
Histopathological results	Atypical (malignant)	3	6.3
	Typical	45	93.8
Total		48	100

The MRI investigation used as a screening test while the histopathological examination considered as the gold standard test to verify and prove the diagnosis of atypical (malignant) meningiomas. All the 11 MRI patterns examined and studied thoroughly and compared to histopathological results, six of the patterns were neither sensitive, specific nor reliable. In contrast, five of the MRI patterns and configurations were valid and reliable by calculating their sensitivity, specificity and running kappa test respectively, the pattern were namely: T1 signal intensity, T2 signal intensity, consistency, calcification and vascularity of the meningioma on MRI imaging Table (4).

Table (4): Radiological parameters in relation to histopathological results

Parameter	Sensitivity	Specificity	Reliability	p-value	Interpretation
T1 signal intensity	100%	93.3%	0.64	0.001	valid and reliable
T2Signal intensity	100%	91.1%	0.56	0.001	valid and reliable
Consistency	66.7%	93.3%	0.48	0.001	valid and reliable
Bone involvement	33.3%	86.7%	-0.01	0.342	neither valid nor reliable
Invasion of Dural sinuses	0%	82.2%	-0.10	0.424	neither valid nor reliable
CSF cleft	33.3%	31.1%	-0.06	0.206	neither valid nor reliable
Calcification	66.7%	93.3%	0.46	0.001	valid and reliable
Cystic changes	0%	97.8%	-0.03	0.794	neither valid nor reliable
Enhancement pattern	66.7%	15.6%	-0.02	0.424	neither valid nor reliable
Mass effect	0%	88.9%	-0.08	0.542	neither valid nor reliable
Vascularity	66.7%	95.6%	0.54	0.001	valid and reliable

Discussion

Neuroimaging especially using MRI is the imaging modality of choice for the early diagnosis and even follow-up of meningioma cases because of the superior soft-tissue capabilities and absence of radiation exposure.[10] The main issue in diagnosis and management of meningioma is the early prediction of tumor recurrence and or progression. Keeping in mind the slow growth rate of meningiomas, the tumor must extend into a substantial size before progression can be diagnosed, so it is critical to select a suitable time for therapy initiation, especially in regions not easy to access like the skull base[11]. Our findings were in concordance with findings of Parmar et al and Leijenaar et al who discovered that heterogeneous contrast enhancement was thought to indicate a heterogeneous distribution of proliferating cells in addition to intratumoral necrosis and has been linked to high-grade meningiomas.[12-13] Hwang et al also concluded that half high-grade tumors displayed heterogeneous enhancement compared with only 31% of low-grade tumors, but unlike our results, they found that absence of tumor calcification was associated with high grade meningiomas.[14] Adeli et al in his study stated that heterogeneous contrast enhancement was significantly associated with brain invasion in meningioma cases, but they explained more on meningiomas mentioning that presence of a contrast enhancing tumour capsule, disruption of the arachnoid layer, intratumoural calcifications and T2-intensity were not significantly related to high-grade histology.[15] Huang et al in their study about imaging and diagnostic advances for intracranial meningiomas revealed that radiological tumor characteristics such as hyperintensity on T2-weighted MRI may be associated with a risk for relevant meningioma progression, surprisingly they end up with inconsistent results. They found that younger age (≤60 years), male sex, radiological tumor characteristics such as hyperintensity on T2-weighted MRI, absence of tumor calcification, or presence of peritumoral edema may be linked to a risk for related meningioma progression.[16] Expectedly, the difference between benign and high-grade meningiomas increases with advanced years of age. Heterogeneous MRI enhancement is associated with uneven distribution of tumor cells or even ischemic necrosis, then with the biological features of malignant tumors.[17] It has been stated that age was an independent variable in predicting tumor recurrence and degree of differentiation according to previous studies.[18-19] However, this statement was not reinforced by other studies especially Hashiba et al and Kane et al.[20-21] Similar to our finding of vascularity being a valid and reproducible indicator for high grade meningiomas, Varlotto found that one of the factors significantly correlating with a diagnosis of WHO Grade II-III tumors in univariate analysis was vascularity of the mass ($p = 0.009$).[22] Heterogeneous enhancement was regarded as independent predictive factor for high-grade meningioma by Kawahara et al who showed that the prediction and probability of high-grade meningioma was 98% in patients with heterogeneous enhancement. Meningioma.[23] Thibaud et al also observed strong associations between specific radiographic features and meningioma histologic grade. In particular, heterogeneous tumors with necrosis and/or hemorrhage, and irregularly shaped (non-spherical) tumors were more likely to be higher grade on univariate analysis.[24] In reverse; Schob and coworkers observed that there was no significant correlation between MRI signal intensities and WHO meningioma grades. Signal intensities did not differ significantly between WHO grade I and II/III meningiomas.[25] Chu et al created a radiomics prediction model which was built on the selected nine characteristic parameters, which performed well in predicting the meningiomas grade. The accuracy rates in the training group and the test group were respectively 94.3% and 92.9%, the sensitivities were respectively 94.8%, and 91.7%, the specificities were respectively 91.7% and 100%, and the area under the curve values were respectively 0.958 and 0.948. The MRI radiomics method based on enhanced-T1WI images has a good predictive effect on the classification of meningiomas and can provide a basis for planning clinical treatment protocols.[26]

Conclusions

Not all the MRI images and patterns were useful for the prediction; some of those patterns were more supportive and conclusive in particular: T1 signal intensity, T2 signal intensity, consistency of meningioma, calcification, and vascularity of the tumour.

Conflicts of interest

The author reports no conflicts of interest.

References

1. Toh CH, Castillo M, Wong AM et al. Differentiation between classic and atypical meningiomas with use of diffusion tensor imaging. Am J Neuroradiol. 2008; 29(9): 1630-5. doi: 10.3174/ajnr.A1170.

2. Wiemels J, Wrensch M, Claus E B. Epidemiology and etiology of meningioma. J Neurooncol. 2010; 99(3): 307–14.
3. Watts, J., Box, G., Galvin, A. et al. Magnetic resonance imaging of meningiomas: a pictorial review. Insights Imaging, 2014;5(1):113-22. https://doi.org/10.1007/s13244-013-0302-4
4. Whittle IR, Smith C, Navoo P, Collie D. Meningiomas. Lancet. 2004; 8;363(9420):1535-43. doi: 10.1016/S0140-6736(04)16153-9.
5. Louis DN, Ohgaki H, Wiestler OD, et al. The 2007 WHO Classification of Tumours of the Central Nervous System. Acta Neuropathol (Berl).2007; 114: 97–109.https://doi.org/10.1007/s00401-007-0243-4.
6. Nagar VA, Ye JR, et al. Diffusion-weighted MR imaging: diagnosing atypical or malignant meningiomas and detecting tumor dedifferentiation. Am J Neuroradiol. 2008; 29(6): 1147-52. doi: 10.3174/ajnr.A0996..
7. Sutton D, Kendall B, Steven J. Intracranial lesions (1). In: Sutton D (ed.) Textbook of radiology and imaging, 6th ed., London, Churchill Livingstone, 2003: 1475-1503
8. Boss A, Bisdas S, Kolb A, Hofmann M, et al. Hybrid PET/MRI of intracranial masses: initial experiences and comparison to PET/CT. J Nucl Med. 2010; 51(8):1198-205
9. Chishty IA, Rafique MZ, Hussain M, et al. MRI characterization and histopathological correlation of primary intra-axial brain glioma. J Liaquat Uni Med Health Sci. 2010; 9(2): 64-9
10. Goldbrunner R, Minniti G, Preusser M, et al. EANO guidelines for the diagnosis and treatment of meningiomas. Lancet Oncol. 2016;17(9):383–91.
11. Nowosielski M, Galldiks N, Iglseder S, et al. Diagnostic challenges in meningioma. Neuro-Oncol. 2017;19(12): 1588–98.
12. Parmar C, Leijenaar RTH, Grossmann P, et al. Radiomic feature clusters and Prognostic Signatures specific for Lung and Head and Neck cancer. Sci Rep. 2015; 5:11044.
13. Leijenaar RT, Carvalho S, Hoebers FJ et al. External validation of a prognostic CT-based radiomic signature in oropharyngeal squamous cell carcinoma. Acta Oncol. 2015;54(9):1423-9
14. Hwang WL, Ariel E, Marciscano AE, et al. Imaging and extent of surgical resection predict risk of meningioma recurrence better than WHO histopathological grade. Neuro-Oncology. 2016;18(6): 863–87
15. Adeli A, Hess K, Mawrin C, et al. Prediction of brain invasion in patients with meningiomas using preoperative magnetic resonance imaging. Oncotarget. 2018; 9(89): 35974-82
16. Huang RH, Bi WL, Griffith B, et al. Imaging and diagnostic advances for intracranial Meningiomas. Neuro Oncol. 2019:14;21(Suppl 1): i44-i61
17. Bon-Jour LB, Kuan-Nein CK, Hung-Wen KH, et al. Correlation between magnetic resonance imaging grading and pathological grading in meningioma. J Neurosurg. 2014;121(5):1201-8
18. Maillo A, Orfao A, Sayagues JM, et al: New classification scheme for the prognostic stratification of meningioma on the basis of chromosome 14 abnormalities, patient age, and tumor histopathology. J Clin Oncol. 2003; 21:3285–95

19. Mermanishvili TL, Dzhorbenadze TA, Chachia GG. Association of the degree of differentiation and the mitotic activity of intracranial meningiomas with age and gender. Arkh Patol. 2010; 72:16–8
20. Hashiba T, Hashimoto N, Maruno M, et al: Scoring radiologic characteristics to predict proliferative potential in meningiomas. Brain Tumor Pathol. 2006; 23:49–54
21. Kane AJ, Sughrue ME, Rutkowski MJ, et al. Anatomic location is a risk factor for atypical and malignant meningiomas. Cancer. 2011; 117:1272–8
22. Varlotto J, Flickinger J, Pavelic MT, et al**.** Distinguishing grade I meningioma from higher grade meningiomas without biopsy. Onco target. 2015; 6(35): 38421–8.
23. Kawahara Y, Nakada M, Hayashi Y, et al. Prediction of high-grade meningioma by preoperative MRI assessment. J Neurooncol. 2012;108(1):147-52
24. Coroller TP, Bi WL, Huynh E, et al. Radiographic prediction of meningioma grade by semantic and radiomic features. PLoS ONE. 2016;12(11):0187908
25. Schob S, Frydrychowicz C, Gawlitza M, Bure L, Preuß M, Hoffmann KT. Signal Intensities in Preoperative MRI Do Not Reflect Proliferative Activity in Meningioma. Transl Oncol. 2016; 9(4): 274–9
26. Chu H, Lin X, He J, Pang P, Fan B, Lei P. Value of MRI Radiomics Based on Enhanced T1WI Images in Prediction of Meningiomas Grade. Acad Radiol. 2021;28(5):687-93.