Original Article

Prediction of Intra Operative Tumor Consistency and Histopathological Subtype with Preoperative MR Imaging in Intracranial Meningiomas – A Prospective Analysis

Karthikeyan KV*, Krishnakumar M**, Ramesh VG***, Siddarth G****, Jayendrapalan****

* Senior Consultant, Department of Neurosurgery, Chettinad Superspeciality Hospital, **Consultant Neurosurgeon , Government Hospital, Pudhucherry, ***Senior Consultant and HOD,****Post Graduate, Department of Neurosurgery, Chetinad Superspeciality Hospital, Chettinad Academy of Research & Education, Chennai, India.

Dr.K.V.Karthikeyan has been working in the Department of neurosurgery of Chettinad Superspeciality Hospital since 2010 as Senior Consultant Neurosurgeon. He finished his MBBS and MCh Neuro from the Madras Medical College in 2006.He is very well trained in Microneurosurgery and Endoscopic Neurosurgery. He is specialised in Skull base and cerebrovascular surgery with special interest in Paediatric Neurosurgery. He was awarded FMMC in 2010 from the prestigious Madras Medical College.

Corresponding author - Dr.Krishnakumar M (drkrishnams5@gmail.com)

Chettinad Health City Medical Journal 2017; 6(1): 13 - 19

Abstract

Aim : To establish the correlation between Magnetic Resonance Imaging (MRI) characteristics and intra-operative consistency of meningiomas and establish the correlation between MRI characteristics and histological subtype of meningiomas.

Materials and Methods : This is a prospective analytical study. All the cases of intracranial meningiomas diagnosed and operated at the Department of Neurosurgery, Chettinad Hospital and Research Institute, Chennai during the 2 year period Jan 2014 to Dec 2015, totally 25 patients were included in the study. Patient clinical details including history and examination findings were noted. The MRI findings including T1 and T2 image characteristics of the tumors were recorded and graded preoperatively based on the previous studies as mentioned below. Intraoperative consistency of the tumor was also noted and histopathological type of the tumor was also recorded. Patient clinical details including history and examination findings were noted. The MRI findings including T1 and T2 image characteristics of the tumor were recorded and graded preoperatively based on the previous studies as mentioned below. Intraoperative consistency of the tumor was also noted and histopathological type of the tumor was also recorded.

Results : Preoperative prediction of the tumor consistency from the MRI correlated with the actual intra-operative consistency in 64% of cases and preoperative prediction of the pathological type from the MRI correlated with actual histopathological report in 36% of cases.

Conclusion : MRI is useful in prediction of intra-operative consistency of meningioma to a larger extent but a prediction of histopathological subtypes on the basis of MRI has not been possible to similar degree possibly because of varying number of subtypes.

Key Words: Meningioma, Consistency, MRI contrast.

Introduction

Harvey Cushing coined the term "Meningioma" in 1922. Meningioma is a dural based tumor that arises from arachnoid cap cells. The incidence is approximately 2.3 per 100,000 for benign meningiomas and 0.17 per 100000 for malignant meningiomas[1]. The principle treatment remains surgical resection with external beam radiotherapy, radiosurgery, arterial embolization and chemotherapy as an adjunct therapy when necessary[2].

The surgical resection remains the mainstay of treatment for meningiomas. The tumor consistency, vascularity, peri tumoral oedema, bone invasion, etc. play important role in planning the surgery. The consistency of the meningioma may be soft, firm or combination of both. In earlier days predicting the intra-operative consistency and histological type of the meningioma were difficult. But, with the advent of Computed tomography (CT) and Magnetic Resonance Imaging (MRI), several papers have reported the correlation between the imaging characteristics, tumor consistency and histological type of meningiomas.

Aim and Objectives

The aims of this study include the following:

1. The correlation between MRI characteristics and intra-operative consistency of meningiomas.
2. The correlation between MRI characteristics and histological subtype of meningiomas.

Materials and Methods

This is a prospective analytical study. All the cases of intracranial meningiomas diagnosed and operated at the Department of Neurosurgery, Chettinad Hospital and Research Institute, Chennai during the 2 years period were included in the study.

The patient details of the individual were entered in a detailed proforma. Patient clinical details including history and examination findings were noted. The MRI findings including T1 and T2 image characteristics of the tumor were recorded and graded preoperatively based on the previous studies as mentioned below. Intraoperative consistency of the tumor was also noted and histopathological type of the tumor was also recorded.

Patient clinical details including history and examination findings were noted. The MRI findings including T1 and T2 image characteristics of the tumor were recorded and graded preoperatively based on the previous studies[3] as mentioned below. Intraoperative consistency of the tumor was also noted and histopathological type of the tumor was also recorded. MRI findings were grouped into three to correlate with consistency (Table 1) as follows.

Group 1	Soft (T1-hypo-intense and T2-hyper-intense).
Group2	Intermediate consistency(T1-iso-intense, T2- iso to hyper-intense).
Group3	Firm (T1-hyper-Intense and T2- hypo-Intense).

Table 1 : MRI Grouping of Meningiomas

This was used to predict the tumor consistency preoperatively and the preoperative prediction was correlated with actual intraoperative consistency of the tumor.

Intraoperative consistency grading was made based on the 5 point scale described by Zada et al (2013)[4] (Table 2)

Grade-1	Extremely soft tumor, internal debulking with suction only.
Grade-2	Soft tumor, internal debulking mostly with suction and remaining fibrous strands resected with easily foldable capsule.
Grade-3	Average consistency, tumor cannot be freely suctioned and requires mechanical debulking and the capsule then folds with relative ease.
Grade-4	Firm tumor, high degree of mechanical debulking required and capsule remains difficult to fold.
Grade-5	Extremely firm-calcified tumor, approaches density of bone and capsule does not fold.

Table 2 - Intraoperative Grading of Meningiomas as described by Zada et al (2013)[4]

For convenience, the five point scale (Zada, 2013)[4] was divided into three groups:

Group I: Zada grade - 1 and grade - 2.
Group II: Zada grade - 3.
Group III: Zada grade - 4 and grade -5.

Similarly MRI and histopathology prediction was made based on the T2 image characteristics (Table 3), and for the purpose of study histopathology was divided into four groups.

Group I	Iso-intense (transitional and meningothelial subtypes).
Group II	Hypo-intense (fibroblastic and psammomatous subtypes).
Group III	Hyper-intense (angioblastic subtypes).
Group IV	Other histopathological subtypes.

Table 3 - T_2 Characteristics of Meningiomas on MRI and their histopathology prediction

Descriptive analysis of base line characteristics of the study population, location of tumor and grading and type of meningioma both before and after surgery was done. Frequencies and percentage was used for categorical variables. Mean and standard deviations were used for quantitative variables. The correlation between the preoperative and post-operative grading was done by cross tabulation. Percentage agreement was calculated by totaling the proportion of concordant pairs in cross tabulation. Kappa statistic and p-value was computed to assess the statistical significance of the agreement between pre and post-operative grading and type of tumor. IBM SPSS version 21 was used for statistical analysis.

Observations & Results

A total of 25 participants were included in the final analysis. The minimum age of the study participants was 23 years and the maximum age was 60 years, with a mean of 43.20 years (SD 9.58). (Table 4 & Figure 1)

Parameter	Mean	Median	95% CI		Standard Deviation	Minimum	Maximum
			Lower	Upper			
AGE (In years)	43.20	41.00	39.24	47.16	9.587	23	60

Table 4 - Age distribution of study population (n=25)

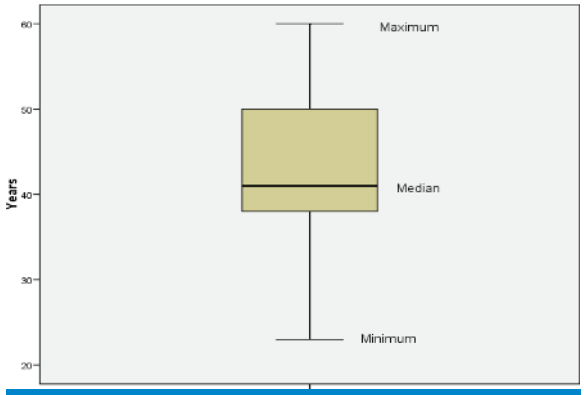

Fig 1 : Box and whisker plot showing age distribution of study population

Out of 25 study participants, 20(80%) were females and only 5 (20%) participants were males.

Gender	Frequency	Percentage
Female	20	80.0
Male	5	20.0
	25	100.0

Table 5 - Gender distribution of study population:

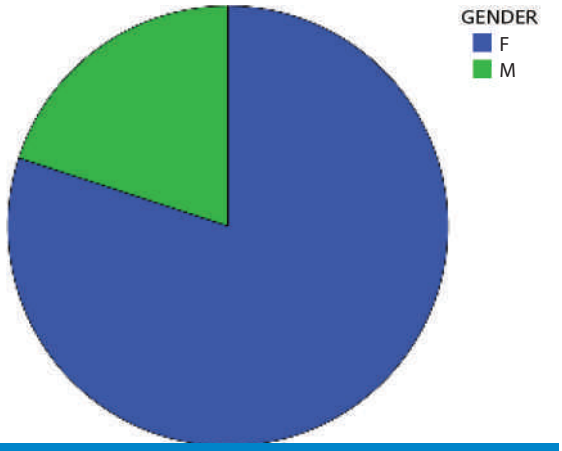

Fig 2 : Gender distribution of study population (N=25)

Location	Frequency	Percentage
Convexity	7	28.0
Sphenoid wing	6	24.0
Parasagittal	4	16.0
Falcine meningioma	3	12.0
Intraventricular	2	8.0
Basal meningiomas	1	4.0
cerebellopontine angle	1	4.0
Suprasellar	1	4.0
Total	25	100.0

Table 6 - Location of the tumor in study population

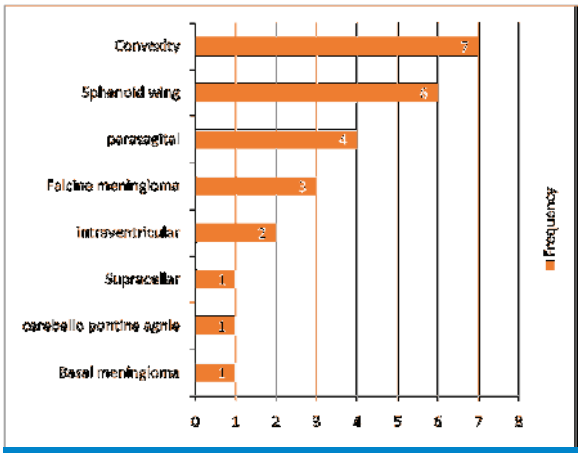

Fig 3 : Location of tumor in study population.

In the study, the most common location of the tumor was convexity (28%) followed by sphenoid wing (24%), parasagital (16%), falcine(12%), intraventricular (8%),basal meningioma, cerebellopontine angle and suprasellar meningioma (4%)[5], as shown in Table 6 and Figure 3.

MRI T_1 intensity	Frequency	Percentage
Isointense	18	72.0
Hypointense	7	18.0
Hyperintense	0	0.0
Total	**25**	**100.0**

Table 7 - MRI T_1 intensity for tumor grading.

T_1 MRI characteristics showed iso-intensity in 18 cases (72%), hypo-intensity in 7 cases (18%) (Table 7).

MRI T_2 intensity	Frequency	Percentage
Isointense	6	24.0
Hypointense	8	32.0
Hyperintense	11	44.0
Total	**25**	**100.0**

Table 8 - MRI T_2 intensity for tumor grading.

T_2 MRI intensity showed hyper-intensity in 11 cases (44%), hypo-intensity in 8 cases (32%) and iso-intensity in 6 cases (24%) (Table 8).

	Frequency	Percentage
Group I	11	44.0
Group II	7	28.0
Group III	7	28.0
Total	25	100.0

Table 9 - Pre-operative consistency grading of the tumor

In this study, most of the tumors were group I (44%) and group II and group III were 28% each (Table 9) in the preoperative assessment. The actual intraoperative grades were 44% group I, and 36% in group II and 20%

	Frequency	Percentage
Group I	11	44.0
Group II	9	36.0
Group III	5	20.0
Total	25	100.0

Table 10 - Intra operative consistency grading of the tumor

in group III (Table 10). In our study most of the tumors were in the group I (soft).

	Frequency	Percentage
Group I	8	32.0
Group II	6	24.0
Group III	11	44.0
Group IV	0	0.0
Total	25	100.0

Table 11 - Pre-operative pathological type.

	Frequency	Percentage
Group I	18	72.0
Group II	2	8.0
Group III	2	8.0
Group IV	3	12.0
Total	25	100.0

Table 12 - Post-operative pathological type.

The predicted histopathological subtypes of meningiomas in the basis of MRI finding were as follows : group I: 8 cases (32%), group II: 6 cases (24%) and group III: 11 cases (44%) (Table 11). The actual histopathological subtypes were as follows : group I: 18 cases (72%), group II: 2 cases (8%), group III: 2 cases (8%) and group IV: 3 cases (12%) (Table 12).

Preoperative and the intra-operative grades of the tumor correlated perfectly in the 16 out of 25 cases. The kappa scoring for the consistency grading was calculated to be 0.446 and the p-value was 0.002 with percentage agreement of 64%. Based on the kappa statistic value there is a moderate agreement.

Pre-operative grading	Intra operative grading			Percentage agreement	Kappa statistic	P-value
	Group I	Group II	Group III			
Group I	8 72.7%	3 33.3%	0 0.0%	64%	0.446	0.002
Group II	2 18.2%	4 44.4%	1 20.0%			
Group III	1 9.1%	2 22.2%	4 80.0%			

Table 13 - Correlation between pre and intraoperative consistency grading.

Pre-operative grading	Intra operative grading			Percentage agreement	Kappa statistic	P-value
	Group I	Group II	Group III			
Group I	8 72.7%	3 33.3%	0 0.0%	64%	0.446	0.002
Group II	2 18.2%	4 44.4%	1 20.0%			
Group III	1 9.1%	2 22.2%	4 80.0%			

Table 14 - Correlation between pre and post-operative histopathological subtype.

The correlation between the pre and postoperative histopathological subtypes showed a kappa score of 0.105 with p-value of 0.239 and percentage of agreement is 36%. The magnitude of inter user agreement on the basis of kappa statistics was only a slight agreement

Illustrative Cases

CASE 1: Anterior 1/3 rd falcine meningioma (Fig 4,5,6)

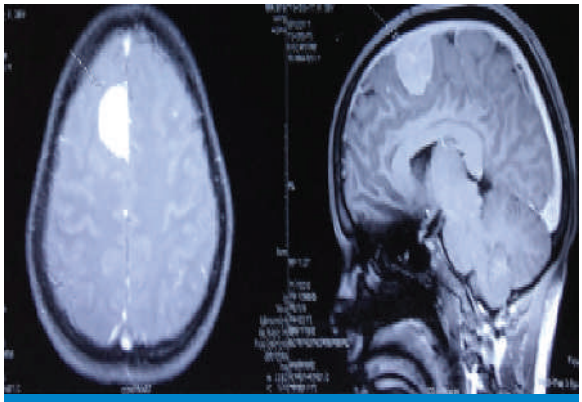

Fig 4 : Preoperative MRI of a middle 1/3rd falcine meningioma with a preoperative consistency of group-II (intermediate consistency).

Fig 5 : Completely excised falcine meningioma specimen with Intraoperative consistency of group-I (soft).

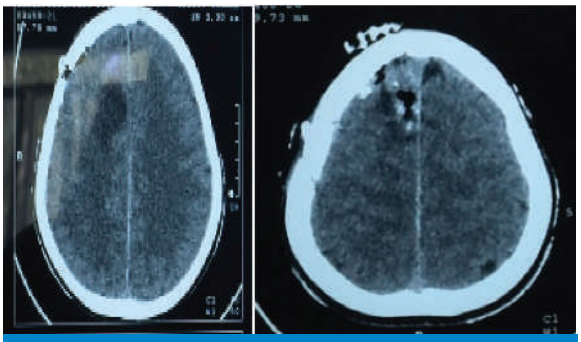

Fig 6 : Post-operative CT brain of anterior falcine meningioma showing complete excision of the tumor with post-op changes.

CASE 2: Case of left parietal convexity meningioma (Fig 7,8,9).

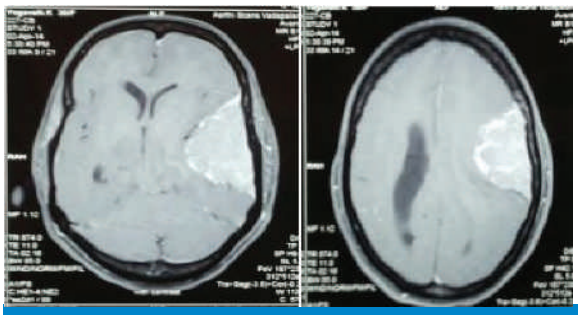

Fig 7 : Pre-operative MRI showing left parietal convexity meningioma with Preoperative consistency of group-I (soft).

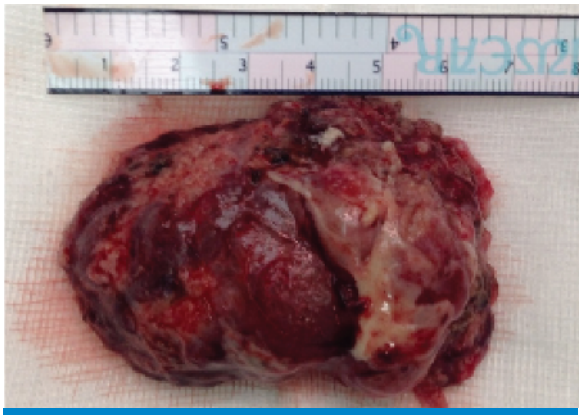

Fig 8 : Image showing the completely excised convexity meningioma.Intraoperative consistency of group-II (intermediate consistency).

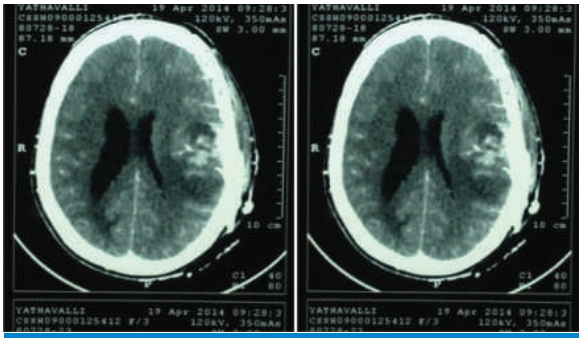

Fig 9 : Post-operative CT brain(contrast) showing post-operative changes with tumor bed hematoma and no residual tumor.

Twenty five operated cases of intracranial meningiomas have been analyzed in this study and correlation has been made between MRI appearance and intra-operative consistency and MRI and the histopathological subtypes. An attempt also made to correlate predicted consistency on the basis of MRI and actual intra-operative consistency and to correlate predicted histopathological subtypes based on the MRI and actual histopathological sub types. In the present study, T_2 hyper-intensity and T_1 hypo-intensity correlated with soft meningiomas, T_1 iso-intensity and T_2 iso to hyper-intensity correlated with intermediate consistency meningiomas, T_1 hyper-intensity and T_2 hypo-intensity correlated with firm meningiomas. Correlation of the image characteristics with various grades of the tumor was similar to previous similar studies. The following results have been derived from this study:

1. T_1 and T_2 weighted MRI were the sequences used in this study T_1-hypo-intensity and T_2-hyper-intensity correlated with soft tumor, T_1-hyper-intensity and T_2-hypo-intensity correlated with firm tumor.
2. T_2-hypo-intensity correlated with fibrous and psammomatous subtypes, T_2-hyperintensity correlated with angioblastic tumors and T_2-iso-intensity correlated with transitional and meningothelial subtypes.
3. Preoperative prediction of the tumor consistency from the MRI correlated with the actual intra-operative consistency in 64% of cases.
4. Preoperative prediction of the pathological type from the MRI correlated with actual histopathological report in 36% of cases.

Discussion

Prior information about the meningioma consistency and histopathological subtypes help in planning surgery and further follow-up. Some of the important factors that affect the decision making in surgical approach and resection of the tumors are tumor size, growth patterns, and invasion of the neurovascular structures and the consistency of the tumor. Many authors have reported that consistency is also a major limiting factor in the surgeon's ability to achieve complete resection of intracranial meningiomas. Little et al (2005)[6] reported in their series of petroclival meningiomas that risk of cranial nerve deficits increased with a multitude of factors, one being a tumor with fibrous consistency. The grading system as proposed by Zada et al (2013) for intra-operative consistency is easy to use method for the assessment of the intra-operative tumor consistency. Over the past few decades the tumor consistency has become an important variable of meningioma surgery as evolving minimally invasive options exist for removing a variety of skull base tumors. The ability to accurately predict the consistency of meningioma preoperatively based on MRI findings helps in selection of appropriate surgical approach and also provides more information regarding the requirement for a staged resection or additional challenges related to consistency.

of skull base tumors. The ability to accurately predict the consistency of meningioma preoperatively based on MRI findings helps in selection of appropriate surgical approach and also provides more information regarding the requirement for a staged resection or additional challenges related to consistency.

Hoover et al (2011)[7] in his series of 101 meningiomas, found that 50 meningiomas were soft and 51 meningiomas were firm. The association of T2 hypo-intensity with firmness and T_2 hyper-intensity with softness were statistically significant in his study and overall sensitivities for detecting soft and firm consistency were 90% and 56% respectively.

Kashimura et al (2007)[8] predicted the tumor consistency using fractional anisotropy (FA) value calculated from the preoperative MR diffusion tensor imaging found that FA values of hard tumors were higher than those of the soft tumors and concluded that FA value was significant predictor of tumor consistency.

In the present study, T_2 hyper-intensity and T_1 hypo-intensity correlated with soft meningiomas, T_1 iso-intensity and T_2 iso to hyper-intensity correlated with intermediate consistency meningiomas, T_1 hyper-intensity and T_2 hypo-intensity correlated with firm meningiomas.Correlation of the image characteristics with various grades of the tumor was similar to previous similar studies.

In our series we analyzed the correlation between the T_2 MRI intensity and the histopathology of the tumor. Maiuri et al (1999)[9] in her study of 35 cases of intracranial meningiomas to determine the intraoperative consistency found that meningiomas T_2 hyper-intense were soft and more frequently of angioblastic or syncytial subtypes, tumors that are T_2 hypo-intense or hypo-isointense were mostly of fibroblastic or transitional subtypes. In their series, meningiomas that are T_2 hypointense were mainly fibroblastic, T_2 hyper-intense were mainly syncytial, angioblastic and party transitional and T_2 iso-intense meningiomas were mainly transitional and partly fibroblastic and syncytial. In her study Maiuri et alconsidered the correlation of MR appearance with other pathologic findings. The cellularity of the tumor seems to be one of the main factors that determine the different signal intensity of various subtypes. Indeed, fibroblastic meningiomas which are mainly hypo-iso-intense have a lesser cell density; on other hand, syncytial and angioblastic meningiomas which are mainly hyper-intense on T_2 have a higher cellular density. However when the relationship between the cellularity and the signal intensity is analyzed in each single subtype, the correlation is weak and probably not significant. The vascularity of meningiomas seems to be well correlated with the MR appearance. In Maiuri et al and Chen et al[10] studies, hyper-intensity on T_2 weighted images predicted microscopical hypervascularity. Angioblastic meningiomas were almost always hyperintense on T_2 weighted images.

Somaya et al (1995)[11] studied the T_2 intensity of 40 patients and correlated with histological sub types; the mean signal intensity scores on T_2 of the fibrous type of meningiomas were lower than those of other sub types and they concluded that meningiomas hypointense on T_2 are composed primarily of fibrous elements.

In the present series, the preoperative prediction of histological subtypes was correct only in 36% of cases. The transitional, meningothelial, fibroblastic, psammomatous and angioblastic subtypes were predicted more easily than other subtypes.

T_2 weighted MRI sequence were useful in prediction of consistency and histological subtypes than T_1 weighted sequence.

The limitations of this study are relatively small sample of cases and less histological subtypes of meningiomas treated. Similar study involving larger number of cases and more varieties of histological subtypes will help to clarify the position better. This is the first time such a study has been conducted in Indian population.

We propose to continue this study on a larger number of cases of meningioma.

References

1) Cushing H, Eisenhardt L. Meningiomas: Their classification, Regional Behaviour, Life History and Surgical End results.BMLA.1938;27(2):185.

2) Mc Dermott MW, Wilson CB. Meningiomas. In : Youmans JR (Ed.) Neurological Surgery 4th Edition. WB Saunders, Philadelpha ; 1996 : 2782-825.

3) Suzuki Y, Sugimoto T, Shibuya M, Sugita K, Patel SJ. Meningiomas: Correlation Between MRI Characteristics And Operative Findings Including Consistency. Acta Neurochir (Wein).1994; 129(1-2):39-46.

4) Zada G, Yashar P, Robison A, Winer J, Khalessi A, Mack WJ et al. A proposed grading system for standardizing tumor consistency of intracranial meningiomas. Neurosurg Focus. 2013 ; 35 (6) : E1.

5) Al-Mefty O, Abdulrauf S, Haddad GF. Meningiomas. In : Winn HR (Ed.). Youmans Neurological Surgery. Philadelphia : Elsevier Saunders ; 2011 : 1426-49

6) Little KM, Friedman AH, Sampson JH, Wanibuchi M, Fukushima T. Surgical management of petroclival meningiomas: Defining resection goals based on risk of neurological morbidity and tumor recurrence rates in 137 patients. Neurosurg. 2005;56(3):546-59.

7) Hoover JM, Morris JM, Meyer FB: Use of pre-operative magnetic resonance imaging T1 and T2 sequences to determine intraoperative meningioma consistency. Surg Neurol Int. 2011; 2:142.

8) Kashimura H, Inone T, Ogasawara, Arai H, Otawara Y, Kanabara Y, et al. Prediction of meningioma consistency using fractional anisotropy value measured by magnetic resonance imaging. J Neurosurg 2007;107(4):784-7.

9) Maiuri F, Iaconetta G, de Divitus O, Cirillo S, Di Salle F. De Caro ML. Intracranial meningiomas: Correlations between MR imaging and histology. Eur J Radiol 1999;31(1):69-75.

10) Chen TY, Lai PH, Ho JT, Wang JS, Chen WL, Pan HB, et al. Magnetic resonance imaging and diffusion-weighted images of cystic meningioma: correlating with histopathology. Clinical imaging. 2004;28(1):10-9.

11) Soyama N, Kuratsu J, Ushio Y.Correlation between magnetic resonance imaging and histology in meningiomas: T2- weighted images indicate collagen contents in tissues. Neurol Med Chir (Tokyo). 1995;35:438-41.