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MAGNETIC RESONANCE IMAGING (MRI) PATTERNS OF INTRACRANIAL MENINGIOMAS

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Abstract

Subtyping of Meningiomas into benign, atypical and malignant entities is of supreme importance in respect to treatment options of surgery, radiation therapy, or a combination of the two, in addition to that, embolization procedure for the feeding arteries is a successful consideration in most of the highly vascular or potentially more malignant meningiomas to evaluate the role of MRI in defining the characteristic pattern of intracranial meningiomas and to correlate MRI with the histopathological findings in an attempt to predict the histological diagnosis (subtype) prior to surgery. A cross-sectional analytic study was performed on Magnetic Resonance Imaging (MRI) of surgically and biopsy verified intracranial meningiomas in 62 patients (21 males and 41 females) in an attempt to predict the histological features. The study was done in Al-Jirahat Specialized Surgical Hospital and in Al-Sadir teaching Hospital, department of radiology beside Alameer MR private center in Alnajaf AlAshraf city during a period between October 2002 and September 2005. On MRI appearance, atypical and malignant meningiomas in contrast with the more benign histology had more heterogeneous signal intensity and enhancement in (80%) and (100%) respectively, less obviously showed meningioma cleft sign, more cystic appearance in (60%) and (100%) respectively, surrounded by marked edema (+++) degree, exert more mass effect and invade the dural venous sinus in almost all the cases. Overall, MRI is an excellent non-invasive tool for the preoperative evaluation of intracranial meningiomas and can predict with a good degree of certainity the aggressive behavior of the more atypical and malignant meningiomas. This study showed lower rate of atypical and malignant meningiomas than other similar studies. Other findings are similar to what have been found in other studies performed on intracranial meningiomas.

Introduction

Meningiomas are particularly gratifying to diagnose since they are the commonest benign intracranial tumors, it constitute about 15% of primary brain tumors[1]. However, because most meningiomas are benign and completely resectable, the mortality figures are much lower; only about 6% of brain tumors causing death are meningiomas. Meningiomas are the tumors of adults, with the main age of incidence ranging between 20 and 60 years. The peak incidence is in the age of 40[1,2]. Overall, women are affected thrice as often as men (3:1 ratio)[2]. Most meningiomas are solitary, but multiple meningiomas can occur in 5% of cases[3]. Meningiomas in children account for less than 2% of meningiomas and less than 2% of intracranial tumors of childhood[4].

Meningiomas can arise anywhere over or under the brain from the arachnoid cell rests, but have several sites of election as: Convexity, parasagittal, tuberculum sellae, sphenoid ridge and pterion, cerebellopontine angle, subfrontal, cerebellar convexity, tentorium, intraventricular, and other well documented sites include the optic nerve sheath and olfactory groove, while they are rarely seen in extra-calvarial or ectopic locations[3].

Histological subtyping of meningiomas[5]: A-Benign meningiomas: Meningothelial

(syncytial), Fibroblastic (fibrous), Transitional (mixed), Angiomatus, Psammomatous, Microcystic, Secretory, Inflammatory, Chordoid and Metaplastic

B-Atypical meningiomas[6]:

The histological features of these include frequent mitosis, increased cellularity, high nuclear/cytoplasmic ratio, prominent nucleoli, sheet like (rather than lobular) pattern of growth, and zones of necrosis. They can be of any histological subtype.

C-Malignant (including papillary) meningiomas[6]: These include obviously malignant cytoplasm, high mitotic index and conspicuous necrosis. Gross or deep cortical brain invasion is considered as a sign of malignancy.

Imaging: 1- Simple skull x-ray: This may show diagnostic evidence of the presence of a meningioma in about one-thirds of cases[7]. 2- Computerized tomography (CT): In a multi-institutional prospective study, the sensitivity of contrast enhanced CT for the detection of an intracranial mass in patients with meningiomas was 96%, 10% of these masses was not detected on non contrast image[8]. 3- MRI: Early MRI studies of meningiomas without the intravenous administration of contrast agent found that some small lesions, those with little mass effect or edema, were more readily identified with CT than with MRI, then image quality has improved considerably, and the detection rate of MRI became equal to, if not greater than, that of CT[9].

The development of Gd-DTPA as an intravenous contrast agent has made MRI one of the most sensitive imaging tests in the detection of meningioma[10].

Atypical meningiomas: Approximately 15% of meningiomas will have atypical features on imaging: Rapid growth occasionally results in area of central necrosis, these areas appear as hypointense on T1-weighted MR images and hyperintense on T2-weighted images and tend not to enhance on contrast study[11]. Cystic meningiomas account for only 2-4% of meningiomas. In general, cystic component is non-enhancing, hypointense on T1-weighted images and are hyperintense on T2-weighted images[12]. Hemorrhage occurs in 5% of cases; The MR signal intensity of hemorrhage is variable and relates to the age of the blood. Typically hemorrhage is visualized as high signal intensity on T1-weighted images and either high or low signal intensity on T2-weighted sequences[13].

Malignant meningiomas: Ten to fifteen percent of all meningiomas are considered malignant[14]. Imaging cannot predict with certainty the future behavior of meningiomas, but certain imaging features may be associated with malignant histology and/or aggressive clinical behavior, these include: Gross bone destruction, Absent or minimal calcification, Irregular inwards projection of the tumor toward the brain, The more heterogeneous signal intensity, Indistinct tumor margins at the brain surface, "Mushrooming" or extension of the tumor away from the main mass, over the surface of the brain.

Angiographic features: Although angiography is little used in tumor diagnosis, it still has a place in the assessment of some meningiomas and some neurosurgeons still require arterial studies of the blood supply and vascular relationships before surgery in highly vascular or potentially more malignant meningiomas, and prior to surgery some tumors of this type have been treated by embolization from the external carotid artery of meningeal feeding vessels not supplying cerebral tissue[15].

Aim of the study is to evaluate the role of MRI in defining the characteristic patterns of intracranial meningiomas, to correlate MRI with the histopathological findings in an attempt to predict the histological diagnosis prior to surgery.

Patients and methods

In this cross-sectional study a sixty-two patients (21 males and 41 females) with

an age ranging from 20-69 years (mean 58 years) were studied at Al-Jirahat Specialized Surgical Hospital and in Al-Sadir Teaching Hospital, department of radiology beside Alameer MR private center in Alnajaf AlAshraf city between October 2002 and September 2005.

Preoperative presumptive diagnosis of intracranial extra-axial meningiomas was made using Philips Gyroscan (N.T. 3000 super-conducting, 1.5 Tesla & Philips 0.5 tesla). Head coil was used which is quadrature detector coil suitable for head imaging. All patients subsequently underwent surgery for their intracranial tumors and tissue sections from each case were viewed by pathologist and a detailed histopathological report was obtained.

Types of the images; Standard brain MRI examination include the following: Sagittal and axial T1-weighted imaging (TR/TE=400-600 msec./20-30 msec.), Sagittal and axial T2-weighted imaging (TR/TE=2200-3000 msec./80-100 msec.), T2-FLAIR coronal, Post-contrast T1-weighted images in axial, sagittal and coronal sections to demonstrate the enhancement pattern of the lesions, MRV examination is performed in all cases of meningiomas that are adjacent to a major dural venous sinus.

Contrast medium; Gadolinium DTPA: The dose is (0.1) m.mol/Kg body weight was given to all patients. Omniscan is a paramagnetic contrast media, each ml. Containing (0.5) m.mol of Gadiamide. It is manufactured by Nycomed, Ireland and supplied readily for use as a sterile solution.

The dose is given through slow I.V. route while the patient is still inside the MR tunnel. Patients were examined immediately after contrast media injection.

All sequences were of 5 mm. Slice thickness with 1 mm. gap in between to get an appropriate resolution with a good signal to noise. The imaging matrix was 256 x 256.

Principle statistical analysis: An expert statistical advice was sought for. Statistical analysis was done using SPSS computer software (statistical package of social sciences). Frequency distribution for selected variables was done first and assessed by spearman's rank correlation coefficient. P value less than 0.05 level of significance was considered statistically significant.

Results

In this study, sixty-two patients (59 newly diagnosed and 3 recurrent) with intracranial extra-axial meningiomas, suggested by MRI according to specific criteria for tissue typing, surgically verified and the final diagnosis proved by tissue biopsy were studied.

These sixty-two patients were 21(34%) males, 41(66%) females, aged between 20-69 years with mean age of 58 years and the histopathological diagnoses we found were benign tumors in 55 cases (88.7%) with no MRI specificity could be found to each tissue type, atypical tumors in 5 cases (8%), and malignant meningiomas in 2 cases (3.3%) only (in this series hemangiopericytomas were excluded). These 55 cases of benign meningiomas were further subdivided histopathologically into: Meningothelial variety which represents 18 cases (33% of the benign type) [8 (44%) males and 10 (56%) females], fibroblastic meningiomas which represents 6 cases (11%) of the benign type [4 (67%) males and 2 (23%) females], transitional variety was found in 28 cases (51%) of the benign tumors [6 (21%) males and 22 (79%) females], angioblastic type that represents 2 cases (3%) all were females and other varieties of benign meningiomas in one male case (2%) which proved to be psammomatus meningioma. While of the 5 cases that proved to be atypical meningiomas they were 2 (40%) males and 3 (60%) females and the two cases of malignant entity were females (100%).

In regard to the tumor location cerebral convexity location was found in 25 cases (40.4%), parasagittal in 20 cases (32.2%), olfactory groove and cerebellar convexity each with 4 cases (6.5%), sphenoid ridge location was seen in 3 cases (5%), the tubercullum sellae and intraventricular location in 2 cases for each (3.2%), while the tentorium and the cerebellopontine angle (C.P.A.) locations shared the same number of cases (one for each) that represent (1.5%) of total cases of meningiomas. Sizes ranged roughly from (1 x 1.4 x 1.8 cm. to 10 x 8.4 x 6 cm.) in the vertical, transverse, and antero-posterior dimensions. The site of the tumor encountered in both sides of the brain by 33 cases (53.3%) in the right side, 18 cases (29%) in the left side while 9 cases (14.5%) were central. The two cases of intraventricular meningiomas were one in each lateral ventricle (1.6 %).
Most meningiomas showed isointense signal intensity on both T1-WI and T2-WI, [56 cases (90.3%)] and [47 cases (76%)] respectively, and homogenous texture in 45 cases (73%).

Forty-seven (76%) of the tumors showed positive meningioma cleft sign on MRI, while 21 cases (34%) showed calcification; just 8 cases (13%) had cystic changes and only 25cases (40%) were avascular on MRI. Regarding peritumoral edema, twelve cases (19.5%) of meningiomas were not surrounded by edema, 31 cases (50%) had mild (+) degree, 10 cases (16%) had moderate (++) degree and 9 (14.5%) cases had marked (+++) degree.

All of these meningiomas showed enhancement with intravenous contrast media to different extent, two cases (3.2%) had mild (+) degree, 26 (42%) had moderate (++) degree and 34 cases (54.8%) had marked (+++) degree. 49 (79%) of the cases had homogenous enhancement with contrast media and 38 cases (61%) show dural tail enhancement.
Mass effect was seen fluctuating between mild sulcus effacement (+) degree and severe one (+++) degree with subfalxial herniation with or without hydrocephalus.
Six cases (11%) of the benign tumors, 2 cases (40%) of the atypical and one case (50%) of the malignant tumors had positive bone involvement, while the ratios for dural venous sinus invasion on MRI were (16.4%), (60%) and (100%) for the benign, atypical and the malignant tumors respectively.

Discussion

Meningiomas are the most common benign intracranial neoplasms and represent the largest group of operable intracranial tumors[16].
Several published reports of attempts to predict the histologic type or malignancy of meningiomas with angiography, scintigraphy had been done. Farkas et al[17]. In reviewing 32 cases, could find no distinguishing features in the radioisotope or angiographic studies. A major advance in imaging was made by Vassilouthis and Ambrose[18], who used CT to predict the histopathological type in 102 resected meningiomas. They conclude that CT is most useful in identifying calcium aggregates, which usually indicates transitional or fibroblastic histologic type. Cystic areas, irregular margins, marked edema, and non-homogenous contrast enhancement pointed to a diagnosis of syncytial or angioblastic subtype.

Meningiomas constitute 15 to 20 % of all primary brain tumors, 10% to 15% of all meningiomas are considered malignant[52] and approximately 15% are atypical[19].

In this study, meningiomas were benign in 88.7% of cases, atypical in 8%, and only 3.3% were found to be malignant, which is slightly different from the above studies.
Meningiomas are the tumors of adults, with the main age of incidence ranging between 20 and 60 years. The peak incidence is in the age of 40. (Overall, women are affected thrice as often as men (3:1 ratio)[4]. Meningiomas are generally

described as distinctly less common in patients less than 21 years old[20].

In this study, the greatest incidence was found during the sixth decade of life with mean age of incidence of 58 years old, the youngest age was 20 years female patient and the oldest patient in this series was also female aged 69 years old, no cases were aged less than 20, which agrees with the previous studies.

Female predominance was also seen in this study, female cases were 41, which represent (66%) of the total, and the male cases were 21 that represent (34%), so in contrast to the above study we found that women affected twice as often as men (2:1 ratio).

No distinct age of predilection for the different histopathological subtypes of meningiomas was found in this study and the difference of distribution was statistically not significant ($P=0.71^{[NS]}$).

Correlation between location & laterality of the tumor and the histological type (tables III & IV): Meningiomas have distinct predilection for certain intracranial locations, although they may occur in any area where meninges exist or there are cell rests of meningeal derivation. There is a close relationship between the location of the arachnoid granulation and the prevalent site of origin for meningiomas, and approximately 50% of convexity meningiomas are parasagittal or attached to the sagittal sinus[21].

In this study, cerebral convexity location was found in 25 cases (40.4%), followed by parasagittal location (fig.19) in 20 cases (32.2%)(fig.19), olfactory groove (fig. 20) and cerebellar convexity each with 4 cases (6.5%), sphenoid ridge location (fig. 21) was seen in 3 cases (5%), the tubercullum sellae and intraventricular location (fig.22) in 2 cases for each (3.2%) (one tumor in each trigone of the lateral ventricle), while the tentorium (fig.23) and the cerebello-pontine angle (CPA)(fig.24) locations shared the same number of cases (one for each) that represent (1.5%) of total cases of meningiomas.

In this study, there was total right laterality in 33 cases (53.3%), total left laterality in 18 cases (29%), and 9 cases (14.5%) were central in location.

Although most of our cases were sited in the cerebral convexity, but we neither found any significant correlation between the location or the laterality of meningiomas and the histological subtypes, nor the occurrence of the 2 cases of malignant meningiomas (100%) in the parasagittal location had any statistical significance ($P=0.2^{[NS]}$).

Correlation between MR signal intensity on T1-WI pre /post contrast &T2-WI with the histological features:

Spagnoli, et al[(22)] studied 25 meningiomas exclusively at high field strength (1.5 Tesla). On T1-weighted images, meningiomas were usually isointense or mildly hypointense to normal gray matter, while although the T2-weighted findings of meningiomas are variable, most meningiomas are reported to be isointense to mildly hyperintense compared with gray matter, and the heterogeneous signal intensity pattern that related to tumor vascularity, calcification, and cystic foci are attributed to the aggressive behavior of the tumor.

In this study, the 62 visualized meningiomas were evaluated for their intensity relative to the gray matter on T1- and T2-weighted images. In case of heavily calcified tumor, the signal intensity of only the soft tissue component was assessed. On T1-weighted image around 90% of cases were isointense to gray matter, while on T2-weighted images, approximately three-quarter of meningiomas were isointense and one-quarter were hyperintense relative to the cortex. These findings agreed with those of Spagnoli et al.

Also we found that all cases of benign meningiomas enhanced intensely with contrast media (80%) with homogenous

enhancement, while most of the atypical and malignant meningiomas by showing areas of central necrosis had heterogeneous and hence less intense enhancement, an observation which is statistically significant (r=0.6)(P < 0.001).

The heterogeneous signal intensity is significantly present in 80% of the atypical and in 100% of the malignant meningiomas and there was statistically significant correlation between the histological feature of meningiomas and their homogeneity on MRI (P 0.005), that is mean the more the homogenous is the tumor, the more its benignity. Although the sample is of small size the results are also agreed with those of Spagnoli et al.

Many authors studied the correlation between tumor histology and tumor intensity on T2-weighted images compared with that of the cortex, Elster AD, et al. [23] found that the signal intensity of meningiomas on T2-weighted images correlates with, and can serve as a crude predictor of histologic type in 75% of cases; tumors significantly iso- to hypointense to cortex tend to be composed primarily of fibrous or transitional elements with a harder character and generally took longer time to resect than softer ones. Tumors significantly hyperintense to the cortex tend to be composed primarily of syncytial or angioblastic elements. The T1- and T2-weighted signal intensity of the malignant or moderately aggressive histologic tumors was not significantly different from those of the benign meningiomas.

In this study, the signal intensity difference on T1- or T2-weighted images does not correlated statistically among different meningioma subtypes with (the P value of >0.5) for both T1 &T2-weighted relaxation values.

An interesting finding on contrast-enhanced MR imaging of meningiomas is the frequent observation of a "dural tail' or a thin line of enhancement extending a variable distance from the tumor mass along a dural surface[22].

A recent study done by Hutzelmann A, et al. In 2002[24], they found that two-thirds of MRI visualized dural tail adjacent to meningiomas harbored actual tumor invasion on histopathological examination, while one-third had no tumor invasion but tissue proliferation, hypervascularity, and vascular dilatation, hence they conclude that resection of the tumor with a wide margin of the dura at least 2 cm from the tumor attachment site is necessary to achieve complete excision of meningioma and to avoid recurrence.

In this study, we didn't found any statistical significant correlation between the "dural tail" sign detected on contrast-enhanced MRI and histological subtype (r=0.18)(P=1.6[NS]).

Meningioma cleft sign: In this study, around one-third of benign meningiomas showed flecks of calcification with no predilection to certain subtype except the psammomatus meningioma case which showed abundant calcification, 40% of the atypical and non of the malignant variety with no statistical significant association between benign, atypical and malignant subtypes with the calcification is observed (P > 0.5).

Cyst formation: Cystic meningiomas are uncommon, probably accounting for only 2 to 4% of meningiomas but rapid growth that occur in atypical or more aggressive tumors occasionally results in areas of central necrosis[25].

In this study, we found 8 cases (13%) with cystic pattern. Five of these were intratumoral and two were peritumoral. One case had both intra- and peritumoral cysts. These appeared hypointense on T1-weighted MR images, hyperintense on T2-weighted images, and tend not to enhance on contrast study except single atypical meningioma that showed ring enhancement. This cystic appearance was found in all cases of malignant tumors, 60% of atypical variety, and only in 5.5% of the benign meningiomas, an

association which is statistically highly significant (P value less than 0.005) and disagreed with the above study.

Brain edema is a common accompaniment of many brain tumors as well as other structural abnormality of the brain. The vasogenic edema is the form of brain swelling most typically associated with intracranial neoplasm due to venous mechanical obstruction or tumor hypervascularity[26].

In a study done by Smith HP, et al.[27] They conclude that in most of meningiomas, no relation existed between the benign histologic subtype (meningothelial, fibroblastic, transitional, psammomatus, and angioblastic) and the production of cerebral edema.

In comparison with our results, perifocal abnormal signal intensity area was diagnosed as vasogenic edema in around 80% of the cases. This area was shown as high signal intensity in T2-weighted MRI and was confined to the white matter. In T1-weighted sequence, this area was shown as slightly low signal intensity, which was readily differentiated from remarkably low intensity ventricular CSF. We found that most benign meningiomas (with the exception of the angioblastic type) is surrounded by mild degree of edema with no correlation with their subtype, while in average, atypical and malignant meningiomas are surrounded by finger like (marked degree) of peritumoral edema extending into the subcortical white matter. This association was statistically highly significant (r=0.45)(P 0.001) that is to say, the more the perifocal edema the more the aggressive behavior of the meningiomas, these results are agreed with the above studies by Smith HP, et al. and Zimmerman RD, et al.

Correlation between bony and dural venous sinus invasion by meningiomas (on MRI) and the histopathology: Regarding adjacent osseous changes, subtle hyperostosis may be difficult to be detected on MRI, and in general CT is more sensitive. However, marked bony hyperostosis or thickening can be observed with MRI as can infiltration of bone by tumor with consequent obliteration of the normal marrow space. Bone destruction can also be detected with MRI[28].

In this study we found that only around 15% of cases have positive bony changes a percent that not permits any statistical significant association among different histological subtypes ($P > 0.05^{[NS]}$).

In the current work, dural venous sinus invasion was demonstrated by partial or complete obliteration of the normal signal void owing to the flowing blood within the sinus and the tissue producing this filling defect has signal intensity comparable to that of the contiguous tumor mass which can be appreciated by both coronal and axial T1- and T2-weighted MRI sequences and by the MRV study for that lesions adjacent to a major dural venous sinuses especially the convexity and the parasagittal meningiomas, and the results were 16.4% of the benign, 60% of atypical, and both cases of malignant meningiomas showed positive dural venous sinus invasion by MRI and MRV. An association which is statistically highly significant ($P<0.005$) between the malignant behavior of meningiomas and this MR finding.

Table I: Age distribution by intracranial meningioma histopathological subtypes.

Age in years	Benign							Atypical		Malign		Total	
	M.	F.	T.	A.	O.	In Total							
	No.	No.	No.	No.	No.	No.	%	No.	%	No.	%	No.	%
20-29	2				1	3	5.5					3	4.8
30-39	2	1	3	2		8	14.5					8	13
40-49	6	1	8			15	27.2	1	20	1	50	17	27.4
50-59	4	2	11			17	31	4	80	1	50	22	**35.5**
60-69	4	2	6			12	21.8					12	19.3
Total	**18**	**6**	**28**	**2**	**1**	**55**	**88.7**	**5**	**8**	**2**	**3.3**	**62**	**100**

* Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.)
** Spearman's Rank Correlation Coefficient between meningioma histopathological subtype and age in years (r=0.05) (P=0.71[NS])

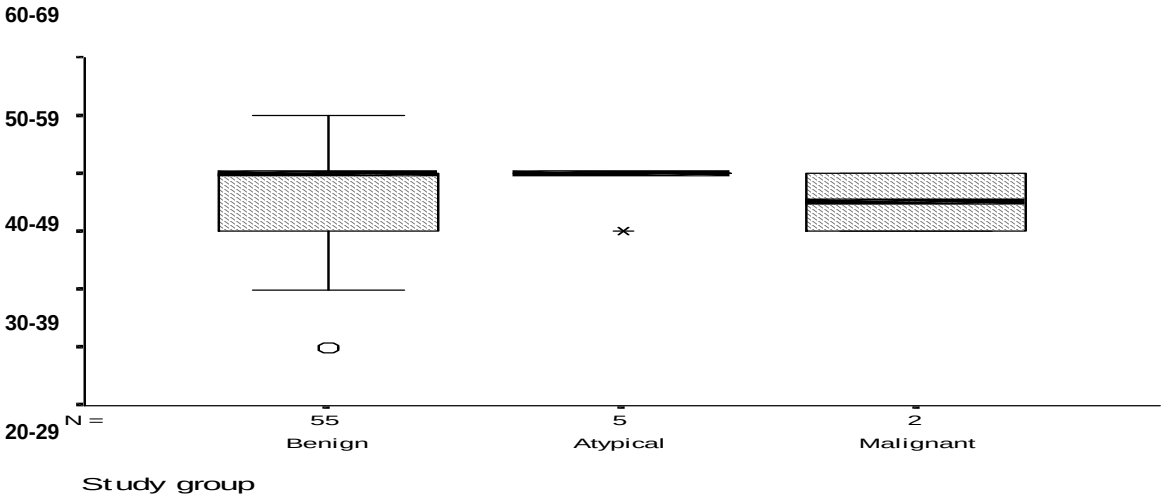

Figure 1: Box plot showing age distribution by meningioma histopathological subtypes.

Table II: Age and gender distribution by intracranial meningiomas histopathological subtypes

AGE IN YEARS	BENIGN												ATYP.		MALIG		TOTAL			
	M.		F.		T.		A.		O.		IN TOTAL									
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	%	F	%
20-29	**2**								**1**		**3**						**3**	**14**		
30-39	**1**	**1**	**1**		**2**	**2**		**1**			**4**	**4**					**4**	**19**	**4**	**10**
40-49	**2**	**4**		**1**	**3**	**5**		**1**			**5**	**11**		**1**		**1**	**5**	**24**	**13**	**32**
50-59	**2**	**2**	**2**			**13**					**5**	**15**		**1**			**5**	**24**	**16**	**39**
60-69	**1**	**3**	**1**	**1**		**2**					**2**	**6**	**2**	**1**		**1**	**4**	**19**	**8**	**19**
TOTAL	**8**	**10**	**4**	**2**	**6**	**22**		**2**	**1**		**19**	**36**	**2**	**3**		**2**	**21**	**34**	**41**	**66**

***** Meningothelial (M.), fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.), Atypical (ATYP.), Malignant (MALIG.)

Table III:Correlation between location of intracranial meningiomas with histopathology

Location	Benign							Atypical		Malign		Total	
	M	F.	T.	A.	O.	In Total							
	No	No	No.	No.	No	No.	%	No	%	No	%	No.	%
Cerebral Convexity	5	2	14			21	38	4	80			25	40.4
Parasagittal	7	1	6	2	1	17	31	1	20	2	100	20	32.2
Olfactory groove	1	2	1			4	7.4					4	6.5
Cerebellar Convexity	2	1	1			4	7.4					4	6.5
Sphenoid ridge			3			3	5.5					3	5
Tubercullm sellae	2					2	3.6					2	3.2
Intraventricular	1		1			2	3.6					2	3.2
Tentorium			1			1	1.8					1	1.5
C. P. A.			1			1	1.8					1	1.5
Total	18	6	28	2	1	55		5				62	100

Figure 2: Bar chart showing the relative frequency of different locations.

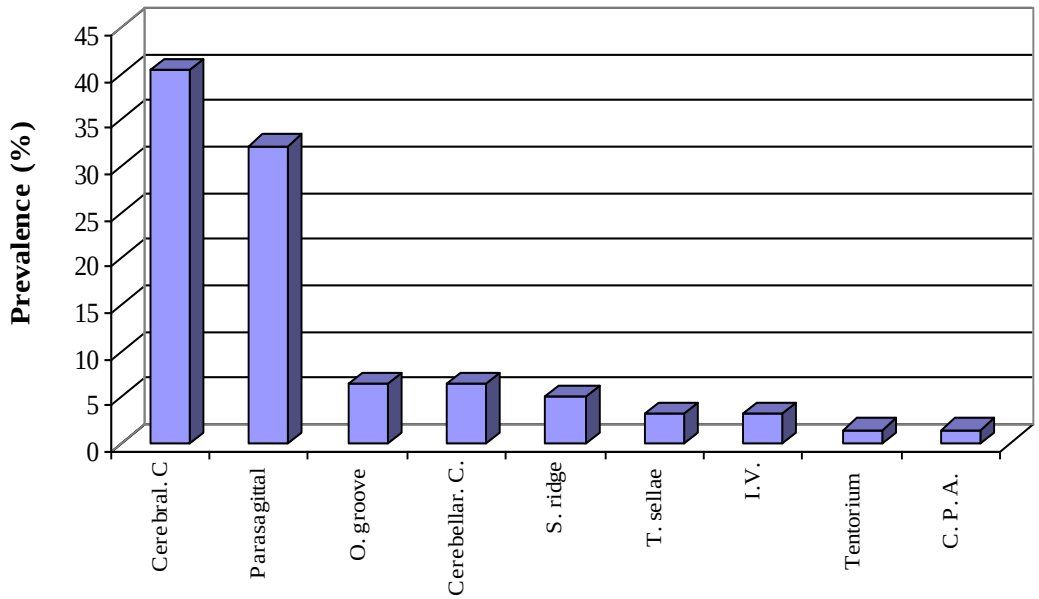

Table IV: Correlation between laterality in location of meniniomas and their histopathology

Location Side	Benign							Atypical		Malignant		Total	
	M	F.	T.	A	O	In total							
	No	No	No	No	No	No	%	No.	%	No.	%	No.	%
Rt. Side	9	3	15	2	1	30	54.5	3	60			33	53.3
Lt. Side	2	1	11			14	25.5	2	40	2	100	18	29
Central	6	2	1			9	16.4					9	14.5
Intravent:													
Rt. L. V.			1			1	1.8					1	1.6
Lt. L. V.	1					1	1.8					1	1.6
Total	18	6	28	2	1	55	100	5	100	2	100	62	100

- Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.). Lateral ventricle (L.V.)
- Statistically the excess right side affected observed here do not depart significantly from the hypothesis of equal proportion between right and left side (p= 0.13[NS]).

Table V: correlation between MRI signal intensity on T1-WI &T2-WI and histopathological subtypes of intracranial meningiomas.

MRI Signal Intensity	Benign							Atypical		Malign		Total		P VALUE
	M.	F.	T.	A.	O.	In Total								
	No.	No.	No.	No.	No.	No.	%	No	%	No.	%	No.	%	No.
T1-hypointense	2	2	1			5	9	1	20			6	9.7	> 0.5
T1- Isointense	16	4	27	2	1	50	91	4	80	2	100	56	90.3	
T2-isointense	13	5	21	2	1	42	76.3	4	80	1	50	47	76	> 0.5
T2-hyperintense	5	1	7			13	23.7	1	20	1	50	15	24	
Homogeneous	12	6	25	1		44	80	1	20			45	73	< 0.005
Heterogeneous	6		3	1	1	11	20	4	80	2	100	17	27	

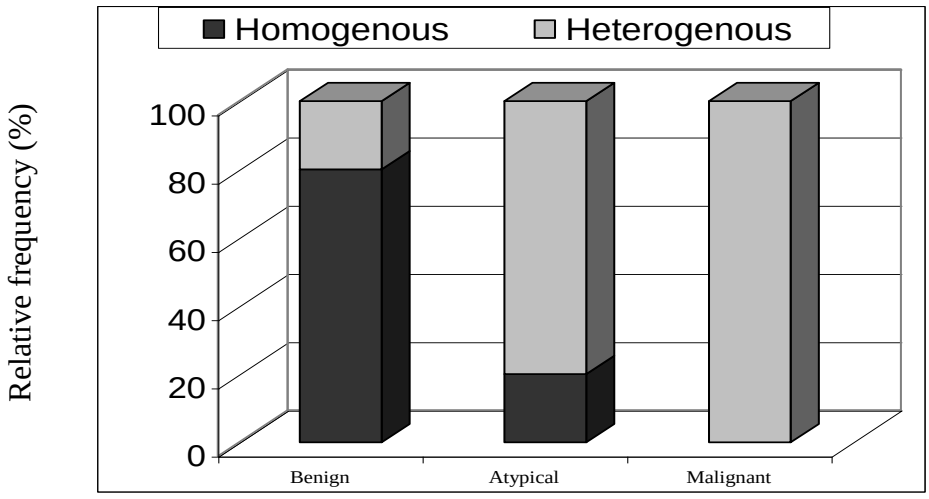

Figure 3: stacked bar chart showing T2 signal heterogeneity

Table VI: Correlation between other MRI findings and histopathological diagnosis of intracranial meningiomas.

MRI findings	Benign							Atypical		Malignant		Total		P value
	M	F	T	A	O	IN TOTAL								
	N	N	N	N	N	No.	%	No.	%	No	%	No	%	
Meningioma cleft:														
Positive	14	6	23	1	1	45	82	2	40			47	76	< 0.005
Negative	4		5	1		10	18	3	60	2	100	15	24	
Calcification														
Flecks of:	7		11		1	19	34.5	2	40			21	34	> 0.5
Absent:	11	6	17	2		36	65.5	3	60	2	100	41	66	
Cystic changes:														
Positive:	1		2			3	5.5	3	60	2	100	8	13	< 0.005
Negative;	17	6	26	2	1	52	94.5	2	40			54	87	
Vascularity														
Avascular:	7	4	12		1	24	43.6	1	20			25	40	> 0.5
Vascular:	11	2	16	2		31	56.4	4	80	2	100	37	60	
TOTAL	18	6	28	2	1	55	100	5	100	2	100	62	100	

* Meningothelial (M.), fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.).

Table VII: Correlation between degree of perifocal edema and intracranial meningioma histopathological subtypes.

Perifocal edema	Benign							Atypical		Malign.		Total	
	M.	F.	T.	A.	O.	In Total							
	No.	No.	No.	No.	No.	No.	%	No.	%	No.	%	No.	%
Absent	5	2	5			12	22					12	19.5
(+)	7	3	19		1	30	54.5	1	20			31	50
(++)	4	1	2	2		9	16.3	1	20			10	16
(+++)	2		2			4	7.2	3	60	2	100	9	14.5
Total	**18**	**6**	**28**	**2**	**1**	**55**	**100**	**5**	**100**	**2**	**100**	**62**	**100**
Median	+	+	+	++	+	+		+++		+++		+	

* Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.)
** (+) mild=extend up to 2 cm around the lesion, (++) moderate=2-4 cm, (+++) marked > 4 cm
*** Spearman's Rank Correlation Coefficient between meningioma histopathological subtypes and perifocl edema (r=0.45) (P<0.001)

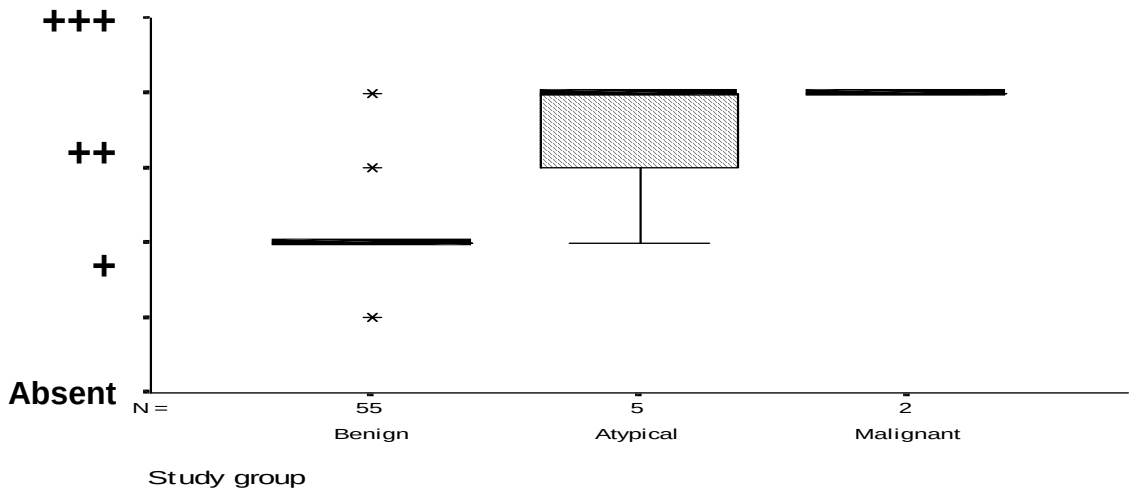

Figure 4: Box plot showing perifocal edema by meningioma histopathological subtypes.

Table VIII: Correlation between degree of enhancement with intravenous contrast media and intracranial meningioma histopathological subtypes.

Strength of enhancement	Benign							Atypical		Malign.		Total	
	M.	F.	T.	A.	O.	In Total							
	No.	No.	No.	No.	No.	No.	%	No.	%	No.	%	No.	%
Absent													
(+)		1	1			2	4					2	3.2
(++)	7	2	11		1	21	38	3	60	2	100	26	42
(+++)	11	3	16	2		32	58	2	40			34	54.8
Total	**18**	**6**	**28**	**2**	**1**	**55**	**100**	**5**	**100**	**2**	**100**	**62**	**100**
Median	**(+++)**	**(+++)**	**(+++)**	**(+++)**	**(++)**	**(+++)**		**(++)**		**(++)**		**(+++)**	

* Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.)
** Spearman's Rank Correlation Coefficient between meningioma histopathological subtype and strength of enhancement (r=-0.18) (P=0.17*[NS]*)

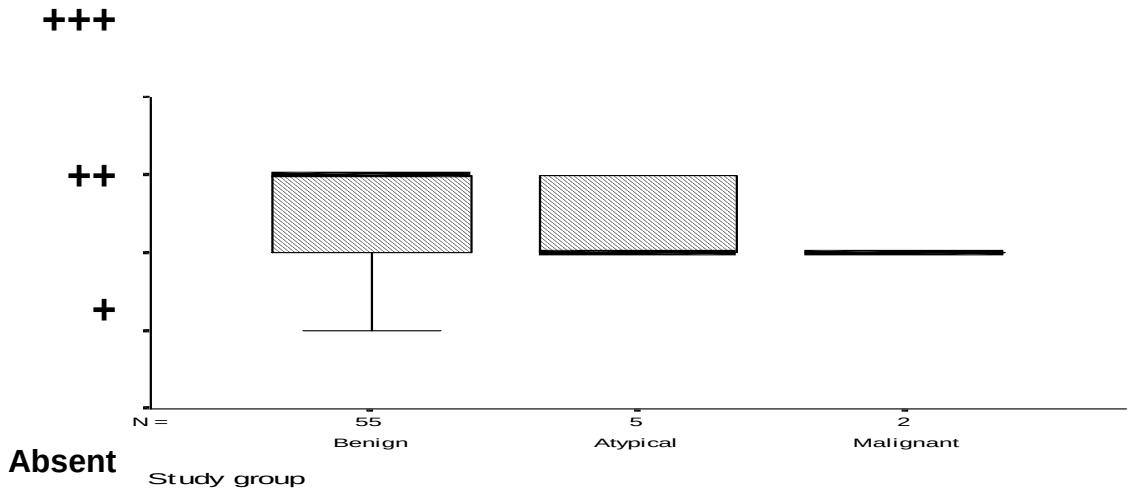

Figure 5: Box plot showing strength of enhancement by meningioma histopathological subtypes.

Table IX: Enhancement pattern by intracranial meningioma histopathological subtypes.

Enhancement	Benign							Atypical		Malign		Total	
	M.	F.	T.	A.	O.	In Total							
	No.	No.	No.	No.	No.	No.	%	No.	%	No.	%	No.	%
Mode of: **													
Homogenous	16	6	25		1	48	87	1	20			49	79
Heterogeneous	2		3	2		7	13	4	80	2	100	13	21
Dural tail: ***													
Absent	8	3	10	1	1	23	42	1	20			24	39
Present	10	3	18	1		32	58	4	80	2	100	38	61
Total	**18**	**6**	**28**	**2**	**1**	**55**	**100**	**5**	**100**	**2**	**100**	**62**	**100**

*Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.)
**Spearman's rank correlation coefficient between meningioma histopathological subtypes and mode of enhancement ($r=0.6$)($P<0.001$)
*** Spearman's rank correlation coefficient between meningioma histopathological subtypes and the presence of the dural tail ($r=0.18$)($P=1.6$ [NS])

Table X: Correlation between degree of mass effect and intracranial meningioma histopathological subtypes.

Mass effect	Benign							Atypical		Malign.		Total	
	M.	F.	T.	A.	O.	In Total							
	No.	No.	No.	No.	No.	No.	%	No.	%	No.	%	No.	%
With H.C.													
(+)	3		2			5	9					5	8
(++)	1		2	1		4	7.3	1	20			5	8
(+++)			1			1	1.8			1	50	2	3.5
Without H.C.													
(+)	8	5	16			29	52.7	2	40			31	50
(++)	5	1	6	1	1	14	25.6	1	20			15	24
(+++)						2	3.6		20	1	50	4	6.5
Total	**18**	**6**	**28**	**2**	**1**	**55**	**100**	**5**	**100**	**2**	**100**	**62**	**100**

* Hydrocephalus (H.C.)
** Meningothelial (M.), Fibroblastic (F.), Transitional (T.), Angioblastic (A.), Others (O.)
*** Spearman's Rank Correlation Coefficient between meningioma histopathological subtype and degree of mass effect ($r=0.3$) ($P=0.02$)

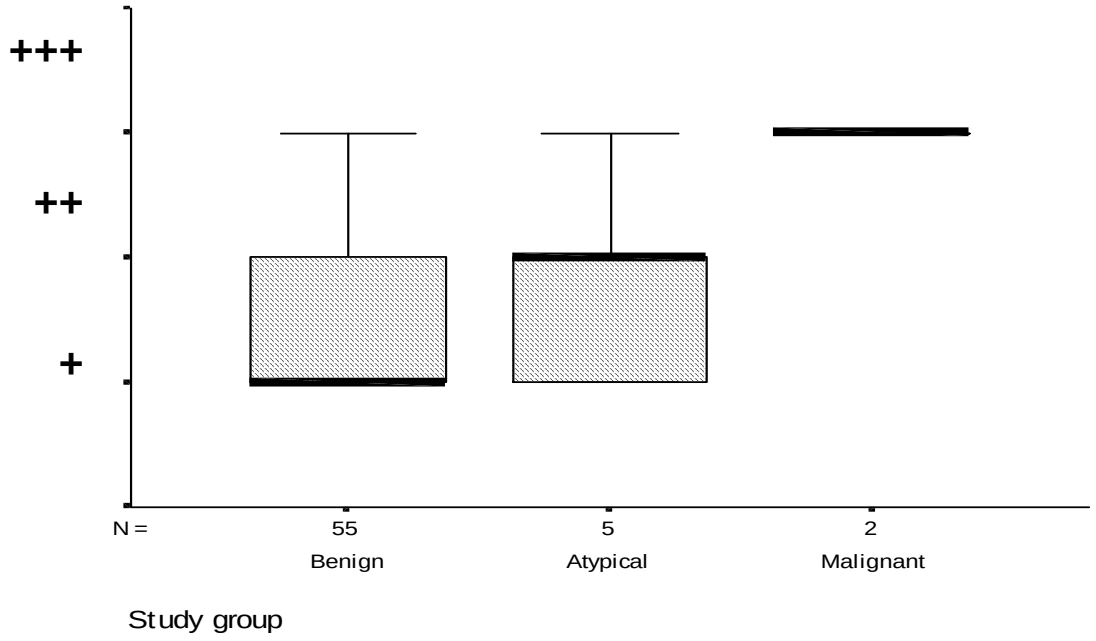

Figure 6: Box plot showing degree of mass effect by meningioma histopathological subtypes.

Table XI: Correlation between bony and dural venous sinus nvasion by meningiomas (detected by MRI) and the histopathology.

MRI Findings	Benign							atypical		Malignant		Total		P value
	M	F	T	A	O	IN TOTAL								
	N	N	N	N	N	No.	%	No.	%	No.	%	No.	%	
Bony involvement														
Positive:	1		5			6	11	2	40	1	50	9	14.5	>0.05
Negative:	17	6	23	2	1	49	89	3	60	1	50	53	85.5	
Dural venous sinus invasion:														
Positive:	2		6	1		9	16.4	3	60	2	100	14	22.5	<0.005
Negative:	16	6	22	1	1	46	83.6	2	40			48	77.5	
Total	18	6	28	2	1	55	100	5	100	2	100	62	100	

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