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Research Article

Comparison Between Magnetic Resonance Spectroscopy and Histopathology in Patients with Meningiomas

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Abstract

Background: Meningiomas are typically benign brain tumors, and their precise characterization is vital for optimal patient management. The comparison between Magnetic Resonance Spectroscopy (MRS) and histopathology in patients with meningioma is a pivotal area of research in the field of neuroimaging and neuropathology.

Aim of the study: The study aimed to compare between magnetic resonance spectroscopy findings and histopathological results in patients with meningioma.

Methods: This was a cross-sectional study conducted at the Department of Radiology & Imaging of Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh during the period from October 2019 to September 2021. A total of 45 suspected cases of meningioma were enrolled in this study as the study subjects purposively. For data collection and analysis, MS Office tools and SPSS Version 23.0 were applied. Results: Magnetic Resonance Spectroscopy (MRS) detected 36 positive cases and 7 negative cases of meningioma. Among the 36 MRS-positive cases, 34 were found to be truly positive upon histopathological examination, indicating a high level of accuracy. However, 2 cases were MRS-positive but turned out to be histopathologically negative, signifying false positives. Additionally, out of the 9 MRS-negative cases, 4 were meningiomas upon histopathological evaluation, which were false negatives, while 5 were genuinely negative.

Conclusion: This analysis suggests that magnetic resonance spectroscopy (MRS) demonstrates a strong ability to correctly identify meningiomas when compared to histopathological diagnosis but has a small rate of both false positives and false negatives.

Keywords: Benign; Histopathology; Magnetic Resonance Spectroscopy; Meningioma; Neuropathology; Tumor

Introduction

Meningiomas are the most common extra-axial tumors of the brain, accounting for 13-26% of primary intracranial neoplasms [1]. They are the most prevalent non-glial tumors of the central nervous system (CNS) [2]. Meningiomas originate from arachnoid cells known as meningothelial cells [3] and typically present as extra-axial tumors with well-defined borders, displaying a solid mushroom-like imaging pattern with intense and uniform contrast enhancement on both CT and MRI scans. Meningiomas are solid, highly cellular, slow-growing tumors that are typically histologically benign (WHO grade I). They most commonly grow inwards from the dura mater, causing indentation and compression of the underlying brain tissue, which can result in neurological symptoms due to the compression of the adjacent cortex [4]. Meningiomas typically manifest in individuals of middle to old age, with the highest incidence occurring in the fifth to seventh decades of life. However, they can be found in individuals of all age groups. Meningiomas exhibit a strong gender preference, with a predominance in females, resulting in a male-to-female ratio of approximately 1:2. Meningiomas associated with hereditary tumor syndromes like NF2 generally occur in younger patients and do not display a gender preference [4]. Magnetic Resonance Imaging (MRI) has largely supplanted CT scans for the precise delineation of the location and soft tissue characteristics of meningiomas [5]. In terms of signal intensities on MRI, meningiomas typically appear isointense or hypointense on T1-weighted images and isointense to hyperintense on T2-weighted images [6]. Magnetic Resonance Spectroscopy (MRS) is a noninvasive imaging technique that provides insights into the biochemical composition of living tissues. It offers valuable information about tumor metabolism, aiding in the diagnostic process [7]. MR spectroscopy can quantitatively assess the concentration of metabolites within a specified region of interest (ROI). Instead of merely detecting the resonance signals of protons, primarily from water molecules, it can discern the resonance signals of protons from various molecular groups within the area of interest. This includes metabolites like N-acetyl aspartate (NAA), Choline (Cho), Creatine (Cr), Glutamine/Glutamate (Glx), Alanine (Ala), and Lactate, among others [8]. In MRI, collected data are initially analyzed in the time domain, plotting signal intensity against time. This analysis provides information about the relaxation times (TR), namely T1 and T2, of the nuclei in the scanned tissues. Notably, Alanine (Ala) is a prominent metabolite observed in meningiomas, often more so than in other neoplastic processes. It is considered a spectroscopic signature for meningiomas [8]. However, it's essential to note that Alanine may not be present in all meningiomas and can show an inverse correlation with necrosis within these tumors [9]. Lactate is another metabolite that has been observed in some studies to be more frequently found in non-benign meningiomas, specifically those categorized as WHO grade II and III. Nevertheless, the presence of Lactate doesn't always indicate aggressive meningiomas. Similarly, the presence of lipid (Lip, 0.9/1.3 ppm), while often considered a marker for aggressive meningiomas, does not consistently represent micro necrosis. Therefore, it cannot always serve as definitive proof of a non-benign meningioma [10]. In a study, it was found that the Cho/NAA ratio, which can be easily and widely obtained through MRS, can predict high-grade meningioma when its value exceeds 2.409. This measurement showed a sensitivity of 61.54% and specificity of 86.36% [11]. High-resolution magnetic resonance spectroscopy (H-MRS) on its own can achieve an accuracy of up to 82.5% (within a 58.7-82.1% confidence interval), with 100% sensitivity and 91.1% specificity in predicting tumor type [12]. Particularly at a long Time to Echo (TE), MRS demonstrates a sensitivity of 86% and a specificity of 97% [13]. The objective of this current study was to compare between magnetic resonance spectroscopy findings and histopathological results in patients with meningioma.

Methodology

This cross-sectional study was conducted at the Department of Radiology & Imaging of Bangabandhu Sheikh Mujib Medical University in Dhaka, Bangladesh. The study was conducted during the period from October 2019 to September 2021. It included a total of 45 patients who were suspected to have meningioma and were referred to the Radiology and Imaging Department of the hospital. The study used a purposive sampling technique for selecting its sample. Ethical approval [IRB/HEC number] for the study was obtained from the hospital's ethics committee and informed written consent was obtained from all participants before data collection. In this study, all patients who had been initially diagnosed with meningioma based on their initial MRI were included, following the inclusion criteria. Conversely, those patients who had strong contraindications to undergo MRI, including individuals with cardiac pacemakers, prosthetic heart valves, cochlear implants, brain aneurysm clips or coils, and those who had already been diagnosed excluded. Demographic and clinical information of all the participants was meticulously recorded. Data analysis was conducted using MS Excel and SPSS version 23.0.

Result

In this study, approximately one-third (36%) of the patients fell within the age group of 41-50 years. The mean ± SD age of the participants was 52.7 ± 10.4 years, with a standard deviation of 10.4 years (Table 1). The majority of our participants (37, 82%) were female, while the male-to-female ratio was 1:4 (Figure 1). Upon analyzing the MRI findings, we observed that the majority (38, 84%) of lesions were located as supratentorial, with 12 (27%) of them being parasagittal. Out of the 45 patients, 40 (89%) had a single lesion, and 33 (73%) of the lesions were round in shape. Regarding signal intensities, 22 (49%) lesions were isointense, 33

(73%) were hyperintense, and 34 (75%) were hyperintense on T1-weighted, T2-weighted, and FLAIR images, respectively. Additionally, 37 (82%) lesions exhibited mass effect, 20 (44%) had perilesional edema, 17 (38%) showed signs of necrosis/cystic changes, and 3 (7%) presented features of bony changes. After the administration of gadolinium contrast, all patients showed enhancement, with more than three-fourths (37, 82%) displaying homogeneous enhancement (Table 2). The study found that the majority of these patients, comprising 89% (n = 34), displayed increased choline levels while 95% (n = 36) exhibited significantly decreased creatine levels. Notably, N-acetyl aspartate (NAA) was undetected in 53% (n = 20) of cases. Moreover, 74% (n = 28) of the patients demonstrated elevated alanine levels, with 16% showing the presence of lipids. Additionally, 53 (n = 20) % had minimally detected lactate levels. The study calculated the mean ± SD choline/creatine ratio at 4.68 ± 2.89 and the choline/N-acetyl aspartate ratio at 4.66 ± 3.34 (Table 3). As per the final MRS diagnosis, in 80% of cases, meningioma was found (Table 4).

In histopathology, out of 45 patients, 38 (84%) patients had meningioma and 7 (16%) had non meningioma. 11 (24%) patients were found to have a high grade and 27 (60%) were low grade meningioma (Table 5). In the comparative analysis of diagnoses between histopathological examination and Magnetic Resonance Spectroscopy (MRS) for meningiomas, it was found that MRS detected 36 positive cases and 7 negative cases. Among the 36 MRS-positive cases, 34 were found to be truly positive upon histopathological examination, indicating a high level of accuracy. However, 2 cases were MRS-positive but turned out to be histopathologically negative, signifying false positives. Additionally, out of the 9 MRS-negative cases, 4 were meningiomas upon histopathological evaluation, which were false negatives, while 5 were genuinely negative (Table 6).

Age (Years)	n	%
36-40	5	11
41-50	16	36
51-60	10	22
61-70	11	24
71-75	3	7
Mean ± SD	52.7 ± 10.4	

Table 1: Age distribution of the study population. (N = 45).

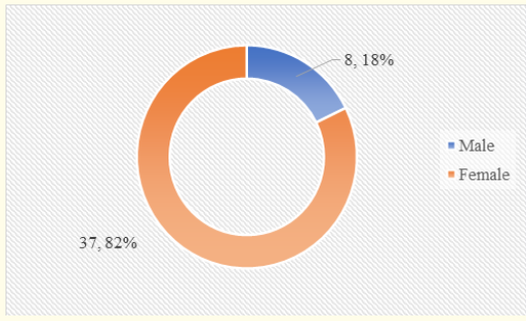

Figure 1: Ring chart showed gender-wise study population distribution.

MRI findings	n	%
Position		
Supra tentorial	38	84%
Infra tentorial	7	16%
Location		
Frontal	10	22%
Parasagittal	12	27%
Temporal	4	9%
Parietal	9	20%
Intraventricular	2	4%
Posterior fossa	7	16%
Supra seller region	1	2%
Number of the lesion		
One	40	89%
Multiple	5	11%
Shape of the lesion		
Rounded	33	73%
Lobulated	12	27%
T1 weighted images		
Isointense	22	49%
Hypo intense	15	33%
Heterogenous	8	18%
T2 weighted images		
Isointense	4	9%
Hyperintense	33	73%
Heterogenous	8	18%
FLAIR images		
Isointense	3	7%
Hyperintense	34	76%
Heterogenous	8	18%
Mass-effect	37	82%
Perilesional edema	20	44%
Area of necrosis	17	38%

Bony change	3	7%
Lesions in post-gadolinium		
Homogenous enhancement	37	82%
Heterogeneous enhancement	8	18%

Table 2: MRI findings distribution. (N = 45).

MRS variables	n	%
Choline (Cho)		
Increased	34	89%
Minimally detected	4	11%
Creatine (Cr)		
Decreased	2	5%
Significantly decreased	36	95%
N-acetyl aspartate (NAA)		
Not detected	20	53%
Minimally detected	18	47%
Alanine		
Increased	28	74%
Detected	6	16%
Not detected	4	10%
Lipid		
Present	6	16%
Absent	32	84%
Lactate		
Increased	11	29%
Minimally detected	20	53%
Not detected	7	18%
Choline/creatine ratio	4.68 ± 2.89	
Choline/N-acetyl aspartate ratio	4.66 ± 3.34	

Table 3: Distribution of MRS parameters in proven meningioma by histopathology. (n=38).

MRS diagnosis	n	%
Meningioma	36	80%
Non-meningioma*	9	20%

Table 4: Final MRS diagnosis. (N = 45).

*Lymphoma, Schwannoma, Hemangiopericytoma.

Diagnosis	n	%
Meningioma	38	84%
High grade	11	24%
Low grade	27	60%
Non- meningioma*	7	16%

Table 5: Major histopathological findings. (N = 45).

MRS	Histopathology	
	Positive	Negative
	(n = 38)	(n = 7)
Positive (n = 36)	34	2
	(True positive)	(False positive)
Negative (n = 9)	4	5
	(False negative)	(True negative)

Table 6: Comparison between histopathological and MRS diagnosis of meningiomas. (N = 45).

Discussion

In this study, more than one-third (35.56%) of patients belonged to the 41–50-year age group. The mean age was found to be 52.7 ± 10.4 years, with a range from 36 to 75 years. The majority (82.22%) of patients were female. Similar studies by Jaskólski., *et al.* (2013) [14], and Lin., *et al.* (2018) [15] reported comparable age and gender distributions in meningioma patients.

In this study, the majority (84.44%) of the lesions were located supra-tentorial, with the supra-tentorial cerebral convexity (42.22%) and parasagittal region (26.67%) being the primary sites. Most lesions (88.89%) were single and rounded (73.33%) in shape. Regarding signal intensity, 48.89% of lesions were isointense on T1-weighted images, 73.33% were hyperintense on T2-weighted images, and 75.56% were hyperintense on FLAIR images. Mass Effect, perilesional edema, necrotic/cystic changes, and bony changes were present in 82.22%, 44.44%, 37.78%, and 6.67% of cases, respectively. Homogeneous contrast enhancement was observed in 82.22% of cases. Stefanovic., *et al.* (2011) [16] reported similar findings in terms of tumor location and signal intensities in intracranial meningiomas. Gangadhar., *et al.* (2013) [17] found enhancement of the lesion in 82.61% of cases, consistent with the current study's findings.

In the MRS results of the 45 patients in this study, the majority (84%) showed increased choline levels with significantly decreased creatine in 84% of patients. In 49% of cases, NAA was not detected. Increased alanine was present in about 67% of cases, while lipid was found in 24% of cases. Increased lactate was present in 31% of patients. The mean choline/creatine ratio was 4.51 ± 2.70. Demir., *et al.* [18] noted that prominent choline was found in all meningiomas, with alanine present in 21 out of 23 cases. NAA (Acetyl aspartate) and creatine (Cr) were either not observed or detected in minimal amounts in both groups of meningiomas on long TE (144ms) spectra. They also highlighted that alanine (Ala) is more commonly seen in meningiomas compared to other neoplastic processes, making it a spectroscopic signature for meningiomas.

In the present study, out of 38 histopathologically confirmed meningiomas, the majority (89.47%) of patients exhibited increased choline levels and significantly decreased creatine metabolite levels in 94.74% of cases. NAA was not detected in 52.63% of patients but was observed minimally in the rest of the cases (47.37%). The mean choline/creatine ratio was 4.68 ± 2.89, and the mean Choline/N-acetyl aspartate ratio was 4.66 ± 3.34. Domingo., *et al.* (1998) [19] found high choline (Cho), low creatine (Cr), and low NAA in eight patients with meningiomas. Hamsini., *et al.* (2018) [20] observed in MRS that patients with a high grade of malignancy had elevated choline peaks, decreased NAA peaks, and choline-to-creatine ratios exceeding 1.5.

Based on histopathology in this study, 84.44% of patients had meningiomas, and 15.56% had non-meningiomas. Among the 38 meningiomas, 24.44% were classified as high grade (grade II and grade III), and 60.0% were low grade (grade I). Lin., *et al.* (2018) [15] reported in their study that 62.9% were low-grade, and 37.1% were high-grade. In Matsusue., *et al.*'s (2021) study [21], 77.8% of patients were found to be in grade I, while 22.2% were in grade II. In our study, MRS identified 36 positive cases and 7 negative cases. Among the 36 MRS-positive cases, 34 were confirmed as true positives upon histopathological examination, indicating high accuracy. However, 2 cases that were MRS-positive turned out to be histopathologically negative, indicating false positives. Among the 9 MRS-negative cases, 4 were histopathologically confirmed as meningiomas, signifying false negatives, while 5 were truly negative. These findings provide valuable insights for future studies in this field.

Magnetic resonance spectroscopy (MRS) is considered valuable in diagnosing meningiomas with atypical radiological appearances and may also aid in assessing their malignant potential [22]. A study [23] reported elevated water content in hyperintense tumors, facilitating increased water diffusion into the surrounding brain based on the pressure gradient theory. Microcystic meningiomas exhibit a characteristic MRI feature, with a high incidence (87.5% in the study by Paek., *et al.* [24] of peritumoral edema, often severe in nature.

Limitation of the Study

This single-center study's limitations include a confined sample size, a lack of interobserver variability assessment, and a brief study period. The absence of genetic and chromosomal analysis hinders comprehensive insights. The findings' applicability is restricted by the study's limited scope and may not represent the broader national situation. Caution is warranted in extrapolating results.

Conclusion and Recommendation

In light of the present study's findings, it can be conclusively affirmed that Magnetic Resonance Spectroscopy (MRS) demonstrates a remarkable proficiency in precisely discerning meningiomas when juxtaposed with histopathological diagnosis. The robust correlation observed underscores the potential of MRS as a reliable diagnostic tool for meningiomas. These results contribute to advancing our understanding of non-invasive diagnostic methodologies, emphasizing the promising role of MRS in enhancing accuracy and efficiency in meningioma identification. This study's outcomes emphasize the practical implications of incorporating MRS into clinical practices for improved meningioma diagnostics, heralding a positive stride in the field of medical imaging.

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Conflicts of Interest

None Declared.

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