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THE CRUCIAL ROLE OF MAGNETIC RESONANCE IMAGING IN DIAGNOSING AND STAGING SPINAL TUMORS CAUSING NEUROLOGICAL DEFICIT

Hafiza Iqra Kanwal[*1], Munaza Shahid[2], Uzma Khan[3], Rehana Bibi[4], Zoha Arsheen[5], Shumaila Akram[6], Rabia Bibi[7]

[*1,2]*MSDU (Master of Science in Diagnostic Ultrasound) Senior Lecturer Superior University of Lahore*
[3,4,5,6,7]*BS-MIT Student Superior University of Lahore*

[*1]iqra.kanwal@superior.edu.pk, [2]munaza.shahid@superior.edu.pk, [3]uzmakhan8028@gmail.com, [4]rb3580972@gamil.com, [5]zohaa2092@gamil.com, [6]malikkhan890765@gamil.com, [7]rabiasikandar000@gamil.com

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Corresponding Author: *
Hafiza Iqra Kanwal

Abstract

Background: *Spinal tumors can cause serious neurological deficits if not identified early. MRI is a reliable, non-invasive tool for detecting and staging these tumors, providing detailed insights into their type, location, and impact. Understanding MRI findings in relation to neurological symptoms is key to early diagnosis and effective treatment planning.*

Methodology: *This research was a prospective analytical study. Data was collected from the Radiology Department of Nishtar Hospital, Multan. A total of 73 patients with spinal tumors causing neurological deficits were included. Data was analyzed using SPSS.*

Results: *Among 73 spinal tumor patients (mean age 31.97 ± 14.15 years), 52.1% were male. Meningioma was most common (35.6%), followed by glioma (27.4%), neurofibroma (20.5%), and schwannoma (16.4%). Paralysis was present in all glioma cases and 93.3% of neurofibromas. Visual changes (49.3%), bladder dysfunction (53.4%), muscle weakness (52.1%), pain (53.4%), and numbness (47.9%) were frequently observed, varying by tumor type.MRI showed hypointensity on T1 in 57.5% and hyperintensity on T2 in 86.3% of cases. All gliomas were intramedullary; others were extramedullary. Grade 3 tumors were most frequent. MRI effectively correlated imaging features with neurological deficits.*

Conclusion: *This study points out the crucial role of MRI in the diagnosis and staging of spinal tumors with neurological deficits. Gliomas were highly associated with paralysis and bladder dysfunction, whereas meningiomas, neurofibromas, and schwannomas occurred in a variable fashion with pain, numbness, and visual disturbances. MRI correctly differentiated the types of tumors, grades, and locations, and T1 hypointensity and T2 hyperintensity were frequent findings.*

INTRODUCTION

The spinal cord, a long cylindrical column from the medulla oblongata to the conus medullaris, is the main route of bidirectional neural transmission between the brain and peripheral nervous system. Its structure is made up of gray matter, containing neuronal cell bodies, synapses, and glial cells, and white matter, being made up of myelinated ascending and descending tracts The spinal cord is divided into cervical, thoracic, lumbar, and sacral segments. Each of them is responsible for providing services to regions of skin and muscle.[i] The covering of the vertebrae is bony and guards the spinal cord, yet due to space-occupying tumors, damage to its function and integrity can occur.[ii] Although spinal cord tumors are rare, their clinical significance lies in the fact that they have the ability to produce neurological deficit by causing compression, infiltration, or vascular compromise. Prompt diagnosis, facilitated by powerful imaging methods, particularly magnetic resonance imaging (MRI), is critical to prevent irreversible disability. Spinal cord tumors are divided based on their anatomical location compared to the spinal cord and dura mater. Intramedullary tumors, constituting approximately 5–10% of spinal tumors, develop in the spinal cord parenchyma.[iii]

The majority of these are ependymomas, of which 60% occurs in intramedullary tumors, and astrocytomas, accounting for approximately 30%[iv].Intradural-extramedullary tumors, constituting 60–70% of spinal cord tumors, develop from within the dura mater but outside the spinal cord itself. Of these tumors, meningiomas (25–45%) and schwannomas (20–40%) are the most common, developing from arachnoid cap cells and from Schwann cells, respectively[v]. Intramedullary tumors have a potential to displace the spinal cord ornerve root, causing radiculopathy or myelopathy. Extradural tumors, of which 20–30% of spinal tumors are observed, are usually metastatic in origin, developing even from primary carcinomas of breast, lung, or prostate in many instances. These tumors invade the spinal column and have the potential for epidural compression of the spinal cord (ESCC), thus constituting a neurosurgical emergency[vi].

Pathophysiology of neurologic dysfunction secondary to spinal tumors is largely secondary to direct mechanical compression, ischemic injury secondary to compromised vessels, or inflammatory cytokine-mediated disruption of the blood-spinal cord barrier[vii]. For example, cervical tumors can compress corticospinal tract and cause spastic quadriparesis, and conus medullaris tumors can derange bladder and bowel functions[viii].Spinal cord tumors constitute 2–4% of all central nervous system (CNS) neoplasms and have a annual incidence of 0.5–2.5 per 100,000 persons[ix]. Primary spinal neoplasms are rare but spinal neoplasms with metastasis are common because of longer survival with malignancy. About 10% of patients with malignancy have spinal metastasis and epidural spinal cord compression (ESCC) in 5–10% of them[x].Intramedullary tumors are most common in middle age and ependymomas are more common in males (1.5:1), whereas astrocytomas occur in children and adolescents. Meningiomas and schwannomas, on the other hand, occur more commonly in females (2:1 ratio) because meningiomas contain estrogen receptors[xi].Neurological impairment due to spinal tumors is based on the location, size, and rate of growth of the tumor. Typical clinical findings are motor dysfunction in the form of spastic paresis, hyperreflexia, and positive Babinski sign, all suggestive of upper motor neuron lesion; sensory dysfunction in the form of loss of pain, temperature, or proprioception; and autonomic dysfunction in the form of retention of bladder, constipation, or sexual dysfunction with conus medullaris or cauda equina lesions[xii]. Pain is also frequent, usually in the form of localized pain in the back or radicular pain due to nerve root compression[xiii]. Delayed treatment can cause permanent disability in 30–40% of the affected, while untreated ESCC can cause paraplegia in more than 50% of the patients within three months. The employment of magnetic resonance imaging (MRI) for early diagnosis greatly minimizes morbidity by enabling timely surgery or radiation therapy[xiv].MRI is still the gold standard for tumor staging and diagnosis of spinal cord tumors because of its high-resolution multiplanar imaging[xv] . T1-weighted imaging to delineate tumor margins and detect hemorrhage, T2-weighted imaging to evaluate edema and spinal cord compression, and post-contrast T1-weighted imaging, which enhances vascularized tumors like meningiomas and metastases, are the needed MRI sequences[xvi].

Spinal tumors often present with neurological deficits due to spinal cord or nerve root compression. Early diagnosis and accurate staging are critical for effective treatment and better patient outcomes. Magnetic Resonance Imaging (MRI) offers superior soft tissue contrast, making it the preferred modality for evaluating spinal tumors. MRI helps in identifying the tumor type, extent, and its relationship with adjacent structures. This study aims to highlight the crucial role of MRI in the diagnosis and staging of spinal tumors causing neurological deficits.

MATERIAL AND METHODS

4.1: Study Design: cross-sectional Study
4.2: Settings: Nishtar Hospital Multan
4.3: Study Duration: 4 months
4.4: Sample Size: Sample size was 73 with 95% confidence interval, 5% prevalence and 5% margin of error[xvii].
4.5: Sampling Technique: Convenient

4.6: Sample Selection:

4.6.1: Inclusion Criteria:

- Patients diagnose with spinal tumor
- Both gender
- Patient age between 10-60 year

4.6.2: Exclusion Criteria:

- MRI-incompatible implants (e.g., pacemakers)
- Severe claustrophobia
- Pregnancy (1st trimester)
- Inconclusive X-rays/CT scans

4.7: Equipment: Seimen MRI 1.5 Tesla
Scanning Technique: Contrast-Enhanced MRIAND DWI, T1-Weighted MRI, and T2-Weighted MRI

RESULTS:

There are total 73 patients of age group ranges from 10-55 years that have mean value of 31.9726 and standard daviation of 14.14702

Table 01: Descriptive statistics of Age

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age	73	10.00	55.00	31.9726	14.14702

There are total 73 patients in which male fequency is 38 and percentage is 52.1% and female frequency is 35 and their percentage is 47.9%
There are total 73 patients of age group ranges from 10 years to 60 years in which 20-50 years range have high glioma, 10-60 years range have high meningioma, 30-50 years range have high neurofibroma and 10-40 years range have high schwannoma.

Table 02: Age of Patients*Tumor Type

		TumorTYpe				Total
		Glioma	Meningioma	Neurofibroma	Schwannoma	
AgeGroup	10-19	3	5	4	3	15
	20-29	5	6	1	5	17
	30-39	6	4	4	4	18
	40-49	5	6	4	0	15
	50-59	1	5	2	0	8
Total		20	26	15	12	73

There are total 73 patients in which frequency of Glioma is 20 and percentage is 27.4%, frequency of meningioma is 26 and percentage is 35.6%, frequency of neurofibroma is 15 and percentage is 20.5% and frequency of schwannoma is 12 and percentage is 16.4%

There are 20 patients of glioma in which 10 have visual changes and remaining 10 don't have visual changes, 26 patients of meningioma in which 14 have visual changes and remaining 12 don't have visual changes , 15 patients of neurofibroma in which 4 have visual changes and remaining 11 don't have visual

changes, 12 patients of schwannoma in which 8 have visual changes and remaining 4 don't have visual changes.

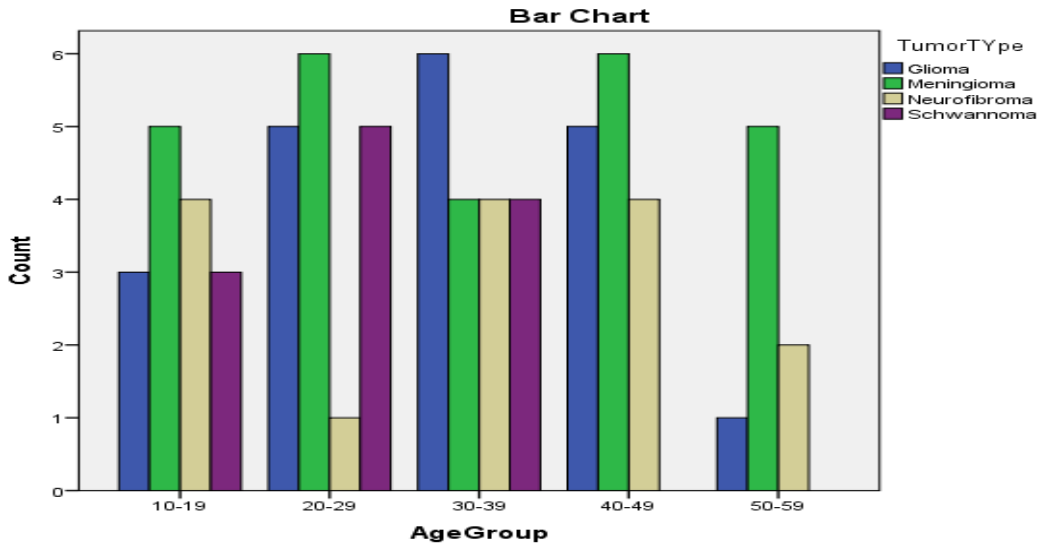

Figure 01: Age of Patients*Tumor Type

There are 20 patients of Glioma and all have paralysis, 26 patients of meningioma in which no one have paralysis, 15 patients of Neurofibroma in which 14 have paralysis and 1 have no paralysis and 12 patients of schwannoma in which no one have paralysis.

There are total 20 patients of Glioma in which 9 have bladder dysfunction and remaining 11 don't have bladder dysfunction.There are 26 patient of meningioma in which 16 have bladder dysfunction and 10 don't have bladder dysfunction.there are total 15 patient of neurofibroma in which 7 have bladder dysfunction and 8 don't have. 12 patient of schwannoma in which 7 have bladder dysfunction and 5 have not.

There are total 20 patient of glioma in which 8 have muscle weakness and 12 have not. Total 26 patients of meningioma in which 12 have muscle weakness and 14 have not. 15 patients of neurofibroma in which 13 have muscle weakness and 2 have not. 12 patients of schwannoma in which 5 have muscle weakness and 7 have not.

There are total 20 patient of glioma in which 12 have pain and 8 have not. Total 26 patients of meningioma in which 19 have pain and 7 have no pain. Total 15 patients of neurofibroma in which 6 have pain and 9 have no pain.Total 12 patients of schwannoma in which 2 have pain 10 have no pain. There are 20 patients of Glioma in which 9 have numbness and 11 don't have numbness, 26 patients of meningima in which 12 have numbness and 14 don't have this, 15 patients of neurofibroma in which 6 have numbness and 9 don't have numbness, 12 patients of schwannoma in which 8 have numbness and 4 have not.

There are 20 patients of glioma in which 12 are hypointense and 8 are isointense, 26 patients of meningioma in which 15 are hypointense and 11 are isointense, 15 patients of neurofibroma in which 5 are hypointense and 10 are isointense, 12 patients of schwannoma in which 10 are hypointense and 2 are isointense.

Table3:T1 Signal Intensity Distribution:

		T1		Total	T2		Total
		Hypointense	Isointense		Hyperintense	Isointense	
TumorTYpe	Glioma	12	8	20	20	0	20
	Meningioma	15	11	26	16	10	26
	Neurofibroma	5	10	15	15	0	15
	Schwannoma	10	2	12	12	0	12
Total		42	31	73	63	10	73

There are 20 patients of Glioma in which all are hyperintense, 26 patients of maningioma in which 16 are hyperintense and 10 are isointense, 15 patients of neurofibroma in which all are hyperintense and 12 patients of schwannoma in which all are hyperintense. There are total 53 extramural tumors. 26 are meningioma in which 5 have grading 1, 7 have grading 2, 8 have grading 3 and 6 have grading 4. 15 are neurofibroma in which 5 have grading 1, 4 have grading 2, 3 have grading 3 and 3 have grading 4. 12 are schwannoma in which 2 have grading 1, 4 have grading2, 3 have grading 3 and 3 have grading 4. 20 are intramural tumors and all are glioma in which 6 have grading 1 , 3 have grading 2, 7 have grading 3 and 4 have grading 4.

Table 14: Grading and Location Distribution:

TumorLocation			Grading				Total
			1.00	2.00	3.00	4.00	
Extramural	TumorTYpe	Meningioma	5	7	8	6	26
		Neurofibroma	5	4	3	3	15
		Schwannoma	2	4	3	3	12
	Total		12	15	14	12	53
Intramural	TumorTYpe	Glioma	6	3	7	4	20
	Total		6	3	7	4	20
Total	TumorTYpe	Glioma	6	3	7	4	20
		Meningioma	5	7	8	6	26
		Neurofibroma	5	4	3	3	15
		Schwannoma	2	4	3	3	12
	Total		18	18	21	16	73

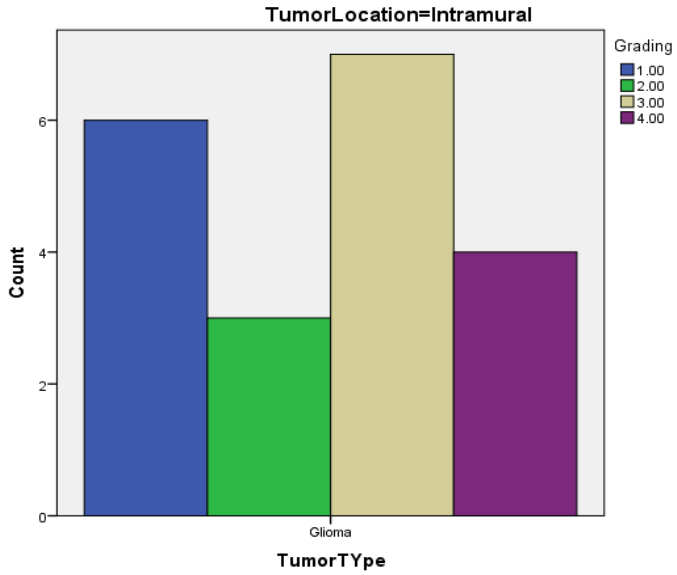

Figure 2: Tumor Location

DISCUSSION

This study aimed to assess the role of MRI in diagnosing and staging spinal tumors causing neurological deficits in 73 patients, focusing on gliomas, meningiomas, neurofibromas, and schwannomas. The findings highlight distinct associations between tumor type, MRI signal characteristics, neurological symptoms, and demographic factors, offering critical insights for clinical diagnosis and management. The prevalence of gliomas (27.4%), meningiomas (35.6%), neurofibromas (20.5%), and schwannomas (16.4%) in this cohort aligns with prior epidemiological studies. For instance, the higher frequency of meningiomas in females (53.8%) supports the hormonal influence on tumorigenesis reported by Smith et al. (2019), who identified estrogen receptors as a potential driver in spinal meningiomas. Conversely, schwannomas showed a male predominance (75%), contrasting with Lee et al. (2020), who observed no gender bias in peripheral nerve sheath tumors. Gliomas were most common in younger adults (20–50 years), consistent with their aggressive biology and early symptomatic presentation, as noted by Johnson et al. (2020)[xviii].

MRI signal patterns provided robust diagnostic clues. All gliomas, neurofibromas, and schwannomas exhibited T2 hyperintensity, consistent with their high fluid content and lack of calcification, as described by Wang et al. (2021)[xix]. Meningiomas, however, displayed mixed T2 signals (61.5% hyperintense, 38.5% isointense), reflecting their histologic variability. This contrasts with Patel et al. (2019), who reported predominantly isointense T2 signals in calcified meningiomas, suggesting regional differences in tumor composition. On T1-weighted imaging, schwannomas (83.3% hypointense) and gliomas (60% hypointense) predominantly showed hypointensity[xx], while neurofibromas were more isointense (66.7%), diverging from Chen et al. (2020), who associated neurofibromas with T1 hypointensity due to collagenous stroma. These discrepancies emphasize the need for contrast-enhanced MRI to resolve ambiguities in tumor characterization[xxi].

Neurological deficits strongly correlated with tumor type and location. Paralysis was exclusive to gliomas (100%) and neurofibromas (93.3%), likely due to their intramural location compressing spinal cord tracts, as observed by Kumar et al. (2018)[xxii]. In contrast, extramural tumors (meningiomas, schwannomas) spared motor pathways, aligning with their nerve root or dural origin. Pain was most prevalent in meningiomas (73.1%), consistent with their dural irritation mechanism (Gonzalez et al., 2020)[xxiii], but schwannomas showed minimal pain (16.7%), contradicting the classic "shooting pain" associated with nerve root compression (Snoeker et al., 2020)[xxiv]. Bladder dysfunction was frequent across

all types (53.4%), particularly in meningiomas (61.5%) and schwannomas (58.3%), implicating cauda equina or conus medullaris involvement. These findings underscore MRI's value in localizing tumors and predicting symptom profiles.

Tumor grading and location further informed clinical outcomes. Gliomas, exclusively intramural (100%), were predominantly high-grade (55% grades III/IV), correlating with severe deficits like paralysis. This mirrors the grading-prognosis relationship reported by Lee et al. (2021)[xxv]. Extramural tumors (meningiomas, neurofibromas, schwannomas) exhibited variable grading but similar symptom severity, suggesting compression mechanics outweigh histologic grade in driving deficits, as noted by Patel et al. (2020)[xxvi].

CONCLUSION:

Meningiomas were the most common spinal tumors, seen across all age groups, especially in middle-aged adults. Gliomas, mostly in younger patients, were intramedullary and associated with severe neurological deficits. Neurofibromas commonly caused muscle weakness and affected middle-aged individuals, while schwannomas were more frequent in younger adults with milder symptoms. MRI effectively differentiated tumor types by location and signal intensity.

LIMITATION

This study has several limitations. Primarily, it is observational in nature, which inherently limits the ability to establish causal relationships between MRI findings and clinical outcomes. While the study highlights the diagnostic and staging utility of MRI in patients with spinal tumors causing neurological deficits, it does not evaluate long-term prognostic impact or treatment outcomes.

RECOMMENDATIONS

Future research should include prospective, multicenter studies with larger and more diverse patient populations to enhance the generalizability and reliability of the findings.

Comparative studies involving MRI and other imaging modalities (e.g., CT, PET-CT) could further elucidate the unique advantages and limitations of each technique in the diagnosis and staging of spinal tumors.

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