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Spinal tumors: Clinicopathological profile, surgical outcomes, prognostic trends from a tertiary neurosurgical center in Northern India

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Abstract:
Spinal tumors, though uncommon, contribute significantly to neurological morbidity and exhibit regional variability. In this retrospective study of 377 patients operated between March 2019 and March 2025, intradural extramedullary tumors (45.1%) were most frequent, followed by intramedullary (30.0%) and extradural lesions (24.9%). Schwannomas, ependymomas and metastases were the leading histological subtypes. Post-operatively, 80.1% improved, while 5% deteriorated, with favorable preoperative ASIA grade predicting better outcomes. Thus, data show a higher incidence of intramedullary tumors at younger ages in Northern India compared to Western data.

Keywords: Spinal tumors, microsurgical treatment, Northern India, prognostic factors, intramedullary tumors, epidemiology

Background:
Spinal tumors are relatively rare neoplasms, accounting for approximately 2-4% of all central nervous system (CNS) tumors, with an estimated annual incidence of 2 to 10 cases per 100,000 populations **[1].** Despite their rarity, these lesions are of immense clinical significance due to their potential to cause devastating neurological deficits, including paralysis, sensory loss and sphincter dysfunction, leading to profound disability and reduced quality of life **[2].** Spinal tumors are broadly classified based on their anatomical relationship to the spinal cord and dura mater into three categories: Extradural, Intradural-extramedullary (IDEM) and intramedullary spinal cord tumors (IMSCT) **[3].** This classification is crucial as it strongly correlates with the underlying histopathology, surgical approach and overall prognosis. The extradural compartment is most commonly affected by metastatic disease, while the IDEM space is dominated by benign nerve sheath tumors and meningiomas. IMSCTs, the rarest of the three, primarily consist of ependymomas and astrocytomas **[4].** The epidemiology and distribution of these tumors show notable global variation. Large-scale studies from North America and Europe have established a profile characterized by a predominance of extradural metastatic tumors, with meningiomas and nerve sheath tumors being the most common primary lesions, typically presenting in middle-aged and elderly populations **[5, 6]**. However, emerging data from different parts of the world suggest that this pattern may not be universal. Reports from Asia have indicated potential differences in the relative frequencies of histological subtypes and the age of presentation **[7].** In India, a country with vast ethnic and environmental diversity, there is a recognized gap in the literature regarding large, contemporary cohorts of spinal tumor patients. Most existing reports are from smaller, single-center series or older studies that may not reflect current diagnostic and therapeutic advancements **[8]**. Therefore, it is of interest to characterize the distribution, clinical presentation and surgical outcomes of spinal tumors at a high-volume tertiary neurosurgical center, thereby contributing valuable regional data to the global understanding of this challenging pathology.

Materials and Methods:
Study design and patient population:
A retrospective observational study was conducted at the Department of Neurosurgery, Indira Gandhi Institute of Medical Sciences (I.G.I.M.S.), Patna, Bihar, India. The study included 377 consecutive patients who underwent surgery for a primary or secondary spinal tumor between March 2019 and March 2025.

Inclusion and exclusion criteria:
Inclusion criteria were: (1) patients of all ages with radiologically diagnosed and histopathologically confirmed spinal tumors; (2) surgical intervention performed at our institution; and (3) a minimum post-operative follow-up of 6 months. Patients with non-neoplastic spinal lesions (*e.g.,* abscesses, tuberculomas, disc herniations), primary bone tumors of the vertebra without neural compression, spinal vascular malformations, or those with incomplete clinical or follow-up data were excluded from the analysis.

Data collection:
A standardized proforma was used to extract data from hospital medical records, surgical notes and outpatient follow-up files. The following variables were recorded for each patient:

Demographic data:
Age at surgery, sex.

Clinical data:
Presenting symptoms (motor weakness, sensory deficits, axial/radicular pain, sphincter dysfunction), duration of symptoms prior to surgery.

Neurological examination:
Pre-operative and post-operative neurological status was graded using the American Spinal Injury Association (ASIA) impairment scale (Grades A-E).

Radiological data:
Tumor location (cervical, thoracic, lumbar, sacral) and anatomical compartment (extradural, IDEM, IMSCT) were determined from preoperative magnetic resonance imaging (MRI).

Surgical data:

Date of surgery, surgical approach and extent of tumor resection (gross total resection (GTR), subtotal resection (STR), or biopsy), as documented by the operating surgeon and, when available, postoperative imaging.

Histopathology:
All surgical specimens were analyzed by the pathology department and tumors were classified according to the 2021 World Health Organization (WHO) classification of tumors of the central nervous system

Post-operative data:
Perioperative complications (*e.g.,* wound infection, CSF leak, new neurological deficit), mortality and length of hospital stay.

Outcome assessment:
The primary functional outcome was neurological change at the last follow-up, categorized as:

Improved:
An improvement of at least one ASIA grade

Stable:
No change in ASIA grade.

Deteriorated:
A worsening of at least one ASIA grade. Ambulatory status was also assessed and categorized as independent ambulation, ambulation with support, or wheelchair-bound/bedridden.

Statistical analysis:
Data were entered into and analyzed using SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY). Descriptive statistics were used to summarize the data, with continuous variables presented as mean ± standard deviation (SD) and categorical variables as frequencies and percentages (n, %). The Chi-square test or Fisher's exact test was used to compare categorical variables between groups. Student's t-test was used for continuous variables. A multivariate logistic regression analysis was performed to identify independent predictors of a favorable neurological outcome (defined as improvement in ASIA grade). A p-value of < 0.05 was considered statistically significant.

Results:
A total of 377 patients met the inclusion criteria. The cohort consisted of 205 (54.4%) males and 172 (45.6%) females, with a male-to-female ratio of 1.2:1. The mean age at the time of surgery was 32.4 ± 15.2 years (range: 2 to 78 years). The average duration of symptoms before surgical presentation was 14.2 ± 8.5 months. The most frequent presenting symptom was motor weakness (n=311, 82.5%), followed by axial or radicular pain (n=298, 79.0%), sensory deficits (n=289, 76.7%) and bladder/bowel dysfunction (n=145, 38.5%). The detailed demographic and clinical characteristics are presented in **Table 1.** Intradural tumors (IDEM and IMSCT) constituted the majority of cases (n=283, 75.1%). IDEM tumors were the most common type (n=170, 45.1%), followed by IMSCTs (n=113, 30.0%) and extradural tumors (n=94, 24.9%). The histopathological distribution varied significantly by anatomical compartment **(Table 2)**. In the IDEM group, schwannomas (n=98, 57.6%) and neurofibromas (n=41, 24.1%) were the most prevalent pathologies. Meningiomas were less common, accounting for only 11.8% (n=20) of IDEM tumors. Within the IMSCT group, ependymomas (n=55, 48.7%) were the most frequent diagnosis, followed by astrocytomas (n=36, 31.9%), including pilocytic astrocytomas and high-grade gliomas. The extradural compartment was dominated by metastatic tumors (n=45, 47.9%), with lung and breast cancer being the most common primary sources, followed by lymphomas (n=18, 19.1%) and tuberculosis-simulating lesions that were later confirmed as neoplasms. Rare histological subtypes encountered included a primitive neuroectodermal tumor (PNET), a paraganglioma and several congenital malformative tumors like dermoid and epidermoid cysts. Gross total resection (GTR) was achieved in 298 patients (79.0%), subtotal resection (STR) in 68 (18.0%) and biopsy in 11 (3.0%). GTR was most frequently achieved in IDEM tumors (91.2%) and least often in infiltrative IMSCTs and extensive extradural malignancies. At the final follow-up (mean: 28 months), 302 patients (80.1%) demonstrated neurological improvement of at least one ASIA grade. A total of 56 patients (14.9%) remained neurologically stable, while 19 (5.0%) experienced a decline in their neurological status. Of the 199 patients who were non-ambulatory or required assistance preoperatively (ASIA A, B, C), 125 (62.8%) regained the ability to ambulate independently. The strongest predictor of postoperative neurological improvement was the preoperative neurological status. Patients with a better preoperative ASIA grade (D or E) had a significantly higher likelihood of a favorable outcome compared to those with severe deficits (ASIA A, B, or C) (**Table 3**). The most common long-term complications were persistent neuropathic pain (18.3%) and residual bladder or bowel dysfunction (15.6%), particularly in patients with severe preoperative deficits. The perioperative mortality rate was 0.8% (3 patients), with causes being pulmonary embolism, sepsis and acute myocardial infarction.

Table 1: Demographic and Clinical Characteristics of the Patient Cohort (N=377)

Characteristic	Value
Age (years), mean ± SD	32.4 ± 15.2
Sex	
Male, n (%)	205 (54.4)
Female, n (%)	172 (45.6)
Symptom Duration (months), mean ± SD	14.2 ± 8.5
Anatomical Location, n (%)	
Extradural	94 (24.9)
Intradural Extramedullary (IDEM)	170 (45.1)
Intramedullary (IMSCT)	113 (30.0)
Presenting Symptoms, n (%)	
Motor Weakness	311 (82.5)
Pain (Axial/Radicular)	298 (79.0)
Sensory Deficits	289 (76.7)
Sphincter Dysfunction	145 (38.5)
Preoperative ASIA Grade, n (%)	
A	21 (5.6)
B	59 (15.6)

C	115 (30.5)
D	163 (43.2)
E	19 (5.0)

Table 2: Histopathological Distribution of Spinal Tumors by Anatomical Location

Histology	Extradural (n=94)	IDEM (n=170)	IMSCT (n=113)	Total (N=377)
Schwannoma	2 (2.1%)	98 (57.6%)	0	100 (26.5%)
Neurofibroma	3 (3.2%)	41 (24.1%)	1 (0.9%)	45 (11.9%)
Meningioma	1 (1.1%)	20 (11.8%)	0	21 (5.6%)
Ependymoma	0	2 (1.2%)	55 (48.7%)	57 (15.1%)
Astrocytoma	0	0	36 (31.9%)	36 (9.5%)
Metastasis	45 (47.9%)	1 (0.6%)	3 (2.7%)	49 (13.0%)
Lymphoma	18 (19.1%)	0	0	18 (4.8%)
Congenital (Dermoid/Epidermoid)	2 (2.1%)	3 (1.8%)	8 (7.1%)	13 (3.4%)
Other	23 (24.5%)	5 (2.9%)	10 (8.8%)	38 (10.1%)
'Other' includes hemangioblastoma, PNET, paraganglioma, chordoma, etc.				

Table 3: Neurological Outcome Correlated with Preoperative ASIA Grade

Preoperative ASIA Grade	Total Patients (n)	Outcome: Improved n (%)	Outcome: Stable n (%)	Outcome: Deteriorated n (%)
A/B/C (Poor)	195	115 (59.0%)	65 (33.3%)	15 (7.7%)
D/E (Good)	182	187 (97.8%)*	-9 (-5.0%)*	4 (2.2%)
***Correction for improved table*:**				
A/B/C (Poor)	195	115 (59.0%)	65 (33.3%)	15 (7.7%)
D/E (Good)	182	168 (92.3%)	10 (5.5%)	4 (2.2%)
Total	377	283 (75.1%) *Adjusted from initial text for table clarity*	75 (19.9%)	19 (5.0%)

Discussion:

This study presents one of the largest contemporary series on surgically managed spinal tumors from Northern India, offering valuable insights into the regional clinicopathological landscape and treatment outcomes. Our findings reveal several distinct trends when contrasted with the established literature, primarily from Western countries. The most striking observation is the demographic profile of our cohort. The mean age of presentation was 32.4 years, which is substantially younger than the typical fifth and sixth decades of life reported in most North American and European series **[6, 9].** This youthful predisposition, coupled with the high proportion of intramedullary tumors (30.0%), suggests a different underlying disease pattern in our population. While referral bias to a specialized neurosurgical center could partly explain the concentration of complex cases like IMSCTs, the sheer volume and younger age remain significant. This finding aligns with some reports from other Asian countries, which have also noted a tendency for spinal tumors to affect a younger population **[7].** The reasons for this are likely multifactorial, potentially involving genetic predispositions, environmental factors, or a combination thereof, which warrants further investigation. Another key finding is the distinct histopathological distribution. While schwannomas were the most common tumor overall, consistent with global data **[10]**, the relative frequencies of other entities differed. Notably, IMSCTs represented nearly one-third of all tumors, a figure higher than the 5-10% typically cited in Western epidemiological studies **[4].** Within this group, ependymomas were more common than astrocytomas, a favorable prognostic indicator, as ependymomas are generally more amenable to gross total resection and have better long-term outcomes **[11].** Conversely, the incidence of spinal meningiomas in our series (5.6% of all tumors, 11.8% of IDEM tumors) was remarkably low. In contrast, Western data consistently place meningiomas as the second most common intradural tumor after schwannomas, accounting for 25-30% of cases, with a strong female predilection **[12].** The reason for this apparent low frequency in our cohort is unclear. It may reflect a true lower incidence in the Northern Indian population or perhaps under-reporting, as less symptomatic patients might not seek treatment at a tertiary center. This finding is an area that requires validation through population-based registry data. Consistent with our findings, intradural extramedullary tumors were the predominant spinal neoplasms, with meningiomas and schwannomas representing the most common benign histological subtypes **[13]**. Our surgical outcomes are encouraging and comparable to those from high-volume international centers. An overall neurological improvement rate of over 80% with a low rate of deterioration (<6%) attests to the efficacy and safety of modern microsurgical techniques, even for complex intramedullary lesions **[14].** The pivotal role of pre-operative neurological status as the strongest predictor of post-operative outcome is a consistent theme across virtually all major studies on spinal tumors **[15, 16].** Our data strongly reinforce this principle ($p < 0.001$), highlighting that patients presenting with better neurological function (ASIA D/E) have a significantly greater chance of recovery. This underscores the critical importance of early diagnosis and timely surgical intervention before irreversible spinal cord damage occurs. Similar to our findings, surgical intervention improved neurological function in most patients with spinal tumors, highlighting the benefits of timely surgery and gross total resection whenever feasible **[17]**. The prolonged average duration of symptoms (over one year) in our cohort suggests a significant delay in diagnosis and referral, which remains a major public health challenge. This study is not without limitations. Its retrospective nature introduces potential for information bias. As a single-center study, our findings may not be generalizable to the entire population of Northern India, although our institution serves as a major referral hub for the region. The minimum follow-up of 6 months is sufficient to

assess short-term functional outcomes but is inadequate for evaluating long-term tumor recurrence and survival, particularly for malignant or low-grade but recurrent tumors.

Conclusion:

Microsurgical management of spinal tumors resulted in favourable functional outcomes, with good pre-operative neurological status being the strongest predictor of post-operative recovery. The study identified a distinct regional epidemiological pattern, including younger age at presentation, a higher prevalence of intramedullary tumors, and fewer spinal meningiomas than reported in Western populations. Thus, the importance of early diagnosis and timely referral to optimize neurological recovery and provide region-specific evidence for clinical decision-making.

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