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Original Research Article

Role of MR Imaging in Spinal Neoplasms

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Conflict of interest: Nil

Abstract:

Background: Spinal neoplasms present a significant diagnostic challenge, manifesting with a spectrum of symptoms that can mimic various spinal pathologies. This study explores the pivotal role of Magnetic Resonance Imaging (MRI) in diagnosing and characterizing spinal tumors. MRI's exceptional resolution and multiplanar imaging capabilities make it the gold standard for evaluating spinal neoplasms.

Methods: comprehensive analysis of 60 patients with suspected spinal lesion, MRI was done to compare tumor characteristics, and discuss the implications for treatment planning and prognosis.

Results: study shows distribution of tumours by age and gender, compartmental distribution and tumoral characteristics.

Conclusion: Study shows the critical importance of MRI in diagnosing and characterising of spinal tumor.

Keywords: Spinal lesions, MRI characteristics.

Introduction

Spinal cord tumors, although relatively rare, have a profound impact on patients' neurological function and overall quality of life. These tumors can be primary or metastatic, benign or malignant, and often present with overlapping symptoms such as pain, numbness, weakness, and gait disturbances. The timely and accurate diagnosis of these tumors is crucial for effective management, and MRI has become the primary imaging tool for this purpose.

MRI's ability to differentiate between various soft tissues without ionizing radiation makes it superior to traditional imaging modalities like computed tomography (CT). Furthermore, the development of advanced MRI techniques, such as diffusion-weighted imaging (DWI) and magnetic resonance spectroscopy (MRS), has enhanced the diagnostic precision for complex cases.

Objectives

1. Primary Objective: To evaluate the effectiveness of MRI in diagnosing spinal neoplasms and distinguishing between different tumor types.

2. Secondary Objectives:

- To describe the characteristic MRI features of various spinal tumors.
- To assess the involvement of adjacent anatomical structures, including the spinal cord, vertebrae, and soft tissues.
- To highlight MRI's role in guiding surgical and therapeutic strategies.

2. Anatomy and MRI Techniques

Understanding the complex anatomy of the spinal cord is essential for interpreting MRI findings accurately. The spinal cord, encased within the vertebral column, extends from the foramen magnum to the first or second lumbar vertebra and is divided into cervical, thoracic, lumbar, and sacral segments. It consists of white matter, which contains myelinated nerve fibers, and gray matter, which houses neuron cell bodies.

Key Structures

Meninges: The spinal cord is covered by three protective layers: pia mater (innermost), arachnoid mater (middle), and dura mater (outermost). The epidural, subdural, and subarachnoid spaces are important for diagnosing specific tumor types.

Spinal Nerves: There are 31 pairs of spinal nerves that transmit sensory and motor information between the brain and the body.

MRI Techniques and Sequences

MRI employs a variety of pulse sequences to capture detailed images of the spinal cord and surrounding structures:

1. T1-Weighted Imaging: Provides high-resolution anatomical details and identifies fat and hemorrhagic components. Tumors often appear hypointense relative to the spinal cord.
2. T2-Weighted Imaging: Highlights fluid-filled structures such as cysts, edema, and CSF, making it useful for visualizing tumor-associated edema or syrinx.
3. Short Tau Inversion Recovery (STIR): Suppresses fat signals, accentuating tumors and inflammatory changes.
4. Post-Contrast Imaging: Involves the use of gadolinium-based contrast agents to enhance vascular tumors and delineate tumor margins.
5. Magnetic Resonance Spectroscopy (MRS): Analyzes the metabolic profile of tissues, aiding in the differentiation of benign and malignant tumors.
6. Diffusion-Weighted Imaging (DWI): Evaluates the movement of water molecules within tissues, useful for detecting tumor cellularity and necrosis.

3. Classification of Spinal Neoplasms

Spinal tumors are categorized based on their anatomical location relative to the dura mater and spinal cord:

1. Extradural Tumors: Arise outside the dura mater, often involving the vertebrae and epidural space. They are frequently metastatic, originating from primary tumors such as breast, lung, or prostate cancer.
2. Intradural Extramedullary Tumors: Occur within the dura but outside the spinal cord, commonly including meningiomas and nerve sheath tumors (e.g., schwannomas and neurofibromas).
3. Intramedullary Tumors: Develop within the spinal cord and are typically glial in origin, such as ependymomas and astrocytomas. These tumors can cause significant cord expansion and myelopathy.

4. Methodology

The study was conducted at the Gujarat Cancer and Research Institute, Ahmedabad. Sectional, observational study involved 60 patients with suspected spinal neoplasms, referred for MRI examination. Imaging findings were correlated with histopathological results to validate the diagnoses.

Study Protocol

- Equipment: Siemens 3T Skyra MRI scanner
- Sample Size: 60 patients, with a gender distribution of 35 males (58%) and 25 females (42%).
- Inclusion Criteria: Patients with clinical symptoms indicative of spinal tumors or those undergoing post-treatment evaluation.
- Exclusion Criteria: Patients with contraindications to MRI, including those with metallic implants, cardiac pacemakers, or severe claustrophobia.

Study Procedures

1. Patient Preparation: Fasting for 4-6 hours before the procedure, sedation administered to uncooperative patients, and written informed consent obtained.
2. Imaging Protocol: Axial, sagittal, and coronal images were acquired, with and without contrast enhancement.
3. Data Analysis: Tumor characteristics, such as location, signal intensity, and enhancement patterns, were analyzed. The findings were compared to existing literature.

Demographics of the Study Population

Gender Distribution 58% Male, 42% Female

Age Range 0-10 years (8%), 11-20 years (10%), 21-30 years (25%), 31-40 years (23%), 41-50 years (17%), 51-60 years (14%), >60 years (3%)

5. Results and Observations

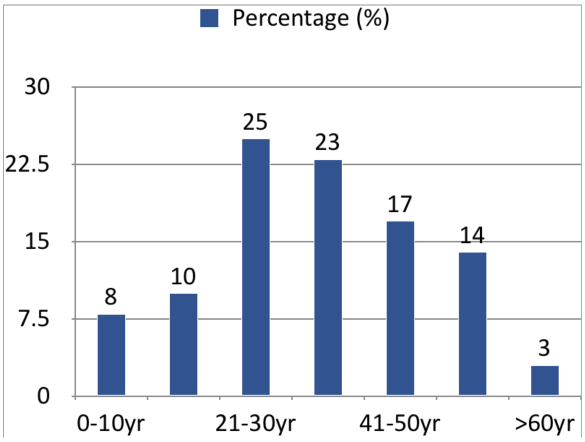
The study results revealed significant patterns in the distribution and characteristics of spinal tumors.

5.1 Gender and Age Distribution [2]

Gender: Males accounted for 58% of cases, while females represented 42%.

Age: The peak incidence of spinal tumors was observed in the 21-30 age group, accounting for 25% of cases.

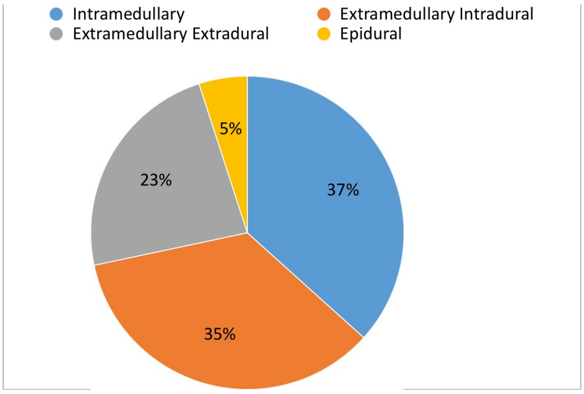
The pediatric population (0-10 years) represented 8%, while only 3% of cases involved patients over 60 years.



Graph 1: Age-wise Distribution of Patients

Graph illustrates the highest incidence of spinal tumors in the 21-30 age group, with a gradual decline in older age groups.

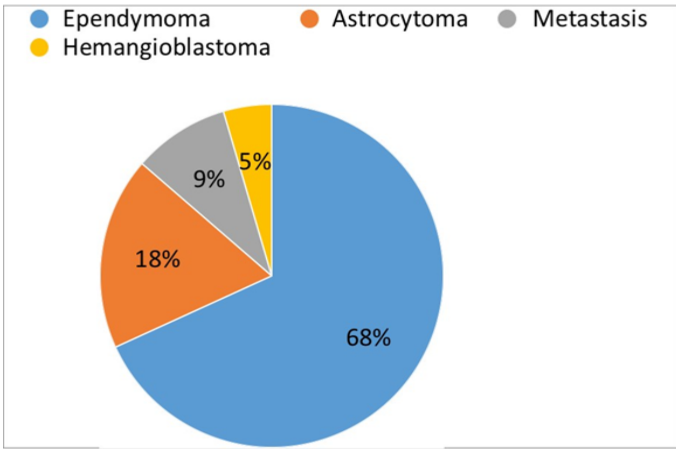
5.2 Tumor Distribution by Compartment



Graph 2: Tumor Distribution by Compartment

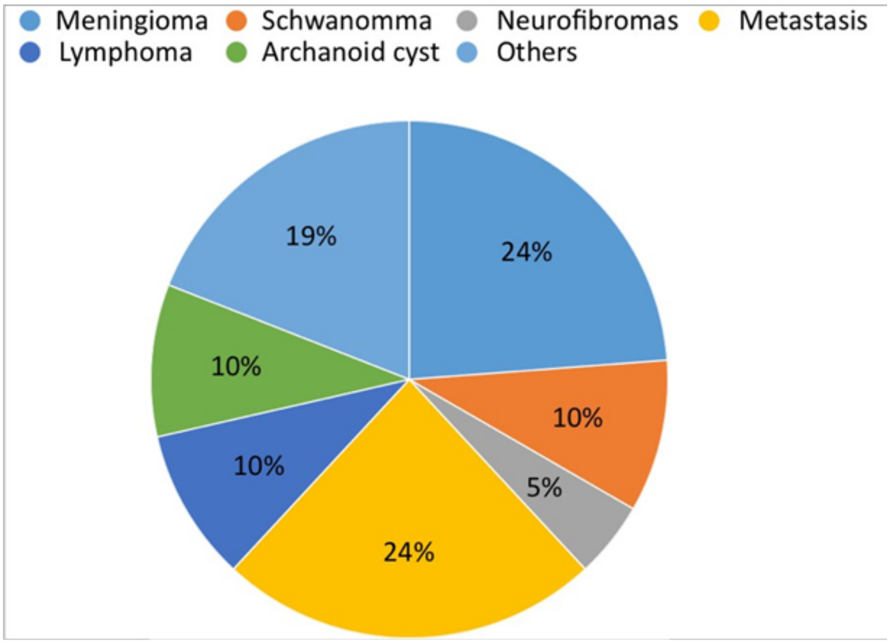
Visual representation showing the percentage of intramedullary, intradural extramedullary, and extradural tumors.

Intramedullary Tumors: 37% of cases, with ependymomas being the most prevalent.



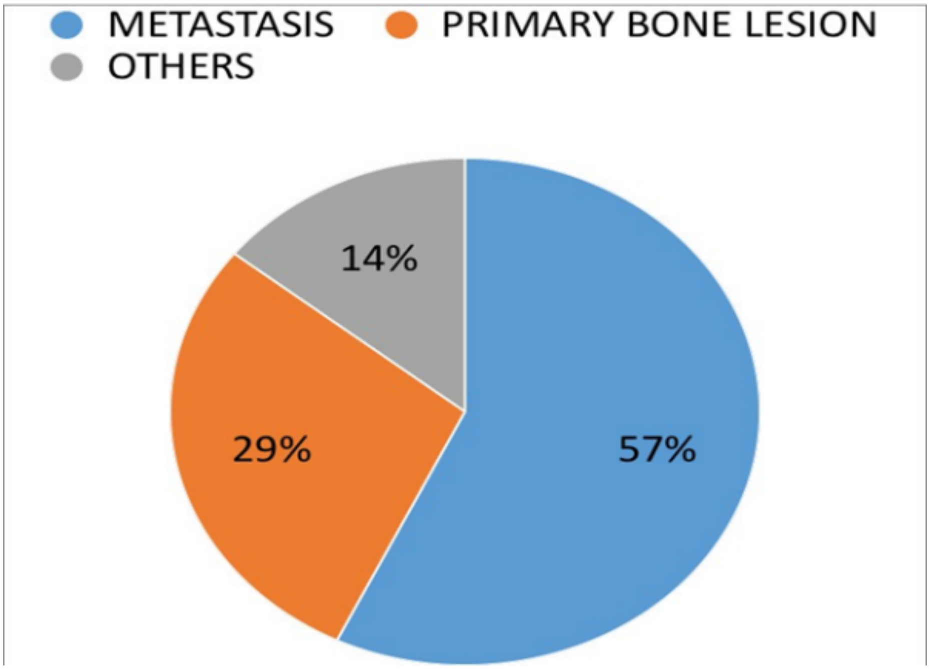
Graph 3: Distribution of intramedullary lesions

Intradural Extramedullary Tumors: 35% of cases, with meningiomas most frequently observed.



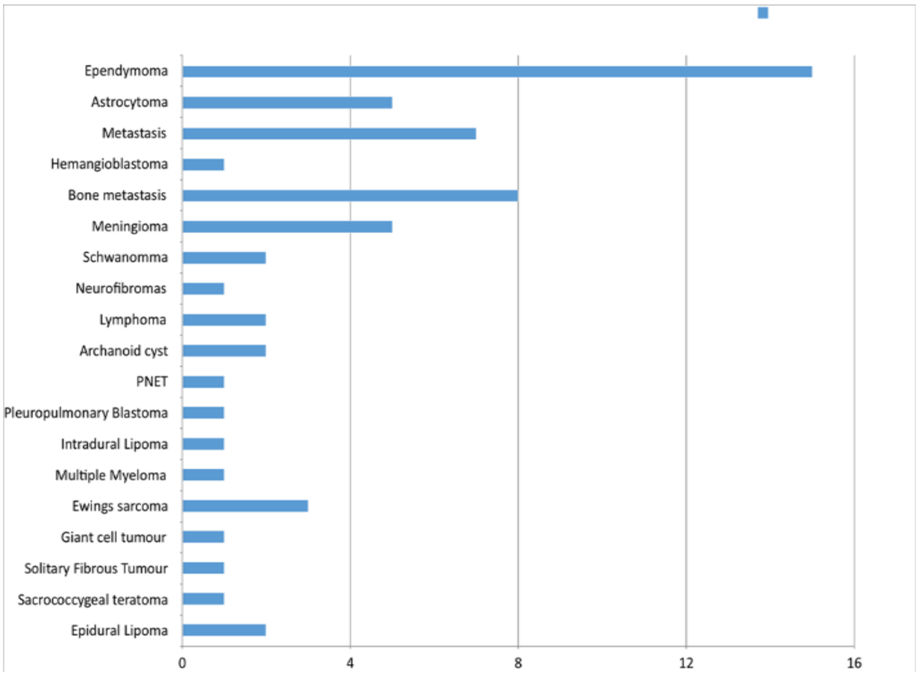
Graph 4: Distribution of Intradural Extramedullary tumour

Extradural Tumors: 23%, predominantly metastatic lesions originating from other primary cancers.



Graph 5: Distribution of Extradural Tumour

Distribution Pattern of Individual Tumour in Studied Population (N=60) [4]



Graph 6:

5.3 Tumor Characteristics and MRI Findings

1. Intramedullary Tumors [1]:

Ependymomas: Central, well-circumscribed masses with homogeneous enhancement post-contrast. Often associated with cysts and syrinx formation.

Astrocytomas: More infiltrative with ill-defined margins, characterized by heterogeneous signal intensity and variable enhancement. Commonly seen in pediatric patients.

2. Intradural Extramedullary Tumors:

Meningiomas: Frequently located in the thoracic spine, appearing isointense on T1 and hyperintense on T2. These tumors exhibit a characteristic "dural tail sign" and homogeneous contrast enhancement.

Schwannomas: Exhibit mixed signal intensity on T2, with heterogeneous enhancement. Often found in the lumbar region.

3. Extradural Tumors: Metastasis: Characterized by variable signal intensities, often hypointense on T1 and hyperintense on T2. Commonly affect the thoracic and lumbar spine, with extensive bone involvement.

Table 1: Common Tumor Types and MRI Characteristics [5]

Tumor Type	Frequency	Common MRI Features
Ependymoma	68%	T1 hypointense, T2 hyperintense, cystic areas
Astrocytoma	18%	T2 hyperintense, patchy enhancement
Meningioma	24%	Broad-based dural attachment, dural tail sign
Metastasis	57%	Variable, multifocal lesions

6. Discussion

Comparative Analysis: The study's results are consistent with existing literature, underscoring MRI's superiority in diagnosing spinal neoplasms. The high prevalence of intramedullary tumors in adults and the predominance of meningiomas in the thoracic spine reflect patterns observed in previous studies.

Table 2: Comparison of present study with previous literature

Study	Intramedullary (%)	Intradural Extramedullary (%)	Extradural (%)
Present Study	37	35	23
Santosh K. Panda et al. [6]	20.2	69.7	10.1
Ming Hau Li [8]	15	18	62.5

Key Findings

1. Ependymomas: The most common intramedullary tumor in adults, often presenting with a syrinx. MRI findings of central location and homogeneous enhancement are characteristic.

2. Astrocytomas: More common in children, with diffuse cord involvement. These tumors exhibit

patchy and irregular enhancement, complicating surgical resection.

3. Meningiomas: Predominantly affect females and are easily identified by their broad dural attachment and homogeneous contrast enhancement.

MRI Limitations and Challenges

- Longer Scan Times: MRI can be challenging in emergency settings due to its duration.
- Contraindications: Patients with metallic implants or severe claustrophobia cannot undergo MRI, limiting its use in some cases.
- Cost and Accessibility: MRI is expensive and not readily available in all healthcare settings, posing challenges for widespread use.

Technological Advances

Emerging MRI technologies, such as 3D imaging and functional MRI, are expected to further improve the diagnosis and treatment of spinal tumors. These advancements may allow for more accurate differentiation between tumor types and better monitoring of treatment response.

Case 1- Ependymoma

7. Conclusion: MRI is a critical tool for diagnosing and managing spinal neoplasms. It provides unparalleled detail about tumor location, extent, and involvement of adjacent structures, enabling effective surgical planning and treatment monitoring. Despite its limitations, MRI's benefits make it indispensable in spinal oncology.

Clinical Implications

- Precision in Diagnosis: MRI's ability to distinguish between different types of spinal tumors influences treatment strategies and improves patient outcomes.
- Guidance for Surgery: Clear visualization of tumor boundaries and vascular structures aids in planning surgical interventions.
- Monitoring and Prognosis: MRI is crucial for assessing tumor progression and the effectiveness of therapeutic interventions.

Case Illustration

Figure 1a: T1 SAGITTAL

Figure 1b: T2 SAGITTAL

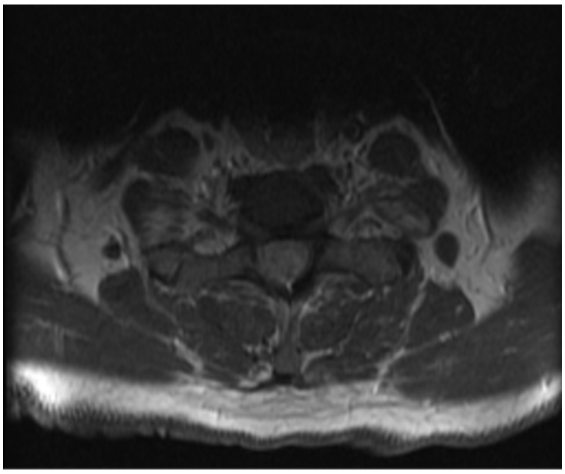


Figure 1c: T1 AXIAL POST CONTRAST

Altered signal intensity intramedullary lesion is noted in the cervico-thoracic spinal cord extending from C5 to D2. It appears hypointense to isointense in T1W and hyperintense in T2W. Mild to moderate enhancement in the nodular rim component. There is associated peritumoral cyst are noted. There is non-enhancing low T1 high T2 signal along the dorsal columns most likely edema

CASE 2 – Astrocytoma

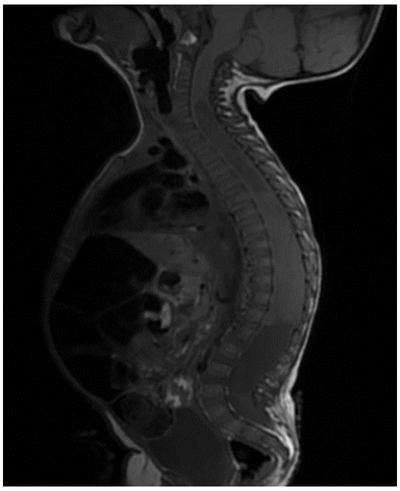


Figure 2 A: T1W SAGITTAL

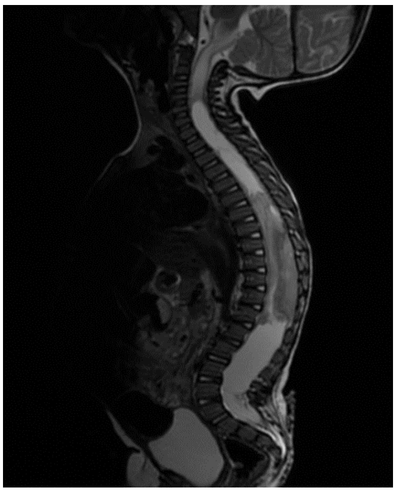


Figure 2 B: T2W SAGITTAL

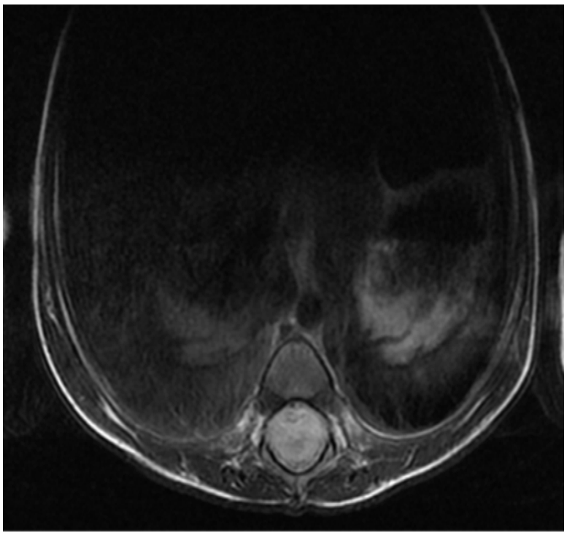


Figure 2 C: T2W AXIAL

There is an expansile intramedullary T1 hypointense and T2 hyperintense lesion is noted extending from the level of D6 to L2 segments. There is also effacement of surrounding extramedullary CSF space.

Case 3 – Hemangioblastoma

Figure 3A: T1W SAGITTAL

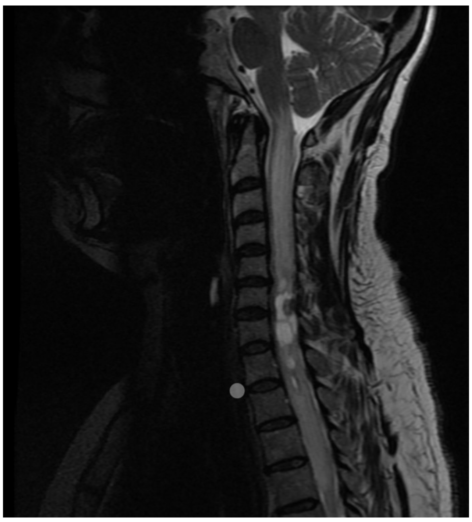


Figure 3 B: T2W SAGITTAL

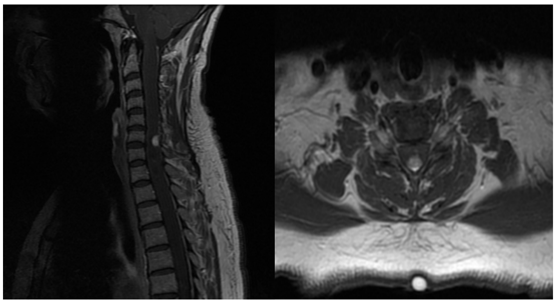


FIGURE 3 C & 3D: T1W POSTCONTRAST SAGITTAL AND AXIAL

Intramedullary altered signal intensity lesion is noted at C6 vertebral level which appears hypointense in T1 and hyperintense in T2 sequences. Lesion shows vivid enhancement on post contrast study. There is associated small focal syrinx is present which is appreciated in T2W sequence.

Case 4 - Arachnoid Cyst

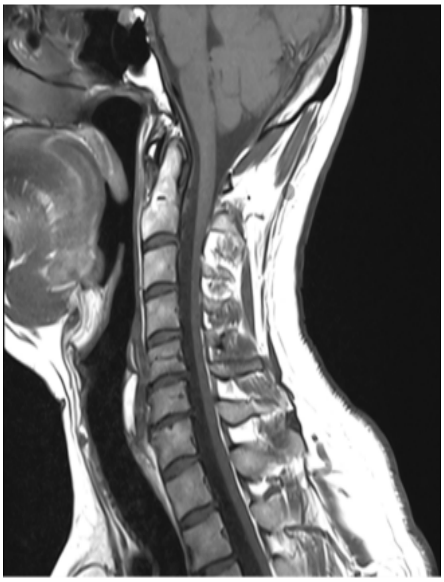


Figure 4a: T1W SAGITTAL

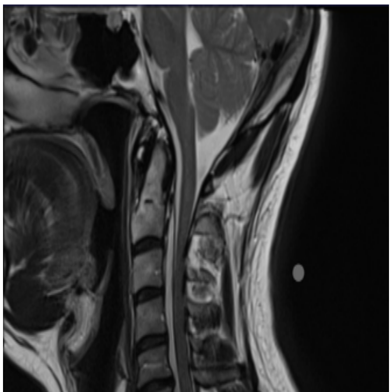


Figure 4b: T2 W SAGITTAL

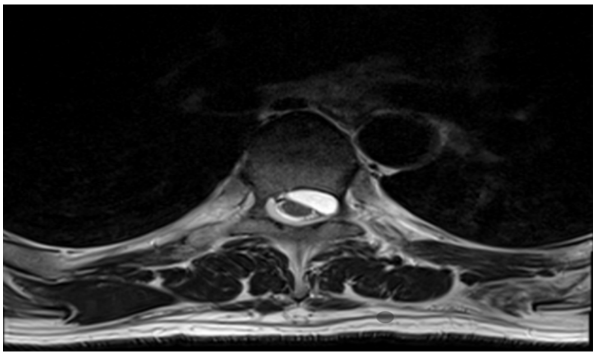


Figure 4c: T2 W AXIAL

A extramedullary intradural lesion is noted extending along anterior aspect of cervical dorsal cord which appears hypointense on T1 and appears CSF intensity on T2. Lesion is focally abutting spinal cord with indentation over it, however no evidence of cord edema is noted

Case 5 – SCHWANOMMA

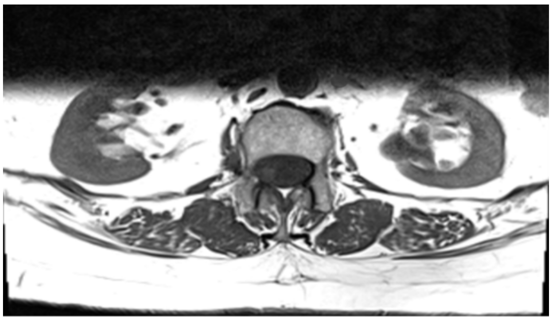


Figure 5a: T1W AXIAL

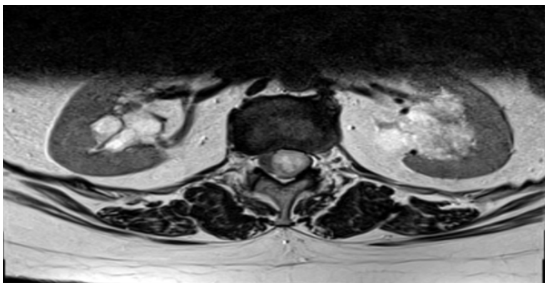


Figure 5b: T2W AXIAL

Figure 5c: T2W SAGITTAL

A Intradural Extramedullary lesion is noted L1 vertebrae at conus medullaris. It appears hypointense on T1 and heterogeneously hyperintense on T2 sequences. It shows multiple hyperintense foci. Lesion occupies most of canal with resultant splaying and compression over Cauda Equina nerve roots.

Case 6 – MENINGIOMA

Figure 6 A: T1W SAGITTAL

Figure 6 B: T2W SAGITTAL

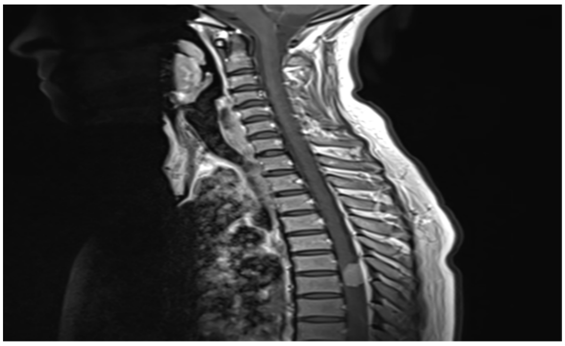


Figure 6 C: T1W POST CONTRAST SAGITTAL

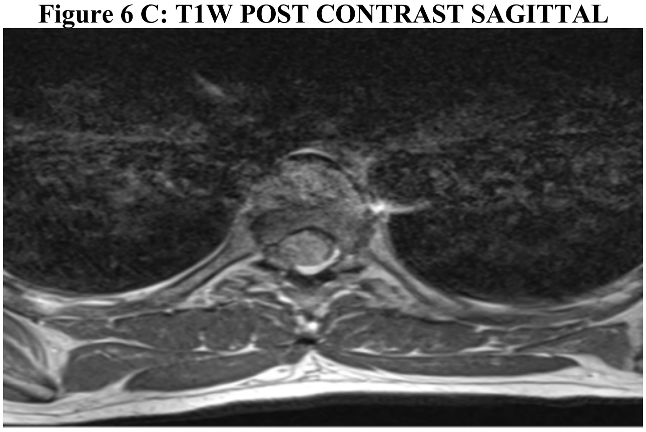


Figure 6 D: T1W POST CONTRAST AXIAL

A Broad Based intradural extramedullary lesion is noted at the level D5-D6 vertebral level which appears mild hyperintense on T1 and hyperintense on T2 sequences. It shows homogenous enhancement in post contrast study. Lesion compresses spinal cord at this level with complete effacement of CSF space

Future Directions: Further studies should explore the integration of advanced imaging techniques, such as functional MRI and diffusion tensor imaging, into routine clinical practice. Additionally, research on cost-effective MRI protocols could enhance accessibility and utility in diverse healthcare settings.

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