



Review Article

Precision-Guided Surgical Approaches for Spinal Tumors: Contemporary Strategies, Challenges, and Clinical Outcomes

Campos R, Guldbbrand T, Shishehbor Y, Marchi Y, Esteban G

Department of Neurosurgery, Brazil

*Corresponding Author: Shishehbor Y, Department of Neurosurgery, Brazil

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Abstract

Spinal tumors represent a diverse group of neoplastic lesions that can affect the vertebral column, spinal cord, nerve roots, and surrounding structures. Their management requires a multidisciplinary approach involving accurate diagnosis, careful surgical planning, and postoperative rehabilitation. Advances in neuroimaging, intraoperative navigation, microsurgical techniques, and spinal stabilization have significantly improved surgical outcomes while minimizing neurological morbidity. The choice of surgical approach depends on tumor location, histopathology, extent of involvement, spinal stability, and patient-specific factors. This article reviews the contemporary surgical approaches employed in the treatment of spinal tumors, including anterior, posterior, lateral, and combined techniques. Furthermore, it discusses preoperative evaluation, surgical indications, emerging technologies, complications, and future directions in spinal oncology. Understanding these approaches is essential for optimizing tumor resection, preserving neurological function, and enhancing patient quality of life

Introduction

Spinal tumors comprise approximately 15–20% of all central nervous system neoplasms and may be classified as primary or metastatic lesions. Based on anatomical location, spinal tumors are categorized into extradural, intradural-extramedullary, and intramedullary tumors. Common primary spinal tumors include meningiomas, schwannomas, ependymomas, astrocytomas, chordomas, and giant cell tumors, while metastatic tumors frequently originate from breast, lung, prostate, kidney, and thyroid malignancies.

Surgery remains a cornerstone in the management of spinal tumors, serving diagnostic, therapeutic, and palliative purposes. The primary objectives of surgical

intervention include tumor removal, neural decompression, pain relief, preservation of neurological function, and restoration of spinal stability

Preoperative Assessment

Successful surgical management begins with comprehensive preoperative evaluation. Magnetic Resonance Imaging (MRI) is the gold standard for assessing tumor location, size, and relationship to neural structures. Computed Tomography (CT) provides detailed information regarding osseous involvement and spinal instability. Additional investigations may include positron emission tomography (PET), angiography, and biopsy for histopathological confirmation.

Important considerations include:

- Tumor pathology and biological behavior
- Degree of spinal cord compression
- Extent of vertebral involvement
- Presence of spinal instability
- Neurological status of the patient
- Overall medical condition and life expectancy

The Spinal Instability Neoplastic Score (SINS) is frequently utilized to evaluate spinal stability and guide surgical decision-making.

Surgical Approaches for Spinal Tumors

1. Posterior Approach

The posterior approach is the most commonly utilized technique for spinal tumor surgery. It provides direct access to the posterior elements of the spine and is particularly useful for intradural and posteriorly located extradural tumors.

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Indications

- Intradural-extramedullary tumors
- Intramedullary spinal cord tumors
- Posterior vertebral lesions
- Tumors requiring decompressive laminectomy

Advantages

- Familiar surgical corridor
- Excellent visualization of neural structures
- Simultaneous decompression and stabilization
- Reduced risk to major visceral structures

Limitations

- Restricted access to anterior vertebral tumors
- Potential postoperative spinal instability after extensive laminectomy

Microsurgical techniques and intraoperative neuromonitoring have significantly enhanced the safety of posterior tumor resections

2. Anterior Approach

The anterior approach provides direct access to lesions involving the vertebral body and anterior spinal column. It is commonly employed for cervical and thoracic tumors causing anterior spinal cord compression

Indications

- Vertebral body tumors
- Chordomas
- Metastatic lesions with anterior compression
- Tumors requiring corpectomy

Advantages

- Direct tumor exposure
- Improved decompression of the spinal cord
- Facilitates reconstruction of the anterior column

Limitations

- Increased surgical complexity
- Risk of vascular and visceral injury
- Longer operative times

Anterior reconstruction may involve cages, bone grafts, or instrumentation to maintain spinal stability

3. Lateral and Extreme Lateral Approaches

Minimally invasive lateral approaches have gained popularity for selected thoracic and lumbar tumors

Indications

- Lateral vertebral body lesions
- Thoracolumbar tumors
- Tumors requiring minimally invasive access

Advantages

- Reduced muscle disruption
- Lower blood loss
- Shorter hospital stay
- Faster recovery

Challenges

- Limited visualization in complex tumors
- Risk of injury to lumbar plexus and surrounding structures

Advances in navigation systems have improved the precision of these approaches

4. Combined Anterior-Posterior Approach

Complex tumors involving multiple spinal columns often require combined surgical approaches

Indications

- Extensive vertebral destruction
- Large primary spinal tumors
- Multilevel disease
- Severe spinal instability

Benefits

- Circumferential decompression
- Improved biomechanical stability
- Greater likelihood of complete tumor resection

Although associated with increased operative time and morbidity, combined approaches may provide superior oncological and functional outcomes in selected patients

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