Avoidance of structural pitfalls in spinal meningioma resection

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Creating a surgical avenue through which to resect an intraspinal meningioma requires dissection of the musculoligamentous structures of the spine. Variable vertebral components must be removed to create a corridor to the intraspinal compartment. The cardinal principles of intraspinal tumor resection are to minimize the intraoperative risk of deformation and traumatic injury of the spinal cord. Therefore, the appropriate planning for access to and removal of the osseous elements is critical. Of equal importance is the consideration of the biomechanics of the spine. In cases of potential spinal instability instrumentation-assisted fusion should be performed at the time of tumor resection. The authors discuss the techniques for creating access to these tumors and propose a simple classification scheme to assist with this decision-making process.

KEY WORDS • spinal meningioma • spinal deformity • tumor

The incidence of spinal meningiomas includes up to 46.7% of intraspinal tumors, and resection is considered their primary treatment modality. Radiotherapy and chemotherapy are not indicated as the primary modalities. The majority of the tumors occur in the thoracic region (75–82%), and there is a female predominance. Roux, et al., reported that one third of the lesions were posterolateral within the canal and greater than one third were located anterolaterally.

Preoperative imaging studies and surgical planning are of paramount importance. The dimensions and location of the tumor should be determined, as well as intraspinal position of the spinal cord, its condition, and the presence of extradural or spinal extension. These factors will help determine the nature of the surgical corridor required to resect the tumor. The required extent of partial vertebral bone removal is planned to create the desired corridor to the targeted lesion. Absolute predictors of delayed spinal deformity or instability after spinal tumor excision include multilevel laminectomy, interference with the facet joints, and corpectomy. Relative risk factors for deformity and deformity progression are the spinal level of involvement and the preexistence of deformity.

Treatment of cervicothoracic and thoracolumbar regions is associated with a higher risk than other levels because of the change in the axis of motion and in degree of mobility occurring at these junctions. Because oblique approaches require variable degrees of structural excision (facets, laminae, and pars interarticularis) depending on individual anatomy, the postoperative risk of instability is also variable.

Failure to address the possibility of acquired instability and/or adjacent-segment hypermobility will result in deformity and possibly chronic pain. An understanding of the basic spinal biomechanics permits minimal bone removal and maximal exposure, providing secure access to the meningioma.

Intraoperative ultrasonography allows assessment of the adequacy of the surgical corridor in the craniocaudal and mediolateral directions when excising intraspinal tumors. The extent of bone removal is measured using a marked dissector (Fig. 1). Once the initial plan is completed, ultrasonography is conducted to evaluate access to the tumor’s margins. If inadequate, additional bone is removed to provide unobstructed surgical access. Additionally the appearance of the ultrasonic image will help differentiate between meningioma and nerve sheath tumors in cases in which the preoperative diagnosis is equivocal; in contrast to neuroma, for example, meningioma has uniform echogenicity and is hyperechoic without cysts. This is important because the principles of tumor resection differ between meningioma and nerve sheath tumor. In addition preoperative MR imaging may fail to distinguish between meningioma and nerve sheath tumor.

Abbreviation used in this paper: MR = magnetic resonance.
Creation of the transosseous corridors is based on spinal morphological features and biomechanics (Fig. 2). The three surgical approaches for creation of such a corridor are illustrated in Fig. 3. The “A” approaches require removal of the posterior elements to various degrees without interfering with the anterior column. In the “B” approaches the anterior vertebral columns are removed, and the “C” approaches involve a combination of the A and B maneuvers. Access to an intraspinal meningioma requires one to choose among the A approaches. Transosseous B and C approaches are reserved for the resection of vascular lesions such as cavernomas and arteriovenous malformations. The latter approaches may also be required in cases of predominantly anterior dural-based and heavily calcified meningiomas. Approaches B and C are more likely to interfere with spinal anatomy and function (Table 1).8,23

REPORT OF CASES

Case 1

This 57-year-old woman presented with a several-year history of left-sided numbness, which was accompanied recently by weakness of grip affecting both hands. Imaging studies demonstrated a broad-based tumor with a dural attachment at the cervicothoracic level (Fig. 4). A left-sided partial laminectomy of C-7 and T-1 (Approach A1) was performed to excise the meningioma.

Case 2

This 50-year-old man presented with progressive weakness and uncoordination involving all limbs. Examination demonstrated asymmetrical myelopathy more marked on the left. Magnetic resonance imaging revealed an intradural tumor at C-2 (Fig. 5 left and center), which was resected via a limited left-lateral laminectomy of C-2 and C-1 and dural splitting dissection (Approach A1). A total resection was achieved without resultant dural deficiency (Fig. 5 right).
Case 3
This 52-year-old man had previously undergone a C3–5 laminectomy for cervical stenosis. He presented with weakness affecting the right upper and lower limbs. Plain radiography of the cervical spine demonstrated loss of the normal alignment and physiological lordosis (Fig. 6 upper left). Sagittal and axial MR imaging revealed a meningioma at C-5 (Fig. 6 upper right and lower left). A posterior-approach resection was performed; anterior C4–6 fusion was then conducted (Approach A1) to prevent delayed mechanical instability and a kyphotic deformity (Figure 6 lower right).

Case 4
This 40-year-old woman presented with a 12-month history of intractable severe lumbar pain that radiated to both buttocks requiring scheduled morphine therapy and disordered micturition. Weakness of both extensor hallucis longi and ankle movement was noted. Imaging studies demonstrated an intraspinal meningioma occupying the thecal sac at the lumbosacral junction, laterally displacing and compressing the cauda equina (Fig. 7). A partial laminectomy approach (excision of a single segment [Approach A2]) was performed. Care was taken to avoid the facet joints. Because the zygoapophysial joints were uninvolved, instrumentation/fusion was not indicated. Postoperatively the patient was weaned from her long-standing narcotic agents.

Case 5
This 54-year-old woman presented with neck and interscapular pain, accompanied by right brachialgia and bilateral paresthesias. Axial and sagittal MR imaging revealed a meningioma occupying an anterolateral location within the spinal canal (Fig. 8 upper left and right). Complete excision was performed after a complete C7–T1 laminectomy removal of the T-1 facet joints, which provided a lateral view to the anterior tumor (Approach A3). Instrumentation was then placed from C-6 to T-2 with autograft bone as fusion substrate (Fig. 8 lower left and right).

DISCUSSION
Spinal meningiomas are predominantly histologically benign tumors of the meningothelial and psammomatous variety. Total resection is the primary objective of treatment. To achieve this, access to the tumor bulk, but equally important, to the tumor margins is needed. Excision of the dural margin, in contrast to simply cauterizing the margins, is associated with a lower recurrence rate (4–8% for dural margin cauterization and 0–5.6% for dural margin excision). The transosseous corridor of access to the intraspinal compartment requires disruption of the musculoskeletal structure of the spine. The natural history of preexisting spinal deformity and the outcome of disrupted sagittal and coronal spinal balance must be understood to ensure a long-term problem-free cure. Maintenance of the midline intervertebral ligament reduces the risk of ligamentous instability because the inter- and supraspinous ligaments are key to resisting force directed forwards acting to induce deformity. To this end, an A1 approach is ideal. Changing the axis of visualization with the microscope allows one to examine the con…
trilateral side if the underside of the lamina is undercut in the midline (Fig. 2). Increased removal of lateral bone (Approach A3) in conjunction with a modified thoracic costotransversectomy permits further visualization of the anterior spinal canal.\textsuperscript{1,2,4} Extensive anterolateral access to the canal will be required in cases involving anteriorly located meningioma and in those involving calcified meningiomas.\textsuperscript{9,19}

The potential for both coronal- and sagittal-plane deformity must be addressed. Approaches A1 and A2 do not interfere with load sharing and thus fusion is not required. In Approach A3, posterior instrumentation/stabilization alone is satisfactory. Pedicle screw/rod and rod/cable constructs, primarily systems that provide compression, can be used to reduce the likelihood of sagittal deformation in cases requiring anterior interbody reconstruction and posterior tension reconstruction (following Approaches B and C). The fusion mass must bridge the defect created by bone removal. To this end, an autograft, in the form of the morcellized bone gathered during the exposure, can be used. In the thoracic region the rib can act as a strut graft on the side of the access corridor. Failure to create adequate stabilization may result in long-term spinal decompensation and therefore deformity.\textsuperscript{6}

![Fig. 5. Case 2. Preoperative sagittal (left) and axial (center) MR images demonstrating a posterolateral intraspinal meningioma. Postoperative axial computerized tomography scan (right) illustrating the unilateral A1 approach for the dura-splitting excision of the entire lesion.](image1)

![Fig. 6. Case 3. Upper Left: Preoperative lateral cervical radiograph obtained in a patient who had perviously undergone a prior cervical laminectomy for cervical stenosis. He presented with cervical meningioma. Upper Right and Lower Left: Preoperative sagittal and axial MR images revealing the C-5 of the meningioma. Lower Right: Postoperative radiograph obtained after bilateral posterolateral approach for tumor resection in prior laminectomy area. Anterior-column fusion was performed to prevent long-term neck pain and deformity.](image2)

![Fig. 7. Case 4. Preoperative axial (left) and sagittal (right) MR images revealing a meningioma at the lumbosacral junction.](image3)
Anterior-column support provided by allografts and titanium cages supplemented by morselized autograft may be indicated to prevent kyphotic deformity if the anterior structural support of the spine has been disrupted. Anterior stabilization allows columnar weight transmission and resistance to axial load–related deformity. Posterior stabilization creates resistance to rotational and translational forces. This circumferential rigid spinal stabilization is required after a combined anterior–posterior approach (Approaches B3, B4, and C2). Creation of this route is required more often for the resection of intraspinal vascular lesions and for resection in patients with postoperative spinal deformity.

The authors of studies on spinal meningioma have documented long-term cures after complete resection.5,9,10,18,19,21 As this is the desired endpoint, excision must be secured. A corridor to the intraspinal meningioma must provide satisfactory microsurgical access to all reaches of the tumor. In addition, a clear surgical margin is desirable. After division of the musculoligamentous structures of the spine, the planned bone removal is performed. The transosseous approach should be tailored to permit direct access to the tumor while avoiding the spinal cord to prevent cord injury. This is dictated by the angle of approach for access to the canal. The number of levels must also be considered. Interference with the facet joints increases the risk for long-term changes in the spine.13,23 One useful technique is the dural splitting dissection by which the margins of the meningioma are excised in continuity with the inner layer of the dura.19 Preservation of the outer layer of the dura minimizes the postresection dural defect, which requires closure, thereby lowering the risk of cerebrospinal fluid leakage. In cases requiring a corridor greater than those achieved by performing Approaches A1 and A2, the issue of postoperative stability must be considered. If the midline ligamentous and osseous structures are preserved as a tension band, there is little chance that subsequent chronic pain will result from asymmetrical load sharing; additionally, a shorter hospitalization period will be required for recovery.1

CONCLUSIONS

The key to successful spinal meningioma resection is judicious planning of the surgical corridor. We have outlined a classification scheme for osseous resection as it relates to spinal stability and the need for postoperative stabilization. Potential for delayed instability, chronic pain, and deformity exists if there is extensive osseous and ligamentous disruption without buttressing of the area. It is best for the approach to remain unilateral and extend bone removal to gain access to the entire spinal canal. In selected cases in which significant bone removal is discussed, instrumentation- and autograft bone–augmented fusion should be considered to reduce the likelihood of long-term mechanical neck and back problems.

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