Minimally invasive keyhole concept in spinal tumor surgery

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Abstract

Despite their histologically benign nature, intradural tumors may become symptomatic by virtue of their space-occupying effect, causing severe neurological deficits. The gold standard treatment is total excision of the lesion; however, extended dorsal and dorsolateral approaches may cause late complications due to iatrogenic destruction of the posterolateral elements of the spine.

In this article, Axel Perneczky's concept of minimally invasive spinal tumor surgery is described. Two illustrative cases demonstrate the feasibility and safety of keyhole fenestrations exposing the spinal canal. The first case is a 67-year-old woman with a 1-year history of severe back pain, right thoracic radiculopathy, and slight gait disturbance. Neuroimaging revealed a right-sided combined intradural-extradural spinal schwannoma at T11/12 , with compression of the spinal cord and lateral extension through the intervertebral foramen. The tumor was successfully removed through a contralateral left-sided hemilaminectomy. The second case is a 38-year-old man with progressive spinal ataxia caused by an intramedullary C6-8 ependymoma. Here, bi-segmental interlaminar fenestrations were performed, allowing safe and minimally invasive tumor resection. In both cases, postoperative imaging confirmed complete tumor removal and both patients showed neither neurological deterioration, nor vertebral instability or pain syndromes.

Key words:

Contralateral hemilaminectomy, Interlaminal fenestration, Keyhole spinal surgery, Preoperative planning, Spinal schwannoma, Spinal ependymoma

Introduction

Despite their histologically benign nature, intradural spinal tumors may become symptomatic by virtue of their space-occupying effect, causing severe neurological deficits (1). The gold standard treatment is total excision of the lesion, while avoiding iatrogenic injury to the delicate neural tissue of the spinal cord and nerves roots. In order to achieve optimal visualization, bilateral extended laminectomy has traditionally been recommended (2). In cases in which tumors extend laterally, a laminectomy may be further enlarged by partial costo-transversectomy. Unfortunately, these extended approaches carry significant drawbacks. Damage to the soft tissues and paraspinal muscles may be associated with greater post-operative pain and higher doses of analgesics, longer hospitalization, and delayed rehabilitation. Numerous clinical and biomechanical studies have reported late complications after extensive dorsal approaches including postoperative spinal instability, severe kyphoscoliosis, and epidural scarring and spinal arachnoiditis; the importance of the loss of posterior bony protection has also been reported in the literature (3-6). Moreover, costo-tranversectomy may be complicated by postoperative pneumothorax, and can cause denervation of the paraspinal muscles over several segments (7). In this article, two cases with intradural spinal tumors operated on through a minimally invasive approach are reported to illustrate application of Axel Perneczky's keyhole concept.

Illustrative cases

Case I – Combined intradural-extradural schwannoma

A 67-year-old woman was admitted with a 1-year history of severe back pain with right-sided lower thoracic radiculopathy and slight gait disturbance. No disturbance of bladder function was noted. Clinical examination revealed a slight gait ataxia but normal lower limb power. Magnetic Resonance Imaging (MRI) Spine demonstrated a right-sided, combined intradural-extradural lesion located at T11/12, suggestive of a spinal schwannoma. The intradural component caused severe compression of the spinal cord, and the extradural lateral extension through the intervertebral foramen showed close proximity to the pleura (Fig.1/A).

Approach planning. The following approaches were considered: *Bilateral laminectomy* with wide exposure of the ipsi- and contralateral side would provide good visualization of the tumor and neural structures but would entail the destruction of the spinous process and interspinous ligaments, the lamina on both sides and ligamentum flavum, and the facet joints.

Ipsilateral hemilaminectomy would preserve more of these posterior elements of the spine compared with a conventional laminectomy. However, on account of the lateral extension of the tumor, a partial costotransversectomy would be necessary in this case. *Contralateral hemilaminectomy* would provide equivalent exposure of the tumor without requiring an ipsilateral costotransversectomy (Fig.2). Moreover, surgical dissection along the tumor axis would allow for efficient resection.

Surgery. After a longitudinal median skin incision, the paravertebral muscles and ligaments were stripped subperiostally on the left side and reflected laterally. A limited hemilaminectomy was carried out at the level T11; the facet joints were not exposed. Using a high-speed drill and small Kerrison punches, the base of the spinous process and the contralateral vertebral arch were carefully undermined to gain optimal access to the opposite side (Fig.3). Endoscope-assisted dissection along the tumor axis allowed complete resection with minimal manipulation of the spinal cord and neighboring structures; intraoperative monitoring showed no changes in SSEP/MEP.

Postoperative course. On the first postoperative day the patient developed hypesthesia related of the right T11 dermatome but had normal power in her lower limbs and her gait had improved. Three weeks postoperatively, following rehabilitation, the patient returned to her previous employment. The histopathological examination confirmed the diagnosis of a benign schwannoma. Postoperative MRI demonstrated that the schwannoma had been completely excised (Fig.1/B).

Case II – Intramedullary ependymoma

A 38-year-old man presented with right C8 radicular paresthesia and progressive gait disturbance. No disturbance of bladder function was noted. Neurological evaluation revealed severe gait ataxia but normal power in his lower limbs. MRI revealed an intradural intramedullary tumor at C6-8, suggestive of an intramedullary ependymoma (Fig. xxx).

Approach planning. The following approaches were evaluated: *Mutilevel laminectomy* with wide intraspinal exposure would allow wide visualization but lead to approach-related destruction of the vertebral lamina. *Multilevel laminoplasty* avoids postoperative loss of posterior bony protection but necessitates stripping of the paraspinal muscles bilaterally leading to muscular injury. *Unilateral hemilaminectomy* or *multisegmental interlaminar fenestrations* offers comparable intraspinal exposure with minimal muscular destruction and without injury to the dorsal spinal structures.

Surgery. After longitudinal median skin and fascia incision, the right paravertebral muscles were reflected laterally. Using the operating microscope, interlaminar fenestrations were performed at the levels C5/6 and C6/7. With a high-speed drill and Kerrison rongeurs, the contralateral vertebral arches were gently undermined, achieving optimal access to the spinal canal. After durotomy endoscope-assisted tumor excision was successfully performed, with no changes demonstrated during continuous neuromonitoring.

Postoperative course. The patients gait disturbance recovered over his 5-day postoperative stay, and he returned to his previous employment 4 weeks after surgery. The histopathological examination confirmed a benign ependymoma. Postoperative MRI demonstrated complete tumor excision (Fig. xxxxxx).

Discussion

There is agreement among authors that the treatment of choice for benign intradural tumors is complete surgical removal; however, opinions vary regarding operative approach. The importance of preserving the posterior bone elements with the attached ligaments and muscles is widely recognized (6). Since the first dorsal laminectomy described by Smith in 1829, the therapeutic possibilities have developed enormously (8). Nevertheless, operative methods have not changed markedly for almost 200 years and laminectomy is described in recent publications as the most commonly performed neurosurgical procedure (9). In order to reduce these postoperative complications, Raimondi et al. (10) has recommended osteoplastic laminotomy and Eggert et al. (4), Yasargil et al. (11) and Sarioglu et al. (12) unilateral hemilaminectomy. Perneczky popularized a more limited approach using multisegmental interlaminar fenestrations to observe intradural lesions (13). Recently, the introduction of tubular retractor systems have assisted such approaches (14-16)

The aim of minimally invasive neurosurgery is to minimize harm to patients by utilizing tailor-made keyhole approaches. Detailed neuroanatomical knowledge and careful assessment

of individual patho-anatomical factors are used to select the least traumatic surgical approach to pathology. The interlaminar fenestration approach is the best example of this concept in spinal tumor surgery, offering minimal soft tissue injury and restricted osteo-destruction. However, limited keyhole approaches to the spinal canal present significant challenges: a predefined and narrow surgical corridor with difficult intra-operative orientation; decreased illumination and visualization of the deep-seated operative field; and difficulty manipulating tissue using conventional microinstruments.

Thorough pre-operative study of an individual patients imaging, consideration of the optimal surgical corridor, and meticulous execution are prerequisites to successful keyhole surgery. Intra-operative fluoroscopy is used to ensure the correct level is identified. The patient positioning, skin incision, and interlaminar fenestration are either carried out or personally supervised by the senior surgeon; because the surgical corridor is predefined it is imperative it is accurately and precisely placed. Intra-operative imaging and neuronavigation may be used to assist with surgical orientation intra-operatively. In addition, neuromonitoring with continuous SSEP and MEP measurements is performed in all spinal tumor cases, to help protect neural structures.

Endoscopes may be used to improve visualization of the operative field down a long and narrow surgical corridor. They offer several advantages over microscopes in this context including an extended viewing angle, increased illumination, and higher magnification.

The use of specially designed slim and tube-shaft instruments allow surgeons to overcome the problems of a narrow surgical corridor and almost coaxial manipulation in spinal keyhole surgery.

In this article we have demonstrated that the obstacles to keyhole approaches to the spinal canal can be systematically addressed through careful planning, the use of improved imaging and instruments, and modifications of surgical technique. In the future further advances such as augmented reality and robotics may be used to enhance the safety and efficacy of such approaches.

Addendum

Both operations were performed by the first author in the University Hospital Mainz under the watchful eye and intraoperative support of Prof. Axel Perneczky. This paper is addressed to him in great respect. We express our gratitude to Stefan Kindel for artistic assistance.

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Figures

Fig.1 Pre- and postoperative T1 weighted contrast-enhanced MRI scans in the axial plane. Note the intradural space-occupying effect of the tumor and the extradural extension through the enlarged intervertebral foramen. Postoperative MRI revealed total removal of the lesion.

Fig.2 Artistic illustration demonstrating the contralateral hemilaminectomy approach compared with the ipsilateral hemilaminectomy and costotransversectomy. The exposure allowed excellent visualization of the contralateral situated pathoanatomical structures. The use of keyhole concept in spinal microneurosurgery with surgical dissection along the tumor axis minimizes surgical traumatization.

Fig.3 Postoperative three-dimensional computed tomography showing the left-sided hemilaminectomy. The base of the spinous process and the contralateral vertebral arch were carefully undermined to gain optimal access to the opposite side; the facet joints were not exposed. Note the limited removal of osseous structures.