Minimally invasive approach for small ventrally located intradural lesions of the craniocervical junction

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OBJECT The surgical management of lesions ventral to the neuraxis at the level of the craniocervical junction (CVJ) and upper cervical spine is challenging. Here, the authors describe a minimally invasive dorsal approach for small ventrally located intradural lesions at the CVJ as an alternative for the more extensive classic transoral approach or variants of suboccipital approaches.

METHODS Between 2012 and 2014, 6 symptomatic patients with a small lesion of the ventral aspect at the CVJ level were treated using a minimally invasive dorsal approach at the University Medical Center in Hamburg-Eppendorf, Germany. The anatomical distance between the posterior atlantooccipital membrane and the posterior atlantoaxial ligament, as determined by CT images, was assessed in the treated patients and in 100 untreated persons.

RESULTS The authors treated 6 patients (mean age 54.7 years) who had a clinical presentation of mild neurological symptoms that disappeared after resection. Minimally invasive surgical dorsal access was achieved by using tubular systems and using the natural space between the occiput (C-0) and C-1, and in 1 case between C-1 and C-2, without having to remove bony structures. The postoperative course in each of the 6 patients was uneventful. The neuropathological findings confirmed a meningotheliomatous meningioma (WHO Grade I) in 5 cases and an extramedullary cavernous hemangioma in 1 case. MRI confirmed complete resection of all the lesions. The atlantooccipital distances ranged from 3 to 17 mm (mean 8.98 mm) in the supine neutral position, and the atlantoaxial distances ranged from 5 to 17 mm (mean 10.56 mm). There were no significant differences between women and men (atlantooccipital p = 0.14; atlantoaxial p = 0.72).

CONCLUSIONS The results of this study demonstrate that the minimally invasive dorsal approach using the space between C-0 and C-1 or C-1 and C-2 provides direct and sufficient exposure for the safe surgical resection of small ventrally located intradural lesions at the CVJ level while reducing the necessity for musculoskeletal preparation to a minimum.

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KEY WORDS cervical spine; craniocervical junction; spinal tumor; minimally invasive; meningioma
a need for additional stabilization in cases of instability. In contrast, minimally invasive approaches to small ventral lesions at the upper cervical spine and CVJ have rarely been reported.4,5,7

Here, we report a surgical technique for accessing small intradural lesions located ventral to the neuraxis at the CVJ. By using a minimally invasive dorsal approach between the occiput (C-0) and C-1 or C-1 and C-2, complete removal of ventrolateral lesions can be achieved while avoiding bone removal and extensive muscular mobilization.

Methods

Six symptomatic patients with small ventrally located intradural lesions at the CVJ level who were eligible for a minimally invasive surgical dorsal approach were included in this study. Tumors with a maximum diameter of > 25 mm, especially in the craniocaudal direction, and those that displayed signs of vascular or bone infiltration were not eligible for this approach and were excluded from this analysis. Each patient was treated in our institution between 2012 and 2014 and gave informed written consent. In accordance with local and institutional laws and data-protection regulations, no approval by the local ethics committee was necessary for this study. Patient data, including demographics, clinical presentation, imaging, surgical treatment, histology, and postoperative results, were analyzed retrospectively. In each case, MRI revealed lesions of the ventral aspect of the CVJ, which is generally defined as the region between the lower third of the clivus and the C-2 vertebral arch.11 Each lesion was suspected to be a meningioma with the exception of 1 case of an unclear cystic lesion. All the patients were evaluated at regular follow-up examinations in our neurological outpatient clinic.

The distances between C-0 and C-1 (posterior atlantooccipital membrane) and between C-1 and C-2 (posterior atlantoaxial ligament) were analyzed using CT scans of 100 randomly selected patients from the radiological archive at our institution. Only CT scans of patients in a neutral supine position and those without a lesion of the musculoskeletal system at the CVJ level were included for analysis. The smallest paramedian distance was measured by using picture-archiving and communication system software (PACS) (GE Healthcare).

Surgical Technique

After oral intubation and placement of the electrophysiological monitoring electrodes, the patient’s head was fixed in a Mayfield skull clamp and the patient was turned to a prone position with slight inclination (Video 1).

**VIDEO 1.** In this video, we demonstrate the minimally invasive dorsal approach via the posterior atlantooccipital membrane for the surgical removal of a ventrally located intradural meningioma (maximum diameter 22 mm) at the CVJ level in a 77-year-old male patient. Copyright Nils Ole Schmidt. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

The Mayfield skull clamp was connected to the operating table. The access was selected under fluoroscopic biplanar guidance in the orthograde lateral and posterior anterior views in cases of a transmuscular approach using a tubular (Spotlight; DePuy Spine) or a standard Caspar retractor (Spine Classics MLD; Aesculap) system. After selecting the point of entry, a 3- to 4-cm skin incision was made (3–5 cm lateral to the spinous process of C-1). The muscle fascia was sharply perforated, and the muscle was dissected with 2 dissectors until the C-1 arch was reached to insert the Caspar retractor or the dilator was inserted until it reached the depth of the C-1 arch. Then, the dilator was advanced a few degrees toward the posterior atlantooccipital membrane (5 cases) or toward the posterior atlantoaxial ligament (1 case). After this muscle dilatative approach was completed using a second and a third sequential dilator, a tubular retractor with a diameter of 14–18 mm and a length of 50–70 mm was inserted (Fig. 1 left). Fixation was achieved by using a table-mounted flexible arm to secure the tubular retractor in place. The following steps were performed using a surgical microscope (NC 4; Carl Zeiss). The membrane or ligament was prepared, and a micro-Doppler catheter was inserted to identify or exclude the course of the vertebral artery within the surgical field. Then, the dura was opened by using a longitudinal paramedian incision and subsequent tack-up sutures for a better overview, which takes some time because of the limited space. The dorsolateral aspect of the spinal cord came into view. The denticulate ligament was uncovered (Fig. 2C) and cut to gain additional room while minimizing manipulation of the spinal cord. The layer between the spinal cord and the lesion was microsurgically prepared while mobilizing the lesion in the field of view and reducing the tumor step by step. Unless it was already identified microscopically, we used the micro-Doppler catheter during tumor preparation to locate and define the course of the vertebral artery. Figure 2D displays the ventral dura, which was coagulated to achieve a Simpson Grade II resection of the meningioma. After resection of the lesion, the dura was closed water-tightly using 6-0 polypropylene sutures; however, because this step of the surgery was somewhat challenging because of the narrow working canal, the dura was covered with medical sponge (TachoSil; Takeda). The tubular system was slowly removed with special attention paid to bleeds originating from the muscle tissue. There was no need for drains in any of the cases. The fascia was closed with 1 suture, and the wound was closed with 3 subcutaneous sutures.

Results

Between 2011 and 2014, we treated 6 patients with small intradural lesions (maximum diameter < 25 mm) located ventral to the neuraxis at the CVJ level. The patient ages ranged from 41 to 64 years (mean 54.7 years); 2 women and 4 men were included. The clinical presentation in each case was mild neurological disturbance in terms of intermittent paresthesias in the lower extremities during inclination. No manifest focal neurological deficits were detected. Each patient underwent surgery in which a minimally invasive dorsal transmuscular approach with access to the intradural lesion via the space between C-0 and C-1 was used without a need for significant bony removal. In 1
case, the lesion was localized intradurally at the level of the dens axis basis, and therefore the space between C-1 and C-2 was used to access the meningioma. Throughout the procedures, somatosensory evoked potentials and motor evoked potentials remained unaltered. The postoperative course in each of the 6 patients was uneventful with no neurological deficits and no postoperative CSF leaks. The neuropathological findings confirmed meningotheliomatous meningioma (WHO Grade I) in 5 cases and an extramedullary cavernous hemangioma in 1 case. Postoperative MRI confirmed gross-total resection (Fig. 3A–D). During the follow-up time period (range 4–48 months; median 28 months), there were no recurrences and we detected no signs of clinical spinal instability. In each patient the presurgical intermittent paresthesia symptoms disappeared.

Because radiologically measured anatomical data on the distances between C-0 and C-1 and between C-1 and C-2 are lacking, we assessed these distances on the CT images of 100 randomly selected untreated individuals (mean age 52.4 years). The atlantooccipital distances ranged from 3 to 17 mm in the supine neutral position (mean 8.98 mm; Fig. 1 right). In the 6 treated patients, these distances ranged from 9 to 13 mm (mean 10.83 mm). The atlantoaxial dis-
stances in the untreated individuals ranged from 5 to 17 mm (mean 10.56 mm; Fig. 1 right) and from 7 to 14 mm in the 6 treated patients (mean 10.83 mm; in the 1 patient for whom the atlantoaxial approach was used, the distance was 14 mm). There were no significant radiologically documented anatomical differences between the women and the men in the group of 100 untreated individuals (atlantooccipital p = 0.14; atlantoaxial p = 0.72).

Discussion

Many variants of surgical techniques for accessing ventrally located tumors at the CVJ have been discussed in the literature, and most of them require extensive musculoskeletal preparation to achieve minimal manipulation of neural tissue. Here, we demonstrate that minimally invasive dorsal access routes through the natural space between C-0 and C-1 or C-1 and C-2 can be used for the removal of small ventrally located intradural lesions at the CVJ. This technique represents a natural adaptation of surgical access to the size of the lesion and prevents the need to use transoral or other extended dorsal approaches such as the far-lateral approach or classic variants of the suboccipital approach.

Several approaches for the treatment of lesions at the upper spine and CVJ levels have been described. The most direct approach to the ventral aspects of the CVJ, especially for extradural but also for intradural lesions, is the transoral route. The transoral route provides a direct and natural approach to the CVJ. However, the approach is sophisticated in terms of avoiding CSF leakage and subsequent infections and in the prevention of velopharyngeal function impairment and loss of stability. Inadequate exposure of the lateral margins of the tumor and the lack of proximal control of the vertebral artery are other disadvantages of this approach. Avoiding the transoral route, Banczerowski et al. used a conventional ventral approach with complete corpectomy and additional stabilization.

This approach has been well described, is often performed for degenerative spinal pathology, C1–2 fractures, and retropophyangeal lesions, and may provide the best overview of the complete ventral aspect of the spinal dura and column. Complete corpectomy of the second vertebral body and removal of the ventral aspect of the first vertebral body to treat lesions in the ventral aspect of the spinal canal are not recommended, because fusion of at least 2 segments is required in any case. Approaching the upper cervical spine and the CVJ anterolaterally and laterally, George et al. and Yasuda et al. reported that the risk of lacerating the esophagus or trachea is minimized and the amount of bone loss is reduced in comparison with the results of a conventional anterior approach with corpectomy. However, the risk of accessory nerve or sympathetic chain injury is higher, and surgical control of the vertebral artery or venous plexus hemorrhage might be challenging.

Multiple variants of the suboccipital approach (dorsal and dorsolateral) have been published. The far-lateral and extreme-lateral variants are very well-described approaches that are clearly indicated for large lesions. Nevertheless, whether using a ventral or dorsal access route, all of these surgical approaches require extensive musculoskeletal preparation, which is time-consuming and associated with the corresponding perioperative morbidity.

To avoid these extensive approaches for small ventrally located spinal lesions, the posterior approach through hemilaminectomy or laminectomy is the most commonly used approach in the upper cervical spine. Martin et al. described a posterolateral approach for vascular malformations and tumors of the ventrolateral aspect of the spinal cord. They proposed a slight rotation of the spinal cord after multilevel division of the dentate ligament cranial and caudal to the lesion, which in our opinion is not possible at the CVJ level because this is where the brainstem begins.

Watanabe et al. noticed the wide space between C-1 and C-2, and Zozulya et al. pointed out that at the C-1 level, the ratio of the squared spinal cord and dural sac cross-section areas is, on average, 1:3. Therefore, one-third is occupied by the spinal cord and two-thirds is occupied by subarachnoid space, which leaves considerable space for potential surgical access. We show here that the para- median spaces between C-0 and C-1 and between C-1 and C-2 are a mean of approximately 10 mm, which is in agreement with the Watanabe et al. report. With our approach, this space is extended as a result of the concord positioning during the operation and the slight inclination of the head (Video 1). Our radiological data of the anatomical distances between C-0 and C-1 and between C-1 and C-2 provide the basis for additional studies, because it is not clear at this point if there exists a minimal distance necessary for using this minimally invasive approach. Nevertheless, if the space is found intraoperatively to be too narrow, it is still possible to achieve additional space by removing bony structures (e.g., undercutting or partial hemilaminectomy of C-1 or C-2). In our experience, a dural opening of 10–15 mm can be achieved in most cases without bone removal. In combination with the considerable subarachnoid space at the CVJ level, enough room is available for the surgical resection of small ventrally located lesions at the CVJ without additional bone removal. In line with the report of Martin et al., additional space can be achieved by dividing or resecting the dentate ligament, which can provide an improved view of the ventral dura or lesion.

The surgical technique we present here is a minimally invasive approach for small ventrally located intradural lesions at the CVJ. This approach does not require anterior or posterior fixation; therefore, physiological mobility is preserved. This can also be achieved by reconstruction after laminotomy, but muscle trauma is much greater if paravertebral muscles on both sides have to be divided. Furthermore, artifacts caused by metal implants have to be expected and may impair imaging at follow-up.

Limitations of this minimally invasive approach are the limited space for manipulation and the restricted view. However, because of the widespread distribution of tubular systems, more and more surgeons can get used to this kind of approach. Conversely, this technique is limited to the resection of small lesions of the ventral aspect at the CVJ. Lesions that extend to the contralateral side of the approach, larger lesions with a diameter of > 25 mm, es-
pecially in the craniocaudal direction or those that display signs of infiltration of the vertebral artery or infiltrative destruction of bone structures, still have to be addressed by extended surgical exposures to handle potential complications while minimizing manipulation of the neural axis.

Conclusions
A minimally invasive dorsal approach involving a tubular system and using the space between C-0 and C-1 or C-1 and C-2 provides direct and sufficient exposure for the surgical removal of small ventrally located intradural lesions at the CVJ level. Therefore, musculoskeletal preparation, with its potentially associated perioperative morbidity, is minimized by avoiding the classical anterior transoral and extensive dorsal approaches.

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References

Author Contributions
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Supplemental Information
Videos

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