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# Using Natural Anatomical Gaps-Posterior Cervical Approach to Skull Base and Upper Craniocervical Meningiomas without Bone Removal

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## Abstract

**Background:** Anteriorly located tumors of the upper cervical spine and Craniovertebral Junction (CVJ) are a particular surgical challenge. Extensive approaches are associated with pain, restricted mobility of neck and head and, for case of foramen magnum and clivus tumors, with retraction of brainstem and cerebellum.

**Methods:** Four symptomatic patients underwent resection of upper cervical and lower clivus meningiomas anteriorly located to the CVJ without laminotomy or craniotomy using a minimally invasive posterior approach. Distances of natural gaps between C0/C1, C1/C2 as well as C2/C3 were measured using preoperative CT scans and intraoperative lateral X-rays.

**Results:** In all patients, safe and complete resection was conducted by opening the dura between C0/C1, C1/C2 and C2/C3. There were no surgical complications. Local pain was very low in all patients and postoperative recovery extremely fast. All tumors had a rather soft consistence allowing mass reduction prior to removal of the tumor capsule and were well separable from lower cranial nerves and vascular structures.

**Conclusion:** If tumor consistence is appropriate for a careful mass reduction before removal of the tumor capsule and if tumor margins are not firmly attached to crucial structures, upper cervical, foramen magnum and lower clivus meningiomas can be safely and completely removed through natural gaps in the CVJ. Both prerequisites become clear early during surgical procedure. Thus, this tumor entity may be planned using this minimally invasive approach and extended if tumor consistence turns out to be less soft or if crucial structures cannot be easily separated from the tumor.

**Keywords: Craniovertebral junction; Spinal tumor; Minimally invasive; Meningioma; Cervical spine**

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## Introduction

Anterior and anterolateral tumors of the upper cervical spine, foramen magnum and clivus are among the most challenging pathologies in neurosurgery. A decisive factor for their successful removal is the appropriate surgical approach. Anterior approaches have been described as well as a variety of posterior approaches to get access to this particular region. The far lateral approach is probably the most extensively used approach for this kind of tumor. However, all these approaches are associated with relevant perioperative morbidities such as nuchal pain, restricted mobility, and CSF leakage, manipulation of cranial nerves and/or crossing vessels and in some cases additional stabilization due to postoperative instability [1-3]. Minimal invasive approaches to the upper cervical spine and Craniovertebral Junction (CVJ) have been described [4-7], but still are rare and have been proposed for small lesions [4].

The posterior aspect of the craniocervical junction exhibits natural bony openings that may be used to access the upper cervical spinal canal, the foramen magnum and the lower clivus. We report a series of four patients with anterior and anterolateral meningiomas of the foramen magnum, upper cervical spine and lower clivus undergoing complete resection *via* a posterior cervical approach without removal of any bony structures.

## Methods

Four symptomatic patients with ventrally located intracranial/intraspinal lesions at the craniocervical junction, which is usually defined from the lower third of the clivus to the vertebral arch of C2 [8], were included in this study. Each patient was operated in our institution between September 2017 and June 2019 and gave informed written consent in accordance to the local ethic guidelines. We summarized patient data including demographic information, clinical presentation, imaging, operation technique, histology and postoperative course and analyzed them retrospectively.

In each case, preoperative imaging (MRI and CT) showed intraspinal, intradural lesions at the CVJ anterior to the dura which were all suspected to be meningioma. In all cases, complete resection of the tumor was possible and patients underwent regular follow-up examinations in our neurosurgical outpatient clinic.

## Case Descriptions and Surgical Technique

Four cases with meningiomas anterior of the denticulate ligament were surgically treated. Each operation was performed using intraoperative electrophysiological monitoring *via* Somatosensory Evoked Potentials (SEPs) and Motor Evoked Potentials (MEPs). After oral intubation and placement of the electrophysiological monitoring, patient's head was fixed in the Mayfield clamp, patient was turned into prone position and the Mayfield was fixed to the OR table elevated and in inclination. The distances of the natural gaps between C0 and C1, C1 and C2 as well as C2 and C3 were measured using preoperative CT scans and intraoperative lateral X-rays (Figure 1).

### Case 1

Due to head and neck pain in a 53 year old female patient an MRI was performed which showed a tumor in the CVJ. The tumor reached from the lower edge of the clivus down to the lower edge of C2 measuring 24 mm × 15 mm × 17 mm (diameter 21 mm), homogeneously contrast enhancing and located mediolateral to the right (Figure 2A and 2B).

After surgical skin disinfection skin incision was performed midline from the occipital protuberance down to C3/4. After subperiosteal preparation of the paraspinal muscles two retractors were placed which exposed the boney structures from C0 to C3. Dura mater was opened between the natural openings C0/1 and C1/2 using tuck-up sutures of the dura, exposing sufficiently the lateral margins of the spinal cord and the exiting nerve roots on the dorsal surface of the tumor. Microsurgical view is satisfactorily above and below the atlas arch. The tumor's posterior surface was covered with multiple sensory fascicles of the nerve roots C1, C2 and C3, which can be detached efficiently using a blunt dissector. After dissection of the dentate ligament the spinal cord could be mobilized. It was not possible to remove the tumor *via* simple suction, so it had to be sharply dissected into small pieces after bipolar coagulation of the tumor and the tumor capsule for mass reduction. After preparation of the adherent medial tumor parts, a broadly based contact point of the tumor was visible intradurally around the foramen of the C2 nerve root. The thickened dura mater was split and the inner sheath of the dura removed with the tumor capsule for complete resection of the tumor using the natural gaps between C0/1 and C1/2 on the right side, (Figure 2C and 2D) without removing any bony structures. Operative time of this surgery was 3 h and 40 min.

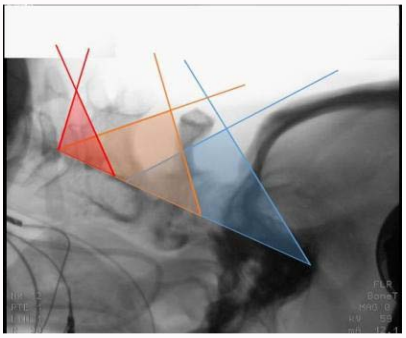

**Figure 1:** Lateral X-ray of case 4 after prone positioning with inclination. Colored sectors indicate the theoretical access supplied by the interspace between the occiput and the posterior arch of C1 (blue), C1 and the cranial edge of the lamina of C2 (yellow) and, at times, between the inferior edge of the lamina of C2 and the superior edge of the lamina of C3 (red).

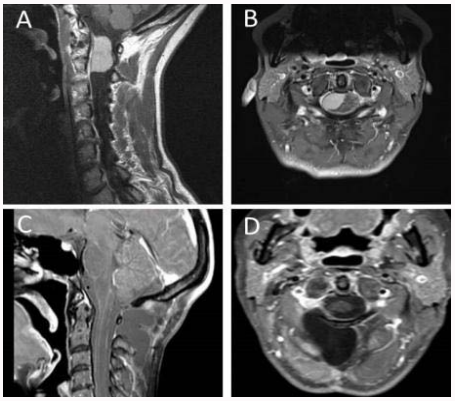


**Figure 2:** Preoperative sagittal (A) and transverse (B) T1-weighted contrast enhanced MRI of case 1 depicting an anteriorly located meningioma of the upper cervical spine with cranial extension into the foramen magnum. Postoperative sagittal (C) and transverse (D) T1-weighed contrast enhanced MRI showing complete resection of the WHO °I meningioma without the need of resecting any boney structures.

### Case 2

A 52year old female patient was complaining about prickling paresthesia in both arms radiation in all fingers, increasing with inclination of the head. She also reported reduction of muscle power and fine motor skills of the right hand. Neuroradiological imaging (MRI and CT) scan showed a homogeneously contrast enhancing tumor with dural tailing in the CVJ, measuring 19 mm × 17 mm × 11 mm (diameter 17 mm) and reaching from the lower edge of the clivus down to the first 3rd of the dens axis (Figure 3A and 3B).

Skin incision was performed from the occipital protuberance down to C2. Paraspinal muscles were subperiosteal prepared and two William retractors were placed exposing boney structures from occiput down to C2. Additional ultrasound navigation was performed and the anatomical gap through the atlantooccipital membrane again evaluated as wide enough gap for tumor resection. After dura tuck up sutures the microsurgical view showed a nicely exposed tumor surface (Figure 3C). Fascicles of the accessorial nerve as well as the exiting C1 and C2 nerve roots were transposition medially, cranially or caudally. The entrance of the vertebral artery could be clearly identified. The tumor was growing towards the entry zone but was not surrounding the vertebral artery. A PICA branch was located at the upper tumor pole and could be detached with a fine dissector. After bipolar coagulation and incision of the tumor capsule, the inner mass

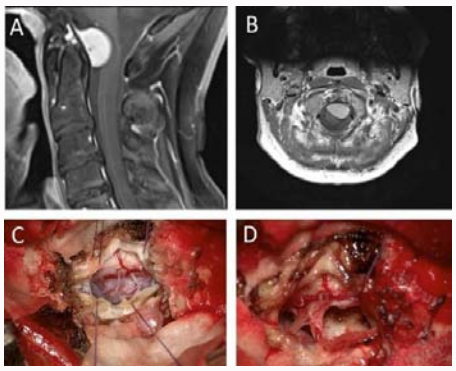


**Figure 3:** Preoperative sagittal (A) and transverse (B) images depicting an anteriorly located craniocervical meningioma (case 2) removed through the atlantooccipital space. After dura tuck up sutures the microsurgical view shows a nicely exposed tumor surface (C) without any removal of boney structures. The vascular tumor base was bipolar coagulated and resected in total so that finally a Simpson °II resection was achieved (D).

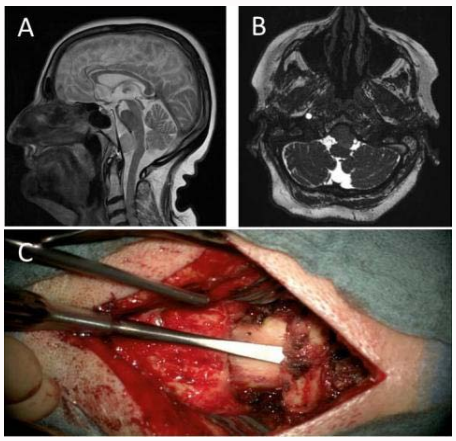


**Figure 4:** Preoperative sagittal T2-weighted (A) MRI of case 3 depicting a foramen magnum and lower clivus meningioma with a cranial extension up to the vertebral junction. Axial 3D-CISS images (B) show a sufficiently wide craniocervical CSF space and a bilaterally well distinguishable vertebral artery. After preparation of the paravertebral muscles, an Adson retractor was placed exposing all boney structures from occiput down to C2 (C) showing a wide enough space for tumor resection.

was of soft character and could be reduced by suction. The vascular tumor base was bipolar coagulated and resected in total so that finally a Simpson °II resection was achieved (Figure 3D). Postoperative CT and MRI scans showed a total resection of the meningioma without removal of any boney structure. Operative time of this case was 3 h and 32 min.

## Case 3

Due to right hemispheric headaches, postural vertigo, gait ataxia and dysmetria since 3 months an MRI was performed in a 79 year old female patient revealing a meningioma in the CVJ with dural tailing to the lower part of the clivus mediolateral to the right measuring 23 mm × 20 mm × 21 mm (diameter 20 mm). Coming from anterior the tumor was dislocating and impressing the back part of the brain stem left accented (Figure 4A and 4B).

After preparation of the paravertebral muscles, an Adson retractor was placed exposing all boney structures from occiput down to C2 (Figure 4C). The atlantooccipital membrane was removed and the dura opened with midline incision between C0 and C1. Extension of the dura incision to the lateral was performed so that the dorsal myelon, the denticulate ligament, the spinal fascicles of the accessory nerve and the entrance of the vertebral artery were clearly visible. Incision of the denticulate ligament, which could be positioned medially, so that medulla and fascicles of the accessory nerve could be slightly torquated which gives way to the meningioma through the foramen magnum. The tumor was soft, but quite good vascularized. After enucleation with a sharp dissector and suction and bipolar coagulation of the tumor capsule, the tumor could finally be completely resected Simpson °II. Endoscope assisted visual checking of the resection cavity confirmed complete tumor resection without tumor remnants on the clivus, the vertebral arteries nor the basilar artery. Operative time of this procedure was 2 h 33 min.

## Case 4

Due to recurrent syncope and downfall events a CT scan was performed in a 79 year old female patient that revealed a tumor in the CVJ by chance. The tumor showed progressive growth in the follow up MRIs and was lastly described as homogenous contrast enhancing tumor measuring 21 mm × 21 mm × 18 mm (diameter 18.6 mm) in the CVJ, compressing the medulla from the anterior right side up to 50% and showed in the CT scan a slightly hyperdense signal thinking of calcifications (Figure 5A-5C). Clinically the patient suffered from reduction of fine motor skills of both hands as well as a mild gait ataxia.

After preparation of the paravertebral muscles, an Aesculap retractor was placed exposing all boney structures from occiput down to C2. Additional ultrasound navigation was performed revealing also a wide enough space for resection of the tumor without removal of boney structures. Incision of the atlanto-occipital membrane was performed and flipped to the right side and the dura opened with midline incision between C0 and C1 including tuck-up sutures. Fibers of the accessoria nerve and the exiting C1 and C2 nerve roots were transposition medially respectively cranially or caudally. The entrance of the vertebral artery could be clearly identified. At the same time an early PICA-outflow at the entrance of the vertebral artery could be observed. The tumor was growing to the entry zone, but was not surrounding the artery. On the upper tumor pole a loop of the PICA could be found, which didn't have to be prepared off of the tumor capsule. The tumor mass in fact could be described as

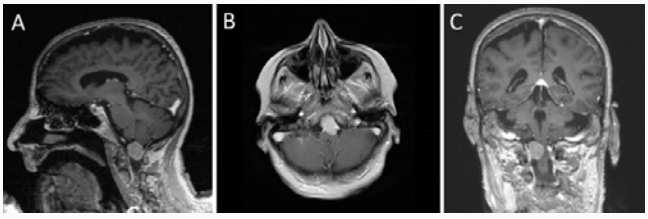


**Figure 5:** Preoperative sagittal (A), coronary (B) and transverse (C) contrast-enhanced T1-weighted image of case 4 depicting a lateral craniocervical meningioma growing anterior and posterior from the denticulate ligament.

soft, but was more of a cartilaginous consistence so it couldn't just be sucked out. Therefore the tumor capsule and the tumor mass had to be coagulated to carefully excise the tumor parts with micro scissor. After coagulation of the tumor contact point a resection grade 2 according to Simpson was achieved. Operative time of this procedure was 2 h and 46 min.

## Results

We treated 4 patients with intradual lesions located anterior and anterolateral to the neuraxis of the CVJ between September 2017 and June 2019. All included patients were female. Patient ages ranged from 52 to 79 years (mean 65.8 years). Tumor diameters ranged from 17 mm to 21 mm (mean 19.2 mm). All patients underwent surgery using a minimally invasive dorsal paraspinal subperiosteal approach using the natural gaps between C0/C1, C1/C2 and C2/3 without the need of resecting or removing any boney structures. None of the operations was converted to a more classical operation technique with bone opening due to intraoperative problems. Mean operative time using this technique was 3 h and 13 min. Throughout all operation procedures the intraoperative monitoring (MEPs, SEPs) remained unaltered in every single patient. All patients underwent complete tumor resection, in case 1 Simpson grade 1 and in all other cases grade 2 according to Simpson. Neurohistopathological investigations confirmed a meningothelial meningioma WHO °I in every case. The postoperative course of all patients was uneventful. Postoperative early MRI of Case 1 just showed a subcutaneous CSF collection which was complete reversible on natural course in the later performed MRI. Clinically the patient was without any neurological deficit postoperatively. Patient of Case 2 reported already a distinct reduction of paresthesia of both arms and fine motor deficits of the right hand only three months postoperatively. Patient of Case 3 had an uncomplicated CSF leak, which was not manageable with lumbar drainage only, so that she underwent a short second operation for CSF leak closure, which was free of any perioperative morbidity and with uneventful postoperative course in total. She was free of headaches and postural vertigo after surgery. Also gait ataxia and dysmetria were clearly regressive compared to pre-operative course. Patient of Case 4 is still in therapy regarding her orthostatic blood pressure symptomatology that revealed the tumor by chance. She shows no signs of sensible or motor deficits and gait variations are unremarkable according to age.

All postoperative MRI scans showed gross-total tumor resection. During the follow-up time period (range 7 to 28 months; median 14 months) no tumor recurrences or clinically renewed worsening of symptoms was observed. None of the patients showed postoperative signs of spinal instability.

## Discussion

Traditionally posterior approaches to the cervical spine are used for intraspinal intradural tumors located dorsal or dorsolateral to the spinal cord and are thought to be the majority of spinal tumors [8-10]. But when it comes to anterior or anterolateral to the neuraxis located lesions the surgeon is often confronted with the challenging question what to do with these tumors and what will be the best operative strategy regarding the approach. Here we demonstrate a minimally invasive approach to anterior or anterolateral to the CVJ located tumors *via* a paraspinal subperiosteal dorsal approach without the need of removal of any boney structure and without any fancy additional equipment than the regular neurosurgical operating set.

When seeking the answer to your question what approach will be the best for your anterior/anterolateral to the neuraxis located lesion in the literature, broad descriptions of ventral and dorsal approaches to the ventral aspect of the CVJ can be found usually dealing with large lesions [9-11]. The most direct and natural to ventral lesions is the transoral approach, which is also known to be sophisticated with a high risk of CSF leakage, subsequent infections, velopharyngeal function impairment and a loss of instability. Another disadvantage of this approach is the inadequate exposure of lateral tumor margins and a lack of proximal control of the vertebral artery. The ventral approach by Banczerowski et al. [12] is usually performed with a complete corpectomy followed by additional stabilization. On the one hand, this approach is well described and often performed for degenerative spinal pathologies, C1/C2-fractures and retropharyngeal lesions and gives a complete overview of the ventral aspect of spinal dura and column. On the other hand, the complete corpectomy of C2 and the ventral aspect of C1 will mandatory require the fusion of at least 2 segments. In contrast to the conventional anterior approach by Banczerowski the anterolateral and lateral approach described by George et al. [13], mainly used in extradural lesions and Yasuda et al. [14], has a reduced bone loss and decreased risk of lacerating trachea and/or esophagus. However, the risk of injury of accessory nerve or sympathetic chain is increased and the surgical control of vertebral artery or venous plexus hemorrhage is challenging using this approach.

Multiple variants for the posterior or posterolateral suboccipital approach have been described, for example the far-lateral and the extreme-lateral variants are well established, are often used and have a clear indication for large lesions [9-11]. In cases of foramen magnum meningioma, almost all of these lesions were resected by B. George through a postero-lateral approach (far-lateral approach) as detailed in a major publication with more than 100 cases [15]. Unfavorable are the time-consuming preparation and the high perioperative morbidity.

In contrast to these approaches, only few reports on minimally invasive approaches to ventral or ventrolateral of the CVJ located lesions can be found in literature [4-7,16,17]. The most commonly used approach to the upper cervical spine is the posterior approach through hemilaminectomy or laminectomy [7]. In 1995, Martin et al. [18] described a minimally invasive posterolateral cervical or thoracic approach to vascular malformations and tumors of the ventrolateral aspect of the spinal cord. After multilevel division of the dentate ligament cranial and caudal to the lesion they perform a slight rotation of the spinal cord to approach the lesion. However, this approach is also linked to brainstem and spinal cord manipulation risking damage to these sensitive neural structures.

In 2009, Watanabe et al. [19], discover and describe the wide space between C1 and C2. In addition, Zozulya et al. [11], described in 2011, that the ratio between squared spinal cord and dural sac cross-section areas on C1-level is 1:3 on average, which means that 1/3 of the area is occupied by the spinal cord and 2/3 of the area by subarachnoid space. The latter can potentially be used as a trajectory space for surgical access.

In 2016 Eicker et al. [4], reported in agreement with Watanabe that the paramedian spaces between C0-C1 and C1-C2 are 10 mm on average. They optimized the surgical approach by increasing

the space through concord/prone positioning of the patient with inclination of the head. They describe an excellent minimally invasive accessibility to small tumors lying in a ventral aspect of the CVJ using a tubular system while avoiding bone removal and extensive muscular mobilization. In accordance with Eicker et al., we used a restricted paraspinal subperiosteal posterior approach, however not using a tubular system. Eicker et al. concluded that the tubular retractor-based bone-sparing approach is restricted only to small lesions anterior to the spinal cord or lower brainstem, respectively. In our experience, using natural anatomical gaps from the atlanto-occipital junction down to C2/C3 for tumor resection without the need of any bony resection we didn't have the impression that the tumor size was the decisive limit using this approach. Dealing with very large tumors, still the conventional anterior, posterior or lateral approaches to the spinal cord or craniotomy for access to large lesions that reach beyond the foramen magnum will be needed. We propose, however, that the cutting point should not be categorically made at a diameter of 25 mm. Other aspects seem more decisive, such as a soft texture of the tumor so that a piecemeal resection can be performed, an appropriate flexibility of the upper cervical spine in order to enlarge and open the natural gaps by inclination of the head and a not too firm adherence especially to the vascular structures in this area. The vertebral junction may be the upper anatomical limit of this approach since microscopic visibility from below along the clivus ends at this point.

We experienced that apparently "calcified looking" tumors that may be expected when seeing hyperdense lesions on preoperative CT scans may not be an absolute exclusion criterion for minimally invasive approaches. We found that in at last two cases that the lesion appeared hyperdense on preoperative CT scan but intraoperatively a very soft and suctionable tumor was found. However, this approach can always be extended into a conventional hemilaminectomy or laminectomy in an uncomplicated way and without the need of changing the OR setting and positioning if the natural space doesn't feel wide enough.

Surgical approaches to anterior or anterolateral located tumors of the CVJ are usually complicated and not rarely involve extensive muscular mobilization and bone removal to get adequate exposure without retraction on neural sensitive structures. The surgical technique we present here is a minimally invasive paraspinal subperiosteal approach to skull base and upper craniocervical meningiomas without the need of any bone resection. The approach is safe, effective, quick and easy to learn. In addition, it prevents some known perioperative morbidities using the classic far-lateral or transoral approaches. Operative time between 2.5 and 3.5 h is short and effective and lowers the patient's operative risk due to general anesthesia. In all operations, the same senior surgeon was present and due to a learning curve effect technical performance and operative time improved from case to case. In addition, postoperative local pain was extremely low, maybe due to the fact that no boney structure was removed. Given that no hemi- or laminectomy was performed and the lamina stays intact, no "sinking effect" of the paraspinal muscles was observed and wound healing in all cases was unimpaired. Finally, there is absolutely no risk of (late) postoperative instability if all boney structures stay "untouched". In summary, the least possible alteration of physiologic biomechanical conditions is achieved. However, very large or calcified lesions will be better and safer operated *via* these classical and conventional approaches.

## Conclusion

A minimally invasive dorsal cervical paraspinal subperiosteal approach to ventrally located tumors of the CVJ without the need of resecting any bony structures or the need of further technical equipment than the regular neurosurgical OR set. Natural gaps between the atlanto-occipital junction, C1/2 and C2/3 are used to approach the tumor. High perioperative morbidities due to large musculoskeletal preparation, infections, CSF leak or postoperative stabilization are minimalized in comparison to the classical anterior transoral or extensive dorsal approaches.

## Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Ethik-Kommission der Universität Würzburg/Deutscher Ethikrat) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

## References


1. Koutourousiou M, Fernandez-Miranda JC, Vaz-Guimaraes Filho F, de Almeida JR, Wang EW, Snyderman CH, et al. Outcomes of endonasal and lateral approaches to petroclival meningiomas. World Neurosurg. 2017;99:500-17.
2. Mazur MD, Couldwell WT, Cutler A, Shah LM, Brodke DS, Bachus K, et al. Occipitocervical instability after far-lateral transcondylar surgery: A biomechanical analysis. Neurosurgery. 2017;80(1):140-5.
3. Steinberger J, Skovrlj B, Lee NJ, Kothari P, Leven DM, Guzman JZ, et al. Surgical morbidity and mortality associated with transoral approach to the cervical spine. Spine (Phila Pa 1976). 2016;41(9):E535-40.
4. Eicker SO, Steiger HJ, El-Kathib M. A transtubular microsurgical approach to treat lateral cervical disc herniation. World Neurosurg. 2016;88:503-9.
5. Eicker SO, Szelényi A, Mathys C, Steiger HJ, Hänggi D. Custom-tailored minimally invasive partial C2-corpectomy for ventrally located intramedullary cavernous malformation. Neurosurg Rev. 2013;36(3):487-91.
6. Fong S, DuPlessis SJ. Minimally invasive anterior approach to upper cervical spine: Surgical technique. J Spinal Disord Tech. 2005;18(4):321-5.
7. Ikuma H, Shinohara K, Maehara T, Yokoyama Y, Tanaka M. C2 lamina reconstruction using locking miniplate for the intradural tumor of the craniocervical junction (two case reports). Eur Spine J. 2012;21(Suppl 4):S509-12.
8. Mei-Hua L, Geng-Sheng X, Zhi-Qun J, Yi-Yun L, Tao H. Supracondylar transjugular tubercle approach to intradural lesions anterior or anterolateral to the craniocervical junction without resection of the occipital condyle. Turk Neurosurg. 2013;23(2):202-7.
9. Kawashima M, Tanriover N, Rhoton AL, Ulm AJ, Matsushima T. Comparison of the far lateral and extreme lateral variants of the atlanto-occipital transarticular approach to anterior extradural lesions of the craniovertebral junction. Neurosurgery. 2003;53(3):662-75.
10. Lanzino G, Paolini S, Spetzler RF. Far-lateral approach to the craniocervical junction. Neurosurgery. 2005;57(4 Suppl):367-71.
11. Zozulya YP, Slynko YI, Al-Qashqish II. Surgical treatment of ventral and ventrolateral intradural extramedullary tumors of craniovertebral and upper cervical localization. Asian J Neurosurg. 2011;6(1):18-25.
12. Banczerowski P, Lipóth L, Vajda J, Veres R. Surgery of ventral intradural midline cervical spinal pathologies *via* anterior cervical approach: Our experience. Ideggyogy Sz. 2003;56(3-4):115-8.

13. George B, Dematons C, Cophignon J. Lateral approach to the anterior portion of the foramen magnum. Application to surgical removal of 14 benign tumors: Technical note. Surg Neurol. 1988;29(6):484-90.

14. Yasuda M, Bresson D, Cornelius JF, George B. Anterolateral approach without fixation for resection of an intradural schwannoma of the cervical spinal canal: Technical note. Neurosurgery. 2009;65(6):1178-81.

15. Bruneau M, George B. Foramen magnum meningiomas: Detailed surgical approaches and technical aspects at Lariboisiere hospital and review of the literature. Neurosurg Rev. 2008;31(1):19-33.

16. Dhandapani S, Karthigeyan M. "Microendoscopic" versus "pure endoscopic" surgery for spinal intradural mass lesions: A comparative study and review. Spine J. 2018;18(9):1592-602.

17. Ruetten S, Hahn P, Oezdemir S, Baraliakos X, Merk H, Godolias G, et al. The full-endoscopic uniportal technique for decompression of the anterior craniocervical junction using the retropharyngeal approach: An anatomical feasibility study in human cadavers and review of the literature. J Neurosurg Spine. 2018;29(6):615-21.

18. Martin NA, Khanna RK, Batzdorf U. Posterolateral cervical or thoracic approach with spinal cord rotation for vascular malformations or tumors of the ventrolateral spinal cord. J Neurosurg. 1995;83(2):254-61.

19. Watanabe M, Sakai D, Yamamoto Y, Iwashina T, Sato M, Mochida J. Upper cervical spinal cord tumors: review of 13 cases. J Orthop Sci. 2009;14(2):175-81.