A Minimal Access Far-Lateral Approach to Foramen Magnum Lesions

James T. Kryzanski[1] Jon H. Robertson[2] Carl B. Heilman[1]

[1] Department of Neurosurgery, Tufts Medical Center, Boston, Massachusetts, United States
[2] Department of Neurosurgery, University of Tennessee College of Medicine, Semmes-Murphey Neurologic and Spine Institute, Memphis, Tennessee, United States

Address for correspondence James T. Kryzanski, MD, Assistant Professor of Neurosurgery, Tufts Medical Center, 800 Washington St. Box 178, Boston, MA 02111, United States (e-mail: jkryzanski@tuftsmedicalcenter.org).

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Abstract

Objectives The far-lateral approach is widely used to treat pathology of the ventral foramen magnum. Numerous methods of exposure have been described, most of which utilize long skin incisions and myocutaneous flaps. Here we present our experience with gaining exposure through a small paramedian incision using a muscle-splitting technique.

Design A cadaveric anatomical study was first performed to verify the feasibility of the approach. We then describe our experience with using the approach in 13 patients. A retrospective chart review was performed and data regarding pathology, imaging, and complications were collected.

Results The cadaveric study confirmed that a small paramedian muscle-splitting approach allows sufficient exposure to approach many foramen magnum lesions. Our case series included 10 patients with meningioma, one brainstem glioblastoma, one posterior inferior cerebellar artery aneurysm, and one odontoid pannus. The exposure was adequate in all cases. For the meningioma patients, six had gross total resections and four had subtotal resection because of tumor adherence to neurovascular structures. Two patients experienced postoperative cardiovascular complications. There were no new neurologic deficits, cerebrospinal fluid leaks, or wound complications.

Conclusions A small paramedian incision may be used to gain exposure and perform successful far-lateral approaches. The small exposure is likely to reduce the risk of local complications such as cerebrospinal fluid fistula and pseudomeningocele when compared with larger exposures.

Keywords
- far-lateral
- foramen magnum
- meningioma
- surgical approach
- complications

Introduction

The far-lateral approach has become a standard technique for surgical treatment of ventral foramen magnum pathology. A variety of skin incisions and muscle dissections have been used to gain the bony exposure necessary for the procedure. The earliest reports of the far-lateral approach typically used long curved or hockey stick-shaped incisions with elevation of a myocutaneous flap.[1–3] The technique has not significantly evolved since that time; most recent reports utilize a similar exposure.[4–7] Although the most serious postoperative complications are neurologic, the most serious local complication is cerebrospinal fluid (CSF) fistula.[4,8–12] Among the numerous factors that lead to postoperative CSF fistula are large

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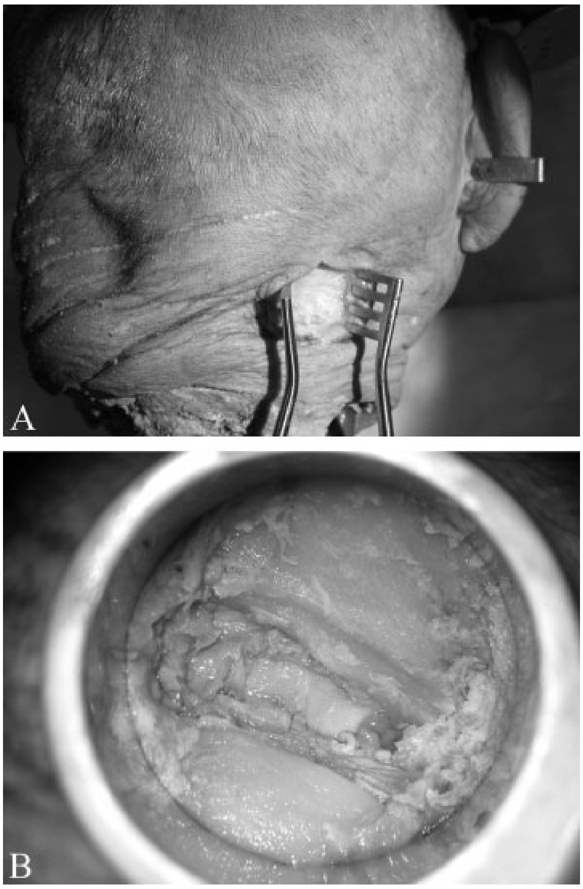

Fig. 1 Right-sided cadaveric dissection. (A) Incision location. (B) Occiput and C1 lamina seen through tubular retractor.

exposures and significant amounts of postoperative dead space. With this in mind we sought to determine if a small muscle-splitting paramedian incision that minimized exposure and dead space would be suitable to perform a far-lateral approach. Muscle-splitting exposures have been described previously as part of a far-lateral approach. Bertalanffy et al[13] utilized a long paramedian incision and muscle-splitting approach in one of the first reports describing a far-lateral transcondylar modification to suboccipital craniotomy. More recently, Lutjens et al[14] reported a modified far-lateral approach using a paramedian muscle-splitting approach for resection of a retro-odontoid dural cyst. Here we present an anatomical and clinical study that demonstrates the feasibility of the minimal access far-lateral approach in treating a variety of foramen magnum lesions.

Methods

Anatomical Studies

Ten formalin-fixed cadaver heads were prepared by irrigation and injection of the internal carotid arteries, vertebral arteries, and internal jugular veins with colored silicone rubber. Prior to dissection the heads were rigidly fixed by a table-mounted headholder in the prone position. The dissection technique is as follows. A 30-mm vertical incision centered over the craniovertebral junction is made ~ 35mm lateral to midline (►**Fig. 1A**). The inion, mastoid, and spinous process of C2 are useful landmarks in localizing the incision. The splenius capitis and semispinalis capitis muscles are then split in the direction of their fibers. At this point the suboccipital bone, lateral arch of C1, and rostral lamina of C2 are palpated to direct the exposure. Deeper exposure then reveals the muscles of the suboccipital triangle including the rectus capitis posterior major. The muscles are then reflected off the occipital bone and lamina of C1, and final bony exposure is obtained (►**Fig. 1B**) with retraction provided by a tubular retraction system (METRx, Medtronic, Memphis, Tennessee, United States). The lateral suboccipital craniotomy, C1 hemilaminectomy, and partial condylar resection are then performed using a high-speed air drill (Midas Rex, Medtronic, Memphis, Tennessee, United States), and the extradural vertebral artery is identified. The dura is opened in a semicircular fashion with the broad base laterally and is retracted with sutures. The dentate ligament can then be sectioned to provide access to the ventral foramen magnum.

Following the dissections, the specimens were taken for computed tomography scanning and registered using a frameless stereotactic navigational device (StealthStation, Medtronic, Memphis, Tennessee, United States). The medial, rostral, and caudal extent of the exposure was then determined (►**Fig. 2**).

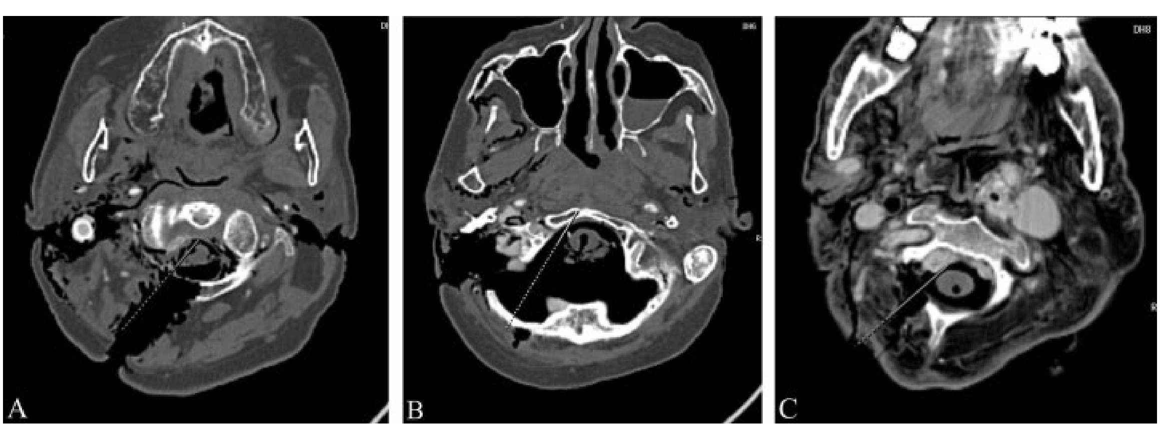

Fig. 2 Frameless stereotactic demonstration of the (A) medial, (B) rostral, and (C) caudal extent of exposure in cadaveric specimens.

Clinical Studies

We identified 13 patients from the corresponding author's institution from 2004 to 2011 who underwent a minimal access far-lateral approach. ►Table 1 summarizes the series. Clinical data were obtained from hospital, operative, and office records as well as radiographic images.

Surgical Technique

After the induction of general anesthesia, patients were placed in a Mayfield three-point fixation device (Ohio Medical Instrument Co., Inc, Cincinnati, Ohio, United States) and turned prone onto a Wilson frame (MizuhOSI, Union City, California, United States). The neck was kept in a neutral position in most cases. Alternatively, a three-quarter prone position was occasionally used. Somatosensory sensory and motor evoked potentials were used in selected cases. The exact location of the paramedian vertical incision was tailored to each patient and was typically 3 to 5 cm lateral to midline depending on the optimum surgical trajectory as judged by preoperative imaging studies. The length of the incision was also tailored to the size of the lesion but was typically 3 to 4 cm in length.

The superficial cervical musculature encountered varies depending on the laterality of the incision, but usually the splenius capitis and semispinalis capitis are first exposed and split in the direction of their fibers. After this, palpation is used to dilate the exposure as well as verify location of the C1 lateral mass, C1 lamina, subocciput, and C2 lamina. This step is crucial because the surgical trajectory also varies significantly depending on the laterality of the incision. In patients who are obese or with thick cervical musculature, a small error in the initial trajectory can lead to a deep exposure well away from the intended location. Intraoperative fluoroscopy is useful for incision planning and landmark localization in such patients.

After palpation and confirmation of bony landmarks, a retractor is placed. Although tubular retractors were used in the anatomical studies, they were found to be too restrictive to surgical freedom. We favor an anterior cervical retraction system such as Shadowline (CareFusion, San Diego, California, United States) that allows the use of blades of different lengths and widths on each side. After retractor placement, bony exposure is obtained by subperiosteal muscle elevation off the lateral subocciput, C1 lamina, and rostral C2 lamina. The C2 nerve root and extradural vertebral artery are identified at this time. A high-speed air drill is then used to perform a standard far-lateral approach. We did not transpose the vertebral artery in any case. Occipital condylar resection was tailored to the individual pathology but never exceeded more than a third of the condyle. A semicircular dural opening was then created with the broad base laterally and the dura tacked up. In tumor cases the dentate ligament is then sectioned to facilitate ventral exposure.

For closure, the curved dural incision is usually amenable to watertight primary repair using small locally harvested fascial grafts to seal any defects. Additional sealants such as fibrin glue or DuraSeal (Covidien, Mansfield, Massachusetts, United States) may be used to supplement the closure. The muscles are then closed in multiple layers using absorbable suture and the skin closed in the standard fashion.

Table 1 Summary of case series

Case no.	Age, y/sex	Operative findings and pathology	Complication	Follow-up
1	64/F	Meningioma; subtotal resection	None	Tumor recurrence requiring reoperation 7 y postoperatively
2	44/M	Meningioma; gross total resection	None	No recurrence
3	60/F	Meningioma; gross total resection	Atrioventricular block requiring pacemaker	No recurrence
4	67/M	Meningioma; subtotal resection	None	Stable tumor remnant
5	82/M	Meningioma; subtotal resection	None	Stable tumor remnant
6	74/F	Meningioma; subtotal resection	None	Stable tumor remnant
7	63/F	Meningioma; gross total resection	None	No recurrence
8	64/F	Meningioma; gross total resection	None	No recurrence
9	57/F	Meningioma; gross total resection	None	No recurrence
10	86/F	Meningioma; gross total resection	None	No recurrence
11	39/F	Brainstem glioblastoma; biopsy only	None	Alive 2 y postoperative with progressive bulbar dysfunction
12	59/M	Subarachnoid hemorrhage and posterior inferior cerebellar artery aneurysm; clipping	Myocardial infarction, pulmonary embolism	Moderate neurologic impairment
13	81/M	Odontoid pannus	None	Stable

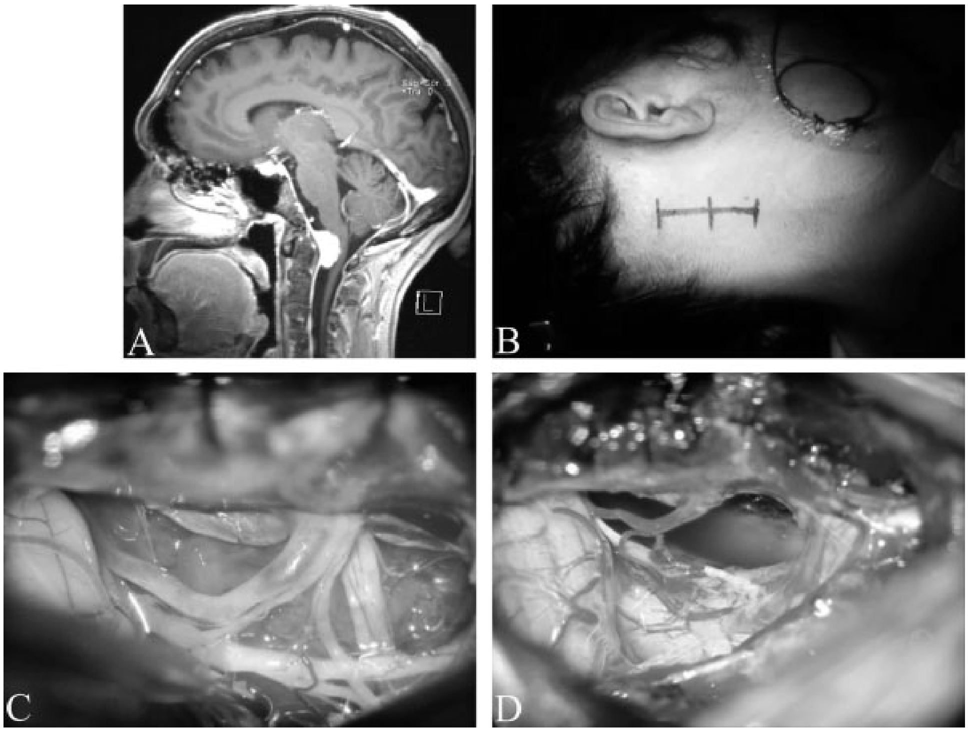

Fig. 3 Case 3. (A) Preoperative sagittal T1-weighted MRI with gadolinium. (B) Positioning and incision. (C) Tumor exposure prior to resection. (D) Exposure postresection.

Illustrative Cases

Case 3

A 60-year-old woman presented with an unsteady gait and right-sided neck pain. A magnetic resonance imaging (MRI) study revealed a ventral foramen magnum meningioma slightly eccentric to the right with compression of the cervicomedullary junction (►**Fig. 3A**). She underwent a right minimal access far-lateral approach for tumor resection (►**Figs. 3B–D**). Operative findings included a proximal origin of the right posterior inferior cerebellar artery (PICA). A minimal occipital condylar resection was performed, and a gross total resection was obtained. Her postoperative course was complicated by cardiac arrhythmia requiring pacemaker placement.

Case 13

An 81-year-old man had a 1-year history of a progressive and severe myelopathy with imbalance and frequent falls. An MRI showed a large odontoid pannus with cervical cord compression and myelomalacia (►**Fig. 4A, B**). Dynamic cervical spine radiographs did not show instability. He underwent a right minimal access far-lateral approach for pannus resection through an intradural approach. His postoperative course was uneventful with improvement in his myelopathy. A postoperative MRI scan showed adequate decompression (►**Fig. 4C, D**); postoperative cervical radiographs showed no instability.

Results

The anatomical study demonstrated the feasibility of this approach in reproducibly providing access to the ventral foramen magnum from the lower clivus to C2 comparable with larger exposures. Adequate access was obtained in all specimens during dissection and verified by use of frameless stereotaxy. Cadaver study is recommended prior to using a minimal access approach because the paramedian exposure may be disorienting at first.

All 13 patients underwent technically successful procedures, and in no case did the exposure need to be extended due to poor access. In the 10 patients harboring foramen magnum meningiomas, there were four subtotal resections. These were related to tumor adherence to neurovascular structures and involved small amounts of tumor. At follow-up, the patients' neurologic status was stable or improved in all patients except two. In those patients the deterioration was due to the underlying pathology (brainstem glioblastoma and grade IV subarachnoid hemorrhage) and not the surgical procedure. Cardiovascular complications occurred in two patients, and there were no CSF fistulae, pseudomeningoceles, or infections.

Discussion

Early reports of foramen magnum meningiomas resected using a suboccipital approach described significant procedure-related morbidity and mortality.[15,16] Along with advances in neuroimaging and microsurgical technique, the advent of far- and extreme-lateral approaches have dramatically improved outcomes in these patients. Among the authors making seminal contributions in this regard are Heros,[2] Sen and Sekhar,[3] and George et al.[1] Consequently, recent surgical series as reviewed by Talacchi et al[7] demonstrate

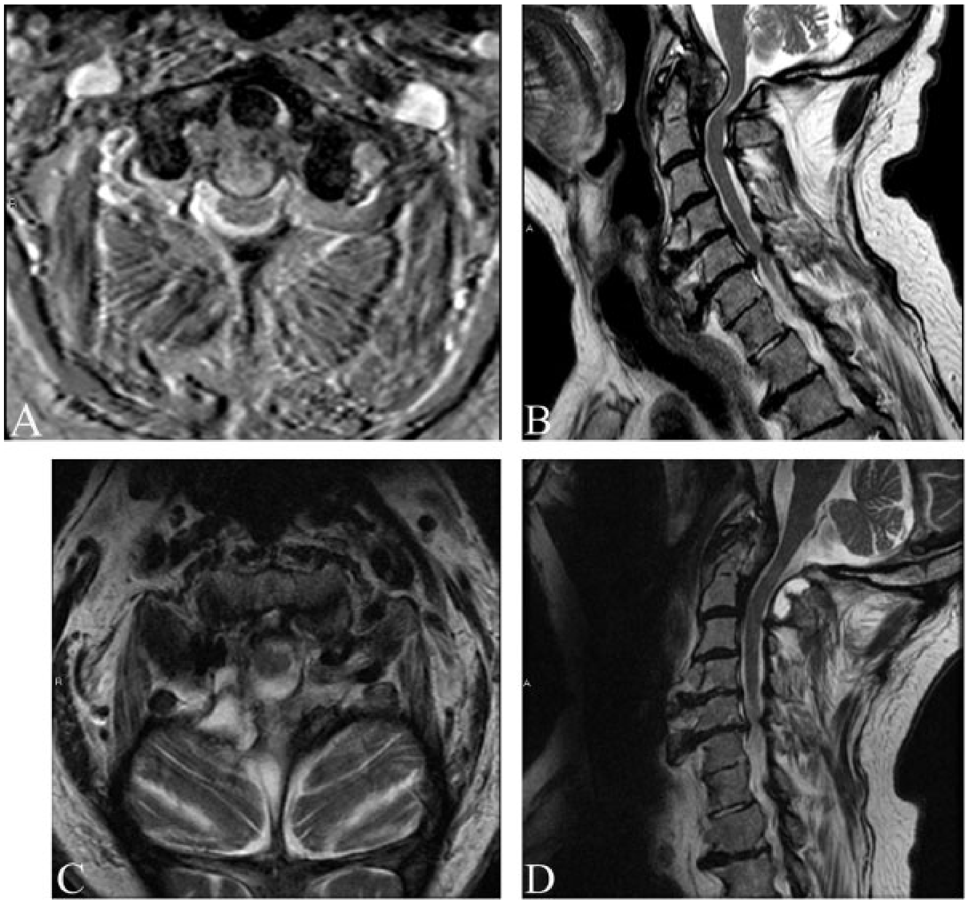

Fig. 4 Case 13. (A) Preoperative axial T2-weighted MRI. (B) Preoperative sagittal T2-weighted MRI. (C) Postoperative axial T2-weighted MRI. (D) Postoperative sagittal T2-weighted MRI.

total tumor removal in 62 to 86% of patients with mortality of 0 to 4%.[4,6,7,10,12,17,18]

In this study we report a modification of the far-lateral approach designed to reduce the invasiveness and complications associated with the procedure. Such modifications have been common in the years since the approach was widely adopted. Most initial authors advocated an extensive procedure with significant occipital condylar resection and vertebral artery transposition. The degree of occipital condylar resection in particular has varied since then. It is clear from numerous anatomical studies that occipital condylar resection improves visibility and exposure.[19–22] However, it also clear that the added exposure is not always necessary. Heros,[2] Samii et al,[23] and Nanda et al[19] described treatment of intradural neoplastic and vascular lesions without any condylar resection. Tumors in particular frequently enlarge the surgical corridor and make the small increase in exposure provided by condylar resection unnecessary. We have taken an approach where the degree of condylar resection is tailored to best suit the lesion and never exceeds 30%. In particular, we have found condylar removal most helpful for pathology in the ventral midline where the surgical corridor may not be significantly enlarged by the lesion. In these situations the additional exposure obtained from condylar resection is often necessary. In our series we performed partial (< 30%) condylar resection in 11 of 13 patients. These included all patients with foramen magnum meningiomas and also the patient with C1–C2 pannus. We did not perform condylar resection in the PICA aneurysm and brainstem glioblastoma cases. We did not recognize any postoperative occipitocervical instability in any of the patients in this series. Brisk venous bleeding is commonly encountered during condylar removal, but in our experience it is easily controlled by the use of topical hemostatic agents such as Surgifoam (Ethicon, Somerville, New Jersey, United States). Vertebral artery transposition was not performed in any case, a strategy advocated by several experienced authors.[9,17,18] However, our meningiomas were all intradural, and we would consider vertebral artery mobilization in tumors with a significant extradural component. We did not encounter any anomalous vertebral artery anatomy in our series, but such anomalies are not uncommon, and attention should be paid to vertebral arterial anatomy on preoperative imaging studies. Specifically, an anomalous vertebral artery located caudal to the C1 lamina would be at risk for inadvertent injury during subperiosteal exposure of the inferior C1 lamina and superior C2 lamina.

The preceding modifications reduce many procedural risks including occipitocervical instability, hypoglossal injury, excessive venous bleeding, vascular injury, and complications related to prolonged surgery. The goal of our minimal access exposure modification is to reduce wound complications such as CSF fistulae when compared with larger exposures. In reports that include wound complications, CSF fistula is the most common, occurring in 6 to 25% of patients with most series having a CSF fistula rate > 10%.[4,6,8–12,24] Many of these patients required further surgery, either wound revision or ventriculoperitoneal shunting. There were no CSF fistula in our series, but admittedly the series is too small to demonstrate statistical superiority. However, it is consistent with basic surgical principles that reduced exposure, and dead space will reduce the risk of such complications. Furthermore, strategies that reduce dead space have reduced CSF leaks in several neurosurgical procedures.[25–27] Although not specifically studied, it is also intuitive that a smaller exposure would reduce postoperative pain and allow early mobilization. Our uncomplicated meningioma patients were discharged on postoperative day 2 or 3.

For foramen magnum meningiomas, a potential drawback of a minimal access exposure is increased difficulty of resection and inferior surgical results. Our 60% rate of gross total resection is lower than some reported series and therefore raises this possibility. However, the subtotal resections were related to tumor adherence on neurovascular structures and involved small tumor fragments. In the literature, the major source of new postoperative neurologic morbidity in these patients is lower cranial nerve dysfunction likely related to tumor adherence.[7,18] Even in cases of transient lower cranial nerve dysfunction, temporary gastrostomy and aggressive therapy may be necessary. It is also clear that newly diagnosed foramen magnum meningiomas as well as postoperative tumor remnants may pursue an indolent course.[6] Furthermore, stereotactic radiosurgery has also been used successfully on foramen magnum meningiomas.[28–30] For these reasons we favor subtotal resection for tumors densely adherent to neural or vascular structures. This still allows for removal of the vast majority of the tumor and decompression of the cervicomedullary area, usually leading to improvement of preoperative long tract dysfunction. Using this strategy we did not encounter any new cranial nerve morbidity postoperatively. The results were durable overall, with one patient in our series requiring reoperation for growth of a tumor remnant 7 years postoperatively. We currently use this minimal access approach for the vast majority of foramen magnum pathology that we encounter. With extensive tumors the incision can be lengthened and additional exposure obtained as necessary through additional suboccipital or laminar bone removal. This approach should be avoided in situations where there is concomitant instability requiring stabilization because it does not provide the exposure necessary for adequate fixation. In these cases we would recommend a midline exposure of sufficient length to allow a lateral trajectory for lesion removal as well as bilateral exposure of the occiput and upper cervical spine for instrumentation.

Conclusion

The far-lateral approach has been modified numerous ways to make it safer and more efficient while still allowing successful treatment of lesions at the foramen magnum. We present a further modification where exposure is obtained using a small paramedian incision and a muscle-splitting approach. This has clear advantages in reducing local complications such as CSF fistula. After a cadaver study confirmed the feasibility of the approach, we successfully used it in 13 patients with several different pathologies. We conclude that the minimal access far-lateral approach is a useful modification that significantly reduces the invasiveness of the procedure without compromising surgical goals.

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