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Technical Notes

Utilizing virtual reality for resection of recurrent ventral, extramedullary cervical meningioma

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ABSTRACT

Background: Virtual reality (VR) platforms are an emerging tool in neurosurgical planning, offering immersive, patient-specific 3D visualization to optimize surgical strategy and intraoperative navigation. Here, VR-assisted mapping was used to remove a recurrent cervical meningioma.

Methods: A 43-year-old female with a recurrent C5-C6 ventral, intradural meningioma presented with newly progressive myelopathy due to recurrent meningioma and worsening multiple limb paresis. Using intraoperative neuronavigation and VR-assisted mapping, the patient underwent a C4-C7 hemilaminotomy for recurrent tumor resection, followed by a C3-T2 fusion.

Results: Postoperatively, the patient had significant neurological improvement, and follow-up studies showed no tumor recurrence.

Conclusion: This case highlights the utility of VR in presurgical planning and intraoperative guidance for complex recurrent cervical spinal tumors.

Keywords: Cervical meningioma, Minimally invasive surgery, Neuronavigation, Virtual reality

INTRODUCTION

The tumor location, size, and relationship to critical neurovascular structures typically dictate surgical approaches to spinal meningiomas. Anterior approaches are often employed for cervical meningiomas, as they provide direct access for tumor resection.[5] Recently, VR platforms have become critical tools for neurosurgical planning, enabling patient-specific 3D reconstructions that optimize preoperative and intraoperative navigation for gross total tumor resection.[1,4] While anterior approaches remain a standard for achieving adequate exposure in treating cervical meningiomas, posterior approaches can provide sufficient access with reduced morbidity, especially when integrated with intraoperative navigation.[6]

CASE PRESENTATION

A 43-year-old female with prior C5-C6 ventral, intradural meningioma and removal presented new-onset paresis of multiple limbs. A magnetic resonance imaging (MRI) performed in February

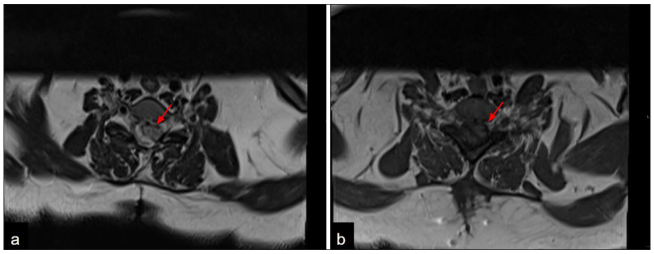

Figure 1: (a) Preoperative axial T2 magnetic resonance imaging with contrast and (b) T1 imaging without contrast showing an elliptical-shaped mass (red arrow) in the anterior left side of the spinal canal in an intradural extramedullary location consistent with the patient's known meningioma.

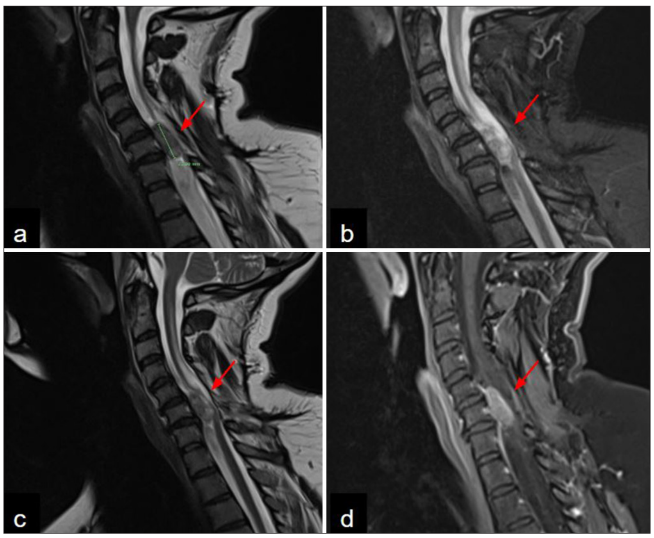

Figure 2: (a) Preoperative sagittal MRI without contrast shows a lateral view of the enhancing mass (red arrow). (b) T1 Short Tau Inversion Recovery (STIR) images reveal focal dilation with increased signal within the cord just above the level of the meningioma (red arrow), with the extension of signal within the cord ending around the C1-C2 level, suggesting the presence of a syrinx. (c) Additional non-contrast sagittal MRI images further demonstrate the extension of signal within the cord and its termination around the C1-C2 level. Here, the red arrow shows a view of the enhancing mass. (d) Preoperative sagittal MRI with contrast displays the enhancing mass (red arrow), with defects from the previous laminectomy visible approximately around the C4-C5 level. A dural tail extending from the cephalad portion of the mass is also observed.

Figure 3: (a) Preoperative axial and (b) sagittal computed tomography scan with no contrast demonstrating a partially calcified meningioma (red arrow).

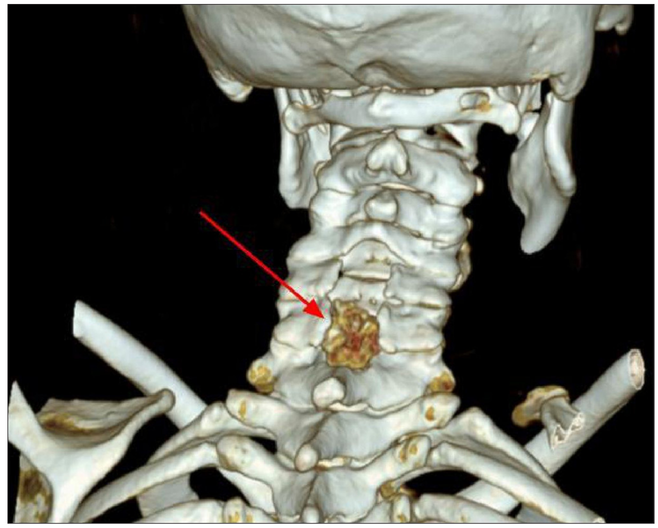

Figure 4: Preoperative 3D reconstruction from patient's computed tomography scans demonstrating bony defect (red arrow) from prior laminectomy.

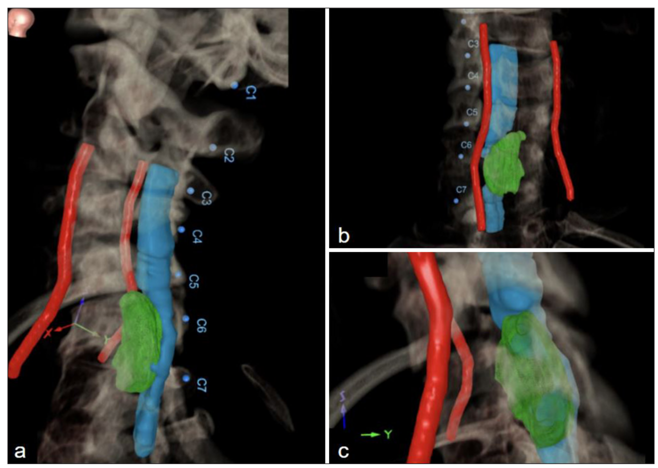

Figure 5: (a-c) A preoperative 3D model of the patient's anatomy used for pre and intra-operative planning through virtual reality technology. Bony anatomy was obtained from computed tomography scans and showed bony defects from previous resection; soft tissue models, such as the spinal cord (blue), vertebral arteries (red), and meningioma (green), were rendered from magnetic resonance imaging.

of 2022 revealed an anterior, elliptical, extramedullary tumor measuring 1 × 1.8 × 2.5 cm, extending from C5 to C7 area, causing severe spinal cord compression and cord edema extending to C2 level [Figures 1 and 2]. Initial surgical planning favored an anterior approach, but VR-assisted mapping demonstrated that a posterior approach would provide greater exposure while minimizing disruption to surrounding structures [Figures 3-6]. Using image-guided neuronavigation, real-time VR guidance, microscopic visualization, and intraoperative neuromonitoring, the

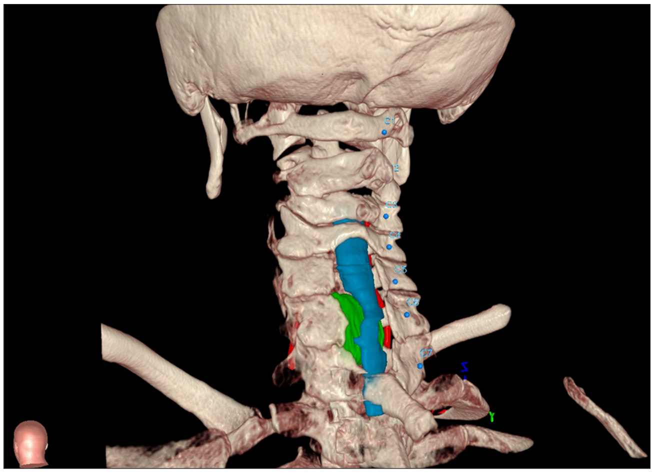

Figure 6: A preoperative 3D model of the patient's anatomy used for pre and intra-operative planning through virtual reality technology. With the bony anatomy faded from view, it allows for better visualization of where the meningioma (green) was encasing the spinal cord (blue) and its distance with respect to the vessels (red). The meningioma is shown to be ventral with respect to the chord.

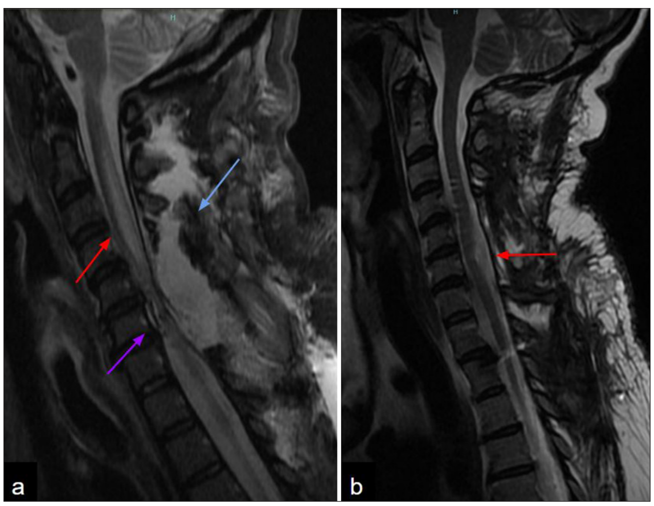

Figure 7: (a) Immediate postoperative sagittal short tau inversion recovery magnetic resonance imaging (MRI) with contrast. The purple arrow demonstrates gross total resection of the lesion; the red arrow points to residual edema of the spinal cord, extending from the C1 level to the C7 level; the blue arrow shows postoperative muscle dissection and laminectomy at C5 and C6 with dorsal fluid collection at the operative site. (b) Imaging, sagittal T2 MRI, at 4 months postoperation shows continued decompression (red arrow) of the spinal cord after resection of the meningioma and improved syrinx.

patient underwent a C4-C7 hemilaminectomy with partial removal of the lateral mass at C5-C6 for posterolateral dural incision and tumor resection, followed by a C3-T2 fusion. Four months postoperatively, the patient demonstrated significant neurological improvement, and recent postoperative MRI monitoring confirmed the absence of tumor recurrence [Figure 7a]. However, residual patchy numbness on the left upper extremity remained. Around this time, MRI showed continuous decompression of the spinal cord [Figure 7b].

DISCUSSION

For cervical meningiomas, optimal surgical outcomes depend on precise preoperative planning, which here was enhanced by VR-based neuronavigation. Traditional 2D imaging can limit spatial understanding, whereas VR-based neuronavigation provides an immersive, patient-specific 3D reconstruction, thus improving visualization of tumor location relative to critical neurovascular structures.[3] Once the 3D model is finalized, it can be synchronized with intraoperative navigation systems, optimizing surgical approaches to minimize the risk of complications.[2]

In this case, while an anterior approach was initially considered, VR-assisted planning demonstrated that a posterior approach would allow for a more complete resection with minimal disruption to normal anatomy. Additionally, VR enhances patient education by offering a direct, interative approach. Using 3D models, physicians can effectively explain the patient's pathology, involving them more actively in decision-making processes regarding their treatment. Given the complexity of neurosurgery, VR also fosters improvement communication and collaboration among surgical teams. Our case highlights the advantages of VR- assisted planning in the successful use of a postero-lateral approach with removal of facets. VR planning allowed us to determine the degree of facet resection that would be required for the optimal resection corridor, and determined the need for instrumentation for stabilization of the spine.

CONCLUSION

We successfully used VR-assisted surgical planning to remove a recurrent ventral cervical meningioma utilizing a posterior cervical approach. By delineating degree of lateral bony removal and exposure that would allow for complete resection through this approach, VR enabled a safer and more effective posterior approach, minimizing disruption to critical neurovascular structures. The successful gross total resection and the patient's significant neurological improvement reinforce the potential of VR as a valuable tool in neurosurgery. As VR technology continues to advance, its integration into surgical workflows may further refine precision, reduce complications, and improve patient outcomes in complex spinal tumor resections.

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