Intraoperative Spinal Navigation for the Removal of Intradural Tumors: Technical Notes

**BACKGROUND:** In recent years, spinal surgery has incorporated the many advantages of navigation techniques to facilitate the placement of pedicle screws during osteosynthesis, mainly for degenerative diseases. However, spinal intradural tumors are not clearly visible by intraoperative fluoroscopy or computed tomography scans, thereby making navigation necessary.

**OBJECTIVE:** To evaluate the use of spinal navigation for the removal of intradural and spinal cord tumors using spinal magnetic resonance imaging (MRI) merged with intraoperative 3-dimensional (3-D) fluoro images.

**METHODS:** After fixing the patient reference frame on the spinous process, the 3-D fluoro images were obtained in the surgical room. Using this image as the reference, the preoperative volumetric MRI images and intraoperative 3-D fluoro images were merged using automated software or manually.

**RESULTS:** From January to July 2016, we performed 10 navigated procedures for intradural spinal tumors by merging MRI and 3-D fluoro images. Nine patients had an intradural extramedullary tumor, 6 had neurinomas, and 3 had meningiomas; 1 patient had an intramedullary spinal cord metastasis.

**CONCLUSION:** The surgically demonstrated benefits of spinal navigation for the removal of intradural tumors include the decreased risk of surgery at the wrong spinal level, a minimal length of skin incision and muscle strip, and a reduction in bone removal extension. Furthermore, this technique offers the advantage of opening the dura as much as is necessary and, in the case of intrinsic spinal cord tumors, it allows the tumor to be centered. Otherwise, this would not be visible, thus enabling the precise level and the posterior midline sulcus to be determined when performing a mielotomy.

**KEY WORDS:** 3-D fluoro images, Intradural spinal tumors, O-arm, Spinal navigation

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**ABSTRACT**

Navigation techniques in neurosurgery have been described since the early 1990s, and are increasingly employed in cranial surgery for their efficacy, ease of use, and time efficiency. Owing to the remarkable development of intraoperative imaging platforms to obtain 3-dimensional (3-D) images, spinal navigation is currently used exclusively for instrumental surgical procedures in order to facilitate the proper positioning of pedicle screws.

Microsurgical resection of spinal intradural tumors usually requires a midline skin incision, monolateral or bilateral muscle stripping, and a hemilaminectomy or laminectomy. The accuracy of a hemilaminectomy or laminectomy depends upon the anatomic knowledge and intraoperative radiographic vertebral target according to the level of the intradural tumor. In neurosurgery, sometimes the extension of the skin incision, muscle strip, or the hemilaminectomy or laminectomy is more excessive than actually necessary, thereby resulting in an increased risk of chronic pain and spinal-acquired deformity.

The possibility of merging preoperative magnetic resonance imaging (MRI) findings with intraoperative 3-D fluoro images allows the surgeon to navigate nonosseous lesions, such as those occupying the vertebral intradural space or the spinal cord, which are typically visible only on MRI.
Herein, we present our experience with this useful and time-efficient technique based on spinal navigation. To the best of our knowledge, this is the first description of using spinal navigation for the accurate targeting of spinal intradural or intramedullary tumors.

METHODS

The procedure and informed consent were approved by the Institutional Review Board. Each patient included in the study gave their informed consent for the use of this navigated procedure.

Before surgery, all patients underwent contrast-enhanced MRI with volumetric acquisition (1-1.20-mm slice thickness) for 3-D reconstruction.

After fluoroscopic identification of the operative level in the operating room, a small skin incision was made on a spinous process above or close to the level of the tumor, either above or below it according to the O-Arm position. After that, the patient reference frame was fixed on the spinous process and 3-D fluoro images were obtained (Figure 1). The frame was usually removed at the end of the navigation and, in any case, before starting tumor removal.

Unlike brain navigation, a point-based registration was not necessary. Using this as the reference, the preoperative volumetric MRI images, previously retrieved from the image archive, and intraoperative 3-D fluoro images were merged. Merging can be automated using software or performed manually by adjusting the image overlay if there is no appropriate image overlap (Figure 2). If the images are manually merged, it is important to identify vertebral bodies that have unusual characteristics (e.g., an irregular shape due to an osteophyte, a collapsed vertebral body, or sacral bone) or other anatomic landmark around the spine in order to easily recognize it on 3-D fluoro images and MRI and begin the merging from it.

In the thoracic and lumbar spine, there is no significant deformation during fusion between the computed tomography performed with the patient prone and an MRI performed with the patient supine. The level of accuracy is high. In the cervical and high thoracic spine, the use of a headholder and the neutral position of the neck enables the deformation to be limited, which maintains an adequate degree of accuracy.

After verifying that the merging is correct on the sagittal, coronal, and axial planes, all surgical procedural steps, including the skin incision, laminectomy or hemilaminectomy, dural opening, and, when required, myelotomy, can be performed under the guidance of MRI-based navigation (Figures 3-5) using a navigated probe.

RESULTS

Between January and July 2016, we performed 10 navigated procedures (O-Arm® and StealthStation® navigation systems, Medtronic, Dublin, Ireland) for intradural spinal tumors by merging the MRI and 3-D fluoro images. Nine patients had intradural extramedullary tumors, 6 had neurinomas, and 3 had meningiomas; 1 patient had an intramedullary spinal cord metastasis as a result of an occult renal cell carcinoma.

The characteristics of all 10 patients and surgical details are reported in Table. The volume of the lesions ranged between 13 and 46 mm. The fusion procedure was completed in all patients.
Accuracies in target and trajectory localization when using image-guided neuronavigation systems were tested in all 10 cases; no target registration errors were detected. The average time to carry out this procedure was 20 min. Every surgeon was able to perform this procedure after a few demonstrations.

**DISCUSSION**

Intraoperative navigation is considered an essential tool in cranial surgery. In recent years, these navigation techniques have also seen use in spinal surgery. The advantages of navigation
FIGURE 4. Intradural extramedullary tumor (meningioma): navigation comparing 3-D fluoro and MRI images before the dural incision (top left).

FIGURE 5. Intradural intramedullary tumor (metastasis): intraoperative navigation using the MRI images before the spinal cord incision (bottom right).
in the positioning of the screws are well demonstrated, and navigation is widely used in surgeries for degenerative disc disease and spondylolisthesis, as well as for tumors and other traumatic lesions. It is well known that navigation facilitates pedicle screw placement, reducing the risk of neurological complications, and system failure. The reduced radiation exposure for the operating room staff is another important advantage of this technique.6

On the contrary, 3-D fluoro images obtained in the operating room cannot accurately display spinal intradural lesions, which can only be identified with MRI. Our idea was to merge volumetric-enhanced MR images with intraoperative 3-D fluoro images, in order to make the navigation on MRI more feasible. This new technique is not described in the literature. We decided to apply this procedure for the removal of spinal intradural or intrinsic spinal cord tumors.

All surgical steps for the removal of intradural tumors were performed under the guidance of spinal navigation. This procedure has very efficiently addressed the problem of erroneously selecting the wrong spinal level. It also allows minimizing the length of the skin incision, muscle strip, and the extent of bone removal, thus reducing the iatrogenic incidence of instability, blood loss, and postoperative pain.7

Moreover, this technique offers the advantage of opening the dura as much as is necessary. In cases of intrinsic spinal cord tumors, this procedure solves the problem of centering the tumor, which is otherwise not visible, indicating the precise level, superior and inferior limits, as well as the midline sulcus, an important landmark when performing a mielotomy. A small lesion volume in our brief experience was not a cause of navigation errors.

Indeed, this technique is particularly useful in case of small intradural as well as intramedullary tumors. This is even more true in the thoracic spine, where it avoids the need for a high radiation dosage to the patient in order to center the correct tumor location, in addition to during surgery. Moreover, the radiopacity of the shoulders is completely overcome.

**Limitations**

A limitation of this technique was the localization accuracy of image-guided navigation that has not been studied extensively. Therefore, there are no experimental studies that can assess the presence of possible discrepancies. The key point is the accurate intraoperative alignment between the preoperative MRI images merged with intraoperative 3-D fluoro images and the intraoperative probe location when it reaches the target under the guidance of navigation. Evaluating the reliability of this technique is heavily dependent on the surgeon’s knowledge of the anatomic landmarks. Additionally, this procedure is not time consuming; in fact, the time spent in merging the images is compensated for by the anatomy-sparing minimal access surgery.

**CONCLUSION**

Although our experience is limited by a small sample size and, currently, different conventional strategies can be used in spine surgery to center the right level of work, we suggest, if it is provided by appropriate technology, the use of spinal navigation in cases of intradural tumors. It is an additional tool that provides key advantages during surgery and, moreover, it has a short and simple learning curve.

**Disclosure**

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

**REFERENCES**


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COMMENTS
The authors describe their technique for providing registration of preoperative MRI with intraoperative 3D-fluoroscopic (O-Arm) images in order to provide navigation for intradural lesions. MRI-based intradural navigation is common in the brain, but a simple solution for this in the spinal cord has not been available, despite CT-based bony navigation being widely available. Registration is accomplished manually in their system, though the system is capable of automatic synchronization. The technique is still rudimentary, and a reasonable neurosurgeon considering the technique could be concerned about the risk of mis-registering and being inaccurate by a level or more. This is a liability that can be overcome in most patients, where local anatomy differs enough to allow correct level identification.

There is undeniable merit in having a simple and accurate method of identifying and navigating to intradural lesions. Although it would be hard to prove, it is certainly plausible to believe that approaches could be smaller and more tailored. On the occasion that the lesion was not found, the approach could be expanded up and down. In most cases I expect that would not happen. We have performed keyhole exposures for simple dural arteriovenous fistulae, using traditional localization methods. It is quite reasonable to imagine employing this method to accomplish the same localization with more ease. Partnership with industry, using whatever system, would be laudable in order to build this into an easy to deploy and highly reliable system that could become part of routine clinical practice.

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Authors reported the use of intraoperative spinal navigation for the removal of intradural tumors. Preoperative volumetric MRI images and intraoperative 3D-fluoro images were merged using a software. They suggested that this technique may decrease risk of surgery at the wrong spinal level and also reduce bone removal extension. We believe that intraoperative spinal navigation may be especially useful for small intramedullary tumors or patients who had inadequate intraoperative fluoroscopy images (such as obese patients or those with tumors in the middle thoracic spine). For routine intradural spine surgeries, when the spine level is well visualized using standard fluoroscopy image, this technique may increase the cost and spend additional time for selecting the adequate level to be treated. Anyway, the authors should be congratulated for reporting the first paper about the use of intraoperative spinal navigation for intradural spine tumors. This may guide future studies about this fascinating topic.

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