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Transtubular Resection of Spinal Intradural Lésions : Techniques, Results, & Complications.

Maduri Rodolfo

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UNIVERSITE DE LAUSANNE - FACULTE DE BIOLOGIE ET DE MEDECINE
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Service de Neurochirurgie

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Préparée sous la direction du Docteur John Michael Duff

et présentée à la Faculté de biologie et de médecine de l'Université de Lausanne pour l'obtention du grade de

DOCTEUR EN MEDECINE

par

Rodolfo MADURI

Médecin diplômé en Italie
Originaire de Catanzaro (Italie)

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Transtubular Resection of Spinal Intradural Lesions : Techniques, Results, & Complications

Lausanne, le 14 novembre 2017

pour Le Doyen
de la Faculté de Biologie et de Médecine

Monsieur le Professeur John Prior
Vice-Directeur de l'Ecole doctorale

Rapport de synthèse

Le travail de thèse ici présenté a été publié sous forme d'un article scientifique ayant le titre « Image guided tailored access resection (IMTAR) of spinal intradural tumors. Technical report of 13 cases »
L'article présente les résultats de la chirurgie per « accès minime » (MAS) utilisée dans notre établissement hospitalier avec une implémentation de la technique guidée par image que nous appelons « technique de navigation chirurgicale guidée par fusion d'image » (en anglais : Image Merge Tailored Access Resection ou IMTAR). IMTAR représente l'application d'une technique de fusion d'image déjà existante pour la chirurgie crânienne qui consiste à fusionner les images de la résonance magnétique préopératoire avec les images de fluoroscopie 3D obtenues pendant la chirurgie pour naviguer à la fois les structures osseuses et les tissus mous. La fusion d'image donne au chirurgien la possibilité de mieux planifier l'accès chirurgical par la navigation virtuelle sur les images avant l'incision. Le chirurgien peut donc adapter l'abord chirurgical selon la localisation de la lésion et également adapter la résection d'os en fonction de la fenêtre d'exposition nécessaire pour la visualisation de la lésion tumorale. Le choix d'utiliser la technique IMTAR est pris en préopératoire par le chirurgien en fonction de la disponibilité de cette technique dans un contexte de chirurgie élective. La technique est une implémentation d'une technique déjà existante et bien validée par la littérature courante dont l'utilisation est faite au niveau crânien, mais ici adaptée à la chirurgie spinale.
L'utilisation de la technique IMTAR a pour but de réduire le risque d'erreur de niveau de la localisation des lésions tumorales spinales, situation décrite en littérature. De plus, le choix de trajectoire d'accès trans-musculaire selon la localisation de la lésion tumorale pourrait améliorer l'angle d'accès aux lésions et minimiser le volume d'os enlevé pendant l'abord chirurgical.
Sur la série préliminaire de 13 patients dont les résultats sont contenus dans l'article ici joint, la technique IMTAR a montré des résultats d'exérèse tumorale superposables aux résultats de la technique MAS non-naviguée. La procédure IMTAR semble être moins invasive en termes de résection osseuse et elle permet une meilleure localisation de la lésion.
Le présent travail de thèse s'est déroulé dans le contexte de l'étude IMTAR, catégorie A (Protocole n. 172/15) approuvé par le CER VD et en cours depuis 01.01.2017 au CHUV de Lausanne (investigateurs principales: Dr Rodolfo Maduri, Dr John Michael Duff).
Les perspectives futures pour cette étude sont de décrire les résultats chirurgicaux sur une « prospective cohort » de patients ayant bénéficié de la technique IMTAR et de la technique MAS non-naviguée jusqu'à la date de fin de l'étude.
L'étude IMTAR a pour but d'évaluer les résultats de l'utilisation de la technique IMTAR pour les tumeurs spinales par rapport à la technique de chirurgie MAS classique en termes de minimisation de la morbidité associée à l'abord chirurgical, de la réduction du risque d'une instabilité spinale iatrogène et de l'optimisation de l'efficacité de la résection de la tumeur.

Image Merge Tailored Access Resection (IMTAR) of Spinal Intradural Tumors. Technical Report of 13 Cases

Rodolfo Maduri, Lukas Bobinski, John Michael Duff

■ OBJECTIVE: **Standard translaminar approaches for intradural extramedullary (IDEM) tumors require extensive soft tissue dissection and partial facet removal. Ventral lesions may necessitate wider bone resection with subsequent possible spinal instability. Any manipulation of an already compromised spinal cord may lead to neurological injury. We describe an image-guided minimal access technique for IDEM tumor resection.**

■ METHODS: **Retrospective chart review of 13 consecutive patients after institutional ethics committee approval. We superimpose preoperative magnetic resonance imaging data with intraoperative 3-dimensional fluoroscopic images, allowing to simultaneously visualize osseous anatomy and the soft tissue lesion using appropriate windowing. We then plan optimal angle of trajectory to the tumor, which defines the skin incision and the transmuscular trajectory. A tubular retractor is placed to span the tumor. Microsurgical tumor resection is then carried out using this angle of approach.**

■ RESULTS: **Thirteen patients (mean age. 57 years; male-to-female ratio, 10:3) were operated on during 28 months. Gross total resection was achieved in all patients. Neurological improvement occurred in 12 of the 13 patients. There was no neurological deficit outside of the expected sensory loss due to intentional nerve root sacrifice. No mechanical pain nor tumor recurrence were noted during the follow-up (mean, 16 months; range, 2–30 months).**

■ CONCLUSIONS: **Image merge tailored access resection appears to be at least equivalent in terms of tumor resection, blood loss, and complications to other tubular techniques. It may reduce risks of neurological deficit and spine instability. Image merge tailored access resection is a novel application of merging intraoperative fluoroscopic images with preoperative magnetic resonance images for tailored IDEM resection.**

INTRODUCTION

Intradural extramedullary (IDEM) spinal tumors are rare, with an incidence ranging from 3–10 per 100,000 individuals.[1] Open laminectomy with partial or complete facetectomy is the standard surgical access for IDEM tumor resection,[2] requiring subperiosteal muscle dissection and division of tendinous muscle insertions. To minimize soft tissue disruption and osseous resection, Yaşargil et al[3] and Chiou et al[4] described a less invasive technique consisting of a hemisemilaminectomy (partial hemilaminectomy) and unilateral partial facetectomy (supraforaminal modification), without compromising access for tumor resection. These techniques were subsequently adopted by other surgeons with encouraging results.[5,6]

The resection of ventral or ventrolaterally placed IDEM tumors using posterior or posterolateral approaches may require extensive removal of a facet joint or of the pedicle.[7] Depending on the spinal level and on the extent of resection, this may destabilize the spine,

Key words
- Fluoroscopy
- Image-guided surgery
- Intradural extramedullary
- Minimal access surgical procedures
- Myelopathy
- Neuronavigation
- Spine
- Spinal canal
- Spinal cord compression
- Spinal cord neoplasm

Abbreviations and Acronyms
3D: 3-dimension
CSF: Cerebrospinal fluid
IDEM: Intradural extramedullary
IMTAR: Image merge tailored access resection
MAS: Minimally access surgery
MRI: Magnetic resonance imaging

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causing pain and spinal deformity and the need of additional surgical stabilization procedures.[8] The overall reported rate of spinal deformity after multilevel laminectomy is 32.9% (range, 89.5% in children and young adults and 10.4% in adults more than 30 years).[9] Ventral or ventrolateral tumors can be difficult to access with a standard translaminar approach, and may require manipulation and rotation of the spinal cord to obtain the necessary exposure. In addition to a limited access for tumor resection, there is a risk of neurological complications.[10] Furthermore, whether such lesions are calcified, densely fibrotic, or highly vascular, resection becomes technically more difficult and direct visualization is necessary to avoid injury to the spinal cord vasculature.[11]

Minimal access surgery (MAS) with tubular muscle dilating retractors has been introduced for the treatment of several degenerative pathologies, such as spinal stenosis, disc herniation, and radiculopathy, with the aim to minimize access-related soft tissue morbidity, yet potentially preventing segmental instability.[12,13] The MAS techniques were subsequently used for the resection of IDEM tumor resection with favorable results with a reduction in the access-related morbidity without compromising quality of tumor resection.[14-18]

The technologic development of 3-dimension (3D) fluoroscopy integrated with navigation technology married with MAS techniques has been used in the entire spine for different applications such as instrumented fusion procedures, disc herniation, and extradural tumor removal in the cervical and lumbosacral spine.[19]

The use of 3D fluoroscopic-based navigation in spinal surgery for osseous lesions is facilitated by excellent bone visualization but is conversely limited for nonosseous lesions by poor soft tissue visualization. Therefore, any soft tissue mass in the spine cannot be clearly visualized using the acquired 3D fluoroscopic images. To overcome this, merging preoperatively acquired magnetic resonance imaging (MRI) with intraoperatively acquired 3D fluoroscopy images allows simultaneous visualization of the bone anatomy and of a soft tissue lesion such as an IDEM tumor for image-guided resection.

We describe a technique that superimposes preoperative MRI data with intraoperative 3D fluoroscopic images, allowing us to simultaneously visualize osseous anatomy and the soft tissue lesion using appropriate windowing. With the vertebrae and the tumor visible on the work station, the surgeon can plan the skin incision, the transmuscular trajectory, the extent of bone resection, and the optimal angle of access to the tumor, yet knowing the location of the spinal cord or cauda equina. This report describes our preliminary experience of 13 consecutive patients using this image merge tailored access resection (IMTAR) technique.

METHODS

After institutional ethics committee approval, a retrospective chart review was carried out. From a total of 49 patients operated for intradural pathologies with MAS tubular technique (unpublished data), the addition of the IMTAR technique was used for the most recent 13 cases. It is this latter modification to MAS resection of IDEM that we want to highlight. The preceding 36 cases (MAS, non-IMTAR) will be the subject of a separate study.

For the IMTAR group, preoperative MRI data parameters consisted of square image matrix, contiguous slides of 1-mm thick, and a circular visual field of 180 mm, to encircle the entire vertebra. MRI acquisition included several additional vertebrae above and below the tumor level.

Figures 1 and 2 are examples of IDEM tumors showing preoperative gadolinium enhanced sagittal (**A**) and axial (**B**) T1 MR images. The postoperative CT image (**C**) and corresponding postoperative MR (**D** and **E**) illustrate the extent of bone resection and of tumor resection respectively.

Surgical Technique

After intubation, patients are placed in the prone position on a Jackson table. A Mayfield headholder was used for cervical and upper thoracic tumors. Continuous neurophysiologic monitoring with transcranial motor evoked potential, somatosensory-evoked potential, and free running electromyography are used in all patients.

A midline 10-mm incision is made 1 vertebral level below the caudal segment of tumor based on manual counting on 2=dimensional fluoroscopic images, and the navigation reference frame (Navlock; Medtronic Coal Creek Circle, Louisville, Colorado, USA) is attached to the corresponding spinous process (Figure 3A). A 3D fluoroscopic image acquisition is carried out using the O-arm (Medtronic, Coal Creek Circle). The 3D images are then manually merged with preoperative MRI images on the Stealth workstation using Synergy Cranial 2.2 software and Stealth Merge 1.2 (Medtronic, Coal Creek Circle) (Figure 3B). Specific morphologic anatomic features of vertebrae within the field of view are used to ensure appropriate matching of vertebral levels. Accuracy of merging of superimposed images is verified on the workstation by manually windowing back and forth between MRI and 3D fluoroscopic images. Windowing is then set at an intermediate chosen level where bone anatomy and the tumor are simultaneously visualized. After registration, trackable instruments are then used to visually verify the navigation accuracy provisionally through the small midline incision and the exposed spinous process. Using a virtual projection, the ideal access to the tumor through the canal is chosen based on the relative positions of the tumor and the spinal cord or cauda equina. This virtual trajectory defines the location of the skin incision and the transmuscular corridor.

After deep intramuscular injection of local anesthesia with bupivacaine (Carbostesine 0.5% with adrenaline 1:200.000, AstraZeneca, London, UK) along the intended transmuscular trajectory is performed, a 30-mm paraspinal incision is carried out, centered on the chosen skin entry point. After fascial opening, a trackable pointed instrument is passed transmuscularly and docked on the bone surface, centered on the tumor. The first of a series of tubular dilatators is placed transmuscularly adjacent to this, and the "pointer" is then removed. The transmuscular corridor is progressively dilated and an expandable tubular retractor (METRx Quadrant, Medtronic Sofamor Danek, Memphis, Tennessee, USA) is placed along the intended trajectory docked onto the vertebral surface overlying the center of the tumor access. The position of the retractor relative to the tumor is verified using trackable instruments, and the expandable retractor blades

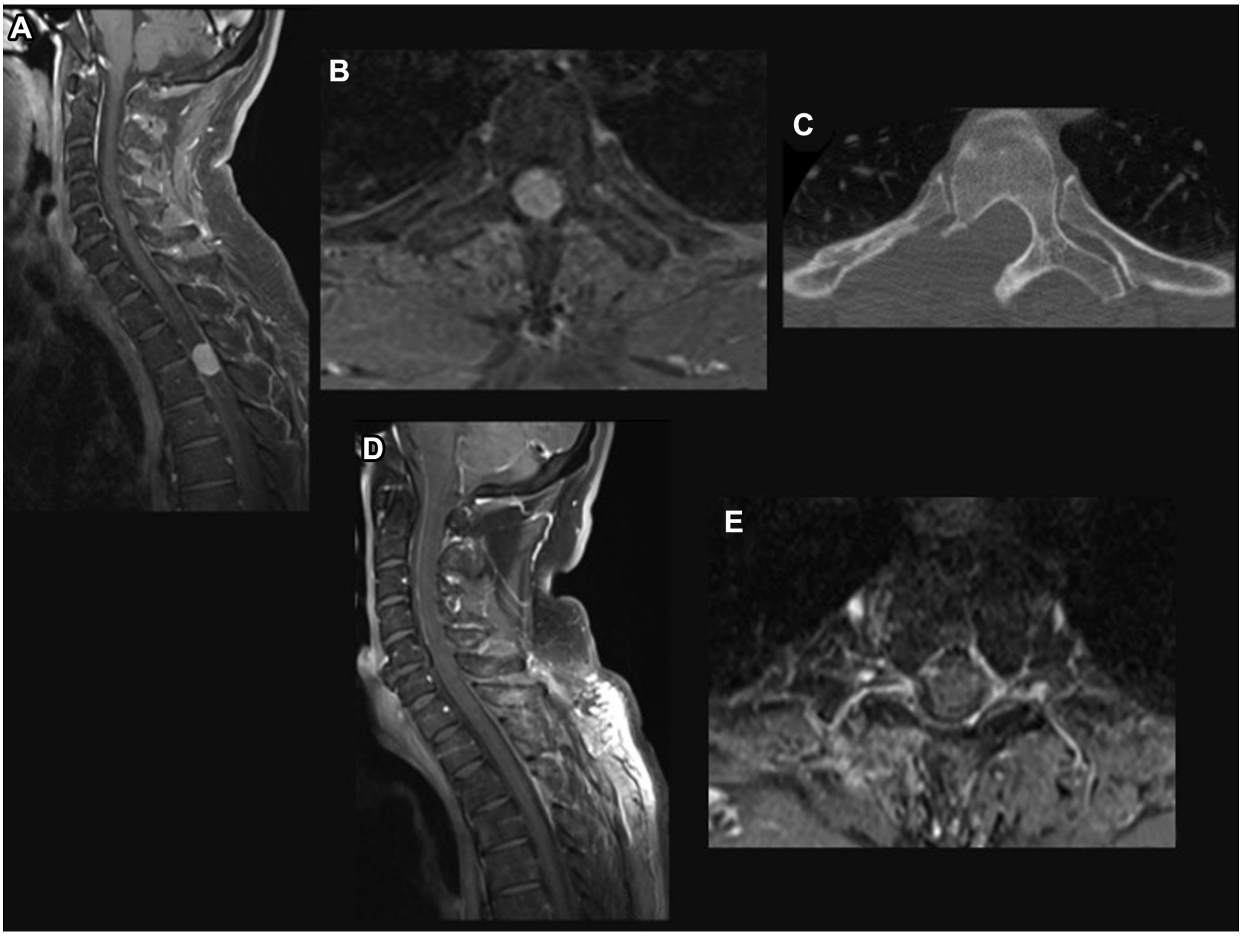

Figure 1. Magnetic resonance (MR) images illustrating a dorsolateral T2-T3 meningioma (**A** and **B**). (**C**) shows the amount of bone resection (costotrasversectomy and hemilaminectomy). Follow-up MR images (**D** and **E**) demonstrate GTR.

are opened to span beyond the upper and lower poles of the tumor. The tailored bone resection is then "mapped out" to optimize tumor access and to avoid exceeding bone resection beyond what is necessary. Precise planned microsurgical resection of the bone is carried out using a high-speed drill. Adequate bone exposure is verified using navigated instruments before dural opening. The extent of bone resection is tailored to resection exposure needs for each lesion, and is detailed in Table 1. The ligamentum flavum is resected, and the dura is opened at or near the midline, and retracted laterally using sutures. In some cases, lateral exposure is facilitated by dural incision extension tailing laterally at either end. The arachnoid is split and suspended to the dural edges with microclips. Tumor resection is achieved using standard microsurgical techniques.

After resection, microsurgical primary dural closure is carried out with running 5.0 Prolene sutures (Ethicon, New Jersey, USA) and reinforced with synthetic dural sealant (Duraseal, Covidien, Dublin, Ireland). After meticulous extradural hemostasis, the expandable retractor is removed. No epidural drain is placed. Wound closure is performed in multiple layers.

All the patients underwent 24 hours of bed rest postoperatively to reduce the risk of postoperative cerebrospinal fluid (CSF) leak.

RESULTS

Patient Demographics and Clinical Presentation

A total of 13 patients were operated using the IMTAR technique during a period of 28 months. Mean age was 57 years (range, 20–92 years) with a male-to-female ratio of 10:3.

Nine patients presented with pure myelopathy, 2 patients with radiculopathy, 2 with local pain without neurological deficit.

Surgical Details

Extent of bone resection, with particular attention to facet resection, tumor level, tumor localization with respect to the

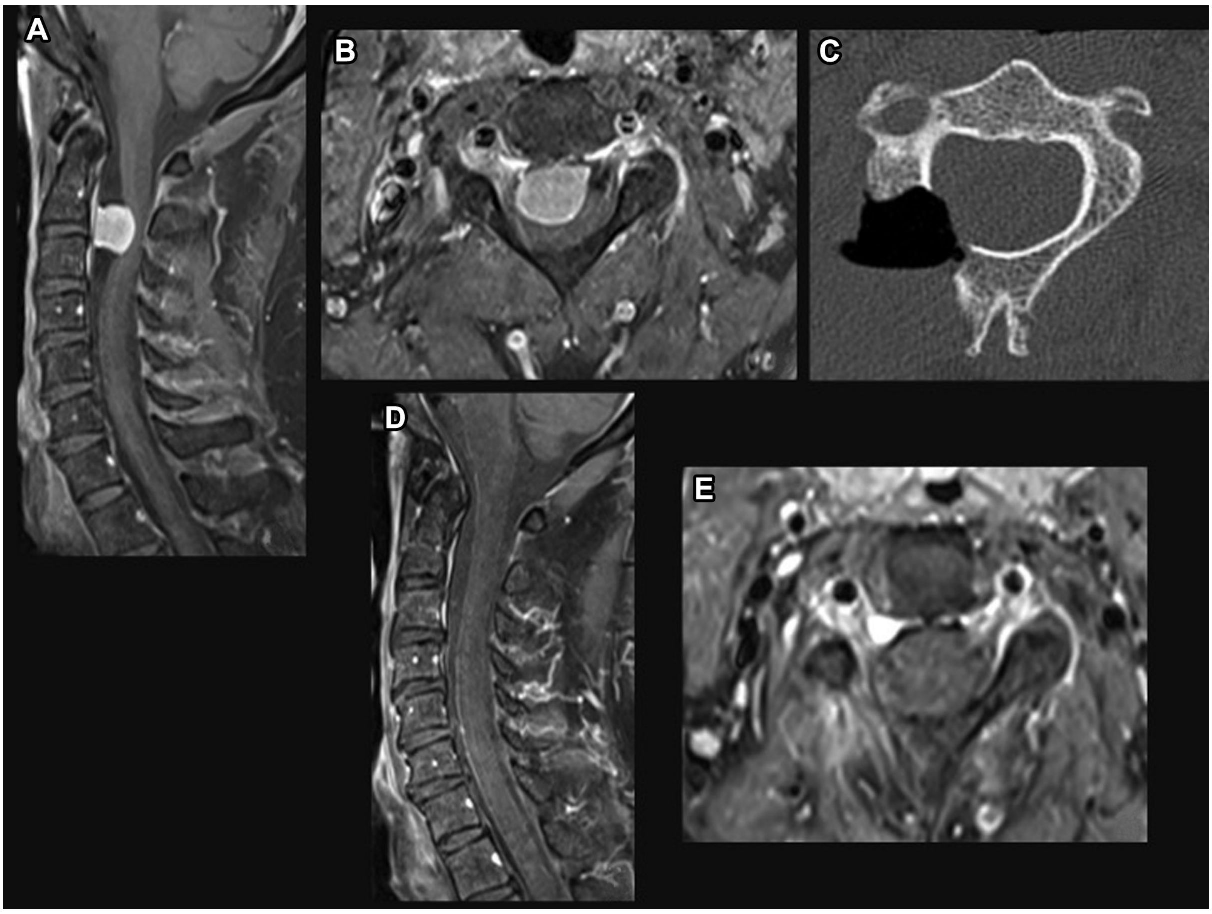

Figure 2. Magnetic resonance (MR) images illustrating a ventral right C2-C3 ventral meningioma (**A** and **B**). (**C**) shows the amount of bone resection (hemilaminectomy). Follow-up MR images (**D** and **E**) demonstrate GTR.

spinal cord (ventral, ventrolateral, dorsolateral, dorsal), and extent of tumor resection and histology are summarized in Table 1. Intentional nerve root sacrifice was performed in 6 patients, 3 of whom had thoracic meningiomas, 2 of whom had schwannomas at T12-L1 and L3-L4, respectively, and 1 who had a C2 neurofibroma. In all patients, gross total resection was achieved. Mean total duration of surgery was 312 minutes (range, 187–440 minutes), with mean incision to surgical dressing application being 85 minutes (range, 66–108 minutes). Mean blood loss was 297 mL (range, 100–1000 mL).

Immediate Postoperative Course

Mean hospital stay was 8.7 days (range, 3–26 days). One patient, a 92-year-old man with severe myelopathy (Nurick IV) and a C3-C4 meningioma had an hospital stay of 26 days awaiting rehabilitation placement.

One patient developed a unilateral keratitis during surgery, which resolved completely with topical antibiotics. One patient developed a subcutaneous hematoma at the operative site in the immediate postoperative period, which was treated conservatively and resolved. One patient presented an acute confusional state related to postoperative steroids, which resolved rapidly with cessation of the steroids.

There was no neurological deficit outside the expected sensory loss due to intentional nerve root sacrifice. Two patients presented with sensory loss in the immediate postoperative period, 1 patient operated on for a T12-L1 Schwannoma and 1 patient operated on for a L3-L4 Schwannoma.

There was no postoperative CSF leak.

Patient Clinical Follow-up

The mean clinical and radiologic follow-up period was 16 months (range, 2–30 months).

Clinical follow-up details are outlined in Table 2. Myelopathic improvement measured by Nurick score was observed in 8 of 9 patients. One patient was neurologically unchanged after 10 months postoperatively, with a Nurick score remaining at 3.

Two patients had persistent dysesthesia on initial follow-up. Both had had intentional nerve root sacrifice to facilitate

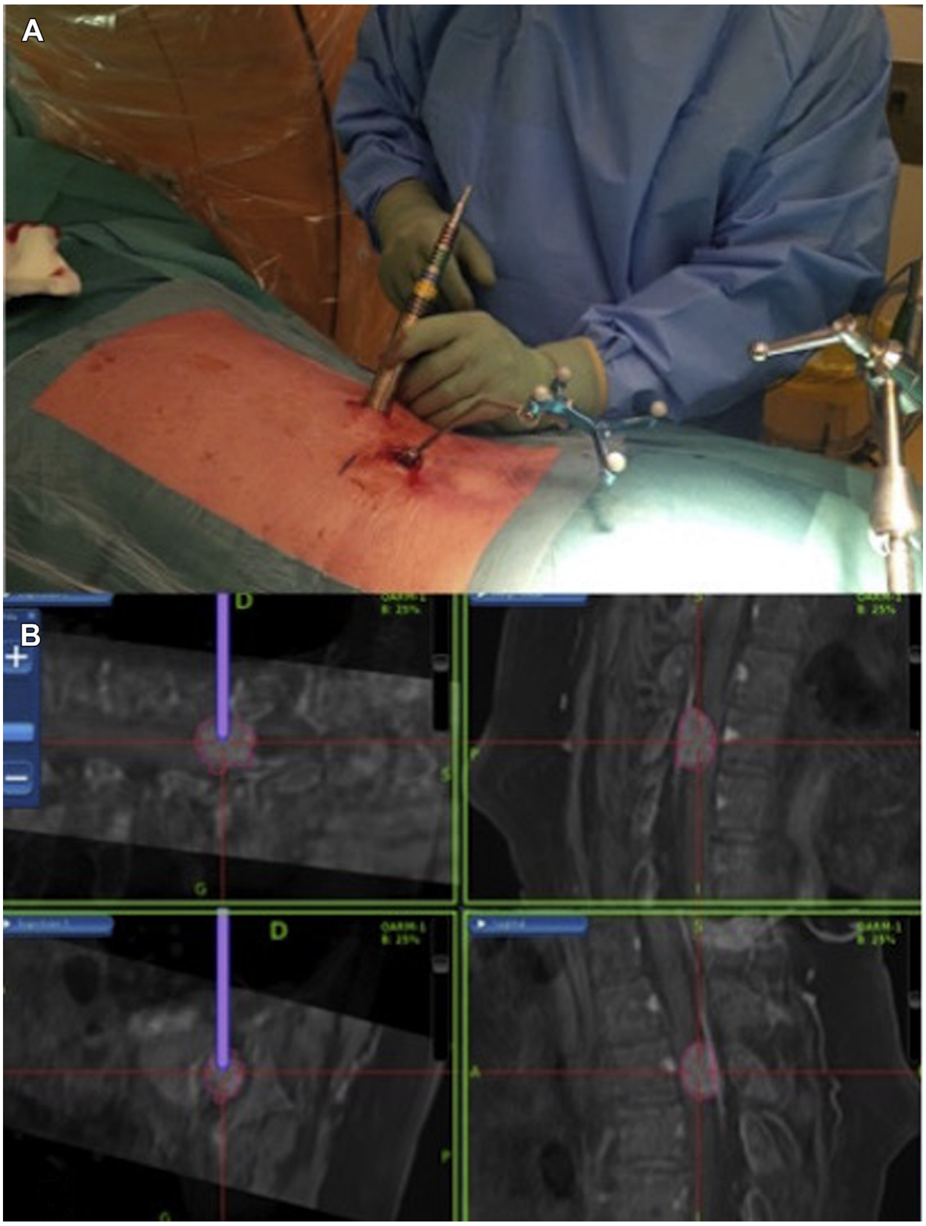

Figure 3. Intraoperative picture: skin incision and transmuscular trajectory are planned based on optimised trajectory for tumor access using merged images (**A**). Preoperative MRI and intraoperative 3D fluoroscopic data are manually merged using Synergy Cranial 2.2 software and Stealth Merge 1.2 (**B**).

tumor resection. The first patient had a subsequent complete resolution of the dyesthesia after 11 months of treatment with pregabalin. The second patient was still under medical treatment at 5 months postoperatively, with a satisfactory pain control.

No clinical symptoms of local mechanical pain were noted at the last follow-up consultation in all patients.

MRI of the involved spine levels scheduled at the same time as clinical follow-up showed no recurrent or residual tumor in any case.

DISCUSSION

The goal of surgical treatment of IDEM tumors is to achieve gross total resection with minimum manipulation of the neural

Table 1. Lesion Characteristics, Surgical Approach, Tumor Resection

Patient Number	Age (years)	Sex	Lesion	Localisation	Side	Hemilaminectomy	Facetectomy	Miniextracavitary-costotrasversectomy	Pediculectomy	Nerve Root Sacrifice	GTR
1	47	M	T2-T3 meningioma, calcified	Lateral	R	Yes	Complete	Yes	Partial	Yes	Yes
2	68	M	T2-T3 arachnoid cyst	Dorsal	M	Yes	Partial	No	No	No	Yes
3	53	M	C2-C3 meningioma	Ventral	R	Yes	Partial	N/A	N/A	No	Yes
4	57	F	T10-T11 meningioma	Ventral	M	Yes	Total	Yes	Complete	Yes	Yes
5	67	F	T2-T3 meningioma	Lateral	R	Yes	Partial	Yes	No	Yes	Yes
6	20	F	C2 neurofibroma	Lateral	L	No	N/A	N/A	N/A	Yes	Yes
7	46	M	T12-L1 sSchwannoma	Lateral	R	Yes	No	No	No	Yes	Yes
8	36	M	L3-L4 schwannoma	Lateral	R	Yes	Partial	No	No	Yes	Yes
9	69	M	C6-C7 meningioma	Ventral	R	Yes	Partial	N/A	No	No	Yes
10	92	M	C3-C4 meningioma	Ventral	L	Yes	Partial	N/A	No	No	Yes
11	49	M	T2-T3 schwannoma	Lateral	R	Yes	Partial	No	No	No	Yes
12	66	M	T12-L1 schwannoma	Lateral	R	Yes	Partial	No	No	No	Yes
13	70	M	T12-L1 arachnoid cyst	Dorsal	M	Yes	Partial	No	No	No	Yes

M, male; F, female; R, right; L, left; M, midline; N/A, not applicable; GTR, gross total resection.

Table 2. Clinical Follow-up Results

Patient Number	Lesion	Nurick Score Before Operation	Nurick Score at Follow-Up	Radicular Sensory Loss	Dysesthesia
1	T2-T3 meningioma, calcified	3	0	No	No
2	T2-T3 arachnoid cyst	1	0	N/A	N/A
3	C2-C3 meningioma	1	0	N/A	N/A
4	T10-T11 meningioma	3	0	Yes	No
5	T2-T3 meningioma	3	1	No	No
6	C2 neurofibroma	0	0	Yes	No
7	T12-L1 schwannoma	0	0	Yes	Yes
8	L3-L4 schwannoma	N/A	N/A	Yes	Yes
9	C6-C7 meningioma	2	0	No	N/A
10	C3-C4 meningioma	4	2	No	N/A
11	T2-T3 schwannoma	4	1	No	No
12	T12-L1 schwannoma	3	3	N/A	N/A
13	T12-L1 arachnoid cyst	3	3	N/A	N/A

N/A, not applicable.

elements. The standard translaminar approach can be useful for tumors in the lumbosacral spine below the conus medularis. In the cervicothoracic spine, a translaminar approach for tumors ventrolateral or ventral to the spinal cord often offer a very limited exposure. This can be circumvented by extensive posterolateral bone resection of the facet joint or pedicle, and by rotation of the often-compromised spinal cord by traction on the ipsilateral dentate ligament. These maneuvers provide at best, a limited window of access, necessitating "blind" dissection. Furthermore, resection of these lesions with standard posterior or posterolateral approachis not without complications, and has been reported to carry a 10%–25% rate of neurological complication, a 41.6% surgery-related total complication rate, and a mortality of 1.5%.[10,20,21]

We describe a novel addition of an image guided technique (IMTAR) used in combination with MAS for spinal intradural lesions. Compared with non-IMTAR MAS techniques, IMTAR defines the midpoint of the skin incision, the angle of transmuscular tubular passage, and "fine-tunes" the bone resection. This technique may facilitate tumor resection by allowing a wider choice of trajectory close to 70 degrees off the midline to one or other side, and therefore may reduce neurological risk due to minimal, if any spinal cord manipulation. MAS techniques have been reported to be safe and effective for IDEM resection.[16,17,22] The feasibility of image-guided techniques combined with MAS for extradural pathologies has also been documented in the literature.[23] Table 3 shows a summary of published MAS tubular techniques for the surgical treatment of IDEM. When we

Table 3. Previous Intradural Extramedullary Series Treated with Minimal Access Surgery and Tubular Retractors

Author, Year	Technique	Number of Patients	Mean OR (minutes)	Mean EBL (mL)	GTR	Neurological Complications (%)	Other Complications (%)*	Follow-up (months)
Tredway et al,, 2006[24]	X-tube	6	247	56	100	0	0	11
Mannion et al., 2011[16]	Quadrant, X-tube	11	156	155	100	0	18.2	16
Haji et al,, 2011[22]	Quadrant	13	188	225.7	69.2	7.6	7.6	6
Gandhi and German, 2013[15]	Quadrant	12	213	197	66.6	0	3.7	13
Nzokou et al., 2013[17]	Spotlight	4	160	181.2	100	0	0	18
Wong et al., 2015[25]	Quadrant	27	256.3	133.7	92.5	0	11.1	16
Afathy et al., 2015[26]	Quadrant, ILLICO	18	95	200	100	0	0	24

OR, operating room; EBL, estimated blood loss; GTR, gross total removal.

*Cerebrospinal fluid leaks, infection, long-term back pain, general medical complications (pulmonary embolism, cerebral infarction).

compare these patient cohorts to our IMTAR group, our overall surgical duration versus the non-image guided tubular techniques was longer by an average of 120.8 minutes. When we make an internal comparison, we compared our IMTAR group of patients ($n = 13$) with our non-IMTAR MAS group ($n = 36$; unpublished data). Mean total mean duration of surgery for the 2 groups from entry into the operating room to exit was 312 minutes and 210 minutes, respectively. Mean duration of actual surgery was 85 minutes and 94 minutes, respectively. The substantial "non-surgical" time for the IMTAR group, an additional mean time of 227 minutes, is accounted for by anesthesia time at the beginning and end of the surgery, patient positioning and prepping, and O-arm positioning into the operating field. Acquisition of 3D fluoroscopic images after placement of the reference arc on a spinous process was part of the surgical time. The mean total surgical time in our non-IMTAR group (210 minutes) is similar to other series in the literature (Table 3). However, the use of the IMTAR technique adds an average of 102 minutes, which is slightly offset by a shorter mean duration of actual surgery for the IMTAR group and which may improve with more experience.

Our resection rate of 100% is equivalent to some series[24] and superior to other series.[15,22,25,26]

Blood loss in our series is higher than comparative series (mean overall, 297 mL vs. 165 mL; Table 3).

Our neurological complication rate of 0 is comparable with most other series, as is the neurological improvement at follow-up of 89%. This is encouraging given that there were 3 cervical and 1 thoracic ventral tumors in the series. There were 3 transient non-neurological complications, which resolved in the early postoperative period. There were no CSF leaks in this small series. It is possible that the smaller anatomic dead space and muscular elastic recoil after transtubular resection may reduce this risk. The overall complication rate in the IMTAR series is comparable with other published series.[15-17,22,24-26] The technique undeniably requires additional time, which we would hope will be reduced with more experience.

Possible clinical advantages related to limited bone resection will be evaluated in a future prospective observation cohort of patients with independent radiologic evaluation.

Concerning postoperative instability, the use of limited open techniques or of MAS techniques during the posterior approach for IDEM lesions has lessened destructive bilateral muscle dissection and bilateral bone removal.[16,20,27] Preservation of facet capsules and the segmental posterior ligamentous complex may further decrease the risk of postoperative instability.[7] Facetectomy after laminectomy, if needed performed to expose IDEM tumors, is correlated with instability in the cervical spine when the extent of facet resection exceeds 50%.[28] IMTAR, by integrating MAS techniques, may reduce the risk of postoperative instability with a more precise bone resection. However, instability remains unlikely with limited partial facet resection.[22,24]

A universal concern with IDEM resection is the risk of wrong level identification, mostly for lesion located in the upper or midthoracic spine.[16] In our series, no patient had this complication of wrong level surgery. This is probably because during the IMTAR procedure, both the tumor and the bone anatomy are localized using navigation techniques, possibly reducing the risk of wrong vertebral level surgery, as the tumor is "visible" on the workstation screen.

Limitations of the IMTAR technique is a significant learning curve, additional surgical time for reference arc placement through a second (midline) 1-cm incision, additional image acquisition time, and additional time for manual image merging due to the lack of a dedicated software. All of these contribute to the overall duration of surgery.

CONCLUSIONS

Resection of IDEM lesions remains challenging. The present report demonstrates a novel application of merging of intraoperative 3D fluoroscopic images with preoperative MRI for a guided approach to the targeted tumor. IMTAR facilitates tumor dissection and removal, yet minimizing surrounding soft tissue damage and avoiding unnecessary bone removal. These preliminary results are encouraging and appear to be at least equivalent to other tubular techniques for IDEM resection. This individually tailored approach minimizes perioperative tissue disruption and bone resection and may reduce the risk for iatrogenic instability without compromise of surgical resection. IMTAR may also help to decrease the risk of wrong level surgery.

To our knowledge this is the first report of the use of this technique applied for IDEM "customized" surgical resection. IMTAR appears to be safe and effective; however, these findings need to be verified by further studies.

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