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HOW I DO IT

Cauda equina tumor surgery: how I do it

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Abstract
Background Tumors of the cauda equina usually require surgery due to their impingement on neighboring nerve roots, often resulting in pain and neurological deficits.
Method The Authors first give a brief introduction on cauda equina tumors, followed by a description of the surgical anatomy, and then develop the microsurgical technique. In particular, tricks to avoid complications are presented, underlining the importance of intraoperative neuromonitoring.
Conclusion Both microsurgical technique and neuromonitoring are important in cauda equina tumor surgery, the goal of which is to achieve complete resection while at the same time preserving neurological function.

Keywords Cauda equina · Tumor · Microsurgical techniques · Neuromonitoring

Introduction

Tumors of the cauda equina are rare entities, accounting for 5 % of all primary intraspinal tumors, and for approximately 0.2 % of all primary central nervous system tumors [5]. Histology of these lesions varies, with the myxopapillary form of ependymoma – almost exclusively found in the conus medullaris and filum terminale – representing the most frequently encountered cauda equina tumor, followed by schwannoma, meningioma, metastatic lesions, lymphoma and plasmocytoma, dermoid and lipoma, hemangioblastoma, neurofibroma and other glioma tumors [5, 10]. Of note, spinal paraganglioma, albeit rare, is mainly found in the conus medullaris, cauda equina and filum terminale [9].

Surgery is the treatment of choice for these lesions, and its goal is decompression – using microsurgical technique and neuromonitoring [1, 7] – aiming at complete resection, while at the same time preserving neurological function. Although its precise modalities are still controversial, adjuvant radiation therapy is generally advocated in cases of subtotal resection and malignant tumors [4–8].

This article presents the relevant surgical anatomy of the cauda equina region, and surgical details of cauda equina tumors resection. Specific surgical considerations on different tumor histological entities are made. Then, tricks to avoid complications are given, focusing particularly on neuromonitoring assistance.

Relevant surgical anatomy

In adults, the conus medullaris is generally found at the L1–L2 level. Below the skin and subcutaneous tissue, the posterior thoraco-lumbar fascia, in continuation with the supraspinal ligament, extends laterally from the spinous processes, covering the underlying deep muscles of the back. These are the erector spinae – also called sacrospinalis – and transversospinalis muscles, lying on either side of the vertebral column. The transversospinalis muscle group lies deep to the erector spinae muscle and, in the lumbar region, is essentially composed of the multifidus, rotatores and interspinales muscles. The bony

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structures encountered are the long and horizontal spinous processes, the wide and broad lumbar laminae, and the facet joints. The ligamentum flavum binds lamina to lamina, arising from the ventral surface of the caudal lamina and inserting to the dorsal border of the neighboring rostral lamina, and is discontinuous in the midline [2, 3]. The epidural space, between dura mater and vertebral periosteum, contains fat and venous plexuses that surround the spinal dura mater, the outermost covering of the spinal cord. The dural sac usually terminates at the level of S2 and is anchored to the coccyx by the external filum terminale. The dura also follows nerve roots to their spinal ganglia, thus forming a sheath that adheres to the periosteum lining the intervertebral foramina. The underlying thin and avascular arachnoid mater lines the dura but is not attached to it, merely adhering to it through the pressure exerted by the cerebrospinal fluid contained within (subarachnoid space). The pia mater, the third and innermost covering of the spinal cord, closely follows its surface features and, caudally to the medullary cone, it forms the internal filum terminale, which extends to the tip of the dural sac. At this level, dentate ligaments do not exist anymore and do not segment the subarachnoid space, as is the case in medullary levels. The enlarged subarachnoid space inferior to the medullary cone is called the lumbar cistern and encloses the nerve roots coursing through it towards their respective intervertebral foramina; together these nerve roots form the cauda equina.

The vascularization of the cauda equina nerve roots is provided by segmental arteries from the aorta and the iliac vessels, respectively, via the lumbar and lateral sacral arteries; these vessels follow the nerve roots to the medullary cone where they reach the three longitudinal arterial axes supplying the spinal cord.

Description of the technique

Under general anesthesia, the patient is settled in the prone position, and neuromonitoring (motor and somatosensory evoked potentials (EPs), anal sphincter electromyography (EMG)) lines are placed. Hallogen anesthetics should be avoided as they interfere with electrophysiological recordings; therefore, anesthesia should solely rely on narcotics (Propofol) and analgesics (Sufentanil). IV Cefazoline, or IV Vancomycine in case of MRSA positive patients, is administered in the immediate pre-operative period as antibiotic prophylaxis.

Fluoroscopic confirmation of the level is made. After skin disinfection and draping, a standard midline approach is performed, subperiostally exposing the desired laminae. It is important to measure the extension of the exposure on preoperative MRI, in order to have access both to the top and to the bottom of the tumor. In adults, we perform standard laminectomy using a high-speed diamond drill and Kerrison rongeurs, while in the pediatric population we prefer laminoplasty to avoid risks of postoperative instability.

Ultrasound may also be used over the dura to better localize the tumor before meningeal opening. After careful epidural hemostasis and under microscopic vision, the dura mater is incised in the midline with a microsurgical knife and is attached to the overlying muscle with 3.0 Vycril sutures. The arachnoid is then also opened and attached to the dural leaves using microclips.

Usually, the lesion is easily identifiable and its relation to neighboring neural structures is clear. The lesion needs to be separated from the surrounding nerves, and we suggest doing this by pulling the lesion away from nerves and not the contrary, so as to reduce nerve manipulation as much as possible; neuromonitoring gives crucial information during this step. Further manipulation should be immediately stopped if a loss or reduction in amplitude of EPs is noted. Coagulation is allowed only if coupled with abundant irrigation. Vessels coursing from the filum terminale to the tumor should be cauterized, while vessels following nerve roots should be preserved (as shown in the video). Surplus cerebrospinal fluid (CSF) is aspirated through a cottonoid interface to avoid suction of nerves. Debulking with the aid of CUSA may be useful for resection of larger tumors. Once the tumor has been excised, the microclips are removed and the dura mater is sutured in a watertight manner. At this point a Valsalva manoeuvre can aid in determining whether this is the case. Epidural haemostasis is achieved using haemostatic sponge (e.g., Gelfoam®) and irrigation. In case of laminoplasty, laminae are reinserted and fixated with microplates and screws. The wound is then closed in layers.

Ependymomas of the filum terminale appear as round, well-circumscribed lesions compressing the cauda equina. They arise from the filum terminale, so this structure needs to be recognized during surgery; it usually presents as a thick cord surrounded by tortuous vessels, which should be coagulated and sectioned about 1 cm cranially and caudally to the lesion (Fig. 1).

In the case of meningiomas, the base of implantation should be identified on preoperative MRI. It should be first addressed during surgery in order to achieve devascularisation of the tumor, and, if possible, it should be resected and duroplasty performed. If the tumor itself is too big, one can also first perform debulking and then attack the base of implantation.

For schwannomas, the surgeon should begin by identifying the nerve roots these tumors arise from. If the involved nerve root is no longer functional (verified using a nerve stimulator, e.g., Neurosign®), it can be sacrificed to remove the tumor. If some function still persists, the nerve root

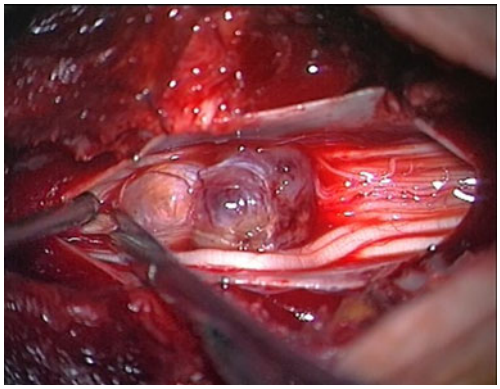

Fig. 1 Intraoperative image showing the relation between tumor and nerve roots as well as the filum terminale, which is being sectioned as described in text

should be dissected under microscope assistance, and only the concerned fascicle sectioned.

Complete resection of malignant tumors (metastasis, MPNST) is difficult, because of the tight adherences usually existing between tumor and rootlets. Resection should be stopped as soon as neuromonitoring signals worsen. The tumor remnant is then addressed to complementary radio-oncological treatment.

Indications and limitations

Tumors of the cauda equina usually require surgery. Small meningiomas and neurofibromas that do not cause symptoms, particularly in elderly patients, need not be removed but should be closely followed.

Benign tumors (ependymomas, paragangliomas, schwannomas) should be completely resected following standard technical procedures, as described above. Patients with neurofibromatosis may have many small tumors involving multiple nerve roots. In this situation only symptomatic tumors should be removed.

The goals of surgery are: 1. obtaining a tissue sample for pathology; 2. decompressing the nerve roots and thus improving symptoms or preventing further neurological deterioration.

Malignant tumors (rare) are associated with greater neurological morbidity, because they are often not well defined, with adherences to nerve rootlets making their resection quite dangerous [6]. Nevertheless, we advocate surgical treatment as a means of providing immediate pain relief and improvement in quality of life in cancerous patients.

In the case of metastasis to the cauda equina, a whole body CT scan should be performed in search of the primary tumor

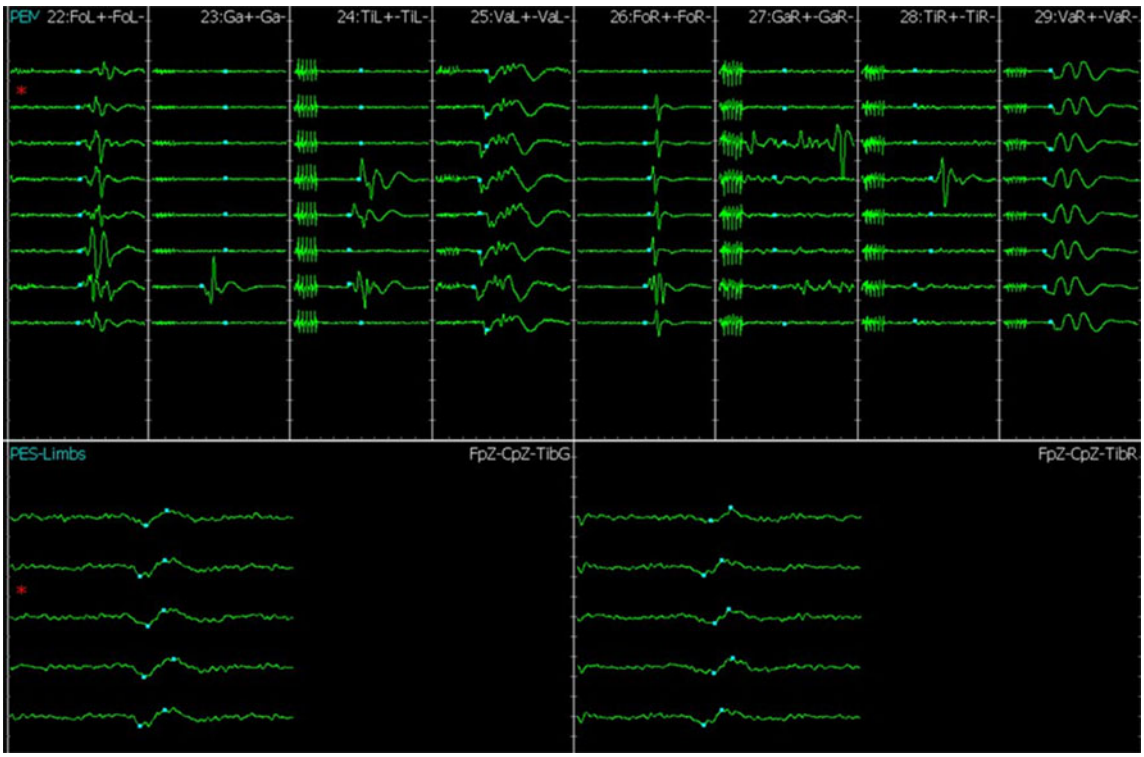

Fig. 2 Intra-operative motor and sensory evoked potentials. Dural incision occurred at the time indicated by the red asterisk (*). Motor evoked potentials (MEPs; Axon Eclipse, Axon Systems Inc, Hauppauge, NY, USA) were conducted and performed with transcranial electric stimulation (5 biphasic pulses, 350 Hz, 0.4 ms phase duration). The amplitude of responses was monitored. Sensory evoked potentials (SEPs) were conducted and performed through tibialis nerve stimulation (80 repetitions, 2.9 Hz, 0.2 ms phase duration). No deterioration in MEPs or SEPs was observed

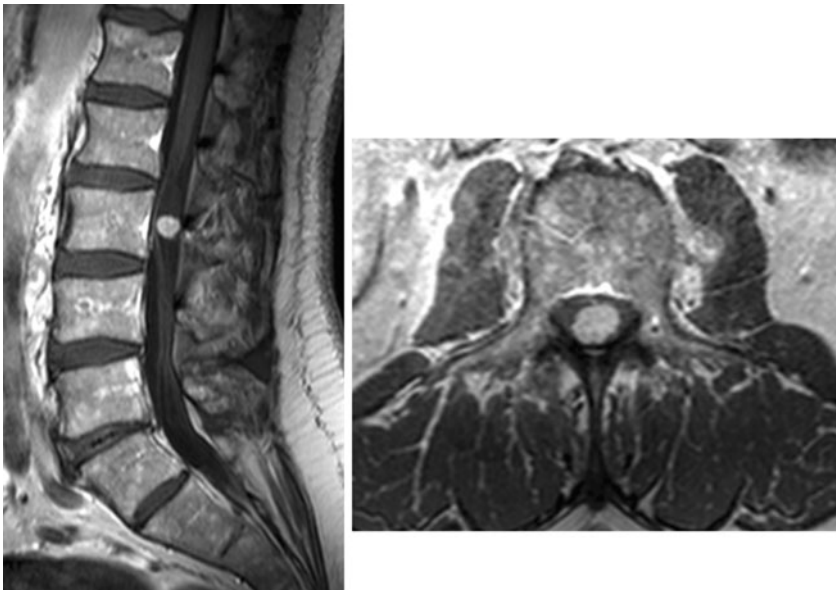

Fig. 3 **a** & **b** Sagittal (**b**) and axial **c** pre-operative MRI sequences showing a round intradural lesion with intense contrast enhancement, at the level of the L3 vertebra, pushing aside neighboring nerve roots

and/or secondary metastatic foci. Dissemination from posterior fossa tumors (medulloblastoma, ependymoma) should also be evoked and ruled out.

If a lymphoma or plasmocytoma is diagnosed, radiotherapy and chemotherapy should be preferred.

How to avoid complications

Microsurgical technique and spinal cord neuromonitoring (Fig. 2) (motor-evoked and sensory-evoked potentials, as well as sphincter electromyography) are considered indispensible in both spinal cord and cauda equina tumor surgery, and should systematically be used, as they increase rates of total resection while preserving neurological function [1, 7]. Gentle nerve dissection should be done under microscope assistance, pulling away the tumor from the nerves and not the opposite.

Careful epidural haemostasis is crucial in avoiding postoperative hematomas, which may lead to a neurological catastrophe and may require surgical drainage.

A postoperative CSF leak may occur if the dura is not closed in a watertight fashion. First-line treatment in such cases is to insert a spinal drainage above the operation site during 5 days to reduce CSF pressure. The patient is not

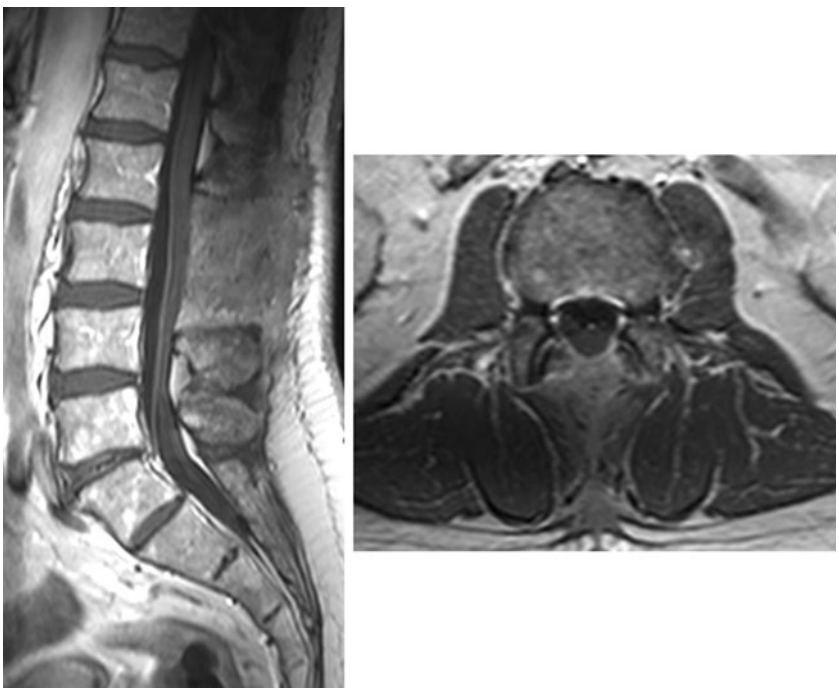

Fig. 4 **a** & **b** Sagittal (**a**) and axial (**b**) post-operative MRI sequences with contrast injection, 3 months after surgery, showing L3 laminectomy and partial laminectomy of L2, and absence of a tumoral recurrence

allowed to stand till the drainage is removed. If this fails or if drainage is not possible, surgical revision is necessary. We usually employ a muscle or fat graft and we reinforce it with fibrin glue.

If a postoperative subcutaneous CSF collection is detected, conservative treatment with recumbency and compressive bandage is recommended. If the skin and stitches are under tension, surgical revision is indicated.

Specific peri-operative considerations

Diagnostic MRI (Fig. 3a, b) provides information concerning tumor localization, extension, and morphology that need to be taken into account during surgery and pre-surgical planning. A pre-operative neurophysiological work up can further inform upon which nerve root is possibly involved.

Histopathological analysis of the excised tumor provides a diagnosis as well as information on the lesion's nature; it is generally accepted – although variation does exist in the literature – that patients with benign subtotally resected tumors or those with malignant lesions should receive post-operative radiation therapy. A neuro-oncological work-up should therefore be performed and each case discussed individually.

We routinely place a bladder catheter preoperatively for surgeries expected to last for more than 3 h. Transient bladder dysfunction is sometimes observed after surgery and a catheter may need to remain in place for a number of days.

Postoperative deep venous thrombosis (DVT) may be prevented with early mobilization and subcutaneous heparin injections.

If neurological deficits are present in the post-operative period, patients should be addressed to a neuro-rehabilitation unit. Patients are able to return home when their medical condition is stable. A post-operative MRI is performed at 3 months after surgery (Fig. 4a, b).

Specific information to give to the patient about surgery and potential risks

In addition to the general risks and complications such as hemorrhage, infection and risks associated to anesthesia, patients should be informed of the specific potential risks associated with surgery in the region of the cauda equina: lower limb sensory-motor deficits, urinary and anal sphincter dysfunction, and CSF leak. Patients should also understand that surgery might not lead to improvement of pre-operative neurological deficits – which is especially so in cases of malignancy – the goal of surgery being rather to prevent further deterioration. However, pain usually does improve, and this normally occurs immediately after surgery, thus significantly enhancing quality of life of patients with malignant tumors.

Key points

- Tumors of the cauda equina are rare entities that usually require surgery.
- Microsurgical technique and neuromonitoring are important as they increase rates of total resection while preserving neurological function.
- During dissection of adherent nerve roots, the tumor should be pulled away from the nerve roots and not the nerve roots from the tumor.
- Vessels coursing towards the tumor should be coagulated, while vessels following nerve roots should be preserved.
- The first step in the surgery of cauda equina meningiomas should be devascularisation of the dural base of implantation.
- In the case of schwannomas, if some function persists in the nerve root in question, the latter should be dissected, and only the concerned fascicle sectioned.
- Neurological function should be favored over complete resection, especially in patients with malignant cauda equina tumors.
- Dura should be closed in a watertight fashion.
- Careful epidural haemostasis should be performed.
- The goal of surgery is to prevent further neurological deterioration and patients should understand that pre-operative deficits might persist after surgery.

Conflicts of interest None.

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