Technical Note & Surgical Technique

Quadrantectomy for resection of spinal ependymomas with a new classification of unilateral approaches regarding bone drilling and the use of a new tool: The Balak ball-tipped water jet dissector

Naci Balak *

Department of Neurosurgery, Göztepe Education and Research Hospital, Kadıköy (Chalcedon), Istanbul, Turkey

1. Introduction

Although unilateral hemilaminectomy is a relatively widespread procedure for decompression of the spinal canal for degenerative diseases, it is seldom used for resection of spinal intradural lesions [1–15]. “The unilateral approach” is a broad term, which can be misleading; its use in the literature to refer to a variety of approaches may result in a failure to distinguish between them. For example, a unilateral approach may or may not include the removal of the unilateral facet joint, the spinous process, the interspinous ligaments, the contralateral muscles or the contralateral hemilamina. It should also be noted that the amount of required bone removal for treatment in the surgery of a spinal intradural tumor differs from that of spinal degenerative stenosis.

These variations in the procedure produce very different results in post-operative spinal instability. Hence, in order to eliminate misunderstandings and provide more sound evaluations of scientific articles in the field, the use of specific terms for modifications of the unilateral approach are needed.

The term “quadrantectomy” to denote a unilateral partial hemilaminectomy, in which the facet joint and spinous process are not removed was first described by Mahmut Gazi Yaşargil in 1991 [3,16]. The word “quadrant” refers to a sector equal to one quarter of a circle. Unfortunately, in a review of the previous literature, we were unable to find a consented description of the anatomical extent of hemilaminectomy in the unilateral approach to spinal intradural tumors. In this report, the technique we used is described, the relevant literature is reviewed and conclusions are drawn. The word “quadrantectomy”, has been used to name the procedure, while, to help eliminate any confusion in the literature regarding bone drilling, a new
classification of unilateral approaches for resection of spinal intradural tumors is proposed. The author also describes an innovative tool, which was found helpful in the dissection of cauda equina nerve roots in the resection of ependymoma.

2. Methods

Two patients who underwent surgical treatment for spinal intradural tumor are presented. Preoperative evaluation consisted of physical examination and radiological imaging, including computed tomography (CT) scans, magnetic resonance imaging (MRI) scans with gadolinium and routine radiographs. The patients gave informed consent and underwent a minimally invasive approach with resection of the intradural tumor. The tumors were resected using microscopic dissection techniques and neuro-monitoring. An instrument specifically designed for the dissection of the cauda equina nerve roots facilitated the surgery. The surgical technique is presented with stepwise photographs.

3. Illustrative cases

3.1. Patient 1

3.1.1. Clinical presentation and imaging

A 27-year-old male patient was admitted to our hospital after complaining of a progressively severe low back pain and radicular pain in the lower extremities, more severe on the left side, for the prior eight months. Neurological examination revealed a positive straight leg-raising test at 50 degrees on the left side. The patient's preoperative spinal axial and sagittal contrast-enhanced T1-weighted, and sagittal T2-weighted MRI scans are seen in Fig. 1A–C.

3.2. Patient 2

3.2.1. Clinical presentation and imaging

A 39-year-old female patient was admitted to our hospital after complaining of a progressively severe low back pain and hypoesthesia in the lower extremities for the prior two years, more prominent on the left side, and radicular pain in the right lower extremity for the prior three months. Neurological examination revealed a positive straight leg-raising test at 40 degrees on the right side and hypoesthesia in both the lower extremities. The patient's preoperative spinal sagittal contrast-enhanced T1-weighted and T2-weighted MRI scans are seen in Fig. 2A–B. There was also a disc protrusion compressing the right L5 nerve root at the level of L4–5.

3.3. Operative technique

In patient 1, one day before the surgery, the level of the spinal mass was defined with the help of a contrast enhanced T1-weighted MRI scan and oil-filled markers stuck on the skin with plasters. This was crucial, since limiting the extent of the bone resection in the planned unilateral approach was vital for the protection of spinal stability. On the day of the operation, the electrodes of the spinal neuro-monitor were inserted. The patient was operated on in the neutral prone position without any bending of the lower back. The level of the spinal mass was checked once again using fluoroscopy in the operating theater. Since the nerve roots were pushed to the left side, a right-sided approach was preferred. A skin incision of approximately 11 cm was made in the skin in the midline at the appropriate level, the fascia was cut and the muscles were dissected subperiosteally without using any unipolar electrocautery. At the stage of the opening of the dura, muscle relaxants were discontinued, and spinal neuro-monitoring was started. The L2, L3 laminas were identified in the center of the exposed area, L1 and L4 being in the opposite corners. Then, facet joints were identified in order for them to be protected from damage. A partial hemilaminectomy of about 10 mm in width on the L2 and L3 along their whole length rostrocaudally was made using an electric drill and kerrison punches under a Zeiss surgical microscope (Carl Zeiss Meditec AG, Germany). The bony exposure was enlarged by approximately 2 mm medially.

Fig. 1. Pre-operative radiological imaging scans of Case 1. A, T1-weighed sagittal contrast enhanced magnetic resonance imaging scan, B, T1-weighed axial contrast enhanced magnetic resonance imaging scan, C, T2-weighted sagittal magnetic resonance imaging scan.

Fig. 2. Pre-operative radiological imaging scans of Case 2. A, T1-weighed sagittal contrast enhanced magnetic resonance imaging scan, B, T2-weighted sagittal magnetic resonance imaging scan.
towards the contralateral side using diamond drills and 1–2 mm sized Kerrison punches (Fig. 3A). The bone drilling was kept about 2–3 mm medial to the facet joints (Fig. 3B). The superior and inferior margins of the mass were checked using ultrasound. The exposure had to be extended a few millimeters inferiorly by removing part of the L4 lamina. Then, the dura mater was opened in the midline and tenting sutures were placed (Fig. 3C). The arachnoid mater was opened and suspended separately (Fig. 3D). The tumor was covered by nerve roots (Fig. 3D–E). Debulking of the tumor was necessary for the safety of nerve roots and the avoidance of retraction on them, since neuro-monitoring showed electrical activity in response to even slight retraction, albeit this activity was neurophysiologically acceptable and deemed to be innocuous (Fig. 3F). The tumor was dissected from the nerve roots first on its superior margin and afterwards on the inferior margin (Fig. 3G and 3H respectively). This was because the dissection of the tumor at its poles at this early stage of the procedure is critical for the protection of the nerve roots as the surgery progresses. Otherwise, it is very difficult to track the continuity of the nerves. The meticulous dissection was continued; the feeders of the tumor were coagulated by bipolar electrocautery, which was low intensity at the level of 10. The filum terminale that was attached to the tumor was coagulated and cut (Fig. 3I). Then the remainder of the tumor among the nerve roots was carefully removed, until no residual tumor was seen under the microscope. The surgical area was washed and hemostasis was checked and secured. The arachnoid mater and the dura mater were tightly closed using a 7/0 suture and a 5/0 suture respectively. The patient did well after surgery and ambulated immediately. The Foley urinary catheter was removed on the second day after surgery and no problem occurred. The patient was discharged on the third day after surgery without any neurological deficits. Moreover, he stated that his radicular pain had completely disappeared. A contrast enhanced MRI scan obtained on the second day after surgery showed that the tumor had been totally removed and the nerve roots had regained their natural shape (Fig. 4A–C). Histopathological diagnosis was a myxopapillary ependymoma. At two-year follow-up after surgery, the patient was perfectly well.

The surgical technique used in Patient 2 was the same as that in Patient 1, apart from the removal of the disc protrusion at L4–5 level using the classical microdiscectomy procedure and the use of a new tool named by the author (NB) as the Balak ball-tipped water dissector.

Fig. 3. Case 1: The intra-operative images show that the intradural exposure was very good. A, The bone is drilled medially towards the contralateral side. D: dura. B, The bony exposure is completed. Fj: facet joint, Sp: spinous process, D: dura. The arrow shows the facet joint. C, The dura mater was opened; the arachnoid mater is seen to be intact. The arrows show the superior and inferior margins of the tumor. T: Tumor. The asterisks mark the nerve roots. D, E, A higher magnification, the arachnoid mater has started to be opened. The nerve roots cover the tumor T: tumor. F, The tumor is being debulked. G, The superior margin of the tumor has been dissected. The nerve roots are seen anteriorly (the arrow). H, The inferior margin of the tumor has been dissected. The nerve roots are seen anteriorly (the arrow). I, The filum terminale is seen before being coagulated and cut. T: tumor, f: filum terminale. The asterisks denote the nerve roots.
This tool was found to be helpful in separating the nerve roots that completely covered the tumor (Fig. 6B–C). It made it easier not only to confirm the exact site of the tumor but also to dissect the nerve roots from the tumor. Histopathological diagnosis in this case was also a myxopapillary ependymoma. At one-year follow-up after surgery, the patient was perfectly well. A summary of the surgery is shown in Fig. 6A–F. A contrast enhanced MRI scan obtained on the second day after surgery showed that the tumor had been totally removed and the nerve roots had regained their natural shape (Figs. 7A–B). The surgical window for exposure drilled in the hemilamina was about 7 mm (Fig. 7C).

3.4. The Balak ball-tipped water jet dissector

The Balak ball-tipped water jet dissector is simply a suction tube, 15 cm in length and 5 mm thick (about the thickness of a pencil) with a 2 cm long thin tube attachment (Fig. 5A). The thickness of the thin tube attachment is that of a regular intramuscular syringe needle. The tip of the thin tube is a 1mm- diameter ball with a micro-hole for the flow of water (Fig. 5A inset). The mechanism of the irrigation system is similar to that of Nagy et al., in other words, hand-controlled. A feeding tube is connected to the suction tube and a scrub nurse or resident applies saline in low water jet pressure through a 20–50 mL syringe (Fig. 5B). The tool was designed by the author and produced by a manufacturer of surgical instruments (Bahadır®, Bayrampaşa, İstanbul, Turkey).

4. Discussion

Standard approaches to spinal ependymomas often involve a simple laminectomy in adult patients or an osteoplastic laminotomy in pediatric patients [17]. However, safe removal of spinal tumors using minimally invasive exposures have also been described, including unilateral hemilaminectomy, hemi-semi laminectomy, multilevel interlaminar fenestration and hemilaminectomy combined with restoration of vertebral laminae [3–5,16,18–26] It is well known that secondary instability, subluxation, or scoliosis may occur after laminectomies, especially in children [3,27]. Therefore, the use by neurosurgeons all over the world of the unilateral approach for spinal tumors is, albeit gradually, increasing.

4.1. Consequences of no universal definition of variants

Unfortunately, there is no universal definition of the standard extent of a hemilaminectomy, despite the fact that there is an extensive literature presenting a comparative analysis of the clinical outcomes of laminotomy, laminectomy and hemilaminectomy, as well as discussion of the effects of increasing degrees of resection of the facet joints upon the normal spinal biomechanics, including expected thresholds for
instability and the inevitability of instrumentation [28–31]. The use of a unilateral approach does not ensure that the surgeon protects facet joints and midline structures during the surgery, although this is the aim and main advantage of the unilateral approach. As seen in Fig. 8D–E–F, it is also possible to transform a unilateral minimally invasive surgery into a total laminectomy by drilling or removing the facet joint and/or midline structures. Fig. 8F depicts one of the worst scenarios of a unilateral approach, with removal of all the posterior bony elements as done in traditional midline total laminectomy while obtaining lesser surgical exposure vision than the traditional procedure. In these situations, it is deceptive to compare a unilateral approach with a regular laminotomy/laminectomy. This is why the author prefers use of the term quadrantectomy instead of unilateral hemilaminectomy.

Thus, the question of how much bone should be drilled medially and laterally and at the base of spinal process can be raised. Multiple factors will affect the decision, including the thickness and shape of the lamina, the weight of the patient, the depth of the working area, the size and site of the tumor, the angle and zoom of the surgical microscope, the microsurgical instruments, the skill of the surgeon etc. The size and shape of the quadrantectomy should be tailored to each individual case. A window in the bone one fourth of the lamina in size and located in the approximate middle of the hemilamina can usually be enough to see all the posterior surface of the spinal dura as seen in Fig. 8C. However, surgical manipulations through a quadrantectomy, which has a sufficient but narrow surgical corridor, are not as easy to perform as in the case of a total laminectomy, which provides a straightforward view as seen in Fig. 8B. If the shape of an imaginary triangle based on the dura as depicted in red in Fig. 8A is obtuse-angled, then a larger laminectomy may be necessary than in the case of an acute-angled triangle. It is possible to extend the size of a laminectomy laterally towards the facet or medially towards the spinal process and opposite site lamina when necessary (Fig. 8D–E–F). However, such a unilateral approach will not be a quadrantectomy. Furthermore, extending a laminectomy towards the opposite hemilamina will not create a significant additional field of vision of exposure and removal of midline bony structures will take away most of the benefits of a unilateral approach.

4.2. Proposal for classification of unilateral approaches for the removal of spinal intradural tumors

To accurately compare the pros and cons of the traditional laminectomy and the unilateral approach in the removal of spinal

**Fig. 6.** Case 2: The intra-operative images show that the intradural exposure was very good. A, The bony exposure is completed, the dura mater have been opened. The tumor is not visible since the nerve roots cover the surface. B, C, The Balak ball-tipped water jet dissector is used. The nerves are seen to be separated to the sides. D, E, The tumor is exposed and totally removed. The Asterisk indicates the tumor. F, The nerve roots resumed their normal shape and position after the resection of the tumor.
opened the dura. Several modifications of unilateral approaches for resection of spinal intradural tumors, which takes account of bone drilling, is proposed as shown in Table 1. This classification is not intended for usage in the same way in the unilateral approach for decompression in spinal degenerative stenosis, where the aim differs. In intradural tumor cases, the exposure, while being sufficient to remove the tumor, should be kept as minimal as possible. The dura is opened and the cerebrospinal fluid is released to gain more space. On the contrary, in the surgery for spinal stenosis, the aim is not to provide exposure, but to drill as much bone as possible to sufficiently decompress the neural structures without opening the dura. Several modifications of the unilateral approach have been reported. These rare techniques cannot be classified separately and are grouped as Type 7 in Table 1. For example, the bone can be re-inserted after unilateral hemilaminectomy performed using different techniques for the removal of the bone [32]. There are other rare unilateral techniques. Among them, Xie et al. used a unilateral approach in the surgery of cervical intramedullary ependymoma and called it unilateral multilevel interlaminar fenestration [33]. Tredway et al. performed a hemilaminectomy with undercutting of the base of the spinous process and removal of the contralateral ligamentum flavum and used a tubular retractor system [34].

4.3. Quadrantectomy - when is it appropriate

Although it was possible to successfully resect an intradural tumor through a relatively narrow corridor using quadrantectomy in the cases presented here, for at least two reasons, the procedure should not be considered appropriate for all cases of intradural tumor lesion. First of all, lengthy microsurgery laboratory training is necessary. Secondly, in these cases, the author presents lesions located at the conus medullaris/cauda equina, in which more aggressive and less delicate manipulation of the neural elements may be nonhazardous. Such an approach may not be equally safe for intradural spinal cord tumors at all levels, including the cervical, thoracic and lumbar spine. Morbidity in spite of delicate manipulation of the neural elements may be higher in the thoracic spine than in other levels, although this may not necessarily be related to the procedure itself.

4.4. Water jet dissector

The appropriate use of water jet dissection instruments in neurosurgery is demonstrated to be safe in the surgery of various pathologies, such as intact removal of a intracerebral hydatid cyst [35–37]. The water dissection technique, using the separating effect of injected low gentle pressure physiological saline, was introduced by Toth et al. in 1980s [38]. This technique has been considerably used in the opening of cerebral fissures in several European centers [39]. However, very few clinical or experimental studies of water jet dissection have been reported to date. The water jet dissector described in this article differs from others mainly in its ball-shaped tip. The author considers that the ball tip causes less trauma to the nerve roots. However, the water jet technique should be used cautiously since injury to normal neural tissue could occur at the higher jet pressures needed for tumor dissection at the tumor-spinal cord interface. Therefore, it should be used selectively in the microsurgical resection of some specific lesions. The author found this instrument to be a very helpful dissecting tool in the region of the cauda equina.

5. Conclusion

Spinal tumors occupying both sides of the spinal canal can be easily removed using the quadrantectomy approach. As long as well refined microsurgical techniques are used, this approach to intradural spinal tumors is a safe method even in the case of totally solid tumors that have completely filled the dural sac, and also permits the surgeon to handle the contralateral side. The correct terminology for a standard partial unilateral hemilaminectomy as described in this article is quadrantectomy, which preserves the facet joints and midline structures. This approach should be regarded as a subtype of unilateral approaches to spinal intradural lesions. This distinction and the use of the new classification proposal for unilateral approaches will be helpful in comparison of the results of various surgical approaches in terms of postoperative spinal instability. The ball-tipped water jet dissector is a beneficial tool for the surgery in region of cauda equina.

Disclosures

The authors report no conflict of interest concerning the materials, devices or methods used in this study or the findings specified in this paper.

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References


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Fig. 8. The size of bone drilling in a unilateral approach. A, an imaginary triangle based on the dura inside the spinal canal is shown. The shape of this triangle as well as the thickness of the lamina is significant for the prediction of how much bone should be removed. B, bone removal in conventional total laminectomy approach, C, bone removal in a quadrantectomy approach, D, bone removal extended towards the ipsilateral facet, E, bone removal extended medially, F, bone removal includes opposite site, similar to total laminectomy approach. The imaginary shapes: blue circle: intradural tumor/neural structures, white circle: dural sac, yellow lines: vision field, black areas: bone removed.

Table 1

Proposal for a new classification of unilateral approaches for resection of spinal intradural tumors regarding bone drilling.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Unilateral partial hemilaminectomy without drilling of the medial facet or the spinal process including its base (quadrantectomy).</td>
</tr>
<tr>
<td>2</td>
<td>Unilateral partial hemilaminectomy with drilling of the base of spinal process, no drilling of the medial facet</td>
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<tr>
<td>3</td>
<td>Unilateral partial hemilaminectomy with drilling of the unilateral facet joint, no drilling of the spinous process</td>
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<tr>
<td>4</td>
<td>Unilateral hemilaminectomy with drilling of the unilateral facet joint and substantial part of spinous process</td>
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<tr>
<td>5</td>
<td>Unilateral hemilaminectomy with drilling of the unilateral facet joint and the entire spinous process</td>
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<tr>
<td>6</td>
<td>Drilling of the entire spinous process and the contralateral hemilamina with or without drilling of the facet joints (similar to traditional total laminectomy).</td>
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<tr>
<td>7</td>
<td>Other non-classified rare techniques, such as so called bridging hemilaminectomies, hemilaminatomy with reinsertion of the bone etc.</td>
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