



# SPLIT LAMINOTOMY AND COMPLEMENTARY SPACER INSERTION FOR OPENING AND ENLARGEMENT OF THE THORACIC SPINAL CANAL AT INFILTRATIVE INTRAMEDULLARY TUMOR REMOVAL

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**SPLIT LAMINOTOMIA ÉS TÁVTARTÓ CAGE BEHELYEZÉSE A GERINCCSATORNA FELTÁRÁSA ÉS TARTÓS DEKOMPRESSZIÓJA CÉLJÁBÓL A THORACALIS INTRAMEDULLARIS DAGANATOK SEBÉSZETÉBEN**

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**Objective** – The author main objective was to improve the previously developed technique of split laminotomy and moderate enlargement of the spinal canal with preservation of the majority of posterior structures, and to avoid the complications of the classic autologous bone grafting procedure.

**Methods** – A multilevel spinous process splitting and distracting laminotomy technique with complementary spacer insertion between the laminar parts was developed. We used Poly-Ether-Ether-Ketone (PEEK) cages. This improved method was used in five patients to remove malignant intramedullary tumors at the thoracic level.

**Results** – Adequate surgery of the tumors located intramedullary, and permanent decompression of the spinal canal was achieved in all patients using our new modified procedure. The results have been postoperatively confirmed with MRI and CT. The affected spine was the thoracic in all cases. The numbers of split laminae were three to five. Histological results were as follows: four intramedullary astrocytomas, one ependymoma. The ependymoma was completely, while the astrocytomas were only subtotally removed. In all cases heterologous grafts were inserted between the sides of the distracted laminae, to achieve the enlargement of the spinal canal. The mean duration of the whole surgical procedure was 118 minutes (range 91 to 145 minutes). The average follow-up was 11.2 months, with the range from five to 16 months. Upon postoperative neurological follow-up, no complications were revealed related to the newly developed procedure. The postoperative follow-up CT scans demonstrated bony healing, with a cage between the osteotomized faces. No compression or dislocation of the spacer was seen. Instability was not detected in any of the patients by flexion or extension lateral radiographs.

**Conclusion** – This modification of the split laminotomy and heterologous grafting method fulfills the requirements of other laminotomy techniques. The split laminotomy is suitable for removing intramedullary tumors, and the poste-

**Célkitűzés** – A szerzők fő célja az intramedullaris tumorok eltávolításához kifejlesztett, a gerincoszlop stabilitását megőrző "split laminotomia" technika továbbfejlesztése volt úgy, hogy a dekompreszió során elkerülhetőek legyenek a saját csontgraft kivételével járó szövődmények.

**Módszer** – Öt beteget operáltunk a háti gerincszakaszon elhelyezkedő intramedullaris daganattal több szegmentumot érintő, a processus spinosusok hosszanti kettévágásával és a gerincsatorna egyidejű tágításával járó technika alkalmazásával. A laminák záródását a behelyezett PEEK távtartók segítségével akadályoztuk meg, így biztosítottuk a gerincsatorna tartós dekompreszióját.

**Eredmények** – Az általunk kifejlesztett műtéti technika alkalmazásával minden esetben megfelelő tumoreltávolítást tudtunk elérni, és egyidejűleg biztosítottuk a gerincsatorna tartós dekompreszióját is. A műtétet követően kontroll-MR- és CT-, valamint neurológiai vizsgálatokkal ellenőriztük betegeinket. Mind az öt esetben a háti gerincszakaszon elhelyezkedő intramedullaris, malignus tumort kezeltünk. A szövettani megoszlás a következő volt: négy astrocytoma, egy ependymoma. Az ependymoma teljes egészében, míg az astrocytomák csak részlegesen kerültek eltávolításra. A feltárás 3–5 laminát érintett. Minden esetben PEEK cage-t helyeztünk a szétfeszített csigolyaívek közé, a gerincsatorna dekompreszióját megőrizendő. Az átlagos teljes műtéti idő 118 perc volt (92–134 perc). A betegeket átlagosan 11,2 hónapig (5–16 hónap) követtük. A műtétet követő rendszeres neurológiai kontrollvizsgálatokon neurológiai szövődeményt nem észleltünk. A kontroll-CT-vizsgálatok kezdődő csontosodást ábrázoltak a behelyezett távtartón keresztül. Az implantátum összeroppanását vagy elmozdulását nem észleltük.

**Következtetések** – A split laminotomia továbbfejlesztett változata az egyidejű heterolog graft behelyezésével alkalmas a korábban használt laminectomiás feltárások kiváltására úgy, hogy a saját csontgraft kivételével járó komplikációk és szövődmények elkerülhetőek. A szétválasztott csigolyaívek és

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rior stabilizing structures of the spine, as the vertebral laminae and the longitudinal musculature are completely prevented. Due to use of allograft the complications of the classic hip bone grafting procedures are avoided. The spacers, inserted between the osteotomized faces, provided permanent decompression of the spinal canal, and bony healing – throughout the spacer – of the splitted vertebral laminae, without iliac graft complications.

**Keywords:** *intervertebral spacer, intramedullary tumor, laminotomy, splitting laminoplasty*

Multilevel laminectomy for exposing the spinal canal to remove spinal cord lesions has been widely used in spine surgery<sup>1-3</sup>. Many of short and late-time complications of this surgical procedure have been reported. Spinal deformities, instability, sUBLUXATION, invasion of haematoma and scar tissue into the spinal canal are the most often mentioned complications in the literature<sup>4-6</sup>. Several surgical procedures have been reported to preserve the posterior structures. Various kinds of laminoplasty techniques have been described with osteoplastic posterior spinal arch reconstruction, in tumor removal and in degenerative cases as well<sup>2, 7-9</sup>. The conventional posterior surgical approaches invariably separate the muscle attachments from the spinous processes and laminae. Damage to these muscles and bony connections can lead to persistent axial pain, cervical malalignment and spinal instability. To preserve the attachments of the musculatures new minimally invasive ways to explore the spinal canal have been developed. To follow the principle of less invasivity the split laminotomy technique for surgery of multilevel lesions located in the spinal canal was introduced<sup>10, 11</sup>. This surgical procedure is suitable for exploring and removing different pathologies located in the spinal canal. It has been proven, that the split laminotomy approach is suitable to remove intramedullary tumors located in the midline.

If total resection of an intramedullary tumor was not possible due to the infiltration to the surrounding spinal cord or regrowing of the malignant tumor is expectable, an enlargement of the spinal canal is needed. To achieve the permanent enlargement of the spinal canal and decompression of the spinal cord, an autologous iliac bone graft implantation was performed between the splitted laminae<sup>10</sup>. The bone grafting procedure is a well developed and widely used method in spine surgery. The tricortical iliac bone graft is most commonly used at ventral cervical discectomy or cervical corpectomy procedures<sup>12-16</sup>. According to the literature many of donor site complications known. Short term complications

processus spinosusok közé helyezett távtartók a gerinccsatorna tartós dekompresszióját, valamint a csontos átépülést biztosítják a behelyezett cage-en keresztül.

**Kulcsszavak:** *intervertebrális távtartó, intramedullaris tumor, laminotomia, split laminoplastica*

immediately related to the surgery most often associated to the graft harvesting area (15-25%). Severe impairment of postoperative quality of life by reduced capability of movement and pain in the iliac crest occurs about 14-18% of cases. Iliac crest wound haematoma were detected in 12-16%, rarely with the need of a second look surgery. Superficial wound infection and healing disturbance reported in 4-6% of patients. Iliac crest bone fracture reported in 1-2% of patients. The only long term complication of the iliac bone graft harvesting procedure is the permanent cutaneous hypaesthesia, found in 1-2% of patients<sup>17-20</sup>. To avoid the above mentioned complications, and to shorten the time of the surgical procedure, the use of different interbody spacers is widely accepted at spinal surgical procedures, as ventral cervical discectomy. With the cage implantation all of the the donor site complications, and the possibility of late-time bone graft resorption or compression is avoidable. The bony healing throughout the spacer is similar to the iliac crest bone graft procedure<sup>21-23</sup>. Solid fusion between the osteotomized parts can be shown about 12 months after the implantation. To push the advantage of allogeneous graft implants, the authors made a modification of the previously developed split laminotomy surgical procedure, by using a specially designed spacer, instead of the autologous iliac bone graft.

## Clinical materials and methods

The authors used the multilevel spinous process splitting and distracting laminotomy technique with complementary intervertebral spacer inserting in five adult patients with malignant intramedullary tumors, located in the thoracic spinal region. The technique is a modification of the multilevel split laminotomy technique with tricortical iliac bone grafting.

All the five cases, Poly-Ether-Ether-Ketone (PEEK) cages were used. There were three women and two men with an average age of 53.2 years (range 44-61 years) at the time of surgery (Table

**Table 1.** Characteristics of the patients

Patient no.	Age (yr)/sex	Histology	Resection (MRI)	No. of split laminae	Preoperative functional assessment	Postoperative functional assessment	Duration of the surgery (min)	Blood loss (ml)
1	44/M	astrocytoma Gr III	subtotal	3	II	II	91	79
2	59/M	astrocytoma Gr III	subtotal	4	II	I	131	90
3	47/F	ependymoma	complete	4	I	I	135	102
4	55/F	astrocytoma Gr III	subtotal	5	III	III	145	194
5	61/F	astrocytoma Gr III	subtotal	3	I	II	88	85

1.). Functional assessment (McCormic) was performed preoperatively and postoperatively every six months at the time of the MRI follow-up visits. To confirm the extension of resection and to check for recurrence or to follow the growing patterns of the tumor, all patients underwent postoperative MRI evaluations at three and six months postoperatively, thereafter every 6 months or as needed by the patient's condition. To check the bony changes, all patients had postoperative CT imaging as well immediately after the operation and repeatedly thereafter (at two, six, and 12 months).

The splitting and distracting of the spinous processes and laminae is identical to the surgical procedure detailed previously<sup>10</sup>. After opening of the dura, the intramedullary tumor was removed. Following removal of space occupying lesions, the dura was partially closed with or without the use of duraplasty. The narrow operative field and the limited lateral view by the operating microscope makes the duraplasty very difficult and time-consuming procedure. In our limited series we left the dural flaps opened, and covered the surface with heterologous dural patch and fibrin glue. Because of total resection of the intramedullary tumor was not possible due to the lack of recognizable cleavage (diffusely infiltrative tumors) and thus intraspinal space occupation was considered to be solved only temporarily, a bony decompression was indicated to create extra intraspinal space. To avoid the laminae returning to their original position – with the aim of moderate enlargement of the spinal canal – an intravertebral spacer was placed between the bony parts facing each other. The space between the distracted laminae was first measured then the appropriate sized, haemostatic gelatin sponge filled PEEK cages were inserted between the osteotomized parts of the spinous processes (**Figure 1.A, B**). We used the SOLIS Cervical Cage (Stryker Spine SAS, Z.I Marticot – 33610 Cestas France). This cage has a D shape design, with 4° wedge configuration. It has serrations on the top and the bottom face, and incorporates titanium spikes for fixa-

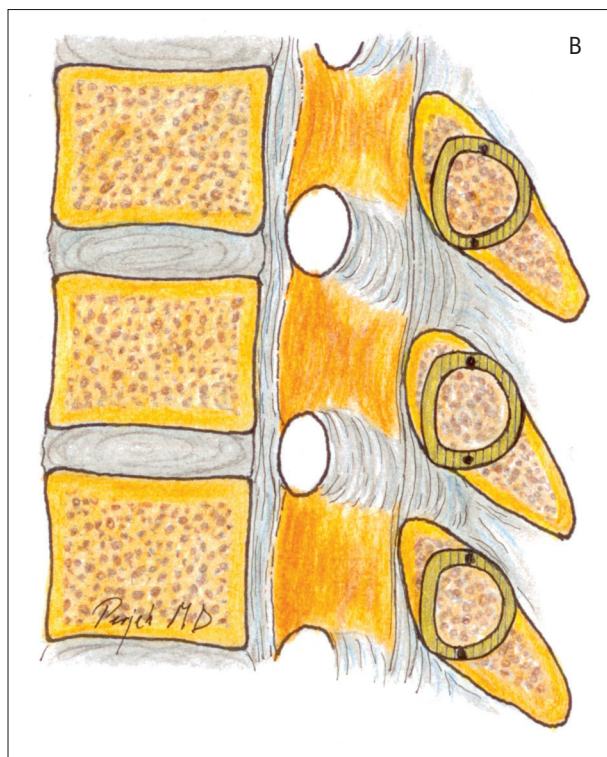
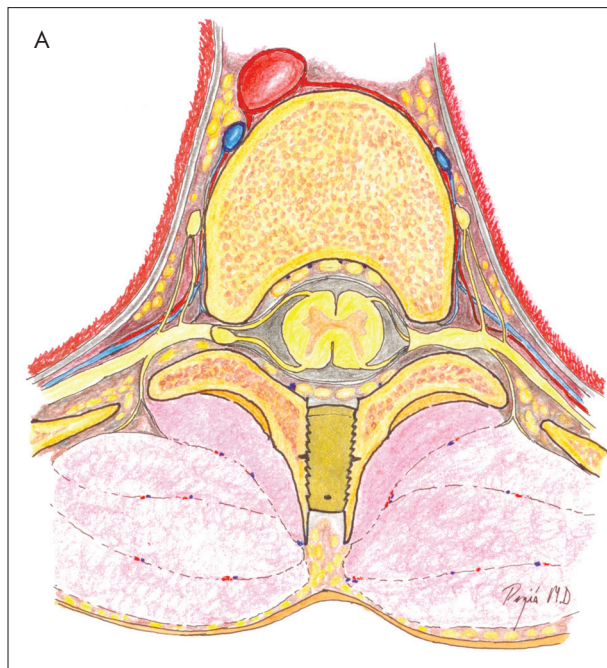
tion as well. The cage is available in two footprints, and a variety of heights ranging from 4mm to 12 mm. We inserted the cage between the laminae as the plane side of the D shaped cage facing toward the spinal cord, and the convex side of the cage facing outward. The wedge shape of the cage preventing it to sliding out, while the serrations on the top and bottom side preventing it to sliding into the spinal canal. The strong grasping power of the retracted laminae – returning to their original position – and the two pairs of titanium spikes – located both side of the cage – fixed it firmly in place. Precise insertion and continuous control of the inner edge of the cage under the insertion process was necessary to avoid penetration of the spacer into the spinal canal, and to avoid compression of the spinal cord. The technique is similar to the placement of an iliac bone graft.

The bony parts were sutured with Vycril (Ethicon, Inc., Sommerville, NJ) by passing the sutures through the cage and the holes of the halves created with a small burr. Finally, the fascia and the skin were closed.

## Results

We performed the modified split laminotomy procedure with cage insertion at the lower thoracic level in all cases. The number of split laminae was three to five. In all cases we inserted heterogenous grafts between all of the osteotomized laminar faces. We used Poly-Ether-Ether-Ketone (PEEK) cages.

The average follow-up was 11.2 months, with a range from five to 16 months. Histological results were as follows: four intramedullary astrocytomas (Grade III), 1 ependymoma Grade II). The resection of the intramedullary tumor was continued only until that layer where the tumor could clearly be differentiated from the surrounding spinal cord. The completeness of surgical removal depended only on the cleavage plane and not on the approach.



**Figure 1.** Illustrations show the splitted and distracted spinous process and the placement of the PEEK cages between the osteotomized faces in axial (A) and sagittal overview (B)

The use of PEEK cages between the osteotomized bony faces requires shorter operative time compared to the classic iliac crest bone grafting method. In our cases the mean duration of the complete surgical procedure was 118 minutes with the

range of 91 to 145 minutes. The unnecessary preparation and isolation of the bone graft harvesting area also spare about 12 to 25 minutes.

The mean blood loss was only 110 ml (range 79-194), as extensive detachment of the muscles, and the second skin incision and iliac bone harvesting was avoided. None of the patients required blood transfusion. No dural tear occurred in our short series. Injury to nervous structures was never observed. No wound infections occurred. The thoracic split patients were not braced due to the minimally disturbed anatomy.

The incidence of postoperative local pain was lower, within acceptable limits (VAS: 2 to 5). Furthermore, the patients needed smaller doses of analgesic medications, and early mobilization was allowed. Lack of the iliac bone harvesting procedure, no iliac crest pain was detected. The average length of hospital stay was 6 days (ranged 5 to 7).

Results of the preoperative neurological functional assessment in the astrocytoma group were as follows: Grade I, one of four patients, Grade II, two of four patients, and Grade III one of four patients. In 50% of all patients the initial neurological state was unchanged after the surgery, while in one case (25%) the initial signs and symptoms improved, and in one other case (25%) we detected the worsening of the neurological functions. The one patient, operated with an intramedullary ependymoma, the initial neurological symptoms were unchanged (Table 1).

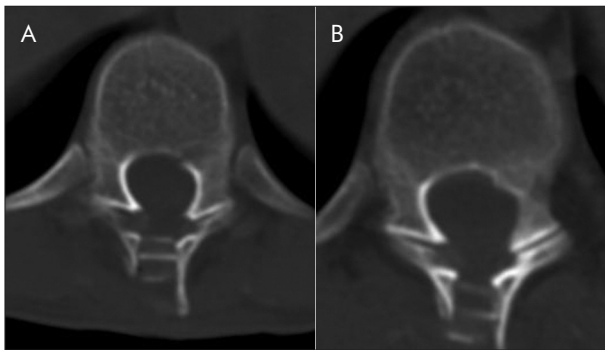
To confirm the extension of resection, all patients underwent postoperative MRI evaluations. The inserted PEEK cage with the incorporated titanium spikes does not disturb the evaluation of the spinal cord on MRI images. The ependymoma was completely removed, and the astrocytomas were subtotally removed, as seen by postoperative MRI at two months (Figure 2.). To check bony changes, all patients had postoperative CT imaging. Early postoperative CT scans and 3D reconstructions show the split halves of the spinous processes are distracted by the spacers with the planned enlargement of the spinal canal (Figure 3.). Later partial bony healing was seen, with permanent distraction of the laminae arches. No graft dislocation or compression were shown (Figure 4.). Some partial fracture of the spinous process were shown on postoperative CT scans, without clinical significance. Instability was not detected in any of the patients by flexion or extension lateral radiographs.

## Discussion

The surgical approach for treatment of intramedullary tumors has been laminotomy until the last

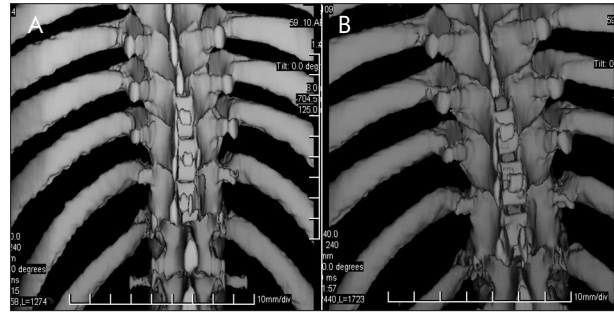


**Figure 2.** Sagittal T2-weighted magnetic resonance imaging scans show an intramedullary tumor in the thoracic region before (A) and 12 months after the surgery (B). On the postoperative MRI scan the inserted spacers are also shown



**Figure 3.** The postoperative axial computed tomographic scans show the distracted spinal processes, and the position of the cages 2 months (A) and 12 months (B) after surgery

decades. With the aim of preventing the frequently reported postoperative complications various types of surgical techniques have been developed. The main objective of this developments to preserve and reconstruct the posterior spinal structures. The spinous process splitting and distracting laminotomy technique fulfills the requirements of other minimal invasive laminotomy techniques and helps to preserve the attachments of the posterior spinal musculature. With this method the operative field is restricted compared to laminectomy, but according to the keyhole principle, it is still enough under the operating microscope for the surgery of lesions located within the spinal canal, especially of intramedullary lesions in the midline. Intraoperative identification of the cleavage plane makes removal of intramedullary tumors possible. If there is no recognizable plane in cases of infiltrative or malignant intramedullary tumors (or if intraoperative appearance suggests an infiltrating tumor), tumor removal



**Figure 4.** Three-dimensional reconstructed computer tomographic images show the distracted spinous processes and the positions of the spacers after surgery (A) and bony healing 12 months later (B)

is not continued at any cost, as this could be dangerous and unnecessary for the patient. If partial tumor removal is performed, or gradually growing residual tumor is expected, bony decompression of the spinal canal is indicated to provide more intraspinal space. The complementary use of iliac bone graft is provide moderate enlargement of the spinal canal at the expense of the postoperative donor site complications. The surgical procedure was modified to achieve the enlargement of the spinal canal by placing heterologous graft between the facing split bony parts of the spinous process in a way similar to the cervical anterior iliac bone grafting technique. The degree of enlargement of the spinal canal depends on the elasticity of the arches, the force of distraction and the size of the inserted spacer. The press force between the closing laminae and the wedge shape and the serrated face of the cage with the titanium spikes does not allow the spacer to penetrate into the spinal canal or slipping out from the splitted laminae after its placement. The precise insertion of the cage between the laminae is important, as spacer penetration during the insertion process is a very rare, but possible complication. With this modification of the split laminotomy process, no iliac crest bone graft needed, and all complications of the graft harvesting procedure avoided.

Lack of the most frequent short time postoperative donor site complications, as local pain and haematoma, early recovery and discharge of the patients were possible.

The time of the surgical procedure was significantly shorter than the iliac bone grafting procedure. The blood loss during the surgical procedure was also less, compared to the classic iliac bone grafting procedure.

Fusion – through the PEEK cages – of the split bony faces of the spinous process was seen in some cases during follow up. There was no patient in whom osseous bridging was missing in all segments.

The bony healing between the osteotomy sites was in agreement with findings of the literature in connection with posterior arch reconstructions of the cervical canal in spondylotic myelopathy cases, and with reconstructions of the laminar roof for a posterior approach. Through our sort follow-up period no compression, nor displacement of the implanted cages have been detected. Developing of specially shaped cages for better positioning and distraction of the splitted laminae need further evaluation.

All of our cases we performed the surgery at the thoracic level of the spine. To use the same splitting and cage grafting technique at the cervical level newly designed spacers needed. To prevent cage displacement and other complications prior to clinical usage, experimental biomechanical studies of the very mobile cervical spine with the inserted spacers is mandatory, and it is under investigation in our institute.

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## Conclusions

The minimally invasive multilevel spinous process splitting and distracting laminotomy approach with heterologous graft (spacer) insertion is a safe and effective surgical management, suitable for removing intramedullary tumors located in the spinal canal, and ensuring permanent decompression of the spinal cord. The posterior stabilizing structures of the spine, as the vertebral laminae and the longitudinal musculature are completely prevented. Due to use of allograft, instead of the autologous iliac crest bone graft, the duration of the surgical process is shorter the blood loss of the patient is less. No donor-site morbidity expected. The bony healing of the splitted laminae and permanent decompression of the spinal cord is identical to the iliac crest bone grafting method.

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