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Ultrasonic Bone Scalpel for Osteoplastic Laminoplasty in the Resection of Intradural Spinal Pathology: Case Series and Technical Note

Scott L. Parker, M.D.,[1] Ryan M. Kretzer, M.D.[2], Pablo F. Recinos, M.D.[2,3], Camilo A. Molina, B.A.[2], Jean-Paul Wolinsky, M.D.[2], George I. Jallo, M.D.[2], Violette Renard Recinos, M.D.[3]

[1]Department of Neurosurgery, Vanderbilt University Medical Center, Nashville, Tennessee
[2]Department of Neurosurgery, The Johns Hopkins University School of Medicine, Baltimore, Maryland
[3]Department of Neurosurgery, Cleveland Clinic, Cleveland, Ohio

Corresponding author:
Violette Renard Recinos, M.D.,
Section Head, Pediatric Neurosurgical Oncology
Cleveland Clinic Foundation
9500 Euclid Avenue, S-60
Cleveland, OH 44195
Telephone: (216) 444-5747
Fax: (216) 445-6878
E-mail: recinov@ccf.org

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Abstract

Background: Osteoplastic laminoplasty is a well-described technique that may decrease the incidence of progressive kyphosis when used in the setting of intradural spinal cord tumor resection.

Objective: The BoneScalpel™ by Aesculap is an ultrasonic osteotome that precisely cuts bone while preserving the underlying soft tissues, potentially reducing the risk of dural laceration during laminoplasty. By producing osteotomies as narrow as 0.5 mm, the device may also facilitate post-operative osteointegration.

Methods: A retrospective analysis was conducted of 40 patients (mean age: 38.0 years, range: 4.0-79.7 years) who underwent osteoplastic laminoplasty using the BoneScalpel™ for the treatment of intradural spinal pathology at the Johns Hopkins Hospital between January 2009 and December 2011. Following lesion resection, titanium plates were used to reconstruct the lamina in all cases. The technical results and procedure-related complications were subsequently noted.

Results: Successful laminoplasty was carried out in all 40 cases. Intraoperatively, one case of incidental durotomy was noted following use of the device, which was repaired primarily without neurological or clinical sequelae. During the follow-up period (mean: 195 days, median: 144 days), there were 2 complications (CSF leak=1, seroma=1) and no cases of immediate post-operative instability.

Conclusion: The BoneScalpel™ by Aesculap is a safe and technically feasible device for performing osteoplastic laminoplasty.

Keywords: ultrasonic bone scalpel, laminoplasty, laminectomy, spinal cord tumor, tethered cord, spinal cord AVM, durotomy, spine surgery

Running title: Laminoplasty with Ultrasonic Bone Scalpel for Intradural Pathology

INTRODUCTION

Laminoplasty is a well-described alternative to laminectomy in the treatment of spinal pathologies including multi-level stenosis, degenerative disc disease, and intra- and extramedullary spinal cord lesions.[1-4] By removing less bone and being able to anatomically reconstruct the posterior elements and posterior tension band, laminoplasty may help to preserve the three-dimensional biomechanical properties of the spine.[4] For instance, laminoplasty when used in the setting of spinal cord tumor resection has been shown to decrease the incidence of progressive spinal deformity.[5-7] Especially in the pediatric patient population, where extensive bone remodeling and healing can be seen well past adolescence, laminoplasty has proven a useful tool in the treatment of intradural pathologies.

A novel device, the BoneScalpel™ by Aesculap, is an ultrasonic osteotome that precisely cuts bone while preserving the underlying soft tissues, thereby potentially reducing the risk of dural laceration during laminoplasty. This device is composed of an ultrasonic system generator that has a hand piece with a dull surgical blade for cutting bone. When turned on, it oscillates longitudinally across a distance of 100 µm at 22,500 times per second. It cuts bone by causing compression through impact, but spares the underlying soft tissue structures which are flexible and elastic. In addition, the device allows for fine osteotomies as narrow as 0.5 mm, cauterizes bone bleeding during use, and offers the added benefit of self-irrigation. Therefore, less bone is destroyed while drilling the bilateral laminar troughs of the ostcoplastic laminoplasty, allowing for improved reconstruction and potentially better post-operative osteointegration.

We performed osteoplastic laminoplasties using the ultrasonic BoneScalpel™ in 29 adult and 11 pediatric patients undergoing surgery for intradural pathology. We report our experience with this device and discuss the theoretical technical advantages and procedure-related complications of using an ultrasonic bone osteotome in the treatment of intradural spinal lesions.

METHODS

Patients undergoing osteoplastic laminoplasty using the BoneScalpel™ for treatment of intradural spinal pathology at the Johns Hopkins Hospital between January 2009 and December 2011 were retrospectively reviewed after Institutional Review Board (IRB) approval. Forty patients (mean: 38.0, range: 4.0-79.7 years) met inclusion criteria for the study. A variety of pathologies were treated including: 30 neoplastic, 6 congenital, 2 vascular, 1 inflammatory, and

1 neuropathic pain. One case was a reoperation in which the BoneScalpel was used to extend a previous laminoplasty, while 39 cases were first time operations, Table 1.

Surgical Technique

After a midline skin incision, the bilateral paraspinal muscles were dissected in sub-periosteal fashion while preserving the posterior tension band including the supraspinous/interspinous ligament (SSL/ISL) complex and the spinous processes. A longitudinal laminar cut at the spinolaminar junction was then made bilaterally using the ultrasonic BoneScalpel™. After scoring of the laminar incision, the BoneScalpel was used to sequentially deepen the laminar cuts until the underlying interior laminar cortex was penetrated, thereby exposing the ligamentum flavum. After verification of detachment of the lamina from the residual posterior elements, the supra- and infra-adjacent SSUISL complex was transected. The lamina-spinous process complex was then removed in *en bloc* fashion using a combination of curved curettes and Kerrison punches to resect the underlying ligamentum flavum, Figure lA. This allowed exposure of the dura and treatment of the intradural pathology as necessary. After completion of the procedure, the dura was closed and the *en bloc* laminoplasty was reattached to the spine using Leibinger titanium fixation plates, Figure lB. The paravertebral fascia, subcutaneous tissues, and skin were then closed in standard fashion.

RESULTS

Successful laminoplasty was carried out in all 40 cases. Intraoperatively, one case of incidental durotomy was noted following use of the device, which was repaired primarily without neurological or clinical sequelae. Median [interquartile range] intraoperative blood loss in this series was 150 [75-300] cc. During the follow-up period (mean: 193 days, median: 142 days), there were 2 perioperative complications (CSF leak= I, seroma= l). The case of CSF leak developed 2 weeks postoperatively, which was managed successfully by oversewing the wound in the outpatient setting. The case of the epidural seroma required operative evacuation and the laminoplasty bone was removed due to the possibility of infection at the time of surgery. There were no cases of spinal instability in the follow-up period. Typical post-operative appearance of the final construct on plain radiographs is demonstrated in Figure 2.

DISCUSSION

Laminectomy has long been considered the traditional approach for resection of spinal cord tumors as it creates a relatively wide exposure of the spinal cord and can be easily extended both superiorl y and infe1iorly.[8] However, approximately 10% of adults undergoing laminectomy for intradural spinal cord tumor resection will develop progressive spinal deformity in the post-operative setting.[6,9-13] The risk of developing delayed spinal deformity is increased in the pediatric population,[12,14,15] with a reported incidence of 16% to 100% in multiple series.[10,16-19] Additionally, the occurrence of post-laminectomy kyphosis often complicates functional outcomes and therefore may necessitate fusion surgery.[6,20] As a result, laminoplasty has been advocated as a potential way to avoid such complications since the posterior elements of the spine are replaced after *en bloc* removal of the lamina.[5,21,22] However, even with these theoretical advantages, clinical studies favoring laminoplasy versus laminectomy in the prevention of post-operative spinal deformity following resection of intradural spinal tumors remains inconsistent.[23,24]

Although several techniques exist for performing a laminoplasty, including the trap-door and spinous process splitting techniques, which are particularly well described in Japan for the treatment of cervical spondylotic myelopathy and OPLL, ostcoplastic laminoplasty in the setting of intradural pathology typically requires *en bloc* removal of the posterior elements of the spine.[1-3,22,25,26] This has traditionally been performed using either a high speed drill or a side-cutting craniotome bit with a foot-plate. These instruments are extremely effective at cutting bone; however, dural laceration and spinal cord injury are known complications.[27] In our experience, the BoneScalpel™ by Aesculap is an ultrasonic osteotome that precisely cuts bone while preserving underlying soft tissues. Because the device uses a blunt-tipped bit, the risk of dural laceration during laminoplasty is theoretically reduced. While the incidence of durotomy varies widely depending on the type and location of the procedure, we experienced a 2.5% durotomy rate with the use of the ultrasonic osteotome in this series. In comparison, our institution has previously reported a durotomy rate of 4.3% with the use of the high speed drill in a consecutive series of 964 patients undergoing decompression and spinal fusion.[28]

While the device is capable of making an osteotomy cut as fine as 0.5 mm in width, it is our experience that due to the depth of cutting required to completely resect the lamina, a 1 mm cut is a more realistic expectation. Nevertheless, this remains a significant improvement over a 3, 4, or 5 mm burr that would traditionally be used in combination with a high speed drill, resulting in a theoretical increase in the ability of the re-attached posterior elements to re-integrate with the native spine, especially in the pediatric population, **Figure** 3. Other advantages of the device include its ability to cauterize bleeding cancellous bone due to its high oscillatory frequency, thereby improving visualization while performing the laminar cut. In addition, it has been our experience that the time required to perform the osteoplastic laminotomy is greatly reduced relative to other techniques due to the minimal amount of bone removed by the BoneScalpel. Although surgeon-dependent, in our experience it takes approximately 1-2 minutes per spinal level to perform a laminectomy with the ultrasonic osteotome, so that a three-level laminectomy would take an estimated 3-6 minutes to complete. In comparison, a three-level laminectomy using a high speed drill to create a trough and completing the laminectomy with a Kerrison rongeur takes approximately 10-15 minutes to complete in our hands. Finally, as the osteotome bit measures only 0.5 mm in width, a precise cut at the spinolaminar junction focuses any downward force lateral to the dura and spinal cord, unlike traditional cutting or diamond drill bits.

In this series of 40 consecutive patients treated with the BoneScalpel, there was one case (2.5%) of incidental durotomy after osteoplastic laminotomy. It resulted in no neurological injury and was repaired primarily without subsequent CSF leakage. This occurred during the user:s first experience with the device and was visualized as a linear heat-related defect likely due to excessive downward pressure after the inner laminar cortex had been cut. In analogy to laminectomy drilling with a high-speed, rotating diamond bit, extended and excessive downward pressure with the BoneScalpel can rarely result in thermal dural injury rather than a true laceration due to its blunt tip. Care is required when making the laminar troughs in order to verify complete transection of the inner laminar cortex. In becoming comfortable with use of the ultrasonic osteotome, the primary hurdle in the learning curve relates to being able to feel and appreciate when the tip of the osteotome bit penetrates the inner laminr cortex. At our institution, residents practice using the ultrasonic osteotome on sawbone models and/or cadavers to gain comfort with the device.

Limitations

Several limitations exist in this case series and technical note that must be addressed. First, long te1m follow-up with imaging at specific pre-dete1mined time-points would show whether or not thinner laminar cuts allow improved osteointegration of the laminoplasty into the native spine and prevent delayed spinal deformity. Although the main goal of this retrospective review was to show the immediate feasibility and safety of the BoneScalpel for this indication, additional studies are planned to justify the long-term effectiveness of this technique compared to traditional drilling. Finally, although this review focuses on laminoplasty for intradural pathology, in our institution the BoneScalpel is used for a variety of indications, including cervical and thoracic laminectomies for degenerative disease, infection, oncology, and trauma, as well as for various other osteotornies. Additional work is under way to study the role of the BoneScalpel in this wider indication for use.

CONCLUSION

The BoneScalpel™ by Aesculap is a safe and technically feasible device for performing osteoplastic laminoplasty. Further studies and longer clinical follow-up are needed to delineate the true role of this device in the treatment of intradural spinal pathology.

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FIGURE LEGENDS

Figure 1. Photograph depicting the (A) *en bloc* removal and **(8)** replacement of the posterior elements.

Figure 2. Post-operative (A) anterior-posterior and **(8)** lateral radiographs demonstrating typical appearance of final construct.

Figure 3. Pre-operative (A & **8)** and post-operative (C & **D)** MR images of a patient who underwent an osteoplastic laminotomy for removal of a Tl intramedullary ependymoma. The post-operative images depict the fine cuts produced by the ultrasonic bone scalpel during laminectomy.

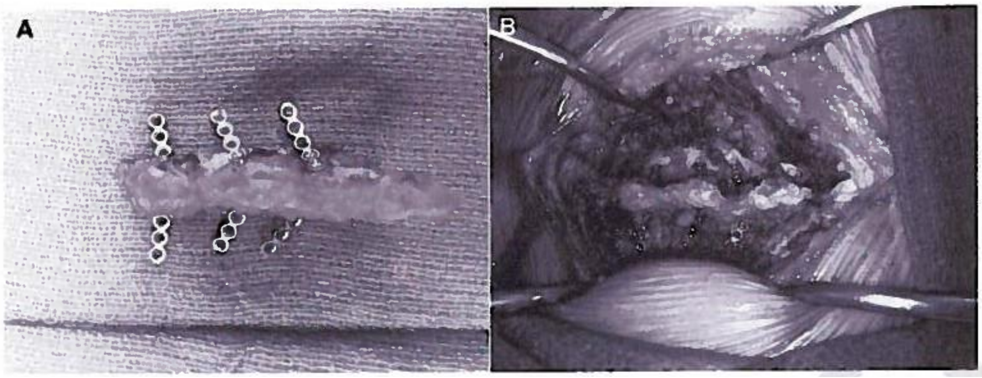
Table 1. Summary of osteoplastic laminotomy cases perfonned with the ultrasonic bone scalpel. All lesions were intramedullary except where specified otherwise.

Age (years) / sex	Level of Lesion	Pathology
13.5/M	T3-T6	Ganglioglioma
14.5/F	T9	Dermoid
54.4/M	C7-Tl	Ependymoma
9.4/F	C7-Tl	Arachnoid cyst
28.2/F	Tl l-Tl2	Genn cell tumor
9.5/F	C1-C3	Lipoma
59.0/M	C5-C6	Cavernous malformation
4.0/M	T9	Pilocytic astrocytoma*
41.7/F	C3-C4	Gliosist
65.0/F	T9-Tl l	Intramedullary, exophytic solitary fibrous tumor
47.2/M	L2-L3	Intradural, extramedullary paraganglioma
57.5/F	T6-T8	lntradural, extramedullary meningioma
55.8/F	C4-C6	lntradural, extramedullary schwannoma
10.9/F	T5-T7	Intradural, extramedullary arteriovenous malformation
48.3/M	C4-Tl	Neuropathic pain syndrome
79.1/M	Tl l-Tl2	Intradural, extramedullary schwannoma
12.6/M	Tl2-L3	lntradural, extramedullary ependymoma
57.7/F	T6-T8	lntradural, extramedullary meningioma
50.7/F	T3	Intradural, extramedullary arachnoid cyst
63.6/F	Tl-T6	Intradural, extramedullary arachnoid cyst
6.5/M	L3-L4	Dermal sinus tract resection and cord untethering
23.3/F	Tl2-L2	lntradural, extramedullary myxopapillary ependymoma
43.2/F	C6-Tl	Hemangioblastomas
67.4/M	T12-L2	Intradural, extramedullary myxopapillary ependymoma
27.8/M	TIO-Tl2	Ependymoma
55.6/M	C4-C6	Ependymoma
45.6/F	Tl l-Tl2	Intradural, extramedullary meningioma

36.4/F	Ll -L2	lntradural, extramedullary myx.opapillary ependymoma
37.1/F	C6-Tl	Ependymoma
20.3/F	C2	Ependymoma
50.2/M	C5-C6	Intradural, extramedullary schwannoma
36.2/M	Tl 2-Ll	lntradural, extramedullary neuroenteric cyst
28.1/F	T1-T3	Pilocytic astrocytoma
22.9/M	C1-C3	Hemangioblastomas
14.4/M	Tl 2-L2	Intradural, extramedullary myx.opapillary ependymoma
79.7/M	Tl 2-LI	lntradural, extramedullary neurofibroma
5.6/M	L5-Sl	Jntradural lipoma and tethered cord release
7.6/M	Ll -L3	Lipoma
63.9/M	C4-C7	Low grade glioma
66.4/F	C2-C4	Ependymoma

* = BoneScalpel used on second operation for tumor recurrence and not on primary operation

t = biopsy only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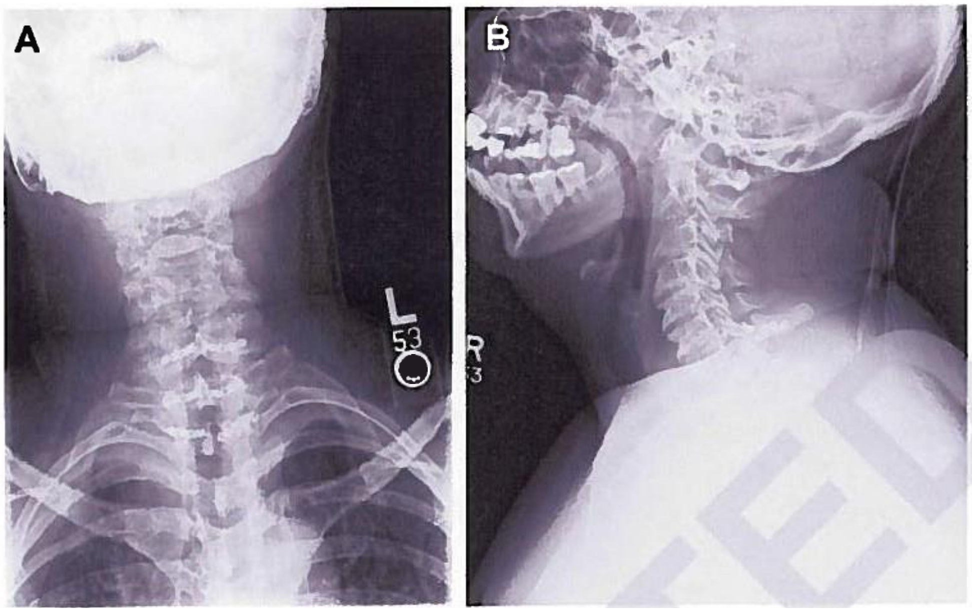
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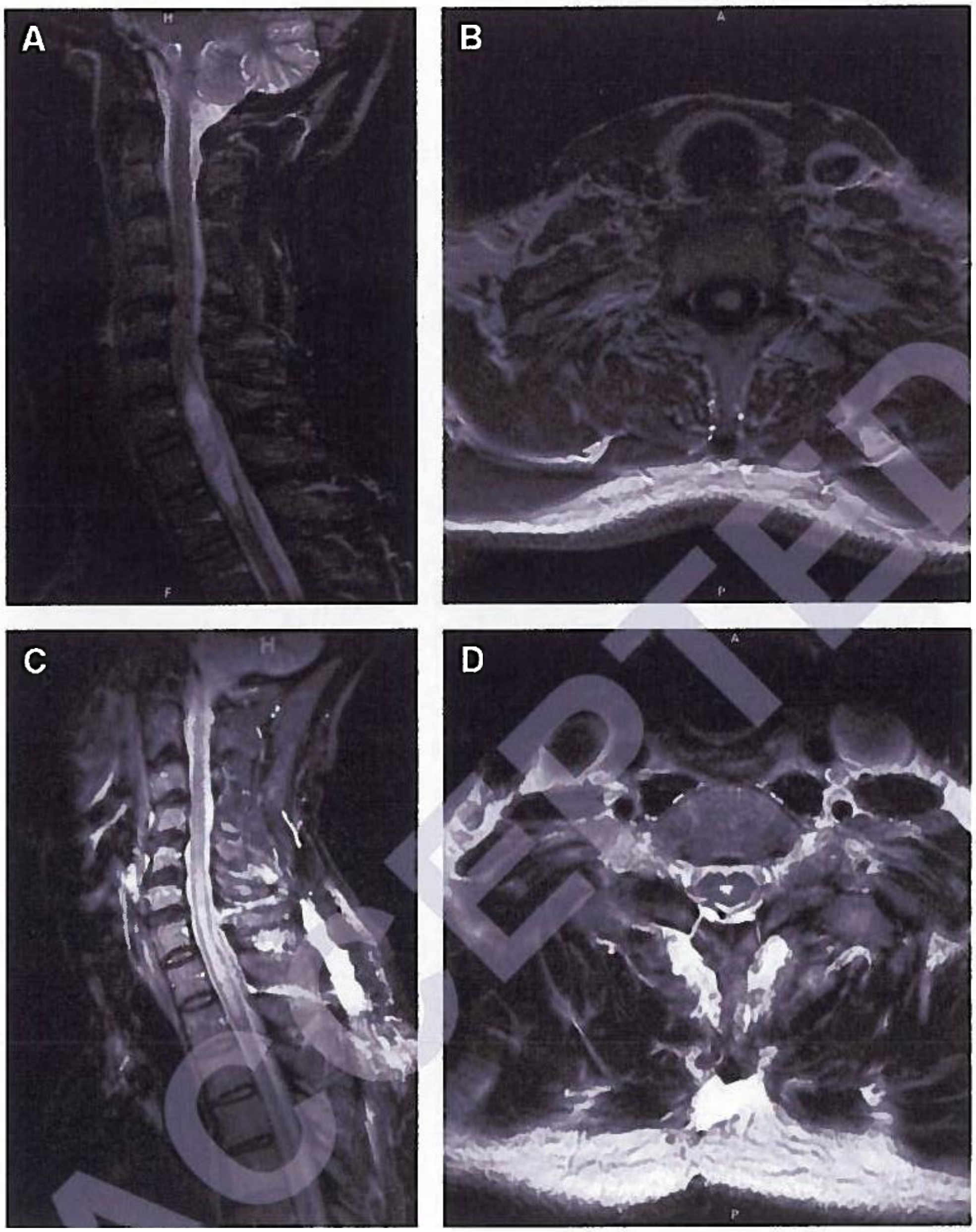
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