The ABC's of Spinal Decompression: Pearls and Technical Notes

Wyatt L. Ramey[2], Juan Altafulla[1,2], Emre Yilmaz[1,2], Basem Ishak[1,2], Andrew Jack[2], Zachary N. Litvack[1,2], Rod J. Oskouian[1,2], R. Shane Tubbs[1,3], Jens R. Chapman[2]

OBJECTIVE: **The foundation of spine surgery centers on the proper identification, decompression, and stabilization of bony and neural elements. We describe easily reproducible and reliable methods for optimal decompression and release of neural structures to alleviate symptoms and improve patients' quality of life.**

METHODS: **Multiple spinal decompression techniques were described in procedures for which the goal of surgery was decompression alone or decompression and fusion. Eight fundamental techniques were described: inverted U-cut, J-cut, T-cut, L-cut, Z-cut, I-track cuts, C-cut, and O-cut.**

RESULTS: **These foundational cuts may be combined, as needed, to develop an individually tailored approach to the patient's pathology.**

CONCLUSIONS: **After properly identifying the anatomic structures, each of these techniques provides a consistent, reproducible, and efficient means to decompress the spine under various circumstances. These techniques provide surgical trainees with a framework for approaching surgical decompression.**

INTRODUCTION

Decompression of neural elements is one of the earliest taught tenets of spinal surgery. Safe decompression of the spine includes preserving neurologic structures, while achieving the desired release from compromising surrounding tissues and maintaining segmental stability. Understanding basic anatomy and following a set of intraoperative guidelines maximizes the surgeon's ability to perform such procedures consistently and effectively. Of particular importance in establishing a set of intraoperative pearls is the educational domain. Spinal surgery trainees are often burdened with learning and adapting to various styles of surgery during training and are then expected to adopt the approach that works best for them. Whereas there is merit in this philosophy, learning the basics of spinal decompression in a safe, reproducible, and efficient fashion is part of the foundational skill set required of spinal surgeons. Surgeons-in-training commonly focus on the desired surgical endpoint of neural decompression and try to mimic their instructors' prior surgical examples, as opposed to following an objective, systematic, and readily communicable pathway to lead them predictably and safely toward this goal. In other words, surgeons may focus on the end rather than the means, which can lead to inefficient execution of surgical steps, longer operative times, inadequate decompression, inconsistent technique, and an increased risk of injury to the neural structures.

We have devised a classification of a series of 8 geometric posterior laminar cuts each illustrated by a graphic letter of the alphabet (Table 1). This use of a letter to describe the cut morphology for an intended decompressive procedure maximizes efficiency and safety, while providing trainees an easy-to-use system for remembering each procedure. In this article, we describe this novel and simple visual letter-based reference system for decompression of the spinal canal to be used to achieve specific surgical objectives in common spinal operations.

MATERIALS AND METHODS

Inverted U-Cut

Unilateral lumbar laminotomies have become a workhorse for lateral recess decompression, foraminotomies, microdiscectomies, and central canal stenosis.[1-4] The primary goal of this procedure is to achieve maximal decompression of the neural elements usually on the ipsilateral side without causing iatrogenic destabilization. To mitigate the risk of destabilization, the key

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- Bone cuts
- Spinal decompression
- Spine
- Surgical technique

From the [1]Department of Neuroanatomy, Seattle Science Foundation; [2]Department of Neurosurgery, Swedish Neuroscience Institute, Swedish Medical Center, Seattle, Washington, USA; and [3]Department of Anatomical Sciences, St. George's University, St. George's, Grenada, West Indies

To whom correspondence should be addressed: Jens R. Chapman, M.D. [E-mail: jens.chapman@swedish.org]

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Table 1. Summary of Each Bone Cut

Technique	Location	When to Use	Brief Description
Inverted U-cut	Lumbar	Midline-sparing lumbar decompression	Open portion of the U along the inferior aspect of the lamina, the superior closed part located just above the pars, the medial aspect along the spinolaminar junction, the lateral part ~5 mm medial to the pars
J-cut	Lumbar	Midline-sparing lumbar decompression	Vertical line along medial superior articulating process and flush with medial pedicle wall; curved bottom portion of the J extends over the superior portion of the lower-level lamina
L-cut	Thoracic, lumbar	Facetectomy in preparation for fusion	Extends medially from the pars to the base of the spinous process; a vertical line is then drilled from this point inferiorly through the bottom of the lamina
T-cut	Thoracic, lumbar	Bilateral facetectomy in preparation for fusion	Begins at each pars interarticularis extending medially and superiorly to midline; a vertical trough is drilled through down the midline to the inferior lamina
Z-cut	Thoracic, lumbar	Facetectomy in preparation for fusion	Horizontal drilling at the cranial edge of the pedicle through the lower level SAP; the medial edge of the pedicle is skeletonized by drilling the medial SAP of the same level; ~5 mm of lamina is drilled horizontally along its superior edge
O-cut	Cervical	Cervical foraminotomy	Middle of the O centered at medial junction of superior and inferior articulating processes of the cervical lateral mass; extends <50% into lateral mass
I-track cuts	Cervical, thoracic, lumbar	Multiple serial laminectomies	Bilateral vertical troughs drilled through the lamina at the laminar/facet junction
C-cut	Cervical, thoracic, lumbar	Decompression at caudal end of laminectomy	Superior portion of the spinous process is removed; a C-shaped cut from each medial pedicle is made with the inferiormost aspect at the level of the corresponding inferior pedicle

SAP, superior articulating process.

landmark often used during this procedure is the pars interarticularis, acting as a lateral border.

Once the pars interarticularis is identified, an upside-down U should be marked, with the open portion of the U along the inferior aspect of the lamina, the superior closed portion of the U located just above the pars, and the medial aspect along the spinolaminar junction undercutting the spinous process (upside-down U-shaped osteotomy) (Figure 1). The lateral superior portion of the inverted U-cut should be at least 5 mm, but preferably 10 mm, medial to the edge of the pars to avoid a postdecompression pars fracture and subsequent instability. After removing this U-shaped portion of the lamina and medial inferior articulating process, both the underlying ligamentum flavum and the medial superior articulating process should be easily identified. These can be resected for full access to the lateral recess, the posterolateral anulus, and the intervertebral foramen above and below the respective pedicle. This systematic approach to lumbar laminotomies relies heavily on the successful identification of the pars and, once done, minimizes the chance of iatrogenic segmental instability. The elevation of the U-shaped cut can be customized to the specific patient's size and the level and the type of surgery performed; a microdiscectomy at the L5-S1 level in a small patient may require a very small U-cut, whereas a high-grade spinal stenosis with significant facet hyperostosis at mid-lumbar levels with foraminal stenosis above and below the laminotomy site would require a much taller U-shaped cut.

J-Cut

A correctly performed laminotomy via the inverted U-cut exposes the underlying medial superior articulating process projecting from the level below, which must be removed to decompress the lateral recess and neuroforamen. A vertical line along the medial superior articulating process should be marked and should ultimately be flush with the medial pedicle wall at its inferior half. The curved bottom portion of the J-cut forms by extending the cut medially over the superior portion of the lamina of the level below (*red dashed line* in Figure 1). It ends at the medial portion of the aforementioned U-cut, thus widening the exposure of the traversing nerve root. In its most medial extent, it can be then curved up along the base of the superior lamina and the spinous process confluence to allow for removal of this prominent leading edge of bone that can protrude into the spinal canal in end-stage lumbar spondylosis. On completion, the J-cut then allows en bloc removal of the superior articulating process and the portion of the lamina from the level below along with the deep layer of the ligamentum flavum, affording full decompression of the lateral recess and its traversing nerve root. Resection of the ligamentum flavum is preferably performed after the J-cut so it can act as a barrier between the drill and thecal sac and nerve root.

L-Cut

The L-cut can provide complete access to the root exit zone and the posterolateral disc space, while preserving midline bony and ligamentous structures, such as that required for performing discectomy and placement of interbody cage from a transforaminal approach. This procedure can be performed either unilaterally or bilaterally, while preserving the posterior ligamentous complex. Similar to the more extensile T-cut described next, the L-cut is started laterally at the pars interarticularis and extends medially to the base of the spinous process at the spinolaminar junction. A

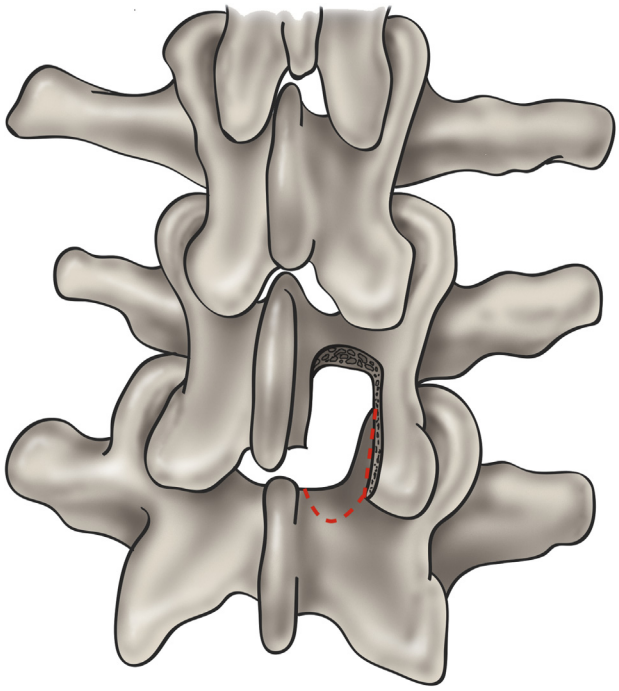

Figure 1. Inverted U-cut and J-cut. Unilateral lumbar laminotomy providing access for lateral recess decompression, foraminotomies, microdiscectomies, and central canal stenosis. *Red dashed line* depicts J-cut, which is performed after U-cut (previously removed bone).

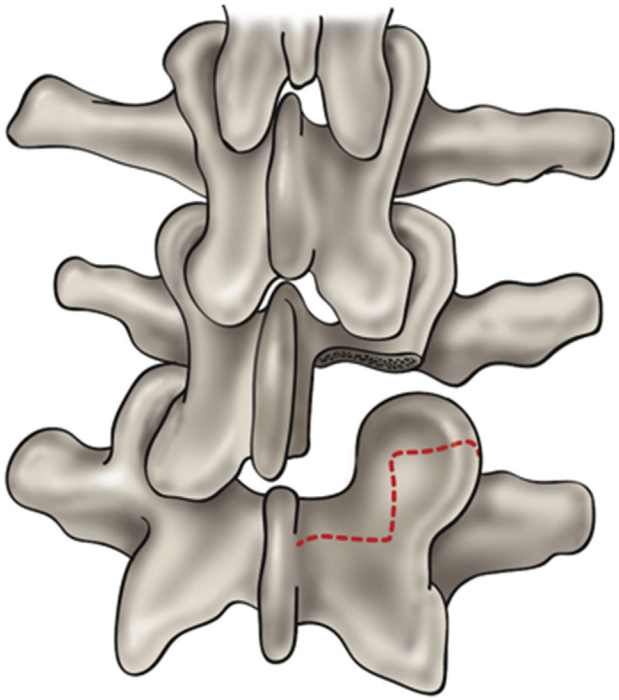

Figure 2. Previously removed bone depicting the L-cut. *Red dashed line* delineates the trajectory of the Z-cut.

vertical line is then drilled from this point inferiorly through the bottom of the lamina (Figure 2). A curette and rongeur are used to disconnect this bony fragment, which includes a portion of the lamina and inferior articulating process, from the underlying ligamentum flavum and facet joint. As stated previously, this procedure can be performed unilaterally or bilaterally at any single segment for discectomy and fusion in the thoracic and lumbar spine. We typically employ this technique in short segment thoracic or lumbar fusions with need for interbody fusions and without need for major deformity correction.

T-Cut

The T-cut represents a bilateral version of the L-cut, with sacrifice of the posterior ligamentous complex. Such comprehensive posterior element decompressions are preferable for a variety of clinical conditions, such as posterior based 3-column osteotomies, vertebrectomies for neoplasia, infection or trauma, and advanced high-grade spinal stenosis. The T-cut allows for effective and full resection of the posterior elements, with the exception of the pedicles, and achieves this goal by simply disconnecting key anatomic posterior lamina and bilateral inferior facet joints with minimal risk of disruption to neural structures in the spinal canal during the actual decompression.

After removal of the spinous process (typically with a rongeur), the transverse part of the T-cut begins at each pars interarticularis and extends medially and slightly superiorly to the midline into the lateral boundary of the interlaminar space, covered by ligamentum flavum (Figure 3A). Care should be taken while drilling laterally through the pars to avoid nerve root injury and more superiorly closer to midline, as there is no underlying ligamentum flavum protecting the dura mater. A vertical trough is then drilled through the lamina down the midline to its most inferior aspect. Making each of these cuts effectively disconnects the bilateral inferior articular processes together with the lamina from the rest of the vertebra so they can be easily removed. We use a small spreader placed in the midline cut to facilitate the elevation and subsequent removal of each of these large bone fragments, which can then be processed as autograft for fusion (Figure 3B). Removal of this bone effectively unroofs the thecal sac and bilateral neuroforamina in preparation for discectomy. This technique is readily adaptable to both thoracic and lumbar spine anatomy.

Z-Cut

After either a T-cut or an L-cut, the next step is to skeletonize the involved pedicle to fully decompress the neuroforamen to allow for full visualization of the exiting nerve root as well as the underlying posterior anulus to its lateral edge. The Z-cut begins by drilling horizontally at the cranial edge of the pedicle through the flattened superior articulating process of the lower level (Figure 2). This area is a relatively safe zone, as the nerve root usually lies within the top half of the neuroforamen. Next, the medial edge of the pedicle is skeletonized by drilling the medial edge of the superior articulating process of the same level so that it fully exposes the traversing nerve root. From the inferior aspect of this point, the lamina is drilled along its superior edge, removing

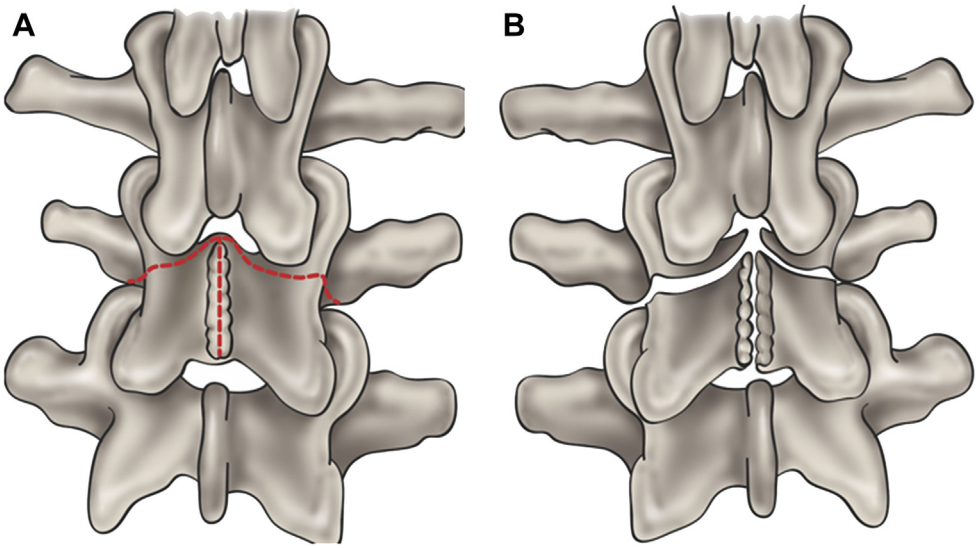

Figure 3. (**A**) T-cut delineation. *Red dashed line* marks the location where the cuts are going to be made. (**B**) T-cut. For bilateral exposure of neural elements, performed in both thoracic and lumbar spine. Large bone fragments can then be used as autograft for fusion.

approximately 5 mm of bone to expose the traversing root more distally within the lateral recess and permit access to the spinal canal below. The Z-cut is the final step in preparing exposure of the intervertebral disc so that a discectomy and preparation for interbody fusion can be safely carried out with little risk to the exiting and traversing nerve roots. It is an inherently destabilizing osteotomy and requires supplemental fixation.

O-Cut

Posterior cervical foraminotomies are commonly employed when 1) anterior cervical surgery is contraindicated or not desirable, 2) the aim is to avoid fusion surgery, or 3) prior anterior surgery prohibits satisfactory access to the neural foramen. The O-cut allows for reproducible access to the cervical spinal canal and exiting nerve root. The middle of the O-cut is centered at the medial junction of superior and inferior articulating processes of the cervical lateral mass (**Figure 4**). The superior and inferior aspects should extend to the midpoint of each corresponding lateral mass in the superior-inferior dimension to avoid instability, which has been shown to occur with the destruction of >40% of the height of the lateral mass in the traumatic setting.[5] The lateralmost aspect of the O-cut should extend no further than to disrupt >50% of the facet joint. The medial portion of the O-cut extends to the spinolaminar junction where the lateral thecal sac should be visualized underneath.

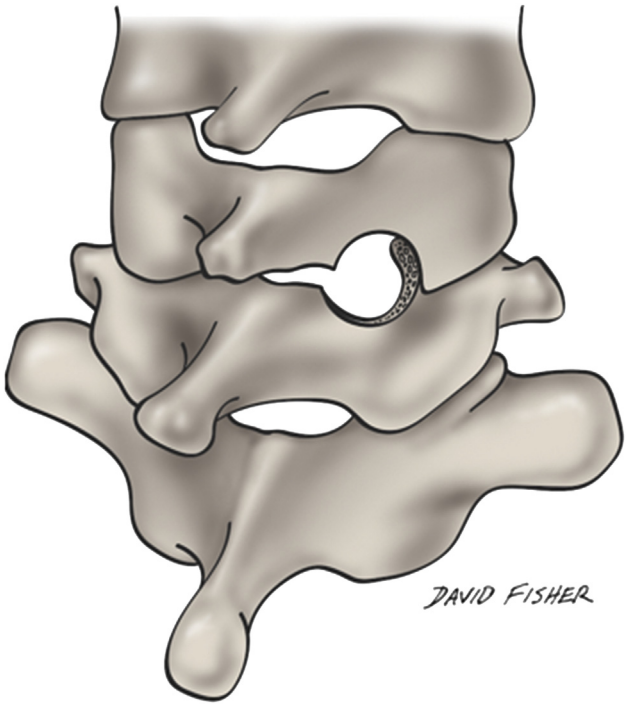

Figure 4. O-cut. The middle of the O-cut is centered at the medial junction of superior and inferior articulating processes of the cervical lateral mass, providing access for cervical foraminotomies.

I-Track Cuts

Serial laminectomies can be efficiently performed with minimal movements in and out of the central canal, thereby decreasing the

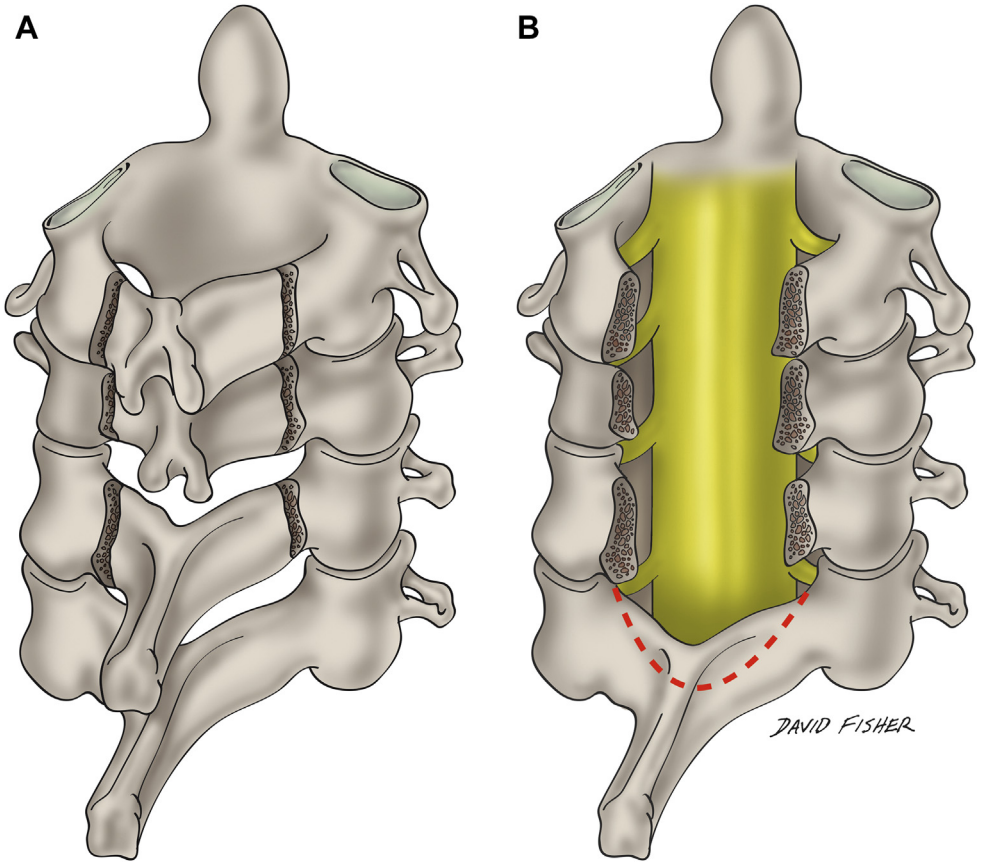

Figure 5. (**A**) I-track cuts. Vertical troughs drilled bilaterally at the junction of the laminae and lateral masses in the cervical spine to perform multiple serial laminectomies. (**B**) I-track cuts and C-cut. After the laminectomy is complete, the C-cut is performed at the caudal end of the decompression extending laterally to the medial pedicle walls and inferiorly to just below the pedicle (*red dashed line*).

risk of injury to the thecal sac and its contents. Bilateral vertical troughs drilled through the lamina on either side are performed at the general laminar-facet junctions at each level anywhere in the posterior spine. More specifically, in the cervical spine, this is performed at the junction of the lamina and lateral mass (Figure 5). In the thoracic spine, the cutline is made at the border of the lamina and the medial half of the facet joint. In the lumbar spine, troughs are drilled through the lamina, approximately 5 mm medial to the pars interarticularis. Variations in terms of laterality are made based on severity of facet hypertrophy and clinical needs.

Once the cuts are made and the lamina and spinous process are free-floating, they are carefully elevated using an upgoing curette and rongeurs. The decompression should be extended to the medial aspect of the pedicles on either side, and, if present, any remaining bone of the inner table of lamina-facet overlying neural elements should be removed with Kerrison rongeurs. Access to the root exit zones above and below each pedicle can usually be readily gained from this general exposure. This technique eliminates repetitive maneuvers that enter the canal and potentially injure intrathecal components.

C-Cut

After a wide laminectomy, the superior aspect of the lamina of the level below can be removed for further decompression with little consequence or risk. This approach becomes most beneficial just below the site of a sagittal deformity correction, where kyphosis correction can result in buckling of the thecal sac underneath the inferior lamina. The superior portion of the inferior spinous process can be partially removed with a Leksell rongeur. Next, a C-shaped cut ranging from each medial pedicle is made with the inferiormost aspect at the level of the corresponding inferior pedicle (*red dashed line* in Figure 5). There is little, if any, ligamentum flavum underlying the laminae this superiorly, so care should be taken not to disrupt the dura.

DISCUSSION

A thorough understanding of the anatomy and the course of the neural and vascular structures oriented in all 3 planes in addition to proper surgical planning individualized to a specific patient's needs will minimize complications and ensure improved outcomes for both the patient and the neurosurgeon.[6-8] Some

pathologies require emergency interventions for which time plays an important role in achieving neural tissue preservation.[9,10] With the techniques described in this article, we aim to provide the surgeon-in-training with an efficient and consistent decision-making strategy for spinal decompression and release of compromised neural structures. For instance, one may wish to decompress unilaterally while preserving bony and ligamentous elements and avoiding fusion. In this case, it is still possible to access the intervertebral disc and the neuroforamina for treating stenosis, using the U-cut in combination with the J-cut for thoracic and lumbar spine, whereas the O-cut is preferable for foraminal decompression of the cervical spine.[11,12] If fusion is unavoidable and the primary goal is to correct a deformity, exposing the lateral recess is necessary to 1) introduce interbody cages or 2) liberate the nerve root. Thus, we recommend performing an L-cut or a T-cut and complementing this osteotomy with a Z-cut for the deeper layered decompression. However, if the surgeon hopes to preserve the posterior ligamentous complex, an L-cut is preferable for this situation.[13] If a multilevel decompression is required without needing interbody reconstructive surgeries, the best option would be I-track cuts followed by a C-cut at the top and the bottom to decompress the thecal sac, thereby avoiding dural impingement at the respective laminectomy ends, such as the beltlike sign around the dura.[14]

CONCLUSIONS

We provide the surgeon-in-training with a framework and foundation of 8 fundamental posterior arch osteotomies to safely and efficiently achieve their desired surgical objective. Each of the aforementioned techniques provides a consistent, reproducible, and efficient means of decompressing the spine under various circumstances. With the use of a high-speed drill under continuous irrigation, it is possible to perform these bone cuts in a very controlled and reproducible manner that minimizes risk of injury to the neural elements. Once disconnected from the surrounding vertebral and ligamentous components, bone can be removed easily and safely. Most importantly, illustrating these bone cuts as letters of the alphabet allows experienced surgeons and trainees alike to communicate and execute decompressive spinal procedures more precisely in a goal-oriented fashion.

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