



Original Article

A reproducible deep dorsal root entry zone lesioning technique for cervical root avulsion: Outcomes from a clinical series

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ABSTRACT

Background: Neuropathic pain following traumatic cervical root avulsion remains a major clinical challenge when conservative therapies fail. Ablative neurosurgical procedures such as dorsal root entry zone (DREZ) lesioning continue to play a role in this refractory population. We present our experience with a standardized, reproducible microsurgical deep DREZ technique and compare outcomes with those reported in the literature.

Methods: We conducted a retrospective series of six patients with intractable neuropathic pain due to root avulsion, treated between 2021 and 2025 at a tertiary referral center in Southern Brazil. All surgeries were performed microsurgically under intraoperative neurophysiological monitoring. Lesions were made at a fixed depth of 4–5 mm targeting Rexed laminae I–VI. Pre and postoperative pain intensity was assessed using the Visual Analog Scale (VAS); postoperative analgesic use and complications were also recorded. Results were contextualized against published data from both superficial and deep DREZ approaches.

Results: Postoperative VAS scores ranged from 0 to 3, corresponding to a 66.7–100% reduction in pain; two patients (33.3%) achieved complete pain abolition. Four patients (66.7%) discontinued analgesic medication entirely. The remaining two patients maintained reduced – but altered – pain patterns compared with baseline. No permanent neurological deficits, cerebrospinal fluid leaks, infections, or autonomic disturbances occurred. One patient had a wound dehiscence that was successfully managed. These outcomes are comparable with modern deep DREZ series and appear superior to those historically reported for superficial techniques.

Conclusion: A microsurgical standardized deep DREZ lesioning technique targeting laminae I–VI demonstrates high efficacy, reproducibility, and a favorable safety profile for the management of refractory neuropathic pain after cervical root avulsion. Our findings support the adoption of this reproducible technique in specialized centers, although larger prospective studies are necessary to confirm long-term durability across institutions.

Keywords: Cervical root avulsion, Dorsal root entry zone, Dorsal root entry zone lesioning, Neuropathic pain

INTRODUCTION

Neuropathic pain represents one of the most significant therapeutic challenges in clinical practice, particularly in refractory cases where both pharmacologic and noninvasive approaches fail, and

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the persistence of symptoms along with their functional impact leads many patients to consider invasive interventions when conservative treatment provides insufficient relief.^[2,10] In such scenarios, the realistic therapeutic objective is not complete pain abolition but rather a reduction in symptom intensity and an improvement in quality of life, as the pursuit of zero pain is rarely achievable in chronic conditions.^[7] Although functional neurosurgical procedures for pain have become less common with the advent of more potent and selective pharmacologic agents, they remain essential for a subset of patients who do not achieve satisfactory outcomes with conventional therapies, either due to refractoriness or limiting adverse effects.^[7-9] The indication for neurosurgical intervention requires a rigorous diagnostic assessment, including precise identification of the underlying pain syndrome, its topographic distribution, and any central or peripheral nervous system involvement.^[7,8]

Among the available neurosurgical options, ablative procedures hold a substantial role in the management of deafferentation neuropathic pain, particularly that resulting from traumatic avulsion of cervical roots.^[7,8,10] Effective treatment requires precise diagnosis, accurate mapping of the painful topography, and a clear understanding of the underlying pathophysiology, as inappropriate selection of the surgical target is a well-recognized cause of therapeutic failure.^[7,8] Among these techniques, dorsal root entry zone (DREZ) lesioning stands out because it directly addresses the neuronal hyperactivity occurring within Lissauer's tract and within laminae I through VI of the dorsal horn – regions that become hyperexcitable following traumatic, radiation-induced, or infectious injury.^[1,2,7,8,10] By attenuating this hyperexcitability, the procedure aims to restore the balance between excitatory and inhibitory pathways in the segmental circuits underlying neuropathic pain generation.^[2,7,8] DREZ lesioning is primarily indicated for conditions characterized by extensive segmental deafferentation, including traumatic cervical root avulsion of the brachial plexus, radiation-induced plexopathy, segmental pain associated with traumatic myelopathy, cauda equina lesions, postradiation sequelae, and postherpetic neuralgia.^[3,7]

Experimental studies demonstrate that mechanisms such as increased excitability of wide-dynamic-range (WDR) neurons, exaggerated responses to peripheral stimuli, and phenomena such as windup are directly implicated in the persistence of neuropathic pain, underscoring the importance of segmental targets for its control.^[13] The technique has a robust historical foundation, rooted in the classical descriptions by Nashold Jr. and Ost Dahl^[6] and the subsequent micro-neuroanatomical refinements introduced by Sindou *et al.*,^[8] which consolidated the understanding of Lissauer's tract and dorsal horn laminae as preferential targets for this approach.^[4] Building on these

principles, several technical variations have been developed, including superficial and deep approaches to the DREZ. Although both aim to modulate segmental hyperexcitability, they differ in the depth of tissue involvement and the extent of intervention across dorsal horn laminae, factors that may influence their respective efficacy and safety profiles.^[1,4,11] Furthermore, the technical standardization proposed by Takai and Taniguchi^[11] has enhanced surgical precision by defining anatomical and neurophysiological parameters for lesion depth and angulation, thereby reducing risks and improving reproducibility.

Thus, while DREZ lesioning remains an ablative procedure, its technical evolution has focused on improving safety, standardizing outcomes, and minimizing complications. Despite its effectiveness, it carries recognized risks – such as residual hypoesthesia, paresthesia, and transient motor weakness – arising from manipulation of the dorsal horn and adjacent roots.^[10,11] Systematic reviews have also reported cases of new-onset neuropathic pain and persistent motor deficits, although these events are less frequent.^[3,10] Autonomic disturbances, including vasomotor instability, have likewise been documented, reinforcing the need for careful patient selection and performance in specialized centers.^[4,10,11]

Given the relevance of this procedure for a specific and often overlooked subgroup of patients with refractory neuropathic pain, institutional studies remain essential for elucidating indications, outcomes, and complication patterns. The analysis of local case series enriches the existing literature and contributes to the continuous refinement of the technique, particularly in centers specializing in pain management and functional neurosurgery.

MATERIALS AND METHODS

This retrospective case series comprised 6 patients diagnosed with intractable pain secondary to root avulsion injury who underwent the modified DREZ procedure between 2021 and 2025. All interventions were performed by a single neurosurgical team at a referral center in Southern Brazil. Notably, the surgical technique utilized a microsurgical approach to enhance visualization and lesioning precision. Regarding neuroimaging assessment, all patients underwent contrast-enhanced magnetic resonance imaging (MRI) preoperatively to assess the root injury and guide surgical planning. Postoperatively, MRI was performed to objectively evaluate the topography and extent of the surgically induced DREZ lesion.

In this case series, the variables analyzed included sex, age, laterality of the injury, and perioperative complications. Clinical outcomes were evaluated using the Visual Analog Scale (VAS) to quantify pain intensity and by assessing the

postoperative requirement for analgesic medication. The collected data were subsequently compared with outcomes reported in the current literature.

Surgical approach

The procedure was initiated by positioning the patient in the prone position with the head secured in a Mayfield clamp. Under general anesthesia, electrodes were placed on the patient’s scalp, skin, and/or directly into muscles to record electrical signals for the intraoperative neurophysiological monitoring. Specifically, transcranial motor evoked potentials were utilized in all cases to monitor the corticospinal tract. A wide laminectomy was performed to expose the dura mater, followed by a longitudinal durotomy and dural retraction.

Under microscopic visualization, the pia mater of the posterolateral sulcus was incised. Upon identification of the root avulsion injury, microsurgical lesioning of Rexed laminae I through VI of the posterior gray matter was performed [Figure 1]. The dissection utilized bipolar coagulation for superficial layers and a blunt dissection technique for the deeper layers to minimize thermal injury, developing the plane between the posterior and lateral funiculi.

Adjacent radiculopial arteries and veins were meticulously preserved. The rostrocaudal extent of the lesion was determined by the levels of the root avulsion. Visual demonstration of the following procedure is demonstrated in figure 2. The depth of the DREZ lesioning was strictly measured intraoperatively using a paper ruler, reaching between 4 and 5 mm from the spinal cord surface [Figure 3]. Finally, laminoplasty was performed, and the laminae were fixed with titanium plates to ensure anatomical reconstruction. The dura was then repaired with duroplasty, and dural anchoring was performed. Final hemostasis was confirmed, and the wound was closed in layers. The wound was covered by a sterile dressing.

Depth definition and measurement

We used a small ruler to measure the depth of dissection intraoperatively, with depth measured from the pial surface. In addition, bipolar forceps with a 4-mm-long tip were used as an auxiliary reference, further assisting with depth estimation and procedural safety. The angle of dissection was maintained at approximately 20° in the medial direction [Figure 4].

Definition of superficial versus deep layers

The distinction between superficial and deep layers was based on depth measurements obtained using the ruler during dissection. In our experience, we did not identify any reliable or consistent anatomical landmark that could be used as a reference for this transition.

Bipolar coagulation parameters

Bipolar coagulation parameters were set between 3 and 5 on the bipolar generator, followed by blunt dissection and medial-to-lateral separation of the lesion margins.

Rostrocaudal extent of lesioning and Lissauer’s tract

Because primary nociceptive afferents may ascend and descend across adjacent segments within Lissauer’s tract before entering the dorsal horn, we chose to extend the lesion 5 mm above and 5 mm below the target lesion area. The final extent of the lesion is demonstrated in figure 5.

Timing of pain improvement and outcome assessment

Pain improvement was assessed in the immediate postoperative period and on postoperative day 1. All patients maintained the same postoperative pain score during outpatient follow-up, which followed a routine schedule at 10 days after discharge, 30 days, and every 3 months thereafter.

Table 1: Clinical characteristics of patients who undergone dorsal root entry zone.

Patient	Date of surgery	Gender, age	Etiology	Laterality	Eva score		Postoperative use of painkillers	Complications
					Preoperative	Postoperative		
1	March 8, 2021	M, 24	*MVC	Left	9	0	No	No
2	May 29, 2021	M, 56	MVC	Left	7	2	No	No
3	October 4, 2023	F, 66	MVC	Left	8	1	No	No
4	December 13, 2023	M, 62	MVC	Right	9	3	Yes	Surgical wound dehiscence
5	March 14, 2025	M, 49	MVC	Left	10	2	Yes	No
6	August 19, 2025	F, 76	MVC	Right	10	0	No	No

*MVC: Motor vehicle collision M: Male, F: Female

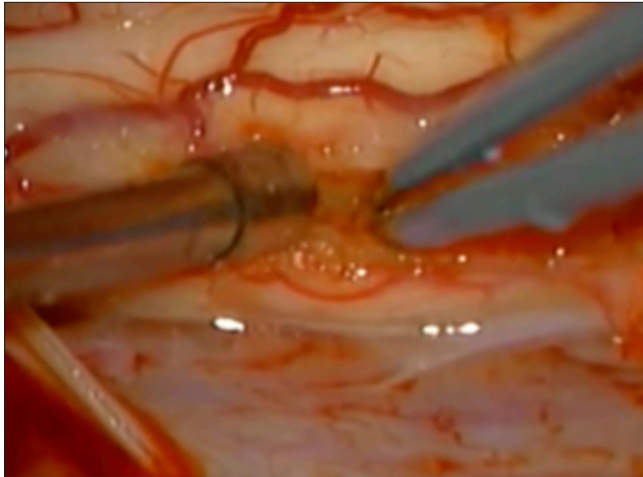


Figure 1: Technique employed for lesioning the posterior horn of the spinal gray matter using bipolar forceps.

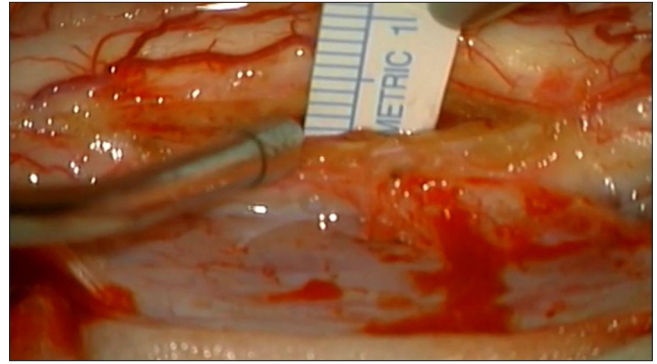


Figure 3: Intraoperative photograph illustrating the dorsal root entry zone lesioning technique. Depth of dissection is measured from the pial surface using a ruler, with bipolar forceps (4-mm tip) serving as an auxiliary depth reference. Lesioning is performed with an approximately 20° medial angulation and extends 5 mm above and below the target segment to account for Lissauer's tract.

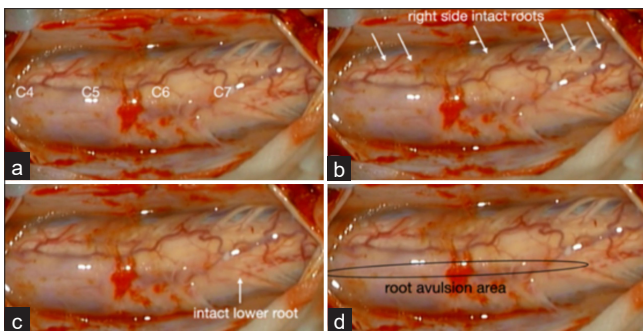


Figure 2: (a) Wide laminectomy from C3 to T1. (b) On the right side of the spinal cord, intact roots are observed (white arrows) (c,d) whereas on the left side, root avulsion (Blue oval) from C4 to C7 is evident.

Study sample

A total of 6 cases of intractable pain secondary to root avulsion injury were treated in this case series [Table 1], from which 4 were men (66.6%) and 2 were women (33.3%). The mean age was 55.5 years old, ranging from 24 to 76 years of age. All root avulsion injuries were caused by motor vehicle accidents, and injuries were mostly located on the left side ($n = 4$) rather than the right side ($n = 2$). Preoperative EVA score ranged from 7 to 10, with a mean score of 8.83.

RESULTS

Pain relief

All patients in the study cohort demonstrated significant pain reduction following the procedure. Postoperative VAS scores ranged from 0 to 3, representing a relative improvement of

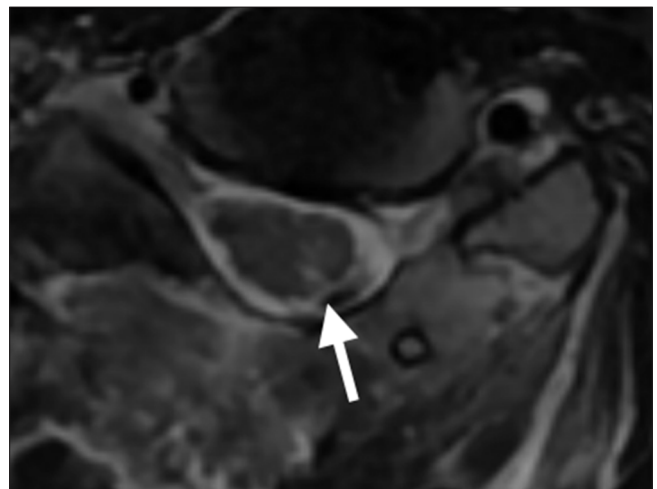


Figure 4: Cervical spine magnetic resonance imaging in the T2 sequence with the arrow indicating the site of the dorsal root entry zone lesion.

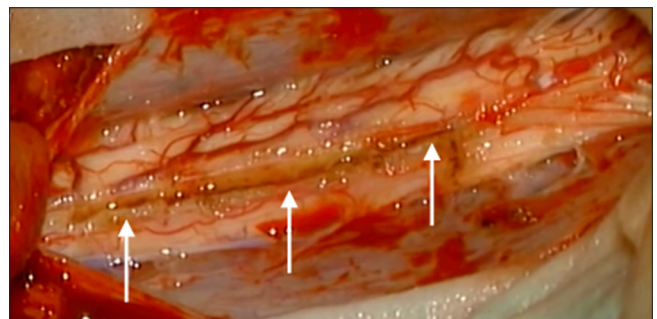


Figure 5: Final appearance of the extent of the injury (arrows) in the posterior horn of the spinal gray matter in the sagittal plane, defined by the spinal cord segmental levels at which root avulsion was observed.

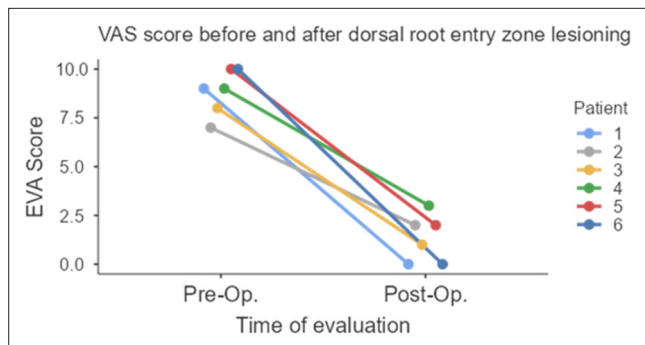


Figure 6: Visual Analog Scale score before and after dorsal root entry zone lesioning

66.7–100% compared to preoperative baselines. Notably, complete pain cessation was achieved in two patients (33.3%). A detailed breakdown of the clinical improvement is illustrated in Figure 6.

Medication independence

Regarding analgesic consumption, four patients (66.7%) achieved complete independence from pain medication postoperatively. Two patients (33.3%) continued to require analgesics; however, this was attributed to a change in the pain pattern rather than the persistence of the original avulsion-related pain, and both reported a reduction in overall pain intensity.

Complications and safety profile

The modified microsurgical technique demonstrated a favorable safety profile. No patients experienced cerebrospinal fluid (CSF) leakage, infection, or new permanent neurological deficits, such as motor weakness or sensory loss, related to the procedure. Autonomic stability was preserved in all cases. One patient developed a surgical site complication involving wound dehiscence, which was successfully managed with surgical revision.

DISCUSSION

The present case series demonstrates particularly favorable outcomes with the systematic execution of deep DREZ lesioning in patients with neuropathic pain resulting from traumatic cervical root avulsion. All 6 patients showed a marked reduction in pain intensity, with postoperative scores ranging from 0 to 3, and 4 of them achieved complete independence from analgesic medications. These findings place the effectiveness of the technique in line with the best contemporary series and suggest that a deep approach to the posterior horn may play a decisive role in achieving sustained pain relief.

The contrast between the results of this series and the significant rates of residual pain described in classic techniques is notable. In the superficial approaches of Nashold Jr. and Ostdahl^[6] and of Sindou *et al.*,^[8] which were limited to Rexed laminae I and II, residual or recurrent pain is reported in 23–70% of patients in long-term follow-up.^[5,11,12] The pattern of improvement seen in this series, characterized by complete or near-complete resolution of initial pain in all patients, is more consistent with the findings of the deep techniques described by Takai and Taniguchi,^[11] who standardized lesioning of laminae I through VI at a depth of 4–5 mm and reported excellent or good pain relief in 100% of patients.

The fact that 4 of the 6 patients completely discontinued analgesic medication reinforces the segmental effectiveness of the deep technique. The two patients who continued pharmacological treatment experienced pain of a pattern distinct from the original deafferentation pain, a phenomenon also reported by Takai in patients who developed new, usually transient pain after surgery.^[11] This suggests that the central mechanism of the primary pain was effectively modulated by the intervention and that continued medication use may reflect secondary sensitization or parallel pain processes.

In our experience, we have found that for refractory pain due to brachial plexus avulsion, the best alternative is treatment with DREZotomy, as an option compared to epidural stimulation electrodes, in addition to being less expensive than device implantation. While techniques such as spinal cord stimulation have been explored in various neuropathic conditions, the direct modulation of the dorsal horn hyperactivity through deep DREZ lesioning remains a primary consideration for the specific pathophysiology of root avulsion.

The safety of the technique in this series also deserves emphasis. No permanent neurological deficits were observed, nor complications such as CSF leak, infection, or autonomic instability, events that may occur in superficial techniques. Only one superficial wound dehiscence was recorded, which resolved after surgical revision. These findings reinforce that the precise division of the posterior and lateral funiculi, combined with the use of blunt dissection, allows safe access to the deep layers of the dorsal gray matter.

The absence of new-onset pain in this series is another important aspect. In Takai's study, pain at adjacent levels occurred in up to 30% of cases, usually transient.^[11] The lack of this phenomenon in the present series may reflect technical differences, more rigorous vascular preservation, or individual variations in spinal anatomy.

From a pathophysiological standpoint, the results of this series reinforce the importance of the findings that motivated the transition from superficial to deep lesioning. WDR neurons, located in Rexed laminae V and VI, become hyperexcitable after root injury and contribute to mechanisms such as

windup, allodynia, and spontaneous pain.^[13] The significant relief observed even in patients with maximal preoperative pain (VAS 10) suggests that interruption of these deep circuits was a determinant of the clinical outcome. The intraoperative observation of gliotic tissue in the internal layers, described by Takai as a potentially hyperactive substrate associated with deafferentation,^[11] also supports this interpretation.

We believe that our study has limitations due to the small number of cases presented and the follow-up period; however, the marked improvement in pain scores has encouraged us to reproduce the technique and report these cases. Comparative studies with larger samples and longer follow-up remain necessary to clarify whether the deep technique provides greater long-term benefit than superficial techniques across different specialized centers.

Nevertheless, the correspondence between our results and those of specialized centers reinforces that the deep DREZ approach, when performed with anatomical precision and neurophysiological monitoring, is a safe and highly effective option for the treatment of neuropathic pain caused by cervical root avulsion.

CONCLUSION

Deep dorsal root entry zone (DREZ) lesioning performed through a standardized microsurgical technique demonstrated a high rate of pain relief in patients with neuropathic pain secondary to cervical root avulsion. All patients in this series experienced substantial reductions in pain intensity, and most achieved independence from analgesic medications, reinforcing the effectiveness of targeting deeper dorsal horn laminae involved in neuropathic pain generation.

The favorable safety profile observed, with the absence of permanent neurological deficits and only a single minor surgical complication, highlights the importance of meticulous microsurgical technique, precise anatomical targeting, and intraoperative neurophysiological monitoring. These elements contribute to minimizing complications while maximizing therapeutic benefit.

Although limited by the small sample size and the retrospective nature of the study, the results are consistent with those reported in specialized centers and support the role of deep DREZ lesioning as a reliable surgical option for patients with refractory neuropathic pain due to cervical root avulsion. Further studies with larger cohorts and longer follow-up are necessary to better define long-term outcomes and to compare the efficacy of deep versus superficial approaches to the dorsal root entry zone.

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