DORSAL ROOT ENTRY ZONE LESIONING FOR BRACHIAL PLEXUS AVULSION: A COMPREHENSIVE LITERATURE REVIEW

Abstract

Dorsal root entry zone (DREZ) lesioning is a neurosurgical procedure that aims to relieve severe neuropathic pain in patients with brachial plexus avulsion by selectively destroying nociceptive neural structures in the posterior cervical spinal cord. Since the introduction of the procedure over four decades ago, the DREZ lesioning technique has undergone numerous modifications, with a variety of centre- and surgeon-dependent technical differences and patient outcomes. We have reviewed the literature to discuss reported methods of DREZ lesioning and outcomes.

Key Words

Dorsal root entry zone lesioning, brachial plexus avulsion, functional neurosurgery, pain relief

Introduction

Brachial plexus avulsion (BPA) is a traumatic injury that often results in profound motor and sensory deficits. In addition to neurological impairment, excruciating and persistent upper limb pain is a frequent contributor to disablement in BPA. While pharmacological treatment is the mainstay of BPA pain management, a small number of patients have continued pain despite treatment. Controlled lesioning of the spinal cord dorsal root entry zone (DREZ) is a highly specialised neurosurgical procedure that can be performed to relieve pharmacologically-unresponsive pain. In this paper, we outline the role of DREZ lesioning for reducing BPA pain, highlighting the concept, exploring the technical details and discussing the results and complications of the procedure.

Pathophysiology of BPA

BPA is a severe form of brachial plexus injury. The defining feature of BPA is that brachial plexus nerve roots are pulled out of the spinal cord at the point where they enter the cord, causing a pre-ganglionic lesion.[1] Depending on the mechanism and force of injury, patients may have some spared roots (partial BPA), or alternatively all five roots, C5–T1, may be avulsed (complete BPA). In partial BPA, there is contention as to whether the avulsed roots contribute to BPA pain, with deafferentation leading to spontaneous bursting activity of dorsal horn neurones at avulsed levels,[2] or whether adjacent spinal levels with preserved, non-avulsed roots are in fact more responsible.[3] The potential significance of non-avulsed roots being the origin of BPA pain is that they may present a target for early surgical intervention in the form of nerve root grafting.[3]

The lesion in BPA is at the interface between the central and peripheral nervous systems, possibly explaining the complex and variable pain phenomena ascribed to BPA, which often differ considerably between patients: continuous and paroxysmal components,[4–13] 'shooting',[4,7] 'crushing'[6,9,11,12] and 'burning'[4–9,11,12,14–16] sensations, cold allodynia,[5] and phantom limb pain.[17] In addition to peripherally-originating neuropathic mechanisms, BPA pain is recognised to have a strong 'central sensitisation' component, whereby nociceptive stimuli are amplified and pain thresholds are reduced.[5] Furthermore, thalamic[18] and cortical remodelling (involving epileptiform neuronal activity in regions representing the deafferented limb[19]) perhaps contribute to the phantom limb pain experienced by a significant proportion of patients in response to lost sensory input.[5]

Epidemiology and diagnosis of BPA

An estimated 1% of multi-trauma patients sustain brachial plexus injury, of which 20% have at least one avulsed nerve root.[20] Several factors, including industrialisation of developing nations and concomitant increases in vehicular and workplace-related trauma, widespread uptake of 'extreme sports' and transportation methods with ever greater speed[1,15] contribute to increasing trends in the global burden of BPA.[1,21] Given these aetiologies, young males are at greatest risk of BPA.[21]

With increasing healthcare provision around the globe, particularly in less developed nations, there is greater understanding and increased diagnosis of BPA. Radiological investigation is helpful in BPA diagnosis, computerised tomography myelography having an accuracy of 85% in identifying root avulsion, and magnetic resonance imaging 52%.[22] Importantly, the hallmark pseudomeningocoeles signifying avulsion are not always visible on preoperative imaging, meaning partially or totally avulsed roots missed on neuroimaging may be encountered intraoperatively.[7] Electrophysiology is also assistive in differentiating between *pre*-ganglionic brachial plexus *avulsion* from other *post*-ganglionic brachial plexus *injuries*, with nerve conduction studies showing preservation of sensory nerve action potentials (SNAPs) in the former but not the latter.[23] It is important to define the varying types and severities of brachial plexus injury, including BPA, for management and prognostication.

Options for the management of BPA pain

BPA pain can be managed conservatively or surgically. Conservative options include pharmacological analgesia (non-steroidal anti-inflammatory drugs, tricyclic antidepressants, calcium channel blockers, antiepileptics, opioids, lignocaine or ketamine infusions and experimental agents such as cannabinoids[24]); supportive devices[21]; physiotherapy; occupational rehabilitation[19] and complementary therapies including acupuncture.[19] By the time a BPA patient is considered for DREZ lesioning, many of these measures will have failed.

In patients for whom conservative approaches prove inadequate, surgical management is an option. The unique symptomatology of the patient, as well as preoperative electrophysiology assessing whether the injury is complete or incomplete,[1,25] are key in selecting the appropriate procedure and tailoring the optimal surgical plan.

Surgical procedures available for BPA pain are classifiable as ablative, modulatory or reconstructive (*Table 1*). Ablative surgery involves destruction of nervous tissue to hinder transmission of pain

processing, DREZ lesioning being by far the most common such procedure. The following less common options have also been described for BPA pain: stereotactic mesencephalotomy, thalamotomy and anterolateral cordotomy.[19] Modulatory procedures, either at the spinal cord or brain level, aim to use electrical or pharmacological stimulation to modify nociceptive transmission without destruction of neural tissue: spinal cord stimulation, intrathecal analgesic pump implantation,[25] direct motor cortical stimulation[14,21,25,26] and thalamic deep brain stimulation[25,27] are examples that have been used for BPA pain. Reconstructive procedures seek to restore original nervous function as much as possible via 'neurotisation', or nerve transfer, for instance using the intercostal nerve.[5] Pain relief may ensue even before motor or sensory improvement after such operations, and the return of muscle activity has been correlated with further improvements in pain.[28]

		TYPE OF SURGICAL INTERVENTION		
		ABLATIVE	MODULATORY	RECONSTRUCTIVE
SITE	BRAIN OR BRAINSTEM	Stereotactic mesencephalotomy Thalamotomy	Electrical motor cortex stimulation Thalamic deep brain stimulation	
	SPINAL CORD	Anterolateral cordotomy Dorsal root entry zone lesioning	Intrathecal pump Spinal cord stimulation	
	PERIPHERAL NERVES			Neurotisation (nerve transfer)

Table 1: Surgical options for management of BPA pain, categorised by site of intervention (left) and type of procedure (top).

Role of DREZ lesioning in BPA

The cervical dorsal root entry zone (DREZ) is the region of the spinal cord at which the dorsal roots (carrying afferent nociceptive and somatosensory information from the upper limb) terminate. A principally surgical rather than neuroanatomical term, the DREZ underlies the posterolateral sulcus (PLS) on the spinal cord surface, and is thought to encompass both Lissauer's tract (a column of white matter comprised of nociceptive fibres ascending or descending a few segmental levels) and superficial layers of the dorsal horn grey matter: Rexed laminae I–V (*Figure 1*). Anatomical and neurobiological evidence strongly implicates all these regions in the transmission and initial central processing of pain. The avulsion of nerve roots in BPA results in damage to Lissauer's tract (itself a key modulator of

incoming sensory information[29]) and Rexed laminae I–III in particular, with impairment of local inhibitory transmission.[30] Surgical ablation of the DREZ destroys and thereby nullifies aberrant nociceptive processing that gives rise to BPA pain.

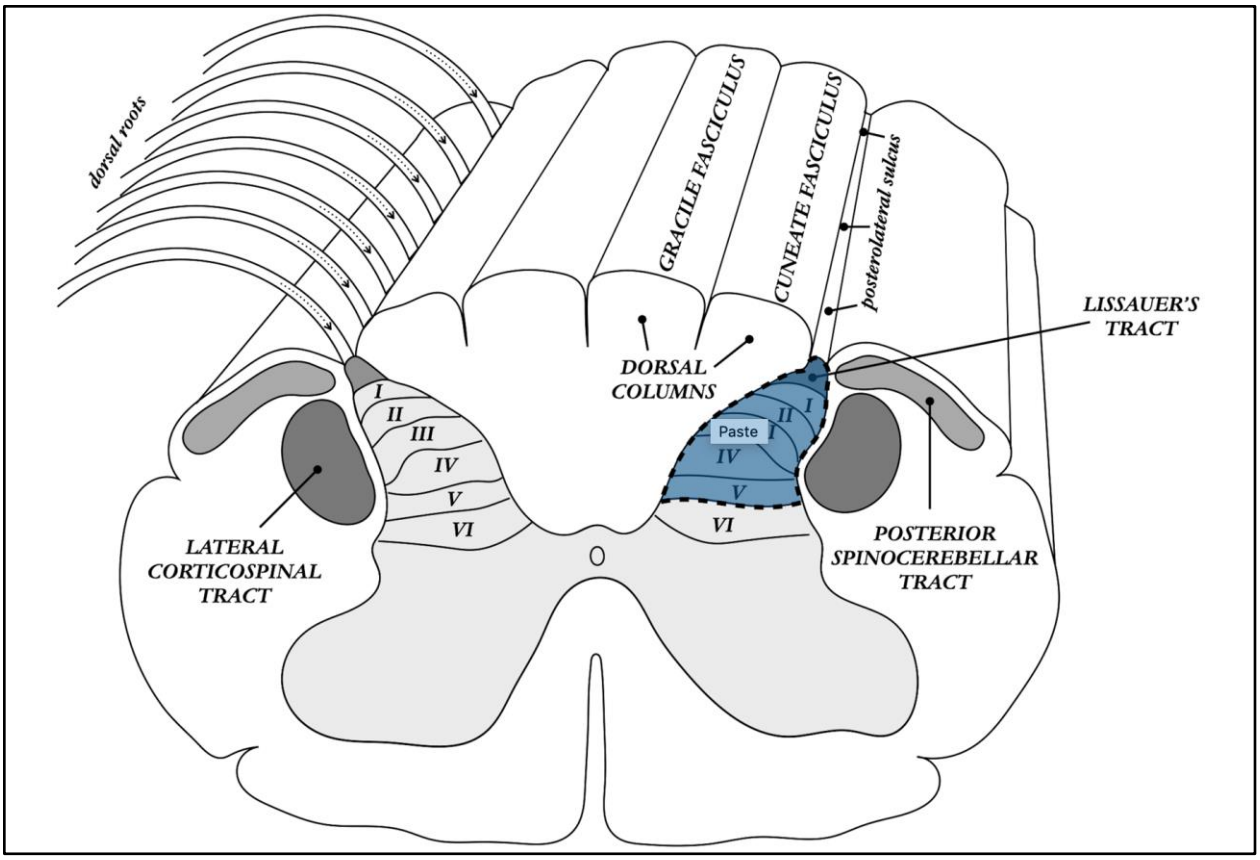

Figure 1: Relationship of surrounding spinal tracts to anatomical structures comprising the DREZ. *I–VI represent the Rexed laminae of the dorsal horn: the shaded region represents the DREZ.*

Since its origins in the 1970s,[15,31] DREZ lesioning has been attempted for relief of an aetiologically diverse collection of pain syndromes: spinal cord injury[32–34]; cauda equina injury[32,35–37]; conus medullaris or lumbosacral plexus injury[30,36,38,39]; phantom limb pain[32,33,40,41]; post-herpetic neuralgia[33,40–42]; syringomyelia[41]; complex regional pain syndrome[32,33]; cancer- or radiation-induced pain[32,34,40]; and spasticity[2,40]. Nowadays, although DREZ lesioning is occasionally used for these alternative pathologies, its primary indication is for BPA deafferentation pain due to more favourable patient outcomes. This is particularly the case for the 'paroxysmal' BPA pain component,[4,14,32] though in some cohorts, the 'constant' pain element is seen to improve to a similar degree.[9]

Modalities for DREZ lesioning

Several variant DREZ lesioning methods have been described, all of which entail the creation of multiple small lesions, or a single longitudinal lesion, along the PLS, the surface landmark of the DREZ region. The principal modalities for creating lesions are 'microsurgical DREZotomy' (MDT), radiofrequency (RF) lesioning, laser lesioning and ultrasound lesioning. All share a similar initial approach. The patient is anaesthetised and usually placed in the prone position. Serial laminectomies or hemilaminectomies are performed to expose the dural sac, which is incised and reflected along with the underlying arachnoid. After exposure of the pial surface and PLS identification, the following specific lesioning methods may be used (technical parameters summarised in *Table 2*).

PARAMETER	LESIONING MODALITY			
	MDT	RF	LASER	US
INTER-LESION DISTANCE	N/A	0.33–3mm (1.5mm)	1–2mm (1.75mm)	unspecified or continuous
LESION DEPTH	1–4mm (2.5mm)	2–2.5mm (2mm)	1–2mm (1.75mm)	1.5–2mm, then microcavity opening
ANGLE	30–45º (45º)	25–45º (28.75º)	45º (45º)	25º
TIME PER LESION	2s (2s)	1–30s (15s)	0.1–0.2s (0.125s)	unspecified
CURRENT OR POWER SETTING	N/A	25–260mA (45mA)	5–20W (16W)	44kHz
TIP TEMPERATURE	N/A	60–80ºC (75ºC)	N/A	N/A
TIP DIMENSION	N/A	L: 1.5–3mm (2mm) D: 0.15–0.5mm (0.25mm)	D: 0.2mm (0.2mm)	unspecified

Table 2: Summary of lesioning parameters used in the literature. The parameter ranges are provided for each lesioning modality, with median values provided in parentheses. *Note that only a single study was performed for ultrasound lesioning, meaning that no medians are required. MDT — microsurgical DREZotomy; RF — radiofrequency lesioning; US — ultrasound; N/A — not applicable; L — tip length; D — tip diameter.*

Microsurgical DREZotomy (MDT)

The original DREZ lesioning method, the 'microsurgical DREZotomy' (MDT) technique, was described by Sindou in 1972[43] and involved dual-modality lesioning of the DREZ (*Figure 2*): both with a 'microknife' incision and subsequent bipolar coagulation, the intention being selective destruction

of 1) fine nociceptive and large myotatic fibres found in the lateral dorsal rootlet; 2) the medial part of Lissauer's tract and 3) the superficial Rexed laminae I–III of the dorsal horn, whilst attempting to spare the large somatosensory fibres, the lateral (inhibitory) Lissauer's tract and the remainder of the dorsal horn.[8,44] The Sindou method has undergone minor alterations over the decades, the typical angle of approach ranging between 30º and 45º[2,4,7,8,32,42,44–48] to the sagittal plane at the entry point of the dorsal rootlets into the PLS identified under magnification.[7,8,32,48] An initial continuous longitudinal incision at a depth varying from 1mm to 4mm[2,5,6,14,33,34,37,42,49,50,51] is created using a microknife, supplemented by use of a sharp bipolar microforceps to form 2-second[45] sequential 'dotted' coagulation lesions, typically 1mm deeper than the initial incision, on either side of the incision.[4,7] Prestor[13,41] omitted microknife incision, using only bipolar forceps to create a 2–3mm-deep coagulation lesion along the DREZ.

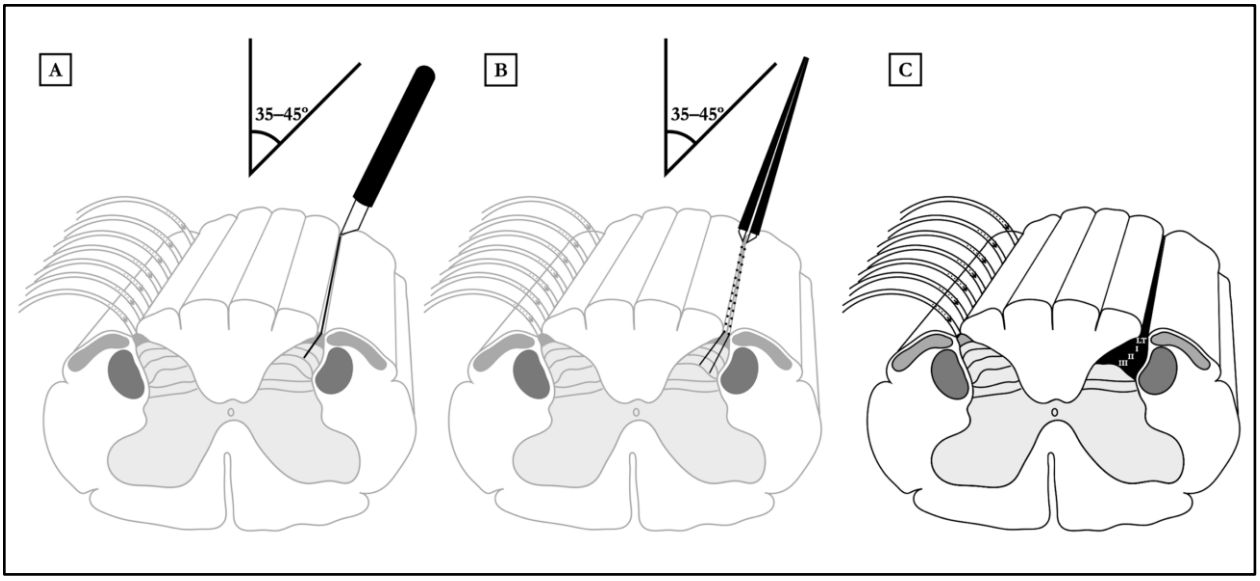

Figure 2: The classical MDT technique for lesioning the DREZ. *Firstly, a microknife is used to incise the DREZ (**A**), before dotted lesions are created on either side of the initial incision, using bipolar forceps (**B**). This is thought to lesion the medial Lissauer's tract [LT] and superficial-most three Rexed laminae: I, II and III (**C**).*

Radiofrequency

Radiofrequency (RF) ablation is the most commonly utilised modality for DREZ lesioning (*Figure 3*). The electrode used for RF lesioning of the DREZ can either be a standard cordotomy electrode, or preferably a dedicated DREZ design. The RF electrode usually has an uninsulated tip 1.5–3mm in length and 0.15–0.5mm in diameter,[6,9–11,15,17,19,33,34,36,38,40,50–58,59] and is often tapered.[15,50,53,56] The electrode

is introduced into the PLS of avulsed spinal cord segments to a depth of 2mm[10,14,15,17,33,34,38,40,53,54,57,59–61] at an angle of 25–45º to the sagittal plane,[10,14,15,33,34,36,38,40,50,51,53,54,61] whereupon a longitudinal series of coagulation lesions are created at 1–3mm intervals.[9–11,14–17,19,33,34,40,50–54,60,62,63] Broadly, there are two approaches for regulating lesion intensity: current-based (ranging between 25mA and 75mA[6,9,15,16,36,50,52–55,60,62]) and temperature-based (60–80ºC[6,9,11,17,19,33,34,36,40,51,52,59,63]), the electrode being left in position for between 5 and 30 seconds[6,9–11,14–17,33,34,36,50–55,57,59,60,62] for both. Notable deviations from the original 1979 procedure include augmentation of the RF coagulation with a further microblade incision of 2.5mm depth in order to maximise destruction of the deafferented dorsal horn tissue,[19] or incision of the pia prior to electrode penetration.[52] Some groups have employed denser lesioning strategies, such as two or three lesions per millimetre using a thinner 0.2mm-diameter electrode,[38,56] with a high-current, short-duration technique (1–2 seconds at 0.16–0.26A).[56]

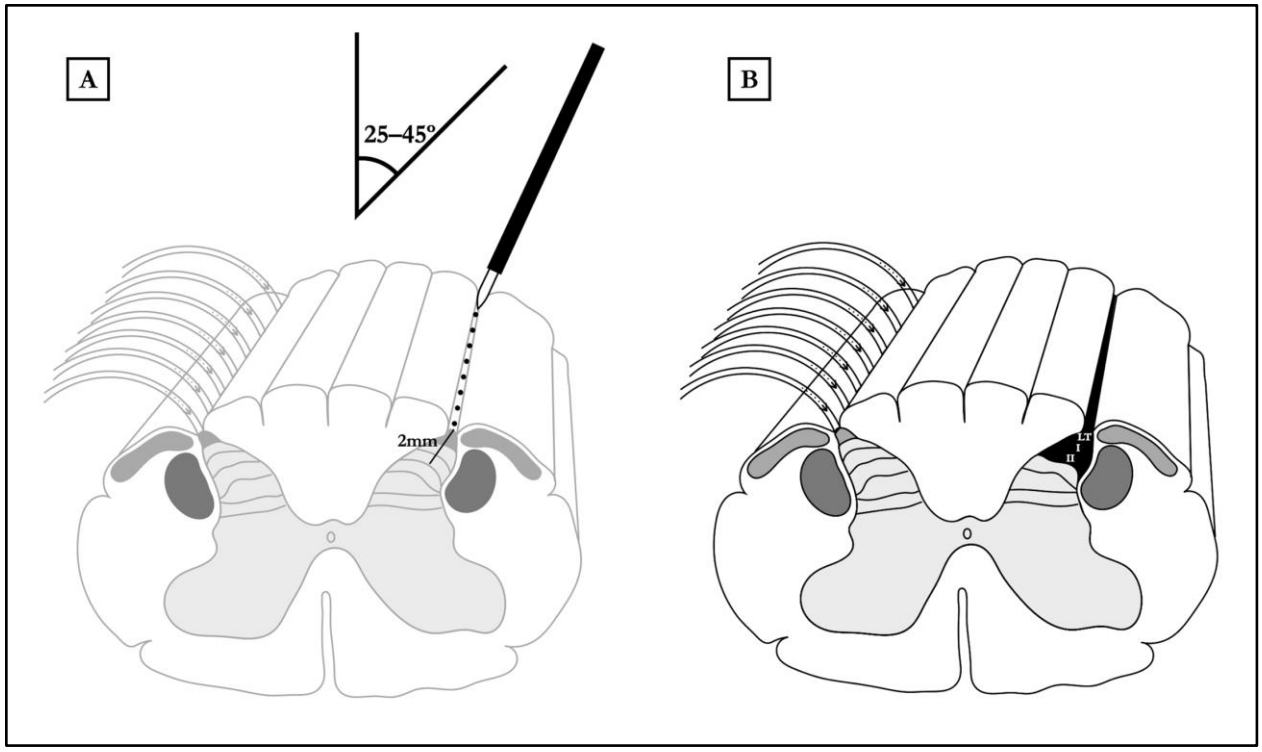

Figure 3: The RF technique for lesioning the DREZ. *An RF electrode is used to make serial coagulation lesions typically of 2mm depth along the posterolateral sulcus (**A**). This is thought to result in destruction of the Lissauer's tract [LT] and the superficial-most two Rexed laminae, I and II (**B**).*

Laser

Either carbon dioxide (CO_2) or argon lasers can be used to create DREZ lesions. However, CO_2 laser beams undergo thermal dissipation when in contact with water and therefore clearance of cerebrospinal fluid from the spinal cord surface is important to avoid damage to surrounding tissue.[29,64] The PLS is identified under the operating microscope using the alignment beam.[65] A pulse duration of 0.1–0.2s paired with 5–20W power,[36,66] or alternatively 1s with 5W,[64] enables the creation of lesions that are 2mm deep longitudinally along the DREZ either edge-to-edge[36] or at 1–2mm intervals,[64,66] using an angle of 15–30º to the sagittal plane.[64] Each lesion has a diameter of 0.325–0.45mm.[64,67] Due to the incompatibility of CO_2 lasers with liquid, blood vessels of diameter 1mm or more are avoided.[66]

With the argon laser technique, small pial vessels are firstly coagulated, either using bipolar microforceps or the laser beam itself (at a far lower power, 1–2W, than for lesion-making).[29,64,65] The laser beam is then set at lesioning power of 16W[65] and aligned with the PLS at an angle of 15–45º[29,64] to the sagittal plane. A series of lesions 0.15–0.2mm[64,65] in diameter, and 1–2mm[29] in depth, can then be formed using a pulse duration of 1s[64] per lesion. These are either edge-to-edge[29] or discretely placed 1–2mm[64] apart.

Ultrasound

In 1993, a technique utilising ultrasound-based DREZ lesioning was described, possible advantages being cited as absence of thermal diffusion phenomena typical of RF, and better preservation of vessels traversing the PLS compared to RF and MDT[68]. The ultrasound procedure entailed the formation of multiple discrete lesions in the PLS using a 44kHz frequency with the ultrasonic probe angled at 25º to the sagittal plane.[68] In later patients, the technique was modified such that a probe with identical settings was used to create a single continuous PLS lesion in affected spinal cord segments: termed a 'sulcomyelotomy'. Lesion depth in both cohorts was typically 2–3mm.[68]

Comparing pain relief outcomes of DREZ lesioning modalities for BPA

Two principal outcomes signify the success of DREZ lesioning for BPA: degree of pain relief (both reduction in pain level and duration of pain relief) and incidence of post-operative deficits. Given the differences in number of studies investigating each of the four chief DREZ lesioning methods and the sample sizes of their cohorts, it is difficult to make valid quantitative comparisons of their relative effectiveness: for instance, only a single 1993 study[68] evaluates the efficacy of the ultrasonic DREZ

lesioning modality in BPA. Moreover, authors grade pain relief outcomes in a number of ways, from pain relief quartiles ('excellent', 'good', 'fair' and 'poor') to less discriminative two-part 'satisfactory' and 'unsatisfactory' categories (simply ≥50% or ≤50%): some groups eschew pain relief percentages entirely, using purely qualitative categories. Most crucially, it is the length of time after which post-operative patient follow-up occurs that appears to determine final outcomes, a further confounding factor when comparing results from studies due to its considerable variability. This is significant due to the well-documented decrease in pain relief efficacy over time after DREZ lesioning.

Table 3 summarises the reported outcomes of DREZ lesioning in studies that evaluated degree of pain relief by percentage. The reported pain relief outcomes are similar across the lesioning modalities. The largest body of evidence is for MDT and RF, with far fewer studies evaluating the efficacy of laser and ultrasound modalities. Moreover, BPA cohort sizes for laser lesioning are significantly smaller, the largest being six patients, meaning that drawing meaningful conclusions from an 100% 'good' outcome (i.e. all six patients with pain relief ≥50%) is difficult.[64]

The existence of both RF and CO_2 laser cohorts in a 1990 study[36] enables direct comparison between these two modalities: of 18 patients that underwent RF ablation, 75% had ≥50% pain relief, while the figure was 50% for the two patients that underwent CO_2 laser DREZ lesioning.[36] The following were cited to represent RF's superiority over laser lesioning: 1) greater accommodation for spinal cord movement during patient respiration, unlike the fixed-position laser beam; and 2) more reproducible RF lesion sizes, in contrast to the occasional size mismatch of laser beams resulting in unintentionally large lesions.[66] Perhaps for these reasons, the modalities used to perform DREZ lesioning for BPA pain since 1993[68] have been restricted to MDT and RF derivatives. Two notable trends have occurred over the years of DREZ lesioning: firstly, a recent tendency by RF ablation groups to use temperature- rather than current-controlled coagulation due to greater reproducibility of lesion character and dimension. Secondly, there has been a gradual increase in depth of MDT lesions, affecting deeper layers of the DREZ and thus maximising the likelihood of successful pain relief, exemplified by a group's recent use of a 4–5mm lesioning depth,[69] in contrast to the 1–2mm typical of earlier studies. These factors may contribute to better pain relief outcomes.

Lesioning method	Reference	No. BPA patients	DEGREE OF PAIN RELIEF AT FINAL FOLLOW-UP (%)			
			75–100%	50–75%	25–50%	<25%
MDT	Jeanmonod and Sindou, 1991[47]	3	67%	0%	33%	0%
MDT	Emery et al, 1997[8]	37	65%	27%		8%
MDT	Guenot et al, 2003[2]	9	44%	22%	11%	22%
MDT	Sindou et al, 2005[7]	55	38%	31%	31%	0%
MDT*	Prestor, 2006[13]	26	76% (12% 'complete')		24%	
MDT	Zheng et al, 2009[45]	14	64%		36%	
MDT	Aichaoui et al, 2011[4]	29	59%	24%	7%	10%
MDT	Dong et al, 2012[49]	7	100%	0%	0%	0%
RF	Nashold and Ostdahl, 1979[15]	18	56%	17%		28%
RF	Thomas and Sheehy, 1983[53]	19	52%	32%		16%
RF	Richter and Seitz, 1984[54]	7	71%	0%	0%	29%
RF	Samii and Moringlane, 1984[16]	22	77%**	14%**		9%
RF	Thomas and Jones, 1984[55]	34	59%	26%		15%
RF***	Bruxelle et al, 1988[19]	18	83%	17%	0%	0%
RF	Campbell et al, 1988[60]	10	80%	20%	0%	0%
RF	Friedman et al, 1988[9]	39	54%	13%	0%	33%
RF	Ishijima et al, 1988[38]	19	82%	18%	0%	0%
RF	Young, 1990[36]	18	75%		25%	
RF	Kumagai et al, 1992[50]	7	29%	14%	57%	0%
RF	Thomas and Kitchen, 1994[12]	44	68%	11%		21%
RF	Fazl et al, 1995[62]	4	100%		0%	
RF	Rath et al, 1997[58]	23	57%	26%		17%
RF	Samii et al, 2001[10]	47	63%	37%		0%
RF	Tomáš and Haninec, 2005[57]	21	62%	38%		0%
RF	Ali et al, 2011[14]	11	55% (P) 27% (C)	18% (P) 0% (C)		27% (P) 73% (C)
RF	Awad et al, 2013[34]	10	60% (30% 'complete')		40% (30% no relief)	
RF	Haninec et al, 2014[59]	52	71%	21%		8%
Laser	Powers et al, 1984[65]	2	100%	0%		0%
Laser	Powers et al, 1988[64]	6	100%	0%		0%

Laser	Young, 1990[36]	4	50%		50%
US	Dreval, 1993[68]	124	87%		13%
Various	Ko et al, 2016[61]	15	33% (13% 'complete')	33%	33%
TOTAL/AVERAGE FOR ALL MODALITIES		754	75.7%		24.3%

Table 3: Percentage pain relief at final follow-up for patients receiving DREZ lesioning for BPA. *Adapted from Sindou et al, 2005[7]. Percentages rounded to nearest whole number. * Modified procedure not incorporating microknife incision; ** Note that this study used slightly modified pain relief categories: '70–100%', '50–70%' and '<50%'; *** Modified procedure also incorporating microblade lesioning of cord. MDT — microsurgical DREZotomy; RF — radiofrequency; US — ultrasound; C — continuous pain component; P — paroxysmal pain component.*

Complications of DREZ lesioning

DREZ lesioning is subject to a significant complication rate, reportedly ranging from 0%[60,61] to 60%[6], a major contributor being unpredictable anatomy following BPA.

The post-BPA spinal cord is often profoundly scarred, distorted and atrophic at levels of root avulsion,[53,64,68,70] greatly hampering identification of the PLS, the chief DREZ landmark. Uncertainty can be reduced in several ways: 1) visualisation of ipsilateral *non-avulsed* rootlet entry points above and below affected spinal segments to facilitate the interpolation of an imaginary line spanning the pathological DREZ segments, which may require caudal and/or rostral extension of the laminectomy; 2) performing complete laminectomy rather than hemilaminectomy to expose the contralateral unaffected zone of dorsal rootlet entry, enabling estimation of the PLS position on the other side; 3) looking for hallmark areas of yellowed discolouration representing old haemorrhages in the PLS region[68]; and 4) use of a dissector or needle to palpate for the relatively indentable PLS compared to the firmer pia mater of surrounding spinal white matter.[60] Some groups have used tissue impedance measurements taken via the DREZ electrode to differentiate between injured cord (with values typically under 1000Ω) and surrounding normal tissue (1200–2000Ω).[10,34,51] For instance, Samii and colleagues used 800Ω as an impedance threshold above which tissue was spared.[10]

In spite of these methods, it is difficult to account for both the patient's individual spinal cord dimensions and the pathophysiological variations seen after BPA. The most commonly reported complications that manifest after DREZ lesioning are motor and sensory deficits of the ipsilateral lower limb. The proximity of the lateral corticospinal tract, dorsal columns and dorsal spinocerebellar

tract to the DREZ (*Figure 4*) mean that these structures are liable to unintentional injury.[32] One mechanism by which this might arise is use of an inappropriate angle of approach, or missing the target of the PLS: straying too medially may compromise the dorsal columns (giving rise to sensory ataxia or proprioceptive deficits, numbness or dysaesthesiae), while the corticospinal tract is threatened if the approach is too lateral, causing motor deficits such as paresis, plegia or spasticity.[71] Furthermore, intraoperative electrophysiological data suggest that, with modalities in which coagulation lesions play a part, heat energy may be propagated through spinal tissue, extending into surrounding tracts and causing these complications.[52] Importantly, diminished sensation at levels receiving DREZ lesioning is an expected result and is therefore not classified as a complication.

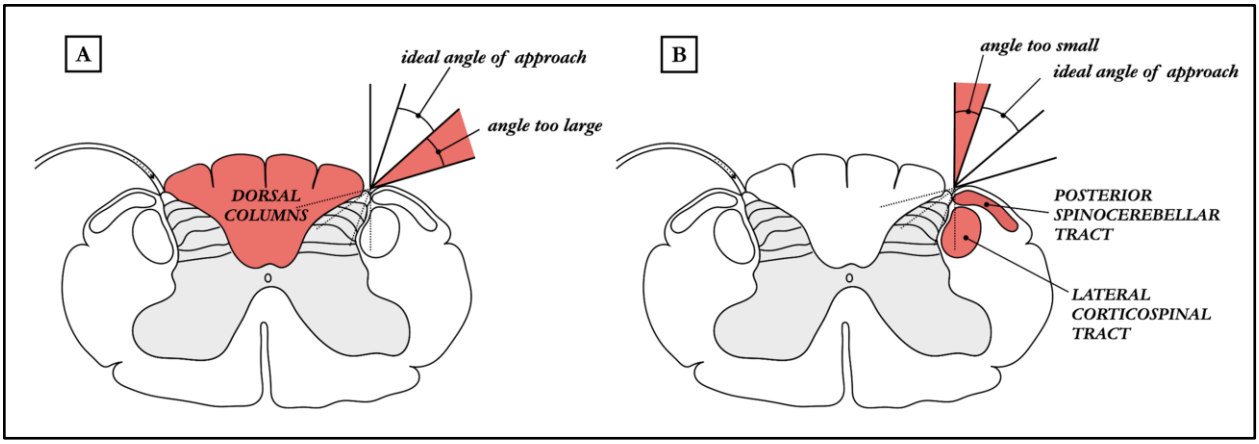

Figure 4: The neuroanatomical basis of complications that may arise after DREZ lesioning. *Use of too large an approach angle (**A**), or medial displacement of the lesions, can result in damage to the dorsal columns, possibly giving rise to sensory deficit or abnormalities, and sensory ataxia. By contrast, an angle of approach that is too small (**B**), or lateral placement of lesions, can damage the lateral corticospinal tract (causing motor deficits) or posterior spinocerebellar tract (with resulting proprioceptive deficits).*

Generic complications associated with spinal neurosurgery also apply to DREZ lesioning, including cerebrospinal fluid leak,[17,37] subdural haematoma,[10] extradural haematoma,[17,64] meningitis,[32] wound infection or dehiscence,[32,37] and infrequently death.[11,36,38,40,54] *Table 4* summarises the salient complications of DREZ lesioning.

COMMONLY REPORTED	RELATIVELY COMMON	UNCOMMON
Sensory deficit or abnormality[6,7,9–12,15,16,19,32,34,36,38,45,50,52–55,58,59,68–70]	**Impaired coordination**[7,9,11,58,68,70]	**Death**[11,36,38,54,58]
New or changed pain character[7,9,38,45,50,60,64,68,69]	*Gait ataxia*[7,11,58,68]	*From myocardial infarction*[11,54,58]
Dys- or hypoaesthesia of ipsilateral lower limb[6,8,12,19,45,59,69,70]		*From gastrointestinal bleeding*[38]
Proprioceptive deficit in ipsilateral lower limb[12,15,36]		**CSF leak or fistula**[7,19,37,40,45]
Paraesthesia or dysaesthesia of ipsilateral limbs[9,19,32]		**Haematoma**[10,37,64]
Dysaesthesia or paraesthesia of ipsilateral half-chest[32,45,59,68]		*Subdural*[10]
Reduced vibration sense on ipsilateral side[12,54]		*Extradural*[64]
Hypoalgesia of contralateral lower limb[70]		*Subcutaneous*[37]
Dysaesthesia of contralateral upper limb[45]		**Bacterial meningitis**[7,32,45]
Hypoalgesia of ipsilateral hemibody[14]		**Wound problems**[32,37,60]
Motor deficit or abnormality[6,7,9,10–12,14–17,19,34,36,38,40,45,47,50,52–55,58–60,64,68]		*Wound infection*[37]
Ipsilateral lower limb weakness[6,7,10,12,14–16,19,34,36,45,47,53,54,59,68]		*Wound dehiscence*[32]
Hyperreflexia or hypertonia of ipsilateral lower limb[6,9,16,36,60]		*Incisional pain*[60]
Paraparesis or paraplegia[36,64]		**Sphincter or genitourinary dysfunction**[17,36,68]
Monoplegia[17]		

Table 4: Post-operative complications of DREZ lesioning, ranked by commonness as reported in the literature.

Conclusion

The continuing popularity of DREZ lesioning more than four decades on from its introduction is testament to its efficacy in relieving refractory BPA pain that is unresponsive to pharmacological management. Four predominant lesioning modalities are described, all aiming to disrupt nociceptive processing in the DREZ and ultimately achieve freedom from pain in a significant proportion of patients. Lesioning must be sufficiently extensive and permanent to increase the extent and longevity of pain relief, whilst taking care not to cause complications by straying into adjacent spinal tracts. The two most popular lesioning methods are currently MDT and RF, both with highly comparable patient outcomes for BPA. Continuing studies of DREZ lesioning in BPA patients will enable refining and development of this procedure to maximise pain-freedom and minimise concomitant morbidity and mortality.

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