

Original Article

Experience with 25 years of dorsal root entry zone lesioning at a single institution

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Abstract

Background: The authors sought to assess long-term efficacy, surgical morbidity, and postoperative quality of life in patients who have undergone dorsal root entry zone (DREZ) lesioning.

Methods: We utilized the electronic chart system at our institution to identify patients who underwent DREZ lesioning since 1986. Of the patients that were able to be identified, 19 (12 males and 7 females) patients were able to be contacted at time of data collection. The mean age was 47 years (ranging from 23 to 70 years) with average preoperative pain duration of 12.5 years and average follow-up of 4.9 years.

Results: Of the 19 patients we were able to contact, 7 (37%) patients experienced “excellent” postoperative (complete) pain relief with another 6 (32%) reporting “good” improvement. Three (16%) patients reported “mild” pain relief, while three (16%) patients reported “poor” results. Sixteen patients (84%) stated they would undergo DREZ lesioning again, if given a choice. Two patients (11%) had objective evidence of a new, mild motor deficit postoperatively. More than half of the patients, who answered, reported “good” quality of life. Two-sample unequal variance *t*-test showed no statistically significant difference in pain improvement between brachial plexus avulsion and end-zone spinal cord injury pain.

Conclusion: With appropriate patient selection, DREZ lesioning is an efficacious and durable procedure that can be performed with low morbidity and good patient outcomes.

Key Words: Brachial plexus, dorsal root, dorsal root entry zone, neuropathic pain, spinal cord

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INTRODUCTION

Dorsal root entry zone (DREZ) lesioning is an important tool in the neurosurgeon's armamentarium for treatment

of medically refractory chronic pain syndromes associated with deafferentation of neurons located in the superficial Rexed layers of the spinal cord. Medical therapy has shown to be a successful treatment for this form of

neuropathic pain on a short-term basis; however, medical tolerance and intractable pain develop in the vast majority of patients, eventually leading to many surgical consultation.^[1,17,23,36]

The decision of whether DREZ lesioning is an appropriate surgical option hinges on whether the diagnosis supports the location of the pain generator *at* or *proximal* to the second order neurons of the dorsal horn. DREZ lesioning is a good option in the treatment of pain that arises from lesions that disconnect the first and second order neurons of the dorsal horn through either trauma (brachial plexus injury, spinal cord injury), infectious disease (herpetic neuropathy), or compression/invasion of the plexus (Pancoast tumor). Neuromodulation in these groups of patients through either spinal cord stimulation or intrathecal drug delivery has usually been either not successful or may even exacerbate the perception of pain in these individuals.

DREZ lesioning is a surgical technique that selectively destroys neurons located in the posterolateral spinal cord; an area through which sensory fibers enter the cord itself. DREZ lesioning is used to ablate neurons that develop paroxysmal hyperactivity following deafferentation injury.^[27] In 1979, Nashold and Ostdahl first performed DREZ microcoagulation for brachial plexus avulsion pain.^[17] In 1981, Nashold and Bullitt used it for posttraumatic spinal deafferentation pain.^[16] Alternative reports in the literature suggest the DREZ myelotomy was first introduced in France by Sindou in 1972.^[31,33]

The literature is replete with various descriptions of how to lesion the DREZ. Mechanical disruption with a surgical blade followed by bipolar coagulation to deepen the lesion is one option (microsurgical DREZotomy).^[31,33] Laser lesioning^[15,21,22] and focused ultrasound lesioning^[7] have also been described. Our preferred method utilizes a series of radiofrequency lesions made with a Nashold electrode.^[10,16,17,27]

DREZ lesioning using radiofrequency lesioning techniques is the method by which we have performed this surgery. In the subsequent manuscript, we present data regarding the past 25 years of DREZ lesioning by two neurosurgeons at our institution. The aim of this study is to provide insight about microsurgical anatomy, surgical morbidity, and patient outcome.

MATERIALS AND METHODS

Patient selection

We reviewed the electronic chart system to identify all patients who under DREZ lesioning since 1986. Altogether, 101 patients were identified. However, only 19 (12 males and 7 females) patients could be contacted by phone at the time of data collection. The mean age at clinical presentation was 47 years (ranging from 23

to 70 years) with average preoperative pain duration of 12 years and average follow-up of 4.9 years. Of the 19 patients who responded to this survey, 13 received cervical lesioning, whereas the remaining 6 were lesioned in the thoracic part of the spinal cord. Table 1 shows clinical characteristics in patients we were able to contact.

Assessment of outcome

Patients were retrospectively asked to gauge their preoperative level of pain on a visual analog scale (VAS) of 1-10 (1 being no pain and 10 being maximum pain). They were then asked to gauge their present (postoperative) level of pain using the same scale. We considered pain relief to be “excellent” when complete improvement was achieved, “good” when relief was 50% or more, “mild” when improvement was less than 50%, and “poor” when there was no pain relief or in cases of pain exacerbation. We gauged quality of life questions using a binary assessment; “good” or “bad.” All patients were asked if they would have chosen to undergo DREZ lesioning again, if given a choice.

Preoperative assessment

Preoperatively, the character of the patient’s pain was closely evaluated to ensure the presentation was consistent with deafferentation of neurons located in the superficial layers of the spinal cord. Next, the pattern of dermatomal involvement was assessed and the corresponding levels were planned (e.g., for typical brachial plexus avulsion pain, exposure/laminectomy from C4 to T2 will allow a view of involved [C5-T1] nerve roots).

Statistical analysis

Two-sample unequal variance *t*-test was employed to compare postoperative pain between major subtypes of pain; brachial plexus avulsion and end-zone spinal cord injury pain. *P* < 0.05 was considered statistically significant.

Operative technique

The ideal location for the lesion should be at the lateral edge of the spinal rootlet as it enters the cord, where the nociceptive fibers are gathered. The electrode should be inserted to the full depth of the exposed tip (2 mm), and in so doing, impedance measurements can be made to identify zones of injury. Nashold and colleagues described low impedance values (around 500-1000 Ω) associated with areas of injury, versus 1200-2000 Ω for normal gray and white matter of the spinal cord, respectively. This may be useful in delineating the DREZ area and avoiding deviating into adjacent spinal tracts. Somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) may also aid in the identification of these adjacent tracts when there is significant anatomical distortion from previous injury. For cervical regions the angle of the electrode is approximately 30° from midline, whereas in the lower thoracic region it is approximately 20°. The weight of the lesioning electrode is usually

Table 1: Clinical characteristics in patients had undergone DREZ lesioning

Case no.	Age (years), gender	Operation date	Preoperative pain duration (years)	Site of lesion	Cause	Source of pain	Vertebral level	Follow-up (years)
1	52, F	1986	2	BP	Falling down	Blunt BP injury without evidence of avulsion	Cervical	0.7
2	23, M	1989	2	BP	Vehicle accident	BP avulsion	Cervical	0.1
3	24, M	1992	1.5	BP	Vehicle accident	BP avulsion	Cervical	3
4	61, M	1996	-	SC	SCI following surgery	End-zone SCI pain	Thoracic	2
5	54, M	1998	4	BP	Motorcycle	BP avulsion	Cervical	12
6	42, M	2000	15	BP	Work injury	BP avulsion	Cervical	12
7	38, M	2000	21	SC	Vehicle accident	End-zone SCI pain	Thoracic	0.5
8	43, F	2001	4	BP	Gunshot	BP penetrating injury	Cervical	11
9	40, M	2002	0.5	BP	Motorcycle	BP avulsion	Cervical	11
10	37, M	2003	3	BP	Work injury	BP avulsion	Cervical	9
11	38, F	2003	1	BP	Vehicle accident	BP avulsion	Cervical	9
12	35, F	2006	11	BP	Work injury	BP avulsion	Cervical	6
13	65, M	2007	46	SC	Vehicle accident	End-zone SCI pain	Thoracic	5
14	52, F	2008	2	BP	Pancoast tumor	Brachial plexopathy (cancer pain)	Cervical	4
15	54, M	2009	3	SC	Blunt trauma to neck	BP avulsion	Cervical	3
16	66, M	2010	1.5	SC	Vehicle accident	End-zone SCI pain	Thoracic	2
17	48, F	2010	9	SC	Vehicle accident	End-zone SCI pain	Thoracic	2
18	70, F	2011	66	BP	Fall off horse carriage	BP avulsion	Cervical	0.1
19	49, M	2011	22	SC	Vehicle accident	End-zone SCI pain	Thoracic	0.5
Average	47		12					4.9

BP: Brachial plexus, SC: Spinal cord, SCI: Spinal cord injury, DREZ: Dorsal root entry zone

adequate to hold the electrode still without inadvertent dislodgement or movement during the brief lesion.

Lesions are made with the radiofrequency generator set to 75°C for 15-20 seconds. This usually results in a 1 × 2 mm lesion. The lesion is repeated down the length of the DREZ spaced about 1-1.5 mm apart, or essentially the width of the insulated end of the electrode. A typical unilateral DREZ procedure may result in a total of 40-60 lesions spanning four or more spinal cord segments. Thus, an efficient DREZ lesioning technique requires a coordinated effort among the neurosurgeon, the surgical assistant, and the individual running the lesion generator. Once a lesion is created, a small tan discolored area is left or a small puncture is seen where the needle penetrated the cord. It is important to continually reevaluate that DREZ lesions are following the dorsal lateral sulcus if no dorsal rootlets are seen.

If avulsed rootlets are seen throughout the intended lesioning zone, the neurosurgeon may find it useful to begin rostral or caudal to the avulsed segments in the region containing spinal rootlets to identify the dorsolateral sulcus and progress into the avulsed region. Finally, it is very unusual to see significant arteries cross the dorsolateral sulcus, since it is a watershed zone between the dorsal spinal arteries and the anterior spinal artery. However, a prudent neurosurgeon should always avoid injuring any significant arterial supply to the spinal cord.

The DREZ lesions are completed when either the lesions encompass one or two spinal cord segments above the painful zone or the impedances of the cord have normalized. Closure of the arachnoid and dura can be accomplished in one layer with a fine suture (4-0 or 5-0). The use of dural sealants such as thrombogenic derivatives (e.g., Tisseel®, Baxter, Deerfield, IL USA) or synthetic derivatives (e.g., DuraSeal®, Confluent Surgical, Waltham, MA USA) may reduce the incidence of cerebrospinal fluid leak. Fascia and cutaneous closure are performed in routine fashion.

RESULTS

Pain relief

Table 2 illustrates clinical results in 19 patients we were able to contact who had undergone DREZ lesioning. Out of the 19 patients we were able to contact, 7 (37%) patients experienced “excellent” (complete) pain relief with another 6 (32%) reporting “very good” improvement. Three (16%) patients reported “mild” pain relief, while three (16%) patients reported “poor” results. Sixteen patients (84%) would choose to undergo the DREZ lesioning again, if given a choice. The three (16%) patients who reported “poor” results did not recommend this operation.

Two-sample unequal variance *t*-test showed no statistically significant difference ($P > 0.05$) in pain improvement

Table 2: Clinical results in patients had undergone DREZ lesioning

Case no.	Age (years), gender	Operation date	New objective motor deficit postoperative	Preoperative pain (VAS)	Pain now (VAS)	Pain relief	Recommend DREZ procedure
1	52, F	1986	No	7	4	Mild	Yes
2	23, M	1989	No	10	7	Mild	Yes
3	24, M	1992	No	9	2	Good	Yes
4	61, M	1996	No	9	4	Good	Yes
5	54, M	1998	RLE	7	9	Poor	No
6	42, M	2000	No	10	3	Good	Yes
7	38, M	2000	No	5	4	Mild	Yes
8	43, F	2001	No	9	0	Excellent	Yes
9	40, M	2002	No	2	0	Excellent	Yes
10	37, M	2003	No	8	9	Poor	No
11	38, F	2003	No	9	1	Good	Yes
12	35, F	2006	No	10	0	Excellent	Yes
13	65, M	2007	No	9	0	Excellent	Yes
14	52, F	2008	No	9	0	Excellent	Yes
15	54, M	2009	LLE	10	10	Poor	No
16	66, M	2010	No	5	2	Good	Yes
17	48, F	2010	No	9	2	Good	Yes
18	70, F	2011	No	7	0	Excellent	Yes
19	49, M	2011	No	8	0	Excellent	Yes
Average	47			8	3		

LLE: Left lower extremity; RLE: Right lower extremity; DREZ: Dorsal root entry zone; VAS: Visual analog scale

between patients who had suffered brachial plexus injury versus those who had suffered spinal cord injury with subsequent “end-zone” pain. Average postoperative pain on VAS scale was 4.1 vs. 2, respectively, as illustrated in Table 3.

Morbidity and mortality

Two patients (11%) reported a new, motor objective deficit after DREZ lesioning. The first (No. 5) patient originally had suffered a brachial plexus avulsion following a motorcycle collision. He reported mild (4/5) right lower extremity weakness, which developed immediately after the operation and had persisted 14 years after it. The second (No. 15) patient initially had presented following blunt cervical injury with brachial plexus avulsion. Postoperatively, he reported mild (4+/5) left lower extremity weakness that was noted to have persisted 3 years later. The two patients were among the three who reported “poor” results in pain relief. There was no death during or following DREZ lesioning.

Quality of life

Table 4 shows quality of life in patients in our study. Among patients who answered the quality of life questions, 6 of 11 (55%) patients reported “good” general activity, 7 of 10 (70%) patients reported “good” mood, 8 of 13 (62%) patients reported “good” sleeping, and 6 of 9 (67%) reported “good” enjoyment of their lives.

DISCUSSION

Neuroanatomy of pain pathways

Pain is carried by sensory nerve fibers that enter through the dorsal rootlet to terminate in the substantia gelatinosa in the posterolateral gray matter of the spinal cord, also known as the DREZ. The lateral division of the dorsal root contains two specific nerve fibers that carry nociceptive stimulus: A-delta fibers that conduct sharp pain and unmyelinated small C fibers that conduct dull pain.^[11] Interestingly, these nociceptive nerve fibers do not synapse immediately with second-order neurons in the spinal cord. Instead, they ascend 1-2 segments in Lissauer’s tract, immediately lateral to the DREZ. This is clinically relevant, as spinal cord levels as many as two segments above an index dermatome may be involved with nociceptive transmission.^[6,14,24]

Neuropathic pain has been recently defined by Treede *et al.* as “pain arising as a direct consequence of a lesion or disease affecting the somatosensory system.”^[35] In neuropathic pain states, damage to axons leads to membrane hyperexcitability of axons and independent pain generation. The imbalance created by deafferentation results in hypersensitivity of substantia gelatinosa manifesting with symptoms of pain associated with light touch (hyperesthesia) and nonnoxious stimuli (allodynia), mild changes in temperature, movement of hair and flushing.^[2,4,5]

Subtypes of neuropathic pain

Subtypes of neuropathic pain sometimes discussed in the context of DREZ lesioning include traumatic brachial and lumbosacral plexus avulsion injuries, pain postamputation (phantom pain), end-zone pain following spinal cord injury, cancer pain, and postherpetic pain.

Brachial and lumbosacral plexus avulsion injuries are usually the result of a motorcycle accident or motor vehicle accident. The patient typically loses sensation and motor function in one or more of the affected limbs at the time of the accident. Bowel and bladder function are often affected in lumbosacral plexus avulsion injuries. Deafferentation pain develops early in 90% of brachial plexus injury cases, but it may be also delayed for 3-4 months.^[18] Unfortunately, one-third of these patients continue to have pain after 3 years.^[19] Fortunately, patients with brachial or lumbosacral plexus injuries traditionally experience very good results after DREZ lesioning.^[17,26,27] 10 of 19 (53%) patients in our series had suffered brachial plexus avulsion.

End-zone pain usually develops after traumatic spinal cord injuries. It is a girdle-like pain that develops in

the transition zone between dermatomes with normal sensation and dermatomes with total analgesia. This zone, when touched, triggers severe segmental pain and radiating pain to the paralyzed limbs. Patients with this type of pain appear to respond well to DREZ lesioning.^[10] In 1997, Siddall *et al.*^[29] proposed a classification for pain after spinal cord injury, which included four major categories: Musculoskeletal, visceral, neuropathic, and other types of pain. Neuropathic pain is divided into two subdivisions: Pain described in a dermatomal distribution at the level of the lesion, known as neuropathic “at-level” pain. The other subdivision is pain described at least three segments below the level of injury, known as neuropathic “below-level” pain. Six of 19 (32%) patients in this series had neuropathic pain secondary to end-zone pain.

Postamputation pain, known as phantom pain, is common after traumatic or surgical amputations of the upper or lower limbs with a reported incidence is 60-80 after amputation.^[37] However, DREZ lesioning results are dramatically different between traumatic amputations and surgical amputations. In contrast to well results achieved with DREZ lesioning after traumatic amputations,^[12] patients with stump pain after surgical amputations often do not respond to this form of therapy.^[28] Patients with phantom pain should be first treated conservatively with medication or less invasive options like spinal stimulations; leaving DREZ lesioning as the last resort. No patients in this series had neuropathic pain secondary to amputation.

Table 3: Comparison between type of pains

Type of pain (No. of cases)	Preoperative pain mean (VAS)	Postoperative pain mean (VAS)
Brachial plexus avulsion (10)	8.2	4.1
End-zone spinal cord injury (6)	7.5	2

VAS: Visual analog scale

Table 4: Quality of life at time of data collection in patients had undergone DREZ lesioning

Case no.	Age (years), gender	Operation date	General activity	Mood	Sleeping	Enjoyment of life
1	52, F	1986	-	-	Good	-
2	23, M	1989	Bad	Good	Good	Good
3	24, M	1992	Good	Good	Good	Good
4	61, M	1996	Good	Good	Bad	Good
5	54, M	1998	Bad	Good	Bad	Bad
6	42, M	2000	-	-	Good	-
7	38, M	2000	Good	Good	Good	Good
8	43, F	2001	-	-	-	-
9	40, M	2002	-	-	-	-
10	37, M	2003	Good	Good	Good	Good
11	38, F	2003	-	Bad	Bad	-
12	35, F	2006	-	-	-	-
13	65, M	2007	-	-	-	-
14	52, F	2008	Bad	-	-	-
15	54, M	2009	Good	Good	Good	Good
16	66, M	2010	Bad	Bad	Bad	Bad
17	48, F	2010	Good	Bad	Bad	Bad
18	70, F	2011	Bad	-	Good	-
19	49, M	2011	-	-	-	-

DREZ: Dorsal root entry zone

Malignancies that infiltrate the brachial plexus (e.g., Pancoast tumors) or lumbar plexus (e.g., hip osteosarcomas) can result in deafferentation pain due to presumed injury of the axonal elements. Depending on patient-specific factors, alternative operations (such as percutaneous cordotomy) are often useful in this patient population.^[31] However, DREZ lesioning has also been shown to be efficacious.^[30] One of 19 (5%) patients in this series had neuropathic pain secondary to cancerous brachial plexus avulsion.

Postherpetic pain develops in 10-25% of herpes zoster patients.^[20] The character of this pain is described as stimulus-independent, burning, shooting, or electric shock sensation. DREZ lesioning is an unconventional method of treatment for postherpetic pain, although other series have demonstrated modest results in this patient subgroup—often with initial success and high rates of pain relapse with longer periods.^[9,25] No patients in this series had neuropathic pain secondary to herpetic neuralgia.

Long-term DREZ lesioning experience in other centers

Good long-term results with DREZ lesioning have been achieved in other centers around the world. Samii *et al.*, from Germany, published a retrospective study on patients with brachial plexus injury underwent DREZ lesioning.^[26] Authors observed 62% pain reduction in patients with average follow-up period of 14 years. Chen and Tu, from Taiwan, reported 50% good to excellent results in 10 years follow-up.^[3] While Dreval and colleagues, from Russia, achieved 87% pain reduction in patients followed up on average of 47.5 months.^[8]

Sindou and Mertens, from France, used microsurgical DREZotomy for pain due to various spinal cord subtypes of neuropathic pain.^[30] They observed that 60% of patients demonstrated good pain reduction with a mean follow-up of 71 months. Recently, Sindou and colleagues, reported that 66% of patients showed excellent pain relief with 6 years follow-up.^[32]

Kanpolat *et al.*, from Turkey, studied DREZ lesioning in spine and nucleus caudalis. They reported 69% satisfactory relief in spinal DREZotomy group after 1 year of surgery.^[13]

Teixeira and colleagues, from Brazil, retrospectively analyzed different techniques for treatment of brachial plexus avulsion pain.^[34] In comparison to dorsal column stimulation (DCS) and thalamic stimulation (TS), authors found that DREZ lesioning was the only technique that achieved immediate pain improvement in all patients. However, DCS and TS were safer.

CONCLUSION

DREZ lesioning has been used for decades to relieve pain in patients with spinal neuropathic pain. Sixteen

patients (84%) stated they would undergo DREZ lesioning again, if given a choice. The average patient follow-up of 4.9 years in this study represents our institutions positive experience with this procedure. With appropriate patient selection, DREZ lesioning is an efficacious and durable procedure that can be performed with low morbidity and good patient outcomes on long-term basis.

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