

Dorsal Root Entry Zone Operation for Brachial Plexus Neuropathic Pain

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ABSTRACT

Background: We sought to assess efficacy, pain relief, surgical morbidity, and postoperative quality of life in patients who have undergone dorsal root entry zone (DREZ) lesioning for intractable brachial plexus injury and spinal cord injury neuropathic pain.

Methods: We analyzed 16 patients who underwent DREZ lesioning between 2011 and 2016 by a single surgeon. All our patient's data was analyzed on pre- and post-op visual analog scale (VAS) scores, SF12, normalized dispersion index (NDI) score, questionnaires, and outcome scores. The mean age was 48 years (31–62 years) with 15 males and 1 female. Average follow up was 3.6 years.

Results: Of the 16 patients, 3 (20%) patients experienced "excellent" postoperative (complete) pain relief with another 11 (69%) reporting "good" improvement and 1 (11%) had "good" improvement. Two patients (16%) had objective evidence of a new, mild motor deficit postoperatively. All the 16 patients (100%) stated they would recommend DREZ lesioning procedure to anyone with similar symptoms. There was a statistically significant improvement in VAS scores and quality of life scores at 5 years. Five patients had objective evidence of a new, mild posterior column and motor deficit postoperatively which improved within 6 months and 87% of them did not take any medication further.

Conclusion: With the appropriate patient selection, DREZ lesioning is an efficacious and durable procedure that can be performed with low morbidity and very good patient outcomes for patients with brachial plexus avulsion and spinal cord injury pain. Awareness among doctors and patients is necessary.

Keywords: Brachial plexus injury, Neuropathic pain, Dorsal root entry zone rhizotomy, Spinal cord Injury pain

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INTRODUCTION

Dorsal root entry zone (DREZ), which is the first important level of modulation for pain can be a target to treat

resistant neuropathic pain in avulsion injuries. The gate control theory proves to show the dorsal horn as the first important level of modulation for pain sensation. DREZ area includes the dorsal root, Lissauer's tract, and the posterior horn of the spinal cord. Several studies in animals and patients with spinal cord section have demonstrated paroxysmal neuronal hyperactivity in this region, which might be the physiopathological basis of deafferentation pain. Various techniques have been described regarding how to lesion the DREZ. Mechanical disruption to deepen the lesion by surgical methods, LASER lesioning, radio-frequency thermocoagulation and focused ultrasound lesioning help to destroy the DREZ region. In all these techniques we can selectively destroy neurons located in the DREZ area that develop paroxysmal hyperactivity following deafferentation injury. In this chapter, we describe the DREZ lesioning technique we use and report our experience and outcomes over a short-term follow up of 5 years with the micro DREZ lesioning for brachial plexus avulsion and spinal cord injury pain.

Indication

Lesioning techniques are indicated in the following situations intractable neuropathic pain due to:

- Brachial plexus avulsion injury.
- Spinal cord injury (predominantly in the conus medullaris).
- Lesions in the Cauda Equina causing segmental pain.
- Peripheral nerve injuries, amputation, or herpes zoster.
- Very severe pain in patients with long life expectancy and cancer that is limited in extent (Pancoast a tumor).
- Disabling hyperspastic states with pain from Spinal cord injury.

Clinical History

Brachial Plexus Avulsion

Brachial plexus injury is caused by extreme traction exerted on the upper limb causing avulsion of the brachial plexus roots between C5 to T1 either completely or partially in the side of the injury. In India, the most frequent cause is road traffic accidents, mainly motorcycle accidents, with most of the victims being young males. Other traumatic causes include fall from heights,

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industrial injuries, incised wounds and rarely sports injuries or patient malposition during surgery. Brachial plexus injury can be preganglionic lesion which involves avulsion of nerve roots, whereas a postganglionic lesion involves disruption or damage distal to the sensory ganglion. Postganglionic injuries are amenable to repair for motor function, and preganglionic lesions are cannot be repaired nerve transfer procedures can improve muscle function.

Pain Characteristics

Patients with preganglionic lesions due to root avulsion lead to pathological changes and scarring that are responsible for the induction of pain sensations. The pain can be divided into paroxysmal (shock-like) pain and continuous (burning) pain. Some of the characters of the pain described by the patients are as follows, " my arm is on fire with continuous electric shocks 24 hours, even a small noise like tapping aggravates pain, I wanted to end my life and attempted suicide several times, I used to have 24 hours of pain very slightly reduced with tablets, pain will start from hand all the way up to neck, pain was like pinpricks or someone was stabbing my arm and every time it was different, 22 years I had pain and even the slightest noise like a baby crying will set it off, I chewed my hand daily for pain relief as it was like on "burning oil". All this explains the paroxysmal and continuous characters. Most patients have moderate to severe depression along with social and family problems. About one-third of patient's pain settled in a few months to years while one third had pain reduction minimally with medication and the remaining had continuous pain despite all medical and conservative treatment. Pain severity seems to be related to the number of roots avulsed. In brachial plexus injured patients, pain is reported from 67 to 71%, the prevalence of neuropathic pain, reaching up to 95%.¹⁻⁵ Patients with brachial plexus avulsions reported having neuropathic pain more frequently than the patients who had an injury in other portions of the brachial plexus.

Assessment of Outcome

The outcome of surgery depends on many factors including the site and type of injury (Root involvement), the degree of damage, timing between and patient characters like age and sex. occupation.

These can be assessed by the following measures:

- Visual analog scale (VAS) of 1 to 10 (1 being no pain and 10 being maximum pain)
- Short form-12, to assess the quality of life pre and post-surgery especially if they develop new deficits post-op.

- Neck disability index (NDI) score in patients with brachial plexus avulsion we can give them a new onset neck pain post-op which could by itself be a disability.
- Would they have the surgery again if pain returned
- Will they recommend to another person suffering from pain—"yes" or "no"
- Depression score

The success of surgery can be classified as:

- "Excellent"—when complete improvement was achieved,
- "Good"—when relief was 50% or more,
- "Mild"—when improvement was less than 50%
- "Poor"—when there was no pain relief or in cases of pain exacerbation.

METHODS

In this study, we evaluated a 5 years' experience of the efficacy of DREZ lesioning for the treatment deafferentation pain from brachial plexus avulsion and spinal cord injury. All consecutive patients from 2011 to 2017 refractory to other treatments were included. During this period, 16 patients had DREZ lesioning, with a mean age of 48 years (31–62 years). Clinical, epidemiological, surgical and outcome data were analyzed. Telephone interviews were also conducted. Improvement of pain was recorded on the basis of the progressive data collected at follow-up visits as well as through telephone interviews of patients. The following outcome measures were assessed, VAS, SF 12 for quality of life (QOL) measure, NDI for brachial plexus patients and oral question if they will recommend to another person suffering from pain. Patients were followed up at intervals of postop before discharge, 3 months, 6 months, 1 year, 3 years and 5 years. Not all patients have completed the 5 years' follow-up. The outcome was measured as "excellent", "good", "mild" or "poor" as described earlier. Post-operative complications were documented. The aim of the surgery was to reduce the intensity of the neuropathic component of the pain, reduce and avoid intake of medication, avoid any complications from surgery and also take precautions to avoid post-op neck pain and kyphotic deformity due to the extensive laminectomy across the cervicothoracic and hence the neck disability index was used.

Preoperative Assessment

Preoperatively, the character of the pain is assessed if it is consistent with de-afforestation type pain. The dermatomal involvement was assessed which helped with planning the level of laminectomy and level of lesion. General comorbidity and fitness for anesthesia is assessed. Neurophysiological assessment preoperatively has not been very useful in our experience as the clini-

cal assessment is sufficient and recording are difficult sometimes due to severe muscle atrophy and wasting.

Statistical Analysis

Two-samples 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.

Surgical Techniques

Microsurgical DREZ Lesioning

General anesthesia and intraoperative neuromonitoring was used for the surgery. After placing the neuromonitoring leads the patient is placed in a prone position in May field head pins in neutral position, avoiding stretching of the brachial plexus roots and the head is elevated about the heart (Fig. 1). The midline skin incision is made, and an ipsilateral hemilaminectomy is done with preservation of the spinous processes. Sometimes only the segments injured may be needed but in most cases from C3 to T2 laminectomy is necessary. Pseudomeningoceles are frequently seen at the level of the avulsed segments and the dura can be very thin and friable. The dura is opened and anchored with stay sutures carefully avoiding dura shear at the pseudomeningocele areas. Arachnoid adhesions are frequent due to the traumatic avulsion. After removing the adhesions, the cord is inspected to look for atrophy and identify the rootlets ventral and dorsal. They may be normal, atrophic, or partially or totally avulsed. Sometimes if all the rootlets are not seen it is best to extend a level higher to anatomically see the roots and their functional status is studied by electrical stimulation. In some cases, a bilateral laminectomy may be needed to study the roots on the opposite side. After brachial plexus avulsion, dissection of the spinal cord is often hard to achieve because of scar tissue adhesion to the cord and severe atrophic and/or distortion. The gliotic changes at the level of the avulsed roots can make identification of the dorsolateral sulcus very difficult. In such cases, it is necessary to start from the remaining root above or below the avulsed segments. The presence of tiny radicular vessels

that enter the cord, a light brownish yellow color which is a sign of old hemorrhages and microcavities in the depth of the sulcus may help to determine the site of the sulcus. Dorsal column somatosensory evoked potentials (SSEPs) and stimulation of corticospinal tract motor cortex (MEPS) is helpful to identify the dorsal column when its atrophied due to trauma. You will need a very dedicated neurophysiologist who can gradually increase the amplitude to obtain a response and identify the level accurately.

The extent of lesions is determined based on the following—(1) level of pain assessed preoperatively; (2) avulsed segments intraoperatively and; (3) to a lesser degree the altered color of the DREZ region or the rootlets of the adjacent segments).⁶ After dissecting and preparing the dorsolateral sulcus lesions are made along the dorsolateral sulcus at a depth of 2 to 3 mm with a micro ophthalmology blade or size 11 blade. The knife is oriented at an angle of 30 to 35° angle ventrally and medially in the axis of the dorsal horn (Fig. 2), dotted micro coagulations are performed inside the dorsal horn. Each nerve approximately has 8 to 12 rootlets, and hence multiple lesions are made along the entire length of the sulcus. Three mm of depth will reach the rexed layer V of the dorsal horn. If the level of pain descends below the avulsed roots and there are changes in the rootlets, as described earlier the lesions are made underneath the rootlets into the dorsal horn. After using the knife, micro coagulations are made under a microscope and a sharp 0.3 to 0.8 mm tip bipolar forceps at a setting of 5 to 10 along the same region where the lesions were made. The procedure is intended to destroy preferentially the nociceptive fibers grouped in the lateral bundle of the dorsal rootlets as well as the excitatory medial part of the tract of Lissauer intending to preventing complete abolition of tactile and proprioceptive sensations and avoiding deafferentation phenomena. Lesions in the thoracic spine are done at 35° to 40° degrees angle for them, and 40° to 45° for the lumbar and sacral segments.

Similarly, for lesions involving the lumbar region after positioning the patient prone in bolsters the head level is slightly brought down to reduce the CSF loss during surgery. The levels are identified according to

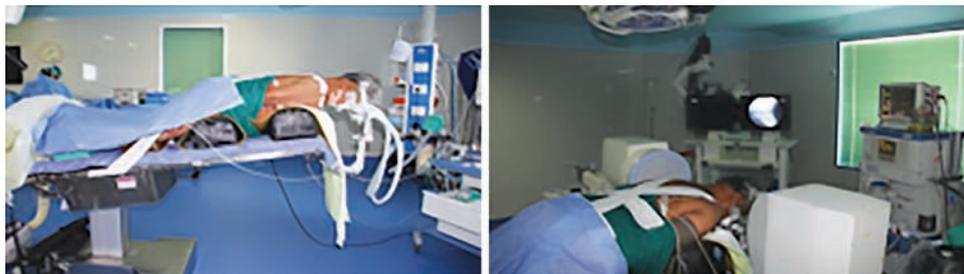


Fig. 1: Patient positioned for brachial plexus DREZ lesioning

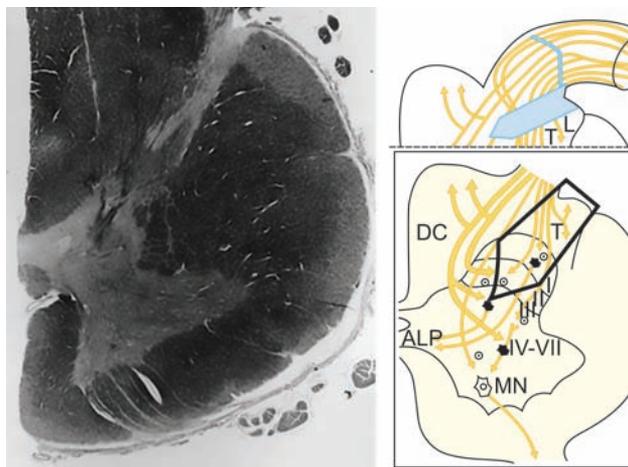


Fig. 2: Cross-section of the avulsed root at the cervical cord level with the arrow showing the direction of the lesioning

pain topography from T10 to L2 (Fig. 3). Either a unilateral or bilateral laminectomy is performed. We prefer a bilateral laminectomy to expose the cord and Cauda Equina. The dura and arachnoid are opened to identify the conus and filum. Fewer of the lumbar rootlets are avulsed unlike the cervical injury; however, when there is severe damage to the conus medullaris from injury it is very difficult to identify the segments due to the severe atrophy and scarring. It is not necessary to fully dissect the traumatic site at the spinal cord level as it increases the risk of further neurological deterioration in incomplete lesions. The L5 and S1 rootlets are larger than the others which can serve as an identification point. Identification of roots is then performed with electrical stimulation. The roots L1 and L2 are easily identified at their penetration into their respective dural sheaths; however the others are difficult to, but stimulation of L2 produces a response of the iliopsoas and adductor muscles. Identification of L3 to L5 roots is difficult as they exit through respective dural sheaths which is caudal to exposure, the dorsal and ventral roots are hidden.⁴ Stimulation of S2 to S4 dorsal roots can be assessed by recordings of the anal sphincter. This may be difficult to record as patients with spinal cord injury may already have a lax anal tone and difficult to get responses. DREZ lesioning at the lumbar-sacral levels involves the same principles as that at the cervical level.

RESULTS

In total there were 16 patients operated between 2011 to 2016. Of this 15 had brachial plexus avulsion injury and 1 had a DREZ lesioning for spinal cord injury. Mean age of the group was 48 years (31–62 years) with 17 male and 1 female patient. The mean time between the onset of pain and DREZ surgery was 8.9 yrs (1.5–22). During that time, patients were treated with any number of medical

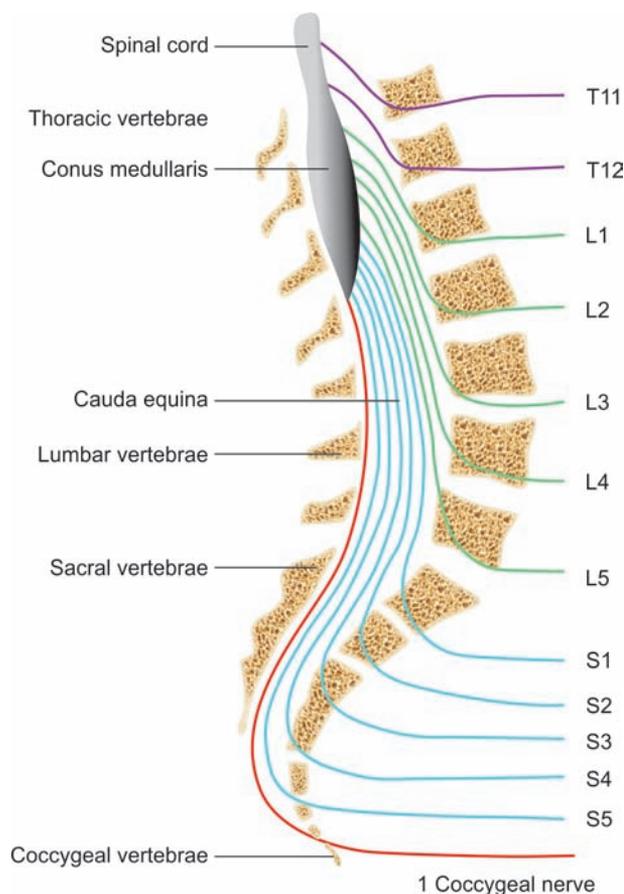


Fig. 3: Representation of the rootlets in the conus medullaris

therapies without achieving pain control and no clear documentation was present. No patients had other surgical procedures in our group. Of the 16 patients, 10 patients had complete avulsion injuries and 6 had incomplete injuries clinically. The average duration of surgery was 6.5 hours (4.5–9 hours) and duration of stay in hospital was 9 days (7–12 days). Neuromonitoring was used in all patients and average blood loss was 700 mL (400 mL–1.2 liter).

The mean level of pain before the surgery according to the VAS was 9.42 and fell significantly to 2.14 at ($p < 0.002$) at 5 years. The SF 12 (MCS) score was 33.65 and improved to 45.98 ($p < 0.0152$) and SF (PCS) score was 30.92 and improved to 47.69 ($p < 0.0021$) at 5 years. The neck disability index (NDI) was slightly more but not significant in the brachial plexus avulsion group at 5 years. The patient-reported result was excellent in 4 cases, good in 12 at 3 years and excellent in 3, good in 10 and moderate in one patient at 5 years. There was a slight deterioration of pain in one patient from excellent to good and another from good to moderate. Pain relief reduced in 87% of the patients and 50% of the patients returned to work. Postoperative neurological complications were seen in five patients (31.25%). In three cases, there was a temporary alteration of proprioceptive and vibratory sensation due to posterior column involvement,

without Gait abnormality. In two patients they had an MRC grade 4/5 in the ipsilateral leg in the immediate post-operative period but recovered to normal power in 3 to 6 months. No permanent neurological deficit was seen in any patient and there was no mortality. No immediate wound complication or post-operative kyphosis was seen. All patients would recommend this operation to anyone else suffering this problem.

DISCUSSION

The micro DREZ lesioning procedure is a neuroablative technique.⁷ The first attempts at microsurgical DREZ lesioning were performed in 1972 by Sindou in Lyon, France⁷ and later in 1974 Nashold⁸ and his group in Duke University by lesioning using radiofrequency (RF) thermocoagulation for pain related to brachial plexus avulsion. In 1981, Nashold et al. used it for post-traumatic spinal deafferentation pain.⁹ Since 1972, DREZ has become the standard first-line operation for all patients with intractable brachial plexus avulsion pain. Although laser and thermocoagulation techniques have been described in micro DREZ lesioning there is direct visualization, and micro neurosurgery has made it safe along with neuromonitoring.⁶ Special care must be taken not to damage the adjacent dorsal column and pyramidal tract (Fig. 4), and hence neuromonitoring must be used especially when the cord is anatomically modified by the injury. However, in some cases, we have had difficulty in recording the MEPS due to various reasons including severe muscle atrophy and wasting. Amputation of the limb provides no relief whatsoever.

There are typically two components to the pain, a chronic burning or stabbing pain that does not ordinarily follow a clear dermatomal distribution usually located in the forearm and the hand, and brief paroxysmal pain on

top of this.^{8,10,11} Patients are debilitated by the paroxysmal pain more than the continuous pain. Deafferentation pain develops early in 90% of brachial plexus injury cases, but it may be also delayed for 3 to 4 months. Approximately one-third of these patients continue to have pain after 3 years. Failed medical treatment was the main indication for surgery, but a clear definition could not be derived with some of the patients as they have tried different medicines at different periods. Some patients respond to analgesics, opiates, anti-epileptic drugs, transcutaneous electrical stimulation, and peripheral or sympathetic blockades.

During lesioning it is important to remember that the A-delta fibers that conduct sharp pain and unmyelinated small C fibers conduct dull pain. These fibers ascend 1 to 2 segments in Lissauer's tract, immediately lateral to the DREZ which indicates that the nociceptive pain sensations travel two segments above an index dermatome^{12,13} (Fig. 5). Hence the lesioning will give relief of this pain which does not need be extended higher than the avulsed level. DREZ lesioning must be limited to the avulsed roots only.

The DREZ lesioning has demonstrated good outcomes in patients with brachial plexus injury due to avulsion with significant pain improvement, considering relief as >50% on the VAS, in 58 to 100% of cases following surgery in various groups (Table 1). Moreover, functional improvement in QOL score SF 16 and return to work in more than one-third of the patients in the literature. Our series offers comparable outcomes with the long-term improvement of pain in 100% of the patients with injury brachial plexus due to avulsion. The outcomes of the long-term follow-up in the literature reveal relapse of pain in 13 to 20% of patients after 5 years, although significant relief is sustained in more than 60% of cases.^{2,14}

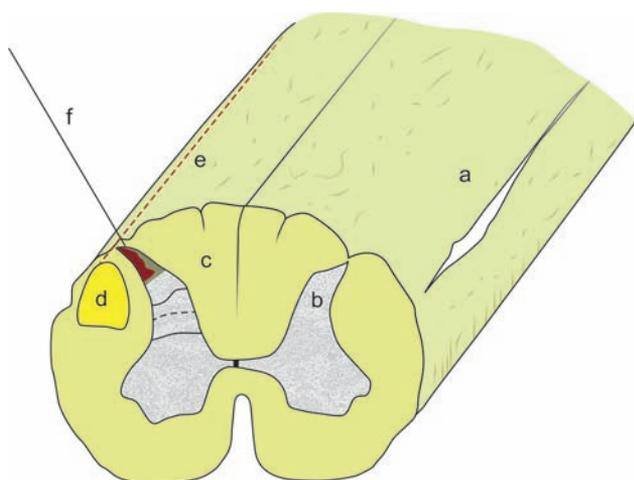


Fig. 4: Showing the thermocoagulation in close proximity to dorsal column (c) and cortico spinal tract (d)

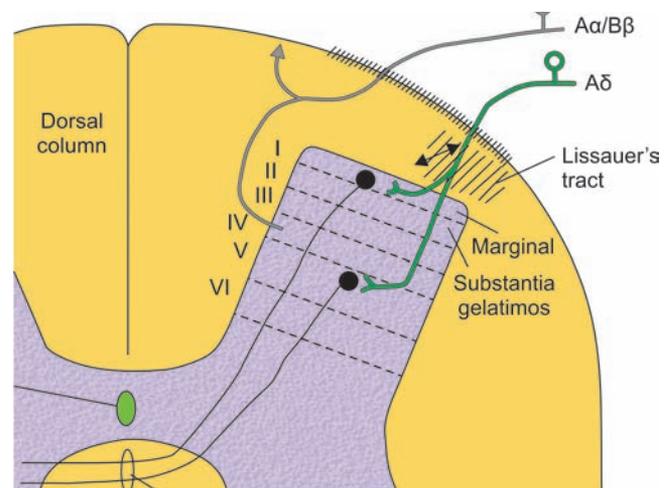


Fig. 5: DREZ area showing the dorsal roots entry, the A-delta ascend 1-2 segments in Lissauer's tract, immediately lateral to the Lissauer's tract the Rexed I-VI levels in the substantia gelatinosa and second order fibres crossing the anterior commissure

Table 1: Outcomes of patients with DREZ lesion in the literature

Centre	Percentage Improve	Follow-up	Number of patients	Procedure
Sami, Germany ¹	62%	14 yrs.	22	Microsurgery
Chen and Tu, Taiwan ²	50%	10 yrs.	18	Laser
Dreval, Russia ⁴	87%	47.5 months	35	Laser
Sindou and Mertens, France ⁶	60%	71 months	34	Microsurgery
Duke University and Queen Square Hospital	60%	8 yrs.	85	Microsurgery
Sindou, France	66%	6 yrs.	24	Microsurgery
Kanpolat, Turkey ³	69%	1 yr.	12	Microsurgery
Teixeira, Brazil	71% (DBS*, TS**, DREZ)	3 yrs.	16	Mixed – DREZ immediate relief
Rath S A ⁵	69%	-	16	Thermocoagulation

DBS*–Deep brain stimulation TS**–Thalamic stimulation

Deafferentation pain is present 10 to 25% of all spinal cord injuries through more than 85% have some pain either nociceptive or musculoskeletal. Patients with spinal cord injury exhibit either a segmental pain at the levels of the injured spinal cord or a diffuse pain below the level of the lesion.¹⁵ DREZ lesioning for SCI pain has an efficacy rate of 41 to 75% for segmental pain compared to 16 to 29% for diffuse pain below the level of lesion.^{5,6,11,16,17} This is particularly true when the pain consists of a permanent burning sensation and is located in an infra-lesional, totally anesthetic, area. Also in patients with incomplete injury extreme care must be taken at the conus level not to penetrate deep to cause new neurological deficits. Serious damage to the conus medullaris causes poor outcome due to severe adhesions in the arachnoid and scarring in the entire conus medullaris (Fig. 6). Patient selection is very important in such cases. DREZ lesion also provides some added benefits in decreasing spasticity by interrupting the reflex in pain severe spasticity. Apart from brachial plexus and spinal cord injury pain DREZ lesioning can be used in pain related to postamputation (phantom pain), cancer pain, and post-herpetic pain.



Fig. 6: Before DREZ lesioning to the conus showing the severe scar tissue and adherent roots at the conus medullaris

CONCLUSION

The DREZ procedure has been a standard interventional option for 4 decades with very good results. Though the results discussed in the literature are promising the technique has a learning curve to avoid serious neurological deficits and careful patient selection is important. Microsurgical DREZ is superior with fewer complications and side effects. We have demonstrated a 68% improvement in 16 patients with a 5 year follow-up. All the patients will recommend this procedure to anyone suffering from intractable neuropathic pain. It can be performed at a reasonably low cost in an Indian setup with minimal morbidity and excellent patient outcomes.

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