A new design of radiofrequency lesion electrodes for use in the caudalis nucleus DREZ operation

Technical note

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Two new right-angled electrodes have been designed for use at the dorsal root entry zone (DREZ) of the caudalis nucleus to provide relief of chronic facial pain. The electrode design was based on an anatomical study of the human caudalis nucleus at the cervicomedullary junction. Previously, caudalis nucleus DREZ operations were often followed by ipsilateral ataxia, usually in the arm. The new electrodes have significantly reduced this complication. A group of 21 patients with varied types of chronic facial pain have been treated, with pain relief in 70%.

KEY WORDS • facial pain • caudalis nucleus • dorsal root entry zone • radiofrequency lesion • electrode • instrumentation

Facial pain due to anesthesia dolorosa, post-herpetic pain, and pontine infarcts involving the trigeminal nerve pathways are often improved after treatment with localized radiofrequency (RF) lesions aimed at the caudalis nucleus of the trigeminal nerve at the cervicomedullary junction. With instrumentation available before 1982, the major complications following this procedure included ataxia of the ipsilateral arm and occasional transient ipsilateral leg weakness and ataxia. Involvement of the leg was probably due to edema of the nearby pyramidal tract as it changes from a ventral to a dorsal position at the cervicomedullary junction, while the ipsilateral arm ataxia was due to the close proximity of the ascending spinocerebellar tract, through which the electrode at the dorsal root entry zone (DREZ) must pass to reach the caudalis nucleus.

Development of Electrodes

From 1982 to 1988, early caudalis nucleus DREZ operations were performed using standard straight electrodes (2.5 mm in length). The RF lesions were made in either a single or a double row beginning at the dorsal root of C-2 and extending cephalad through the caudalis nucleus to the level of the obex. Almost every patient (90%) exhibited mild to moderate arm ataxia following the earlier DREZ lesion procedures; however, the ataxia usually resolved before the patient left the hospital.

In 1988, a second-generation caudalis nucleus electrode was designed by increasing its length to 3 mm, with insulation of the proximal 1 mm in order to reduce the RF lesion effect on the nearby spinocerebellar tract. With the use of this electrode, only about 50% of patients exhibited varying degrees of ataxia. In 1989, a third generation of caudalis nucleus electrodes was designed (by A.E.N.) based on data from a detailed anatomical study of the human caudalis nucleus (conducted by M.A.H.).

Anatomical Study

The neuroanatomical study was performed using material from three human autopsy cases to determine the exact dimensions and relationships of the caudalis nucleus to both the spinocerebellar and the corticospinal tracts. Detailed measurements of the fresh, fixed, and histologically prepared spinal cord were made at the cervicomedullary junction. The paraffin-embedded spinal cords were sectioned in 250-μm steps from 5 mm above the obex to the C-2 dorsal root level, then stained with cresyl violet and counterstained with Luxol fast blue.

The caudalis nucleus of the trigeminal complex is the principal recipient of pain afferents from the face.
Radiofrequency electrodes for DREZ lesions

Fig. 1. Illustration of the dorsal aspect of the human cervicomedullary junction with representative cross sections drawn from histological material at the level of the obex, 11 mm caudal to the obex (C-1), and 18 mm caudal to the obex (C-2). The orientation and relationship of the pyramidal, corticospinal, and dorsal spinocerebellar tracts to the caudalis nucleus and spinal tract of the trigeminal nerve (V) are shown. At the level of the obex, the dorsal spinocerebellar tract overlies laterally the caudalis nucleus and the spinal tract of the V; the corticospinal tract is closely adjacent to the caudalis nucleus at and below the C-1 level. The caudalis nucleus is represented with stippling, which is less dense where the nucleus is overlain by fiber tracts. The posterior borders of the spinal tract of the V and the dorsal spinocerebellar tract are indicated by dashed lines. At and above the obex, the posterior and anterior borders of the spinal tract of the V are indicated by dash-dot lines to show that it is covered by the spinocerebellar tract.

via the spinal tract of the trigeminal nerve. This nucleus is located in the region of the cervicomedullary junction and is over 20 mm in length (Fig. 1). Rostrally, it merges with the trigeminal nucleus intermedius (oralis and suboralis) just above the obex and extends caudally from the obex to C-2 and beyond, where it merges with the cervical dorsal horn. The caudalis nucleus varies considerably in diameter. Near the obex, it is rounded and 2.0 ± 0.2 mm (mean ± standard deviation) in diameter. At this level, it is covered laterally by its afferent fibers in the spinal tract of the trigeminal nerve (0.6 ± 0.2 mm in diameter) as well as by the dorsal spinocerebellar tract (0.6 ± 0.2 mm in diameter). Approximately 3 mm caudal to the obex, the dorsal spinocerebellar tract overlies laterally both the nucleus and the spinal tract of the trigeminal nerve. Below the C-1 level, the caudalis nucleus diminishes in size and changes its shape. Near C-2, it is elongated and elliptical in configuration (0.8 × 1.5 ± 0.3 mm) and is overlain dorsolaterally only by the reduced spinal tract of the trigeminal nerve (0.4 mm in diameter). The pyramidal tracts, which are ventrally located at the obex, begin to decussate at about 5 mm caudal to the obex. The brachial fibers decussate first and, by the C-1 level (10 to 12 mm below the obex), much of the tract is located contralaterally and dorsally and lies just lateral and ventral to the caudalis nucleus.

Design of DREZ Electrodes

The anatomical study revealed considerable variation in the size and shape of the caudalis nucleus at the cervicomedullary junction. Variations in the width of the cervicovertebral canal often made a direct lateral approach with a straight electrode difficult; therefore, the shank of the DREZ electrode was redesigned with a right-angled bend, 2.5 mm from the shouldered Teflon insulation, to allow an angled approach to the nucleus.

Two right-angled DREZ electrodes were made.* The first electrode (Fig. 2A) was designed to produce lesions in the smallest part of the caudalis nucleus between the C-1 and C-2 vertebral levels. The second caudalis nucleus electrode (Fig. 2B) was longer, with a larger area of exposed tip for lesioning the deeper and larger portion of the caudalis nucleus from the C-1 level to above the obex. Both electrodes were insulated

* Electrodes manufactured by Radionics Inc., Burlington, Massachusetts.
proximally to prevent lesioning of the spinocerebellar tract. The RF lesions were made in a single row at 1-mm intervals at 75°C for 15 seconds (Fig. 3).

**Clinical Results**

**Patient Population**

A group of 21 patients (15 women and six men) with chronic facial pain were operated on using the two new right-angled caudalis nucleus DREZ electrodes. The origins of the facial pain are shown in Table 1. Seven patients, who originally suffered from classic tic douloureux, were treated medically and surgically without relief of pain. Their present complaint was that of a new pain (post-tic dyesthesiasia). The previous surgical procedures were often multiple, including gasserian ganglion coagulation, microsurgical decompression, injection of chemicals, or simple avulsion of the branches of the trigeminal nerve. A second group of five patients suffered from post-herpetic pain involving the trigeminal distribution, usually the first division. Four patients had facial pain due to brain-stem lesions, either vascular or associated with plaques of multiple sclerosis. Facial or surgical trauma (bilateral sinus operations) accounted for two patients, and one woman suffered a severe facial and oral dyesthesiasia after the successful removal of meningioma of the gasserian ganglion. One woman suffered from migraine and cluster headaches which had been treated unsuccessfully for many years. One young man had an atypical trigeminal neuralgia which had not responded to microsurgical decompression. The follow-up period averaged 1 year.

**Operative Results**

The relief of pain was judged as follows: excellent, pain-free with no medication; good, pain-free but taking analgesic drugs; fair, less pain, on less drugs including narcotics; poor, pain unchanged or worse. The overall pain relief of these 21 patients was excellent in 48%, good in 5%, fair in 5%, and poor in 43% (Table 1). No patient's pain was made worse. Results for the seven patients with post-tic dyesthesiasia were excellent to good in 43%, fair in 14%, and poor in 43%. Improvement in the five patients with post-herpetic pain was quite different, with excellent results in 80% and fair to poor results in 20%. The young man with the atypical tic pain initially had an excellent result for 3 months, with recurrence of pain in a small area over the bridge of the nose. Extending the RF lesions above the level of the obex at a second operation relieved this pain; however, the follow-up period is only 3 months. It was noted early in the initial caudalis nucleus DREZ operation that if the RF lesions did not extend at least up to the level of the obex, there could be sparing of the central portions of the face (onionskin pattern). The onionskin pattern is also organized within the caudalis nucleus; the central portion of the face is more cephalad (at or above the obex), while the reference of the lateral aspect of the face is situated in the caudal portion of the nucleus (near the C-2 dorsal horn).

The caudalis nucleus DREZ operation in this group of patients was always extended to or slightly above the obex, but in the young man with atypical facial pain the recurrence may represent a variation of this onionskin pattern. The woman with migraine-cluster headache enjoyed a good result for several months, but then her pain returned. The woman with multiple sclerosis was completely relieved of pain, and 67% of those with vascular brain-stem lesions experienced excellent pain relief. Poor results were noted in all three patients with facial trauma, one of whom had a trigeminal nerve tumor.

**Complications**

There were no operative deaths. Seven patients exhibited postoperative ataxia. Five had preoperative ataxia due to previous operations (microsurgical decompression in three) or disease (brain-stem lesions in two); the ataxia was no worse after surgery. Two patients experienced mild to new ataxia which quickly resolved. One woman complained of a “tingling” sensation in her leg without neurological findings, and this sensation cleared. The rate of ataxia in this group of patients was 33%, an improvement compared with the results of earlier caudalis nucleus operations (90% ataxia with the 1982 operation and 50% with the procedure described in 1987).1

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**TABLE 1**

Results of caudalis nucleus DREZ surgery in 21 patients

<table>
<thead>
<tr>
<th>Etiology of Pain</th>
<th>Ex</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Total Cases</th>
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<td>2</td>
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<td>1</td>
<td>3</td>
<td>7</td>
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<tr>
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<td>0</td>
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<td>1</td>
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* DREZ = dorsal root entry zone; MS = multiple sclerosis. Results: Excellent (Ex) = pain-free with no medication; good = pain-free on analgesic drugs; fair = less pain, on less drugs including narcotics; poor = pain unchanged or worse.

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Radiofrequency electrodes for DREZ lesions

![Diagram of the operative site at the cervicomedullary junction illustrating the placement of radiofrequency lesions.](image)

**FIG. 3.** Drawings of the operative site at the cervicomedullary junction illustrating the placement of radiofrequency lesions (line of circles). XI = the accessory nerve; m = muscle; n = nerve; a = artery.

Discussion

The best results from the DREZ operation are achieved in patients suffering from deafferentation pain such as brachial plexus avulsion and spinal trauma. The poorest results are seen in individuals with peripheral nerve pain such as postherpetic syndrome and stump pain. In theory, deafferentation pain probably represents a disturbance of the secondary sensory neurons that make up the central pain pathways, and the DREZ RF lesions are designed to destroy these neurons. Relief of facial pain seems to follow a similar pattern insofar as pain from trigeminal dysesthesia and peripheral facial injury, which represent peripheral involvement, was less improved than pain of central origin such as pathological lesions of the brain stem (for example, multiple sclerosis or thrombosis). The exception is post-herpetic facial pain, which was improved significantly in contrast to the poor pain relief of post-herpetic pain involving the spinal dorsal ganglion (thoracic and abdominal). The reason for this difference is not clear. In theory, herpetic involvement of the trigeminal nerve may be both peripheral and central, involving the caudalis nucleus, an idea originally suggested by Sjöqvist who developed the medullary tractotomy for facial pain. The Sjöqvist tractotomy was designed to section the descending fibers of the trigeminal tract at the level of the olive while the caudalis nucleus DREZ operation attempts to destroy the secondary sensory neurons in the caudalis nucleus and portions of the ascending trigeminal tract from the level of obex to the C-2 dorsal root. Kerr pointed out in 1961 that the major neural input to the caudalis nucleus was via afferent pain fibers from the trigeminal nerve; he later suggested that selective caudalis nucleus lesions might relieve facial pain in man (personal communication, 1966).

Stereotactic lesions of the caudalis nucleus were carried out by Hitchcock and Schwarzer and Crue et al. and were successful in relieving pain. However, based on recent anatomical studies, the complex anatomy of the caudalis nucleus suggests that a stereotactic operation performed blindly is not likely to destroy this entire nucleus. As noted above, the caudalis nucleus is quite large in its cephalad portion and much smaller as it blends with the dorsal horn at the level of the cervicodorsal roots. For this reason, the caudalis nucleus DREZ electrodes were redesigned to make specific lesions in the two dissimilar portions of the nucleus.

The major complication of the trigeminal medullary tractotomy as well as the earlier caudalis DREZ lesions was the postoperative occurrence of ipsilateral ataxia. This was due to involvement of the ascending spino cerebellar tracts, which overlie the caudalis nucleus throughout its entire length in the cervicomed-
ulla region. The new DREZ electrodes were designed specifically to reduce this complication by confining the RF lesions to the deeper portions of the caudalis nucleus, thereby sparing the major part of the spino-cerebellar tract; the reduction in the incidence of ataxia in the cases treated with these devices attest to their value. These observations and the DREZ treatments for facial pain emphasize the importance of our continued understanding of the neuroanatomy of regions under treatment and the application of the newest technology to produce pain relief with minimal complications.

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Disclosure

The authors have no financial interest in the instrumentation being advanced by this publication.

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