COMPUTED TOMOGRAPHY-GUIDED PERCUTANEOUS TRIGEMINAL TRACTOTOMY-NUCLEOTOMY

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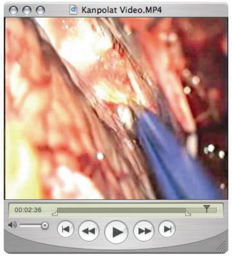

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OBJECTIVE: The destruction of the descending trigeminal tractus in the medulla is known as trigeminal tractotomy (TR), whereas the lesioning of the nucleus caudalis is known as trigeminal nucleotomy (NC). Trigeminal TR and/or NC procedures can be used in a large group of pain syndromes, such as glossopharyngeal, vagal, and geniculate neuralgias, atypical facial pain, craniofacial cancer pain, postherpetic neuralgias, and atypical forms of trigeminal neuralgia.

METHODS: In this study, anatomic and technical details of the procedure and the experience gained from 65 patients over the course of 20 years are discussed. Patients' pain scores and Karnofsky Performance Scale scores were evaluated pre- and postoperatively (postoperative Day 1).

RESULTS: The best results were obtained in the second-largest group (vagoglossopharyngeal neuralgia, n = 17) and in geniculate neuralgia (n = 4). Patients with atypical facial pain (n = 21; 13 women, eight men) accounted for the largest group to undergo computed tomography-guided TR-NC surgery; pain relief was achieved in 19 of these patients. In the third-largest group (craniofacial and oral cancer pain, n = 13), 11 of 13 patients were successfully treated with TR-NC. Four of five patients with failed trigeminal neuralgia were also effectively treated with TR-NC.

CONCLUSION: We propose that computed tomography-guided TR-NC provides direct visualization of the target-electrode relation and can be considered a first-step procedure in patient management. In view of its high efficacy, low complication rate, and minimal invasiveness, computed tomography-guided trigeminal TR-NC is a safe and effective procedure in the treatment of intractable facial pain syndromes.

KEY WORDS: Central pain, Facial pain, Nociceptive pain, Trigeminal tractus-nucleus

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Craniofacial pain is one of the most important topics in pain practice and surgery. The accurate diagnosis of craniofacial pain is the first important step of our clinical practice (32, 34, 45, 46, 51). Although diagnosis and treatment of trigeminal neuralgia (TN) are generally very popular topics among neurosurgeons, at present there is no standard regarding the diagnosis, definition, or surgical treatment. Some specific forms of craniofacial pain problems are related not only to pain fibers of the trigeminal nerve but also to the pain fibers and area of the VIIth, IXth, and Xth cranial nerves, where they are located in the descending trigeminal tractus and terminate in the nucleus caudalis. Destruction of the descending trigeminal tractus in the medulla is known as trigeminal tractotomy (TR), a procedure first termed by Olof Sjöqvist (44) in 1938. He cut the tractus at the inferior olive level in an open technique via craniectomy in a posterior fossa exploration. In 1942, White and Sweet (52) observed hypoalgesia after trigeminal TR in the innervation area of the VIIth, IXth, and Xth cranial nerves. Sweet then used this procedure in the treatment of glossopharyngeal neuralgia. Kunc (28) performed selective TR 12 mm above the second cervical root level, which successfully relieved glossopharyngeal neuralgia.

In 1967 and 1968, Crue et al. (5) and Hitchcock (13) independently developed a percutaneous technique using radiofrequency (RF) thermocoagulation and performed the first stereotactic trigeminal TRs. Trigeminal TR was used for the treatment of postherpetic facial pain in 1972 by Hitchcock and Schvarcz (14).

Schvarcz (36, 37) also used the same procedure to create lesions primarily in the second-order neurons at the oral pole of the nucleus caudalis at the level of the occipitocervical junction and termed this procedure trigeminal nucleotomy (NC). Some authors advised performing the nucleus caudalis lesions with the help of multiple RF lesions for trigeminal pain states by C1 laminectomy and a small occipital craniectomy (1, 43). Nashold et al. (31) described a new open surgical technique in the treatment of craniofacial pain. In this procedure, the nucleus of the substantia gelatinosa was destroyed extensively with RF between the dorsal root of C2 and 5 mm above the obex. Gorecki and Nashold (10), Gorecki et al. (11), and Nashold et al. (31) named the procedure the trigeminal nucleus caudalis dorsal root entry zone (DREZ) operation. Gorecki (9) explained midbrain TR and its surgical techniques. The senior author (YK) developed the percutaneous technique for trigeminal tractotomy-nucleotomy (TR-NC) to facilitate topographical localization of the electrode tip in the spinal cord, guided by computed tomography (CT) (17, 21, 23).

ANATOMIC DESCRIPTION OF TRIGEMINAL PAIN PATHWAYS FOR SURGICAL ORIENTATION

Trigeminal afferents, which carry the sensations of pain and temperature, enter the pons and send a caudal ward branch (the descending trigeminal tractus) into the medulla. The descending trigeminal tractus overlies the spinal trigeminal nucleus in the posterolateral part of the spinal cord at the cervicomedullary junction. Primary sensory fibers from the VIIth, IXth, and Xth cranial nerves also enter the descending tractus of the trigeminal nerve (2, 15, 49). The three divisions of the trigeminal nerve have a special topographical organization in the descending tractus of the nerve. The fibers from the VIIth, IXth, and Xth cranial nerves lie slightly medially behind the tractus; trigeminal afferents that carry the sensations of pain and temperature, unlike other sensory modalities, descend in the spinal trigeminal tractus and enter the nucleus (25). The spinal trigeminal nucleus has three distinct subdivisions along its pontospinal extent: 1) the nucleus oralis, located rostrally between the pons and medulla; 2) the nucleus interpolaris, located intermedially; and 3) the nucleus caudalis, located at the medullospinal junction and extending down to the C2 segment level. The nucleus caudalis represents the substantia gelatinosa, and there is extensive overlap between facial and high cervical afferents, where the VIIth, IXth, and Xth cranial nerve afferents also end. Destruction of the oral pole of the nucleus caudalis plays a special role in pain relief (16, 29).

There is a topographical representation of the ipsilateral face on the spinal tractus of the trigeminal nerve, i.e., the most central areas of the face terminate highest on the nucleus caudalis, whereas the most peripheral areas of the face end lowest. This alignment is referred to as "onion-skin organization" and causes the central area of the face to be spared from hypoalgesia after nucleus caudalis DREZ operation, if the lesion does not extend above the obex (2, 17, 49).

PATIENTS AND METHODS

Trigeminal TR and/or NC procedures are used for pain denervation in selected cases. These are cancer pain and deafferentative pains, atypical facial pain (AFP), atypical trigeminal pain, chronic cluster headache, and vagoglossopharyngeal and geniculate neuralgias located not only in the area of the Vth, but also the VIIth, IXth, and Xth cranial nerves and nucleus caudalis (1, 4–6, 12, 27, 29, 31, 36, 43). AFP is a throbbing pain situated deep in the eye and malar region, often radiating to the ear, neck, and shoulders. The pain is generally not within any dermatomal or anatomic boundaries. AFP and psychological pathologies such as depression are strongly associated, and anxiety is known to exacerbate the condition. The term "atypical" is used to distinguish facial pain from TN because this pain syndrome is neither responsive to anticonvulsant drugs nor present in the sensory area of the trigeminal nerve (26). Because the targets in this procedure are the tractus and nucleus, this unique technique can be used for postherpetic neuralgia as well as for cluster headache. The pain measurement scale was determined as follows: I, no pain; II, partial satisfactory pain relief; III, partial nonsatisfactory pain relief; and IV, no change in pain. In this grading system, we considered Grade I and II patients as having pain relief after surgical intervention. We also used the visual analog scale (VAS) to score the severity of the pain and the Karnofsky Performance Scale (KPS) to determine the performance status of the patients on postoperative Day 1. We used the Wilcoxon signed-ranks test to test the difference between preoperative and postoperative VAS and KPS scores. Finally we used SPSS for Windows software (version 11.5; SPSS Institute, Chicago, IL) for statistical analysis. A P value of less than 0.05 was considered significant.

TR-NC Technique

TR-NC is performed at the occiput-C1 level, with the targets of the descending trigeminal tractus and nucleus caudalis of the spinal trigeminal nucleus. The suitable fasting period for the patient before surgery is 5 hours. First, the contrast agent is injected into the subarachnoid space by lumbar puncture. If necessary, the contrast agent can be given at the occiput-C1 level at the beginning of the procedure. The patient is placed in the prone position on the CT table with his or her head in the flexed position. The procedure can be difficult in some anatomic anomalies, especially in obese patients with short necks. Oxygen should be given at the required dose. A nasal catheter is necessary for the administration of oxygen because of facedown and flexed posture. Every level of the procedure must be explained to the patient. Subsequently, the contrast agent must be monitored to ensure homogeneous spread by obtaining slices from the upper spinal canal. Spinal cord diametral measurements are recorded. The operation can be painful, especially during the insertion of the electrode tip into the tractus. After local anesthesia, the subarachnoid space is reached with a 20-gauge needle specially designed for CT-guided procedures at the occipitocervical region (*Fig. 1*). The skin insertion of the needle is 6 to 8 mm lateral from the midline at the occiput-C1 level (*Fig. 2*). The targets for destruction are the spinal trigeminal tractus and nucleus caudalis, located at the first third of lateral midline and lateral surface of the upper spinal cord (*Fig. 3*). It is described as being at a depth of 3 to 3.5 mm from the surface of the spinal cord (13). In our diametral measurements, the depth of the electrode was between 2.8 and 4.6 mm. These measurements can vary and should be determined in each individual. At this point, placement of the needle can be visualized in the lateral scanogram, and the direction of the needle can be manipulated toward the occipitocervical space with the help of axial CT sections (*Fig. 4*).

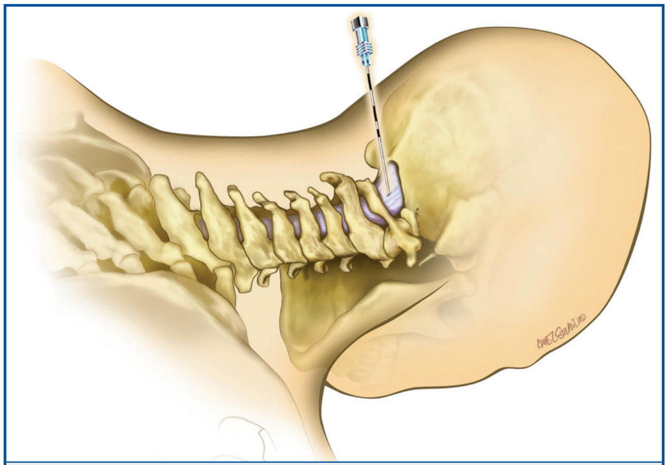

FIGURE 1. *Schematic drawing of the percutaneous tractotomy-nucleotomy (TR-NC) approach at occiput–C1 level.*

At the occiput-C1 level, the dura-skin distance ranges from 44 to 58 mm (mean, 50 mm) by the posterior paramedian approach. Diametral measurements of the spinal cord are taken at the occiput–C1 level, and the inserted part (3–4 mm) of the active electrode is adjusted accordingly. The diameters were found to range from 7 to 12.8 mm (mean, 9.13 mm) anteroposteriorly and from 9.3 to 14 mm (mean, 11.6 mm) transversely (19). By obtaining CT slices, the surgeon can determine whether the electrode has penetrated the cord, any cord displacement, the extent of electrode penetration into the spinal cord, and whether the tip of the electrode has reached its target. Functional confirmation of the target is obtained by electrical stimulation. As previously described, the rostral dermatome is located ventrolaterally, and the caudal dermatome is located dorsomedially (46). After correction of the localization, the electrode is checked by impedance measurement and stimulation. RF lesions can then be made. Impedance values are approximately 100 to 200 ohm in the cerebral spinal fluid, increase to approximately 200 to 400 ohm when the electrode tip contacts the pia mater, and finally exceed 1000 ohm after insertion into the cord. Electrical stimulation with low (2–5 Hz, 0.3–1 V) and high (50–100 Hz, 0.1–0.3 V) frequencies is used (17).

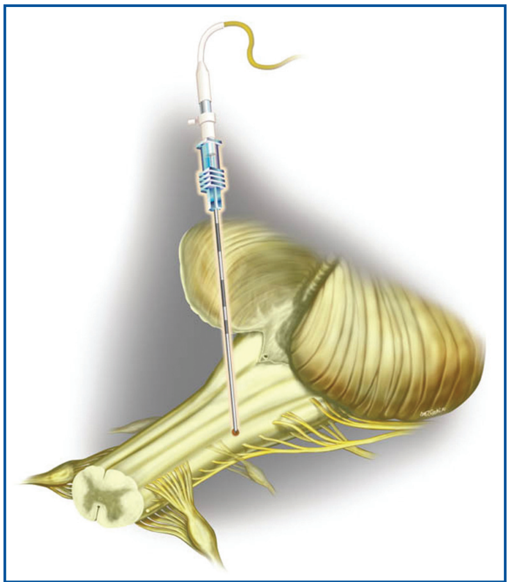

FIGURE 2. *Illustration of needle placement. Skin insertion is 6 to 8 mm lateral from the midline to reach the first third of lateral midline of the upper spinal cord.*

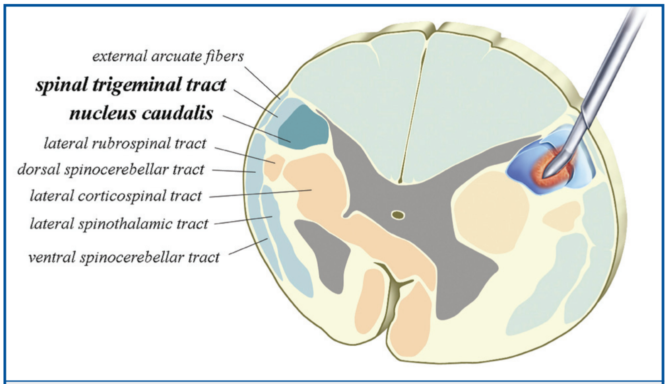

FIGURE 3. *Schematic drawing of the target-electrode relation and main anatomic structures in percutaneous TR-NC.*

It should be remembered that high-voltage stimulation is painful at this point. Stimulation starts with minimum voltages. Paresthesia of the ipsilateral half of the face can be observed. If paresthesia of face occurs, slight withdrawal of the tip and restimulation may cause a dysesthetic sensation in the throat or inside the ear, indicating that the tip is in the nociceptive fibers of the VIIth, IXth, and Xth cranial nerves. Stimulation and lesioning of the tractus-nucleus complex may lead to painful, uncomfortable dysesthesias for the patient, at which point additional pain medication should be administered (we usually prefer 0.5 μg/kg of fentanyl and 0.05 mg/kg of midazolam). Persistent lesions can usually be achieved at a tip temperature of greater than 60°C within 30 seconds. A maximum of two or three lesions should be performed. During the creation of lesions, the energy and tip temperature are increased gradually, and neurological functions must be continuously tested. The final lesion is made at 70 to 80°C for 60 seconds (17, 19, 21, 23). This part of the procedure is the most critical. The creation of lesions in the tractus is sometimes not tolerable, in which case pain medication is administered.

RESULTS

Between 1987 and 2007, CT-guided TR-NC was performed 73 times in 65 patients. The patients who undergo TR-NC are the most problematic cases of pain surgery found throughout the world. The mean follow-up period of our patients was 5.3 years (range, 6 mo–16 yr). Early pain relief, as defined previously, was obtained in 55 patients (84%); detailed information about late follow-up is given below.

The most satisfactory results were obtained in the second-largest group (vagoglossopharyngeal neuralgia, n = 17) and in the geniculate neuralgia group (n = 4). Three patients in the vagoglossopharyngeal group had unsatisfactory results (Grade III and IV). In the long-term follow-up period, two of them underwent the DREZ operation, after which pain relief was obtained in one. Fourteen patients in the vagoglossopharyngeal group had no

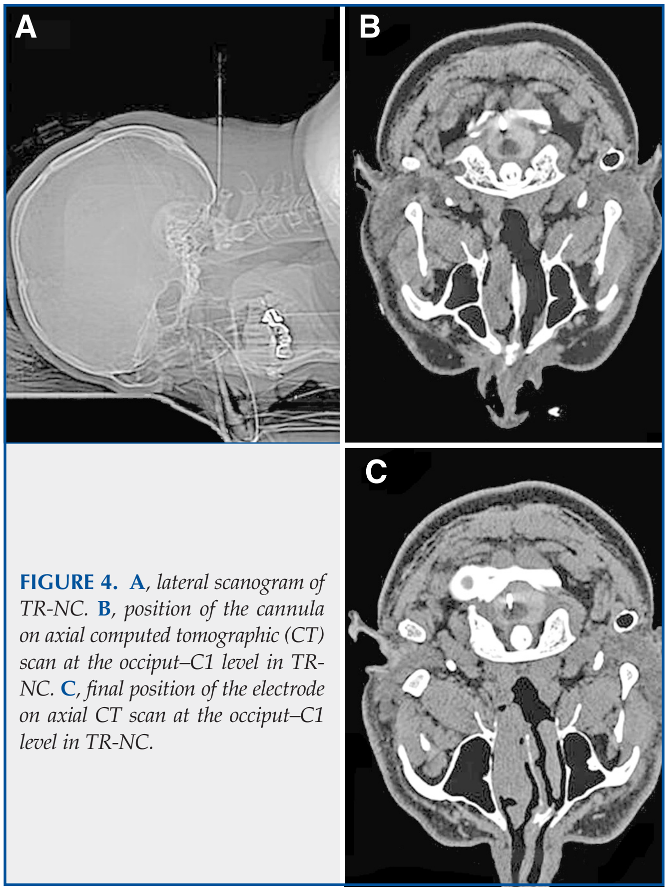

FIGURE 4. **A**, *lateral scanogram of TR-NC.* **B**, *position of the cannula on axial computed tomographic (CT) scan at the occiput–C1 level in TR-NC.* **C**, *final position of the electrode on axial CT scan at the occiput–C1 level in TR-NC.*

pain; however, half of them experienced recurrent pain during the long-term follow-up period (5–12 yr). Four underwent a second procedure, three of them with rhizotomy. Three of the four patients in this recurrent group had no pain after the second surgical intervention. In one of four in the geniculate neuralgia group, the patient's pain was uncontrolled. He underwent a second TR-NC procedure but, again, without satisfactory results. A nucleus caudalis DREZ operation was then performed, but the patient later died from cardiopulmonary causes.

AFP accounted for the largest group to undergo CT-guided TR-NC surgery, with 21 patients (13 women, eight men). A Grade I pain score was achieved in 15 patients, and a Grade II pain score was achieved in four patients. Two patients whose pain was uncontrolled after the procedure underwent a nucleus caudalis DREZ operation, and pain scores of Grade I and Grade II were obtained. Fifteen years later, these two patients remained free of pain.

The third-largest group consisted of 13 patients with craniofacial and oral cancer pain. These patients had both nociceptive and neuropathic pain. Hence, TR-NC was chosen as the first treatment option. In this group, 11 of 13 patients were successfully treated by TR-NC. Two patients whose pain relief was uncontrolled despite a second TR-NC procedure underwent a nucleus caudalis DREZ operation. In one of the patients, who had invasive hypophysial tumor, the pain was not controlled, and this patient later committed suicide; pain control was obtained in the other patient. Because the cancer patient group is not uniform, we have evaluated only the early results.

Four of five patients with failed TN were effectively treated with TR-NC. All had failed atypical and bilateral TN. One patient in this group underwent a DREZ operation after unsatisfactory results after first operation; Grade II control was obtained.

In three patients with postherpetic neuralgia pain, Grade I pain control was obtained after TR-NC. TR-NC was also applied in a patient with cluster headache; Grade I pain control was achieved. This procedure was ineffective in a patient with anesthesia dolorosa. The patient groups and surgical results are presented in *Table 1*.

The KPS was used immediately pre- and postoperatively as a measure of patient performance change. However, long-term VAS and KPS scores for most of the patients are not available. There was a highly significant statistical difference between minimum and maximum early preoperative scores (20 and 80, respectively; mean, 66.1 ± 12.1) when compared with minimum and maximum postoperative scores (0 and 100, respectively; mean, 81.1 ± 16.7) ($P < 0.001$). Mean preoperative VAS score was 7.76 ± 0.68 (minimum, 6; maximum, 9). On the first postoperative day, the score decreased sharply to 2.39 ± 2.95 ($P < 0.001$). Mean, median, minimum, maximum, and standard deviation values of KPS and VAS are summarized in *Table 2*. Mean values of KPS scores and VAS with respect to the etiology are presented in *Figures 5* and *6*, respectively.

There was no mortality in CT-guided TR-NC; only four cases (approximately 6%) of transient ataxia were observed because of large lesions affecting the spinocerebellar tractus. Transient motor complications were observed in two cases (approximately 3%). These complications resolved in 2 weeks. In our

TABLE 1. **Patient outcome after the trigeminal tractotomy-trigeminal nucleotomy procedure**

Diagnosis	No. of patients	Results
Atypical facial pain	21	15 Grade I 4 Grade II 1 Grade III 1 Grade IV
Geniculate neuralgia	4	3 Grade I 1 Grade III
Vagoglossopharyngeal neuralgia	17	14 Grade I 2 Grade III 1 Grade IV
Craniofacial malignancies	13	11 Grade I 2 Grade III
Failed trigeminal neuralgia	5	4 Grade I 1 Grade III
Postherpetic neuralgia	3	1 Grade I 2 Grade II
Cluster headache	1	1 Grade I
Anesthesia dolorosa	1	1 Grade IV

TABLE 2. Mean, median, minimum, maximum, and standard deviation values of Karnofsky Performance Scale and visual analog scale[a]

	Preoperative		Immediately postoperative		*P* value
	Mean ± SD	Median (min–max)	Mean ± SD	Median (min–max)	
VAS (n = 66)	7.76 ± 0.68	8 (6–9)	2.39 ± 2.95	2 (0–9)	<0.001
Karnofsky (n = 66)	66.1 ± 12.1	70 (20–80)	81.1 ± 16.7	80 (0–100)	<0.001

[a] SD, standard deviation; VAS, visual analog scale.

previous reports regarding TR-NC, results varied somewhat from those presented in this report. This discrepancy may be explained by both the experience gained over time as well as dynamism in the number of patients.

DISCUSSION

(see video at web site)

Destructive procedures on the descending trigeminal tractus and the spinal trigeminal nucleus are not common in neurosurgery practice. Among these, DREZotomy is the more common destructive procedure, despite its risky and invasive nature (3, 9, 29, 31, 38–40, 42). We believe that CT-guided percutaneous TR-NC is an effective, less-invasive, and less-complicated procedure in this group. It is applicable under pain medication, as explained previously in this report, with the advantage of patient cooperation. In addition, it is applicable in the patient whose general condition is poor, and it can be repeated easily if necessary in the case of a recurrent and/or failed result. Some authors have performed trigeminal TR separately by open surgery (1, 38, 50) or percutaneous stereotactic surgery (5, 13, 14, 30, 41, 50, 52).

One of the main problems with this procedure is the difficulty of correctly inserting the active electrode tip into the target. The most essential guidance is obtained anatomically by CT slices and neurophysiologically by impedance measurements and stimulation. The establishment of the anatomic localization of the active electrode in the medulla and the upper spinal cord is determined by diametral measurements of this area (19) and stimulation and recording of somatosensory-evoked potentials (5). Finally, the controlled lesion (or lesions) is performed if neuroanatomic and neurophysiological parameters confirm the localization. As a result, TR-NC could well become a preeminent procedure in the future of neurosurgery. The visualization of the target-electrode relation is important in these procedures. Direct x-ray imaging provides only indirect visualization, despite the use of water-soluble contrast agents. In our modern technological era, the use of x-ray imaging should be replaced in these procedures by CT guidance, an imaging method that allows direct visualization of the target. This guidance is applicable not only for TR-NC, but also for percutaneous cordotomy (22) and extralemniscal myelotomy (20). Magnetic resonance imaging and tractography are the other available imaging methods that could be used. Fountas et al. (7) successfully applied this procedure with magnetic resonance imaging guidance in percutaneous cordotomy. Neuronavigational assistance may be the other option for TR procedures in the future.

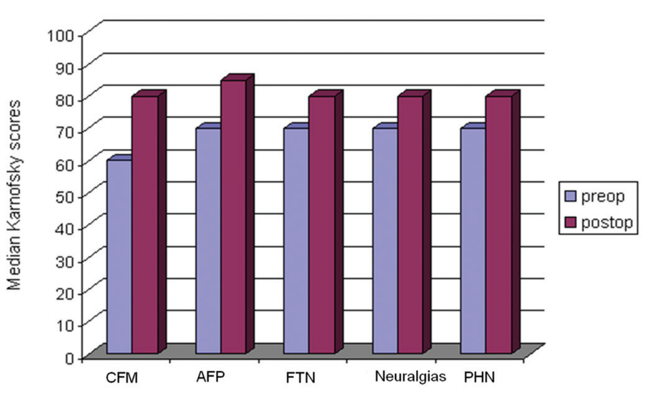

FIGURE 5. *Karnofsky Performance Scale scores according to patient groups.* CFM, *craniofacial malignancies;* AFP, *atypical facial pain;* FTN, *failed trigeminal neuralgia;* Neuralgias, *vagoglossopharyngeal and geniculate neuralgias;* PHN, *postherpetic neuralgia;* preop, *preoperative;* postop, *postoperative.*

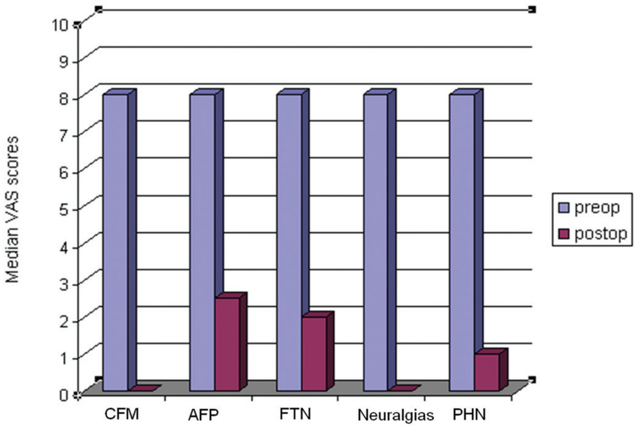

FIGURE 6. *Visual analog scale (VAS) according to patient group.* CFM, *craniofacial malignancies;* AFP, *atypical facial pain;* FTN, *failed trigeminal neuralgia;* Neuralgias, *vagoglossopharyngeal and geniculate neuralgias;* PHN, *postherpetic neuralgia;* preop, *preoperative;* postop, *postoperative.*

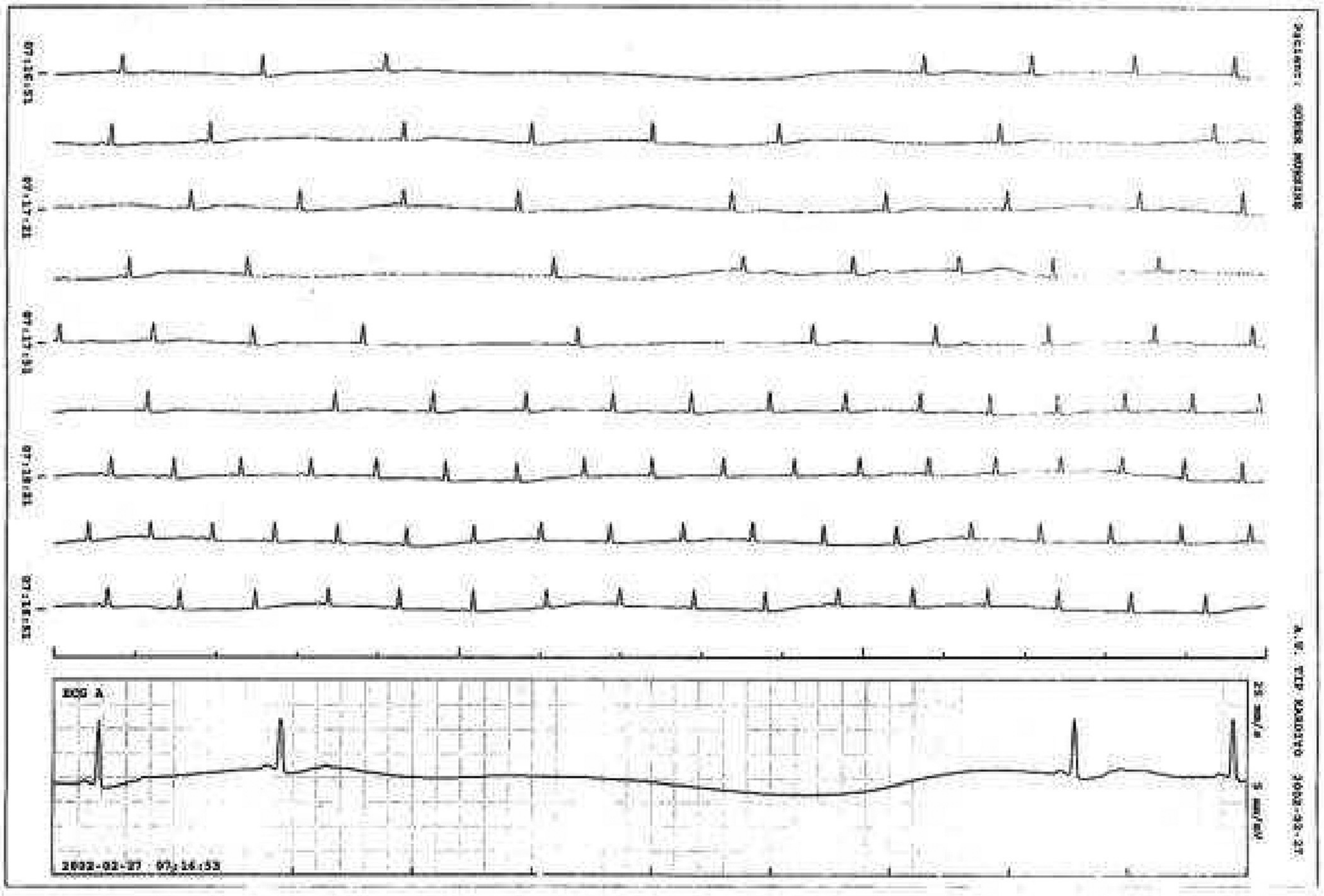

FIGURE 7. *Electrocardiogram trace of a patient who had cardiac arhythmia during pain attack before microvascular decompression.*

Trigeminal TR-NC may be used before microvascular decompression (MVD) in patients with vagoglossopharyngeal and geniculate neuralgias. In our practice, its use resulted in a lower complication rate and, despite the excellent results observed with MVD, mortality and morbidity rates in MVD are approximately 5 and 8% (permanent dysfunction of glossopharyngeal nerve), respectively, in reported series (33, 48). MVD can be used in some special cases, especially in those patients presenting with arterial compression of the root entry zone (35). We used MVD in two patients as an initial procedure. In these published cases, the cranial nerves were compressed by the parent arteries. Interestingly, one of the patients had cardiac rhythm problems that accompanied the vagoglossopharyngeal attacks (*Fig. 7*). If the patient has obvious clinical and radiological evidence, we strongly recommend MVD as a first choice of treatment (29, 37, 38, 40, 42). The patient presented in the video serves as a good example of this situation. TR-NC may be performed before the DREZ operation, which can be performed subsequently if TR-NC is ineffective. In addition, it is known that TR-NC is an effective procedure in other pathologies such as craniofacial and oral malignancies, intractable neuralgia and neuropathic pain of the VIIth, IXth, and Xth cranial nerves, and AFP (8, 18, 24–26, 47). With the aid of TR-NC treatment, patients can live relatively independent of both drugs and hospitals.

CONCLUSION

In conclusion, we propose that CT-guided TR-NC provides direct visualization of the target–electrode relation and can be considered as a first-step procedure in patient management in view of its high efficacy, low complication rate, and minimal invasiveness. It can be applied only by the neurosurgeon, because this unique procedure requires not only expert surgical technique but also extensive knowledge of neuroanatomy and neurophysiology.

Disclosure

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COMMENTS

This article is a valuable contribution to our continuing understanding of pain surgery, and there are few individuals, if any, who approach this type of surgery with the skill and scholarly bent exhibited by Kanpolat et al. in this article.

The history of our specialty is filled with the pioneering efforts of neurosurgical innovators such as Sjöqvist, Kerr, Sweet, Rosomoff, Crue and Nashold, and others, who demonstrated that anatomically informed destructive lesions can play a role in the management of intractable pain. Unfortunately, with the advent of neuromodulation, the impetus for the production of nervous system lesions to alleviate pain has diminished dramatically, and as a result many of the requisite skills and experience necessary for the performance of these procedures has not been passed along to the current generation of neurosurgeons. Furthermore, much of the proof of efficacy of these past procedures does not meet contemporary standards of evidence-based medicine. As a result of these two conditions, the knowledge gained by our predecessors in pain surgery is in danger of being completely lost to our discipline.

Dr. Kanpolat has shown us that a rather simple and minimally invasive procedure, performed in a computed tomographic (CT) scanner, can ameliorate some of the most difficult pain problems encountered by neurosurgeons. Moreover, he has almost single-handedly reinvigorated interest in destructive procedures for a variety of pains. He has demonstrated that percutaneous trigeminal tractotomy can be effective for vagoglossopharyngeal and geniculate neuralgias, for postherpetic neuralgia, and for atypical variants of trigeminal neuralgia. If trigeminal postherpetic neuralgia was the only condition relieved by his procedure, it would be a major contribution. Well-established postherpetic neuralgia does not have a safe or practical surgical solution in many instances, and so his results are particularly encouraging. Most importantly, he has shown that this procedure can be highly effective for craniofacial cancer pain, harkening back to the pioneering neurosurgical pain control efforts that were directed to cancer pain.

Kanpolat et al. had good results in the group they labeled as having "atypical facial pain." As much as I have respect for the progress they have demonstrated in this article, I would like to see the terminology atypical facial pain disappear from use. We have included that term in our categorization of facial pain (1), but it is only applicable to patients with proven psychopathological disorders. In our parlance, it is most equivalent to "somatoform pain disorder." Atypical facial pain is otherwise not a diagnosis, and it is simply a term that neurosurgeons and other pain specialists use to describe facial pains that do not fit any clear taxonomy or semiology. It is not a useful term, and it should be relinquished.

Although this article may be met with a degree of skepticism, I believe it is prudent to recall that medical and neurosurgical care is subject to fashion that in retrospect defies rigorous explanation. Kanpolat et al. have pointed out that sometimes some of the old ways are still quite effective and may, in fact, be the best ways.

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Kanpolat et al. stress the importance of diametral measurements in deriving the depth of penetration, which varies from 2.8 to 4.6 mm. In my experience with open cervical DREZotomy and spinal cord penetrations for transplants in the pig, the cord invariably buckles inward as the needle pushes against it. The cord springs up as the pia is penetrated. It is challenging even under direct visualization to be sure of one's depth during these procedures because of the elasticity of the cord. In the procedure described here, CT scanning plays a critical role in displaying the depth. Measuring these distances on the CT scan in the presence of an artifact is challenging in the best case scenario. Although I defer to Dr. Kanpolat's experience, I remain skeptical about the accuracy of this part of the procedure. Ultimately, the intraoperative physiological setting allows for localization, providing further security about the localization of the electrode. First, the change in impedance gives the surgeon a landmark for when pial penetration occurs. Then, stimulation confirms localization. The ability to perform this procedure on an awake patient is a critical advantage over open approaches. However, Kanpolat et al. emphasize the patient discomfort that occurs during stimulation and lesioning. They do not describe in depth their technique to ensure that the patient remains still during this process. One wonders about the consequence of sudden neck extension during lesioning that depends on submillimeter accuracy of localization. Although Kanpolat et al. recommend the judicious use of fentanyl and midazolam, these agents are highly likely to compromise patient compliance, which is critical during lesioning to prevent damage to the corticospinal tract that is in close proximity. Moreover, in the current article they do not provide explicit information about the expected results of stimulating deep (corticospinal) or medially (dorsal column). Presumably, motor contraction or contralateral paresthesias suggest alterations in electrode position.

Microvascular decompression and rhizotomy procedures are commonly used in North America for the treatment of cranial nerve neuralgias. The inherently more controlled nature of these procedures is likely to preserve the bias toward them. The dilemmas posed by atypical facial pain and craniofacial oncological pain are greater. I will continue to use a variety of neuromodulation procedures (peripheral nerve stimulation, motor cortex stimulation, and thalamic deep brain stimulation) for the former, because of a bias toward nondestructive procedures. However, I will consider trigeminal tractotomy-nucleotomy as a salvage procedure for a select group. The population of patients presenting with atypical facial pain is rife with those who have psychological overlays. Even with careful preoperative pain psychological evaluation, I have found that psychopathological disorders are present in a percentage of these patients. The series of Kanpolat et al. includes no failures owing to a missed diagnosis. In my experience, ablative procedures give the patients with borderline tendencies a lifetime pass to hold the surgeon responsible for their pain, whereas neuromodulation is, at least in principle, reversible.

Patients with oncological pain are an excellent subgroup for application of this procedure. First, because implanted devices may prevent use of magnetic resonance imaging scanning, and, second, because unlike in patients with oncological pain of the body, use of an intrathecal narcotic is more difficult to manage for facial pain.

Nicholas M. Boulis
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Trigeminal tractotomy belongs to a class of operations rarely done these days, having been relegated to the dustbins of neurosurgical history in many centers. Nevertheless, such procedures are still being done in certain centers of excellence, and these surgeons continue to develop their art. Dr. Kanpolat is among a decreasing number of neurosurgeons who have maintained the art of neurosurgical ablation and have improved the technique using modern localizing tools such as CT scanning. In this article, Kanpolat et al. describe their experience using CT guidance in the performance of lesions of the spinal trigeminal tract for the relief of intractable facial pain. This "Operative Technique" article describes their technique in detail and provides readers with useful pearls in the performance of such procedures and also the pitfalls. The main weakness of this article is that it does not provide very useful guidance to the reader as to when to perform this rather significant operation and how effective it is in the long term. The terminology of pain syndromes treated is rather nonspecific (e.g. "atypical facial pain," an all-encompassing term for poorly understood, poorly localized pain syndromes involving the head). Moreover, the reported results for this procedure are extremely short term, so it is impossible to gauge whether it is effective in the long run.

Finally, I caution readers that although this procedure may seem straightforward to experienced groups such as Dr. Kanpolat's, it should by no means be considered "minimally invasive." The physical size of the invasion here is not a measure of its potential risk, and those who wish to perform such procedures should do so only after proper training.

Oren Sagher
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Is there still a place for ablative procedures in the neurosurgical treatment of chronic pain? Increasingly sophisticated neuromodulatory techniques are now in widespread use, providing relatively safe and reversible treatment options where few existed previously. In the treatment of facial pain, the question is even more problematic. For true trigeminal neuralgia, there are many effective treatments that can provide a real "cure," allowing patients to lead pain-free lives without medication. However, for non-trigeminal neuralgia facial pain, there are far fewer options for effective treatment. Denervation procedures such as radiofrequency ablation or open rhizotomy have a risk of causing anesthesia dolorosa and may be ineffective for constant, nonlancinating pain. Trigeminal stimulation has been reported to be effective in some patients, but the procedure is fraught with technical difficulties. Motor cortex stimulation is a promising technique that nonetheless has unpredictable results from patient to patient. And "success" with most of these salvage techniques is traditionally defined as 50% pain relief, hardly a cure in the usual sense of the word.

This report of an accumulated 20 years' experience in trigeminal tractotomy-nucleotomy by one of the world's foremost experts in ablative procedures for pain is an impressive demonstration of the results achievable with care and experience. Of the 65 patients, 49 (75%) achieved complete relief from facial pain of varying etiologies, with no mortality and only temporary neurological side effects. Although follow-up is listed as being between 6 months and 16 years, there are no aggregate figures for long-term pain relief, making it difficult to compare long-term results with those of other, similar series. Durability of ablative lesions is a constant concern, especially for patients without malignancy (52 of 65 patients in this series).

This technique is clearly effective and safe in experienced hands. However, having sufficient experience to gain and maintain proficiency is crucial to achieving good results in such a technical procedure. Even in this group's specialized referral center, only approximately 3 patients per year were operated on. Unfortunately, lack of experience and a relatively small patient population could keep this procedure from becoming a "preeminent procedure" as Kanpolat et al. hope. However, as with dorsal root entry zone lesioning for brachial plexus avulsion or cordotomy for cancer pain, trigeminal tractotomy is clearly a valuable ablative technique that should be kept in our surgical armamentarium.

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Trigeminal tractotomy has a long history in neurosurgery. It was first used as an alternative treatment for trigeminal neuralgia. The technique was also in common use for relief of pain from head and neck tumors. In fact, the procedure usually included both tractotomy and nucleotomy of the subnucleus caudalis. Kanpolat et al. emphasized the anatomic localization of these lesions and their potential effects quite well. Originally, these operations were done under direct vision after exposure of the upper cervical spinal cord brainstem. They now describe a percutaneous technique using CT control with which impressive results have been obtained. Excellent results are reported for several different head and neck pain syndromes. The majority of patients treated had an atypical facial pain syndrome, and 19 of 21 patients in this extremely difficult-to-treat group are reported to have achieved satisfactory relief of pain. The best results were obtained in patients with vagoglossopharyngeal neuralgia. They also treated patients with pain secondary to craniofacial cancer and reported good results in a small group of patients in whom other treatments for trigeminal neuralgia had failed.

Kanpolat et al. summarized the history of this neurosurgical procedure quite well, and they described the various methods different surgeons have used to destroy the anatomic targets. The description of the anatomy of the trigeminal pain pathway is worth review by all neurosurgeons. The technique is described in adequate detail so that any neurosurgeons skilled in the use of percutaneous techniques with CT control could perform it. However, this technique is not for inexperienced neurosurgeons or for infrequent use. Localization is extremely important and the management of the patient during the procedure very difficult in my experience. Severe pain often accompanies lesion-making, and a skilled neuroanesthesiologist is an important part of the procedure. However, the results are excellent. Because the so-called atypical facial pain syndromes respond so poorly to most forms of management, this technique offers hope to an otherwise extremely difficult-to-treat group of patients. The refinements of Kanpolat et al. make this old neurosurgical procedure an effective part of the armamentarium of the expert today.

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