Computed Tomography-guided Percutaneous Cordotomy for Intractable Pain in Malignancy

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OBJECTIVE: Pain, usually a response to tissue damage, is accepted as an unpleasant feeling generating a desire to escape from the causative stimulus. Although, in the early stages of malignant diseases, pain is seen in 5% to 10% of cases, this rate reaches nearly 90% in the terminal stage, and pain becomes a primary symptom. Cordotomy is one of the treatment choices in pain caused by malignancies localized unilaterally to the extremities as well as the thorax and the abdomen.

METHODS: The target of computed tomography (CT)-guided percutaneous cordotomy is the lateral spinothalamic tract located in the anterolateral region of the spinal cord at the C1–C2 level. Between 1987 and 2007, CT-guided percutaneous cordotomies were performed in 207 patients; most (193 patients) suffered from intractable pain related to malignancy. The patients' pain scores and Karnofsky Performance Scale scores were evaluated pre- and postoperatively.

RESULTS: The initial success rate of CT-guided percutaneous cordotomy was 92.5%. The success rate was higher in the malignancy group. In the cancer group, selective cordotomy (pain sensation denervated only in the painful region of the body) was achieved in 83%. In 12 cases, bilateral selective percutaneous cordotomy was successfully applied.

CONCLUSION: In the treatment of intractable pain, CT-guided cordotomy is an option in specially selected cases with malignancy. In this study, anatomic and technical details of the procedure and the experience gained from treating 207 patients over a 20-year period are discussed.

KEY WORDS: Cancer pain, Computed tomography-guided cordotomy, Operative technique

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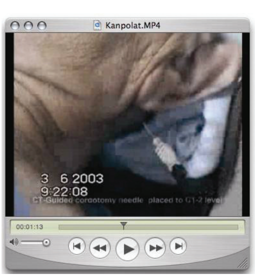

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Intractable pain is a considerable medical and social problem. Neurosurgeons began their special mission to treat this condition early in the 20th century. Neurosurgical pain procedures were usually based on destruction of the pain-conducting pathways. However, in the past 3 decades, stimulation techniques and morphine pumps have increased in popularity. Despite the availability of new treatment options, destructive pain procedures with computed tomographic guidance can still be successfully applied in selected patients (16, 42). With the help of contrast agents, computed tomography (CT)-guided procedures make it possible to demonstrate the exact anatomic structure of the spinal cord segment in which the procedure will be performed. Computed tomographic imaging also allows direct real-time visualization of the spinal cord and anatomic sections, determination of diametric measurements, direct visualization of the target-to-electrode positioning, and direct calibration of the depth of insertion of the electrode system (9, 15, 18, 33). The procedure is preferred especially for treatment of nociceptive intractable pain in malignancy (21). Currently,

ABBREVIATIONS: CT, computed tomography; **KCTE**, Kanpolat computed tomography electrode; **RF**, radiofrequency; **VAS**, visual analog scale

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destructive pain surgery is performed using needle electrodes with the help of computed tomographic imaging (17, 22). The procedures are primarily used in selected intractable pain patients with cancer, one of the most significant causes of death in the world (1).

The vast majority of pain in the cancer population is nociceptive, which generally is more responsive to opioids and more amenable to destructive procedures. Neuropathic pain is a consequence of nerve damage and is often caused by tumor infiltration or nerve compression. This type of pain is more responsive to augmentative modalities based on chronic stimulation of peripheral nerves, the dorsal columns, or the medial lemniscal system (2). Cancer pain in its beginning is nociceptive, caused by irritation of the nerves, but over time it progresses to neuropathic pain owing to nerve damage, and this type of pain is continuous (42). The pain sensation, as defined by patients, is burning and throbbing. Defining the type of pain and choosing the right surgical procedure are the most important determinants for success and for prevention of complications (18, 39).

The target in cordotomy is the lateral spinothalamic tract located in the anterolateral part of the spinal cord (8, 13, 41). This ascending tract carries information chiefly about pain and temperature and relays some tactile information. The fibers, organized from the outside inward, reflect superficial pain, temperature, and deep pain (39). Because most fibers in the anterolateral system decussate over 2 to 5 segments before entering the anterolateral columns, spinothalamic cordotomy aims to interrupt the spinothalamic tract ascending contralaterally to the painful side. Although the majority of pain-transmitting fibers decussate normally, the decussated axon rate and position may vary considerably among individuals; thus, unilateral cordotomy can, on rare occasions, produce ipsilateral analgesia in some individuals owing to nondecussated neurons (41).

The anterolateral sensory system has a somatotopic relationship with fibers from higher levels laminating medially and ventrally and those from lower levels laminating laterally and dorsally within the lateral spinothalamic tract (13, 39). Segmentation of the fibers provides the opportunity for selective cordotomy, given that anteromedial lesions denervate the contralateral arm and upper chest region, while posterolateral lesions denervate the sacral and lumbar areas (Fig. 1).

Between the anterior extent of the pyramidal tracts and the posterior aspect of the lateral spinothalamic tracts is a narrow "safety zone" of white matter (41). There is considerable variation in the size and location of the ventral corticospinal tract; absence of any decussation is also observed. Because motor decussation may extend from the obex to the C1 level, contralateral leg weakness may also occur if the lesion is too high (39). The lateral spinothalamic tract is in close proximity to the ventral spinocerebellar tract, autonomic nervous fibers, and descending respiratory tract. The ventral spinocerebellar tract is located in the lateral part of the lateral spinothalamic tract. Lesioning of this tract causes ipsilateral ataxia of the arm. Autonomic fibers related to bowel and bladder function are found in the lateral part of the lateral horn of gray matter. Immediately posterior to the autonomic fibers are vasomotor fibers; bilateral lesioning of these fibers causes hypotension (39). The most important region in cordotomy practice is the medial aspect of the lateral spinothalamic tract, where the descending respiratory pathway is located (Fig. 2). Unilateral destruction of this pathway results in little functional respiratory loss. However, bilateral lesions involving the medial portion of the lateral spinothalamic tract are extremely dangerous, possibly resulting in impaired respiration during sleep (39).

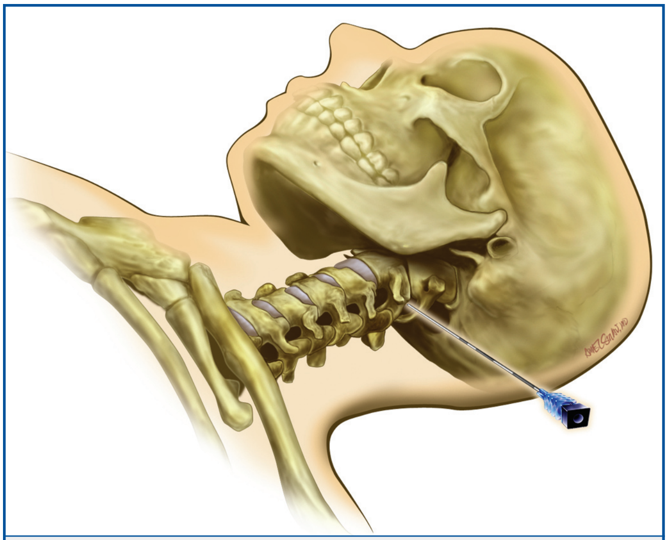

FIGURE 1. *Schematic drawing of percutaneous approach at the C1–C2 level.*

PATIENTS AND METHODS

The percutaneous cordotomy operation is principally based on the lesioning of the lateral spinothalamic tract, which carries pain and temperature sensations, at the C1–C2 level (Figs. 1 and 2). These fibers decussate in the spinal cord (8, 16, 23). The procedure is thus performed contralateral to the pain site. In the past, the procedure was widely performed in patients with both benign and malignant intractable pain. In our daily practice, CT-guided percutaneous cordotomy is performed especially in cancer patients.

The best candidates are those with unilaterally localized intractable nociceptive-type cancer pain, as seen in mesothelioma of the chest wall or malignancy of the lower extremities, and in other cases of unilaterally localized pain (12, 15, 16, 23, 24). Secondary candidates are patients with nociceptive pain at the onset of the disease, but in whom the pain may progress to the neuropathic form if the tumor infiltrates the brachial plexus, as in Pancoast tumors. These patients are accepted as candidates for cordotomy; however, they are informed about the probable existence of another kind of pain, since its character may differ from the neuropathic form. Patients suffering from pure neuropathic pain were not candidates for cordotomy in our series.

Bilateral CT-guided cordotomy is chosen for patients with intractable pain that is localized in the lower body and extremities (see Video, Supplemental Digital Content 1, http://links.lww.com/A693). Bilateral upper body pain is not accepted because of the risk of complications

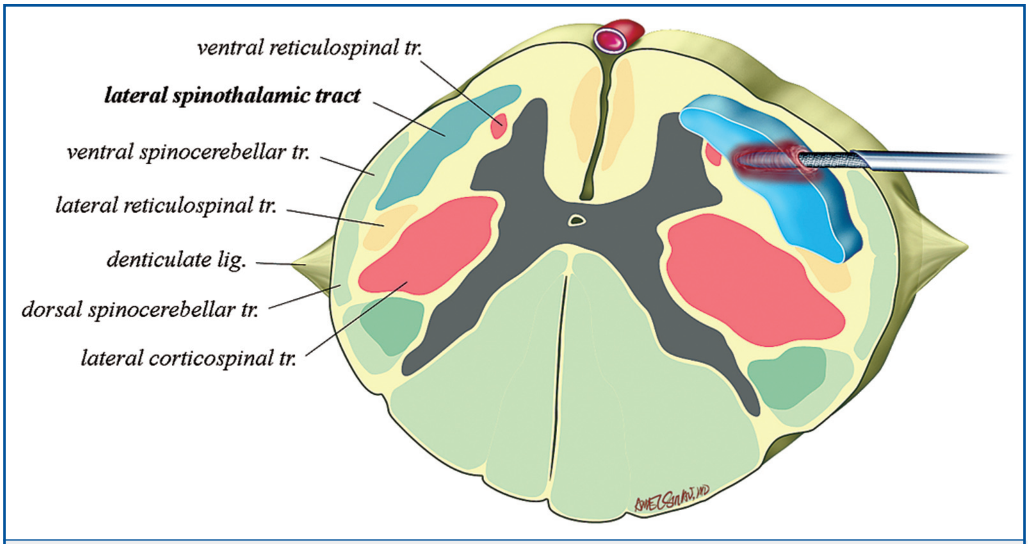

FIGURE 2. *Schematic drawing of the target-electrode relation and main anatomic structures in percutaneous cordotomy.*

such as sleep-induced apnea (Ondine's curse) (3, 4, 19, 25, 27, 31, 32, 34). Patients with severe pulmonary dysfunction and in whom partial oxygen saturation is lower than 80% are not suitable candidates for cordotomy. We also do not consider percutaneous cordotomy if the patient's expected survival is less than 3 months, but this is subjective. The only criterion for cordotomy concerning life expectancy was given by Gybels (12), in 1991, as a minimum of 2 to 5 months. The most important consideration in percutaneous bilateral cordotomy is pain location.

The cordotomy procedure should be considered carefully if the patient is receiving chemotherapy or radiotherapy for cancer. We usually prefer to postpone the cordotomy procedure until such treatment is completed. Detailed information about the procedure and outcome expectations should be discussed in full with both the patient and family (20). In benign diseases, cordotomy is not the first treatment of choice, but in some selected cases, such as in intractable post-thoracotomy pain or failed back syndrome, we occasionally apply the procedure (21).

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. A visual analog scale (VAS) was also used to score the severity of the pain, and the Karnofsky Performance Scale was used to determine the performance status of the patients on the first postoperative day.

The Wilcoxon signed rank test was used to test the differences between pre- and postoperative VAS and Karnofsky Performance Scale scores. SPSS for Windows (Version 11.5; SPSS, Inc., Chicago, IL) was used for statistical analysis. A P value of less than 0.05 was considered significant.

CT-guided Percutaneous Cordotomy Technique

The surgical procedures are carried out in a CT unit (see Video, Supplemental Digital Content 1, http://links.lww.com/A693). In each case, a cranial computed tomographic scan must be taken to rule out a mass lesion attributable to metastasis, as this would be a contraindication for cordotomy, because it may lead to herniation. The patient is placed on the CT table in the supine position. With the help of a head support, the patient's head is kept in flexion. The head is immobilized with a fixation band, with attention given to patient comfort so that the long procedure (approximately 1 hour) can be tolerated. Computed tomographic images (512 × 512 matrix) with 2-mm slice thickness are used. The quality of the image is enhanced by reducing the diameter of the image formation area (14, 16).

A special electrode system is used in the procedure. The KCTE (Kanpolat CT electrode) kit is a temperature-monitoring radiofrequency (RF) electrode system for percutaneous cordotomy procedures. It is designed to avoid or minimize imaging artifacts, allowing optimal placement under computed tomographic control. The 2.0-mm noninsulated exposed tip, with straight or curved electrodes of 0.25-mm diameter, is positioned in the lateral spinothalamic tract for percutaneous cordotomy. During the procedure, with the help of computed tomographic guidance and stimulation responses, the curved or straight electrode can be chosen. The exposed electrode tip is calibrated for each patient according to the diametric measurements of the spinal cord. Each KCTE contains a thermocouple sensor that measures tip temperature, which is required to quantify lesion size, to safeguard against boiling and charring, and to confirm that a lesion is truly being made (17).

The target of the procedure is the lateral spinothalamic tract located in the anterolateral region of the spinal cord at the C1–C2 level (Figs. 1 and 2). Localization of the target is defined by computed tomographic visualization (Fig. 3). In our experimental and clinical studies, it has been demonstrated that diametric measurements of the spinal cord are not standard. At the C1–C2 level, the anteroposterior diameter of the spinal cord was measured as 7.0 to 11.4 mm and the transverse diameter as 9.0 to 14.0 mm (16). The skin-dura distances were measured as 46 to 66 mm (mean, 52.1 ± 4.3 mm) in men and 43 to 56 mm (mean, 48 ± 3.1 mm) in women (18). Thus, diametric measurements of the spinal cord are determined for each patient before the procedure, and calibration of the inserted part of the active electrode is obtained with the help of these measurements. If the patient has a small spinal cord diameter, the depth of electrode insertion into the spinal cord is restricted.

The patient should fast for 5 hours before the procedure. The required dose of analgesics is given parenterally; the dosage differs between patients because of different pain tolerances and pain conditions. We usually prefer fentanyl 0.5 μg/kg and midazolam 0.05 mg/kg. Iohexol (7–8 mL, 240 mg/mL) is given 20 to 30 minutes before the operation by lumbar puncture (23, 24). If the general condition of the patient does not permit lumbar puncture, contrast material is injected during the procedure at the C1–C2 level. After the injection of the local anesthetic agent, the cordotomy needle is inserted inferior to the mastoid process in a vertical plane perpendicular to the axis of the spinal cord. Ideal placement of the needle is initially just localized in the anterolateral part of the dura of the upper spinal canal. After every step of cannula movement, new computed tomographic slices are taken with the lateral scanogram. Axial computed tomographic slices are also taken if necessary, not only to demonstrate the final position of the cannula but also to determine the localization of the cannula tip. In some cases, especially in cancer patients

FIGURE 3. *Computed tomographic scan showing right anterolateral localization of the electrode system in the spinal cord at the C1–C2 level in computed tomography-guided percutaneous cordotomy.*

who have previously undergone radiotherapy, the dura is very thick and difficult to puncture. Repeated computed tomographic slices can aid the surgeon in preventing improper puncturing. If the tip of the cannula turns around, it may cause malposition of the electrode. After proper localization of the cannula is confirmed, we recommend no further repositioning, since, in some instances, the cannula may become angulated. Manipulation of the cannula may cause malpositioning of the tip. After the dural puncture, ideal localization of the cannula tip is 1 mm anterior to the denticulate ligament for lumbosacral fibers and 2 to 3 mm anterior to the denticulate ligament for thoracic and cervical fibers (24). This morphological appearance must be confirmed by stimulation.

After ideal positioning of the needle tip, the straight or curved electrode is inserted. With the help of neurophysiological confirmation via impedance measurement and stimulation, the functional response of the target is confirmed. Impedance measurements are taken to identify whether the active electrode tip is in the cerebrospinal fluid (approximately 100–200 Ω), in contact with the spinal cord (approximately 300–400 Ω), or inside the spinal cord (>800–1000 Ω). The target-electrode relationships are easily detected by direct visualization of the needle-electrode system under computed tomographic guidance (14, 21–24).

Real neurophysiological confirmation of the target is obtained by stimulation, necessitating that the patient be alert and cooperative. As a rule of functional neurosurgery, stimulation must be initiated at minimal voltage values: 2- to 5-Hz stimulation with 0.4 to 1.5 V causes ipsilateral trapezius muscle contraction, indicating that the electrode is within or near the anterior gray matter. Ipsilateral motor responses in the arm or leg indicate that the electrode is in the corticospinal tract. Stimulation of 100 Hz with 0.2 to 1.5 V causes pain, paresthesia, or warmth in the spinothalamic tract, and that is the target (21–24). The most critical part of the procedure is the stimulation step. If 100-Hz stimulation gives a response around 0.2 V, it indicates that the electrode is located in the target. If more stimulation is required, the voltage can be increased to 1.2 or 1.5 V. Higher-voltage stimulation indicates that the electrode is near the target. The response to stimulation from specific parts of the lateral spinothalamic tract usually corresponds to destruction of the selected part of the tract. Selective cordotomy (anteromedial for arm and posterolateral for leg) can only be obtained if stimulation response overlies the painful area (41).

With our needle electrode system, permanent lesions can usually be achieved at a tip temperature of greater than 60°C within 30 seconds. Energy and tip temperature of the active electrode are continuously monitored on the generator, and both are gradually increased. During and after the lesioning, motor functions, pain perception, and discrimination of hot and cold sensation are tested. Usually, the final lesion is made at 70° to 80°C for 60 seconds. If the required level of analgesia is not obtained, the lesion is repeated using the same parameters. Temperature is gradually increased over 60 seconds. In the repeated lesion, the final temperature level is used. We prefer a maximum of three 60-second lesions for unilateral cordotomy. In bilateral cordotomy, we prefer to minimize the number of lesions, but we sometimes use 2 or 3 lesions for the dominant pain side (15, 19).

After the procedure, patients are usually monitored in the intensive care unit. If the patient's vital parameters are sufficient, the patient can be sent home 5 or 6 hours after the procedure. The patient is usually informed regarding his/her postcordotomy life. If the patient is dependent on any narcotics, the doses are gradually decreased; there is no standard. In bilateral cordotomy, the patient is usually monitored for at least 1 night in the intensive care unit. Bilateral staged procedures are performed at 1-week intervals (19, 23).

RESULTS

Between 1987 and 2007, we performed CT-guided percutaneous cordotomies in 207 patients in the Department of Neurosurgery, Ankara University. Most (193 patients) suffered from intractable pain related to malignancy. In 12 cases, bilateral CT-guided cordotomy was performed with a 1-week interval. In 181 cases, CT-guided cordotomy was performed unilaterally. In the malignancy group, the majority of cases (49.7%) were attributable to pulmonary malignancies (n = 58), mesothelioma (n = 23), and Pancoast tumors (n = 15). In addition, there were 23 patients with gastrointestinal carcinoma, 21 with metastatic carcinoma, and 53 patients with other malignancy types. The procedure was also applied to 14 cases with benign pain attributable to various causes: single root avulsion of brachial plexus phantom pain (n = 1), epidural fibrosis causing postsurgical hip and leg pain (n = 1), spinal perineural cyst (n = 1), gunshot trauma (n = 1), tuberculosis (n = 1), electrical burns (n = 1), postherpetic neuralgia (n = 2), and failed back surgery (n = 6). Pulse RF procedure was applied to the patient with electrical burns, and the pain resolved thereafter. However, 15 days later, the pain recurred, and a second cordotomy was applied with CT-guided percutaneous RF cordotomy. Two years later, the patient returned to our department and insisted on a third cordotomy, after which successful pain relief was obtained.

Cordotomy was retrospectively determined not to be the correct choice in 2 patients with benign pain, since the patients failed to show improvement with regard to their pain. The first patient was considered as post-amputation pain; however, root avulsion was detected later. The second patient had post-thoracotomy pain. In these 2 patients, cordotomy was not the

TABLE 1. Mean, median, minimum, maximum, and standard deviation values of Karnofsky Performance Scale and visual analog scale scores[a]

Cordotomy	Preoperative		Postoperative		*P* value
	Mean ± SD	Median (range)	Mean ± SD	Median (range)	
VAS	7.61 ± 0.61	8 (5–9)	1.29 ± 2.21	0 (0–10)	<0.001
KPS	45.2 ± 14.4	40 (10–80)	65.7 ± 13.4	70 (20–100)	<0.001

[a] SD, standard deviation; VAS, visual analog scale; KPS, Karnofsky Performance Scale.

correct treatment decision, which was given by the senior author (YK). A dorsal root entry zone operation was later applied to 1 of these patients; no further procedure was applied to the other, as he suffered from neurosis.

After cordotomy, patients reported initial pain relief as 92.5% (Grade I, 60.6%; Grade II, 31.9%; Grade III, 4.1%; Grade IV, 3.4%); however, long-term follow-up data are not available for most of the patients. The initial success rate was slightly higher in the malignancy group. In the cancer group, selective cordotomy (pain sensation denervated only in the painful region of the body) was achieved in 83%. In 12 cases, bilateral selective percutaneous cordotomy was successfully applied (19, 20).

The Karnofsky Performance Scale was used immediately pre- and postoperatively as a measure of change in patient performance. Minimum and maximum preoperative scores were 10 and 80, respectively (mean, 45.2 ± 14.4), versus postoperative scores of 20 and 100, respectively (mean, 65.7 ± 13.4), and the difference was determined to be highly significant ($P < 0.001$). The mean preoperative VAS score was 7.61 ± 0.61 (minimum, 5; maximum, 9). On the first postoperative day, the score dropped sharply to 1.29 ± 2.21 ($P < 0.001$). Mean, median, minimum, maximum, and standard deviation values of Karnofsky Performance Scale and VAS scores are summarized in Table 1.

The most important cause of complications in the conventional cordotomy is incorrect localization and therefore incorrect electrode positioning; however, this has been solved via direct imaging with computed tomographic scanning. Another important complication is the creation of large lesions with thick electrodes, which can be prevented by using thinner electrodes, e.g., the KCTE. In this series of 207 percutaneous cordotomy, there was no mortality or major morbidity, because we tactically denervate the pain area with an optimum small number of lesions. We observed only 5 cases (2.4%) of temporary slight motor paralysis and 5 cases of temporary ataxia. Resolution of these complications in all cases was within 3 weeks. In the bilateral cordotomy series, there were 3 cases (1.4%) of temporary hypotension and 2 cases (0.9%) of temporary urinary retention; these also resolved within 1 month. The only permanent complication postcordotomy in our series was dysesthesia, seen in 4 cases (1.9%). Bilateral cordotomy procedures are associated with a higher rate of complications than unilateral procedures. Most complications after bilateral cordotomy are attributable to bilateral lesioning of the anteromedial portion of the spinal cord. In our series, there were no complications in the cases with intractable benign pain, and all operations were conducted by the same surgeon (YK).

DISCUSSION

Cancer is a significant cause of death in the world, and its incidence increases each year. Fifty to sixty percent of all patients with malignancy in the terminal stage will probably experience intractable pain (42). In most centers, systemic analgesia provided by narcotics is usually the first choice of treatment in pain relief, and a neurosurgical pain procedure is considered only if the patient does not respond to narcotics administered orally, parenterally, or intrathecally (16, 20, 24, 42, 43).

The purpose of the surgery (cordotomy) is to damage the lateral spinothalamic tract that carries the pain sensation. Open cordotomy with laminectomy in animals was first performed by Schüller (36). Anterolateral cordotomy for relief of pain was first performed by Martin using the suggestions of Spiller in 1912 (38). In 1963, Mullan et al. (31) devised an approach to the cervical spinal cord by inserting a needle through the neck under fluoroscopy control. They introduced radioactive strontium needles to produce a lesion interrupting the lateral spinothalamic tract. In 1968, Mullan and Hosobuchi (30) simplified the procedure by using an electrical current to produce the lesion. In 1965, Rosomoff et al. (34) developed an improved technique using RF, which achieved wide popularity. Since then, RF and thermocoagulation have been used for percutaneous cordotomy with the help of stimulation and impedance measurement (6, 7, 10, 11, 35, 39, 40).

In the past 20 years, destructive surgical pain procedures have declined in popularity to a significant extent. This can be attributed not only to the high efficacy of new methods like morphine pumps and neurostimulation but also to neglect in the field of surgical pain procedures and electrode technology. The important change involves the replacement of x-ray guided cordotomy with that of computed tomographic imaging technology. With the help of this system, the spinal cord diameter can be measured for each patient individually, the target-electrode relation can be assessed directly in real time, and the needle electrode system can be inserted into the specific part of the pain-conducting system for the achievement of selective cordotomy (15).

Selective destruction of the lateral spinothalamic tract was first described and performed by Hyndman and Van Epps (13). Brihaye et al. (5) and White and Sweet (41) emphasized the possibility of selective lesioning by open cordotomy but also concluded that there was a risk of pain recurrence owing to incomplete dissection. In CT-guided cordotomy, destruction of a specific part of the lateral spinothalamic tract is possible. With the help of selective lesioning, it is possible not only to denervate the painful area but also to preserve other important tract functions. Hence, percutaneous cordotomy has been performed in our department with a 92.5% success rate and with very few complications, recognizing, of course, the key role of the experience of the surgeon.

We believe that cordotomy should be considered as a treatment option in controlling unilaterally localized chronic cancer pain states. From among the works of the past 2 decades, there have been very few large series about percutaneous cordotomy. Two important collected series were published by Lorenz (28) and Sindou et al. (37). They stated that cordotomy is an effective procedure, but it carries a high risk of mortality and morbidity, at 0% to 9%. In bilateral cordotomy, mortality rates increase dramatically, up to 50%. However, these mortality rates are given for the conventional x-ray-guided percutaneous cordotomy group (28, 37). These complications significantly decrease, to nearly 0%, with computed tomographic and/or magnetic resonance imaging guidance (9, 22, 29, 33, 43). In the very important work of Lahuerta et al. (26), it was reported that approximately 20% of the cord must be destroyed to achieve adequate pain relief. This is a critical point related to the efficiency and complications of percutaneous cordotomy. The most important part of this procedure is to anatomically localize how to approach this 20% of the spinal cord with a real-time, direct, morphologically based visualization system instead of x-ray visualization. As we have stated previously, the first step of the procedure is anatomic localization, the second step is neurostimulation, and the final procedure is controlled lesioning (22–24). Sindou et al. (37) criticized the procedure, citing a diminished hypoanalgesia level and percentage of pain relief over time. However, if pain recurs, reoperation is easy and safe with the help of computed tomographic guidance. In our series, 5 patients in whom we achieved satisfactory pain scores insisted on repeated cordotomy for the comfort it provided; this is perhaps one of the strongest testimonies to the value of the procedure.

Most physicians involved in pain practice consider destructive procedures only in the terminal stages of malignant diseases. However, we suggest that destructive procedures like cordotomy should be used as early as possible. If surgeons can denervate the painful area, the patient's quality of life will improve, and he/she will be able to conduct a normal active life, virtually eliminating dependence on doctors and hospitals (22).

CONCLUSION

Sectioning of the lateral spinothalamic tract in the anterolateral spinal cord, known as cordotomy, is an effective and selective surgical treatment for intractable cancer pain. With the help of computed tomographic imaging and new electrode technology, the procedures can be used more accurately and selectively. Neurosurgeons are encouraged to use this approach in dealing with intractable pain in malignancy. At present, CT-guided cordotomy is not widely used for benign intractable pain; long-term large trials will no doubt point to future indications.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

Dr. Kanpolat and his group have one of the most prolific experiences with percutaneous cordotomy procedures in the world. Possibly their greatest contribution to this procedure, however, is its modernization with the use of intraoperative computed tomographic (CT) scanning. This modification to the classic technique described by Spiller and Martin (1) in 1912 is not often performed, and there are few centers with significant experience in its performance. Therefore, this article is a welcome addition to the neurosurgical literature.

In this article, Kanpolat et al. describe in detail the technical nuances of computed tomography-guided percutaneous cordotomy performed for the treatment of cancer pain. This is a report of a very large series (207 patients in a period of more than 2 decades). The authors describe the technical details of this procedure to allow other practitioners to understand it better and to be more comfortable with it. The description of the technique is greatly enhanced by the inclusion of an operative video in the online article. The figures are also clear, and they are a useful addition to the textual description.

This article also includes a relatively brief description of the authors’ results in this large series. Unfortunately, the results are not quite as useful as the actual technical description. The pain outcome scales used are fairly broad and not well validated, and the use of functional outcomes, such as the Karnofsky score on the first postoperative day, are really not very meaningful in this report. The complications from the procedure are relatively well documented, although, in a retrospective series, it is difficult to know whether the incidence of such complications is fully captured.

Despite these drawbacks, this is an excellent technical nuance article. It does a good job of conveying the practical steps of a procedure that is rarely performed in few centers of excellence. Without this type of documentation, the impact of the experience of such pioneers as Dr. Kanpolat would not be easily transmitted to future generations of neurosurgeons.

Oren Sagher
Ann Arbor, Michigan

1. Spiller WG, Martin E: The treatment of persistent pain of organic origin in the lower part of body by division of the antero-lateral column of the spinal cord. **JAMA** 58:1489–1490, 1912.

Dr. Kanpolat and his team have considerably refined the classic technique of anterolateral cordotomy and applied it to a very large number of patients suffering malignant pain. We agree with the authors that ablative pain surgery is underused for cancer pain, especially in patients with: 1) circumscribed neoplasias responsible for topographically well-delineated pain, 2) a not-too-short life expectancy (3 to 6 months), and 3) good general health conditions.

Anterolateral cordotomy, performed in the depths of the anterolateral quadrant (i.e., the spinoreticulothalamic area, which is the real pathway of pain) can be very effective for (nociceptive) pain of malignant origin. The help of CT imaging (as introduced by Dr. Kanpolat himself), followed by electrophysiological testing, makes the procedure reasonably accurate and selective.

However, we do not recommend the use of cordotomy, even when very selectively performed, for nonmalignant pain. Consideration of literature data on long-term results shows that antalgic effects tend to decrease after 1 to 2 years of follow-up and that anterolateral cordotomy may sometimes generate (delayed) dysesthesias and spinothalamic pain in the deafferented territory.

Marc P. Sindou
Lyon, France

The use of CT guidance for percutaneous procedures is an extremely important technique, which more neurosurgeons should master. We have used CT guidance for many years for epidural, transforaminal, and periarticular injections. Once the operator is familiar with the technique, it can be done without any x-ray exposure for those doing the procedure; it is fast, and the exact position of the needle is verified for every procedure. The use of the technique for cordotomy will undoubtedly improve the accuracy with which the cord puncture is made. The authors provide a detailed account of needle placement. This is a technique which any neurosurgeon who still wants to use cordotomy in the treatment of pain could master. I agree with the authors that cordotomy is underutilized today. There are many patients who could be spared the side effects of significant drug doses by the judicious use of cordotomy. There are still a number of cancer sufferers who can be relieved by this safe and relatively minor procedure.

Those skilled in the use of percutaneous cordotomy are able to perform it with minimal morbidity; even seriously ill patients can be treated. The judicious use of narcotics and other medications has greatly reduced the need for cordotomy, because many patients can have their pain controlled with oral medications. However, the side effects of these medications can be significant, and percutaneous cordotomy should be a part of the armamentarium of any pain specialist neurosurgeon. CT control is a simple addition to an old-fashioned technique, which both improves the success rate and reduces morbidity. I am pleased that the authors have published their excellent experience.

Donlin M. Long
Baltimore, Maryland

Dr. Kanpolat is clearly the leader in application of percutaneous cordotomy, a procedure that is rarely used in North America. The present article provides a detailed description of the procedure, including preoperative considerations, contraindications, and patient selection. The diminished application of this technique heightens the importance of this operative nuance article at the present time.

The strength of this article is the demonstration of the technique's feasibility. It is a tremendous shame that Dr. Kanpolat does not have the "long-term" follow-up on these patients. Certainly, follow-up with terminal patients in the context of a developing country presents unique challenges. However, this limitation leaves the article, and hence the technique, open to dismissal by skeptics. Another weakness of the present report is the contention that the computed tomography-guided approach provides improved specificity and reduced morbidity over the fluoroscopic procedure. This contention pivots on the notion that imaging plays a more important role than physiological mapping. Unfortunately, the article fails to provide any head-to-head (or neck-to-neck) comparison of the 2 techniques.

The application of a variety of ablative pain procedures depends on obtaining the necessary electrodes. Moreover, the accurate function of these electrodes, including the thermocouple and radiofrequency delivery, is critical for avoiding complications. Recently, Integra Radionics (Burlington, MA) discontinued production and distribution of DREZotomy and cordotomy electrodes, making maintenance and procurement difficult. Luckily, Dr. Cosman, who initially developed the radiofrequency generator, has begun to manufacture generators and electrodes, allowing new pain neurosurgeons to adopt these techniques.

Nicholas M. Boulis
Atlanta, Georgia

The authors present a rather large contemporary series of percutaneous cordotomy for the treatment of intractable cancer-related pain. The authors enthusiastically cite multiple reasons why they prefer CT guidance for added safety and effectiveness of the procedure. Although I certainly would agree that computed tomography-guided cordotomy is a safe and effective procedure in Dr. Kanpolat's hands, I would respectfully disagree that the use of CT guidance is necessary for performing percutaneous cordotomy. I still personally perform this procedure using the classic method of biplane fluoroscopy, introduction of intrathecal contrast to identify the dentate ligament, and confirmation of the target using physiological localization. In my opinion, physiological localization represents the most important aspect of the procedure. Indeed, there are numerous reports in the literature that provide evidence that the classic technique is both safe and effective. Moreover, there is no evidence that I am aware of that conclusively shows that computed tomography-guided cordotomy is any safer or more effective than the classic technique.

For me, the most important aspect of this report is not the details of the technique or the authors' preference for using CT guidance. Rather, I believe that the extensive contemporary experience of Dr. Kanpolat with percutaneous cordotomy and other ablative neurosurgical techniques should be an indelible reminder for neurosurgeons, oncologists, and other health care providers who deal extensively with intractable cancer pain that these techniques are indeed safe and effective. There is no doubt in my mind that techniques such as percutaneous cordotomy are severely underutilized in the treatment of cancer pain. I firmly believe that those of us who have been fortunate enough to be trained in these procedures need to make a concerted effort to educate our oncology and pain medicine colleagues as to the tremendous benefit of these techniques. It is also our responsibility to educate our younger neurosurgical colleagues and residents in training so that they can continue to provide these services. Those of us who believe in these techniques need to be the standard bearers; otherwise, I am afraid that, over the next 10 to 20 years, we will witness a continued decline and eventual extinction of these techniques. I, for one, think that would be a tragedy, not only for the profession of neurosurgery, which developed these techniques, but also for the scores of patients who might benefit from them.

Richard K. Osenbach
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