The Neurosurgical Treatment of Pain

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The referral of a patient to a neurosurgeon for pain relief was once considered bad news, because the choice of procedures was limited to the creation of lesions offering significant risk and only modest success. The good news is that much has changed. Advances in technology and an improved understanding of pain have added sophisticated options and have guided attention to more effective procedures. An awareness of these capabilities has expanded the surgical indications for pain relief so extensively that a recent definitive textbook[1] discusses more than 30 types of procedures used in more than 18 major categories of pain.

This review will discuss some of the major neurosurgical interventions used for pain. More comprehensive articles can be found in several excellent books and reviews.[1-4]

ABLATIVE SURGERY

Many ablative procedures have been replaced by treatment with electrical stimulation or the precise delivery of medication. We discuss some notable exceptions, ablative procedures retained in the armamentarium because of their proved efficacy.

Methods of Ablation

Although lesions have been produced in the past with wire loops, alcohol injections, or cryoprobes, most lesions are now made with a probe that heats the tissue at its tip with radiofrequency current while maintaining a constant temperature with an incorporated thermocouple. Precise control of lesion size is accomplished through adjustments of time and temperature.

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Cordotomy

The goal of this old operation is to cut the spinothalamic tract either through a laminectomy or percutaneously; the latter technique is more recent and less morbid. Although benefits are immediate and extend to both nociceptive and neuropathic pain,[5] the procedure is restricted to cancer pain because the effects rarely last more than 2 years. Bilateral cordotomy is required for abdominal, pelvic, or bilateral extremity pain, and cordotomy above cervical vertebra C5 carries a risk of respiratory depression without any added efficacy for the relief of arm pain.

Dorsal Root Entry Zone Lesions

Lesions of the dorsal root entry zone of the spinal cord have been used in various pain syndromes, although the best indication is the otherwise intractable pain following cervical (brachial plexus) or lumbar root avulsion. A series of as many as 60 small lesions placed along the entry zone are created with a needlelike probe through a large laminectomy. The procedure may also be effective for pain following spinal cord injury that is restricted to the level of injury,[1,4] especially if electrophysiological guidance is used.[6]

Sympathectomy

Portions of the sympathetic chain can be ablated to treat complex regional pain syndrome I or II. Open procedures have mostly been replaced by the less invasive technique of thoracic endoscopy. The role of a prior sympathetic block in assessing the efficacy of these procedures is traditional,[7] but questionable.[1,4] Pain relief is usually last-

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Figure 1. Lateral skull radiograph showing placement of a motor cortex stimulator electrode. The axis of the electrode is perpendicular to the gyrus.

ing in a third of the patients after 5 years, and a common complication is compensatory hyperhidrosis.

Myelotomy

The recognition that visceral pain travels deep within the dorsal columns confirmed the use of midline myelotomies for the treatment of this pain.[8] Success rates of 60% to 70% have been reported for different variations of this operation,[7] and efficacy has also been reported for painful spasticity following spinal cord injury.

Mesencephalotomy

The close proximity of the spinothalamic tract, the quintothalamic tract, and the periaqueductal gray in the mesencephalon creates an attractive target for pain surgeons. Good results have been reported for malignant head and neck pain that is too high for cordotomy or intraspinal drug delivery.[1-3]

Cingulotomy

Cancer pain associated with intolerable suffering often responds to the placement of lesions in both cingulate gyri. The ablation is done with a stereotactically guided radiofrequency probe and confers relief in about 50% of patients. It is the emotional impact, and not the pain itself, that is modulated by this procedure.[1]

STIMULATION

The ability of electrical stimulation to block or "jam" pain pathways has long been recognized, leading to the development of implantable systems and electrodes for that purpose. These procedures are often tried before attempts with ablation.

Spinal Cord Stimulation

After the prediction that stimulation of Aβ fibers might inhibit pain signals,[3,4] spinal cord stimulation was used to treat a wide variety of pain syndromes. Catheterlike electrodes are inserted into the epidural space through a spinal needle or flat and rectangular paddles are inserted through a lumbar laminectomy. Because pain relief occurs only in areas where stimulation produces paresthesias, the patient is kept awake so that electrode position can be modified as needed. The electrodes are connected to an external stimulator for a trial period of several days; if pain relief is achieved, the electrode is connected to a stimulator that is permanently implanted in a subcutaneous pocket.

The generator is about the size and shape of a hamburger patty, and is programmed in the office with a computer-driven electromagnetic coupling device that allows adjustments of voltage, pulse duration, and pulse frequency and the choice of active electrodes. The entire generator (but not the electrode) must be replaced surgically every 3 to 5 years when the battery becomes exhausted.

Achieving stable paresthesias in painful areas is not always straightforward because the pain pattern can be complex, the electrodes can migrate, and the spread of current can be unpredictable. These problems have been addressed by the simultaneous use of 2 electrodes with multiple contacts placed in parallel and programmed to "steer" the current and by the use of novel electrode shapes.[9]

Spinal cord stimulation is often the first neurosurgical intervention tried because it is not ablative and carries only a small risk of morbidity. The most common indication is the pain of the "failed back" syndrome, relieved in 50% of patients; leg pain seems to respond better than back pain.[10] Spinal cord stimulation is also strikingly effective for the ischemic pain of peripheral vascular disease,[4] Raynaud disease, and angina, although these indications are more common in Europe than in the United States. More than 80% of patients will benefit from spinal cord stimulation by a decrease in anginal frequency and a decreased need for nitrates,[11] and there is evidence[12] for improvement in cardiac efficiency. Spinal cord stimulation is also a mainstay in the treatment of complex regional pain syndromes I and II,[1,4,10] peripheral nerve injury, and peripheral neuropathy. There has also been success in the treatment of postherpetic neuralgia[13] and spinal cord injury,[14] but only if sensation is intact. A consensus statement of indications has been published.[15]

Motor Cortex Stimulation

Tsubokawa et al[16] first demonstrated that stimulation of the motor cortex could relieve neuropathic pain, especially central pain due to stroke and atypical trigeminal pain. The mechanism by which the motor cortex modulates sensory pathways is unclear, but reports[4,17] of efficacy rates of 50% for otherwise intractable central pain are common. In this promising procedure, an electrode is placed in the epidural space overlying the motor strip through a craniotomy. It is essential that the electrode lies directly over the motor cortex, mandating careful location of the motor strip with techniques such as image-guided navigation, functional magnetic resonance imaging, evoked potentials, and cortical stimulation (**Figure 1**). Intriguingly, some patients obtain long-lasting relief after the device is turned off.[17]

Deep Brain Stimulation

Stimulation of either the sensory thalamus or the periaqueductal gray is achieved with a stereotactically implanted electrode connected to a permanently implanted generator placed over the chest. Nociceptive pain seems to respond better than neuropathic pain, although results are variable. The highest success rates are for the failed back syndrome, and the lowest are for central pain. Morbidity is relatively low, and deep brain stimulation is often tried before any ablative procedures.[1]

DELIVERY OF INTRASPINAL MEDICATION

Delivery of medication directly to the spinal cord achieves high concentrations of drug adjacent to the neuraxis and avoids the necessity for large systemic doses and their adverse effects. The procedure begins with the percutaneous placement of a catheter into the midlumbar subdural space, adjusted so that the tip is adjacent to thoracic vertebra T10. Connection to an outside reservoir permits a trial period of several days, and permanent implantation of the pump is offered if pain is reduced by 50%.[18] The pump can be programmed for complex drug delivery patterns, and lasts for up to 3 years before replacement is required. The pump reservoir is percutaneously refilled every few months.

Long-term intraspinal drug delivery was at first limited to cancer pain, with significant improvement achieved in more than 80% of patients.[1-3,18] More recently, various types of benign pain have been treated, with response rates as high as 50%.[18] Although morphine is the most commonly used drug, mixtures of morphine with bupivacaine or lidocaine have been tried, and a mixture with clonidine has been used for neuropathic pain. Experience with these mixtures is early, and safety data are inconclusive.

Complications include respiratory depression due to overdosing and suppression of the hypothalamic-pituitary axis. Equipment-related problems, such as obstruction or leakage, are relatively common.[1,8]

SELECTED PAIN SYNDROMES

Cancer Pain

The most common neurosurgical intervention for cancer pain is intraspinal drug delivery, because it is not ablative, confers a success rate of more than 80%, and has a low morbidity. If life expectancy is less than 3 months, the catheter can be connected to an outside reservoir to avoid permanent pump implantation. Other patients may benefit from cordotomy for extremity pain, myelotomy for visceral pain, or mesencephalotomy for head and neck pain. Cingulotomy can be helpful if the affective component of the pain is high. Spinal cord stimulation is rarely used.

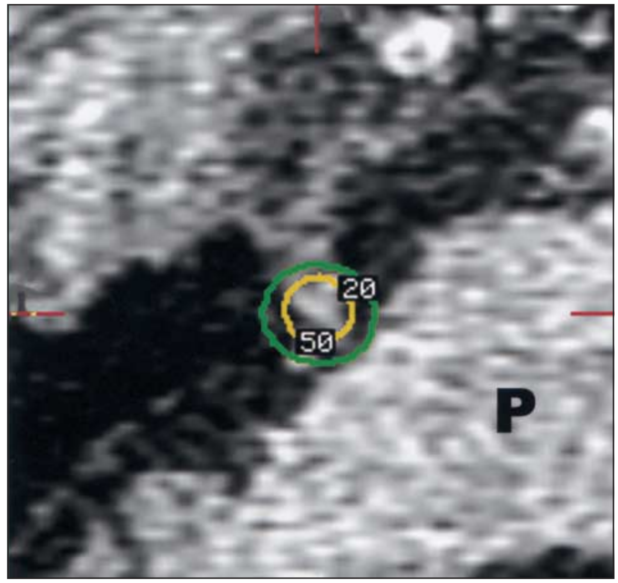

Figure 2. Gamma knife radiosurgical plan showing isodose lines superimposed on an axial magnetic resonance image. The 50% isodose line is centered on the trigeminal nerve, and the 20% isodose line touches the brainstem. P indicates pons.

Failed Back Syndrome

This mixture of nociceptive and neuropathic pain responds well to spinal cord stimulation in 50% of patients.[1-3] The success rate of deep brain stimulation is also high, although this procedure is rarely used. Treatment with intraspinal drug delivery systems is controversial.

Spinal Cord Injury

Treatment of the pain of spinal cord injury is notoriously difficult. Pain at the level of injury responds to the dorsal root entry zone procedure, especially if aided by electrophysiological monitoring. Success rates as high as 68% have been reported, with paroxysmal pain responding better than constant pain.[19] Pain due to spasticity responds to myelotomy, but the results of deep brain stimulation have been dismal. Spinal cord stimulation may be of some benefit if the injury is incomplete.[14]

Trigeminal Neuralgia

Three types of neurosurgical procedures are useful for trigeminal neuralgia. First, in microvascular decompression, an artery is dissected and held away from the trigeminal nerve through a suboccipital exposure to reduce the pulse pressure believed to be related to the pain. Success rates are as high as 70% in 10 years.[20] Second, percutaneous procedures are performed by passing a needle under fluoroscopic guidance into the trigeminal ganglion through the foramen ovale. The needle can be used to pass a radiofrequency current until a pinprick is felt as light touch over the appropriate area of the face. Pain relief is immediate, with recurrence rates of 10% to 25% and a low rate of anesthesia dolorosa. The needle can also be used to bathe the ganglion in glycerol or to compress the ganglion with a small balloon.[20]

The third type of procedure used for trigeminal neuralgia is radiosurgery, in which a high dose of radiation is precisely aimed at the proximal few millimeters of the trigeminal nerve as it exits the brainstem (**Figure 2**). Typical doses of 8000 rad (80 Gy) produce a 70% rate of complete pain relief at 1 year, declining to 56% after 5 years.[20] Pain relief is not immediate, and may take as long as 2 to 6 months. Anesthesia dolorosa is rare, and sensory deficits are usually not noticed by the patients. Finally, radiosurgery may be repeated if pain recurs.[21]

The existence of several procedures for trigeminal neuralgia suggests that none is ideal. Microvascular decompression is often recommended for young and healthy patients, or for those who want to avoid sensory deficits, whereas percutaneous procedures are often chosen for elderly and frail patients. Radiosurgery is also well tolerated by elderly patients, although its use for those able to undergo microvascular decompression is controversial because of its lower rate of success. Many patients will choose radiosurgery rather than microvascular decompression because of its low morbidity, while some will choose otherwise to achieve immediate relief of pain.

CONCLUSIONS

An improved understanding of pain syndromes and advances in technology have allowed modern neurosurgeons to offer optimistic choices to those suffering with pain. However, a discussion of a list of procedures and syndromes is not to be taken as a suggestion that neurosurgical intervention should be offered in isolation from other methods or that neurosurgical procedures should always be the first line of treatment. The chances for pain relief are greatest when neurosurgery is but one piece of a comprehensive plan incorporating all possible treatment modalities.

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