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230. NEUROSURGICAL TREATMENT AND IMPLANTABLE DEVICES

THORKILD VAD NORREGAARD

Individuals suffering from chronic pain often seek a surgical solution to their problem. This is indeed a logical approach and significant time is often required explaining physiologic and pharmacologic aspects of pain transmission for the patient to understand why this approach may or may not be a viable solution to their problem. Anatomic and physiologic studies have been very helpful in elucidating pathways transmitting acute pain. The exact mechanisms underlying chronic pain are, however, much less well known. Since appropriate chronic animal pain models are scarce, neurosurgical intervention has often been based on knowledge derived from acute pain.

Neurosurgical interventions in chronic pain management are often, and appropriately, reserved for conditions intractable to other less invasive measures. A chronic pain condition can be either initially largely insensitive to pharmacologic manipulation or can develop a tolerance to the same. Interruption of peripheral and central pain pathways may initially be effective but subsequently lose its effectiveness after the emergence of either a similar or slightly different pain. This might be thought of as a "tolerance" to destructive lesions in the nervous system and serve as an example of pain being a very essential protective mechanism for the individual and evolution having provided strong mechanisms for its upkeep.

Neurosurgical pain management should be seen in a multidisciplinary setting. The overall treatment of an individual in chronic pain should follow an algorithm in which treatment attempts follow a logical ladder from least invasive to more invasive and from few side effects to more potential side effects. The treating team has to be sure that the pain is not amenable to direct attack. The team must generate a background of sympathetic understanding of the patient's personality and general medical problems. Also, they must clearly understand the limitations inherent to the use of drugs, nerve blocks, central administration of drugs into the ventricular system or subarachnoid space, electrical stimulation of the central and peripheral nervous system, and classic ablative neurosurgery.

INTRATHECAL OR EPIDURAL ADMINISTRATION OF PHARMACOLOGIC AGENTS

Discovery of morphine receptors in the spinal cord and consequent experimental studies showing the analgesic effect of intrathecal administration of opiates prompted extensive use of this modality for the treatment of pain in human beings. Morphine sulfate is by far the most common agent used in this context. Morphine sulfate is highly hydrophilic and diffuses throughout the intrathecal space. The exact position of the catheter tip in the intrathecal space is therefore less important. This is in contrast to lipophilic substances such as fentanyl, which binds rapidly and locally and therefore is dependent on the exact site of administration for its efficacy. When using a mixture of morphine sulfate and, for instance, bupivacaine, one is again faced with the importance of catheter tip location.

Spinal administration of narcotics is extremely potent. Ten and 1 percent of an intravenous dose administered in the epidural space or subarachnoid space, respectively, produce an equianalgesic effect. It should be kept in mind that a patient whose pain is not responding well to narcotics will not have a better response when the drug is given by an intraspinal route. The best candidate for intraspinal administration of narcotics is the individual who has good analgesic effect from systemic narcotics but intolerable side effects such as constipation or sedation. Pain of a nociceptive nature such as from cancer or from certain degenerative conditions is usually a good candidate for this approach. The combination of narcotics and local anesthetics offer certain clear-cut advantages. Local anesthetic such as bupivacaine can be given in a dose up to 20 mg per 24 hours in the subarachnoid space without causing motor disturbances. There can, however, periodically be slight tingling in lower extremities.

Subarachnoid administration is preferable to epidural administration since there is a tendency for scarring around the catheter tip and decreased diffusion, necessitating an increase in doses with systemic side effects as a consequence.

A candidate for spinal narcotics first undergoes a test trial. During the test, a percutaneously inserted catheter is hooked up to a minipump that delivers the drug on a continuous basis. This allows for titration and assessment of the effect. During this phase, the patient is fully ambulatory but initially needs to be observed for respiratory depression, which rarely occurs. If the projected survival time, for example, in a patient with cancer, is 1 or 2 months, one can continue with percutaneous administration using this concept. For patients with longer survival times and certainly for those with benign pain conditions responding to this treatment, a subcutaneous reservoir could be implanted. This reservoir can be filled via a percutaneous needle stick, and the delivery rate can be electronically altered. More complex infusion rates, including automatic bolus, can also be programmed into the pump.

Infection around the implanted system is usually the most serious complication, which would necessitate explantation of the system. In addition to the above-mentioned possibility of respiratory depression, there can be urinary retention; nausea and vomiting, which usually is transient; and tolerance.

For certain pain syndromes related to the face and pain related to cancer of head and neck, intraventricular administration of morphine should be considered.

ELECTRICAL STIMULATION OF PERIPHERAL NERVES AND CENTRAL NERVOUS SYSTEM

Melzack and Wall's gate control theory presented in 1965 predicted a possible effect on pain transmission from stimulation

...ts of the nervous system. This indeed has also to be a powerful tool for the control of pain. The ...g years have seen a significant development and im-nent of implantable stimulating devices. Completely im-able devices, including implantable stimulating units and ...plex electrode configurations, are now available for implantation.

Patient selection is still difficult, thereby also necessitating a test trial. Pain of a neuropathic nature seems to respond better than pain of a nociceptive nature. Luckily the latter is often more amenable to pharmacologic control than neuropathic pain. It is still not completely understood how electrical stimulation causes pain relief. The gate control theory, implying a modulatory effect from stimulation of large fibers, can explain certain aspects but, for instance, not explain why often, after turning the stimulator off, there is pain relief lasting minutes to hours. Measurement of transmitters in spinal fluid during stimulation has indicated an involvement of certain neurotransmitters such as substance P. From a practical point of view, it is important to notice the need for stimulation-induced paresthesia to cover the geographic area of pain in order to obtain pain relief. When dealing with causalgia or other pain syndromes clearly referable to a single peripheral nerve, it is natural to consider stimulation of the actual nerve in question. This involves the surgical implantation of test electrodes, allowing the patient to stimulate the nerve until a clear-cut answer can be given as to its effect.

Pain covering more than a single peripheral nerve territory is common. Chronic sciatica and failed low-back syndrome, including cases of multiple back surgeries and/or arachnoiditis, typically fall into this category. Phantom pain, postherpetic neuralgia, and sympathetically mediated pain such as reflex sympathetic dystrophy also fall into this category. After careful medical trials and evaluation by a multidisciplinary pain group, including psychological assessment, it may be reasonable to proceed with a trial of spinal cord stimulation.

Most spinal cord stimulators are inserted using a percutaneous technique in which a Tuohy needle is positioned in the epidural space and a spinal cord test stimulator lead is inserted into the epidural space under fluoroscopic guidance. If large areas are to be covered, it is often beneficial to insert more than one electrode with multiple stimulation sites on each electrode. The leads are then exteriorized through a separate stab incision, and the patient is typically discharged wearing an external stim-...lar... The individual will then go through a careful trial period in which pain intensity during stimulation is charted and compared with pain during stimulation-free periods. If the patient experiences at least 50 percent pain relief and considers this a valuable asset, then permanent implantation takes place. Depending on the electrode configuration used, a stimulating unit is either implanted subcutaneously or a subcutaneous receiver is implanted and this receiver is then stimulated using an external stimulator taped to the skin.

When applying strict selection criteria, success rates can be as high as 80 to 85 percent, with the long-term success rate being in the 60 to 65 percent range. Good results usually indicate more than 50 percent pain relief. Some individuals have a spectacular 100 percent pain relief; other individuals fall short of this desirable level of relief.

Deep brain stimulation focuses on two areas. As a rule, somatic nociceptive pain responds better to periventricular gray and periaqueductal gray stimulation; neurogenic pain seems to respond better to stimulation of the ventral posteromedial and ventral posterolateral areas of the thalamus. The technique involves stereotactic implantation of electrodes, and the final electrode site is reached during test stimulation. Deep brain stimulation seems overall to have a 50 to 60 percent or more pain reduction in 50 to 60 percent of implants.

Electrical stimulation on the peripheral and central nervous system is overall a safe modality. Infections can occur, which necessitate explantation of the system. Injury to peripheral nerves or the central nervous system rarely occurs. Why there is an overall reduction in efficacy over time is not entirely known. Local mechanical factors such as electrode migration can obviously play a role, but it seems apparent that neural physiologic aspects also play a role.

Together with intrathecal administration of drugs, the concept of stimulating the peripheral and central nervous system is minimally invasive and testable, and patients do not run the risk of worse outcome from trying these modalities, which otherwise can be the case in, for instance, repeated spinal surgery.

NEUROABLATIVE PROCEDURES

All of the following procedures have in common an irreversible destruction of nociceptive pathways in the peripheral or central nervous system. They are associated with variable degrees of neurologic deficits, which usually are well tolerated. There is a risk from a few percent to 10 to 15 percent of anesthesia or analgesia dolorosa (i.e., a painful or unpleasant sensation in the anesthetic or analgesic area). Excellent pain relief over time can decrease, and the original pain can recur.

Peripheral Neurectomies

Morton's metatarsalgia and trigeminal neuralgia are well known cases in which resection of a peripheral postganglionic nerve branch can result in pain relief. If it is possible clearly to locate the nerve with the tip of a needle, a percutaneous destructive lesion can also be performed, either using a neurolytic agent such as alcohol or phenol or by applying radiofrequency heat. The latter application has been well established for the treatment of trigeminal neuralgia. Through this procedure, a needle with an uninsulated tip is inserted percutaneously, under fluoroscopic guidance, through the oval foramen into the trigeminal ganglion. Gentle stimulation in the awake patient verifies the needle's position with reference to the three different divisions. The advantage of this technique is the possibility of applying gradually increasing heat and at the same time performing a sensory examination. The goal is a moderate hypalgesia with otherwise preserved sensation. This procedure is associated with 95 to 100 percent initial pain relief and a recurrence rate below 25 to 30 percent. The procedure can be repeated with an equally good up-front response. Other invasive procedures for trigeminal neuralgia include glycerol injection into Meckel's cave; percutaneous insertion of inflatable balloons, causing compression of the trigeminal ganglion; and posterior fossa microvascular decompression of the trigeminal root. The latter procedure is based on the remarkable observation that, when explored, up to 80 to 90 percent of patients with trigeminal neuralgia have compression by a vessel loop against the trigeminal root. Pain relief is accomplished when this vessel is dissected and gently repositioned in a noncompressing manner or when a piece of Teflon, for instance, is interpositioned between the nerve root and the vessel loop. A successful microvascular decompression is associated with pain relief and no sen-

sory deficits. In the absence of a major vascular compression, a partial rhizotomy can be performed. A percutaneous radiofrequency lesion of the trigeminal nerve is usually the treatment of choice when medical treatment fails in the elderly individual and is well tolerated by people in their 70s and 80s. Careful blood pressure control during the procedure is necessary since hypertension often occurs during the lesion. Intravenous and intra-arterial access is therefore mandatory.

Cluster headache or its more chronic variant, chronic migrainous neuralgia, when medical treatment fails, can be treated along the guidelines of radiofrequency ablation of the gasserian ganglion. This should, in general, be preceded by a diagnostic lidocaine block of the gasserian ganglion under induced attack. In the absence of effect of a radiofrequency lesion in this condition, lesions at the cervicomedullary junction should be entertained. The cephalic pain pathways loop down into the upper cervical cord with a fairly predictable relationship to surrounding structures before synapsing on second-order neurons in the nucleus caudalis. Fibers from not only cranial nerve V but also VII, IX, and X are associated with this, the so-called descending nociceptive tract. A carefully placed lesion of the tract around the level of the obex can render the entire ipsilateral face, oral cavity, and pharynx analgesic with preserved sensation to touch. This procedure has been utilized in the treatment of chronic migrainous neuralgia with success. In a variant of the same procedure using a radiofrequency technique, the entire nucleus caudalis is destroyed, resulting in successful treatment of the pain of postherpetic neuralgia and anesthesia or analgesia dolorosa of the face.

The much less common vagoglossopharyngeal neuralgia can be treated according to similar guidelines using percutaneous rhizotomy or open exploration with microvascular decompression or rhizotomy of ninth and parts of the tenth cranial nerve.

These procedures are primarily aimed toward benign cephalic pain conditions. When used in a setting of head and neck cancer not responding to narcotics, nucleus caudalis nucleotomy is usually indicated, including dorsal root entry zone lesions of the upper cervical dorsal root zones.

Procedures Directed Toward Dorsal Roots and Dorsal Root Entry Zones

Dorsal rootlets can be sectioned through an open intradural procedure. The dorsal root ganglion can also be resected, and this procedure often has more merit since some sensory fibers travel through the ventral rootlets. Removing the entire ganglion should therefore also result in degeneration of fibers in the ventral root. These procedures have been used in chronic benign pain such as chronic radiculopathies and in cancer pain. Particularly patients with Pancoast tumors have benefited from these procedures. Since these two described procedures result in complete analgesia and anesthesia of the involved areas, other less invasive procedures should be tested first. There is also a not insignificant risk of postlesion dysesthesia and recurrence of pain owing to the plasticity of the central nervous system. These considerations spurred interest in the dorsal root entry zone where open radiofrequency lesions in Rexed's laminae have been proposed and successfully applied, particularly in brachial plexus avulsion injuries. These so-called dorsal root entry zone lesions can again be associated with denervation paresthesias and, not infrequently, transient motor weakness. An open superficial surgical lesion of the dorsolateral aspect of the nerve root entry zone is an anatomically more pleasing procedure aimed at interrupting the small-diame... Collectively, these procedures should be reserved for c... intractable cases in which spinal cord stimulation or intrat... drug administration has failed.

Lesions in the Spinal Cord

Interruption of the spinothalamic tract in the anterior cord can be an extremely successful procedure for pain in the extremities and trunk when the pain is clearly off the midline. This procedure can be offered in malignant pain conditions and more benign pain conditions, particularly pain in an amputation stump. This so-called anterolateral cordotomy can be performed either through an open procedure or through a percutaneous procedure using a radiofrequency technique. The procedure can be performed either in the high thoracic or high cervical region. When performed bilaterally, there is not infrequently an often transient bladder paralysis. Bilateral high cervical anterolateral cordotomy can be associated with respiratory failure owing to lesion of the descending respiratory pathways controlling involuntary breathing.

Pain located in the midline of the body, such as, for instance, pelvic pain, is more difficult to control surgically. These pain conditions can be associated with pelvic or rectal cancer. A procedure for this often-debilitating pain condition is commissural myelotomy. This procedure takes into account the fact that pain fibers, after ascending one or two cord segments, cross to the contralateral hemicord. Since pain fibers are the only crossing fibers, it is feasible to eliminate pain, for instance, from pelvic structures by dividing the spinal cord over several segments in a vertical anteroposterior plane. A peculiar phenomenon of this procedure is that the resulting sensory deficit can be rather moderate in spite of the successful pain relief.

Cerebral Lesions for Pain Control

Lesions in the diencephalon are thalamotomy and hypothalamotomy. Both of these procedures, and, in particular, the la... should be reserved for otherwise completely intractable c... tions. Thalamotomy, as other procedures, can be assoc... with dysesthesia and only transient effect. Additional re... based on lesion experiments and stimulation of these ... may result in a better understanding and possibly better ... in the future.

Pituitary ablation can be, for reasons that are not completely known, an effective procedure for the control of severe cancer pain refractory to other therapeutic attempts.

Cingulotomy is a bilateral lesion of the cingulate gyrus. This procedure can be done with remarkable effect, again, in highly selected cases. There is remarkable absence of side effects from this procedure when utilized in pain treatment and for obsessive-compulsive disorders.

Sympathectomy for Pain Control

The sympathetic nervous system clearly plays a role in a number of pain conditions. More modern nomenclature collectively refers to these pain conditions as sympathetically mediated pain. These conditions include causalgia and post-traumatic reflex sympathetic dystrophy. Any pain condition considered to belong to this category should initially be treated with local anesthetic blocks of the relevant portions of the sympathetic nervous system. Since a number of neurolytic drugs are avail-