Neurosurgical treatment of chronic pain

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Introduction

Neurosurgery is not a first-choice treatment for chronic pain. It is indicated when chronic pain is insufficiently relieved by analgesics, or when medication is effective but causes unacceptable side effects. Neurosurgical procedures may be ablative or augmentative (stimulating). An ablative procedure interrupts pain pathways at one of various levels in the central nervous system (CNS). In contrast, an augmentative procedure is non-destructive and is generally considered to activate the inhibitory system in the CNS, thereby suppressing pain perception.

There is, however, no neurosurgical procedure which affords permanent pain relief. This stems from the fact that pain is not simply the result of stimulation of specific sensory fibres in the peripheral and central nervous systems. As discussed elsewhere, there are two varieties of pain: nociceptive (somatic) and dysaesthetic (deafferentation). Some neurosurgical procedures relieve both nociceptive and dysaesthetic pain, while others relieve only one or other type.

Which procedure should be used in a specific case depends on many variables, including efficacy, indications for use, advantages and disadvantages, limitations and complications. These differ with each procedure. Familiarity with neuroanatomical and neurophysiological concepts of pain mediation and perception, and with a range of techniques, together with the necessary equipment, are all required for the safe and effective use of neurosurgery in the treatment of pain.

It is still sometimes thought that medication is no longer necessary after neurosurgery even if the procedure has resulted in incomplete relief. This misunderstanding must be corrected. The goal of pain treatment is always to provide a pain-free state and, if necessary, it should be achieved through a multi-modality approach.

The following discussion of several neurosurgical procedures is based both on my personal experiences and on data reported in the literature.

Cordotomy

Cordotomy—section of the spinothalamic tract in the anterolateral quadrant of the spinal cord—used to be carried out through a laminectomy until Mullan *et al.* (1963, 1965) introduced the percutaneous technique. Cordotomy is the treatment of choice to relieve somatic non-dysaesthetic pain of organic origin in C5 dermatome or below. The most common candidates for cordotomy are cancer patients, though cordotomy is also performed for pain of benign origin (Lorenz, 1976). Lipton (1979) states that percutaneous cervical cordotomy (PCC) is not sufficiently used, in spite of its superiority over all other types of pain-relieving procedures. There are two popular varieties of PCC: High (C1–C2) through a lateral approach and low (C5–C6) through an anterior approach (Lin, Gildenberg and Polakoff, 1966). Both provide excellent pain and thermal anaesthesia in the contralateral half of the body.

The technique has been described in detail by Lipton (1979, 1983). In high PCC, a guide needle is inserted in the lateral cervical region on the contralateral side to the pain. When the needle enters the subarachnoid space, a myelography is performed. It allows the needle to be positioned approximately (Fig. 1). Then an electrode is introduced through the needle, and intraoperative physiological studies are performed: measurement of impedance, electrical stimulation, etc. The latter induces cool or warm tingling in the contralateral half of the body when the electrode is properly placed within the spinothalamic tract. The site of tingling induced by electrical stimulation delineates the area in which pain relief will develop after cordotomy. A radiofrequency coagulation lesion is then produced. A somatotopographic organization for the contralateral half of the body within the lateral spinothalamic tract at C1 level has been proposed by Tasker (1976a).

The C5–C6 PCC is performed by inserting an electrode from the anterior cervical region through the disc space. Bilateral PCC is carried out on a

FIG. 1. C1-C2 lateral percutaneous cervical cordotomy. (From Lipton 1979: *Relief of Pain in Clinical Practice*, Blackwell Scientific Publications, courtesy of the author and publisher).

patient with bilateral pain. Since it is associated with more postoperative hazards than a unilateral cordotomy, Lipton (1979) suggests that high lateral PCC is performed on one side and low anterior PCC on the other side.

Tasker (1976b) reports 96% incidence of immediate pain relief in 199 consecutive unilateral procedures, and a 66% incidence of bilateral relief following bilateral procedures. Lipton (1983) performed PCC 809 times on 701 patients and obtained complete pain relief in 86% of the cases. The effects of a cordotomy tend to wear off within two or three years (Lipton, 1983).

Motor paresis, disturbance of micturition, dysaesthesia, ataxia and Horner's syndrome sometimes occur temporarily after PCC. Respiratory failure, resulting from impairment of automatic respiratory failure during sleep is the most serious potential complication after high PCC, as the reticulospinal tract may be destroyed if the lesion in the spinothalamic tract extends ventrally. Caution should be exercised when a unilateral cordotomy is performed on a patient with contralateral pulmonary dysfunction.

Neurovascular decompression

The most frequent pathological process in tic douloureux, or classical trigeminal neuralgia, is now considered to be distortion of the trigeminal nerve by cross-compression of blood vessels (Jannetta, 1967, 1977). Neurovascular decompression is done through

a small retromastoid craniectomy with supracerebellar exposure using a microsurgical technique. After dissection of the blood vessel from the nerve root, a spongy pad is placed between the blood vessel and the nerve. Since Jannetta (1967) popularized this procedure, it has become the most attractive surgical treatment of tic douloureux. Pain can be relieved by this treatment without loss of neural function (Jannetta, 1977). Preoperative diagnosis is based on clinical assessment as cerebral angiography often fails to show nerve compression. Intraoperative detection of a tumour compressing the nerve root is not rare. Removal of the tumour results in pain relief.

Jannetta (1977) reports excellent results following surgery in 200 patients with tic douloureux. In the first 100 patients, he found compression-distortion of the root entry zone of the trigeminal nerve by normal blood vessels in 88 cases, by tumours in four cases, by arteriovenous malformations in two cases and by multiple sclerosis plaque in six cases. Recurrent pain is documented in nine cases out of 200. This usually results from slippage of the pad or missing a second vascular loop. Both situations can be corrected by further surgery. Trigeminal rhizotomy is indicated for multiple sclerosis plaque.

Postoperative complications, e.g., meningitis, cerebellar infarction and haematoma, and hearing loss occur less often with greater surgical experience. Glossopharyngeal neuralgia can also be relieved by neurovascular decompression (Laha and Jannetta, 1977).

Cranial nerve rhizotomy

Trigeminal rhizotomy

As stated by Tew and Keller (1977), ophthalmological complications and a significant mortality rate following retrogasserian trigeminal rhizotomy using a direct intracranial approach have encouraged the development of alternative procedures such as percutaneous injection (Harris, 1940) and coagulation (Kirschner, 1932). Sweet and Wepsic (1974) revised the percutaneous radiofrequency coagulation technique, preserving touch sensation in the zone rendered analgesic. Percutaneous radiofrequency rhizotomy of the trigeminal nerve is indicated, at present, for the alleviation of tic douloureux, mainly in elderly patients, because it can be carried out under local anaesthesia. It is also performed in the treatment of some other types of chronic facial pain e.g., cancer pain, but it often fails to be effective against postherpetic neuralgia and atypical facial pain.

Through fluoroscopic control, the foramen ovale is punctured percutaneously from the cheek, using three landmarks (Fig. 2). A brief contracture of the masseter muscle and a wince indicate that the needle or electrode has entered the foramen ovale (Fig. 3). The position of the electrode is adjusted further according to the patient's response to electrical stimulation elicited through the electrode. Electric stimulation produces paroxysmal bouts of pain in the domain of each ipsilateral sensory rootlet. When the electrode is placed in contact with the motor root, stimulation produces masseter contraction. Postoperative motor dysfunction is thus eliminated. After the

correct position of the electrode is finally determined, the sensory root is destroyed with a radiofrequency current.

Sweet and Wepsic (1974) obtained relief of trigeminal neuralgia in 91% out of 217 patients, with a recurrence rate of 22% in 125 patients over the next 2.5–6 years. Based on results from 400 patients, Tew, van Loveren and Keller (1982) report that 61% obtained excellent relief and 13% good relief, while 5% have undesirable side effects, such as troublesome dysaesthesia in the face, and 1% have no relief. Pain recurred in 20% of the patients during a follow-up period which averaged 6 years.

The most serious complication is production of an anaesthetic cornea, which sometimes results in corneal scarring. Dysaesthesia in the analgesic region, masseter weakness and extraocular cranial nerve palsies are also reported (Tew *et al.*, 1982).

Glossopharyngeal rhizotomy

This nerve can be approached at the posterior foramen lacerum through percutaneous puncture under physiological control. Radiofrequency coagulation with a very selective morbidity (sensory deficit in the ninth nerve) is achieved. Broggi and Siegfried (1979) report long-lasting relief in two cases with cancer pain.

Combined multiple rhizotomies (CMR)

CMR of the fifth and ninth cranial nerves and, if necessary, of the upper cervical ones, have also been proposed (Pagni, 1979b).

FIG. 2. Three landmarks in percutaneous trigeminal rhizotomy: a point 3 cm anterior from the external auditory meatus, a point beneath the medial aspect of the pupil and a point 2.5 cm lateral to the oral commissure. The first two points indicate the site of the foramen ovale and the third is the point at which the needle penetrates the skin (Tew and Keller, 1977).

FIG. 3. Roentgenogram in axial view, showing a needle approaching the foramen ovale.

Thalamotomy

Although it has been disputed, it is now generally agreed that the centre-median, parafascicular, and intralaminar complexes are the best target nuclei. Their destruction results in pain relief without sensory loss and risk of central pain (Mark, Ervin and Hackett, 1960; Mark, Ervin and Yakovlev, 1963). Since the medial thalamic nuclei receive pain fibres through the reticular formation, effective and long-lasting pain relief may necessitate a bilateral approach (Roth and Mark, 1973). Pulvinar is also included among the targets despite the lack of significant physiological and anatomical evidence of its role in central nociception (Siegfried, 1980). Ohye (1983) finds that a lesion in the ventral intermediate-centre lateral complex, a common target in stereotaxic thalamotomy for tremor, often relieves central pain which is aggravated by movement. Tasker (1976b) reports, from clinical observation, a diagrammatic representation of the dual somatotopographic organization of the body in the somatosensory thalamus, i.e. in the posterior portion of the ventro-basal complex and posteriorly adjacent nuclei. The advantages of thalamotomy are that the procedure

carries minimal mortality and morbidity, and it controls pain over the entire opposite side of the body (Richardson, 1979), though pain often recurs several months later.

Thalamotomy is carried out through a stereotaxic surgical procedure under local anaesthesia (Figs. 4 and 5). Access to target nuclei is carried out precisely with the aid of both topographical measurement and physiological studies such as thalamic stimulation, and the recording of spontaneous electrical activity and evoked potentials in response to peripheral natural stimuli. A radiofrequency current is applied to produce a lesion of an appropriate size.

Postoperative complications include temporary drowsiness, motor weakness, hallucinations and other neurological problems. These can be minimized by conscientious intraoperative physiological studies.

Other ablative procedures

Commissural myelotomy consists of section of the pain fibres at the midline of the spinal cord where they cross to ascend in the contralateral anterior quadrant: a matter of historical interest rather than of practical value (Pagni, 1979a).

Medullary tractotomy is spinothalamic tractotomy at medullary level to relieve pain in the upper limb (Birkenfeld and Fisher, 1963; Pagni, 1979a).

Medullary trigeminal tractotomy, proposed by Sjöqvist (1938), has been refined with intraoperative physiological studies, radiofrequency coagulation and microsurgical technique (Bricolo, 1979). The operation is done through suboccipital craniectomy and high cervical laminectomy. A radiofrequency current is used to produce one or more lesions in the descending trigeminal tract. These lesions relieve pain in the face and head with preservation of touch sensation and corneal reflex (Bricolo, 1979).

Selective glossopharyngeal tractotomy in the medulla oblongata relieves glossopharyngeal neuralgia (Kunc, 1965).

Mesencephalotomy attacks the pain pathways in the midbrain by interrupting the spinothalamic and spinoreticulothalamic tracts. An electrode is stereotactically placed in the dorsal tegmentum of the midbrain. The rate of postoperative complication is relatively high (Nashold *et al.*, 1977).

Rostral mesencephalic reticulotomy, proposed by Amano *et al.* (1978), alleviates thalamic pain and cancer pain.

Posteromedial hypothalamotomy was carried out by Sano (1979). Unilateral and bilateral stereotaxic lesions are made in the posteromedial (ergotropic) hypothalamus which is the continuation of the periaqueductal gray. This procedure was more effective in the treatment of intractable cancer pain than

FIG. 4. A stereotaxic thalamotomy, being carried out on a patient with central pain. Leksell stereotaxic instrument is applied to the patient's head.

FIG. 5. Stereotaxic thalamotomy. Intraoperative roentgenogram, showing an electrode which is placed in the internal medullary lamina. The ventricles are delineated with contrast media.

pain related to other causes. This procedure was done initially in psychologically aggressive patients (Sano *et al.* 1970).

Ventral cingulumotomy is a procedure to relieve pain suffering: a multifaceted reaction to chronic pain (Foltz and White, 1962).

Deep brain stimulation

This contemporary therapeutic advance is based partly on the gate control theory of pain (Melzack and Wall, 1965) and partly on the discovery of the descending pain control system mediated by endogenous opioids. Electrical stimulation of peripheral nerves may close the spinal 'gate', thereby reducing spontaneous pain (Wall and Sweet, 1967). Stimulation of the dorsal column in the spinal cord also produces pain relief (Shealy, Mortimer and Hagfors, 1970; Nashold, 1976).

Many investigators have placed electrodes in several targets in the human CNS with a view to activating the descending pain control system, and so to produce both acute and chronic alterations of pain perception and awareness (Ray, 1981). Common targets in the brain are the primary sensory relay nuclei of the thalamus and their afferent and efferent pathways and the periaqueductal and periventricular gray substance.

An electrode is stereotactically placed in one of these targets. The patient's response to stimulation is essential to determine the final position of the electrode. Temporary stimulation may make the pain disappear for a varying length of time, though in some patients it may only reduce the pain or even increase it. After the effectiveness of stimulation is confirmed, the electrode is connected to a subcutaneous radio-receiver, activated transcutaneously by an external radiotransmitter. Patients control the transmitter to produce appropriate electrical stimuli to suppress the pain as necessary.

In Ray's report (1981), some 850 cases are documented, all treated by outstanding experts. There is considerable variation in the clinicians' personal experience of pain cases, targets used and results. Suppression of both somatic and dysaesthetic pain ranged from 50% to 75%. Gybels (1983) reports the results of a survey by the European Cooperative Study Group. Stimulation in the thalamic relay nuclei (VPL-VPM) and their afferent and efferent pathways resulted in successful suppression of dysaesthetic (deafferentation) pain in 106 patients out of 182, while it failed to relieve neurogenic and cancer pain. Stimulation in periaqueductal nuclei and periventricular gray substances resulted in the successful relief of dysaesthetic pain in 19 patients out of 76, neurogenic pain in 24 patients out of 31, and cancer pain in 17 patients out of 36. There is no obvious explanation of why stimulation successfully suppresses pain in some patients and fails to do so in others with very similar syndromes (Adams, 1976).

Electrical stimulation of the CNS is a promising procedure in relieving chronic pain because, theoretically, it is a non-destructive approach and, when

stimulation is no longer necessary, the electrode can be removed without any postoperative sequelae. However, much remains to be determined about patient selection, mechanism of action and instrumental refinement.

Pituitary ablation

Surgical hypophysectomy

Hypophysectomy, initially carried out via a craniotomy, has been performed through the transsphenoidal approach since it was popularized by Hardy (1971). It often results in objective tumour regression in disseminated breast and prostate carcinoma (Brodkey and Pearson, 1976; Tindall, Payne and Nixon, 1979; Takeda *et al.*, 1983a). It also relieves pain in a high percentage of cases, whether or not tumour regression is achieved (91% by Tindall *et al.*, 1979; 88% by Takeda *et al.*, 1983a). Pain relief following hypophysectomy in non-hormone dependent carcinomas is also reported (Tindall *et al.*, 1977). Hypophysectomy is not effective against non-cancer pain. Surgical hypophysectomy is a major surgical intervention and is not indicated in high-risk patients (Table 1). Corticosteroid replacement therapy is necessary postoperatively. Diabetes insipidus is seen in the majority of cases.

Pituitary neuroadenolysis

Moricca (1974) injected ethanol into the sella turcica to relieve cancer pain. This technique is called neuroadenolysis. Under neuroleptoanalgesia, a needle is inserted into the sella turcica through a nostril (Fig. 6). Pure ethanol, usually about 2 ml, is instilled into the sella turcica very slowly. The advantages of neuroadenolysis are its simplicity, repeatability if pain recurs, acceptance even by terminally ill patients, minimal post-treatment discomfort and short hospital stay (Table 1).

Pain relief is frequently obtained immediately after ethanol instillation, and lasts for weeks, months or sometimes over a year. Moricca (1974) reports that he achieved pain relief in almost all of the patients. However, Lipton *et al.* (1978) state that one-third of the patients obtains complete pain relief and the second one-third has partial relief, while the remaining one-third is unaffected. Takeda *et al.* (1983a) performed neuroadenolysis 136 times on 102 patients and obtained satisfactory relief of pain in 80% of the cases: 95% in 43 hormone-dependent carcinomas, and 69% in 59 non-hormone-dependent carcinomas.

Visual field defects are seen in a few patients when instilled ethanol damages the optic chiasm. Unilateral ophthalmoplegia is also temporarily but infrequently observed. The author and colleagues have

TABLE 1. Comparing neuroadenolysis with surgical hypophysectomy

	Neuroadenolysis	Surgical hypophysectomy
Technique	Simple	Major and traumatic
Time for performance	Short	Time-consuming
Suitability in high-risk patients	Suitable	Limited
Repeatability in pain recurrence	Possible	Impossible
Postoperative discomfort	Minimal	Considerable
Acceptance by terminal patients	Excellent	Poor
Pituitary dysfunction following procedure	Slight to marked	Always marked
Hospital stay	Short	Not short
Percentage pain relief:		
hormone-dependent tumours	95%*	88%*, 91%†
non-hormone-dependent tumours	69%*	67%‡
Objective tumour regression rate		
in hormone-dependent tumours	6.9%*	39%*, 36%†

*Takeda *et al.*, 1983a; †Tindall *et al.*, 1979; ‡Tindall *et al.*, 1977.

FIG. 6. Pituitary neuroadenolysis. A needle is placed in the sella turcica.

recently utilized instillation of aqueous phenol-metrazamide solution instead of ethanol to preclude ophthalmological complications. This solution acts as effectively as ethanol does, and is visible on a TV-monitor. The surgeons can stop injecting the solution if they observe its unwanted spread to the suprasellar cistern.

Some clues in elucidating the mechanism by which neuroadenolysis relieves cancer pain were recently reported (Takeda *et al.* 1983b, c). There are evidences that the alcohol instilled into the sella turcica acts as a destructive as well as a stimulative agent on the hypothalamopituitary axis (Lipton *et al.*,

1978; Lipton, 1979; Takeda *et al.* 1983b, c). When investigating hypothalamo-pituitary interactions, continuous elevation of adrenocorticotrophin, thyrotrophin-releasing hormone, arginine-vasopressin and beta-lipotropin is observed in the cerebrospinal fluid after neuroadenolysis. There is no significant increase of endorphins in the cerebrospinal fluid. Pain threshold determination indicates increased C-fibre threshold following neuroadenolysis. Observation indicates that the increase of peptides in the cerebrospinal fluid, which are mainly synthesized in the hypothalamopituitary axis, would exert a suppressive effect on the mediation and perception of

cancer pain through C-fibres and the CNS (Takeda *et al.* 1983b).

Other procedures of pituitary ablation

Isotope implantation into the pituitary gland (Johnson, West and Rutledge, 1958), radiofrequency thermal hypophysectomy (Zervas and Gordy, 1969) and cryohypophysectomy (Gye *et al.*, 1979) also alleviate pain in hormone-dependent carcinomas.

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