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Physiological Guidelines for the Localization of Lesions by Percutaneous Cordotomy

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With 1 Figure

Spinothalamic tractotomy, theorectically, is an ideal operation for the relief of intractable pain. But not until the introduction of the percutaneous technique by Mullan et al. (1963) could its benefits be extended to the majority of cancer patients; for most of them are too ill for open surgery. Moreover the precision of the new technique increases its effectiveness and at the same time minimizes complications.

After preliminary experience with 29 percutaneous cordotomies, we adopted the lateral C 1 C 2 approach and the protocol for electrode localization outlined by Taren et al. (1969) using biplanar X-rays, electrical impedance and spinal cord stimulation. 140 additional procedures have been done by these means, 90% for pain due to carcinoma, more than half lesions of cervix or rectum.

This account summarizes the results and then retrospectively examines the role of stimulation, the single most valuable tool, in the identification of the lateral spinothalamic fibres and the avoidance of the corticospinal tract.

Method

Percutaneous cordotomy is performed under fentanyl neuroleptanalgesia with local infiltration of 2% lidocaine hydrochloride and norepinephrine. Prior sedation is avoided. Image intensification in the lateral projection guides the introduction of a sharp, thin-walled, 18 lumbar puncture needle into the mid-anteroposterior plane of the appropriate C 1 C 2 interspace. The needle is supported on an upright post capable of fine three-dimensional manipulation. As soon as the subarachnoid space is entered, sufficient myelodil*, shaken up with a little normal saline solution and air, is injected to outline the dura, spinal cord, and, hopefully, dentate ligament. Previous horizontal alignment of the upper cervical spine facilitates the contrast study. The horizontal progression of the needle is followed with spot, rapid-process, antero-posterior, X-ray films; cord contact takes place when the needle tip lies about the centre of the image of the odontoid process. Upon completion of the myelography, the stilette of the L. P. needle is replaced by the cordotomy electrode, an electrolytically sharpened 0.4 mm stainless steel wire projecting 2 mm beyond the tip of its tubular teflon insulation. The insulation in turn projects 2 mm beyond the tip of the L. P. needle as shown in Fig. 1. Electrical impedance is continously monitored as the whole assembly is advanced under image intensification to just anterior to the dentate ligament. If the latter has not been outlined its position must be estimated. Impalement of the cord is usually palpable as the impedance rises, at first slowly, and then rapidly, from the 400 w characteristic of CSF to the 1200–1400 w of cord. The collar effect of the teflon tubing arrests the progress of the electrode so that its tip always comes to lie suspended 2 mm deep to the pia. Care is taken to avoid further penetration, for effective destruction of any part of the spinothalamic tract can be achieved at this depth and elimination of one dimension of electrode movement simplifies localization. Trains of 3 msec negative rectangular waves, first at 2 then at 100 Hz are used for stimulation while voltage is gradually increased to threshold or to about 4 volts**. Motor effects are observed while the patient is questioned about any sensory experience. Both motor and sensory effects are nearly always seen. Radiofrequency lesions are made at 30 mA for 30 seconds while the patient's ipsilateral motor power is monitored. Local neck pain and discomfort in the contralateral half of the body which may accompany lesion-making are best anticipated with additional injections of fentanyl. The patient is examined to ensure that analgesia to superficial and deep pain and to heat has been produced in the desired dermatomes and the lesion is increased, usually after repositioning the electrode, only if the initial effect is inadequate. It is seldom possible to enlarge the lesion by raising the current above 30 mA. Impedance, stimulation, and lesion-making are provided by a commercially available instrument***. If bilateral pain requires repetition of the procedure on the second side, this is done after a week's interval exactly as before,

* Glaxo-Allenbury brand of iophendylate.

** With our equipment 1 volt results in approximately 1 mA current flow.

*** The Owl Cordotomy System, 4634 Yonge Street, Willowdale, Ontario, Canada.

except that the patient is carefully monitored for 3–5 days post-operatively for evidence of inadequate ventilation. A rare complication, we feel that its risk after bilateral procedures is more than compensated for by the unique degree of precision afforded by the lateral C 1 C 2 approach.

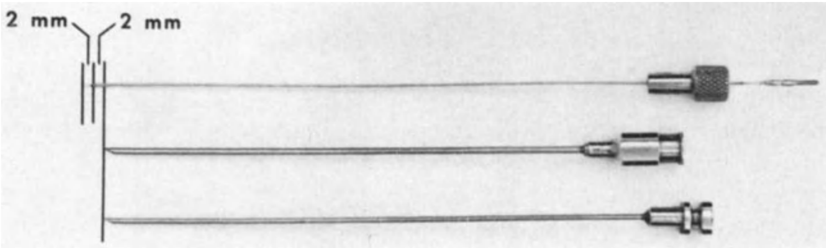

Fig. 1. The cordotomy electrode (above) showing the 2 mm projection of its sharpened tip beyond its tubular insulation which in turn projects 2 mm beyond the tip of the L.P. needle when the electrode is inserted into the latter in place of the stilette

Results

A total of 78 consecutive procedures, 23 on the second side of the body, was attempted up until January 1, 1972 using the above method. The spinothalamic tract was identified at operation in 96%, two of the three failures occurring in confused unco-operative patients. At the time of discharge 93% of operations had resulted in the relief of the pain for which they had been performed, and at latest follow-up, 84% were still successful. Though occasionally pain relief was achieved with lesser degrees of sensory loss, it was most certain when sufficient analgesia had been produced in the painful dermatomes so that skin perforation with a hat pin and maximal manual compression of achilles tendon, a digit, or of subcutaneous tissue was not painful and radiant heat could not be identified until sufficient to cause discomfort in normal skin. Pain persistance was associated with less than this degree of analgesia in 80% of cases. Adequate analgesia was readily achieved from C6 dermatome distally, with less certainty in C5, and only occasionally in C4. There was a slightly greater incidence of failure in lumbosacral than in cervicothoracic dermatomes.

Complications were few even though 20% of the operations were performed on bedridden patients, and most were able to return home post-operatively. There was one death arising from reduced ventilation, one case of reversible hypoventilation, one of reversible acute hydrocephalus presumably due to haematoma of the cisterna magna. Four per cent of procedures resulted in loss of bladder control, all but 1 after lesions on the second side. The risk was greatest when there were pre-existing disturbances of micturition. Transient paresis was seen after 6% of operations but not a single case of persistent significant weakness. Post-cordotomy dysaesthesia occurred after 10% and was a significant disability after 3%; 21% resulted in Horner's syndrome.

Stimulation: During the first consecutive 100 cases, the cord was stimulated at 365 sites, and a lesion was made at 162. An attempt was made to localize all sites as anterior to, posterior to, or within the lateral spinothalamic tract on the basis of analgesia produced if a lesion had been made at that site, or by reference to another site at which a lesion had produced analgesia. 146 sites with lesions and 127 without could be so characterized.

Motor effects were studied first, 95% being ipsilateral. At 2 Hz the threshold required to produce a motor response was lower (less than 1 mA in half) for points anterior to spinothalamic tract than for those within or posterior to tract. The pattern of motor response was also helpful. Within or anterior to tract, 75% of motor responses with 2 Hz stimulation were confined to cervical muscles, especially trapezius, the rest involving usually in addition, hand or upper limb. Virtually none involved trunk or lower limb. At posterior sites however, 1/3 of the responses involved trunk or lower extremity. Surprisingly, when the stimulus frequency was increased to 100 Hz, motor responses (tetanization) were uncommon and precluded a satisfactory position when they did occur. Tetanization was seen at 24% of sites anterior to tract where neck muscles were involved, and 28% of sites posterior to tract when limbs or trunk were involved.

We concluded then that neck muscle contractions can occur above 1 mA with 2 Hz stimulation without tetanization with 100 Hz when the electrode lies in spinothalamic tract and must be due to stimulation of ventral horn or root by volume conduction. If the threshold is lower and/or tetanization of neck muscles occurs, the electrode lies anterior to tract where ventral horn or root are stimulated directly. Contractions of muscles in trunk or lower extremity with 2 Hz stimulation, usually accompanied by tetanization with 100 Hz stimulation, are seen when the electrode lies posteriorly and corticospinal tract is stimulated directly.

There is no obvious explanation for the contractions seen in the upper extremity with 2 Hz stimulation when the electrode lies in the spinothalamic tract. More distal musculature is never involved and no tetanization is seen. Since these contractions often occur in myotomes as remote as those of the thenar muscles, stimulation of ventral horn or roots seem unlikely.

Whenever a lesion did produce paresis the latter was virtually restricted to the lower extremity and any associated analgesia occurred distally in the body. These observations are in keeping with the teaching that the most caudal fibres of the corticospinal and spinothalamic tracts abut at the level of the dentate ligament.

Sensory effects were examined next. Although sensory effects were produced by 2 Hz stimulation at 31% of sites within the spinothalamic tract, it was usually necessary to increase the rate of stimulation before a sensory experience was reported. We have arbitrarily used 100 Hz. Sensory threshold with 100 Hz stimulation was independent of the site stimulated, being less than 3 mA at 94% of them and usually less than 1 mA. Absence of a sensory response up to 4 mA as found at 5% of sites, precluded suitable positioning.

Strictly *ipsilateral* sensory responses were seen in sites posterior to spinothalamic tract, suggesting subthreshold stimulation of the corticospinal tract, an effect repeatedly observed with stimulation of the internal capsule during stereotactic surgery. Similar ipsilateral responses were also seen at anterior sites where they are more difficult to explain. Ipsilateral responses also occurred at 12% of sites within the spinothalamic tract but then always in association with more prominent contralateral responses. These could well be due to stimulation of ipsilateral spinothalamic fibres. Such a conclusion would be in keeping with identification of ipsilateral fibres in the spinothalamic tract in the midbrain and in the more posterior of the two somatotopographic representations of the body demonstrated in the human somatosensory thalamus[3, 4, 5, 6]. Stimulation of dorsal columns must be a rare occurrence but could account for some ipsilateral responses at posterior sites.

Once a contralateral sensory response had been obtained, careful questioning of the patient revealed that at 84% of sites in the spinothalamic tract, the experience was a sense of tingling associated with warmth or burning occasionally cold and pain. Usually only tingling, vibration, or mild electric shock were felt with stimulation elsewhere. Again, these observations parallel those made during stereotactic surgery in the midbrain and thalamus where stimulation of medial lemniscus and most of the somatosensory thalamus are reported as paraesthesia, and burning or temperature effects are restricted to spinothalamic tract and some thalamic points.

The location of the contralateral sensory effect was instructive. In half the sites anterior to tract, it was confined to the neck, but at only 2% of sites within the spinothalamic tract, and infrequently more posteriorly. Thus such a response indicates that the electrode lies too anteriorly. The physiological explanation for it is unclear, as it is for the bizarre sensory experiences often referred to the midline of the body seen in this same region.

Contralateral sensory responses located more distally in the body virtually always occurred at sites within the spinothalamic tract, though rarely, presumably because of technical problems, a lesion made at an apparently ideal site might fail to produce analgesia. Surprisingly, the distribution of such stimulation-induced sensory effects did not necessarily conform to that of the analgesia produced by a lesion at the same site. However, an existing "level" of analgesia could be "raised" by extending the lesion that produced it anteriorly, or "lowered" by extending it posteriorly. Moreover, all dermatomal levels from C5 to sacral were accessible for lesion-making with the electrode tip 2 mm deep to pia. These findings suggest that the spinothalamic tract extends in a somatotopographically organized band of uniform depth in the anterolateral quadrant of the cord.

When the sensory effect produced by stimulation was felt in the contralateral upper extremity, particularly the hand, a lesion at that site usually induced analgesia over most of the contralateral half of the body below C4. Half the sites where lesions produced such extensive analgesia were associated with stimulus-induced sensory responses in the upper limb compared with a quarter of the sites where lesions resulted in less complete analgesia. When the stimulus-induced contralateral sensory effect occurred distal to upper extremity, the lesion made at the same site was much more likely to induce analgesia more distally in the body, and most instances of leg paresis were associated with such sensory responses. From these observations we can conclude that direct stimulation of the spinothalamic tract usually gives rise to the contralateral experience of tingling and warmth or burning, the location of which is not necessarily the same as that of the analgesia produced by a lesion at the same site. Nevertheless, there is obvious anteroposterior somatotopy in the tract, most of which is occupied by fibres from the hand. Fibres from neck, trunk and lower limb occupy thin bands anterior or posterior as the case may be, to these central hand fibres a finding again reminiscent of the pattern seen in thalamus and midbrain. Thus, a 2–3 mm lesion centred in the hand fibres usually involves the more rostral and caudal fibres of the tract as well.

Summary

For practical purposes, with our equipment and technique, ideal location of the electrode in the central spinothalamic tract can be anticipated if the following observations are made with stimulation:

AT 2 HZ.

1. Contraction of ipsilateral neck muscles.
2. Especially trapezius.

3. At thresholds between 2–3 mA.
4. Simultaneous contralateral sensory experience is favourable.

At 100 HZ.

1. No tetanization.
2. A contralateral sensory experience.
3. Extending distal to neck.
4. Particularly in the hand.
5. At a threshold below 1 mA.
6. Described as tingling and warmth or burning.

Lesion-making should be avoided if:

1. Tetanization occurs at 100 Hz.
2. 2 Hz stimulation causes contractions in trunk or lower extremity.
3. In the absence of contralateral sensory effects below the neck at 100 Hz.
4. With extensive ipsilateral sensory effects.

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