Five-year follow-up of a cordotomy
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In 1963, Mullan et al (1) introduced percutaneous cervical cordotomy (PCC) for chronic, therapy-resistant pain. It was widely used for chronic pain at first, and was later adapted for cancer pain only. During PCC, sensory transmission through the lateral spinothalamic tract is interrupted at the C1-C2 level (Figure 1), which disrupts pain fibres from below the C4 level on the contralateral side.

Immediate pain relief (being pain free without the need for additional analgesics) is achieved in 64% to 90% of treated patients (2-4). However, this rate declines to 40% after two years (2). In part, this is due to the development of deafferentation pain. This pain syndrome, which is difficult to treat, arises three months or later after the procedure (5). Based on these data, PCC is advocated for patients with a life expectancy of less than six months (5).

Other complications of PCC are due to unwanted lesioning of structures adjacent to the lateral spinothalamic tract. Reported complications include ataxia, paresis and sympathetic dysfunction (hypotension, Horner’s syndrome and bladder dysfunction) (5). Also, the sexual sensitivity in the analgesic area may be impaired or lost (6). Procedure-related mortality (1% to 6%) is mainly due to respiratory dysfunction (3,7). In recent studies (8) that used more accurate ablation techniques, no respiratory dysfunction occurred.

We quantified the long-term effects of a PCC in a patient who underwent the procedure five years previously. To assess the long-term effects of the PCC, an interview, physical examination, and neurophysiological and cardiovascular function tests were performed.

CASE REPORT

In 2001, a 54-year-old man presented with abdominal pain on the left side. Other than a four-year history of diabetes mellitus, his medical history was unremarkable. An evaluation revealed intra-abdominal and retroperitoneal masses. Despite high doses of opioids, adequate pain relief was not achieved. Because his prognosis was considered to be poor due to metastatic cancer, a PCC was performed. The anterolateral spinothalamic tract was interrupted with four intermittent radiofrequency lesions made...
at 95°C over 15 s using a JK4 lesion generator (NeuroTherm, United Kingdom). Further diagnostic workup revealed a stage IIC seminoma. With chemotherapy that consisted of four cycles of carboplatin, vincristine and cyclophosphamide, complete remission was achieved.

**METHODS**

The function of the lateral spinothalamic tract and its adjacent tracts was evaluated by interviewing the patient, performing a physical and clinical neurological examination, and performing neurophysiological and autonomic function tests, as well as magnetic resonance imaging (MRI) of the spinal cord at the C1-C2 level.

**Neurophysiological tests**

To evaluate the efficacy of the PCC, the warm-cold discrimination threshold was assessed because temperature and pain sensation follow the same central pathway.

The temperature discrimination threshold was quantified using the MSA Thermotest (Somedic, Sweden). Testing was performed on fixed locations of the skin – the lateral side of the foot, palmar side of the hand and lateral side of the face. The temperature of the Peltier element was gradually increased or decreased. The patient pressed a button if he perceived a difference in temperature; the mean of five consecutive warm-cold differences was taken as the warm-cold discrimination threshold.

Somatic sensation (such as touch) is mediated by the anterior spinothalamic tract (Figure 1, tract 3b), which is anatomically adjacent to the pain and temperature pathway. The function of the anterior spinothalamic tract was studied using a Touch-Test kit (North Coast Medical Inc, USA). This test consists of 20 different Semmes-Weinstein monofilaments with different buckling forces, ranging from 0.008 g to 300 g. The touch perception threshold is defined as the lowest perceived buckling force.

Discriminative touch and vibration sense are mediated by the ipsilateral dorsal column (Figure 1, tracts 1a and 1b). Vibration perception was quantified on the second digit of both hands and on the lateral malleolus of both feet, using a Vibrameter (Somedic, Sweden). The vibration amplitude of the probe was steadily increased until the subject perceived the vibration (the vibration perception threshold). Also, the discriminative touch was tested, determining the two-point discrimination threshold.

Because diabetic and chemotherapy-induced neuropathy are symmetrical, all of these tests were performed on both sides of the patient to discriminate between the effects of the PCC and other possible causes of neuropathy.

**Cardiovascular autonomic function tests**

The reticulospinal fibres (Figure 1, tract 6b), which transmit sympathetic outflow, are located near the spinothalamic tract (11). Cardiovascular autonomic function was assessed during deep metronomic breathing, the Valsalva manoeuvre, standing up and the cold pressor test (12).

**MRI scanning**

To visualize the anatomical location of the lesion, MRI scanning was planned.

Patient history

The PCC induced immediate, complete analgesia and numbness from segment C4 to S5 on the left side. Although the
somatic sensory function improved during the first 12 months after PCC according to the patient, there was no full recovery. Warm-cold and pain sensation remained absent, which made the patient unaware of small injuries in the affected area. Wound healing was unremarkable. He was able to perform his daily activities in spite of this sensory dysfunction.

Two weeks after the PCC, tingling sensations in the left arm and leg developed. Although still continuously present (Figure 2), this sensation decreased over time with respect to intensity and the area affected.

Sexual sensation was absent, resulting in diminished sexual pleasure. Erection was obtained with the use of sildenafil. No alteration in bladder function occurred.

Physical examination
On physical examination, an obese man (138 kg, 186 cm) was seen with a blood pressure of 190/90 mmHg and a regular pulse rate at 80 beats/min. No Horner’s syndrome was observed. A full clinical and neurological examination was unremarkable, apart from nearly absent pinprick perception in the left C4 to S5 segments. Also, touch and vibration sensations were slightly diminished in this area. Strength and tone of the arm and leg musculature were normal. No atrophy was observed. Furthermore, coordination and reflexes were normal.

Neurophysiological examination (Table 1 and Figure 2)
The thresholds for temperature and touch perception were elevated in the left C4 to S5 segments. The vibration threshold was elevated in the lower extremities, with higher thresholds in the left side. The two-point perception threshold was normal, apart from a slight elevation of the threshold in the left hand.

Cardiovascular autonomic function test (Table 2)
All cardiovascular autonomic function test results were normal.

MRI scanning
Due to the patient’s claustrophobia, it was impossible to obtain adequate imaging of the spinal cord at the C1-C2 level.

DISCUSSION
Five years after PCC on the right side, sensory disturbances without motor or autonomic dysfunction were found in the left side of the body. Pain and temperature sensations were most affected, but touch and vibration senses were also abnormal.

The long-term effects of the PCC can all be explained by damage to pathways in the spinal cord. According to our investigation, the assumed PCC lesion at the C1-C2 spinal cord level is depicted in Figure 1. Unfortunately, we were unable to prove this assumption with MRI.

The diminished touch perception on the left side of the body suggests involvement of the anterior spinothalamic tract in the lesion. The nearby anterior spinocerebellar (mediating proprioception), reticulospinal (mediating autonomic outflow) and cerebropinal (mediating voluntary movement) tracts seem unaffected in the present patient because there were no signs of ataxia, disturbed coordination, or autonomic or motor dysfunction.

### Table 1

| Neurophysiological tests | Right | Left | Normal ± SD |
|--------------------------|-------|------|-------------|
| Warm-cold discrimination threshold (ºC)* | Face 1.0 | 1.4 | 0.9±0.8 |
| Thenar 7.0 | 20.7 | 1.9±1.1 |
| Lateral malleolus 7.7 | 24.5 | 4.2±3.2 |
| Vibration perception threshold (µm)† | Hand 3.4 | 2.5 | 2.6±1.1 |
| Foot 10.0 | 24.3 | 5.2±2.1 |
| Stationary two-point discrimination threshold (mm)‡ | Arm 12 | 12 | 42.3±4.4 |
| Palm 5 | 9 | 7.5±1.3 |
| Trunk 12 | 10 | 34.3±4.4 |
| Leg 25 | 25 | 27.1±3.5 |
| Foot 12 | 12 | 22.8±1.5 |

*The temperature of a Peltier element was gradually increased or decreased. The patient pressed a button if he perceived a difference in temperature. The mean of five consecutive warm-cold differences was taken as the warm-cold discrimination threshold. Normal values were derived from Meh and Denislic (19); †The stimulating probe, a 13 mm diameter plastic cylinder, vibrated at a constant frequency of 120 Hz and induced sinusoidal displacement of the tested tissue. The application pressure was kept constant at the stimulator’s weight of 650 g. The vibration amplitude of the probe was steadily increased until the patient perceived the vibration (the vibration perception threshold). Normal values were derived from Yea-Huey et al (20); ‡Assessed by using a Disk-Criminator (AliMed, USA). Normal values were derived from Davey et al (21).
Also, the asymmetry in the vibration perception threshold can be explained by the PCC lesion. Fibres that mediate vibration sense bifurcate when they enter the spinal cord. One branch enters the dorsal column; the other terminates at second-order neurons in the dorsal horn. Both branches remain ipsilateral. However, at the C1-C2 level, the second-order neurons (originating from the dorsal horn) terminate at neurons in the lateral cervical nucleus. Postsynaptic neurons from this nucleus cross the midline and ascend to enter the medulla (13). At this level, the PCC lesion may have disrupted the vibration sense pathway.

The autonomic function test results were all normal. The increase in blood pressure during the cold pressor test was equal on both sides, although only the right pain- and temperature-transmitting spinothalamic tract was disrupted during the PCC. This increase in blood pressure is therefore not likely to be centrally induced. It may be a spinal reflex (14) or non-neurogenic vasoconstriction in response to local cooling of the skin (15).

The tingling sensations experienced by the patient may have been an expression of lesions on the second-order neurons of the nociceptive pathway (16).

The patient experienced sexual dysfunction after the PCC. Although absence of sensation in the penis is a known side effect of PCC (6), erectile dysfunction is not. This finding was more likely to have resulted from diabetic neuropathy in our patient.

These long-term effects are comparable with a description in the literature of sensory function evaluated shortly after a PCC procedure (17). Only some studies (2,9,10) describe long-term effects of PCC.

One study comprised 789 patients (2). The data were collected by means of mailed questionnaires and patient self-examination. One year after the procedure, 25% of the patients were available for follow-up; the number of patients decreased rapidly toward the eighth year of follow-up. Among these patients, permanent ataxia was found in 3%, sexual dysfunction in 4% and dysesthesia in 16%.

In other studies addressing the long-term effects of PCC, patient survival is usually short. However, in a retrospective study (9), three of 273 patients survived for five, six and eight years after the PCC, without pain or long-term complications. In a third study (10), one patient lived 3.7 years after the procedure. This patient experienced so-called mirror pain (new postcordotomy pain, experienced in the mirror-image area contralateral to the original pain). None of these studies reported quantitative assessment of long-term effects of a PCC.

**CONCLUSION**

In the present patient, PCC produced a long-lasting decrease of nociception and temperature sensation without major side effects.

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