

COLD-INDUCED VASOSPASM AFTER FINGER REPLANTATION; ABNORMAL SENSORY REGENERATION AND SENSITISATION OF COLD NOCICEPTORS

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Abstract. Cold-induced vasospasm which may present clinically as “white fingers”, after hand injuries has been reported to be as high as 100% after replanted digital amputations. The exact cause of this is obscure and no specific treatment is available. To try to shed light on the cause of post-traumatic cold-induced vasospasm we evaluated replanted digits in seven patients who had had replantations more than 10 years ago. Our results show that cold-induced vasospasm occurred in six out of seven patients. Cold nociceptors were sensitised in patients who had abnormal two point discrimination, all of whom responded to cooling by vasospasm. One patient with normal circulation did not recover cold nociception during cooling. This indicates that secondary Raynaud's syndrome after injuries to the hand may be related to sensitisation of cold nociceptors. Even simple nerve injuries may lead to secondary Raynaud's syndrome.

Key words: digital replantation, cold-induced vasospasm, temperature thresholds, two point discrimination.

The post-traumatic “cold intolerance syndrome” or “secondary Raynaud's syndrome” is common after major hand injuries, and may lead to functional restrictions during cold periods of the year (17). Cold-induced vasospasm in replanted digits is one of the major problems in otherwise well-rehabilitated hands. The incidence of secondary Raynaud's syndrome after hand injuries has been reported to be as high as 100% (1, 4, 5, 11, 12, 19). The reason for this is obscure and there is no specific treatment so there is a high incidence of the disability. Suppression of myelinated fibre input can cause sensitisation of C nociceptors and

cold allodynia (21), suggesting that impaired post-regenerative function of low threshold mechanoreceptors may have a role in the sensitisation of cold nociceptors and in the development of secondary Raynaud's syndrome after hand injuries. We therefore evaluated cold-induced effects on the circulation, recovered low threshold mechanoreceptor function, and the cold nociceptor thresholds, in replanted digits and control fingers, 10 years after replantation, to ensure sufficient time for sensory recovery.

PATIENTS AND METHODS

Seven patients who had had successful digital replantations more than 10 years ago were included in the study (Table I). All patients had both digital nerves sutured end to end. None of the patients had symptoms of causalgia or reflex sympathetic dystrophy according to Payne's definition (13).

Low threshold mechanoreceptor function (light pressure sensation that did not cause pain) was evaluated by measuring the two point discrimination in the replanted finger and the contralateral finger on the uninjured hand (7).

The temperature stimulus was applied with a Peltier thermode. The temperature was maintained to within 0.1°C of the desired value by measuring with a thermocouple at the skin-thermode interface. The thermode was centred over the finger pulp, and the control finger (the finger contralateral to the replanted digit) was tested first in all sequences. The temperature threshold was tested by a computerised change in the thermode temperature. Subjects were instructed to signal cold pain thresholds by using a switch, and the temperature of the thermode was then recorded electronically. The test was repeated three times for evaluation. Similar tests were then

Table I. Pain thresholds to cold and two point discrimination

| Case No | Finger/level amputated | Mechanism of injury | Age (years) | Vasospasm | Cold pain thresholds (°C) | |
|---------|------------------------|---------------------|-------------|-----------|---------------------------|----------|
| | | | | | Replants | Controls |
| 1 | Thumb/proximal phalanx | Avulsion | 30 | Yes | 20.3 | 3.6 |
| 2 | Thumb/MCP joint | Avulsion | 42 | Yes | 17.7 | 1.1 |
| 3 | Thumb/proximal phalanx | Avulsion | 54 | Yes | 18.1 | 12.9 |
| 4 | Thumb/proximal phalanx | Avulsion | 60 | Yes | 25.5 | 17.3 |
| 5 | Index/PIP joint | Cut | 18 | Yes | 18.7 | 5.9 |
| 6 | Index/PIP joint | Avulsion | 24 | No | < 0.0 | 17.4 |
| 7 | Index/proximal phalanx | Cut/crush | 20 | Yes | 22.7 | 17.5 |

carried out on the replanted digit. The patients rested for more than an hour before the test of the circulation.

The peripheral circulation was examined in the replanted finger by measuring the finger systolic pressure (FSP) before and after cooling. Before measurements the patient rested for 15 minutes at room temperature (20–22°C). Blood pressure was then measured with an occluding cuff placed around the base of the finger and a strain gauge around the distal part of the phalanx (9, 11). The finger was cooled with a double inlet plastic cuff (Medimatic, Denmark); systolic pressure was measured after five minutes of perfusion with water at 30°C, after arterial occlusion of the proximal phalanx, and after five minutes cooling with water at 10°C.

A reduction in the finger systolic pressure during cooling reflected an increase in the digital arterial tone (10). The reduction was calculated from the following formula: $100 \times (\text{FSP } 30^\circ\text{C} - \text{FSP } 10^\circ\text{C}) / \text{FSP } 30^\circ\text{C}$.

A reduction in the blood pressure by 20% or more during cooling was considered to indicate vasospasm (11).

The Wilcoxon paired rank sum test was used to assess the significance of differences, and a probability of less than 0.05 was accepted as significant (14).

RESULTS

Patients with finger systolic pressure that exceeded the 20% limit at 10°C are shown in Table I. This suggests that about six of the seven patients who had had finger amputations may have developed circulatory disturbances in the replanted finger, which become chronic. The cold pain thresholds are also shown in

Table I. All but one patient showed a vasospastic pattern (reduction of finger systolic pressure by 20% or more) at 10°C and recovered cold nociception (pain caused by cooling) above 0°C. The patients who recovered cold nociception had cold-induced pain at significantly higher temperatures in the replanted fingers compared with the control fingers ($p < 0.0001$).

Low threshold mechanoreceptor function was absent in the patient who had no cold nociception; the other patients developed an abnormal two point discrimination in the replanted finger compared with their control fingers (Table I).

DISCUSSION

I do not know how often chronic pain and allodynia develop after peripheral nerve injuries (22). Cold-induced vasospasm, however, is a common symptom after injuries to the hand and may be the main cause of discomfort in an otherwise well-rehabilitated hand (1). The physiological background to the "icy cold feeling which can progress to pain", triggered by the patient's exposure to low temperatures, is unknown (2).

Several studies have been carried out after digital replantation and all have focused on the arterial component (1, 3, 6, 8, 11). Despite these, I still do not know if the condition is an immediate consequence of the stenosis of the

Two point discrimination (mm)

| Replants | Controls |
|----------|----------|
| 16 | 6 |
| 8 | 6 |
| 12 | 4 |
| 10 | 6 |
| 6 | 5 |
| >20 | 6 |
| 14 | 5 |

artery at the anastomotic site, a pathological arterial reaction to cold, or caused by other factors.

The results of this study show that cold nociception is activated at higher temperatures after regeneration compared with those in the control fingers. I know of no previous studies that have evaluated the cold nociceptors thresholds after nerve injury and regeneration. All patients who recovered cold nociception had vasospasm in the replanted finger when cooled to 10°C. The patient who lacked cold nociception had unaltered circulation at 10°C and lack of two point discrimination. All the patients who recovered cold nociception, however, had some, but abnormal, two point discrimination.

These results suggest that absence of cold nociception provides some protection against cold-induced vasospasm. This confirms results from cold stress tests on replanted fingers which showed normal measurements before axonal regeneration (1), which indicates that secondary Raynaud's syndrome is related to nerve regeneration and functional recovery of cold nociception.

Other factors (such as post-traumatic reflex sympathetic dystrophy) could have influenced the outcome of functional recovery of cold nociception, as pointed out by Rizzi et al. (18). Indeed this may emphasise our results, though the subjects evaluated in this study showed no clinical signs of post-traumatic allodynia. However, the impaired function of myelinated

axons shown here on evaluation of the low threshold mechanoreceptor function (by measuring two point discrimination) may explain the sensitisation of cold pain receptors. Our findings are supported by the works of Wahren et al. (21), who found that reduced cold pain thresholds during nerve compression mainly affected large myelinated axons that were related to slow adapting type II mechanoreceptors (20). Functional studies after neurotomy and suture in rats showed better functional recovery of nociception than low threshold mechanoreceptor function (15, 16). These results strengthen the link between cold-induced C-fibre pain (pain mediated through c-fibres) and normal function of myelinated axons after nerve injury and regeneration.

I conclude that cold-induced vasospasm in replanted digits is caused by the nerve injury and abnormal axonal regeneration, and that the post-regenerated cold nociceptors become sensitised leading to cold allodynia. Where functional cold nociception returns this does not return to normal with time. This sensitisation may be related to regenerated but abnormal function of the low threshold mechanoreceptors. This may suggest why circulatory disturbances develop even after nerve injuries alone. Total absence of functional low threshold mechanoreceptors and cold nociception seems to provide protection against cold-induced vasospasm.

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