

Prevention of Cold Injuries: What can be Learned from Nerve Injury Patients?

J.B. Jaquet, M.D., Ph.D.¹, M. Brandsma², H.A.M. Daanen, Ph.D.²,
S.E.R. Hovius, M.D., Ph.D.¹

¹Department of Plastic and Reconstructive Surgery, Erasmus Medical Center Rotterdam,
Torenlaan 27, 3043 BP Rotterdam, The Netherlands

²TNO Defence, Security and Safety, Business Unit Human Factors,
Soesterberg, The Netherlands

jaquet@rdgg.nl / daanen@tm.tno.nl

ABSTRACT

Patients who acquired an upper extremity nerve injury often complain about cold intolerance, reduced sensitivity and decreased task performance. This study tried to quantify these complaints and look in more detail at the thermal reaction to local cold exposure of the affected limb. We found that 36% of 107 subjects could be classified as cold intolerant. Eight of the cold intolerant subjects immersed their hands in 15°C water for 5 minutes after which infrared pictures of their affected hands were taken. The cold strain was acceptable for the patients. The damaged regions could easily be identified, most clearly 5 minutes after the hands were removed from the water. We conclude that the infrared temperature profile of the damaged hand after cold water immersion may be a helpful tool to assess the nerve damage. Similar tests exist for assessing the severity of non-freezing cold injuries (NFCI). We suggest that comparison of the results between NFCI and nerve injury patients may yield interesting information about the nervous involvement in NFCI. The method may also be valuable to identify subjects that have a higher risk for cold injuries.

1.0 INTRODUCTION

Cold intolerance (= pain sensation in the hand on exposure to cold) is a frequent and invalidating finding both in nerve injury patients (Irwin et al., 1997; Lenoble et al., 1990) and in patients with non-freezing cold injuries (NFCI). The pathogenesis of cold intolerance is still essentially unclear. Cold intolerance is usually evaluated using the CISS (Cold Intolerance Severity Score) questionnaire in nerve injury patients (McCabe et al., 1991).

In this study we aim to quantify the cold intolerance and sensitivity decrease in nerve injury patients and make a link to NFCI-patients. For NFCI-patients tests were developed to assess the cold injury severity (Francis and Oakley, 1996). We used a similar test for nerve injury patients to evaluate the outcome.

2.0 MATERIALS AND METHODS

2.1 Subjects

A total of 107 upper extremity nerve injury patients participated in the study of which 88 patients performed the sensory recovery test. Eight subjects participated in a test using cold immersion of the hand.

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2.2 Measurements

The patients completed the CISS (Cold Intolerance Symptom Severity) questionnaire at different time intervals. Sensory recovery was assessed by Semmes Weinstein monofilaments (North Coast Medical Inc, Morgan Hill, CA). The monofilaments (2.83, 3.61, 4.31, 4.56 and 6.10) were used according to the procedure described by Bell-Krotoski et al. (1995). Ten zones in the hand were tested, 6 in the area of the median nerve and 4 in the area of the ulnar nerve. The scores were interpreted as suggested by Imai et al. (1989).

Based on the total score on the CISS questionnaire, eight patients were selected for investigation of thermoregulation in both hands (Posh et al., 2003). After 5 minutes immersion of both hands in a 15°C waterbath, infrared images were obtained at 0, 2, 5 and 10 minutes. Furthermore continuous temperature measurements during immersion and re-warming were performed. A FLIR ThermoCam SC2000 camera was used to measure the hands during re-warming.



Figure 1: The subjects immersed both hands up to the styloids in a thermostat-controlled waterbath at 15°C for 5 minutes.

3.0 RESULTS

3.1 CISS

Mean CISS score was 38.4 (SD 25.6). 36% of the patients reported sufficient symptoms to be classified as cold intolerance (CISS 36 or higher). Symptoms of cold intolerance do not decrease over the years. Ancova analysis, adjusted for age, gender and lesion of the artery, showed a very close relation between the level of sensory recovery and the level of cold intolerance ($p < 0.01$). No difference was found in CISS between patients with or without vascular injury ($p = 0.48$).

3.2 Sensitivity

Frequency distribution of quality of sensation (n=88), according the classification of Imai et al. (1989) is shown in table 1.

Table 1: Frequency distribution of quality of sensation test, according to the classification of Imai et al. (1989).

Quality of sensation	Filament	No. of patients
Normal	2.83	2 (2.3%)
Diminished light touch	3.61	20 (22.7%)
Diminished protective sensation	4.31	38 (43.2%)
Loss of protective sensation	4.56	24 (27.3%)
Anaesthetic	6.10	4 (4.5%)

3.3 Thermoregulation

Figure 2 shows the skin temperature of the affected hand during immersion in cold water of the little and index finger, averaged over the patients.

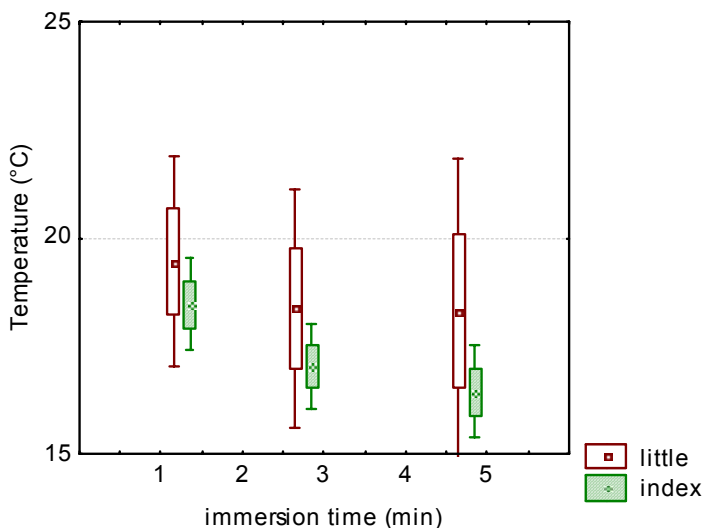


Figure 2a: Mean little and index finger skin temperature for four subjects with median nerve damage. The error bars indicate the standard deviation.

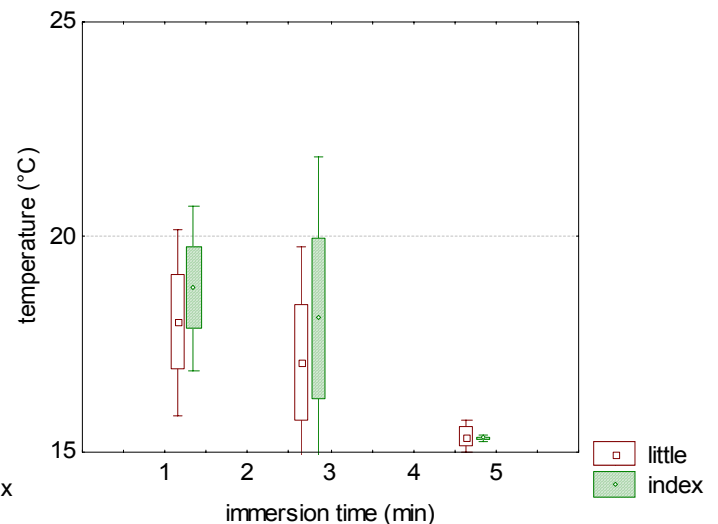


Figure 2b: Mean little and index finger skin temperature for four subjects with combined nerve damage. The error bars indicate the standard deviation.

The finger skin temperature dropped during immersion and there was no difference ($p=.58$) between index and little finger for both the groups (median nerve damage and combined damage).

Fig 3 shows a typical example of infrared pictures in a patient with median nerve damage.

Thermoregulation differed markedly between the affected and contralateral hand. The capacity to warm the hand appears to correlate with the reported degree of cold intolerance and degree of sensory recovery. ‘Hunting reaction’ does not appear in patients with cold intolerance.

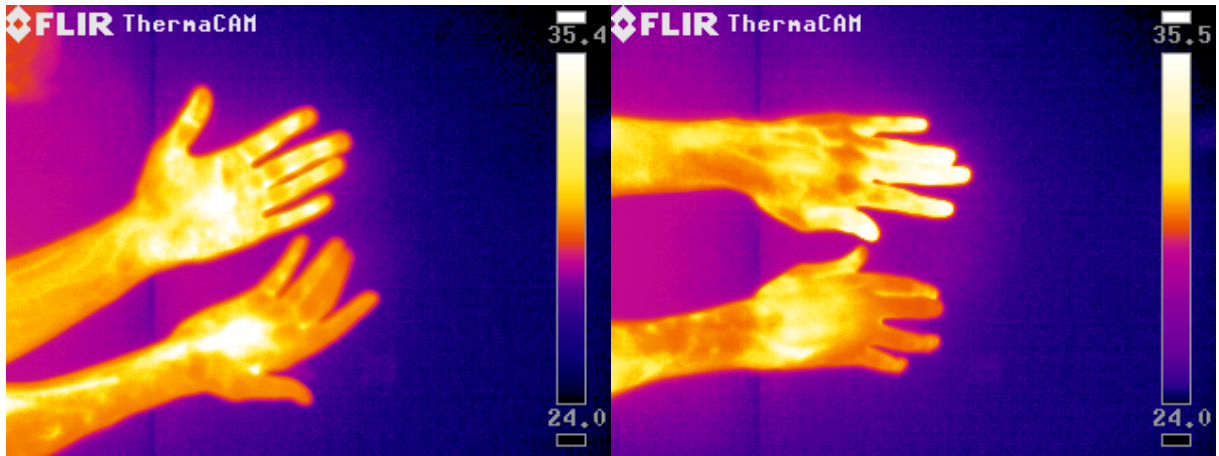


Fig. 3a: Infrared thermograms of a typical subject prior to cold water immersion (left: palmar view, right: dorsal view).

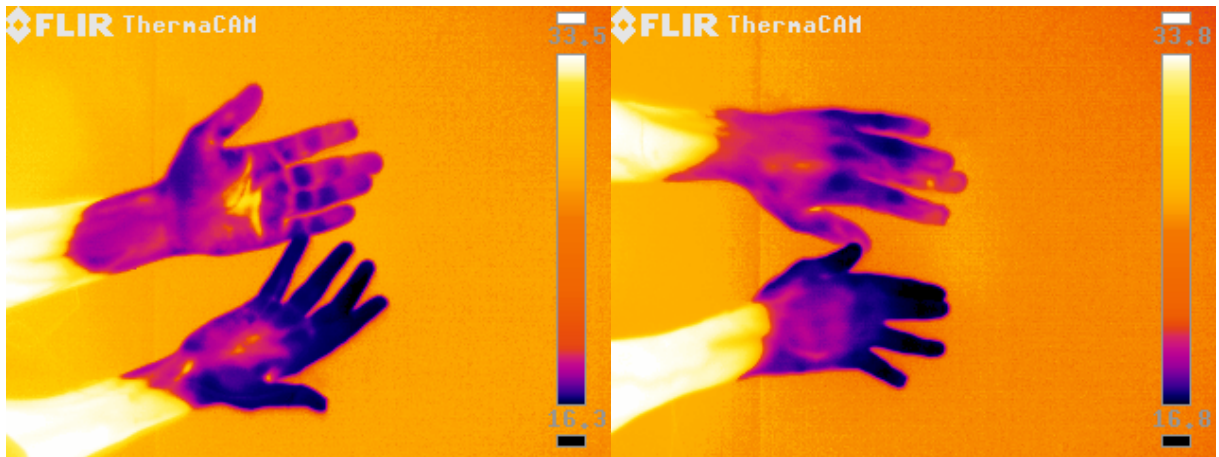


Fig. 3b: Infrared thermograms of a typical subject just after removal from cold water immersion (left: palmar view, right: dorsal view).

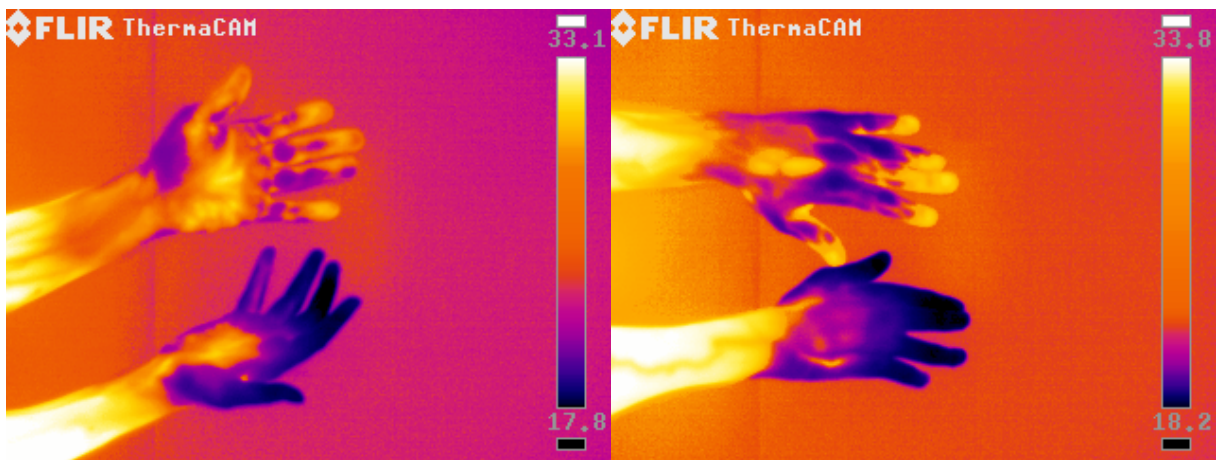


Fig. 3c: Infrared thermograms of a typical subject two minutes after removal from cold water immersion (left: palmar view, right: dorsal view).

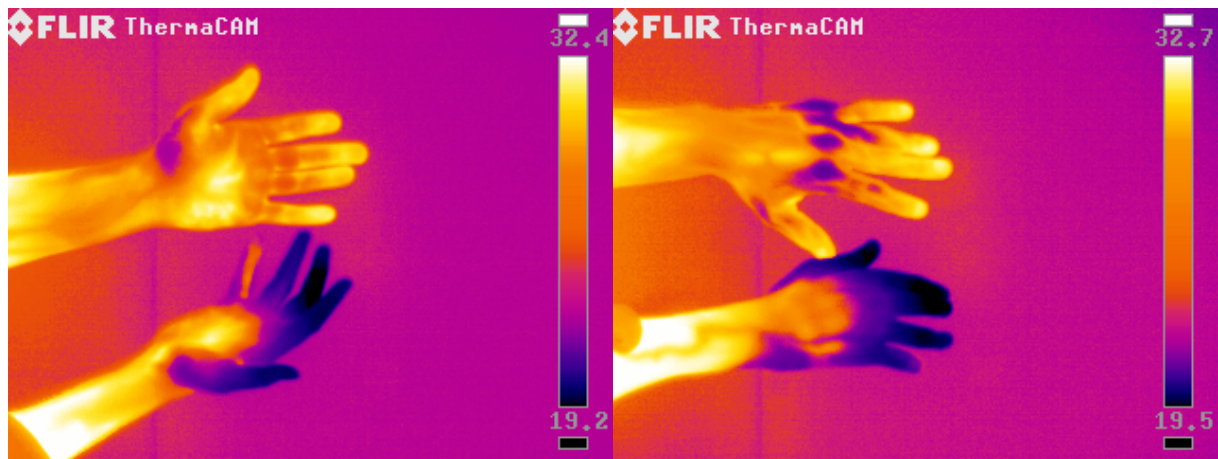


Fig. 3d: Infrared thermograms of a typical subject five minutes after removal from cold water immersion (left: palmar view, right: dorsal view).

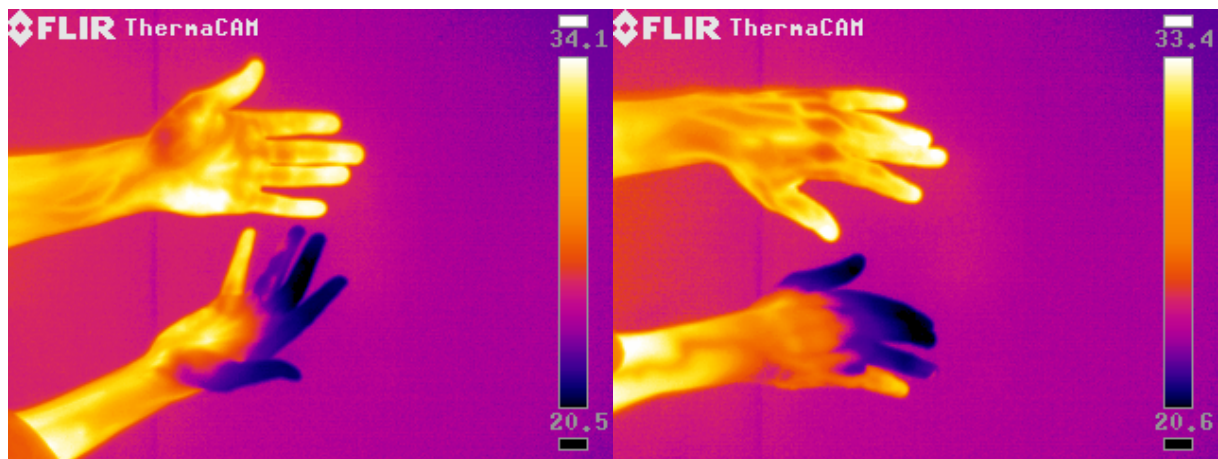


Fig. 3e: Infrared thermograms of a typical subject ten minutes after removal from cold water immersion (left: palmar view, right: dorsal view).

4.0 DISCUSSION

Francis and Oakley (1996) used a 2-minute period for immersion. In our study we used 5 minutes at the same water temperature of 15°C. The rationale behind this choice is that the cold stress is more severe, but still acceptable. Only one subject could not tolerate the immersion any more towards the end of the immersion time. Since the tissues are cooled longer and more profoundly, we expected larger differences in temperature increase during rewarming between pathologic and non-pathologic situations. A longer immersion time is not recommended since cold induced vasodilation might occur that may bias the results (Daanen, 2003). The sensitivity of the test may be improved by exercise prior to immersion (Eglin et al., 2005).

The infrared pictures during rewarming revealed unambiguously the areas of the skin that were innervated by the affected nerves (Fig. 3). The temperature profile during immersion is less conclusive (Fig. 2). Since it is more tedious to measure during immersion, we propose to focus on rewarming only.

We suggest that comparison of the results between NFCI and nerve injury patients may yield interesting information about nervous involvement in NFCI. The method may also be valuable for identifying

subjects who have a higher risk of cold injury. Perhaps further evaluation of the peripheral nerve is needed to better understand patients with cold injuries.

5.0 REFERENCES

- [1] Bell-Krotoski JA, Fess EE, Figarola JH, Hiltz D (1995). Threshold detection and Semmes-Weinstein monofilaments. *J Hand Ther* 8(2): 155-62.
- [2] Daanen, H.A.M. (2003). Finger cold-induced vasodilation: a review. *Eur.J.Appl.Physiol.* 89: 411-426.
- [3] Eglin C, Golden F, Tipton M. (2005). The effect of gentle exercise prior to a cold sensitivity test used to classify non-freezing cold injury. NATO Specialist meeting on prevention of cold injuries, NATO RTA, Paris.
- [4] Francis TJR, Oakley EHN (1996). Cold injury. In: Tooke JE, Lowe GDO (Eds). *A textbook of vascular medicine*. Chapter 23, p353-370. Arnold, London.
- [5] Imai H, Tajima T, Natsuma Y. (1989). Interpretation of cutaneous pressure threshold (Semmes-Weinstein monofilament measurement) following median nerve repair and sensory reeducation in the adult. *Microsurgery* 10(2):142-4.
- [6] Irwin M, Gilbert S, Terenghi G, Smith R, Green C. (1997). Cold intolerance following peripheral nerve injury. Natural history and factors predicting severity of symptoms. *J Hand Surg [Br]* 22(3):308-16.
- [7] Lenoble E, Dumontier C, Meriaux J, Mitz V, Sokolow C, Lemerle J. (1990). Cold sensitivity after median or ulnar nerve injury based on a series of 82 cases. *Ann Chir Main Memb Super* 9(1):9-14.
- [8] McCabe S, Mizgala C, Glickman L. The measurement of cold sensitivity of the hand. *Journal of Hand Surgery* 1991;16A:1037-1040.
- [9] Posch N, Ganghi A, Jaquet J, Daanen H, Hovius S. (2003). Diminished thermoregulation in nerve injury patients: A reason for cold intolerance? *Journal of Hand Surgery* 28B (Supplement):19.