ORIGINAL ARTICLE

Management Algorithm of Spontaneous Neuropathic Pain and/or Touch-evoked Neuropathic Pain illustrated by prospective observations in clinical practice of 66 chronic Neuropathic Pain Patients

To MD 
To patient 
To neuroscientist 
To therapist 

Claude Jacques Spicher (University scientific collaborator, OT, Swiss certified HT) [2, 3]
Patricia Fehlmann (MD) [4]
Christian Maihöfner (MD, PhD) [5]
Pierre Sprumont (MD, PhD) [6]
Eva Létourneau (BSc OT, M. Read., Certified Somatosensory Therapist of Pain CSTP®) [3]
Joseph-Omer Dyer (PhD, pht) [7]
Julie Masse (BSc OT, MSc) [8]
Marina López-Solà (PhD) [9]
Eric Maupas (MD, PhD) [10]
Jean-Marie Annoni (MD) [11]

[3]Somatosensory Rehabilitation Centre, Clinique Générale, Hans-Geiler St. 6, CH-1700 Fribourg, Switzerland
[4]Pain Unit, Clinique Générale, Hans-Geiler St. 6, CH-1700 Fribourg, Switzerland
[5]Department of Neurology; General Fürth Hospital, University of Erlangen-Nuremberg, Jakob-Henle-Str. 1, D-90766 Fürth, Germany
[6]Unit of Anatomy, Department of Medicine, Faculty of Sciences, University of Fribourg, Route Albert-Gockel 1, CH-1700 Fribourg, Switzerland
[7]Physiotherapy Program, Rehabilitation School, Faculty of Medicine, University of Montreal, H3C 3J7 Montreal (Qc), Canada
[8]Occupational Therapy Program, Rehabilitation School, Faculty of Medicine, University of Montreal, H3C 3J7 Montreal (Qc), Canada
[9]Department of Psychology and Neuroscience, University of Colorado, Muenzinger D158, Boulder, CO, 80309-0345, United States of America
[10]Rehabilitation Centre; 11, Rue Angely Cavaillé, F-81000 Albi, France
[11]Unit of Neurology, Department of Medicine, University of Fribourg, Chemin du Musée 5, CH-1700 Fribourg, Switzerland

[2] **Address for correspondence (proofs and reprint):**
Domain of Physiology and Program in Neurosciences, Department of Medicine, Faculty of Sciences, University of Fribourg, Chemin du Musée 5, CH-1700 Fribourg, Switzerland
claude.spicher@unifr.ch

ABSTRACT

Background Thoracic neuropathic pain may be related to an area of altered skin sensation over the territory of cutaneous thoracic branches. The somatosensory rehabilitation method (SRM), a non-pharmacological treatment, focuses on the detection, classification and treatment of this condition. The aim of this prospective observational case series of 66 thoracic neuropathic pain patients (tNPP) was to evaluate a management algorithm of two different types of neuropathic pain: spontaneous ongoing neuropathic pain (**type A**) and touch-evoked neuropathic pain (**type B**). **Material and methods** The authors precisely explain the assessment and treatment algorithm for findings of tactile hypoaesthesia versus static mechanical allodynia (SMA). 66 chronic tNPP referred in a single centre were assessed by two mapping techniques of the skin A) aesthesiography (in case of tactile hypoaesthesia) or B) allodynography (in case of SMA) and pre/post treatment evaluations with the McGill pain questionnaire (MPQ). In clinical practice, hypoaesthetic territories were treated by basic somatosensory rehabilitation. Allodynic territories were treated initially by distant vibratory counter-stimulation (DVCS), then by basic somatosensory rehabilitation once the allodynia disappeared. **Results** All tNPP presented somatosensory abnormality on at least one damaged cutaneous thoracic branch: 52 hypoaesthetic and 47 allodynic. At a mean of 76 days, 34 of these 47 were converted by DVCS into hypoaesthetic territory, which finally is amenable to treatment by basic somatosensory rehabilitation. 61 % of the tNPP treated with SRM had a pain reduction of at least 50% on the MPQ. **Conclusion** These observations illustrate a management algorithm for assessing and treating A) hypoaesthesia and B) SMA.

Keywords: Algorithm, Mechanical allodynia, Somatosensory rehabilitation method, Tactile hypoaesthesia, Thoracic neuropathic pain.

Table of abbreviations

DMA	Dynamic Mechanical Allodynia
DVCS	Distant Vibrotactile Counter-Stimulation
MPQ	McGill Pain Questionnaire
NPP	Neuropathic Pain Patient
PHN	Post-Herpetic Neuralgia
PNI	Peripheral Nerve Injury
PPT	Pressure Perception Threshold
SMA	Static Mechanical Allodynia
SRM	Somatosensory Rehabilitation Method
tNPP	thoracic Neuropathic Pain Patient

1. Introduction

Pain can be physiological or pathological (Woolf and Mannion, 1999). Physiological pain is a protective signal provided by the somaesthetic system. Neuropathic pain (NP) has been classified as spontaneous ongoing neuropathic pain and/or touch-evoked neuropathic pain (Ochoa and Yarnitsky, 1993; Hansson, 2003). The first described etiopathological mechanism of spontaneous NP pointed to aberrant activity in nociceptive C neurofibre (Wall et al., 1979; Scadding and Kolzenburg, 2013). If pain itself is at the centre of concern for both patient and physician, the somatosensory abnormalities that often occur in the painful area have been considered of secondary importance (Lindblom and Verrillo, 1979; Lindblom, 1994). The local sensitivity or tenderness (Nathan, 1960), which can grow in absolute pain at the slightest pressure was first described by Morton (1876). This symptom of hypersensitivity was defined by Merskey (1979) as allodynia: "Pain due to a stimulus which does not normally provoke pain" (Merskey and Bogduk, 1994; Loeser et al., 2011). Devor's group stated that tactile allodynia "is fundamentally paradoxical. Partial denervation of the skin ought to blunt sensation, not to amplify it" (Sukhotinsky et al., 2004 p. 135).

In peripheral nerve injury (PNI) with partial denervation, Aβ neurofibre lesions lead to tactile hypoaesthesia, of part of the largest territory of cutaneous distribution of its branch (Lanz von and Wachsmuth, 1935; Taylor et al., 2009; Spicher et al., 2010, 2013). Tactile hypoaesthesia affecting a cutaneous nerve can be expected to fall within the skin territory boundaries outlined in clinical anatomy studies (Carmichael, 2013), a finding recently corroborated in a prospective study of 1947 neuropathic pain patients (NPP) by our group (Spicher et al., 2013). The mapping of hypoaesthesia, named aesthesiography, can be reproduced by considering this hypoaesthesia principle (Létiévant, 1869; Tinel, 1916 [1917] ; Inbal et al., 1987; Spicher, 2013 [2006]).

Based on the hypothesis regarding which cutaneous branch is damaged, partial tactile hypoaesthesia in a specific territory can be mapped using aesthesiography. Another physiological consequence of Aβ neurofibre lesions is to induce hypersensitivity with underlying partial hypoaesthesia: a paradoxical painful-to-touch hypo-aesthesia (Spicher et al., 2008) named static mechanical allodynia (SMA) (Spicher, 2006; Spicher et al., 2008). The cutaneous territory affected by SMA can be mapped using allodynography. After treating SMA with a specific non-pharmacological treatment, only the underlying hypoaesthesia remains. On this basis, one can hypothesize that a management algorithm considering the time-course of two types of somatosensory altered skin (tactile hypoaesthesia and mechanical allodynia) would lessen symptoms in neuropathic pain patients (NPP).

The aim of this prospective observational case series of 66 thoracic neuropathic pain patients (tNPP) was to evaluate a management algorithm for treating two types of neuropathic pain: spontaneous ongoing neuropathic pain (**type A**) and/or touch-evoked neuropathic pain (**type B**). This algorithm of somaesthetic and/or neuropathic conditions consists of two phases: 1. Clinical anatomy diagnosis of somatosensory abnormalities mapped in at least one thoracic branch on each tNPP (**type A** aesthesiography or **type B** allodynography). 2. Successive non-pharmacological somatosensory treatments.

SOMATOSENSORY REHABILITATION of PAIN NETWORK

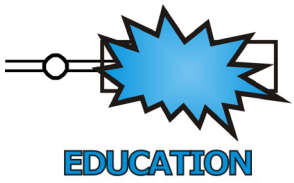
Brussels | Montpellier | Paris | Freiburg | Montreal | Bordeaux

www.neuropain.ch

6, Hans-Geiler Street

Departement of
Continuous education

CH - 1700 FREIBURG
info@neuropain.ch



The **100th** course for **somatosensory rehabilitation of neuropathic pain** - 8th to 11th of February 2016 - is a four day comprehensive theoretical and hands-on course for therapists, physicians and others, about a method to treat neuropathic pain patients (NPP). **www.neuropain.ch/education/calendar**

Somatosensory Rehabilitation of Pain (Spicher, 2006; Spicher et al., 2013; Spicher et al., 2015) includes: Assessment of cutaneous sense disorders and their painful complications (CRPS, mechanical allodynia, neuralgia i.e post carpal tunnel syndrome release) and also rehabilitation.

Problem

Cutaneous somatosensory disorders, including hypoaesthesia and/or mechanical allodynia are often significant contributors to chronic pain, interfering with activities.

The normalisation of the cutaneous sense has a positive impact on **neuropathic pain**. The shooting pain, the burning sensations decrease and hypersensitivity resolves, offering NPP a better quality of life.

Concepts

The concept of Aβ pain was proposed by Marshall Devor [*Exp Brain Res* 2009] many years after Tinel (1917) suggested that neuropathic pain is conducted partly through the Aβ fibers. The etiology of neuropathic pain hinges on this idea. It means that chronic neuropathic pain can arise from the alteration of the somatosensory system and not only from the alteration of the C fibers. Therefore, the painful area must be carefully assessed in order to determine the presence of Aβ fibers lesions (tactile hypoaesthesia and/or mechanical allodynia). Consequently, the normalisation of the cutaneous sense has a positive impact on neuropathic pain.

Overall Learning Aims

- To integrate precise techniques for identification and treatment of somatosensory changes
- To rehabilitate cutaneous somatosensory disorders on the basis of the somatosensory system neuroplasticity;
- To avert the outbreak of painful complications by rehabilitating the cutaneous sense;
- To build bridges between rehabilitation, medicine and the neurosciences.

2. Material and Methods

2.1 Subjects

A cohort of 71 chronic neuropathic pain patients (55 females and 16 males, mean age ± SD, 45 ± 13.63 years), with "intercostal" neuralgia [3] were consecutively included in this prospective observational case series between the 1st of July 2004 and the 19th of February 2009. They attended the Somatosensory Rehabilitation Centre (Fribourg, Switzerland) for testing and treatment of neuropathic pain according to the somatosensory rehabilitation method (SRM) as described below (Spicher, 2003, [2006]).

All seventy-one patients (Fig. 1) fulfilled the following inclusion criteria: (1) Presence of neuropathic pain symptoms and signs on the trunk: "intercostal neuralgia" (either a positive aesthesiography or a positive allodynography – see below for details); (2) McGill Pain Questionnaire (MPQ) score of at least 20 points; and- (3) Clinical pain symptoms for at least six months (Supplementary Table 1).

Five patients were excluded for the following reasons: four patients were unable to complete the MPQ and one patient was paraplegic (Fig. 1) – confounding diagnosis of paraplegia Th9 with static mechanical allodynia of anterior cutaneous branch of Th12 left. Considering that a stable medication - antiepileptic, antidepressant or opioid drugs - is reported by the majority of these patients (Spicher and Quintal, 2013) cannot be discontinued due to ethical reasons, this was not considered as an exclusion criterion. A small subgroup of four patients presented with post-herpetic neuralgia (PHN). The average pain duration reported on initial assessment was 4.5 years (range: 0.5 - 43.5 years). Numerous provisional diagnoses were made (Supplementary Table 1) including: status post traumatic (*n*=20), cancer sequelae (*n*=6), miscellaneous etiology (*n*=5), status post surgery (*n*=33) and PHN (*n*=4).

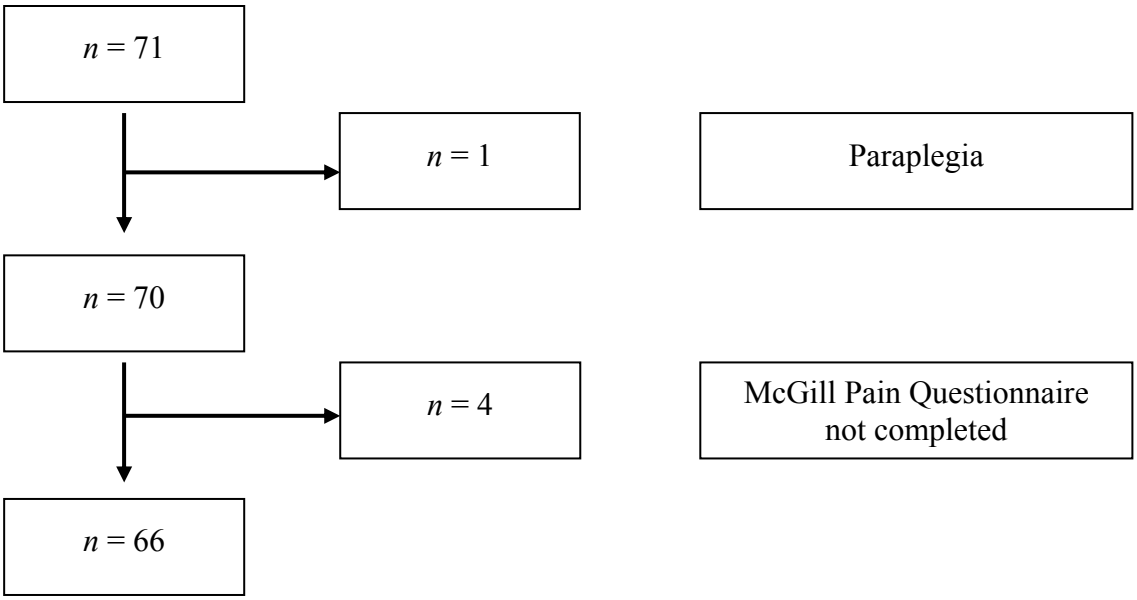


Fig. 1. Demographic diagram of the 71 thoracic neuropathic pain patients (tNPP). Inclusion criteria: (1) Presence of neuropathic pain at least on the trunk, (2) McGill Pain Questionnaire (MPQ) score of at least 20 points, (3) Clinical pain symptoms of at least six months. Exclusion criteria: unable to complete MPQ, confounding diagnosis of paraplegia.

[3] Clinical anatomy comment: the term of intercostal is unfortunately not appropriate for the subcostal neuralgia (Th 12), and for the intercostobrachial neuralgia (Th 2).

2.2 General procedure and design of the prospective observations

Patients were referred to the Somatosensory Rehabilitation Centre to assess and treat their chronic neuropathic pain condition. This case series is the interpretation of clinical observations collected in a prospective way on 71 tNPP extracted from a clinical database of observations on 980 NPP (trigeminal neuralgia, occipital neuralgia, brachial neuralgia, femoral neuralgia, pudendal neuralgia, etc.). Demographic, medical history and treatment data were prospectively recorded in clinical practice with a standardized protocol reflecting the daily practice of the Somatosensory Rehabilitation Centre of the Human Body. Referrals to somatosensory rehabilitation of pain were initiated by medical doctors (n=41), including pain specialists, physicians, general practitioners, neurologists, neurosurgeons, thoracic surgeons, general surgeons, and rheumatologists through a written prescription of occupational therapy. All patients received the standard care of the centre. Spicher (2003, [2006]) provides a detailed description of this non-pharmacological intervention: occupational therapy with SRM – evidence-based practice level 2b (see also Dellon, 2000; Spicher, 2003, [2006]; Spicher and Quintal, 2013; Spicher et al., 2008; Spicher, 2008; Quintal et al., 2013). All data were collected in a single centre, following a specific clinical protocol for each chronic pain patient. Each patient attended a weekly treatment session, and was seen alternately by two "SRM trained therapists" which were occupational therapists. All participants received the standardized program of assessment and intervention, including a structured daily home program to follow between visits. Each weekly somatosensory rehabilitation session lasted from 30 to 75 min (average: 45 min). To avoid any misunderstanding, this is *NOT* a study of experimental research.

2.3 Clinical assessment

If the patient's complaints are about neuropathic pain, then he/she has Aβ neurofibre lesions of a cutaneous branch (Spicher et al., 2013). This theoretical hypothesis supports the neuropathic symptoms anamnesis (from the Greek word "to remember" Ανάμνηση) evaluated by the SRM trained therapists and the search for hypoaesthetic territory on the skin with psychophysical tests. It is the first step in order to progress from pain complaints of NPP to a clear identification of the somatosensory abnormalities of the skin.

In order to identify which cutaneous branch is damaged, the SRM trained therapist relies on the clinical anatomy knowledge that the localization of burning pain sensation, or even solely heat sensation, corresponds to the hypoaesthetic territory. The somatosensory mapping is then performed, beginning with this target territory of tactile hypoaesthesia.

2.3.1 Rating of pain intensity and clinical anatomy diagnosis

During the evaluation (t_0), the SRM trained therapist used the original McGill Pain Questionnaire to qualify the phenomenon of pain and identify which cutaneous branch is involved. Therapists are trained to then decide whether to carry out an aesthesiography (**type A**) or an allodynography procedure (**type B**) (Fig. 2 & 3). Depending on the mother tongue of the patient either the original McGill Pain Questionnaire in English was used (Melzack, 1975),

or alternatively the *Questionnaire de la douleur St-Antoine* in French (Boureau et al., 1984), the *McGill Schmerz-Fragebogen* in German (Stein and Mendl, 1988) or the Italian version of the McGill Pain Questionnaire (Maiani and Sanavio, 1985).

Change in reported pain was assessed using the MPQ at baseline (initial evaluation), every 4 weeks and during the final treatment session. The presence of altered somatosensory function was searched in at least one thoracic branch for each patient, using the aesthesiography procedure (Fig. 2).

2.3.2 Aesthesiography

Aesthesiography (Fig. 2) is the first clinical examination sign of the SRM utilized to map the tactile hypoaesthetic territory (Spicher 2003 [2006]). The term "aesthesiography" (Létiévant, 1876 [1875]; Spicher and Kohut, 2001) is used because it refers to a mapping of the hypoaesthesia (Létiévant, 1869; Tinel, 1916 [1917] ; Inbal et al., 1987; Quintal et al., 2013). This examination took place at the beginning of each session, before treatment. Testing was always performed in the same environment. Testing room temperature was maintained at $20^{o} \pm 1^{o}$ C.

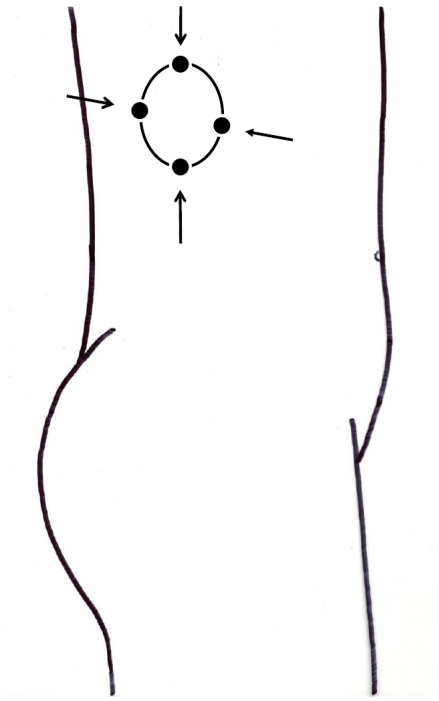


Fig. 2 Type A aesthesiography of the lateral cutaneous branch of the 8th right thoracic nerve; on the lateral side of the trunk with a Semmes-Weinstein 0.7 g aesthesiometer (mark 3.84). The aesthesiography outlines the hypoaesthetic territory: the portion of skin where aesthesiometer is not detected. Arrows show the axes along which the stimulus is applied. Points indicate where the application of the 0.7 g aesthesiometer is not detected.

The aesthesiography procedure cannot be administered in the presence of hypersensitivity to touch (allodynia symptom). Therefore, in such cases, allodynography was performed (Fig. 3).

2.3.3 Allodynography

Allodynography (Fig. 3) is the second clinical examination sign of the SRM which quantifies and maps SMA using a standardized procedure in the territory of the skin where the patient reports symptoms of tenderness, hypersensitivity to touch (Spicher 2003 [2006]; Spicher et al., 2008, pp. 80-81 and its Appendix A pp. 90-91). Mapping of the SMA territory facilitates visual inspection in diagrammatic form of the allodynic skin area. The assessment is conducted with a Semmes-Weinstein 15 g aesthesiometer (mark 5.18) in order to delineate the borders of the SMA territory. On the longitudinal axis of the damaged cutaneous branch, from proximal to distal, the first allodynic point is found by sequential application of stimuli in a standardized pattern to precisely identify the first allodynic point at the prescribed pain threshold (3/10 VAS rating) along this axis (Fig. 3). The procedure is repeated on the perpendicular axis. A polygon is traced by joining the border sites obtained to outline the hypersensitive territory (Spicher et al., 2008).

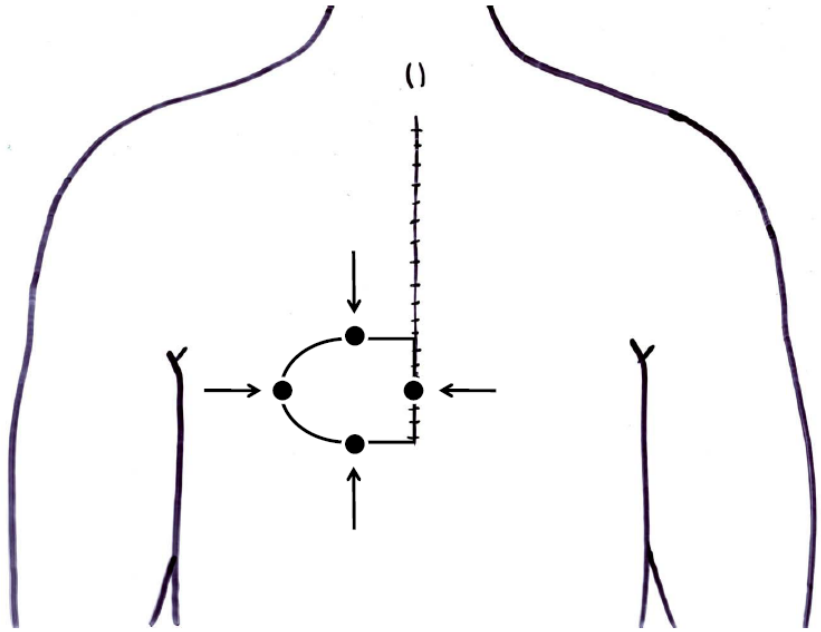


Fig. 3 Type B allodynography of the posterior branch of the 3rd left thoracic nerve tested on the posterior side of the trunk with a Semmes-Weinstein 15.0 g aesthesiometer (mark 5.18). The allodynography outlines the hypersensitive territory: where aesthesiometer is perceived as painful. Arrows indicate the axes along which the stimulus is applied. Points indicate where the application of 15.0 g aesthesiometer is perceived as a pain of 3 (on a VAS of 10 cm).

2.4 Algorithm for clinical reasoning

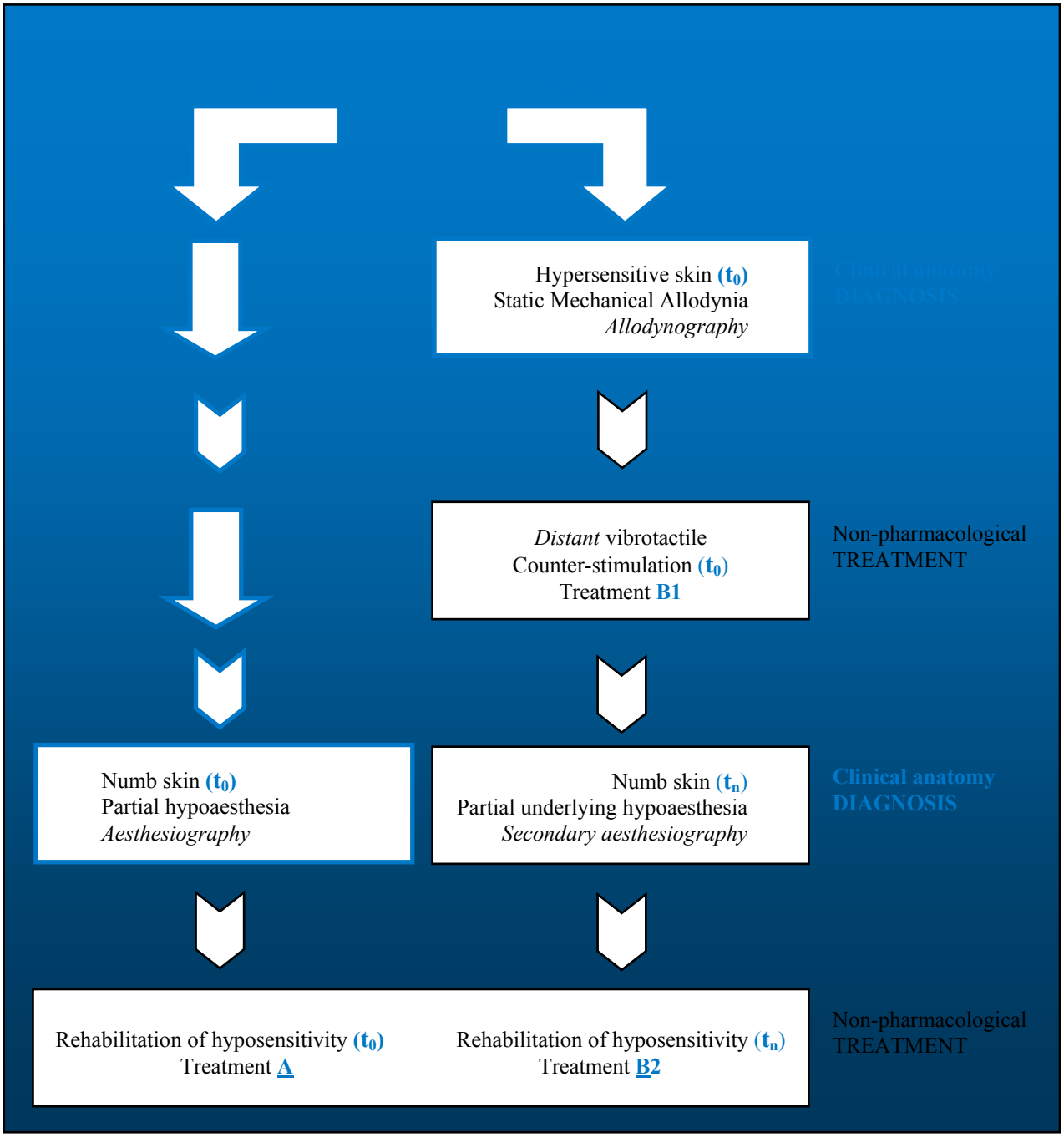


Fig. 4 Management algorithm to treat spontaneous ongoing neuropathic pain and/or touch-evoked neuropathic pain: At t_0, the therapeutic management of somatosensory testing and rehabilitation is either: Treatment A) Rehabilitation of hyposensitivity, if a part of the skin is numb (aesthesiography) or: Treatment B1) *Distant* Vibrotactile Counter-Stimulation (DVCS), if the skin is hypersensitive (allodynography). At t_n, when the allodynography becomes negative (secondary aesthesiography) the therapeutic management is: Treatment B2) Rehabilitation of hyposensitivity (Quintal et al, 2013).

A complex clinical anamnesis and clinical examination of tNPP is required in order to choose between the clinical anatomy **type A** and **type B** (Fig. 4). During the assessment of NP symptoms, which can occur spontaneously, if the patient complained about tenderness to touch, the SRM trained therapist interrupted the assessment of the MPQ and started using the Visual Analogue Scale (VAS) to begin assessing the hypersensitivity to touch following the

allodynography procedure. Figure 5 summarizes the different moments when the SRM trained therapist can interrupt the first **type A** of somatosensory testing – hypoaesthesia assessment - towards this second **type B** of clinical examination sign: the allodynography.

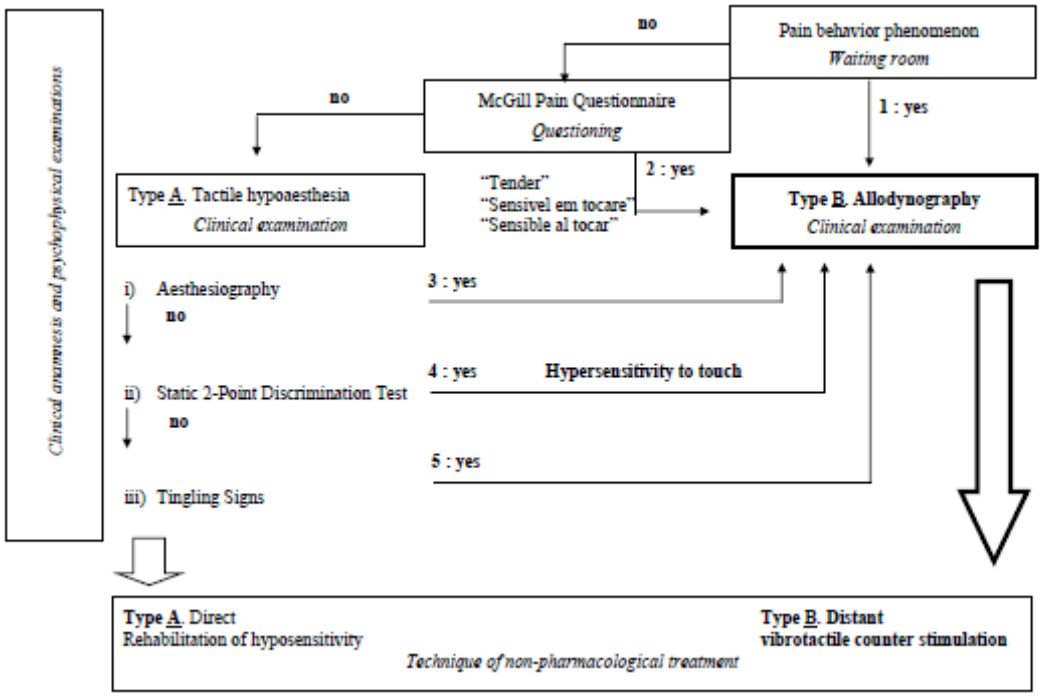


Fig. 5 Clinical reasoning process (from upper right corner to bottom): the five different moments when the SRM trained therapist can start assessing the hypersensitivity to touch instead of hypoaesthesia (i.e. change from aesthesiography to allodynography) and choose the *distant* vibrotactile counter stimulation instead of the rehabilitation of hyposensitivity as a therapeutic management. 1 and 2 are the moments when the patient gives either a non-verbal or a verbal clue of hypersensitivity to touch to the SRM trained therapist. 3, 4 and 5 are the moments when the SRM trained therapist cannot complete specific test due to the hypersensitivity to touch.

2.5 Clinical anatomy of the thoracic cutaneous branches

Previous work has been undertaken to provide a detailed understanding of somatosensory testing and rehabilitation in thoracic Neuropathic Pain Patients (tNPP). The twelve thoracic nerves I - XII arise out of about fifty-seven branches (Spicher et al., 2010, 2013): each thoracic nerve comprising three cutaneous branches – anterior (Fig. 6A), lateral and posterior (Fig. 6B) – and each anterior and lateral branch issuing itself from a medial and a lateral branch (N.B: the lateral branch of the 2nd thoracic nerve is the intercostobrachial nerves). In tNPP, this clinical anatomy can inform the understanding of the clinical presentation and management of pain arising from Aβ fibers lesions (Hansson, 2003; Hehn von et al, 2012).

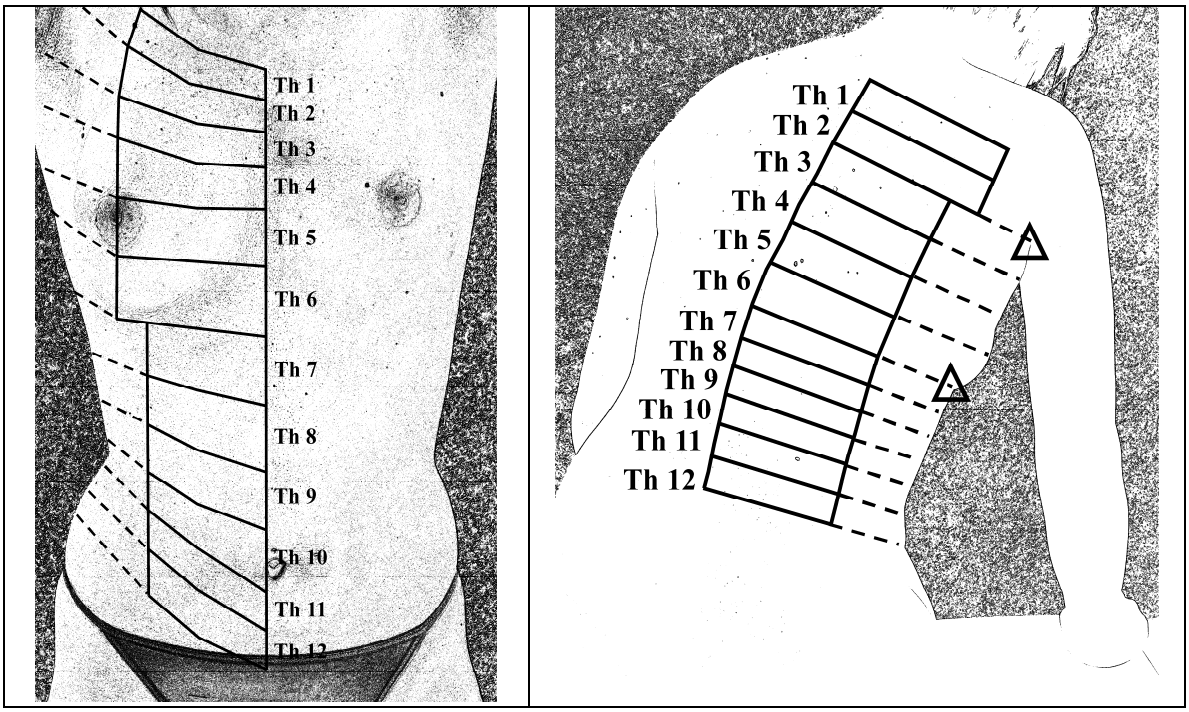


Fig. 6A. Territory of cutaneous distribution of anterior pectoral cutaneous branches of the twelve thoracic nerves.
Fig. 6B. Territory of cutaneous distribution of the posterior branch of the twelve thoracic nerves.
Fig. 6A & 6B were adapted by the authors (Spicher et al., 2010, 2013) with the kind authorization of the publisher.

2.6 Intervention protocol

All patients underwent the non-pharmacological somatosensory rehabilitation method. This semi-structured protocol is based on the technical guidelines, described partly in the Textbook for somatosensory testing & rehabilitation (Dellon, 2000 (4th ed.)), then in the Handbook for somatosensory rehabilitation (Spicher, 2003 (1st ed.) [2006]; Spicher & Quintal, 2013 (2nd ed.)).

2.6.1 Therapeutic management

Therapeutic management is the choice between two types of somatosensory rehabilitation of pain techniques (Fig. 4 & 5):

Type A: Rehabilitation of hyposensitivity;

Type B: *Distant* Vibrotactile Counter-Stimulation (DVCS) and then rehabilitation of hyposensitivity.

SRM was previously described in details (Spicher, 2003 [2006]; Spicher and Quintal, 2013). The whole method can be taught to doctors and rehabilitation professionals in 56 hours, although the aesthesiography and allodynography testing procedures need 14 hours of training.

2.6.2 DVCS

While the technique has already been described in details in Spicher et al. (2006, 2008, 2009), a brief overview follows. In the presence of an allodynic territory, a tactile device (used at home) and a vibratory device (used in therapy) were employed to provide comfortable somatosensory stimulations in a zone that is proximal to the territory of SMA but that is *distant* enough to ensure that the patient's experience is described as comfortable. The variable parameter of DVCS is the localization of the stimulus application. The tactile device was made of any material providing a comfortable stimulus to the individual patient (for example, fur, silk, microfiber fleece) and the vibratory device generated mechanical vibrations (parameters of stimulation: frequency 100 Hz, amplitude 0.06 mm: Spicher et al., 2008).

In this protocol, the SRM trained therapists had initially i) to hypothesize the cutaneous branch involved, ii) to designate an anatomically relevant zone of skin where DVCS must be applied (at home eight times a day for 1 minute and in therapy once a week) and iii) to delineate the zone of skin where touch stimuli should be avoided as it would induce painful perceptions.

2.6.3 Rehabilitation of hyposensitivity.

The technique (Spicher, 2006; Spicher and Quintal, 2013) is based on the neuroplasticity of the somatosensory system, involving direct stimulation of the hypoaesthetic skin mapped by aesthesiography. A tactile device was used at home and a vibratory one in therapy. The home program was prescribed four times a day for 5 minutes. In therapy, the variable parameter of the rehabilitation of hyposensitivity is the magnitude of the mechanical vibration (as identified by the Vibradol^{TM}): the Vibration Perception Threshold plus 0.1 mm to ensure the patient perceived the vibration.

2.6.4 Secondary aesthesiography

When the allodynography becomes negative because of the successful disappearance of the SMA (Spicher et al., 2008, p. 81 and its Appendix C p. 92) in **type B** tNPP treated with DVCS, secondary aesthesiography was used to assess the area of underlying hypoaesthesia (Fig. 4). The term "aesthesiography" is used because it refers to a mapping of hypoaesthesia, while "secondary" is used to avoid any confusion with the initial aesthesiography used to identify those tNPP with **type B** somatosensory changes. As previously described, there is always an underlying hypoaesthetic skin under SMA (Spicher et al., 2008). "Look for hypoaesthesia, because, by decreasing hypoaesthesia neuropathic pain decreases" (Spicher and Clément-Favre, 2008, p. 25): this paradigm of the SRM explains the search for hypoaesthesia.

2.6.5 Short-form pressure perception threshold

The pressure perception threshold (PPT) introduced by von Frey (1896) is a test used to determine the patient's ability to perceive the application of a force on the skin (this ability is

named also mechanical detection threshold). The PPT used in SRM is based on the application of seven aesthesiometers (from a kit of twenty) (Semmes et al., 1960; Malenfant et al., 1998, Spicher, 2006). It is conducted during the initial assessment in the centre of the area identified by aesthesiography (**type A**).

The short-form pressure perception threshold score is determined by the mean value of the force application of the three aesthesiometers detected in an ascending, descending and ascending series (ADA) (Spicher et al., 2008, pp. 81-82; Spicher and Quintal, 2013). In the ascending series (from the thinnest to the thickest of the seven aesthesiometers), it corresponds to the first of the aesthesiometers that is detected by the patient. In the descending series (from the thickest to the thinnest), it corresponds to the last one detected. During the session following the disappearance of the SMA, this test was also conducted in the centre of the secondary aesthesiography (**type B**).

We have chosen the short-form of PPT to reduce the duration of the test and also to diminish the risk of SMA reappearance. If applied earlier, when the SMA is still present, the application of the stimulus may increase the severity of the hypersensitivity to touch, which limits the possibility of decreasing SMA.

2.7 Parallel pharmacological treatment

As the seventy-one chronic patients were referred by forty-one prescribing doctors, their pharmacological treatment was usually based on antiepileptic drugs (Dworking et al., 2007, 2010; Attal et al., 2010) (i.e. pregabalin, gabapentin, clonazepam) through individual titration (**Suppl. Table 1 provides a complete summary of this information**).

Patients with strong NP or who did not respond to first line medications, were given opioid analgesics such as oxycodone, or tramadol, in combination with the first line medication. Combined of medication is a frequent pattern with patients followed at the Somatosensory Rehabilitation Centre in Fribourg (Spicher and Quintal, 2013). With this cohort, the focus was on rehabilitation interventions rather than pharmacological management.

2.8 Statistics

The quantitative data of the pressure perception threshold were analyzed statistically using the Sigmaplot 12.0 software. Group comparisons were based on the non-parametric unpaired Mann-Whitney Rank Sum Test. The scores of the original MPQ are described by mean (ranges), standard deviation (SD) and median.

3. Results

The clinical data of 66 patients at the time point of the first investigation are listed in details in table 1: a total of 99 cutaneous branches were damaged. They were distributed amongst 35 cutaneous thoracic branches (Table 1). 34 patients presented intercostal neuralgia with involvement of a single cutaneous branch.

Posterior branch of Th1	5			Anterior cutaneous branch of Th1	1
Posterior branch of Th2	6	Intercostobrachial nerves	10	Anterior cutaneous branch of Th2	4
Posterior branch of Th3	3	Lateral cutaneous branch of Th3	3	Anterior cutaneous branch of Th3	1
Posterior branch of Th4	3	Lateral cutaneous branch of Th4	7	Anterior cutaneous branch of Th4	1
Posterior branch of Th5	1	Lateral cutaneous branch of Th5	9	Anterior cutaneous branch of Th5	8
Posterior branch of Th6	1	Lateral cutaneous branch of Th6	4	Anterior cutaneous branch of Th6	3
Posterior branch of Th7	1	Lateral cutaneous branch of Th7	3	Anterior cutaneous branch of Th7	3
Posterior branch of Th8	0	Lateral cutaneous branch of Th8	0	Anterior cutaneous branch of Th8	1
Posterior branch of Th9	1	Lateral cutaneous branch of Th9	1	Anterior cutaneous branch of Th9	5
Posterior branch of Th10	0	Lateral cutaneous branch of Th10	2	Anterior cutaneous branch of Th10	2
Posterior branch of Th11	3	Lateral cutaneous branch of Th11	0	Anterior cutaneous branch of Th11	1
Posterior branch of Th12	4	Lateral cutaneous branch of Th12	0	Anterior cutaneous branch of Th12	2

Table 1
Distribution of the 99 damaged cutaneous branches (*n*=66 patients).

At the evaluation (t_0), all cutaneous branches were classified (Table 2) as either hypoaesthetic (with a positive aesthesiography, 53 % of the total) or hypersensitive (with a positive allodynography, 47 %). None of them presented any somaesthetic disorders: a negative aesthesiography and a negative allodynography (Table 2).

When the skin was hypoaesthetic (**type A**: *n*=52), the importance of partial hypoaesthesia measured with PPT was 38.0 g ±SD = 28.2 g (range: 0.2-75.1 g). At baseline (t_0), 47% of those 99 cutaneous branches (Table 2) that were damaged were hypersensitive with a positive allodynography (**type B**: *n*=47). After DVCS treatment, 72% of these allodynographies became negative (*n*=34). The average DVCS duration was 76.3 days ±SD = 74.1days (range: 6-355 days).

	At the evaluation (t_0)
Hypoaesthetic skin **Type A** *Positive aesthesiography*	**53 %** *n*=52
Paradoxical painful-to-touch hypo-aesthetic skin **Type B** *Positive allodynography*	**47 %** *n*=47
Normal skin *Negative aesthesiography* *Negative allodynography*	**0 %** *n*=0

Table 2
At the evaluation (t_0), clinical anatomy status of the 99 damaged cutaneous branches (*n*=66 patients) either hypoaesthetic **type A** or painful to touch **type B**.

The 34 damaged cutaneous branches with partial hypoaesthesia following treatment of their SMA (**type B** in the Figure 4) exhibited PPT values similar from those of the 52 damaged cutaneous branches with initial partial hypoaesthesia (**type A** in the Figure 4), (p=0.767; Mann-Whitney Rank Sum Test).

The median score was 2.2 in **type B** subgroup (Q1 = 1.3; Q3 = 15.1) and 2.65 in **type A** subgroup (Q1 = 1.3; Q3 = 11.7). Pain intensity as described by MPQ, at first day of testing (**Supplementary Table 1**), for the 66 patients from our cohort was 45.5 points ±SD = 28.2 points (range: 20-86 points). Pain intensity of 14 tNPP was ≥ 60 points.

	Discontinued before 4 weeks (*n*=11)	**Discontinued after 4 weeks** (*n*=13)	**Completed** (*n*=42)
Pain reduction ≥ 50%	0	4	36
Algorithm efficacy	0%	31 % (4 / 13)	86 % (36 / 42)
	61 % (40 / 66)		

Table 3
Algorithm efficacy: In clinical practice (*n*= 66 patients), somatosensory rehabilitation has been either discontinued at the beginning of the treatment (< 4 weeks), discontinued during the treatment (≥ 4 weeks) or completed. A pain reduction of at least 50% on the McGill Pain Questionnaire., pre- and post- treatment, is considered successful.

At clinical anamnesis, all 66 patients complained of neuropathic symptoms on the trunk. 32 patients had several, from one to four, neuralgias associated with the intercostal neuralgia: trigeminal (2), occipital (3), cervical (10), brachial (27), another intercostal (42), lumbar abdominal (7), lumbar femoral (3), femoral (1), sciatic (8), sacral (2).

Of the 66 patients treated with SRM, 24 (36.3 %) discontinued their somatosensory rehabilitation of pain before normalization of their hypoaesthetic skin. These interruptions of treatment were either caused by another medical disorder (i.e. patient required abdominal surgery) or by the patient's choice (i.e. patient chose to follow another treatment such as physical therapy). One treatment was interrupted by the prescribing doctor authorizing return to work. In one case, treatment was discontinued by the SRM trained therapist, because the patient was unable to attend to her own body perceptions and could not complete the evaluation.

Of these 24 patients, 11 did not complete one MPQ. Of the 42 patients of the original cohort that completed their treatment, all completed a final MPQ. Within the initial cohort of 66 patients, 40 patients (Table 3) presented a pain reduction of at least 50% on the final MPQ: 61 % (66 / 40 = 1.65).

5. Discussion and conclusions

From all observations in chronic tNPP, 100 % (Table 2) of the altered cutaneous sensibilities of the skin (n=99 branches) investigated in real conditions were either A) a hypoaesthetic (positive aesthesiography) or B) a hypo-aesthetic paradoxically painful-to-touch (positive allodynography). None of them presented a normal somaesthetic profile: a negative aesthesiography and a negative allodynography. Consequently, it is worthy to evaluate somatosensory abnormalities in tNPP, more specifically, Aβ neurofibre lesions and their tactile hypoaesthesia – this common clinical characteristic of pain in an area with partial or complete somatosensory loss (Jensen & Finnerup, 2014). These two subgroups of somatosensory abnormalities are summarized in Table 4.

	Type of neuropathic pain	Skin status	Symptoms	Clinical examination sign	Diagnostic
Type A	Spontaneous	Tactile hypoaesthesia	Numbness	Aesthesiography	Neuralgia
Type B	Touch-evoked	Tactile allodynia	Hypersensitivity	Allodynography	Static mechanical allodynia

Table 4

The concept of Aβ pain allows neuropathic pain to be evaluated according to two subgroups, categorized by distinct clinical signs: **A**) aesthesiography mapping the territory of tactile hypoaesthesia and **B**) allodynography objectively describing and mapping the territory of tactile allodynia (Packham et al., 2013).

In clinical practice, our observations that 40 out of 66 patients (61 %) treated with SRM had pain reduction of at least 50% on the MPQ suggest that it is valuable to consider somaesthetic and/or neuropathic conditions with an appropriate management **algorithm** (Fig.

4) to treat spontaneous ongoing neuropathic pain and/or touch-evoked neuropathic pain. Hypoaesthetic territories were treated by basic somatosensory rehabilitation named rehabilitation of hyposensitivity (**treatment A**). Allodynic territories were treated initially by DVCS (**treatment B1**), and later, when allodynia disappeared, by basic somatosensory rehabilitation. If we only consider the tNPP who completed their treatment by reaching normal skin sensitivity, the positive outcomes increase from 61 % to 86 % (Table 3).

As for peripheral neuropathic pain conditions, non-pharmacological treatments should be considered (Finnerup et al., 2005). Its clinical anatomy diagnosis is based on somatosensory abnormalities. One of the main interests of the present study is that the data were collected in clinical practice (Johnson et al., 1991; Johnson et al., 2012), in a single rehabilitation centre. An inter-tester assessment of twelve medical doctors with no specific training demonstrated the unsatisfactory reliability in detecting tactile hypoaesthesia in order to diagnose diabetic sensorimotor polyneuropathy (Dyck et al., 2010). In the present study, in order to maximize the inter-tester reliability, the data were collected exclusively by SRM trained therapists, who had completed the training course to assess NPP for tactile hypoaesthesia and tactile allodynia.

In tNPP with neuropathic pain in a specific dermatome, the mapping of aesthesiography or allodynography is easier than in general NPP because the clinical anatomical concept of largest territory of cutaneous distribution is not necessary (Lanz von and Wachsmuth, 1935; Spicher et al., 2010, 2013). 34 patients (52 %) were presenting an intercostal neuralgia with only one damaged cutaneous branch (and not the three branches of one thoracic nerve as in PHN). Consequently, the complete dermatome is not always damaged. It is essential to consider that tNPP are not only PHN patients. In our cohort of intercostal neuralgia (n=71), associated diagnoses (Fig.1) extend beyond post-surgical patients (n=33) and PHN patients (n=4). Numerous provisional diagnoses were made, including: status post traumatic (n=20), cancer sequelae (n=6), idiopathic pain (n=4), etc.

In tNPP, as in PHN (Head and Campbell, 1900; Watson et al, 1991; Nurmikko, 1994; Gilron et al., 2006), hypersensitivity often spread outside the innervation territory of the affected nerve and overlapped the neighbouring nerve territories (one dermatome, or more, above and/or below), outside the area of spontaneous neuropathic pain (i.e. burning sensations). In tNPP, this cutaneous somatosensory abnormality, which has been named overlapping (Arner et al., 1990) or dyslocalization (Hansson, 1994), is considered as a qualitative and spatial widespread touch-evoked pain that can be precisely mapped. As tactile allodynia involves an increase in the duration of response to brief stimulation (Coderre et al., 1993), the testing of the allodynography needs a careful mapping of only four points and not more (Fig. 3). As increased pain after repetitive stimulation - temporal summation of pain (Pfau et al., 2014) - and pain persisting after stimulation are specific descriptors of touch-evoked pain (Jensen & Finnerup, 2014), we did *NOT* test for hyperalgesia. In order to increase the level of sophistication in pain psychophysics (Magerl and Klein, 2006), we preferred to map only tactile hypoaesthesia and tactile allodynia.

The mechanisms of basic somatosensory rehabilitation that normalize tactile hypoaesthesia remain unclear. Their review is beyond the scope of this paper. Further research is needed to corroborate the current findings and elucidate neuroplastic mechanisms in the somaesthetic system, accounting for these treatment effects: neighbour cutaneous

branches, ascending paths, parieto-occipital cortices (Inbal et al., 1987; Sadato, 2004) could be one of them.

The mechanisms of DVCS need to be discussed. In NPI, if we consider the axonal lesions are both C and Aβ neurofibre injuries and *NOT* only C neurofibre injuries, it is reasonable to expect partial tactile hypoaesthesia. The residual Aβ neurofibre evoke hypoaesthetic touch sensation. If central sensitization (Woolf, 1983; Woolf, 2011) is present, they should cause pain (Aβ pain). If DVCS turns off central sensitization, then sensation will return to what is expected after partial denervation: partial tactile hypoaesthesia. In the present sample of 66 patients, some suffered from neuropathic pain over a period of several years (up to 40 years). These observations indicate that, even if the peripheral and central sensitizations have been established for a long time (Woolf et al., 1992; Koerber et al., 1999; Kohama et al., 2000; Klede et al., 2003; Todd and Koerber, 2006), they can still be reversed to eliminate touch-evoked neuropathic pain. But the neurophysiological mechanisms underlying the reversal of central sensitization, in particular how vibrotactile stimuli may relieve pain, are still unclear (Inui et al., 2006; Spicher et al., 2008; Hollins et al. 2014). Even if the dynamic between the uninjured and the injured Aβ-fibres should be considered differently at three weeks, thirty months or three years after the lesions, touch-evoked neuropathic pain is largely due to impulses in large myelinated Aβ-fibres (Gracely et al., 1992; Devor, 2009, Sandkühler, 2009). Moreover, tactile allodynia, maintained by peripheral input (Devor and Tal, 2014), provides a partial explanation for DVCS mechanisms. One of the tasks of the SRM trained therapist is to delineate the zone of skin where tactile stimuli should be avoided and to educate the tNPP to transfer this prescription in his activities of daily living. In brief, damage in Aβ neurofibre and their tactile hypoaesthesia is peripheral; the mechanisms for pain sensitization are mostly centrally driven, with referral back to the peripheries where it is perceived as a paradoxical painful-to-touch hypo-aesthesia (McCabe, 2009).

In 1979, the IASP replaced the concept of hyperaesthesia (Dejerine, 1914; Noordenbos, 1959) with three different concepts: hyperalgesia, secondary hyperalgesia and allodynia in order to study their different underlying physiological mechanisms (Merskey, 1979). If the pathogenesis of hyperalgesia and dynamic mechanical allodynia (DMA) is C fibers lesions (Baron and Saguer, 1995; Attal et al., 1998; Maihöfner et al., 2010; Scadding and Kolzenburg, 2013), the physiological mechanism of SMA is different. Sensitized nociceptors show an exaggerated response to suprathreshold heat and mechanical stimuli: heat and mechanical hyperalgesia (Campbell and Meyer, 2006; Scadding and Kolzenburg, 2013). However, the sensitized nociceptor hypothesis does not explain tactile allodynia. A significant body of evidence indicates that hypersensitivity to touch is signalled by low-threshold Aβ touch afferents, *NOT* sensitized nociceptors (Bouhassira and Attal, 2012; Hehn von et al., 2012; Scadding and Kolzenburg, 2013; Devor, 2013; Marchand, 2014). At baseline (t_0), 47 positive allodynographies (**type B**) were mapped on 66 tNPP. Through DVCS, 34 of these 47 allodynographies became negative and their underlying hypoaesthetic territory always appeared. In PNI, these data confirm a relationship between the hypersensitive territory (SMA) and the underlying territory of partial denervation (Spicher et al. 2008). Even if they did not formally correlate these two somatosensory abnormalities, other authors have documented the two clinical examination signs (Muller and Winkelmann, 1969; Moriwaki et al., 1994; Moriwaki and Yuge, 1999; Jensen and Finnerup, 2014).

In conclusion, in tNPP, the evolution of two types of initial somatosensory abnormalities **A**) partial tactile hypoaesthesia and **B**) paradoxical hypo-aesthesia painful- to-touch into similar clinical presentations confirms the management algorithm for clinical reasoning (Fig. 4). The Aβ neurofibre, whose partial lesions are physiologically reflected in an area of partial hypoaesthesia and generate spontaneous and/or touch-evoked neuropathic pain (Hansson, 2003), should be considered co-contributors to pain perception (Packham et al., 2013; see also Table 4). To elaborate these findings, the presence of Aβ neurofibre lesions as a hypothetical cause of neuropathic pain should not be considered merely theoretical. It is a clinical hypothesis which supports the treatment of NPP, in particular amongst thoracic neuropathic pain patients (tNPP). This article demonstrates the possibility of mapping cutaneous somatosensory abnormalities through aesthesiography and allodynography but with a very specific evaluation using the qualifiers of the MPQ. "Another problem in translating from a symptom or sign to the underlying mechanism relates to the methods used to classify patients." (Jensen and Kehlet, 2011, p.12). The SRM provides the opportunity not only to objectively classify, but to reduce neuropathic pain in Aβ neurofibre lesions, and ultimately the suffering of these patients, as well.

Acknowledgments

The authors wish to thank Professor Marshall Devor, PhD, Professor Eric M. Rouiller, PhD, Professor Isabelle Decosterd, MD, Professor Alain Golay, MD, Prof Candy McCabe, PhD, RGN and Georges Kohut, MD, for critical review of the manuscript; all the staff of the Somatosensory Rehabilitation Centre, in particular Nadège Buchet (-Desfoux), Certified Somatosensory Therapist of Pain (CSTP®), for collecting data, Tara L. Packham, PhD candidate, OTReg(Ont), CSTP®, Elinor Behar, CSTP® Rebekah Della Casa, CSTP®, Barbara Shankland, BSc OT, CHT and Renée Hamilton, BSc OT, for editorial comments and Mélanie Kaeser, PhD, for her help with statistics.

Declaration of interests

The authors have no financial or any other relationships that might lead to a conflict of interest.

References

Arner S, Lindblom U, Meyerson BA and Molander C. Prolonged relief of neuralgia after regional anesthetic blocks. A call for further experimental and systematic clinical studies. Pain 1990;43:287-297.

Attal N, Brasseur L, Chauvin M and Bouhassira D. A case of 'pure' dynamic mechano-allodynia due to a lesion of the spinal cord: pathophysiological considerations. Pain 1998;75:399-404.

Attal N, Cruccu G, Baron R, Haanpää M, Hansson P, Jensen TS, Nurmikko T. EFNS guidelines on the pharmacological treatment of neuropathic pain : 2010 revision. Eur J Neurol 2010;17:1113-23.

Baron R and Saguer M. Mechanical allodynia in postherpetic neuralgia: Evidence for central mechanism depending on nociceptive C-fiber degeneration. Neurology 1995;45:S63-S65.

Bouhassira D and Attal N. Douleurs neuropathiques (2ème éd.). Paris : Arnette-Wolters Kluwer France ; 2012, p. 220.

Boureau F, Luu M, Gay C, Doubrere JF. Elaboration d'un questionnaire d'auto-évaluation de la douleur par la liste des qualificatifs. Thérapie 1984 ;39 :119-129.

Campbell JN and Meyer RA. Mechanisms of neuropathic pain. Neuron 2006;52:77-92.

Carmichael SW. Foreword of the 2nd edition. In: Spicher CJ, Buchet (-Desfoux) N, Sprumont P. Atlas des territoires cutanés du corps humain humain : Esthésiologie de 240 branches (2ème éd.). Montpellier, Paris: Sauramps Médical; 2013. p. 6 (one page).

Coderre TJ, Katz J, Vaccarino AL, Melzack R. Contribution of central neuroplasticity to pathological pain: review of clinical and experimental evidence. Pain 1993;52:259-85.

Dejerine J. Sémiologie du système nerveux. Paris: Masson; 1914.

Dellon AL. Somatosensory testing and rehabilitation. Baltimore : The institute for peripheral nerve surgery; 2000.

Devor M. Ectopic discharge in Aß afferents as a source of neuropathic pain. Exp Brain Res 2009;196:115-28.

Devor M. Neuropathic Pain: Pathophysiological Response of Nerves to Injury. Chapter 61. In SB McMahon, M Koltzenburg, I Tracey and D. C. Turk editors. Wall and Melzack's Textbook of Pain, 6th ed. Philadelphia: Elsevier Saunders; 2013. pp. 861-888.

Devor M and Tal M. Nerve resection for the treatment of chronic neuropathic pain Commentary on the Clinical Note by: Watson, C.P., Mackinnon, S., Dostrovsky J, Bennett, G., Farran P., Carlson, T. Nerve resection, crush and grafting relieves complex regional pain syndrome II (causalgia): a case report. PAIN® 2014;155(6):1053-4.

Dworkin RH, O'Connor AB, Backonja M, Farrar JT, Finnerup NB, Jensen TS, Kalso EA, Loeser JD, Miaskowski C, Nurmikko TJ, Portenoy RK, Rice AS, Stacey BR, Treede RD, Turk DC, Wallace MS. Pharmacologic management of neuropathic pain: evidence-based recommendations. Pain 2007;132:237-51.

Dworkin RH, O'Connor AB, Audette J, Baron R, Gourlay GK, Haanpää ML, Kent JL, Krane EJ, LeBel AA, Levy RM, Mackey SC, Mayer J, Miaskowski C, Raja SN, Rice ASC, Schmader KE, Stacey B, Stanos S, Treede RD, Turk DC, Walco GA, Wells CD. Recommendations for the Pharmacological Management of Neuropathic Pain: An Overview and Literature Update. Mayo Clin Proc 2010;18:S3-S14.

Dyck PJ, Overland CJ, Low PA, Litchy WJ, Davies JL, Dyck PJB, O'Brien PC; Cl vs. NPhys Trial Investigators, Albers JW, Andersen H, Bolton CF, England JD, Klein CJ, Llewelyn JG, Mauermann ML, Russell JW, Singer W, Smith AG, Tesfaye S, Vella A. Signs and symptoms versus nerve conduction studies to diagnose diabetic sensorimotor polyneuropathy. Muscle Nerve 2010;42(2):157-164.

Finnerup NB, Otto M, McQuay HJ, Jensen TS, Sindrup SH. Algorithm for neuropathic pain treatment: an evidence based proposal. Pain 2005;118:289-305.

Frey von M. (1896). Untersuchung über die Sinnesfunktion der Menschlichen Haut: Erste Abhandlung : Druckempfindung und Schmerz. Des XXIII Bandes der Abhandlungen der mathematisch – physischen Classe der Königlichen Sächsischen Gesellschaft des Wissenschaften (pp. 175-266). Leipzig : S. Hirzel, III. (translated in English as : HO Handwerker and K Brune, editors [1987]. *Classical German contributions to pain research*; [1987]. pp. 69-131).

Gilron I, Watson CPN, Cahill CM, Moulin D E. Neuropathic pain: a practical guide for the clinician. CMAJ 2006;175:265-275.

Gracely RH, Lynch SA, Bennett GJ. Painful neuropathy: altered central processing maintained dynamically by peripheral input. Pain 1992;51(2):175-194.

Hansson P. Possibilities and Potentials Pitfalls of Combined Bedside and Quantitative Somatosensory analysis in Pain Patients. In J Boivie, P Hansson and U. Lindblom, editors. Touch, Temperature, and Pain in Health and Disease : Mechanisms and Assessments, Progress in Pain research and Management, Vol. 3. Seattle : IASP Press; 1994, pp. 113-132.

Hansson P. Difficulties in stratifying neuropathic pain by mechanisms. Eur J Pain 2003;7:353-357.

Head H and Campbell AW. The pathology of herpes zoster and its bearing on sensory localisation. Brain 1900;23:353-523, plate 1 to 16.

Hehn von C, Barron R, Woolf CJ. Deconstructing the Neuropathic Pain Phenotype to Reveal Neural Mechanisms. Neuron 2012;73:638-352.

Hollins M, McDermott K, Harper B. How does vibration reduce pain? Perception 2014;43:70-84.

Inbal R, Rousso M, Ashur H, Wall PD, Devor M. Collateral sprouting in skin and sensory recovery after nerve injury. Pain 1987;28:141-154.

Inui K, Tsuji T, Kakigi R. Temporal analysis of cortical mechanisms for pain relief by tactile stimuli in humans. Cereb Cortex 2006;16(3):355-365.

Jensen TS and Kehlet H. Pain following thoracotomy: Is it neuropathic pain? PAIN® 2011;152:12-13.

Jensen TS and Finnerup NB. Allodynia and hyperalgesia in neuropathic pain: clinical manifestations and mechanisms Lancet Neurol 2014;13(9):924-935.

Johnson MI, Ashton CH, Thompson JW. The consistency of pulse frequencies and pulse patterns of transcutaneous electrical nerve stimulation (TENS) used by chronic pain patients. Pain. 1991;44(3):231-4.

Johnson S, Hall J, Barnett S, Draper M, Derbyshire G, Haynes L, Rooney C, Cameron H, Moseley GL, Williams AC de C, McCabe C, Goebel A. Using graded motor imagery for

complex regional pain syndrome in clinical practice: failure to improve pain. Eur J Pain 2012;16(4):550-561.

Klede M, Handwerker HO, Schmelz M. Central origin of secondary mechanical hyperalgesia. J Neurophysiol 2003;90:353-359.

Koerber HR, Mirnics K, Kavookjian AM, Light AR. Ultrastructural Analysis of Ectopic Synaptic Boutons Arising From Peripherally Regenerated Primary Afferant Fibers. J Neurophysiol 1999;81:1636-1644.

Kohama I, Ishikawa K, Kocsis JD. Synaptic Reorganization in the Substancia Gelatinosa After Peripheral Nerve Neuroma Formation : Aberrant Innervation of Lamina II Neurons by Aβ Afferents. J Neurosci 2000;20:1538-1549.

Lanz von, T. and Wachsmuth, W. Praktische Anatomie; Erster Band / Dritter Teil: Arm. Berlin: Julius Springer; 1935. p. 276.

Létiévant E. Phénomènes physiologiques et pathologiques consécutifs à la section des nerfs du bras. Lyon médical 1869;3:150-164, 225-243, planches I à VI.

Létiévant E. Esthésiographie. In Compte rendu de la 4ème session de Nantes en 1875 . Association française pour l'avancement des sciences, secrétariat de l'association ; 76, rue de Rennes, Paris ; 1876, pp. 1037-1043 (republished as : Association française pour l'avancement des sciences. Esthésiographie, par le « Dr Jean-Joseph-Emile Létiévant ». Paris : Hachette; 2013[1875]).

Lindblom U. Analysis of Abnormal Touch, Pain, and Temperature Sensation in Patients. In J. Boivie, P. Hansson & U. Lindblom, editors. Touch, Temperature, and Pain in Health and Disease: Mechanisms and Assessments, Progress in Pain Research and Management, Vol. 3. Seattle: IASP Press; 1994. pp. 63-84. p. 533.

Lindblom U and Verillo RT. Sensory functions in chronic neuralgia. J Neurol Neurosurg Psych 1979;42:422-435.

Magerl W and Klein T. Experimental Human Models of Neuropathic Pain. In F Cervero F and TS Jensen TS, editors. Handbook of clinical neurology, Vol. 81 3rd series. Edinburgh : Elsevier; 2006, pp. 501-514.

Maihöfner C, Jesberger F, Seifert F, Kaltenhäuser M. Cortical processing of mechanical hyperalgesia: A MEG study. Eur J Pain 2010;14:64-70.

Malenfant A, Forget R, Amsel R, Papillon J, Frigon JY, Choinière M. Tactile, thermal and pain sensibility in burned patients with and without chronic pain and paresthesia problems. Pain 1998;77:241-251.

Marchand S. Guesteditorial: Basic neurophysiology of the development, persistency and treatment of pain. e-News Somatosens Rehab 2014;11(1):3-17.

Maiani G and Sanavio E. Semantics of Pain in Italy: the italian version of the McGill Pain Questionnaire. Pain 1985;22:399-405.

McCabe C. Complex Regional Pain Syndrome: myth, madness or miscommunication. (2009). e-News Somatosens Rehab 2009;6:2-8.

Melzack R. The McGill Pain Questionnaire: Major Properties and Scoring Methods. Pain 1975;1:277-229.

Merskey H. Pain terms: a list with definitions and notes on usage. Pain 1979;6:247-252.

Merskey H, Bogduk N, editors. Classification of chronic pain: descriptions of chronic pain syndromes and definitions of pains terms, (2nd ed.). Seattle: IASP Task Force on Taxonomy, 1994.

Moriwaki K, Yuge O, Nishioka K, Yamanoue T, Nakao M. Reduction in the Size of Tactile Hypesthesia and Allodynia Closely associated with Pain Relief in Patients with Chronic Pain. In Gebhart GF, Hammond DL, Jensen TS, editors. Proceedings of the 7th world Congress on Pain, Progress in Pain Research and Management, Vol. 2. Seattle: IASP Press; 1994. p. 819-830.

Moriwaki K and Yuge O. Topographical features of cutaneous tactile hypoesthetic and hyperesthetic abnormalities in chronic pain. Pain 1999;81:1-6.

Morton TG. A Peculiar and Painful Affection of the Fourth Metarso-Phalangeal Articulation. Am J Med Sci 1876;71:37-45.

Muller SA and Winkelmann RK. Cutaneous nerve changes in zoster. J Invest Dermatol 1969;52:71-7.

Nathan PW. Improvement in Cutaneous Sensibility associated with Relief of Pain. J Neurol Neurosurg Psychiat 1960;23:202-206.

Noordenbos W. PAIN Problems pertaining to the transmission of nerve impulses which give rise to pain. Amsterdam : Elsevier; 1959. p. 182.

Nurmikko T. Sensory dysfunction in Postherpetic Neuralgia. In J. Boivie, P. Hansson & U. Lindblom, editors. Touch, Temperature, and Pain in Health and Disease: Mechanisms and Assessments, Progress in Pain Research and Management, Vol. 3. Seattle: IASP Press; 1994. pp. 133-141. p. 533.

Ochoa JL and Yarnitsky D. Mechanical hyperalgesias in neuropathic pain patients: dynamic and static subtypes. Ann Neurol 1993;33(5):465-472.

Packham TL, Della Casa R, Hamilton R, Spicher CJ and Annoni JM. Neuropathic Pain or Aβ Pain ? e-News Somatosens Rehab 2013;10:10-12.

Pfau DB, Krumova EK, Treede RD, Baron R, Toelle T, Birklein F, Eich W, Geber C, Gerhardt A, Weiss T, Magerl W, Maier C. Quantitative sensory testing in the German Research Network on Neuropathic Pain (DFNS): reference data for the trunk and application in patients with chronic postherpetic neuralgia. PAIN® 2014:S0304-3959(14)00058-X.

Quintal I, Noël L, Gable C, Delaquaize F, Bret-Pasian S, Rossier Ph, Annoni JM, Maupas E, Spicher CJ. La méthode de rééducation sensitive de la douleur. Encyclopédie Médico-

Chirurgicale (EMC), Kinésithérapie-Médecine physique-Réadaptation 2013, 26-469-A-10:1-16.

Sadato N, Okada T, Kubota K, Yonekura Y. Tactile discrimination activates the visual cortex of the recently blind naive to Braille: a functional magnetic resonance imaging study in humans. Neurosci Lett. 2004;359(1-2):49-52.

Sandkühler J. Models and mechanisms of hyperalgesia and allodynia. Physiological reviews 2009; 89(2):707-758.

Scadding JW, Kolzenburg M. Painful Peripheral Neuropathies. Chapter 65. In SB McMahon, M Koltzenburg, I Tracey and D. C. Turk editors. Wall and f, 6th ed. Philadelphia: Elsevier Saunders; 2013. pp. 926-951.

Semmes J, Weinstein S, Ghent L, Teuber HL. Somatosensory changes after penetrating brain wounds in man. Cambridge, MA : Harvard University Press; 1960, pp. 91.

Spicher CJ. Handbook for Somatosensory Rehabilitation first ed. Montpellier, Paris: Sauramps médical; 2006. p. 199 [published firstly as: Spicher C. Manuel de rééducation sensitive du corps humain 1ère éd. Genève, Paris: Médecine & Hygiène; 2003. p. 204].

Spicher CJ. Efficacy of Somatosensory Rehabilitation for Chronic Neuropathic Pain of the Upper Extremity. J Hand Surg Br 2008;33E (1 Suppl.):S201 (one page).

Spicher CJ and Clément-Favre S. Chronic Neuropathic Pain decreases through Somatosensory Rehabilitation. RAE : Recueil Annuel francophone belge d'Ergothérapie 2008;1:25-37.

Spicher CJ and Kohut G. Jean Joseph Emile Létiévant : A Review of His Contributions to Surgery and Rehabilitation. J Reconstr Microsurg 2001;17:169-177.

Spicher CJ and Quintal I. La méthode de rééducation sensitive de la douleur (2ème éd.) Montpellier, Paris: Sauramps Médical; 2013. p. 369.

Spicher CJ, Degrange B, Mathis F. La désactivation des signes d'irradiation provoquée; une nouvelle technique de rééducation sensitive pour traiter les douleurs chroniques. ergOThérapies 2006 ;22 :13-18.

Spicher CJ, Mathis F, Degrange B, Freund P, Rouiller EM. Static Mechanical Allodynia is a Paradoxical Painful Hypo-aesthesia: Observations derived from neuropathic pain patients treated with somatosensory rehabilitation. Somatosens Mot Res 2008; 25(1):77-92.

Spicher CJ, Desfoux N, Sprumont P. Atlas des territoires cutanés du corps humain : Esthésiologie de 240 branches (1ère éd.). Montpellier, Paris: Sauramps Médical; 2010. p. 96.

Spicher CJ, Buchet (-Desfoux) N, Sprumont P. Atlas des territoires cutanés du corps humain humain : Esthésiologie de 240 branches (2ème éd.). Montpellier, Paris: Sauramps Médical; 2013. p. 100.

Stein CH and Mendl G. The German counterpart to McGill Pain Questionnaire. Pain 1988;32:251-255.

Sukhotinsky I, Ben-Dor E, Raber P, Devor M. Key role of the dorsal root ganglion in neuropathic tactile hypersensibility. Eur J Pain 2004;8:135-143.

Taylor KS, Anastakis DJ, Davis KD. Cutting your nerve changes your brain. Brain 2009;132:3122-3133.

Tinel J. Les blessures de nerfs. Paris: Masson ; 1916. [Translated in English as: Tinel J. Nerve wounds. London: Baillère, Tindall and Cox, 1917].

Todd J and Koerber HR. Neuroanatomical substrates of spinal nociception. In SB McMahon and M Koltzenburg, editors. Wall and Melzack's Text-book of Pain, 5th ed. Philadelphia : Elsevier; 2006. pp.73-90.

Wall PD, Devor M, Inbal R, Scadding JW, Schonfeld D, Seltzer Z, Tomkiewicz MM. Autonomy following peripheral nerve lesions: experimental anaesthesia dolorosa. Pain 1979; 7:103-111.

Watson CPN, Deck JH, Morshead C, Van der Kooy D, Evans RJ. Post-herpetic neuralgia: further post-mortem studies of cases with and without pain. Pain 1991;44:105-117.

Woolf CJ. Evidence for a central component of post-injury pain hypersensitivity. Nature 1983;306:686-688.

Woolf CJ. Central sensitization : Implications for the diagnosis and treatment of pain. PAIN® 2011;152:S2-15.

Woolf CJ and Mannion RJ. Neuropathic pain : aetiology, symptoms, mechanisms, and management. Lancet 1999;353:1959-1964.

Woolf CJ, Shortland P, Coggeshall RE. Peripheral nerve injury triggers central sprouting of myelinated afferents. Nature 1992;355:75-78.

Web references

Loeser, J.D. & IASP Taxonomy Working Group (2011). *IASP Taxonomy*. http://www.iasp-pain.org/Taxonomy?navItemNumber=576 (16/01/02).

http://www.ergotherapie.ch/resources/uploads/Ethik/Berufskodex_FR.pdf (16/01/02)

Suppl.Table 1 Demographic data, pain duration and intensity of neuropathic pain at first session in 71 patients with intercostal neuralgia (66 NPP included + *5 NPP excluded*)

Patient			Diagnosis	Treatment	Pain duration (years)	t_0 pain intensity MPQ (%)
Nb.	F/M	Age (years)				
1	F	46	L Status post traumatic[1]	Gabapentin	4	50
2	H	40	L Idiopathic pain	Gabapentin	3	52
3	H	63	R Status post surgery[2]	Flupantixol	3.5	28
4	H	43	R Status post surgery	Bupivacaine blockade	1.5	59
5	F	39	R Status post traumatic	Gabapentin	2	17
6	F	48	R Status post surgery	Oxycodon	2	59
7	F	39	L Status post traumatic	-	3	47
8	F	62	L Status post breast cancer	-	2	30
9	H	37	L Status post traumatic	Bupivacaine blockade	0.5	62
10	F	54	L Idiopathic pain		12	63
11	F	53	L & R Idiopathic pain	Gabapentin	14	28
12	*H*	*49*	*L & R Status post surgery*	*Gabapentin*	*2*	*Not Completed*
13	H	53	R Status post traumatic & post breast cancer	Bupivacaine blockade, Capsaicin, Gabapentin	2	28
14	F	51	L Idiopathic pain		1	34
15	F	39	R Status post thyroid cancer	-	0.5	53

F, female; M, male; L, left; R, right. *In italic: NNP excluded* (*n*=5)
t_0, at the day of the initial testing; MPQ, McGill Pain Questionnaire
[1] Post traumatic as: car crash (*n*=2), intimate partner violence (*n*=2), boots kicks in the back during Bosnia war (*n*=1), violent sneezing (*n*=1), parapente crash (*n*=1), etc.
[2] Post surgery as: thoracotomy (*n*=9), cholecystectomy (*n*=5), post breast implant (*n*=2), foraminectomy, C_6-C_7 (*n*=1), post liver transplantation (*n*=1), etc.

Patient			Diagnosis	Treatment	Pain duration (years)	t_0 pain intensity MPQ (%)
Nb.	F/M	Age (years)				
16	H	46	R Status post traumatic	Naltrexone	5.5	25
17	H	44	L Status post surgery	Clonazepam	1	45
18	F	47	R Status post surgery	Gabapentin	1	31
19	H	61	L Status post surgery	Gabapentin	1	36
20	F	44	R Status post surgery	Clonazepam, Amitriptyline	0.5	33
21	F	51	R Status post breast cancer	Bupivacaine blockade, Amitriptyline	1	43
22	F	56	R Status post traumatic	Duloxetine	3.5	67
23	F	39	R Status post surgery	-	11	33
24	F	58	L & R Status post breast cancer	Gabapentin	1	61
25	F	24	L Anorexic polyneuro-Pathy	-	0.5	53
26	F	29	L Status post surgery	Tramadol	1	36
27	F	46	L Status post breast cancer	Gabapentin	2	60
28	H	52	L Status post surgery	Oxycodon, Clonozepam	43.5	36
29	F	72	L & R Status post surgery	-	0.5	22
30	F	44	R Status post traumatic	Tramadol	3	52
31	F	58	L Status post-herpetic	Pregabalin	0.5	5
32	F	25	R Status post traumatic	Oxycodon	6	74
33	F	48	L & R Status post surgery	Oxycodon	3.5	86
34	F	68	L Skeletal hyperosthosis	-	4.5	41
35	F	50	R Status post surgery	Gabapentin	30	67
36	F	71	R Status post-herpetic	Tramadol	3.5	45

F, female; M, male; L, left; R, right. *In italic: NNP excluded* (*n*=5)
t_0, at the day of the initial testing; MPQ, McGill Pain Questionnaire

Patient			Diagnosis	Treatment	Pain duration (years)	t_0 pain intensity MPQ (%)
Nb.	F/M	Age (years)				
37	F	40	L & R Status post traumatic	Gabapentin	5	73
38	F	47	R Status post surgery	Codeine	1.5	38
39	F	45	L & R Status post surgery	Pregabalin	1.5	62
40	F	40	L Status post traumatic	Gabapentin	5	20
41	F	33	L & R Status post surgery	Oxycodons	16	72
42	F	56	R Status post surgery	Pregabalin	0.5	47
43	F	46	L Status post surgery	Clonazepam	0.5	22
44	F	61	L Status post traumatic	SCS	4.5	64
45[4]	F	45	L & R Status post traumatic	Pregabalin	1.5	34
46	*H*	*34*	*L Status post surgery*	*-*	15	*Not Completed*
47	F	25	L Status post traumatic	Pregabalin	0.5	31
48	F	41	R Status post surgery	-	2.5	52
49	H	45	R Status post-herpetic	Bupivacaine blockade, Topical lidocaine	2	66
50	F	16	R Fibromyalgia	Topical lidocaine, trimipramine	2	31
51	F	57	R Status post surgery	Morphine	0.5	25

F, female; M, male; L, left; R, right. *In italic: NNP excluded* (*n*=5)
SCS: Spinal Cord Stimulation
t_0, at the day of the initial testing; MPQ, McGill Pain Questionnaire

[4] Desfoux, N., Al-Khodairy, A. & Spicher, C.J. (2008). Névralgie dorso-intercostale avec allodynie mécanique: Diminution rapide de douleurs neuropathiques chroniques par rééducation sensitive. *e-News Somatosens Rehab, 5*(1), 10-32. http://www.unifr.ch/neuro/rouiller/somesthesie/enews2008/e-News%205%281%29.pdf#page=10 (16/01/02)

Patient			Diagnosis	Treatment	Pain duration (years)	t_0 pain intensity MPQ (%)
Nb.	F/M	Age (years)				
52	F	20	L Status post surgery	Pregabalin	2.5	59
53	F	46	L & R lumbo-costovertebral syndrome	Oxycodon, trimipramine	20	42
54	F	47	L Status post traumatic	Tramadol	0.5	77
55	F	73	R Status post surgery	Duloxetine	0.5	22
56	F	17	L & R Status post surgery	Pregabalin	1	75
57	H	33	R Status post traumatic	Tramadol	0.5	25
58	F	17	R Status post surgery	-	2	27
59	H	61	L & R Status post traumatic	Pregabalin	0.5	38
60	H	61	R Status post surgery	Oxycodon, trimipramine	5	45
61	H	51	L Status post-herpetic	Gabapentin	0.5	41
62	F	38	R Status post traumatic	Pregabalin	0.5	51
63	F	26	L Status post traumatic	-	1	44
64	*H*	*33*	*L Status post surgery*	*Pregabalin*	*4*	*Not Completed*
65	*F*	*58*	*R Status post surgery*	*Neurontin*	*4*	*Not Completed*
66	F	19	L Status post surgery	-	2	31
67	*F*	*22*	*L & R Paraplegia*	*Pregabalin*	*4.5*	*62*
68[5]	F	35	L Status post surgery	Pregabalin	2.5	27
69	F	44	R Cervical syndrome	-	43	69
70	F	50	R Status post surgery	Gabapentin	0.5	44
71	F	64	L Status post surgery	Carbamazepin	0.5	60

F, female; M, male; L, left; R, right. *In italic: NNP excluded* (*n*=5)
t_0, at the day of the initial testing; MPQ, McGill Pain Questionnaire

[5] Desfoux, N., Fehlmann, P., de Reynier, J.-C. & Spicher, C.J. (2009). Névralgie dorso-intercosto-brachiale incessante avec allodynie mécanique : Fait clinique d'une diminution rapide de douleurs neuropathiques chroniques par rééducation sensitive. *e-News Somatosens Rehab, 6*(3), 105-127 : http://www.unifr.ch/neuro/rouiller/somesthesie/enews2009/e-News%206%283%29.pdf#page=18 (16/01/02).