

Allergic contact dermatitis caused by acrylic acid used in transcutaneous electrical nervous stimulation

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Transcutaneous electrical nervous stimulation (TENS) is an effective therapy for chronic lower back pain, and has few side effects as compared with pharmacological treatment (1, 2). Electrodes are patched onto the skin, and an electrical current running between these inhibits the neural conduction of pain stimulation. The electrodes are self-adhesive and stay on the skin for up to several days, and can therefore cause both irritant and allergic contact dermatitis.

Case Report

An 81-year-old man was referred to us with erythema, superficial erosions, haemorrhagic crusts and some petechiae on the lower back at the site where TENS had been applied continuously for the last 3 years to treat his chronic lower back pain (Fig. 1a). The symptoms first appeared 14 months after the start of treatment. Since then, a total of six different TENS electrodes have been prescribed, all of them causing the same symptoms. The TENS device was switched on continuously during the day but not at night, although the electrodes stayed on the skin. The TENS electrodes prescribed were: Flexibele Elektroden (Klinerva, Ankeveen, The Netherlands), Klinerva Silver Electrode, Klinerva Stimtrode (Model ST50505) (Klinerva), Dura-stick[®] plus (Ref. 42198), Dura-stick[®] (Ref. 42191), and Dura-stick[®] premium (Ref. 42209) (DJO Global, Guildford, UK).

The patient was patch tested with our extended European baseline series (TRUE Test[®] panels 1 and 2;

SmartPractice Europe, Barsbüttel, Germany), supplemented with additional chamber-loaded allergens and a (meth)acrylates series (Chemotechnique Diagnostics, Vellinge, Sweden), tested in Van der Bend chambers (Van der Bend, Brielle, The Netherlands) attached to the back with Fixomull stretch[®] (BSN Medical, Hamburg, Germany). Additionally, five of the six electrodes were patch tested 'as is', without an electrical current. One of the six, Klinerva Silver Electrode, was no longer in production, and could therefore not be patch tested. A 'use test' (with electrical current) was performed with four of the five electrodes on the lower back. The TENS devices were turned off during the night to reflect real-life conditions. The patch tests and electrodes were applied on the back for 2 days under occlusion, and readings were performed on day (D) 3 and D7, according to the guidelines of the ICDRG/ESCD (3). The results are shown in Table 1 and Figure S1. The patient had weak positive reactions to several (meth)acrylates, and strong positive reactions to four of the five tested TENS electrodes, but not to Flexibele Elektroden.

Material data safety sheets (MSDSs) of all electrodes were retrieved, and showed that the same adhesive gel was used in Klinerva Stimtrode, Dura-stick[®], Dura-stick[®] plus and Dura-stick[®] Premium: Multistick[®] Hydrogel. The composition was as follows: glycerol (glycerin) (non-tallow), water, and poly(acrylate) copolymer (CAS no. 28062-44-4; acrylic acid-*N*-vinylpyrrolidone copolymer). The data sheet did not mention the presence of any of the (meth)acrylates to which our patient was sensitized. Our hypothesis was that, despite this fact, there could still be traces of (meth)acrylates present in the adhesive layer. The MSDS for Flexibele Elektroden showed that no (meth)acrylates were present, and we postulated that the patient most likely had developed irritant contact dermatitis initially. Another TENS electrode without (meth)acrylates was prescribed: Dura-stick premium Blue (PALS[®] Platinum Blue Electrode with Blue Hydrogel). The

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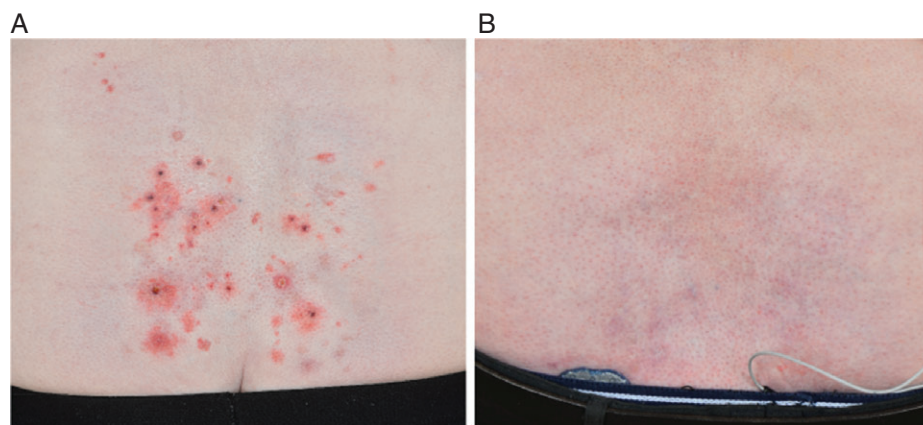


Fig. 1. (a) Itchy rash on the lower back with erythema, superficial erosions, haemorrhagic crusts, and some petechiae. (b) Skin lesions on the lower back disappeared after switching to the Dura-stick premium Blue transcutaneous electrical nervous stimulation electrodes.

Table 1. Patch test results for electrodes 'as is' and electrodes 'use test' (with electrical current applied), the positive reactions to the (meth)acrylates series, and results for the acetone extracts, the thin-layer chromatograms (TLCs), glycerol (10.0% aq.), and acrylic acid (0.1% pet.), as assessed according to the guidelines of the ESCD/ICDRG

	Day 2	Day 3	Day 7
Electrodes 'as is'			
Flexibele Elektroden	NR	–	–
Klinerva Stimtrode	NR	+++	+++
Dura-stick® plus	NR	++	++
Dura-stick®	NR	+++	+++
Dura-stick® premium	NR	++	++
Electrodes 'use test'			
Flexibele Elektroden	NR	–	–
Klinerva Stimtrode	NR	+++	+++
Dura-stick® plus	NR	+++	+++
Dura-stick®	NR	+++	+++
(Meth)acrylates series (positive reactions)			
2-Hydroxyethyl acrylate 0.1% pet.	NR	++	+
2-Hydroxypropyl acrylate 0.1% pet.	NR	+	+
2-Hydroxyethyl methacrylate 2.0% pet.	NR	+	+
Ethyleneglycol dimethacrylate 2.0% pet.	NR	+	+
1,4-Butanediol diacrylate 0.1% pet.	NR	+	+
Diethyleneglycol diacrylate 0.1% pet.	NR	+	+
Acetone extracts, TLCs, and ingredients			
1. Dura-stick® plus extract	–	–	–
2. Stimtrode extract	–	–	–
3. Dura-stick® extract	–	–	–
4. Dura-stick® premium extract	–	–	–
Mixture of electrodes 1–4, acetone extract, non-evaporated	?+	++	+
Mixture of electrodes 1–4, acetone extract, evaporated	++	+++	++
TLC strip, non-evaporated	–	–	–
TLC strip, evaporated	–	–	–
Glycerol 10.0% aq.	–	–	–
Acrylic acid 0.1% pet.	?+	++	+++

NR, no reading performed; –, negative; ?+, doubtful reaction.

ingredients according to the MSDS were: polyethylene glycol, water, magnesium acetate, and polyvinylpyrrolidone (CAS no. 9003-39-8). The skin lesions disappeared completely (Fig. 1b).

To ascertain whether there were any (meth)acrylates present in Multistick® Hydrogel, and to identify the true culprit allergen, additional patch testing was performed with acetone extracts of the electrodes, thin-layer chromatograms (TLCs), and the ingredients according to the MSDS. Non-evaporated extracts of each electrode containing Multistick® Hydrogel on its own and combined as a mix were prepared in acetone, and an evaporated extract of all electrodes combined (mix) in acetone was also prepared. Extraction was performed with an ultrasonic bath, and the supernatant was concentrated with a vacuum evaporator (4). Two TLCs were prepared, one by application of 100 µl of the non-evaporated mix, and the other by application of 60 µl of the evaporated mix, and then separated on silica gel (5). The mobile phase was 50:50 heptane/ethyl acetate. Of the ingredients, acrylic acid (CAS no. 79-10-7) was patch tested 0.1% pet., and glycerol (CAS no. 56-81-5) was patch tested 10% aq. The extracts, acrylic acid, glycerol and TLCs were applied for 48 h, and read on D2, D3, and D7 (Table 1). Both extracts of the mixes and acrylic acid 0.1% pet. (Fig. 2) gave positive results, but the TLCs gave negative results. Subsequently, one Dura-stick® premium electrode was analysed for the presence of acrylic acid by the use of high-performance liquid chromatography coupled with ultraviolet detection (HPLC-UV). The electrode was extracted in the mobile phase used for the analysis of acrylic acid (20:80 acetonitrile/water with 0.1% phosphoric acid). HPLC-UV of this extract showed an undisturbed spectrum of acrylic acid, and quantification

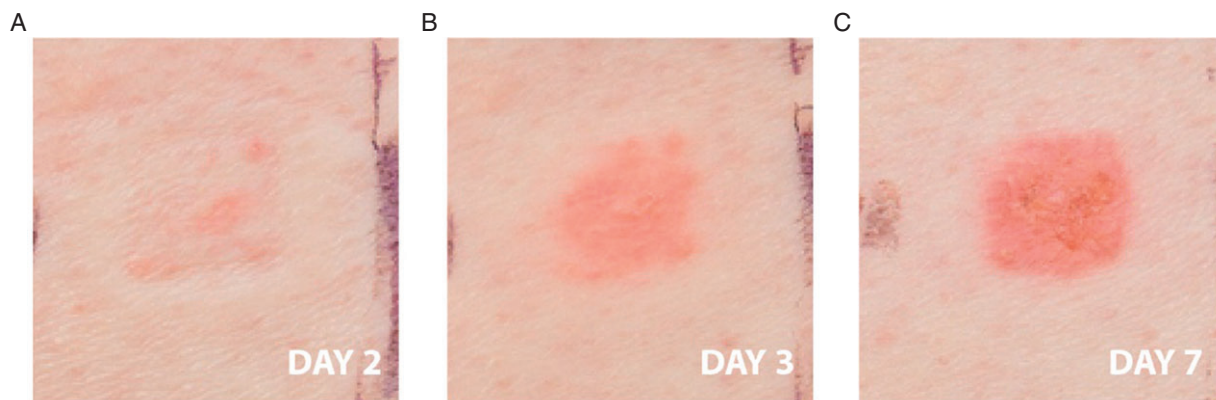


Fig. 2. Patch test reactions to acrylic acid 0.1% pet. on day 2 (a), day 3 (b), and day 7 (c), showing a clear crescendo pattern.

showed that there was $\sim 57 \mu\text{g}$ of acrylic acid per gram of electrode. When calculated for the electrode when it was attached to the back, the release of acrylic acid from the electrode was $\sim 7.6 \mu\text{g}/\text{cm}^2$ (the patch test preparation of 0.1% acrylic acid corresponds to a dose of $\sim 39 \mu\text{g}/\text{cm}^2$).

Discussion

Previously, 4 cases of contact allergy to (meth)acrylates used in TENS have been reported (6–8). Prior to that, there were reported cases of allergic contact dermatitis caused by propylene glycol in a conductive gel used for TENS application (9, 10), 1 case report of contact allergy to nickel in a TENS electrode (11), and 1 case report of TENS contact dermatitis in which the allergen was not identified (12). When (meth)acrylates were identified as the causative allergens, this was based on information from the MSDS or from the producer.

In the present case report, the initial patch test showed (weak) positive reactions to (meth)acrylates. Although the MSDS only showed the presence of a poly(acrylate) copolymer, it has been shown through analysis of products containing acrylate polymers that the MSDS often provides incomplete information regarding the acrylate monomers present in the product (13). Our initial hypothesis was that traces of (meth)acrylate monomers were the likely cause of the skin symptoms; however, further testing with acetone extracts and the ingredients according to the MSDS provided new information. The patient developed a +++ reaction to acrylic acid, showing a clear crescendo pattern. Positive reactions were also seen to the extracts of multiple electrodes combined, but not to extracts of the individual electrodes. This can be explained by the differences in concentrations of

substances between the different extracts. It is interesting to note that the TLCs did not give positive reactions, even though they were prepared from the extracts that did give positive reactions. This might be explained by the volatile nature of (meth)acrylates (14). Another explanation might be a too low surface concentration of acrylic acid on the TLC plate, as it showed poor resolution on TLCs, without a well-defined spot for this substance.

HPLC-UV of a sample of the Dura-stick® premium electrode (containing Multistick® Hydrogel) showed that acrylic acid was indeed present in the adhesive, and we therefore believe that acrylic acid was the culprit allergen. The MSDS of Dura-stick® premium Blue, which the patient tolerated, showed that it did not contain any acrylic acid. Acrylic acid was also shown to be the culprit allergen in a recent case report of allergic contact dermatitis caused by the adhesive layer of electrocardiogram electrodes (15).

The release per cm^2 of acrylic acid in the electrode was lower than that of the concentration in pet. with which the patient was patch tested ($7.6 \mu\text{g}/\text{cm}^2$ as compared with $39 \mu\text{g}/\text{cm}^2$). However, given the fact that 0.1% acrylic acid gave a +++ reaction, it is not unlikely that the elicitation threshold might even be $< 7.6 \mu\text{g}/\text{cm}^2$. Furthermore, the electrodes were attached to the lower back continuously, whereas the patch test is applied for only 48 h. The positive reactions to the various (meth)acrylates might be explained as cross-reactions, although a recent patch test study did not show any cross-reactions between acrylic acid and (meth)acrylates (16). Another explanation might be previous sensitization, even though a detailed history of the patient did not show exposure to products containing (meth)acrylates.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Patch test results of the electrodes at day 3. The top row shows the patch test results of the electrodes

‘as is’. The bottom row shows the patch test results of the ‘use test’; i.e., electrodes exposed with electrical current. A1/2, Flexibele Elektroden; B1/2, Klinerva Stimtrode; C1/2, Dura-stick® plus; D1/2, Dura-stick®; E, Dura-stick® premium.

Table S1. Further positive cases with their test results.

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