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Erythemas caused by electrodes while monitoring neuromuscular blockade: three cases

Kumi Nakamura[1], Naoko Terasawa[2], Keisuke Konishi[2], Atsunari Kino[1], Izumi Nakanishi[1], Hiroshi Sumida[1], Tomoyuki Yamakawa[1], Rie Kitamura[1], Kayoko Tsutsumi[3], and Setsuko Toyoda[3]

[1] Department of Anesthesia, Kyoto City Hospital, 1-2 Mibu-Higashitakadacho, Nakagyo-ku, Kyoto 604-8845, Japan
[2] Department of Dermatology, Kyoto City Hospital, Kyoto, Japan
[3] Department of Nursing, Kyoto City Hospital, Kyoto, Japan

Abstract Skin erythemas formed in three patients during surgery at the sites where negative electrodes had been attached to stimulate the ulnar nerve for a neuromuscular transmission monitor (Relaxograph). The patients were all women, aged 52, 62, and 74 years, and general anesthesia lasted 8 h 20 min, 4 h 50 min, and 8 h 45 min, respectively. The electrodes used were disposable ECG electrodes in the first two patients and one designed for a neuromuscular monitor in the third; all were carbon-coated and then covered with gel. However, when the electrodes were detached from the lesion, they all showed loss or damage of the carbon coating under the gel. We recommend balancing the merit of monitoring with the risk of complications, even when applying an apparently safe, noninvasive monitor.

Key words Neuromuscular monitoring · Electrode · Complication · Skin · Erythema · Burn

Disposable, pregelled electrocardiogram (ECG) electrodes have long been used for peripheral nerve stimulation without reports of severe skin lesions [1–3]. However, using such electrodes attached to a Relaxograph neuromuscular transmission monitor (Datex-Ohmeda, Louisville, KY, USA), we recently observed three cases of skin erythema, one of which was followed by formation of a bulla.

Case 1

A 52-year-old woman, 148 cm tall and weighing 48 kg, underwent 8 h 20 min of general anesthesia combined with epidural anesthesia for subtotal resection and reconstruction of the esophagus. For neuromuscular monitoring, five disposable ECG electrode pads (Ambu, Copenhagen, Denmark) (Fig. 1A and B) were applied before induction of general anesthesia: two on the wrist for left ulnar nerve stimulation (A and B in Fig. 2), two on the palm to record evoked electric activity of the abductor digiti minimi manus muscle (C and D in Fig. 2), and the fifth on the radial side of the wrist as a reference electrode (E in Fig. 2). The ECG pad used was rectangular (19 mm × 38 mm) and consisted of a 10-mm diameter electrode coated with carbon to obtain electrical conductance, a rectangular adhesive tape, and gel that fully covered the patient's side of the pad (including the adhesive tape). Train-of-four (TOF) stimulation consisting of four successive stimulations at 0.5-s intervals, at a current determined automatically by the device, was applied every 20 s. The width of each stimulus was determined to be 0.1 ms by the device. The evoked electrical activity of the muscle was recorded by the Relaxograph during the whole course of general anesthesia.

On transfer of the patient to the recovery room, an erythema, with almost the same shape and size as the electrode, was found on the wrist where the negative electrode (B in Fig. 2) had been applied for ulnar nerve stimulation. The surface of the electrode that had been removed from this lesion was colored gray with brownish material on the edge, although other electrodes were black, as usual. A vesicle formed on the erythema on the second to the fifth postoperative days (POD). Application of corticosteroid ointment was started on the third POD. The pigmentation on the lesion was not completely restored until the patient was discharged from the hospital (30th POD). We asked the agency of the Relaxograph (IMI, Saitama, Japan) for a careful examination of the device, including any possible leakage of electric currents, but they reported that they did not find any fault in the device.

Address correspondence to: K. Nakamura
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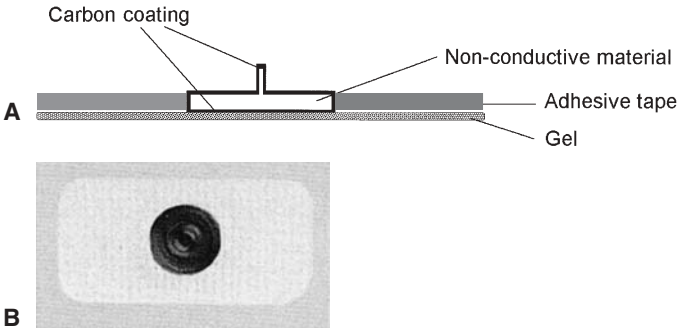

Fig. 1. Electrode pads. The ECG electrode pad that we used for neuromuscular monitoring in the first two patients, shown in sagittal section (**A**) and a photograph (**B**)

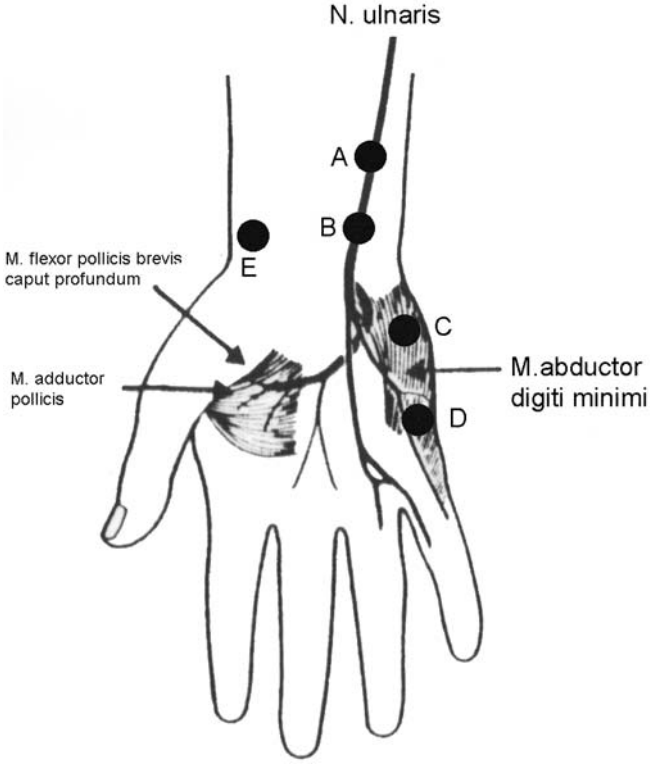

Fig. 2. Placement of the electrodes. Two electrodes were placed for left ulnar nerve stimulation (a positive electrode at *A* and a negative one at *B*); two more to record the evoked electric activity of the abductor digiti minimi manus muscle (*C* and *D*); and the fifth on the radial side of the wrist (*E*) as a reference electrode

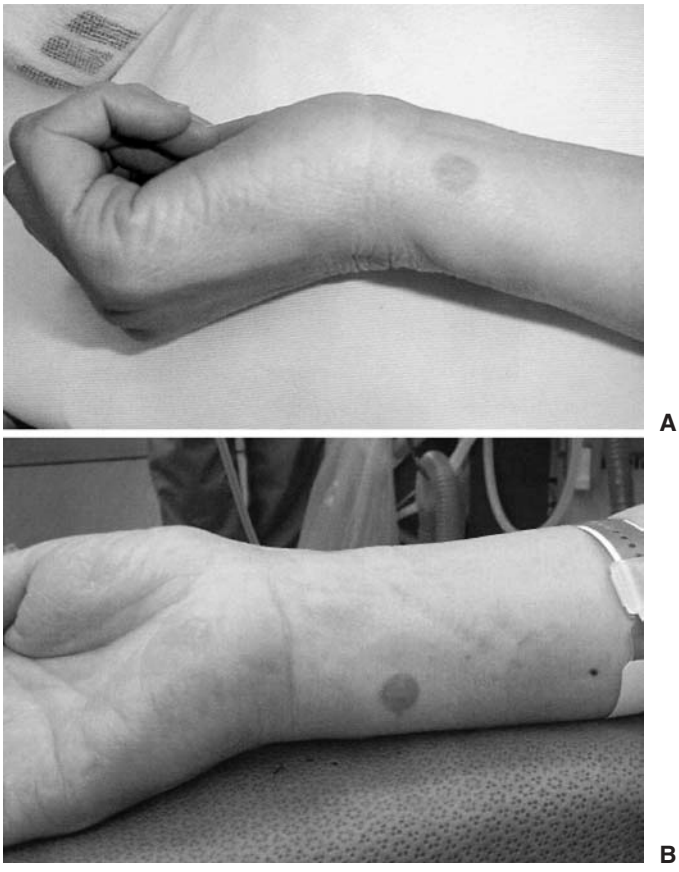

Fig. 3. Skin lesions of the second patient on the first postoperative day (**A**) and of the third patient on the day of operation (**B**)

Case 2

A 62-year-old woman, 154 cm tall and weighing 43 kg, underwent 4 h 50 min of general anesthesia for right radical mastectomy 22 days after the first case. The ECG electrode pads (Ambu) were applied in the same manner as in the first case, and TOF stimulation with the current, duration, and interval determined automatically by the device were applied to monitor neuromuscular transmission using the same Relaxograph device as in the first case. The anesthetic course was uneventful. After tracheal extubation and on removal of the electrode pads, a circular erythema almost the same size as the electrode was found at the site of the negative electrode for ulnar nerve stimulation (Fig. 3A). The electrode that was detached from this lesion showed disappearance of the black carbon coating and had brownish material on the edge, but was still covered with gel. Corticosteroid ointment was applied immediately over the lesion. The skin lesion faded gradually without any formation of vesicles.

Case 3

A 74-year-old woman, 148 cm tall and weighing 56 kg, underwent 8 h 45 min of general anesthesia combined with epidural anesthesia for subtotal resection and reconstruction of the esophagus, 42 days after the second case. In this case, pads, circular with pregelled electrodes approximately 10 mm in diameter, supplied for

the neuromuscular monitor by the manufacturer (NMT electrode, Datex-Ohmeda), were applied in the same manner as in the previous cases. The same Relaxograph device was used in the same automatic manner for TOF monitoring as in the previous two cases. The threshold current automatically determined and recorded was 45 mA in this case. On removal of the electrode pads, a circular erythema almost the same size as the electrode was found under a negative stimulating electrode, as in the two cases described above (Fig. 3B). The electrode detached from this lesion, although covered with gel, showed an irregular surface coating under the gel. Corticosteroid ointment was applied immediately over the skin lesion. The skin lesion of the patient started to fade on the third POD and was completely restored on POD 20. The Relaxograph used in these three cases is now being examined by the manufacturer.

Discussion

Surface burns caused by a neuromuscular monitor were first documented by Lippmann and Fields in 1974 [4]. They applied metal ball electrodes to the skin over the median nerve to induce tetanic stimulation, and produced erythemas with punctate and vesicular lesions. Myyra et al. [5], using similar instruments, produced erythematous macules that faded within 45 min. Kopman [1] has shown that disposable ECG electrodes covered with gel can be safer than the metal tools that were previously used for peripheral nerve stimulation. The pregelled electrodes insure wider and more stable contact with the skin.

Furthermore, TOF stimulation has now nearly replaced classic methods of neuromuscular assessment, such as tetanus stimulation, as it provides easy quantitative evaluation of the effects of relaxants and provides comfort and safety for the patient. Dorsch and Dorsch [3] reported that ECG electrodes can be used safely for TOF measurement when the stimulation current is determined depending on the threshold for each case. With the use of the Relaxograph, the current needed to induce the maximal response (threshold) is first measured in calibration, and thereafter 120% of the threshold current (supramaximal current) with 0.1 ms duration is applied throughout the monitoring. If maximal stimulation cannot be obtained by the current up to 60 mA, its built-in safety feature interrupts the calibrating current. Thus, it is clear that the Relaxograph is one of the safest neuromuscular monitoring devices, as long as it has no fault.

The disposable electrodes we used were properly covered with the gel, as recommended by previous authors [1,2], and were attached firmly to the skin. However, the carbon coating under the gel of the negative stimulating electrode (Fig. 1) had deteriorated or almost disappeared during use. All three cases occurred in the same operating room with the use of the same Relaxograph device. Although this device had been used without problems otherwise, including more than 50 cases even in the period between the first and third cases, we must speculate that this device had some fault that had damaged the carbon coating of the negative-stimulating electrode and skin of the patient, particularly during long operations.

The skin lesions could have been caused by the pressure between the electrode and the skin; by contact dermatitis caused by one of the materials constituting the ECG pad, such as the gel [6]; or by burns caused by heat or electrolysis [7]. We cannot deny the possibility that the pressure produced by the belt keeping the patient's arm in position, in addition to the pad attaching the electrode firmly to the skin, might have facilitated both erythema formation and the disappearance of the electrode carbon coating. Contact dermatitis caused by the gel [6] cannot explain why the lesion was circular and the same diameter as the electrode, whereas the area covered by the gel was rectangular or bigger, nor the coincidental loss of the carbon coating from the electrode. Irritative or allergic contact dermatitis elicited by the inner material that should have been coated by carbon may be more likely, if the gel did not protect its contact with the skin in these cases. However, more importantly, the material inside the coating of this type of electrode is not electrically conductive, as shown in Fig. 1. Therefore, following the deterioration of the coating, the increased electrical resistance probably induced mild heating capable of causing burns during long and tight contact with the skin.

Neuromuscular monitoring with the TOF mode is now considered a safe, noninvasive procedure and is used frequently during general anesthesia. However, the possibility of complications, even though minor, cannot be completely abolished and should be considered. Conditions with a higher possibility of developing complications might include long periods of anesthesia, malnutrition, or female patients [8], or situations in which monitoring electrodes are hardly observed during operation because of their position, as in these cases. We therefore recommend considering the balance of the merit of monitoring and the risk of complications even when applying an apparently safe, noninvasive monitor.

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