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A Complication of Intraoperative Facial Nerve Monitoring: Facial Skin Burns

*André Haenggeli, †Michel Richter, *Willy Lehmann, and *Pavel Dulguerov

**Department of Otorhinolaryngology Head and Neck Surgery, †Division of Maxillo-Facial Surgery, Geneva University Hospital, Geneva, Switzerland*

Objective: To report on three cases of severe facial skin burns resulting from intraoperative facial nerve monitoring in patients undergoing parotidectomies.
Study Design: This study is a retrospective case review.
Setting: A tertiary referral center.
Patients: This study includes three patients who underwent parotidectomies with concurrent facial nerve monitoring.
Results: Facial skin burns were proven to result from a technical defect of the intraoperative facial nerve monitoring device. Burns were sustained at electrode insertion sites and their extent was related to the duration of monitoring. The most probable explanation of these burns is electrolysis.
Conclusions: Successful retracing of technical defaults with biomedical engineers at the device manufacturer have led to the upgrade of the facial nerve monitor apparatus. The benefits of facial nerve monitoring largely outweigh the fortuitous occurrence of skin burns reported in this study. Therefore, this complication should not represent a drawback to the use of facial nerve monitoring. **Key Words**: Facial nerve—Intraoperative nerve monitoring—Burns—Parotidectomy—Electrolysis—Direct current.
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Intraoperative facial nerve monitoring (FNM) is based on the recording of electromyographic activity (EMG) generated by mechanical or electrical stimulation of the facial nerve. It has been developed to prevent nerve injury during surgical procedures in which the facial nerve is at particular risk (1).

The most widely used technique relies on the placement of 3-needle electrodes per monitoring channel, inserted in facial muscles, ipsilateral to the operated side. Each set (channel) consists of two active and one ground electrode. This configuration is a differential recording because the output reflects the difference between the signals of the two active electrodes. Usually two monitoring channels are available in commercial devices. Because of the functional and esthetic importance of the periocular and perioral regions, the most often monitored muscles are the orbicularis oculi and the orbicularis oris muscles. Ground electrodes are most often placed in the paranasal area. To provide the surgeon with immediate feedback information, the output of the evoked electromyographic activity is visible on a screen display or audible over a loudspeaker.

Facial nerve monitoring has become an integral adjunct in facial nerve identification and preservation in patients undergoing major neurotologic procedures (2,3). Conditions in which intraoperative facial nerve monitoring seems to meet large approval for routine use are skull base procedures such as cerebellopontine angle tumor resections, congenital aural atresia repairs, or cases of revision parotid surgery (4–7). Some training centers seem to favor the technique for teaching purposes (8). Although FNM has been proven to help preserve the facial nerve during surgical procedures potentially placing the nerve at risk, the method is not considered as the standard of care for routine otologic surgery or uncomplicated parotid gland surgery (9), and therefore, the precise role of FNM remains a matter of debate.

While the discussion has been on the reliance of the method, no direct complication of FNM has been reported. This paper describes a potential and unexpected hazard of this technique.

Address correspondence and reprint requests to Dr. Pavel Dulguerov, Department of Otorhinolaryngology - Head and Neck Surgery, Geneva University Hospital, Rue Micheli-du-Crest 24, CH-1211 Geneva 4, Switzerland.

CASE REPORTS

Case 1

A 47-year-old woman underwent a total parotidectomy, radical neck dissection, partial composite mandibular resection, and reconstruction with a fibula free flap and pectoralis major myocutaneous flap for an osteosarcoma of the left mandible. Intraoperative FNM was conducted using the Neurosign 100 (MAGSTIM Company Limited, U.K.) apparatus with habitual electrode configuration. After this 18-hour procedure, the surgeons discovered large skin injuries at the electrode implantation sites. Skin defects were 2 × 3 cm in width (Fig. 1). Electrical skin burns were

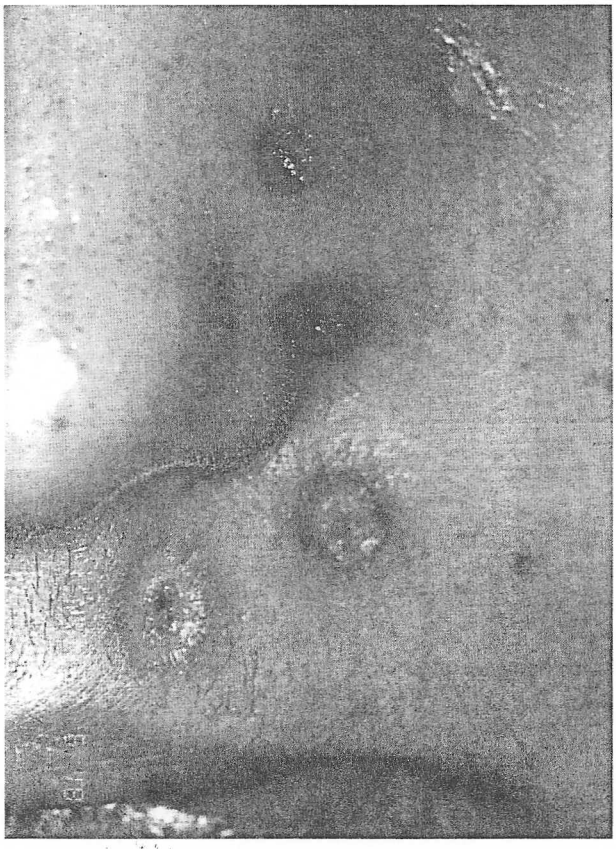

FIG. 1. Photograph of Case 1, 5 days after parotidectomy, radical neck dissection, partial composite mandibular resection, and reconstruction with a fibula free flap and pectoralis major myocutaneous flap for an osteosarcoma of the left mandible. Large skin burns located at facial nerve monitoring electrode implantation sites were found at the end of the 18-hour procedure. Skin defects were 2 cm in width, more marked and ulcerated at reference electrode sites (paranasal area).

attributed to a short circuit caused by prolonged contact with soaked draping. Postoperative outcome was marked by infection of the lesions, requiring a course of intravenous antibiotics and repeated wound debridement of necrotic material. Further healing finally generated marked indurated fibrotic lesions at each electrode implantation site.

Case 2

A 37-year-old man underwent a subtotal parotidectomy for chronic parotitis. Usual FNM was used. At the end of the surgery (3 hours), facial skin burns centered on all six electrode implantation sites were present (Fig. 2). During the following 8 months, the lesions regressed only partially. The patient may request corrective surgery.

Case 3 (after revision of the apparatus)

A 50-year-old woman underwent a subtotal parotidectomy and a supraomohyoid selective neck dissection for a low-grade mucoepidermoid carcinoma. A revised monitor was used, and for additional safety, the electrode implantation sites were exposed in the operating field and regularly inspected during the procedure. After 20 minutes, greyish skin discolorations were noticed, mainly centered on the ground electrode sites (Fig. 3). The skin injuries healed while the resulting scar tissue remained visible. Excision was performed 6 months after the primary operation, with a satisfactory cosmetic result.

DISCUSSION

Unexpected discovery of third degree electrical facial skin burns at the completion of a surgical procedure was encountered in two consecutive patients. In the first case, facial burns were attributed to a short circuit caused by electrode contact with blood-soaked surgical draping. The same apparatus was used 3 days later by another surgical team during a routine parotidectomy, as is customary in our institution. After a second patient suffered facial burns, the apparatus was sent to the distributor for technical revision and repair. No defects were detected through a detailed inspection. Furthermore, possible electrical interference between monitor and cauthery unit cables was measured and tested on a piece of beef, in the operating room, simulating surgical conditions. No burns were noted and results remained inconclusive.

For the third case, electrode sites were kept directly exposed in the operating field so that the needles could be removed if signs of tissue damage were noticed. Lesions

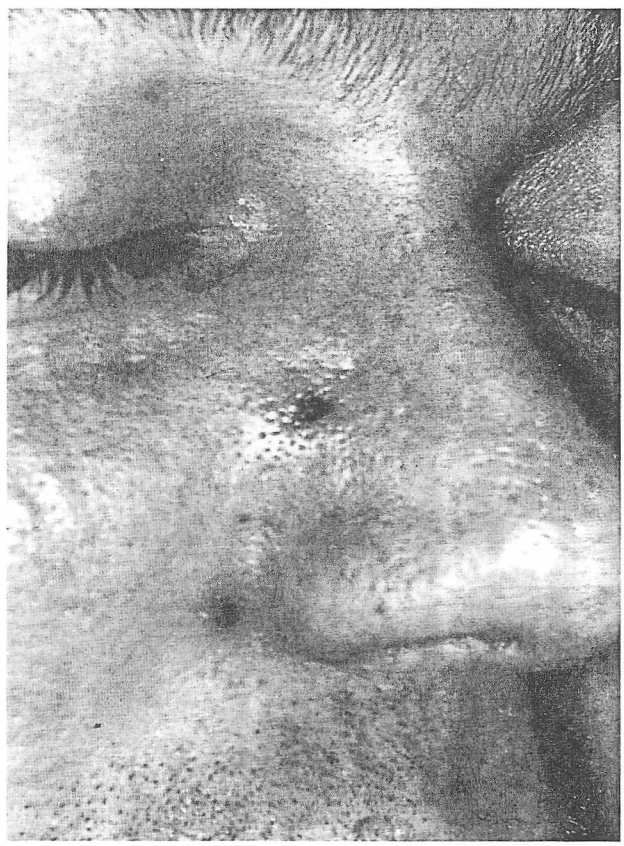

FIG. 2. Photograph of Case 2, 3 days after parotidectomy performed in conjunction with intraoperative facial nerve monitoring. The facial skin burns centered on electrode implantation sites are demonstrated. The most severe lesions were found in the paranasal area where the reference electrodes were inserted (see text).

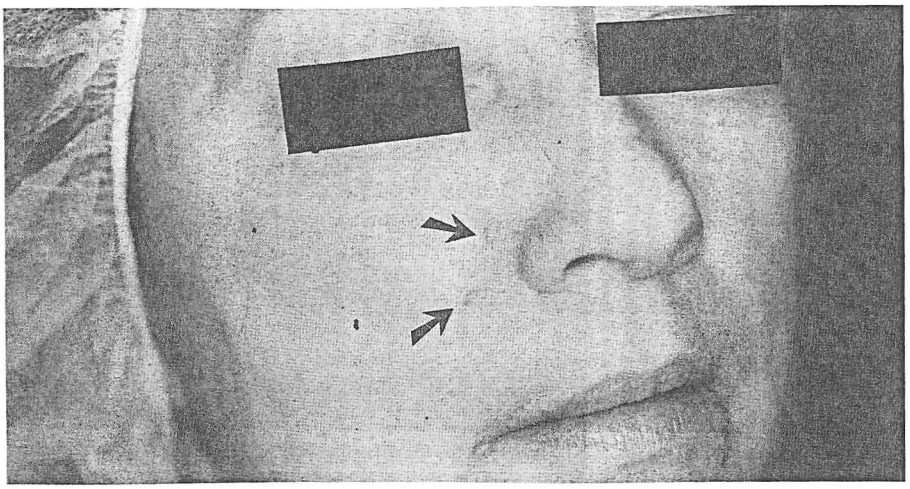

FIG. 3. Photograph of Case 3 after parotidectomy for a low-grade mucoepidermoid carcinoma. Facial nerve monitoring was interrupted after 20 minutes because of the occurrence of facial skin burns at electrode implantation sites. Status 6 months after the initial procedure, at the time of cosmetic repair. Scar tissue is mainly visible at both sites in the paranasal area.

occurring for the third time, the FNM apparatus was then sent to the manufacturing company. A defect (break) in the cable between the monitor's main component and the preamplifier pod was discovered. The wire involved was the 15-volt power supply line to the input amplifiers, resulting in an intermittent leakage of DC currents from the differential amplifiers into the electrode leads. A voltage potential of −14.7 volts was measured between the inputs V_1 and V_2 (Fig. 4) and ground electrodes. This is an open circuit measure with the differential amplifier leads directly connected to a potentiometer. Resulting currents could be quantified by placing a 200-ohm resistor to simulate body tissue between the inputs V_1 and V_2: 0.7 mA was measured on the first channel and 1.2 mA on the second channel. This is a voltage drop measurement in a closed circuit and calculations cannot be derived directly from Ohm's law but should take the entire circuit into consideration.

Skin lesions were centered on all six needle electrode implantation sites, although the most severe injuries were observed in the paranasal area, where the reference electrodes were inserted. This is explained by the fact that the current flowing through the reference electrode is the sum of the currents flowing through each active electrode. A time factor seems relevant because burns were much more extended and deeper in the first patient with longest duration of operation.

Bodily damage secondary to electricity is a direct consequence from the flow of electric currents in tissues and results in thermal tissue damage and electrical breakdown of cell membranes (10). The extent of injury is proportional to current, voltage, duration of exposure, cellular architecture, and current mode (AC or DC). AC, the more common cause of electrical injury, is more dangerous than DC because AC can produce cardiac arrest, coma, and the

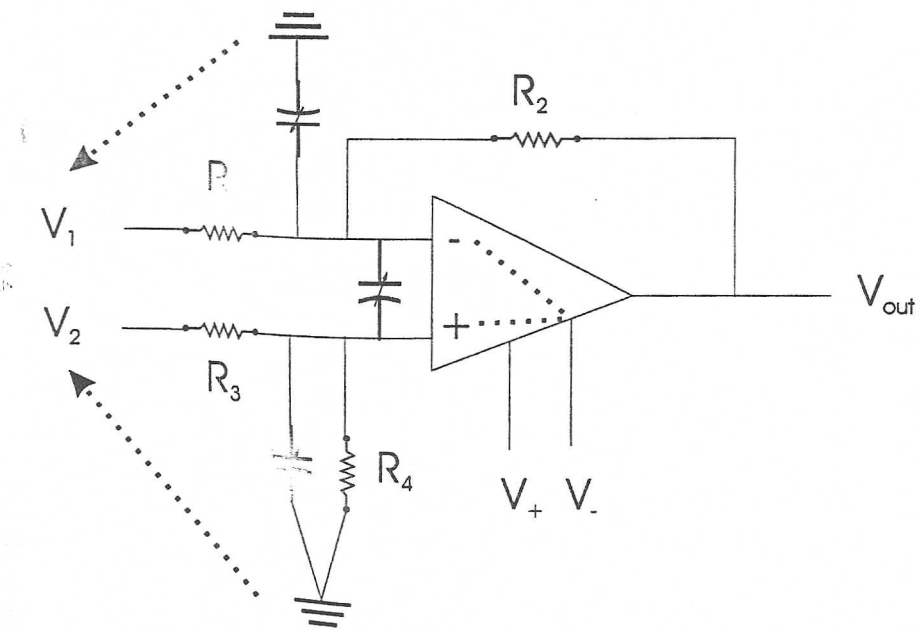

FIG. 4. Drawing of the circuit of the input stage of the Neurosign 100 apparatus. It is essentially the circuit of a differential amplifier with input voltages V_1 and $_2$, output voltage Vout, and power supply voltages V_+ and V.. Power supply voltages are usually ±15 V. The defect was a break of the positive power supply wire to the amplifier, resulting in a fixed DC voltage at both inputs (V_1 and V_2), shown by the dashed line within the amplifier symbol. The current will than flow within the patient's tissues, shown by dashed arrowed lines between the ground electrodes (W) and the V_1 and V_2 electrodes.

victim may be unable to release the source of electricity. In general, AC current injuries involve high voltages, result from the thermal dissipation of electrical energy, and can be caused by four mechanisms: direct contact, conduction, arc, and secondary ignition (10).

The mechanism of tissue damages induced by DC currents has been less well studied and described. Three previous case reports of low-voltage DC current burns could be found in the literature. All three cases involved a malfunctioning electronic biomedical devices that generated hidden DC currents on body tissues: an electrosurgical unit (11), an electrical nerve stimulator used by anesthesiologists (12), and an external pacemaker used during cardiac bypass surgery (13). As in our case, in these previous reports, voltages of approximately 10 V and currents in the 5 to 10 mA range were measured. In these cases the tissue damage could be reproduced in experimental settings. We attribute our failed attempts to reproduce the lesions to the intermittent malfunctioning of our device.

The physiopathologic mechanism postulated in these cases was electrolysis. The low DC voltage acts as a battery and results in electrochemical reactions at the electrode-tissue interface. Toxic compounds are generated at the anode (chlorine gas, hydrochloric acid, oxide, oxygen gas) and cathode (sodium hydroxide, hydrogen gas, free electron radicals) (11). These reactions result in large local changes in pH and in the production of toxic compounds that could be responsible for the observed tissue necrosis.

It is doubtless that the burns sustained by these patients were caused by the low-voltage DC potentials generated by the faulty connection within the monitoring apparatus. The question arises as to the cause, which produced the damage. Although a manufacturing defect cannot be ruled out completely, careless manipulation of cables and preamplifier pod sockets by inadvertent operating theater personnel seems to be the most likely hypothesis. As a result of the misfortune of our patients, the manufacturer has placed additional electronic circuits in the preamplifier to prevent similar mishappenings to patients. A virtual ground has been created to isolate the patient electrodes from similar possible leakage currents to the patient.

The manufacturer has informed Neurosign owners of the problem and the circuit modification, which is available free of charge. To date, approximately 50% of all Neurosign 100 monitoring devices have been upgraded to this safer design. This modification is also incorporated in newer facial nerve monitor models.

The complication described should not be a deterrent to the use of facial nerve monitoring devices. We have used the same apparatus during more than 100 surgical procedures, without other problems. Furthermore, the unit has given complete satisfaction since being repaired. This report is intended to inform other institutions, should they encounter similar complications.

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