ELECTROCHEMICAL BURNS: A RISK WITH MYOELECTRIC PROSTHESES

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ABSTRACT

The authors describe their experience with incidents of minor trauma, to users of myoelectric prostheses, which is thought to be associated with electrochemical burns arising from a dc potential existing between electrodes. These incidents have occurred over the period 1968 - 1996, in Winnipeg, Toronto and Fredericton. A possible mechanism is suggested for electrochemical burns where a dc potential of one volt or more exists. Finally, recommendations are made for increased vigilance concerning this possible problem.

INTRODUCTION

Most persons consider the low dc voltages used in powered prostheses (usually 6 V, but ranging from 3 to 24 V) to be harmless, and common experience supports this view. However, it is not intended that any electric potential be applied to the amputee. When equipment malfunction or damage to the prosthesis causes even a small potential to be applied to the skin over an extended period of time, harm can result.

In such circumstances it appears possible that persons using myoelectric prostheses are at risk of electrochemical burns. Incidents have been observed by the authors of minor trauma, ranging from redness to blisters, with discomfort described as mild to severe. In all cases healing was uncomplicated following removal of the prosthesis, and subsequent use of the prosthesis following replacement of the electrode module was without incident. In some, but not all cases, it was possible to measure a dc potential between the electrode contact under which the problem occurred and another electrode contact, after the prosthesis had been removed from the amputee.

The authors are concerned that this risk to users of prostheses is not widely known, and that incidents may be mis-diagnosed as contact sensitivities, allergic reactions, etc. The purpose of this paper is to urge prosthetists and others responsible for provision of powered prostheses to exercise particular caution to avoid the possibility of chronic exposure of amputees to such dc potentials.

BACKGROUND

There is little evidence in published literature of concern about possible harm from low voltage dc sources. One striking exception is a paper by Cooper et al [1]. They reported third degree burns under nerve stimulator electrodes following an elective coronary revascularization procedure. (Note that this procedure extended over a short period of time, compared to routine

use of prostheses). Careful investigation led to the conclusion that these burns were caused by an accidental contact between the stimulator battery case and the anesthesia machine case, which established a nine volt dc potential between the stimulator electrodes and the (grounded) dispursive electrode of the electrosurgical unit. The actual burn was considered to have been caused by presence of a strong alkaline solution on the skin surface, resulting from electrolysis of saline at the electrode-to-skin interfaces, (the electrolysis products include sodium hydroxide). Consultation by the authors confirmed that less than two volts would be sufficient to cause electrolysis in such a situation [2].

INCIDENTS IN PROSTHETICS

Each of the authors has experienced incidents of trauma attributed to electrochemical burns, of which four are reported here.

One such incident occurred in 1967, where a below-elbow amputee (female, age about 20 yrs) reported discomfort under the "ground" electrode contact of a myoelectric prosthesis. Upon examination, symptoms included redness and blistering. Replacement of the module from stock only exacerbated the problem. Both myoelectric control modules were examined and both were found to have a dc potential between the active and ground electrode terminals. This potential was measurable with a common multitester. Further investigation by the supplier attributed the problem to unauthorized substitution of a low resistivity encapsulating material during manufacture of the batch including both units used by this patient. After allowing adequate time for the skin to heal, the patient reported no difficulty with a second replacement myoelectric control module from a different production batch, which had been tested carefully and was free of this defect.

A second incident, in 1985, involved a three year old male below-elbow amputee. The prosthesis had been used for a considerable time without incident. A few days following a socket adjustment the amputee's mother reported "burn marks" under the ground electrode. Investigation revealed some blistering of the skin: no defect was found in the control system, which was nonetheless replaced. It was suspected that the control system was distorted mechanically in assembling the prosthesis, resulting in a temporary connection between the electrodes and the power circuits. After allowing a week for healing, no further problem was reported.

A third incident occurred in 1988, involving a 4 year old female amputee. "Burns" were observed under the ground contacts of one active electrode, with blistering. No problem was detected with the active electrode assembly, which was returned to the manufacturer and replaced. After time for healing, no further problem was reported by this amputee.

A fourth incident, in 1996, involved a 45 year old male amputee. This case differed in that "burns" were reported under all contacts of an active electrode assembly together with a "tingling sensation" down to the wrist. No electrical problem was found, and the electrode assembly was returned to the manufacturer and replaced. No further problem has been reported.

IDENTIFYING ELECTROCHEMICAL BURNS

The electrochemical burns observed by the authors are characterized by localized irritation at the site of electrical contact to the skin. Usually only one electrical contact is affected, although this is not always true, as illustrated by the fourth incident described above. The skin may be slightly inflamed and red. In most cases small water blisters are observed

It is essential that overall skin condition, prosthesis fit, and the presence of possible irritants be considered before assuming that an electrochemical burn has occurred.

In several cases of electrochemical burns, the situation was misdiagnosed and the amputees were supplied with steroid creams while continuing to use their prostheses, thereby aggravating the condition and delaying its resolution.

GENERAL CONCERNS IN PROSTHETICS

The prosthetics incidents described above are attributed to defects in commercial myoelectric control hardware. The incident which occurred during a surgical procedure resulted from careless mounting of a battery case during modification of a commercial stimulator, and may be an apt model for possible problems in prosthetics. As prosthetists are faced with requirements to pack an increasing amount of hardware into limited space, one of the most common solutions is innovative rearrangement of commercial battery packs or substitution of an ad hoc assembly of individual battery cells. There is a significant risk of accidental contact between such arrangements and some grounded metal part of the prosthesis. This risk becomes greater with more complex prostheses, such as those involving several powered functions

Indeed, at least one proposal has been published recommending a wiring technique which is very likely to cause chronic contact with low voltage dc supply. In this proposal [3], Moseley and Baron recommend using snap fasteners to hinge a humeral cuff supporting the battery and to carry current to a below-elbow prosthesis. The intention is to move the weight of the battery proximally. However, the full dc supply voltage appears between the two snap fasteners, both of which could easily come in contact with the amputee's skin.

As to the myoelectric control systems themselves, despite careful design and the vigilance of the manufacturer there is some very slight risk that a dc voltage will appear between electrode contacts in any system. It is not possible to eliminate this risk, but it is essential that clinical personnel recognize the symptoms and respond appropriately.

RECOMMENDATIONS

The first recommendation is for vigilance so that problems similar to those described above are identified early and possible electrical causes are considered from the outset.

The second recommendation is for great caution when modifying myoelectric components or creating custom installations of any kind in powered prostheses. Accidental

contact between metallic components and the skin should be prevented, even when those metallic components are not supposed to be connected to electric potentials.

When an electrochemical burn is suspected, the prosthesis must not be worn until the skin is well healed. The myoelectric control system and power supply must be examined carefully and tested for evidence of any dc potential between any metal parts which are in contact with the skin. Even if no electrical potential is found, it is recommended that the complete electrical system be replaced: intermittent malfunctions are notoriously difficult to locate, and may be causing the problem. It is recommended that suspect system components be returned to the manufacturer, with a full description of the problem.

POSTSCRIPT

The literature on electrochemical burns at electrode sites is sparse, as noted earlier. However, in reviewing the literature on electrode problems generally, a problem of potential interest to persons working with myoelectric control systems research and development was noted. This is a condition known as calcinosis cutis, a heterotopic calcification in the skin which can be caused by contact with calcium-containing electrode creams or gels, particularly when skin preparation involves abrasion. Usually associated with EEG examinations, at least one case of calcinosis cutis has been reported following EMG monitoring [4]. Because of the possibility of calcinosis cutis, it would seem prudent to choose electrode creams or gels which do not contain calcium salts. This precaution could also be applied in selecting pre-gelled electrodes. It should be noted that myoelectric control systems, which use dry metallic electrode contacts, are not a potential source of calcinosis cutis.

REFERENCES

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