

## CASE REPORT

# Radiofrequency electrocution (196 MHz)

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Radiofrequency (RF) electrocutions are uncommon. A case of electrocution at 196 MHz is presented partly because there are no previous reports with frequencies as high as this, and partly to assist in safety standard setting. A 53-year-old technician received two brief exposures to both hands of 2A current at 196 MHz. He did not experience shock or burn. Progressively over the next days and months he developed joint pains in the hands, wrists and elbows, altered temperature and touch sensation and parasthesiae. Extensive investigation found no frank neurological abnormality, but there were changes in temperature perception in the palms and a difference in temperature between hands. His symptoms were partly alleviated with ultra-sound therapy, phenoxybenzamine and glyceryl trinitrate patches locally applied, but after several months he continues to have some symptoms. The biophysics and clinical aspects are discussed. It is postulated that there was mainly surface flow of current and the micro-vasculature was effected. Differences to 50 Hz electrocution are noted. Electrocution at 196 MHz, even in the absence of burns may cause long-term morbidity to which physicians should be alerted. Safety standards should consider protection from electrocution at these frequencies.

*Key words:* Electrocution; radiofrequency; ultra-sound therapy.

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## INTRODUCTION

Radiofrequency (RF) electrocution injuries are uncommon and knowledge of their health effects is limited. A contact current, *i.e.*, electrocution, occurs when there is physical contact between a person and an object at a different electrical potential, resulting in a flow of current. This differs from the effects of induced current flow when a body part is exposed to an RF field which, if sufficiently intense causes current to flow with resulting heating and burns, *e.g.*, a hand entering a (faulty) micro-wave oven.

A recent statement by the International Commission on Non-Ionizing Radiation Protection<sup>1</sup> which reviewed the literature on health effects of RF fields and currents noted that in developing safety standards for electrocution an upper limit of 110 MHz was imposed 'by a lack of data on higher frequencies rather than by an absence of effects'.<sup>1</sup> The intent of this paper is to report an electrocution accident at 196 MHz and to note the symptoms which differ from the usual reports of shock and/or burns.<sup>2</sup>

## CASE REPORT

A previously well 53-year-old technician was changing a switch ('U-link') in a Phase Alternating Line (PAL) TV transmitter. He was removing the switch with both hands and holding his elbows close to his chest when there was a blue flash for 2–3 secs. This movement was repeated once more with a further brief flash occurring. He felt no shock or heating or burn and was able to walk away. He was wearing safety shoes with insulation. (Subsequently an electrical fault was found and a burn was noticed on the switch.)

When seen four months later he gave the following history:

- He was shaken but otherwise well after the accident. The next day a wart on his hand split open and subsequently healed.
- Day 2: he noted a symmetrical, 3–4 cm diameter pink rash bilaterally over his lower rib cage. It lasted 24 hours. He related it to the position of his elbows against his chest when removing the switch.
- Day 5: he noticed aches and puffy swelling about the metacarpal-phalangeal joints (mc-p joints) of both hands.
- Day 7: the aches had affected his wrists and elbows.

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- Day 9: he felt severe pain in his hands and found it painful to press buttons at work. He also began to feel fatigue and slept for 1½ hours in the afternoon which was unusual for him.
- The aches in his fingers, wrists and elbows persisted and he had an X-ray and ultrasound (10 MHz) imaging study of his hands. The results showed no abnormality. However he noticed relief within 2 hours of the ultrasound and this lasted 24 hours. One week later he commenced physiotherapy with ultrasound and had further relief.
- Day 19: he noticed mild headaches which were generalized, non-pulsating, not aggravated by light and which he felt were not due to anxiety. They lasted for 1–2 weeks. He rarely has headaches.
- He also noticed impaired dexterity in that he felt like he was wearing 'leather' gloves when handling screws. This had improved by 4 months so it felt more like wearing thin 'rubber' gloves.
- 2 months: he began to notice a sensation of 'pins and needles' when holding a phone for about 15 minutes (in either hand). This returned to normal in a few minutes after ceasing to hold the phone.
- 2.5 months: he noticed changes in temperature sensation. For example he often checks a diesel coolant pipeline with a thermostat set for 105°F, but this now felt abnormally hot to his left hand. Similarly when feeling the temperature of water under the shower with either hand it hurt 'like sunburn'.
- 4 months: when examined he complained of abnormal temperature sensation; recurrent aches in his middle and ring fingers, mc-p joints, wrists and elbows (not shoulders) of both arms and pins and needles when holding the phone. He obtained relief from his joint pain by ultrasound therapy.

His health otherwise was good. There was no history of significant exposure to neurotoxic chemicals.

Clinical examination was unremarkable. His blood pressure was 150/100 (but had always been 'mildly raised' according to his GP). Investigations including full blood examination and electrolytes, sugar and X-ray of his hands found no abnormalities. An ophthalmic examination found no abnormality.

The neurophysiological tests performed on this patient, as recommended by the Consensus Conference on Neuropathy 1992<sup>3</sup> included conventional nerve conduction studies of larger myelinated fibres, cold and warm thermal acuity measurements for small myelinated and unmyelinated sensory fibres, respectively<sup>4</sup> and current perception tests (CPT) which measure perceptual thresholds for all classes of sensory fibres.<sup>5</sup> Function of large (myelinated) nerves by conventional nerve conduction studies and CPT were normal. However, his perceptual acuity for warm and cold on the palm was increased compared to the anterior aspect of the wrist. There was also a temperature difference between the dorsum of the hands, 32.4°C on the right and 34.5°C on the left, measured by emission thermography (Biotherm C600M) and the asymmetry was increased after bilateral cold water 20°C immersion for 2 min. Such a pattern

suggests abnormal vascular reactivity affecting hand skin temperature.

- Eight months after the accident he reported shooting pains in the forearms, a relapse of painful swelling of the mc-p joints and upper forearm and diminution of touch sensation. His finger dexterity was still impaired (like wearing rubber gloves).
- On review at 11 months his palms were blotchy, and swollen in some interdigital spaces on one day and others the next day. Pulses and blood flow into the hands were normal. A microvascular disturbance was postulated and he was trialed on phenoxybenzamine and had relief of symptoms, but unacceptable side effects developed. Subsequently glyceryl trinitrate patches cut into small portions and locally applied to the hand have given partial relief. Clonidine was ineffective.
- Twenty months after the accident he has tactile and dexterity problems and persisting pains.

## DISCUSSION

RF electrocution accidents are uncommon. First the biophysics will be discussed and then the clinical aspects.

The patient sustained two brief episodes of current flow in his forearms and across his chest. His forearms, with both hands clenched on the switch would be close to 40 cm in length, which is about one-quarter of the wavelength at 196 MHz (1.5 m) in free space. This would lead to maximum voltage near the chest where his elbows were held. The red rash on the chest occurring on day 2 was likely to be an axon reflex arising from this stimulus.

The current flows to the forearms have been estimated. Both hands were holding the switch with the elbows against the chest. The switch had a potential of about 700V (196 MHz) and it is assumed 100V was lost in arcing and another 100V lost in capacitance giving a voltage to the arms of 500V. His resistance has been measured '*in situ*' using a network analyzer with low voltages applied, to be a load of 220 ohm (P. Lawson, personal communication). By Ohms law ( $I = V/R$ ) the current flow around his arms and chest was about 2A. (The power along his arms was approximately 1.1KW.) He also wore safety boots which lessened flows to earth. There was no DC or 50Hz in the circuit.

196 MHz current flow is mainly over the surface ('skin effect') rather than inside a conductor, unlike 50Hz current. The likelihood of burn marks depends on the surface area in contact with the conductor. In this case both hands presented a large surface over the metal surfaces of the switch and hence there were minimal burns. The absence of burns may partly explain the absence of shock sensation. The finding of an abnormality in the patient's right index finger but not his left may have been due to the left index being in contact with the release lever which was insulated from the switch.

The surface current flow in superficial veins and capillaries could have affected the endothelium which in turn may have caused vasodilatation or constriction. The 'pins

and needles' felt on holding the phone may be due to a relative ischaemia arising in labile blood vessels. The benefits of the ultrasound therapy may be due to reversing vasoconstriction, but the later swelling in the arms may have been due to vasodilation. The benefits of phenoxybenzamine and nitrates but not clonidine confirm the suggested vascular basis for his symptoms.

The 'blue flash' was a plasma arc which would have briefly exposed him to 196 MHz, harmonics and transients. He did not feel warm afterwards which suggests his exposure was brief or not great. Exposure to diverse radiofrequency radiations arising from the 'blue flash' possibly caused his episodes of headaches and fatigue (now ceased). This condition has been called 'microwave sickness'.

A psychosomatic basis of his symptoms is unlikely in view of the rash occurring on his chest, the demonstrated thermal abnormalities, the swelling of his hands noted by us and the specific response to vascular therapy.

This case differs from a previous report<sup>7</sup> of RF shock and burn where the patient sustained burns but evidently no long-term sequelae which are a feature of the present case. This is possibly because the wavelengths were different; in the previous case the frequency (700 KHz) has wavelengths 100 m long and so there was less coupling to the body than in this present patient's arms. The previous case also had brief arcing, whereas in this present case the patient had a good hold of the conductor facilitating current flow through the arms and chest for a few seconds. There were also some differences in harmonics, with the former having AM speech modulations and this present case having PAL TV modulations.

It is interesting to note that this present case of electrocution, which resulted in a large current flow across the chest, was not lethal, whereas a 50 Hz current would likely have been. The signal was modulated including 50 Hz AM pulses. It is postulated the flow across the chest was surface, not visceral and hence the heart was not involved.

Present safety standards, such as in Australia and New Zealand, limit contact current to 100 mA for frequencies up to 3 MHz.<sup>6</sup> This is primarily to avoid shock and burn. There is a lack of information about the effects of electrocution at higher frequencies, so this report provides some relevant information. This report also indicates that shock and burn are not the only effects that need to be considered by clinicians and that long-term debilitating effects may occur.

## CONCLUSION

This case of RF (196 MHz) electrocution shows that whilst death does not occur even with large current flows, significant morbidity may result. In this case there was altered threshold for sensation, joint pains, loss of dexterity and parasthesias in the hands for several months. A vascular basis for the pathophysiology is likely.

Clinicians should be aware that unusual symptoms may arise in association with RF current accidents, even in the absence of shock and burns.

The case is also relevant to the consideration of frequency limits when setting safety standards regarding RF currents. Consideration should be given to extending the standard to well above 110 MHz to at least 200 MHz. Safety standards should refer to 'electrocution' rather than 'shock and burn' since neither shock and/or burn are necessary for injury to occur and hence these terms are misleading.

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