Microwave oven electromagnetic radiation injury to a paediatric hand: a case report

J Rademan
Department of Orthopaedic Surgery, Frere Hospital, South Africa
Corresponding author, email: jacobusrademan@yahoo.com

Injuries sustained from microwave oven electromagnetic radiation are rare and very few cases have been documented. Most microwave oven-related injuries that present to the emergency department, are related to thermal injuries sustained from the oven's contents. Although seemingly similar in presentation, the mechanism of injury and biological effects on tissue are quite different. An eight-year-old boy sustained partial- and full-thickness burns to his right hand after exposure to electromagnetic radiation from a microwave oven. The patient's wounds were debrided and a full-thickness thickness skin graft was applied at a later stage. After extensive occupational therapy and regular check-ups, the patient regained good range of motion in the hand. The skin graft had a 100% take with minimal stiffness over the first web space and an area of anaesthesia was present over the skin graft.

Keywords: electromagnetic radiation, hand trauma, paediatrics, burns

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Introduction

Microwave ovens emit microwaves, which through a process of intense molecular vibration friction, will produce heat to cook the contents. Electromagnetic radiation is subdivided according to wave frequency into radio waves, microwaves, terahertz radiation, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays.[1,2] Electromagnetic radiation behaviour depends on its wavelength. Higher frequencies will have shorter wavelengths and lower frequencies will have longer wavelengths (Figure 1). Microwave radiation forms part of non-ionising radiation, appearing in the high-frequency range of the electromagnetic spectrum (between infrared and radio frequencies ranging from 10 to 100 000 MHz).[3] In recent years, microwave ovens have become more affordable and readily available with most households or workplaces having access to them.[4] Microwave ovens have the advantage over conventional heating systems as microwave energy provides faster cooking times, requires smaller space and requires less energy.[4] The basic components of an electromagnetic wave consist of two parts: an electric field and a magnetic field.[5] The interaction of these electromagnetic radiation components on the human biological system is of significant interest to researchers and physicians, as their alteration and modification of the biological design of the human body cause a wide variety of pathophysiological changes.[5] The magnetic field created by the microwave has little effect on the human body and is usually of less concern.[6] The electric field, on the other hand, has a far greater interaction with our biological design, in particular with water molecules.[7] Once the electric field interacts with the water molecule, a dipole is formed. The heat produced by the electric field results from

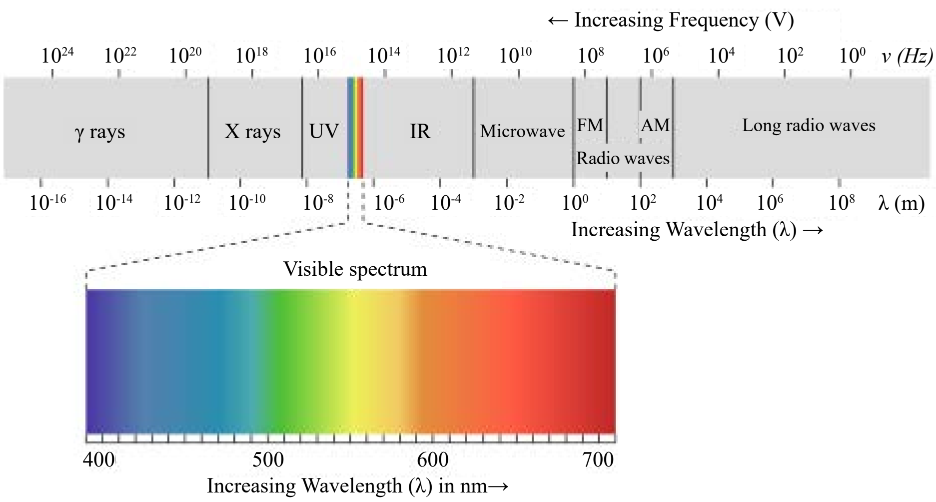

Figure 1: The electromagnetic spectrum (Adapted from the New World Encyclopaedia[16])

dipole rotation and relaxation as the dipole attempts to align itself with the rapidly alternating electric field.[7] This constant relaxation and rotation leads to friction from molecular motion, causing heat production.[8,9] The amount of absorption or reflection of this energy will depend on the dielectric properties of each of the materials it comes in contact with. The depth of tissue penetration and damage will depend on the dielectric properties of these tissues and the frequency of the microwave.[7] Each of the components of the human tissue (i.e. bone, nerves, arteries, muscles, etc.) have a different dielectric property.[6] This makes studying and predicting the outcome of microwaves on the human biological system difficult.[10] Electromagnetic radiation from microwaves causes tissue damage mostly by heat production, as their low energy source of 10⁻7 to 10⁻3 electron volts.

Varying effects of exposure to microwave radiation have been reported, from local skin burns and hyperthermia, to cataract formation, retinal damage, testicular damage and nerve damage.[11] Non-thermal damage to most of the organ systems has also been described. In vitro studies reveal that microwave radiation causes severe depression of phagocytic activity and an absolute fall in lymphocyte count on a cellular level. This seems to reverse when the insult from the electromagnetic radiation is stopped.[12] Of great importance in the rehabilitation of any patient with a burn injury, is the functionality of their central and peripheral nervous system. Several research papers have suggested that damage to Na-K-ATPase pump, or quite simply an 'overburdening' of this pump, can damage and cause loss of nerve function.[13] It is therefore imperative that emergency room physicians evaluate all exposed patients for systemic injury and ensure early speciality referral.

Case report

A previously healthy eight-year-old boy presented to the emergency room with isolated burn wounds to his right hand. The patient switched on the microwave and placed his hand into the appliance through the back panel which was removed for repairs. The duration of exposure was unknown. Primary and secondary survey according to ATLS principles was done and showed only an isolated injury to the right hand. No neurological fallout was identified. Resuscitation fluids were commenced according to parkland's formula and urine output was monitored via a trans-urethral catheter. Electrocardiography (ECG) showed no acute ischaemic changes and continuous cardiac monitoring was done. The patient was taken to theatre for debridement soon after presenting to the emergency room by the on-call orthopaedic surgeon and paediatric surgeon. Intraoperative findings showed areas of partial- and full-thickness burns to the first web space of his right hand and the base of the thumb, extending onto the thenar eminence (Figure 2). The metacarpophalangeal joint of the thumb and index finger, proximal interphalangeal joints of the index, ring and little finger had burst open. After confirming that the vitality and vascularity of the patient's hand were not threatened, the surgeons continued with the debridement and excision of the necrotic skin. The open joints were washed with normal saline, the wounds covered with petroleum gauze dressings and the hand splinted in the functional position. The fingertips were left exposed to assess for capillary refill. After the initial debridement, the patient was monitored in the ward and managed with per os analgesia, intravenous fluids and a full ward diet as tolerated. After 72 hours, the hand was reassessed in theatre by the orthopaedic surgeons. The initial defect had demarcated slightly and the excess necrotic skin was excised until healthy, bleeding tissues were encountered. This left the interosseous muscles, superficial nerves in the first web space and thenar eminence exposed. The wounds were again washed with normal saline, covered with petroleum gauze and the hand splinted in the functional position.

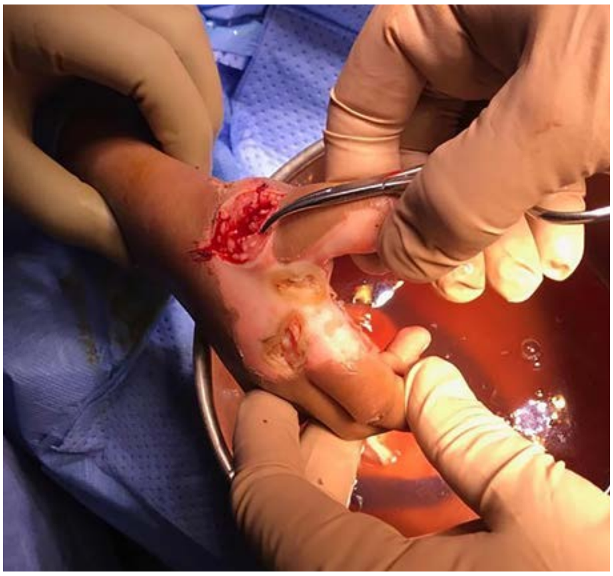

Figure 2: Hand at presentation

Figure 3: Dorsal aspect of hand after skin graft

Figure 4: Palmar aspect of hand after skin graft

The relook surgery was deemed a success, and the next step in managing this patient was getting soft tissue coverage. The patient's next wound review showed no extending demarcation and all of the exposed soft tissue was clean and healthy. A full-thickness skin graft was taken and stapled in place. The graft site was covered with petroleum gauze dressings, covered with paddings of fluffed-up gauze and the hand splinted in the functional position. The donor site was closed primarily and covered with petroleum gauze. Occupational therapy was consulted for both postoperative hand care as well as wound care. The graft site and donor site were inspected after five and seven days respectively. The graft showed no signs of necrosis and the donor site was clean. The patient was discharged home and given dates for follow-up at occupational therapy and the orthopaedic outpatient department. Subsequent follow-ups at the orthopaedic outpatient department showed the graft and donor site healing well. The extensive occupational therapy rehabilitation programme assisted the patient to regain most of the range of movement in his hand (Figures 3 and 4). The wounds over the joints healed well. A small area of anaesthesia remained over the skin graft.

Discussion

Electromagnetic radiation from microwave ovens can cause various injuries, spanning from transient pain, paraesthesia, swelling, and even skin and underlying tissue necrosis. Injuries from electromagnetic radiation itself are difficult to sustain, as microwave ovens are built to enclose the radiation. In the case of our patient, one of the safety features (i.e. the back panel) was taken off to repair the microwave. Modern microwaves have a multitude of built-in safety features to prevent accidental exposure to microwaves. To keep microwave radiation exposure to a minimum, microwave leakage may not exceed 1 mW/cm^2 at 2.5 cm from the oven at the time of manufacture and 5 mW/cm^2 during the product's life.[8] Most microwaves now also have an integrated locking mechanism that stops the electromagnetic field once the door is opened. The two independently operating interlocking switches are activated when the door latch (located near the door rims) is opened. This process implements a circuit breaker, diverting the internal power circuits to an internal neutral line. If the primary switch fails and the oven door is opened, a backup circuit will cause the oven fuse to blow, preventing any operation of the oven. The microwave screen is covered with a meshed metal screen to absorb radiation without obscuring a view into the oven. Furthermore, the doors of the oven are fitted with radiation-absorbing seals.[8]

With the back of the microwave open, some of the radiation could have escaped when the appliance was switched on, possibly decreasing the amount of damage done to the underlying structures. There was no appreciable delay in the presentation of the patient to the emergency room, initial resuscitation or time to theatre (for initial washout and debridement). Both the relook surgery and final skin grafting of the patient's hand happened without delay. A full-thickness skin graft was deemed a better option for this particular case, as it provided a slightly thicker soft tissue cover and less contracture of the graft as it healed. Superficial- and partial-thickness burns to the hand can be managed with regular dressing changes, hand splinting and rehabilitation from occupational therapy. Deeper burns (deep dermal and full-thickness burns) will require debridement and skin graft once a healthy vascular bed is available. The hand (and fingers) should be splinted in a functional position to allow graft healing (limiting movement) and prevent/limit contracture of the graft.

Conclusion

Electromagnetic radiation injuries are rare.[5] Limited data and information exist about the management of these injuries; to date, no clear-cut protocol has been developed for this. The author suggests that time to presentation, resuscitation time and initial debridement be kept to an absolute minimum. Adequate analgesia is of cardinal importance (especially when changing dressings and checking wounds).[14] Early referral to an occupational therapist or hands therapist is key. Splinting should be commenced early on to prevent excessive contraction of the skin graft and surrounding tissues. Burns injuries, and in particular injuries to hand, have monumental influences on a child's well-being and quality of life.[15] The psychological, social and physical impact of burn injuries in children is often underappreciated. It is therefore imperative that continued evaluation of safety standards, product quality and public education and awareness prevent such injuries at all costs.

Conflict of interest

The author declares no conflict of interest

ORCID

J Rademan https://orcid.org/0000-0003-0545-8785

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