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Case Report

Direct microwave burns in an infant: Description of burn characteristics, management and outcome

Eveline Bijlard [a], Naomi Ketharanathan [b,*], Suzan C.M. Cochius [b], Antien L. Mooyaart [c], Christianne van Nieuwenhoven [a]

[a] Department of Plastic Surgery, Erasmus Medical Center Sophia Children's Hospital, Rotterdam, The Netherlands
[b] Department of Pediatric Surgery, Erasmus Medical Center Sophia Children's Hospital, Rotterdam, The Netherlands
[c] Department of Pathology, Erasmus Medical Center, Rotterdam, The Netherlands

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ABSTRACT

A month old infant was directly exposed to a 900 W microwave oven for unknown duration (estimated <30 s). The infant suffered severe burns to the left arm and leg. Initial treatment involved ICU monitoring and fasciotomies of the affected extremities. After four days a forearm amputation was performed because all muscle and extensive skin areas were nonviable. Microwave burns affect water containing tissue most and tissue closest to the radiation source generates more heat. Macroscopic skin condition is a poor indicator of burn severity. Hence fasciotomies and surgical exploration are indicated in combination with initial ICU monitoring for systemic and neurologic effects. Eighteen months post-injury the child had recovered fully, the amputation healed well and there was no apparent growth disturbance of the left leg. This case demonstrates the importance of rapid and frequent wound exploration and other diagnostic modalities to identify non-ionizing radiation injury. Long term follow-up into adulthood is recommended to monitor growth disturbances or other unknown long term effects of non-ionizing radiation exposure.

1. Introduction

Microwave injuries caused by direct exposure to full microwave radiation (i.e. placement in the microwave) are rare and present with unusual patterns of thermal injury. This should trigger the clinician to query burn wound etiology if the medical history is unclear or inconsistent with the burn wound pattern at presentation. Given the circumstances under which these injuries occur and the potential severity of deep tissue injury, it is imperative one is aware of this rare etiology of pediatric burns and maintains a close collaboration with surgeons and pediatricians for clinical management. This case report details burn wound characteristics, treatment and outcome of an infant exposed directly to microwave radiation. We highlight items we feel are imperative in clinical management.

2. Case report

A 4 week old infant presented to the emergency department after suffering direct microwave oven exposure of 900 W for an uncertain duration (estimated 2–32 s) whilst laying on its right side in the microwave oven. The burns were immediately cooled with running water for 30 min. Pre-hospital fluid resuscitation was initiated. At presentation a crying, painful, tachycardic infant with peripheral vasoconstriction and a core temperature of 35.4 C was observed. Blistering burn wounds were noted on the lateral side of the left upper leg and ulnar side of the left arm with eschar on the left forearm and hand. The middle and ring finger were discolored dark purple and the little finger was blanched. There was no spontaneous movement of the left arm. The estimated burned total body surface area (TBSA) was 15%. The burns were surgically managed with fasciotomy and escharectomy of the left forearm and hand, skin releasing midlateral incisions on all fingers, and blister removal. The ulnar artery had thrombosed from elbow to wrist. The arterial arcus palmaris was unrecognizably damaged, as were all digital arteries. The thumb and index finger were supplied by the dorsal branch of the radial artery. All intrinsic muscles were severely injured, the extrinsic extensors and ulnar flexors were also affected.

In the acute phase, the patient received invasive ventilator support during the time frame of frequent wound explorations and surgical

* Corresponding author at: Erasmus Medical Center, Sophia Children's Hospital, Wytemaweg 80, Room Sp3435, 3015 CN Rotterdam, The Netherlands.
E-mail address: n.ketharanathan@erasmusmc.nl (N. Ketharanathan).

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intervention. Fluid resuscitation was commenced based on an estimated TBSA of 15%. Pain management was achieved with a continuous morphine infusion, supplemented with continuous Esketamine infusion post-amputation to prevent neuropathic pain. Furthermore, the ophthalmologist was consulted and no corneal injuries were noted. A brain MRI/MRA 5 days after the event showed no signs of injury.

One day post-injury the ulnar three digits developed progressive necrosis, the radial two remained in a hyperemic state and the burned areas developed edema. In addition, the infant developed a low body temperature and ceftriaxone was initiated. Blood cultures grew a Bacillus Megaterium and antibiotics were continued for 7 days.

Three days post-injury a second look surgery was performed; all tissues of the ulnar three digits were necrotic, the palm of the hand was necrotic at the ulnar side, the forearm muscles were almost completely necrotic, and the radius and the ulna showed osteonecrosis. It was an atypical deliquescent necrosis of the involved tissues. An amputation through the elbow was performed. Tissue was sent for histological evaluation and showed third degree skin burns with subcutaneous fat necrosis, necrotic muscles, electrolyte extravasation with edema and inflammatory reaction. Histological review of the skin flap that covered the amputation showed focal degenerative changes in the collagen. The left upper leg was much less affected and did not require additional surgical intervention. Macroscopic and microscopic burn wound evolution over the first days of admission are depicted in Fig. 1.

On follow-up the amputation wound had healed without complications. The left leg healed well with a flexion contracture of the knee that treated by serial redressing splints. Hypertrophic eczematic scars were seen 6 months after injury, without functional impairment. Child abuse investigation, legal consequences, and parental authority issues are subject to National legislation and are outside the scope of this report.

3. Discussion

Microwave ovens expose contents to non-ionizing radiation in the range of 2.4–2.5 GHz, creating an electromagnetic field (see Fig. 2). Polar molecules, like water, are rotated in line with the electrical magnetic field, which generate heat. The effects of exposure seems limited to thermal injury. There is no known cumulative carcinogenic risk of microwave radiation. The thermal effect penetrates 2–5 cm from the surface. Burns occur to tissues nearest to the emitting device and are well demarcated with no charring [1,2]. However, heating is uneven and since the skin is not involved as such, it is not indicative of the severity of injury for three reasons. First, tissues with high water content generate more heat, resulting in sparing of the subcutaneous fat layer. Second, the electromagnetic field is uneven throughout the oven due to the standing wave: instead of the peaks of the wave moving (like waves at the beach move towards the shore), parts of the wave move up or down (nodes) and parts do not move (anti nodes). This is caused by the reflection on the metallic surface of the oven. Third, the contents in an oven act as a resonance cavity for the electromagnetic field creating a thermal peak in the center. Skin and subcutaneous tissue thickness influence microwave absorption (i.e. increased thickness leads to less absorption) [3]. Microwave radiation temperature variations and subsequent tissue damage depend on thermal conductivity, power density, exposure time, and blood perfusion rate (as good vascularity dissipates generated heat) [4].

Microwave-related injuries have been reported since the introduction of consumer microwave ovens. The majority of microwave injuries are conductive burns caused by overheating or differential heating. Heat explosions have also been reported [5]. Only a few reports on direct exposure injury (i.e. placement in the microwave oven) are available, mostly dated from the early 80 s in the context of child abuse [1]. Alexander et al described 2 infants with direct microwave oven burns. One 5-week-old infant who was exposed for possibly 45–60 s sustained

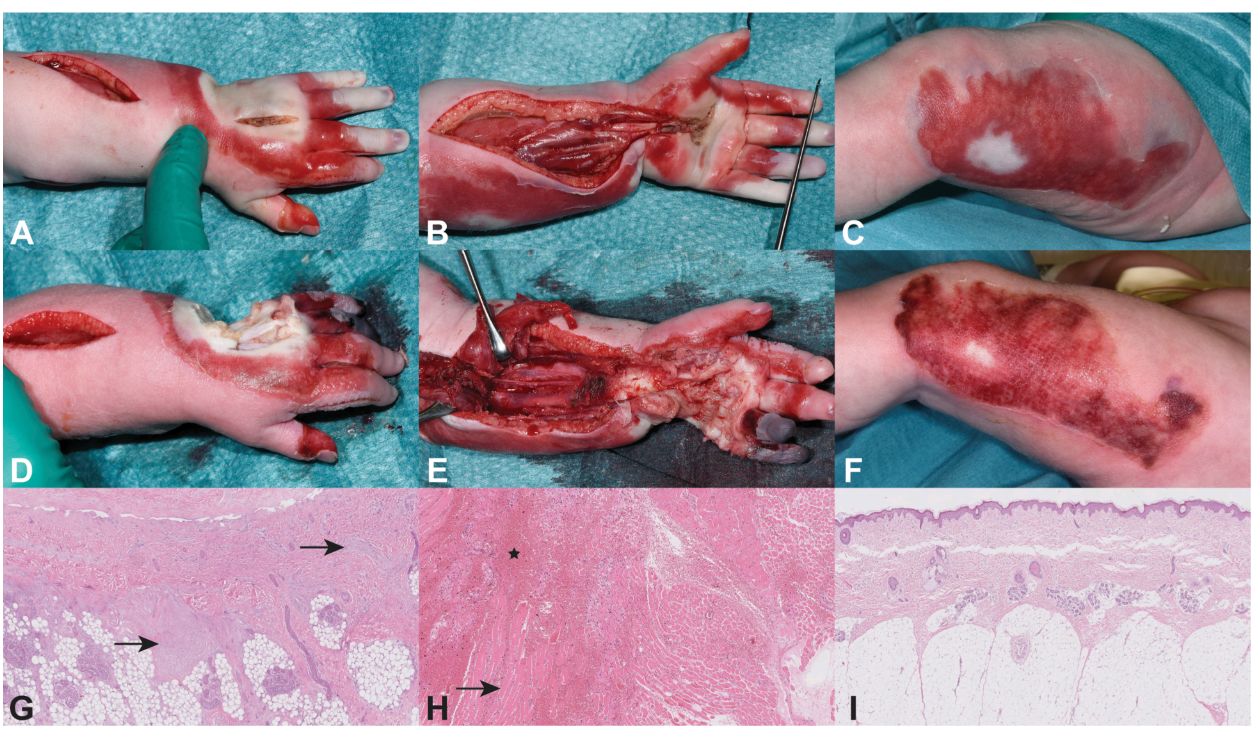

Fig. 1. Microwave burn wounds and histology on sequential exploration. Left dorsal forearm, left volar forearm, and left leg 2 h after microwave burn (A, B, and C respectively) and 3 days after microwave burn (D, E, and F respectively). Histology with hematoxylin and eosin stain with 5–10 times magnification. G. severely burned palmar skin showing large areas with loss of basophilic nuclei marked (arrows showing less purple stained nuclei). H. Flexor digitorum profundus muscle showing intramuscular erythrocytes (*) and large areas with loss of basophilic nuclei, while myocytes should have multiple nuclei (arrow). Clinically unharmed skin just proximal to the elbow that was used to cover the upper arm amputation, only focal signs of necrosis were found. I. normal skin histology without signs of necrosis.

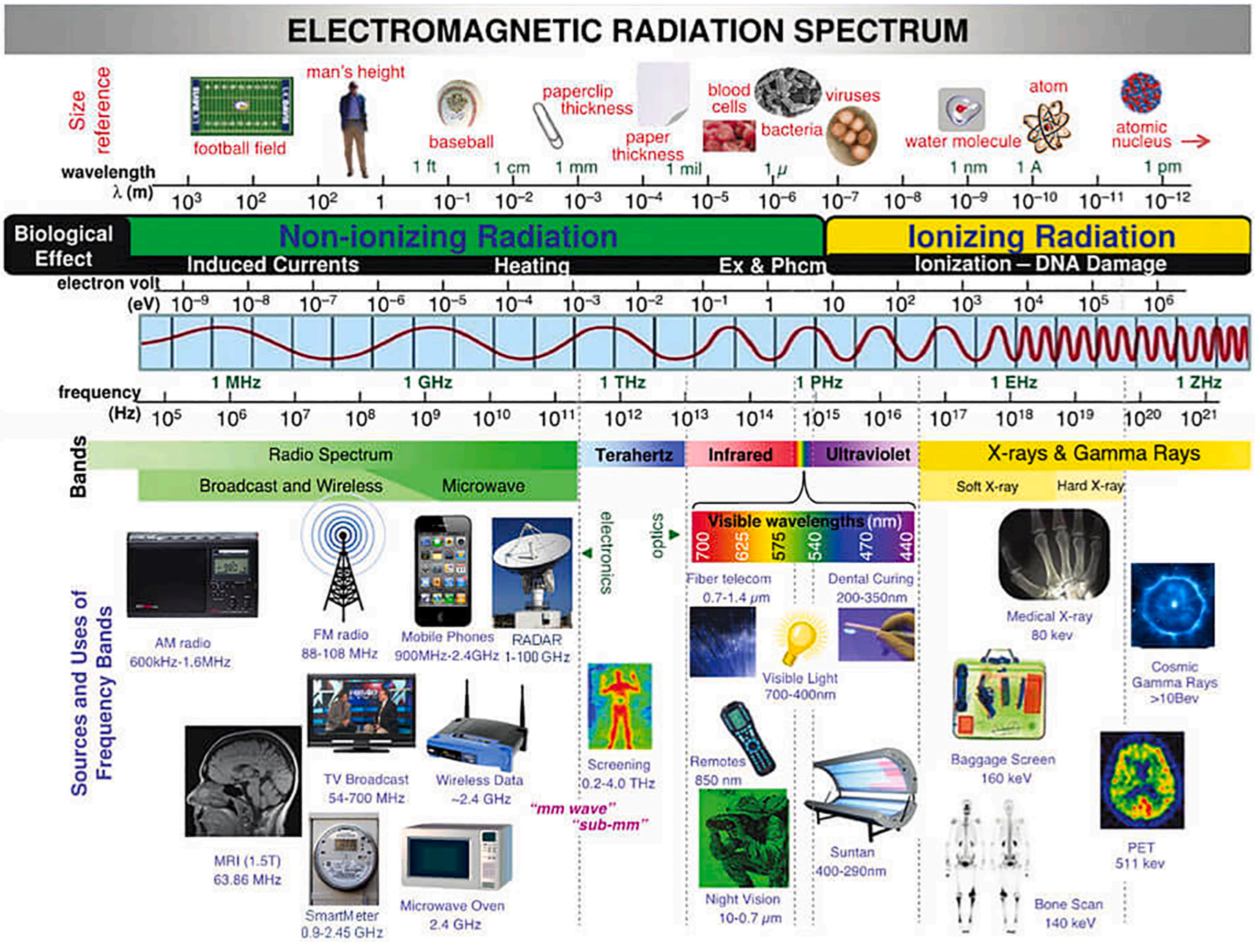

Fig. 2. The electromagnetic radiation spectrum. Illustration of the electromagnetic radiation spectrum showing the position of microwaves within this spectrum [11].

extensive burns resulting in hand amputation, and treatment of defects with large skin grafts. Histology showed tissue sparing of the subcutaneous fat layer compared to skin and muscle. No ocular damage occurred. The other child was a 14-month-old infant exposed to 60 s microwave resulting in a second to third degree burn wound of 12 by 17 cm on the back who was treated with skin grafts. No ocular damage occurred. At 9-year follow-up, no long-lasting complications or cognitive impairment were seen and normal CT cerebrum [1].

Several cases of isolated hand injury have been described, with or without skin erythema and swelling in the acute phase. All cases resulted in paresthesia, neuropathic pain and mild muscle weakness, without changes in nerve conduction velocity. No systemic changes were seen due to the small body volume exposed. One patient developed complex regional pain syndrome [6–9]. An adult woman suffering industrial microwave exposure to one hand (sealing machine, 15,000 W) presented with severe thermal injury and vascular thrombosis, as in our case, leading to forearm amputation a day after presentation. Vitality assessment was done preoperatively and pathology showed necrosis of skin, subcutaneous tissue and muscle, occluded arteries and swollen nerves [7].

A report on electrical force injury states that microwave burns should be treated like deep thermal burns, including fluid resuscitation, attention for compartment syndrome, rhabdomyolyses-kidney failure, and debridement. Intact skin and fat does not imply unharmed muscle underneath. They suggest MRI or SPECT to localize the injury and recommend a second look at 48–72 h [10].

We highlight the following clinical management items based on experience obtained with our case. Firstly, we subscribe to the necessity of emergency fasciotomy and escharotomy at presentation to evaluate the extent of deep tissue injury and determine temporization of further surgical procedures. The literature suggests using tissue ultrasound or MRI as a mode to screen for tissue injury as macroscopic assessment of the extent of necrotic tissue can be misleading. Furthermore, physical examinations are painful and not enabling evaluation of severe deep injuries, therefore they should be limited. However, we opted not to implement radiographic assessments after consulting our radiologist due to uncertainty on interpretation, subjecting the patient to painful procedures and potential infection risk in the case of ultrasound. Our judgment was that peroperative exploration was the best assessment of tissue vitality. To verify this clinical judgement, we sent multiple biopsies for histological examination that confirmed our approach (Fig. 1).

Secondly, we feel subacute burn treatment has several aspects. We aimed to minimize the frequency of dressing changes and perform them under general anesthetics to minimize pain and trauma for the infant. However, it is unclear how long one should wait for tissue recovery and when to debride necrotic tissue in severe burns. This choice involves taking the systemic condition, and particularly the infectious state of the infant, into account which could warrant early debridement.

Thirdly, we advocate evaluating for additional injuries in the acute phase. Ocular screening and cerebral imaging (preferably by MRI) have preference. Identification of additional (deep) thermal injuries enables a complete clinical picture yet can also set boundaries for clinical management.

Because this type of injury is extremely rare, there is hardly any literature on the effect of microwave oven injury on growth or potential long-term complications. Therefore, we strongly recommend follow-up into adulthood and outcome reporting in the literature as this will improve clinical management and patient counseling in the future.

In conclusion, microwave oven burns due to direct exposure are rare and present with inhomogeneous burn degrees whereby water rich tissues, near the radiation source are most affected and deep tissue injury can occur without substantial macroscopic skin defects. Initial surgical burn management should be considered in a specialized center with ICU-monitoring. Definite burn treatment depends largely on the extent of tissue necrosis for which we advocate frequent surgical exploration. Further diagnostic work-up should include evaluation of water rich tissues, such as ophthalmological review and MRI cerebrum to identify (subclinical) injuries. Long term follow-up into adulthood is recommended to monitor growth disturbances or other potential long-term effects of non-ionizing radiation exposure.

Consent for publication

Consent for publication was obtained from the legal guardians of the patient.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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