Investigation of acute ocular injury threshold by 76 GHz band exposure in rabbits

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Abstract

The acute ocular injury threshold of 76 GHz band millimeter wave (MMW) exposure was investigated using an *in vivo* rabbit model. Pigmented rabbits were exposed unilaterally to 200, 100, 75, 50, 10 mW/cm^2 76 GHz band MMW for 6 min with a lens antenna. Corneal opacity, epithelial injury, miosis, and ocular inflammation were present up to 2-3 days after exposure at a dose of 200 mW/cm^2. No ocular changes other than reversible corneal epithelial injury were seen following exposure at 100 and 75 mW/cm^2. There were no ocular changes after exposure at doses of 50 or 10 mW/cm^2.

Six-minute exposure to 76 GHz 10 mW/cm^2 did not induce any detectable ocular tissue damage.

1. Introduction

Millimeter waves (MMWs) are prevalent in high-speed wireless communication, automobile collision prevention systems, and high-resolution radar imaging, such as airport full-body scanners. We previously developed an experimental model to examine the effects of 60 GHz exposure to the eye [1]. Here, we investigated the acute ocular damage threshold of 76 GHz band MMW exposure in rabbit eye.

2. Materials and Methods

All animal experiments were conducted in accordance with the guidelines for animal studies established by Kanazawa Medical University and the Association for Research in Vision and Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research. Specific pathogen-free (SPF) pigmented rabbits (n = 52, Dutch, 16 – 17 weeks old, body weight: 1.90 – 1.99 kg; Sankyo Lab Service Co., Inc., Toyama, Japan) were exposed unilaterally to 200, 100, 75, 50, or 10 mW/cm^2 76 GHz band MMW for 3 to 6 min with a lens antenna (–3 dB beam width: 3.9 mm long, 4.9 mm wide). Medetomidine hydrochloride (0.4 mg/kg, Domitor®; Orion Corporation, Espoo, Finland) was injected intramuscularly for systemic anesthesia during MMW exposure and ocular examination. A 2% lidocaine hydrochloride topical anesthetic (Xylocaine® 2% injection; AstraZeneca, Osaka, Japan) was administered to each rabbit just before exposure. The upper and lower eyelids were retracted with tape to keep the eyes open during MMW exposure. A cooling pad (Hiepita for Kids; Lion Corporation, Tokyo, Japan) was used to avoid heating the tissue surrounding the eyes. Ocular changes were evaluated by slit-lamp biomicroscopy (SL-130; Zeiss, Tokyo, Japan) for detection of ocular injury or inflammation. Corneal surface temperature during MMW exposure was measured using a thermograph camera (Neo Thermo TXS-700; Nippon Avionics Co., Ltd., Tokyo, Japan).

Temperature during MMW exposure (200, 100, 75, and 50 mW/cm^2) was measured with a Fluoroptic

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Thermometer (Luxtron 790; Luxtron, Santa Clara, CA, USA), set up as described previously by Kojima *et al*. [2]. After both general and topical anesthesia, thermometer probes (0.5 mm in diameter) were inserted into the corneal stromal layer, lens nucleus, and the center of the vitreous, with the tip of each probe positioned at the center of the pupillary area. After stabilization of the basal ocular temperature, rabbit eyes were unilaterally exposed to 76 GHz band MMW at doses of 10 – 200 mW/cm^2 using a lens antenna for 3 min per dose at a distance of 135 mm from the corneal apex.

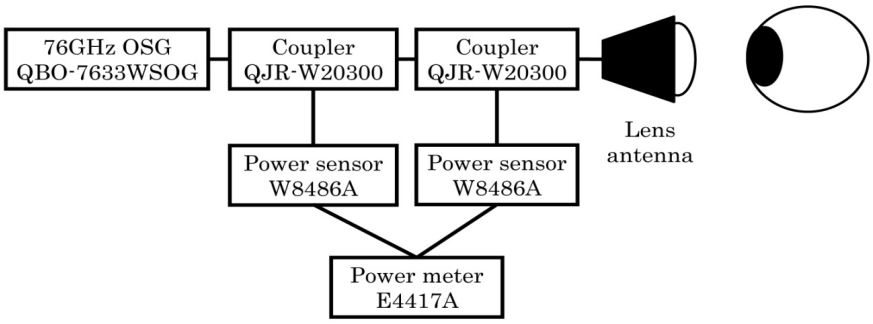

Figure 1: Diagrammatic representation of the ocular exposure system

A standardized exposure position of the eye was established as follows: 1) The target was set 135 mm from the lens antenna, namely at the focal point of MMW.(Figure 2A). 2) Since the focal point of MMW cannot be seen by the eye, red and green lasers were used to pinpoint the MMW focal point to facilitate accurate positioning of rabbit eye. 3) After removal of the target, the apex of the cornea of each rabbit was positioned at the exposure point established in 2) (Figure 2B). Temperature and humidity during MMW exposure were maintained at 20° – 25°C and 40% – 68%, respectively, using air-conditioning.

Wherever appropriate, the data were analyzed using Student's two-tailed t test, with $P < 0.05$ considered statistically significant.

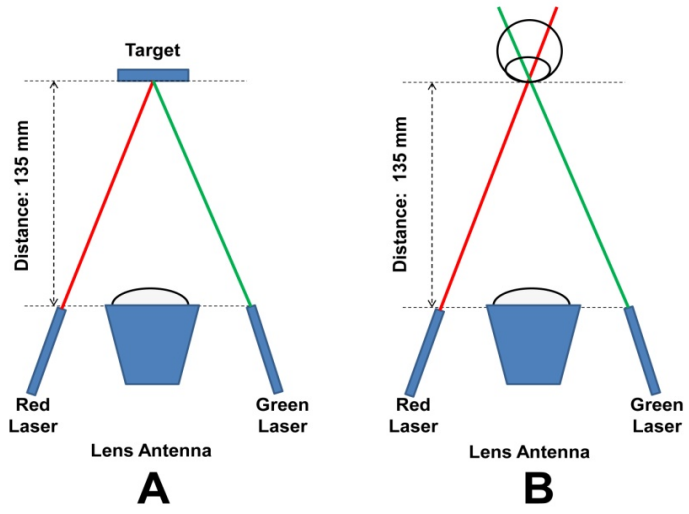

Figure 2: Eye positioning system

3. Results

The highest recorded corneal surface temperature during MMW exposure was 46.4°C ± 1.2°C (200 mW/cm^2), followed by 42.0°C ± 3.5°C (100 mW/cm^2) , 41.8°C ± 0.4°C (75 mW/cm^2), and 37.5° ± 0.7°C (50 mW/cm^2). Temperature changes in the lens and vitreous were smaller than those in the cornea.

Figure 3 shows representative clinical courses of ocular injuries after exposure at doses of 200 or 100 mW/cm^2. Miosis and corneal epithelial damage other than corneal stromal opacification were observed immediately after 6 min exposure at a dose of 200 mW/cm^2. Corneal stromal opacification and corneal epithelial damage occurred from 1 to 3 days after exposure. Keratitis and uveitis occurred 1 day after exposure. Slight corneal epithelial damage was induced immediately after 6 min of exposure at a dose of 100 or 75 mW/cm^2; however, this epithelial damage healed within 24 h. Upon slit-lamp examination, no signs of anterior uveitis were observed in eyes exposed at a dose of 100 mW/cm^2. No ocular changes were observed in the 50 or 10 mW/cm^2 exposure groups from immediately to 3 days after exposure.

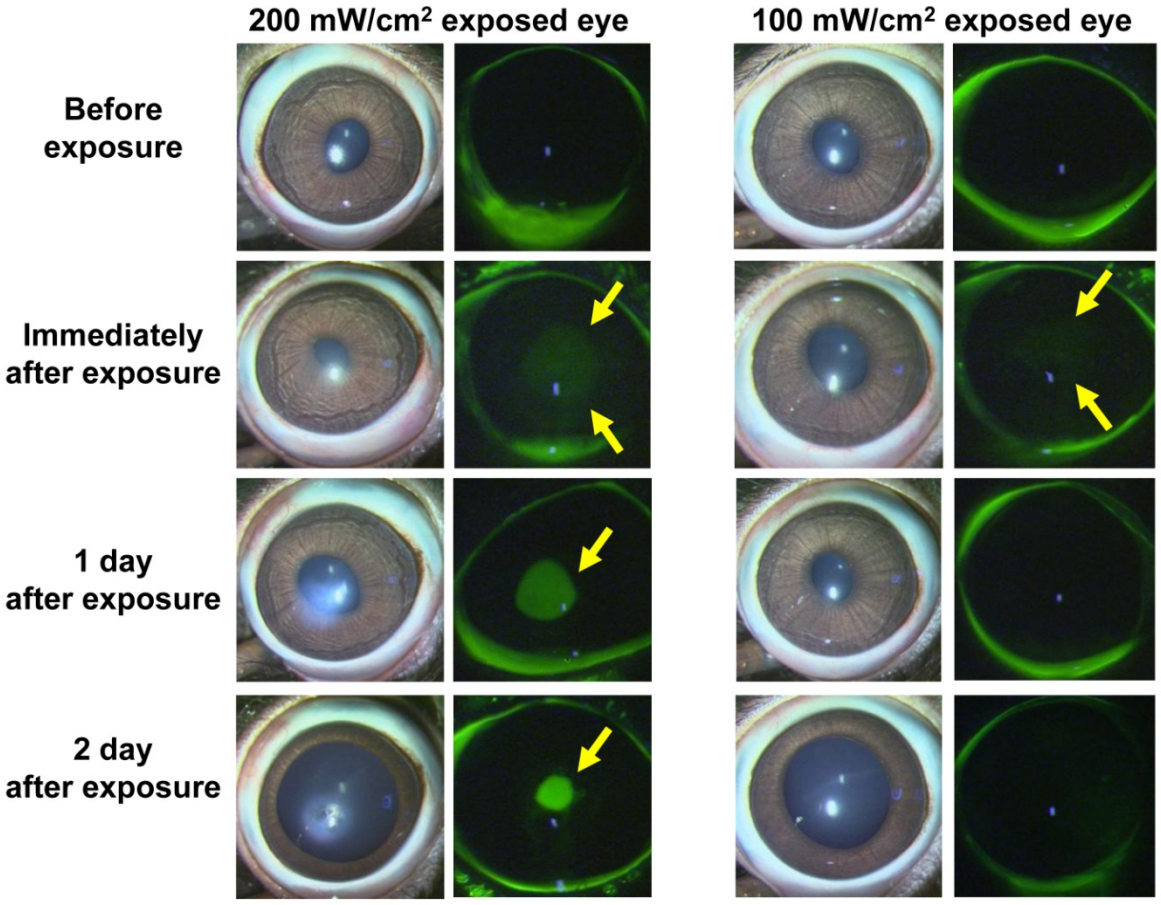

Figure 3: Ocular damage after exposure at doses of 200 or 100 mW/cm^2

Summary and Conclusions

The acute ocular damage threshold of 76 GHz band millimeter exposure (MMW) was investigated using an *in*

vivo rabbit model. Pigmented rabbits were exposed unilaterally to 200, 100, 75, 50, or 10 mW/cm^2 76 GHz band MMW for 6 min with a lens antenna. Corneal opacity, epithelial injury, miosis, and ocular inflammation were observed up to 2-3 days after exposure at a dose of 200 mW/cm^2. No ocular changes other than reversible corneal epithelial injury were seen following exposure at 100 and 75 mW/cm^2. No ocular changes were seen following exposure at 50 or 10 mW/cm^2.

Six-minute exposure to 76 GHz MMW at a dose of 10 mW/cm^2 did not induce any detectable ocular tissue damage.

Acknowledgments

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