Heliyon 9 (2023) e18705

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Accidental macular injury from short-term exposure to a handheld high-intensity LED light

Li Zhang [a], Chun-Yan Lei [a], Zhi-Cheng Zhang [b], Jin-Yue Gu [a], Mei-Xia Zhang [a,*]

[a] Sichuan University West China Hospital, Chengdu, Sichuan Province, China
[b] Fourth People's Hospital, Zigong, Sichuan Province, China

ARTICLE INFO

Keywords:
LED light
Macular injury
Public health

ABSTRACT

Objective: To report a case of macular injury caused by short-term exposure to a handheld high-intensity light emitting diode (LED) light.
Design: Interventional case report.
Participant: A patient with macular injury caused by short-term exposure to the light of a handheld high-intensity LED device.
Intervention: The patient was examined and followed for 3 months after exposure with ophthalmologic examinations (including funduscopy, optical coherence tomography [OCT], fluorescein angiography [FA], and multifocal electroretinography [mfERG]). The injured eye was treated with one retrobulbar injection of 20 mg triamcinolone acetonide at 5 days after exposure.
Main outcome measures: Visual acuity, ophthalmoscopic, and OCT findings.
Results: 3 days after exposure, the best corrected visual acuity (BCVA) of the right eye was 6/20. OCT revealed the acute stage of the injury with eminence of the retinal pigment epithelium (RPE). BCVA was improved to 16/20 and 20/20 at 19 and 33 days after exposure, respectively. OCT results of follow-ups at five days, 19 days, 33 days and 3 months after exposure have demonstrated the restoration process of the injury.
Conclusions: Short-term exposure to high-intensity LED light may cause damage to the retina. As the expansion of LED use in modern life, education and supervision are of urgent need for public health.

1. Introduction

Artificial lighting is now widely applied in people's daily life, among which the light emitting diode (LED) technology is the undoubtedly most high-profile one. However, the expansion of LED use has also raised public concerns for its potential retinal hazard [1]. Nevertheless, accidental retinal injury caused by exposure to high-intensity LED light has rarely been reported, and the potential mechanisms remain unelaborated. Here, we report the ocular findings and clinical course of a case with macular injury after short exposure to a handheld high-intensity LED light in an adolescent and reinforces the urgent need for education and supervision of LED use.

* Corresponding author.
E-mail addresses: 819957622@qq.com (L. Zhang), 710131676@qq.com (C.-Y. Lei), 464598959@qq.com (Z.-C. Zhang), 1726416442@qq.com (J.-Y. Gu), zhangmeixia@scu.edu.cn (M.-X. Zhang).

https://doi.org/10.1016/j.heliyon.2023.e18705
Received 21 February 2023; Received in revised form 27 June 2023; Accepted 25 July 2023
Available online 26 July 2023

2. Case presentation

A 13-year-old female presented to our clinic complaining of vision loss and scotomas in the right eye. Five days ago, her classmate directed an online-bought handheld LED light to her right eye for several times at a very short distance with flash mode. This LED product is used for outdoor lighting with high-output light sources (30 chip-on-board LEDs emitting a total of 5 W, 100 lm/W at 500 mA LED). She was attended to a local hospital immediately for blurred vision and scotomas but was suggested to transfer. Three days post-exposure, she visited a municipal hospital and at that time, best corrected visual acuity (BCVA) was 6/20 for the right eye. On optical coherence tomography (OCT; Stratus OCT, Carl Zeiss Meditec Inc), a hyperreflective area at the external retinal layers was demonstrated, corresponding to the disruption of the ellipsoid zone (EZ), outer segment photoreceptor (OS), and interdigitation zone (IZ) in the right eye [Fig. 1]. And mild eminence of the retinal pigment epithelium (RPE) was presented at the fovea, indicating an acute localized inflammatory response to the injury. No treatment was adopted and because of no improvement of symptoms, the patient came to our hospital for further treatment on the fifth day after exposure. On presentation, BCVA was 6/20 and 20/20 for the right and left eye. The anterior segment and fundus examinations were not remarkable. Fluorescein angiography (FA) images revealed no leakage [Fig. 2]. Spectral-domain OCT (SD-OCT; Heidelberg Engineering) demonstrated a mosaic-like hyporeflective outer retinal space outlining the profile of the lesion with flat RPE [Fig. 3A]. This patient was diagnosed with photic maculopathy derived from LED light. We treated the patient with one retrobulbar injection of 20 mg triamcinolone acetonide. 19 days post-exposure, BCVA in the right eye was improved to 16/20. On SD-OCT, partial restoration of the EZ was clearly presented [Fig. 3B]. And a hyporeflective defect was still presented at the IZ. No treatment was adopted since then. 33 days post-exposure, BCVA was improved to 20/20 in the right eye. On SD-OCT, restoration of the EZ and IZ was demonstrated [Fig. 3C]. Three months after exposure, no abnormality was noted on OCT image of the right eye [Fig. 3D]. Total restoration of the anatomical structure of the external retinal layers was achieved in the right eye, and BCVA has remained stable. Results of multifocal electroretinography (mfERG) examinations also showed functional improvement of the fovea [Fig. 4 (A-C)].

3. Discussion

Our findings in this case demonstrated that viewing of a high-intensity LED light at a short distance is potentially harmful even for a short-period of time. To the best of our knowledge, this is the first case report of human retinal damage derived from exposure to a handheld LED lighting device. The whole course of this disease from the acute stage to recovery was demonstrated by OCT images. However, the patient was admitted to our clinic at five days post-exposure, so detailed examinations were not acquired instantly after the exposure.

The white LEDs have now been widely used for domestic lighting, and the general population can get easy access to some high-intensity LED devices. Actually, no evidence of direct adverse health effects from LEDs has been found in condition of normal use [2]. However, misuse of LEDs may occur and cause damage to the eye, especially in children and adolescents who are more vulnerable. In the present case, causative factors for the retinal damage might be the short but repeated exposure, the close distance from the lighting source, the particularly high luminance produced by the LED device, and high blue light content within the LED light. Currently, to produce high-brightness white LEDs, the method of combining a diode emitting at a short wavelength with a phosphor emitting at a larger wavelength is commonly used. And the blue-light component, which is always present in the LED spectrum, has thus made the white LEDs spectrum blue-rich. It is known that the blue emission is the most energetic part of visible light, and the maximum of the blue action spectrum occurs between 435 and 445 nm, which is very close to the blue peak of a white LED (450 nm). The blue light causes retinal phototoxicity through photochemical effects and the increased reactive oxygen species (ROS) production is the mostly accepted molecular mechanisms of blue light-induced hazard, which involves loss of photoreceptors, lipid peroxidation and cell apoptosis [3]. Presently, there are limited reports describing the phototoxicity of exposure to high-intensity LEDs in human eyes. Liang et al. [4] reported a case of macular damage derived from LEDs for bar illumination. However, the exposure details were

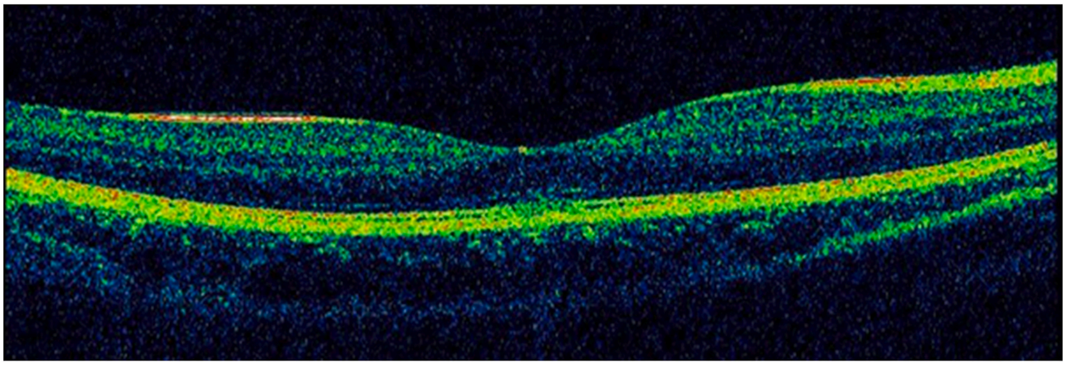

Fig. 1. Initial OCT image of the right eye at 3 days after exposure. A subfoveal hyperreflective area at the external retinal layers was demonstrated, which corresponded to the disruption of the ellipsoid zone, outer segment photoreceptor and interdigitation zone. Mild eminence of the retinal pigment epithelium was also presented at the fovea.

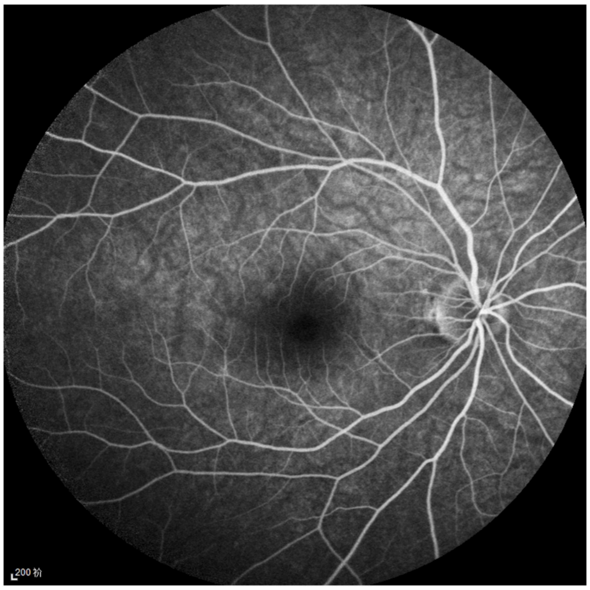

Fig. 2. Fluorescein angiography image of the right eye showed no leakage five days post-exposure.

not clearly described, and the accurate cause was not confirmed. Kim et al. [5] described a parafoveal chorioretinal lesion induced by a LED face mask for skin care one month before presentation, but the acute phase of the disease was not recorded. Recently, in animal experiments, Park et al. [6] has found that application of high-power LED light (25W, 150lm/W at 700mA) with short duration (5 seconds) at 1 cm from the corneal surface could cause temporary phototoxicity to visual function in rabbits, but it could recover within 24h. Another report by Araújo et al. [7] using Wistar rats, after exposure to high-intensity LED light (3200 mW/cm^2) for 144 seconds at 30 cm, morphometric alterations in the retinal structures were presented, specifically in the nuclear area of the photosensitive cells.

For our patient, OCT findings of outer retina disruption were particularly similar to those presented in patients with solar maculopathy [8], welding arc maculopathy [9] or maculopathy associated with viewing of a plasma flash produced by a femtosecond laser [10], suggesting that they may share the same putative phototoxic etiology. Generally, in retinal injuries from light, the intense light energy is preferentially absorbed by the RPE melanosomes and damage the RPE, and the damage could then extend to involve the photoreceptor outer segment [1]. While restoration commonly occurs from the inner to the outer retinal layers [11], and the restoration of the outer retinal layers is in correspondence with the regeneration of photoreceptors [12]. This could explain the pathogenesis and corresponding clinical findings of the present case. Our patient was lucky to get complete functional and anatomical resolution, while cases of permanent retinal disruption and persistent visual symptoms were not rare in other conditions of retinal injuries from light with permanent loss of photoreceptors [13]. As the development of LED technology, LEDs with higher intensity will be achieved and be accessible to the general population. Therefore, it's of vital importance and urgent need to warn people of this potential risk, and further research should be established to explore the underlying mechanisms.

In conclusion, the findings reported here have demonstrated that high-intensity LEDs may cause macular injury if directed to human eyes and possible mechanisms causative for this rare condition was discussed. As the expansion of LED use in modern life, education and supervision are of urgent need for public health.

Financial Support

This work was supported by 1.3.5 project for disciplines of excellence, West China Hospital, Sichuan University (ZYJC21025) and Sichuan Provincial Science and Technology Support Project (2021ZYD0110).

The sponsor or funding organization had no role in the design or conduct of this research.

Informed consent for publication

Written informed consent for publication of this case and any accompanying images was obtained from the patient's parent.

Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

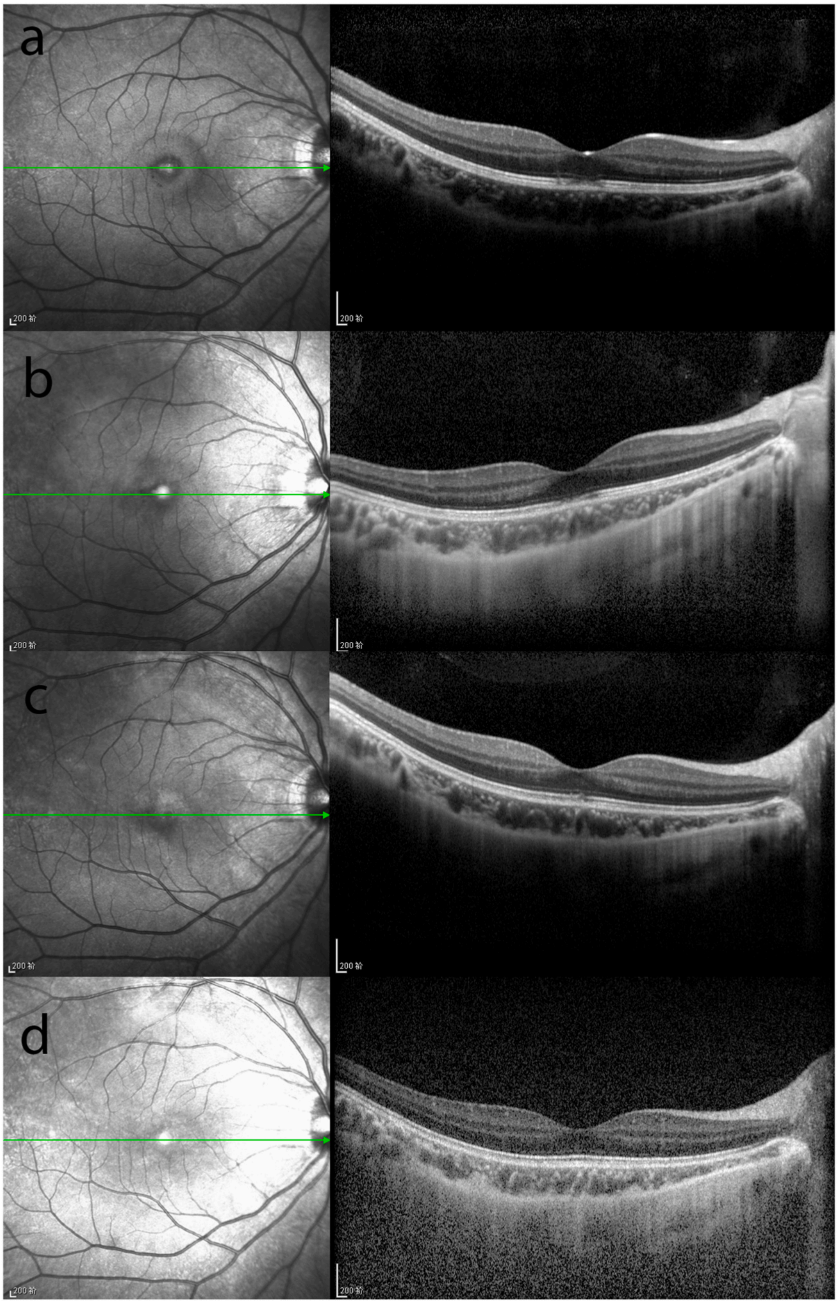

Fig. 3. The restoration process of the retinal structure demonstrated on SD-OCT images using the same scanning line. (A) Five days post-exposure: a mosaic-like hyporeflective outer retinal space outlining the profile of the lesion with flat RPE. (B) 19 days post-exposure: partial restoration of the ellipsoid zone and hyporeflective defect at the interdigitation zone. (C) 33 days post-exposure: further restoration of the ellipsoid zone and partial restoration of the interdigitation zone. (D) Three months post-exposure: normal appearance of the external retinal layers with intact structure of the ellipsoid zone and interdigitation zone.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

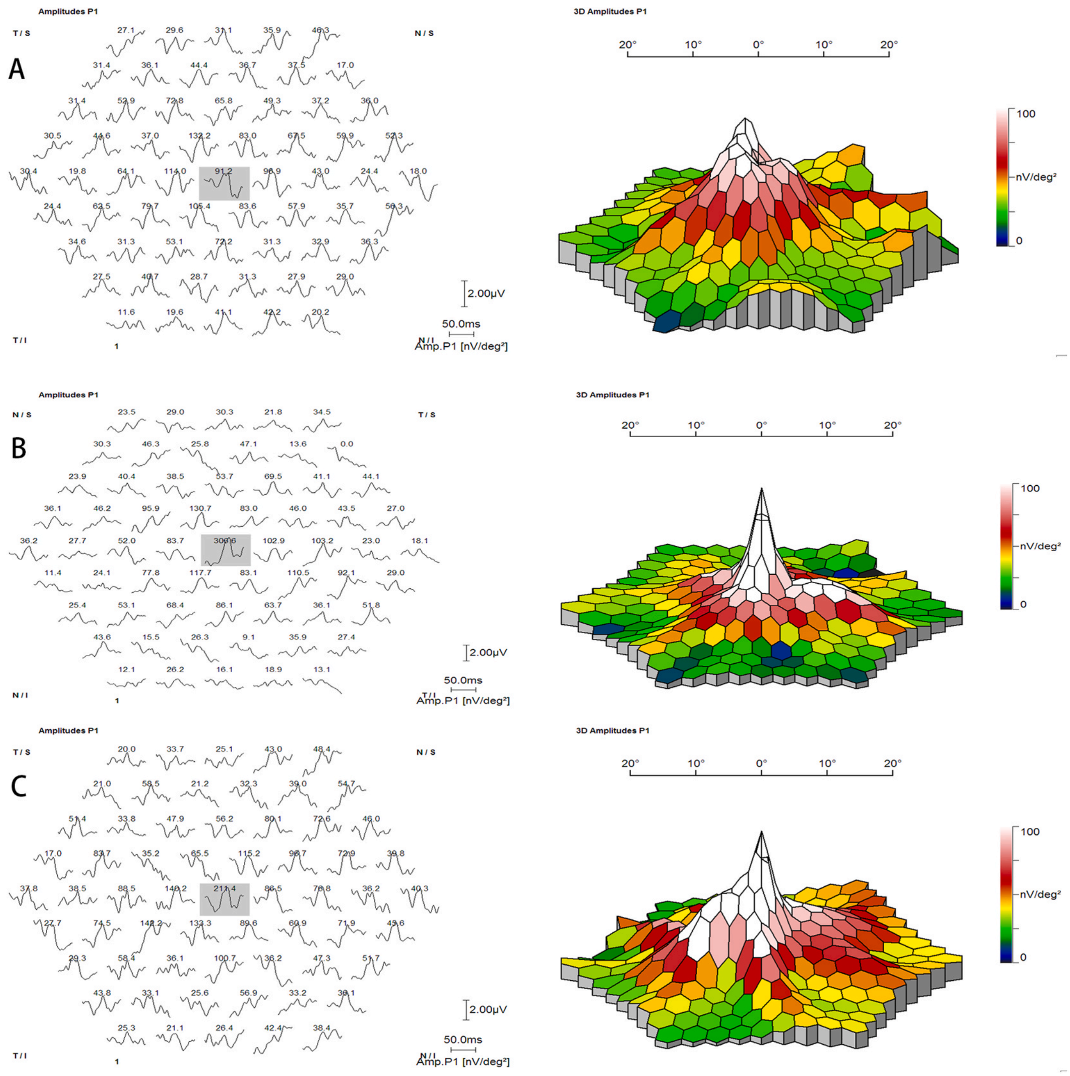

Fig. 4. MfERG results demonstrated functional restoration of the fovea in the right eye.(A) Decreased foveal peak P1 amplitudes of the right eye at 19 days post-exposure. (B) Normal foveal peak P1 amplitudes of the left eye at 19 days post-exposure. (C) Improved foveal peak P1 amplitudes of the right eye at 33 days post-exposure.

influence the work reported in this paper.

Acknowledgments

This work was supported by 1.3.5 project for disciplines of excellence, West China Hospital, Sichuan University (ZYJC21025) and Sichuan Provincial Science and Technology Support Project (2021ZYD0110).

References

[1] F. Behar-Cohen, et al., Light-emitting diodes (LED) for domestic lighting: any risks for the eye? Prog. Retin. Eye Res. 30 (4) (2011) 239–257.
[2] Y. Touitou, S. Point, Effects and mechanisms of action of light-emitting diodes on the human retina and internal clock, Environ. Res. 190 (2020), 109942.
[3] X. Ouyang, et al., Mechanisms of blue light-induced eye hazard and protective measures: a review, Biomed. Pharmacother. 130 (2020), 110577.
[4] L. Liang, et al., Damage to the macula associated with LED-derived blue laser exposure: a case report, BMC Ophthalmol. 17 (1) (2017) 49.
[5] T.G. Kim, et al., Photochemical Retinopathy induced by blue light emitted from a light-emitting diode Face Mask: a case report and literature review, Medicine (Baltim.) 99 (24) (2020), e20568.
[6] H. Park, et al., A safety test for ocular phototoxicity in the rabbit after short-term exposure to strong light, In Vivo 36 (1) (2022) 233–240.
[7] M.E. Araújo, et al., Retinal damage related to high-intensity light-emitting diode exposure: an in vivo study, Am. J. Orthod. Dentofacial Orthop. 161 (4) (2022) e353–e360.
[8] O. Birdsong, J. Ling, J. El-Annan, Solar retinopathy, Ophthalmology 123 (3) (2016) 570.
[9] L. Uniat, R.J. Olk, S.J. Hanish, Welding arc maculopathy, Am. J. Ophthalmol. 102 (3) (1986) 394–395.

[10] X. Yang, et al., Accidental macular injury from prolonged viewing of a plasma flash produced by a femtosecond laser, Ophthalmology 117 (5) (2010) 972–975.
[11] C.H. Symons A, M.A. Mainster, *Retinal injuries from light: mechanisms, hazards and prevention*. Ryan's retina, in: Schachat AP vol. 6, Elsevier, China, 2018.
[12] M.O. Tso, D.O. Robbins, L.E. Zimmerman, Photic maculopathy. A study of functional and pathologic correlation, Mod. Probl. Ophthalmol. 12 (0) (1974) 220–228.
[13] A.N. Stangos, et al., Optical coherence tomography and multifocal electroretinogram findings in chronic solar retinopathy, Am. J. Ophthalmol. 144 (1) (2007) 131–134.