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Video

Structural changes in laser-induced retinopathy examined by adaptive optics optical coherence tomography

Takahiro Kogo, Yuki Muraoka *, Masaharu Ishikura, Naomi Nishigori, Yuki Akiyama, Masayuki Hata, Akitaka Tsujikawa

Department of Ophthalmology and Visual Sciences, Kyoto University Graduate School of Medicine, Kyoto, Japan

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ABSTRACT

Purpose: We report a case of laser-induced retinopathy that posed diagnostic challenges with conventional spectral domain optical coherence tomography (SD-OCT), but was successfully diagnosed using adaptive optics-optical coherence tomography (AO-OCT).

Observations: A 27-year-old man with a history of occupational laser device use presented with central scotoma and visual disturbances in the right eye. Conventional SD-OCT only revealed decreased reflectivity in parts of the foveal ellipsoidal zone band. However, other multimodal observations indicated damage to the retinal pigment epithelium (RPE) and choriocapillaris. Additionally, a well-defined circular, dark lesion, approximately 80 μm in diameter, was identified in the outer retina. AO-OCT demonstrated the absence of the RPE and Bruch's membrane, accompanied by the loss of inner and outer segments of cone photoreceptors and dropout of cone cell nuclei, with Müller cells remaining unaffected.

Conclusions and Importance: This case of laser-induced retinopathy advances our understanding of the pathophysiological effect of laser exposure on the retina, suggesting a higher incidence of laser-induced retinopathy than previously diagnosed. It also serves as a crucial reminder for laser users to exercise caution and highlights the necessity for ophthalmologists to carefully observe and examine such cases.

1. Introduction

Laser-induced retinopathy presents a complex range of clinical manifestations that are not fully understood.[1,2] It is traditionally held that significant ocular risk is associated with high-power lasers emitting blue to green light.[1] However, accumulating evidence suggests that even low-power lasers, akin to light from laser pointers, can cause retinal damage.[3,4] The clinical spectrum of this condition includes subtle disturbances in the retinal pigment epithelium (RPE) at the onset of macular edema and damage to the outer retinal layers, complicating its diagnosis.[1,2]

The integration of adaptive optics-optical coherence tomography (AO-OCT) has substantially refined the visualization of retinal structures at the cellular level.[5] It sheds light on retinal pathology previously obscured by limitations in conventional spectral domain optical coherence tomography (SD-OCT). In this case, we used AO-OCT to elucidate cellular-level changes in retinal neuroglia that are critical for diagnosis, but typically unresolvable using conventional SD-OCT.

2. Case report

A 27-year-old man presented with a 6-month history of central scotoma and visual disturbances in the right eye. The best-corrected visual acuity of the affected eye was 20/33. Initial examinations, including fundus photography and autofluorescence, revealed no major abnormalities (Fig. 1). Further investigation revealed a history of occupational use of a laser device emitting light at a wavelength of 638 nm at a power of 35–40 mW for semiconductor chip testing for over a year. Additionally, it was noted that the patient occasionally worked in environments where lasers were operated without the use of protective eyewear.

Conventional SD-OCT showed decreased reflectivity in parts of the foveal ellipsoidal zone band (Fig. 1). Fluorescein and OCT angiography revealed no retinal vascular abnormalities (Fig. 1). However, indocyanine green angiography along with *en face* images from the inner and

* Corresponding author. Department of Ophthalmology and Visual Sciences, Kyoto University Graduate School of Medicine, 54 Shogoin Kawahara-cho, Sakyo-ku, Kyoto, 606-8507, Japan.
E-mail address: muraoka@kuhp.kyoto-u.ac.jp (Y. Muraoka).

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outer segment lines to the RPE and OCT angiography of the choriocapillaris slab revealed damage to the RPE and choriocapillaris (Fig. 1). Additionally, a well-defined, circular, dark lesion, approximately 80 μm in diameter, was identified in the outer retina.

Enhanced imaging of the retina was performed using a prototype AO-OCT system (Canon Inc.; lateral resolution, approximately 3 μm; axial resolution, 3.4 μm). AO-OCT imaging demonstrated the absence of the RPE and Bruch's membrane, with a corresponding loss of the inner and outer segments of the cone photoreceptors and dropout of cone cell nuclei (Fig. 2). Müller cells remained unaffected. No retinal damage was detected in regions where the RPE was preserved.

The diagnosis of laser-induced retinopathy in the right eye was made based on clinical presentation, including occupational history, fundoscopic evaluation, and AO-OCT imaging findings. Given the confinement of photoreceptor loss to the fovea and the nonprogressive findings, conservative management was considered appropriate. The patient received counseling on the critical importance of avoiding laser exposure and using protective eyewear. Follow-up visits were scheduled at 6-month intervals.

3. Discussion

This case highlights a subtle laser-induced retinopathy caused by a low-power (35–40 mW) and long-wavelength laser, detected using AO-OCT. AO-OCT enabled detailed retinal visualization, revealing RPE and Bruch's membrane loss, inner and outer photoreceptor segment degradation, and concurrent nuclei dropout. Our findings indicate that the RPE and choriocapillaris were the origins, impairing photoreceptors and correlating with symptoms. While this patient showed mild changes, severe cases with shorter-wavelength and higher-powered laser exposure may feature outer nuclear layer disruption and inner retinal hyperreflective material,[2] potentially affecting Müller cells.

The enhanced resolution and contrast of AO-OCT significantly improves the diagnostic process for identifying laser-induced retinopathy. The specificity of AO-OCT in this study, which captured subtle retinal pathologies in areas corresponding to RPE damage and preserved the integrity of Müller cells, implies a higher prevalence of such retinopathy among laser users. This case reinforces the implementation of precautionary measures, advocating safety eyewear use. Clear diagnostics obtained from AO-OCT are crucial for healthcare providers to offer informed counseling on laser safety. The insights gained from AO-OCT imaging not only reaffirm its diagnostic value, but also improve our understanding of the pathophysiological effect of laser exposure on the retina, while demonstrating the importance of detailed observation in its diagnosis. Further research is needed to better understand laser-induced retinal damage and its long-term outcomes.

4. Conclusions

In summary, this case of laser-induced retinopathy advances our understanding of the pathophysiological effect of laser exposure on the retina and suggests a higher incidence of laser-induced retinopathy than previously diagnosed. This case serves as a reminder for laser users to exercise caution, and also highlights the necessity for ophthalmologists to carefully observe and examine such cases.

Patient consent

The patient provided written consent to publish this case report.

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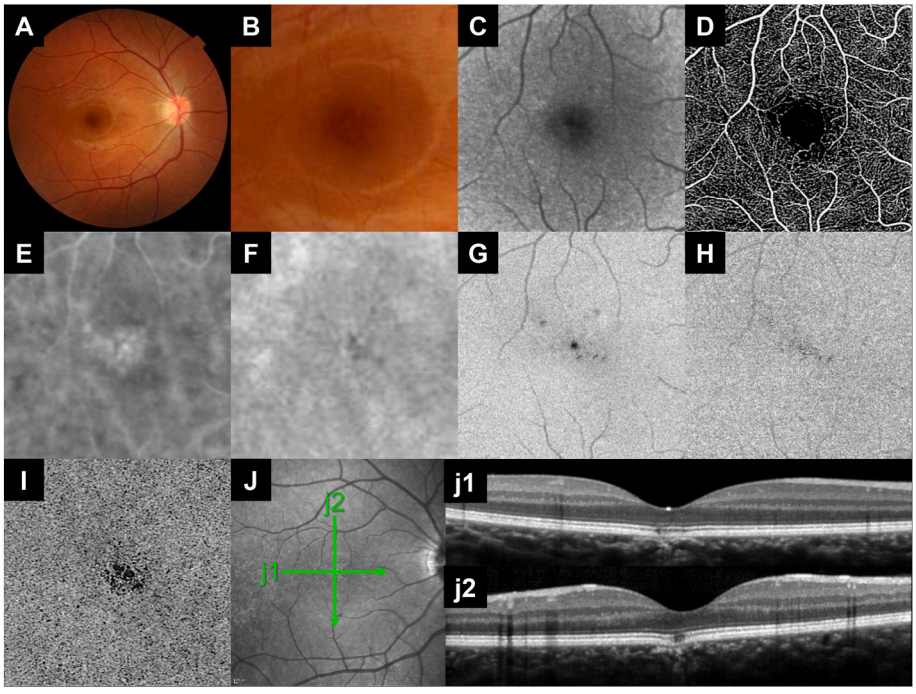

Fig. 1. Multimodal imaging of fovea of the affected eye. The lesion was unremarkable on color fundus photography (A, B), fundus autofluorescence imaging (C), and retinal swept source (SS)-optical coherence tomography (OCT) angiography (OCTA) (D). Damage to the retinal pigment epithelium (RPE) without neovascularization was observed in the early (E) and late (F) phases of indocyanine green angiography. *En face* SS-OCT image from the inner and outer segment line to the RPE revealing a low-intensity circle of approximately 80-μm diameter at the center of fovea (G). *En face* SS-OCT image from the RPE to the Bruch's membrane showing RPE damage (H). SS-OCTA of the choriocapillaris slab showing impaired blood flow in the fovea (I). Conventional spectral domain OCT, due to its lower resolution, only indicated a reduction in reflectivity in parts of the foveal ellipsoid zone band without retinal thinning (J). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

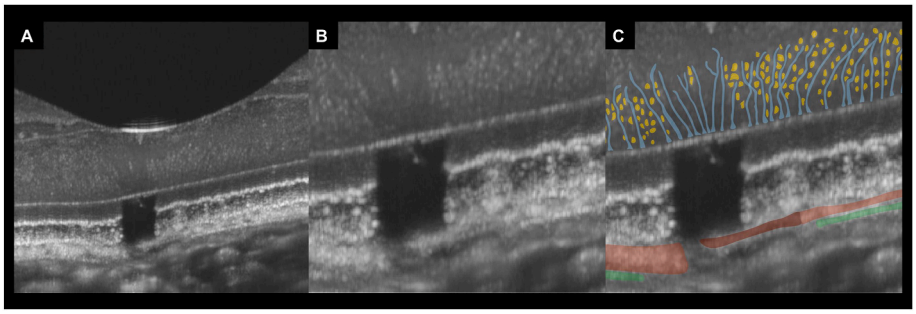

Fig. 2. Evaluation of the foveal morphology with adaptive optics optical coherence tomography (AO-OCT). (A–C) AO-OCT revealed the absence of the retinal pigment epithelium (red: normal regions; dark red: damaged but remaining regions) and Bruch's membrane (green: normal regions), distinct loss of inner and outer segments in the photoreceptors (width, 83 μm), and the corresponding dropout of photoreceptor nuclei (yellow), all with clear boundaries while Müller cells appeared unaffected, visualized within the outer nuclear layer (light blue). Photoreceptors are missing only in the area affected by the laser. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

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CRediT authorship contribution statement

Takahiro Kogo: Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization. **Yuki Muraoka:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Funding acquisition, Data curation, Conceptualization. **Masaharu Ishikura:** Writing – review & editing, Supervision, Methodology. **Naomi Nishigori:** Writing – original draft, Supervision, Methodology, Conceptualization. **Yuki Akiyama:** Writing – review & editing, Supervision, Methodology. **Masayuki Hata:** Writing – review & editing, Supervision. **Akitaka Tsujikawa:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

T. Kogo: None, Y. Muraoka: Bayer Yakuhin, Novartis Pharma, Canon, Santen Pharmaceutical, Senju Pharmaceutical, M. Ishikura: None, N. Nishigori: None, Y. Akiyama: None, M Hata: Novartis Pharma, Senju Pharmaceutical, Kyoto Drug Discovery & Development, A. Tsujikawa: Canon, Findex, Santen Pharmaceutical, Kowa Pharmaceutical, Pfizer, AMO Japan, Senju Pharmaceutical, Wakamoto Pharmaceutical, Alcon Japan, Alcon Pharma, Otsuka Pharmaceutical, Tomey Corporation, Taiho Pharma, HOYA, Bayer Yakuhin, Novartis Pharma, Chugai Pharmaceutical, Astellas, Eisai, Daiichi-Sankyo, Janssen Pharmaceutical, Kyoto Drug Discovery & Development, Allergan Japan, MSD, Ellex, Sanwa Kagaku Kenkyusho, Nitten Pharmaceutical, AbbVie GK.

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