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Comparative Study of the Use of Nd: YAG Laser and Argon Laser for Angle Closure Glaucoma Management

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ABSTRACT

Angle-closure glaucoma (ACG) is a major cause of blindness worldwide. This study aims to evaluate Nd: YAG LASER and Argon LASER for (ACG) treatment. The investigation took place in the COMSOL Multiphysics simulation environment. The eye's iris was modeled, and the two LASERs were exposed on the anterior face of the iris to create an invasive hole. The thermal responses of the eye due to the transmission of the electromagnetic energy carried by the two LASERs were measured. The results indicated that a lower thermal intensity of 350K from 1064 Nd: YAG LASER with a pulse duration of 1ns and a heat flux of 1000 W/m² was more effective and safer for creating a hole through iris and reducing intraocular pressure (IOP) with minimal risk of iris tissue damage compared to the higher thermal response of 400K induced by 488nm argon LASER with the same pulse duration of I ns and a heat flux of 1000 W/m² . The finding improves clinical practice in the ophthalmology field.

1. Introduction

Glaucoma is a multifactorial disease [1]. It is characterized by increased intraocular pressure (IOP) due to the accumulation of aqueous humor in the anterior chamber of the eye. Glaucoma suspects will have an increased intraocular pressure (IOP) of more than 21 mmHg (IOP), which is thought to cause glaucoma because it damages the blood vessels and optic nerves in the eye [2]. Diagnosis of glaucoma is mainly based on the increased intraocular pressure (IOP), medical history of the patient's family, and change in optic disc structure [3].The main different types of glaucoma are chronic or open-angle glaucoma (OAG) and acute or angle-closure glaucoma (ACG). (ACG) is a major cause of blindness worldwide [4].

Primary angle-closure glaucoma is a type of glaucoma associated with a physically obstructed anterior chamber angle. Obstruction of the anterior chamber angle blocks drainage of fluids (aqueous humor) within the eye and may raise IOP. Elevated IOP is associated with glaucomatous optic nerve damage and visual field loss [5]. While conventional treatments, such as topical IOP-lowering medications, are available. However, they have potential systemic side effects with patients' adherence and high financial costs. LASERs peripheral iridotomy are a procedure to eliminate pupillary block by allowing aqueous humor to pass directly from the posterior to anterior chamber through use of a laser to create a hole in the iris.

This study was simulated in the COMSOL multiphysics environment; the eye's iris was modeled the two LASERs were configured and exposed on the anterior face of the iris to create an invasive hole. the thermal responses of 350K when we exposed on the iris 1064nm Nd: YAG LASER with a plus duration of 1ns and heat flux of 1000W/m^2 was capable to create a hole on the iris surface without more tissue damage and secondary effect compared to the higher thermal response of 400K when we exposed 488nm of argon LASER with plus duration of 1ns and heat flux of 1000W/m^2. These findings improve clinical practice in the field of ophthalmology.

2. Background theory

The eye's iris thermal response is solved in the COMSOL Multiphysics environment with the heat transfer in a material as Fourier's law of heat conduction, which defines the heat flux vector .

$$\rho c_\rho \frac{\partial T}{\partial t} + \nabla.(-k\,\nabla T) = Q + Q\,ted \qquad (1)$$

$$\vec{q} = K\nabla T \qquad (2)$$

where ρ is the density of the tissue, c is the specific heat capacity of the tissue, T is the temperature of the tissue, t is time exposed by laser, $\vec{q}$ is heat flux vector, Q is the heat generated by unit volume by the laser energy, Q ted is heat generated due to mechanical effects and k is the thermal conductivity of the tissue

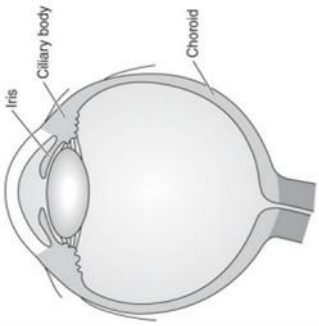

Figure1: Anatomy of human eyeball) [6].

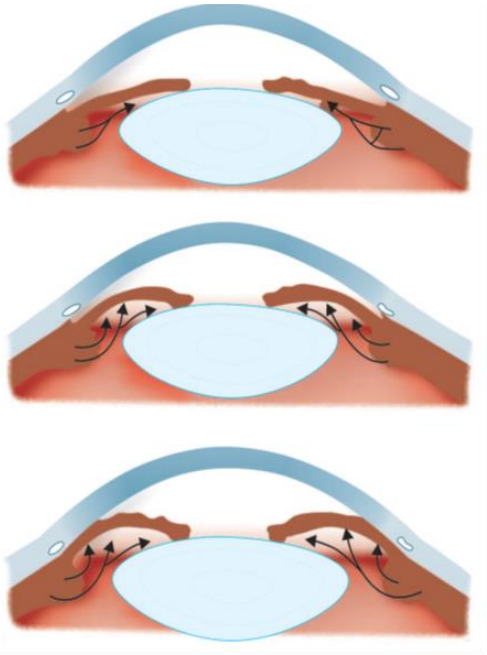

Figure 2: Mechanism of angle closure glaucoma: A, relative pupil block; B, iris bombe formation; C, appositional angle closure [7].

3. Methodology

This study was simulated in the COMSOL Multiphysics environment, version 5.6. A 3D model of the eye's iris was modeled in the geometry section of the COMSOL environment. We selected tours shape to build the iris with a major radius of 1 mm and a minor radius of 0.5 mm before exposing the lasers on its surface. The materials chosen in the COMSOL environment included bioheat transfer in biological tissue (muscle), which has a heat capacity at constant pressure of 3421 J/kgK, a density of 1090 kg/m³ for the iris, and a thermal conductivity of 0.49 W/mK. The two LASERs, 1064 nm Nd: YAG LASER and 488 nm argon LASER, were simulated in a COMSOL environment with a pulse duration of 1 ns and heat flux of 1000 W/m². The two LASERs were exposed on the anterior surface of the iris to create a hole by an action called laser iridotomy, as shows in Figures 3 and Figure 4.

4. Results and Discussion

The thermal responses of the eye due to the transmission of the electromagnetic energy carried by the two lasers were measured. The overall thermal responses of the eye's were measured and are presented below.

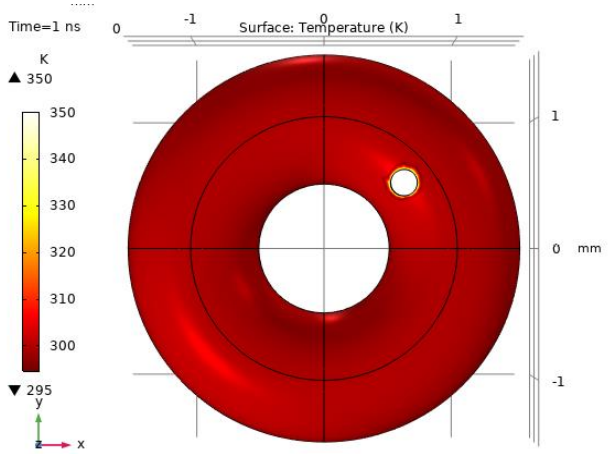

Figure 3: A 3D of iris model on used 1064nm Nd: YAG LASER iridotomy with plus duration of 1ns and heat flux of 1000W/m^2.

The result was indicated by the yellow bright colors on the diagram as shows in Figure3 the thermal responses of 350K when we exposed on the iris 1064nm Nd: YAG LASER with a plus duration of 1ns and heat flux of 1000W/m^2 was capable to create an invasive hole on the iris surface without more tissue damage and secondary effect that help the aqueous humor or the flued outflow and reduce intra ocular pressure to overcome angle closure glaucoma.

For the second LASER, we obtained its result as shows in Figure 4.

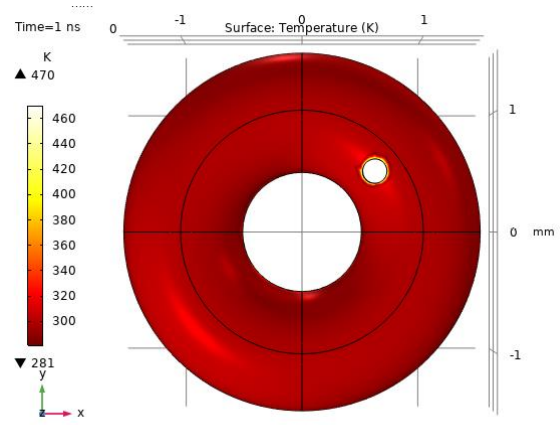

Figure 4: A 3D of iris model on used 488nm of argon LASER iridotomy with plus duration of 1ns and heat flux of 1000W/m^2.

In Figure 4 the result of 400K of thermal responses was indicated in diagram by the yellow color

when we exposed 488nm of argon LASER with plus duration of 1ns and heat flux of 1000W/m^2 on the anterior surface of the eye's iris to create an invasive hole for reducing intra-ocular pressure and treat angle closure glaucoma. This 488nm of argon LASER is useful in dark or bleeding iris but it has mor side effect like tissue damage due to its higher thermal responses when compared by 1064nm Nd: YAG LASER.

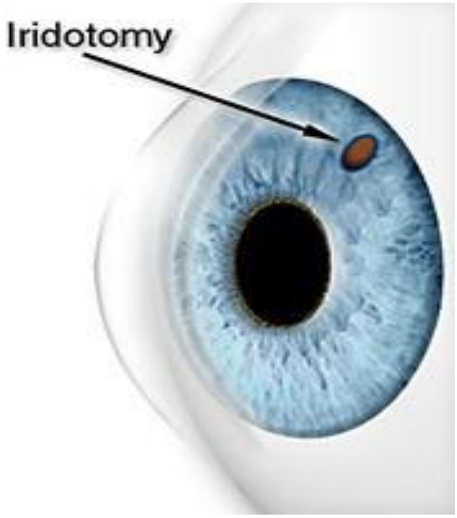

Figure 5: Angle-closure glaucoma after laser iridotomy [8].

Laser peripheral iridotomy (LPI) is the standard first-line method of treating. The main therapeutic treatment is performed with the neodymium-doped yttrium aluminum garnet (Nd: YAG) solid-state laser, emitting at 1,064 nm angle-closure glaucoma [9]. Laser iridotomy (LI) has been the standard therapeutic modality for the treatment of primary angle closure glaucoma to avoid blindness [4]. The main treatment for angle-closure glaucoma is laser iridectomy. The use of an algorithm for performing laser iridectomy in patients with angle-closure glaucoma and concomitant somatic pathology makes it possible to achieve the target intraocular pressure early after surgery and to avoid complications [10].Commonest cause of angle closure is pupillary block and Nd: YAG laser iridotomy is effective in reducing IOP and opening the drainage angle in primary angle-closure [11].The use of the laser therapy in the patients with acute closure glaucoma does not cause significant side effects, and leads to the prevention of primary angle closure glaucoma significant reduction of IOP, minimal changes of functional visual acuity and stability the changes in visual field [12].

5. Conclusion

This study evaluated the effectiveness of 1064nm Nd: YAG LASER and 488nm of argon LASER. The investigation took place in the COMSOL Multiphysics environment. The results confirmed that a lower thermal intensity of 350K from 1064nm Nd: YAG LASER with a pulse duration of 1ns and a heat flux of 1000 W/m² was more effective and safer for creating an invasive hole on the anterior surface of the iris reducing intraocular pressure (IOP) with minimal risk of iris tissue damage compared to the higher thermal response of 400K induced by 488nm of argon LASER iridectomy with a plus duration of 1ns and heat flux of 1000W/m^2. Finding improves clinical practice in the ophthalmology field it enhances the clinical favorite for Nd: YAG LASER iridotomy in ACG treatment, offering a safer and more controlled method to reducing IOP. This study contributes to improving ophthalmological LASER treatments, supporting evidence-based practices in glaucoma management.

References

[1] J. S. Yoon, Y. eun Kim, E. J. Lee, H. Kim, and T. W. Kim, "Systemic factors associated with 10-year glaucoma progression in South Korean population: a single center study based on electronic medical records," *Sci. Rep.*, vol. 13, no. 1, pp. 1–10, 2023, doi: 10.1038/s41598-023-27858-z.

[2] S. Farooq and A. Rizwan, "Glaucoma Detection and Classification Using Improved U-Net Deep Learning Model," 2022.

[3] M. P. Lehekar, "International Journal of Trend in Scientific Research and Development (IJTSRD) Implemetation of Kanban," no. June 2021, pp. 598–621, 2017.

[4] B. Chen, Y. Zhao, and D. Li, "Numerical Simulation of Aqueous Flow in Laser Iridotomy," August 2019 pp. 1–11, doi: 10.11159/htff19.174.

[5] L. Jt, B. Rouse, and G. Gazzard, "Iridotomy to slow progression of visual field loss in angle- closure glaucoma (Review)," no. 6, 2018, doi:10.1002/14651858.CD012270.pub2.www.cochranelibrary.com.

[6] Vaughan & Asbury's, *General Ophthalmology*, 19th ed. New York Chicago San francisco Athens London: McGraw-Hill Education, Inc, 2018.

[7] A. Khurana, *Comprehensive Ophthalmology-Diseases of the Retina 6th Edition*. 2015.

[8] R. Emberson, "Laser Peripheral Iridotomy (LPI) Information for patients. http://www.glaucoma.org," pp. 1–2, 2023.

[9] M. D. Thesis, "POLITECNICO DI TORINO Master Degree Course in Biomedical Engineering Master Degree Thesis Olmo Sibille," 2018.

[10] E. I. Belikova and G. A. Sharova, "Algorithm for performing laser iridectomy in patients with angle-closure glaucoma and concomitant somatic pathology," *Oftalmologiya*, vol. 17, no. 4, pp. 705–710, 2021, doi: 10.18008/1816-5095-2020-4-705-710.

[11] V. Ramnani and V. Damle, "Outcome of laser peripheral iridotomy in the spectrum of primary angle closure disease," vol. 7, no. 1, pp. 20–24, 2021.

[12] S. Paunovic, M. A. Janicijevic Petrovic, S. Sreckovic, M. Paunovic, K. Janicijevic, and Z. Stankovic, "Comparing the Effectiveness of Laser Therapy, Medicaments and Surgical Treatment in Patients with Angle Closed Glaucoma," *Exp. Appl. Biomed. Res.*, vol. 24, no. 3, pp. 213–218, 2023, doi: 10.2478/sjecr-2021-0050.