МЕДИЦИНСКИЕ НАУКИ

УДК:617.741–004.1

АНАЛИЗ ИМПУЛЬСОВ YAG-ЛАЗЕРА ВНУТРИ АНИМАЛЬНОГО ГЛАЗА С ПОМОЩЬЮ ОСЦИЛЛОГРАФА

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ANALYSIS OF THE OPHTHALMIC YAG-LASER PULSES INSIDE THE ANIMAL EYES USING AN OSCILLOSCOPE

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DOI: 10.31618/ESU.2413-9335.2022.4.101.1708

Statements and Declarations

Funding: This research is supported by the Ministry of Health and Science of the Samara Region, the Foundation for the Assistance to Small Innovative Enterprises in Science and Technology No. 384 dated 26.08.2020.

Conflict of Interest: The authors have no relevant financial or non-financial interests to disclose.

АННОТАЦИЯ

Цель: изучение иррадиации лазерного импульса внутри глаза.

Методы: мы провели моделирование и анализ физического воздействия YAG-лазера при лазерной капсулотомии на энуклеированные глаза половозрелых кроликов путем фиксации импульсов фотодетекторами и оценки их на осциллографе.

Результаты: наше исследование показало, что воздействие лазерного импульса на оболочки глаза может быть измерено с помощью высокоскоростного фотодетектора, что результаты стабильны и воспроизводимы, полученные импульсы имеют одинаковую конфигурацию во всех точках регистрации.

Заключение: амплитуды импульсов за задней капсулой хрусталика и на сетчатке, при подаче импульса на заднюю капсулу, не имеют статистической разницы, это можно объяснить отражением лазерного излучения внутренней поверхностью глаза. Используя нашу экспериментальную модель, можно рассчитать пик импульса, достигающего сетчатки, и использовать эти данные в дальнейших экспериментах и клинической практике.

ABSTRACT

Purpose: to study laser irradiation inside the eye.

Methods: we performed simulation and analysis of the physical effects of YAG laser during laser capsulotomy on the enucleated eyes of mature chinchilla rabbits by pulses fixation with photodetectors and evaluation of them on an oscilloscope.

Results: our study shows that the effect of the laser pulse on the eye membranes can be measured with a high-speed photodetector, that the results are stable and reproducible, the obtained pulses have the same configuration at all recording points.

Conclusion: the pulse amplitudes behind the posterior capsule of the lens and at the retina, when the pulse is applied to the posterior capsule, have no statistical difference, this can be explained by diffuse scattering of laser radiation inside the eye by the inner surface of the eye. Using our experimental model, it is possible to calculate the peak of the pulse reaching the retina and use this data in further experiments and clinical practice.

Ключевые слова: YAG-лазерная дисцизия, высокоскоростной фотодетектор, измерение лазерного импульса, оптическое волокно.

Keywords: YAG-laser capsulotomy, high-speed photodetector, laser pulse measure, optical fiber.

Introduction

Posterior capsular opacification (PCO) is the most common (to 50-70%) complication of cataract surgery and may develop soon after surgery or 5,5 years after it [1-6]. The younger the patient, the higher the incidence of posterior capsule opacities, in children it is up to 60-100% [7-9] and can cause a decrease in best corrected visual acuity (BCVA), contrast sensitivity and cause the appearance of optical aberrations [10]. The main method of treatment is YAG-laser capsulotomy.

There are several mechanisms of damaging effects of laser radiation (thermal effects, photochemical processes, thermoacoustic transients and nonlinear effects) - all these mechanisms are the same for any biological systems [10]. Different studies showed that at the YAG-laser wavelength (1064 nm) the effective absorption coefficient (μ_{eff}) of laser radiation is determined by light scattering processes - we continued this study using high-speed photodetectors [11, 12]. The development and deepening of methods for studying the response of cells, tissues, organs, and the body to laser exposure is essential [13]. The results of these studies will serve as a basis for further development of laser medicine as well as for adjustment of current maximum permissible limits of laser exposure [14, 15]. Therefore, research into the physics of laser ophthalmology with new highly sensitive devices remains relevant.

Purpose: to study laser irradiation inside the eye.

Methods

The procedures used in this study adhere to the tenets of the Declaration of Helsinki. The study was approved by the Bioethics Committee of the Samara State Medical University, Russia (No.186).

We performed physical simulation and analysis of laser influence on the eye during laser capsulotomy on animal models by fixation of pulses with photodetectors and evaluation of them on an oscilloscope.

A digital oscilloscope is a measuring device for studying electrical signals and converting them into a digital form with the possibility of visual observation on an LCD screen, measurement of pulse time and amplitude and its mathematical processing [12, 16, 17]. Photodetector - a device that converts optical energy into electrical energy [18]. Optic fiber - an optical waveguide in which light propagates with minimal losses because of internal reflection [17, 19].

6 eyes were enucleated in mature chinchilla rabbits [20] weighing 3.0-4.0 kg in the Tissue Bank of the Institute of Experimental Medicine and Biotechnology of Samara State Medical University. The length of the rabbit's eye was measured with a caliper - and was 20,0±0,2mm.

The first step was the aspiration 20 cm3/min, vacuum 0 mmHg. The eye was then fixed on a Yatagan-4M YAG - laser. A two-channel laser power measurement system was assembled consisting of a GDS-71102A dual-channel digital oscilloscope, two DET025AFC/M high-speed photodetectors - Si photodetector with FC/PC connector, bandwidth: 2 GHz, operating spectral range: 400 - 1100 nm, mount: M4, Thorlabs and two TELCOM SHOS-0.9-FC/PC-MM62.5-1.5m - LSZN fibres with 20V battery power supply. The optical fiber is a pt FC 62.5/125 OM1 multimode MM (0.9mm) optical pigtail (Fig.1 and fig.2).

Figure 1: Photograph of the experimental model, consisting of a YAG laser, an eyeball and a laser power measurement system (two optical fibers, two photodetectors and two-channel oscilloscope)

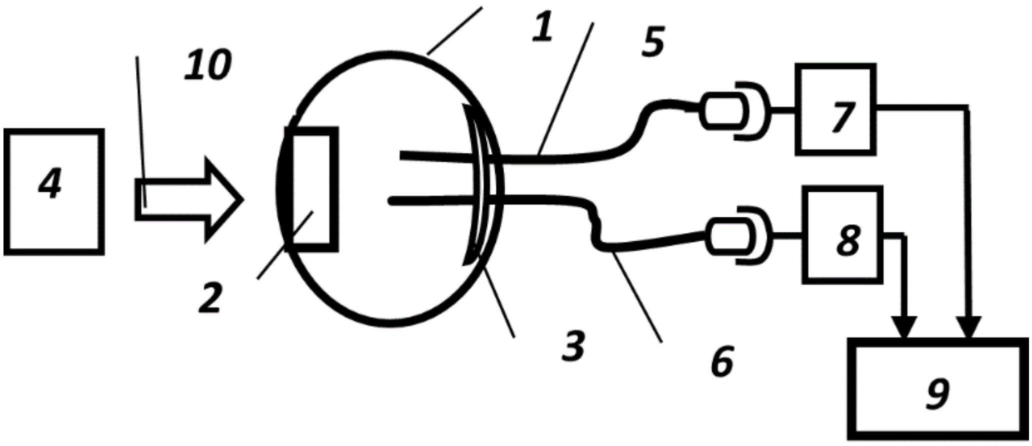

Figure 2. Scheme of the experiment, consisting of a YAG laser, an eye, a system for fixing laser radiation (two optical fibers), two photodetectors and an oscilloscope: 1 - eyeball; 2 - posterior capsule of the lens; 3 - retina; 4 - YAG laser Yatagan-4M; 5, 6 – multimode optical fibers «pigtails» FC 62.5 / 125; 7, 8 - high-speed photodetectors; 9 - digital oscilloscope GDS-71102A; 10 - a stream of laser radiation

The distal ends of the optical fibers were fastened with tape and installed in one of three positions inside the eye (fig.3). Key positions of the distal ends of optical fibers: 1) behind the lens capsule 8; 2) 6 - 7 mm inward from the retina (conventionally the middle of the distance between the posterior capsule of the lens and the retina) 9; 3) near the retina 10.

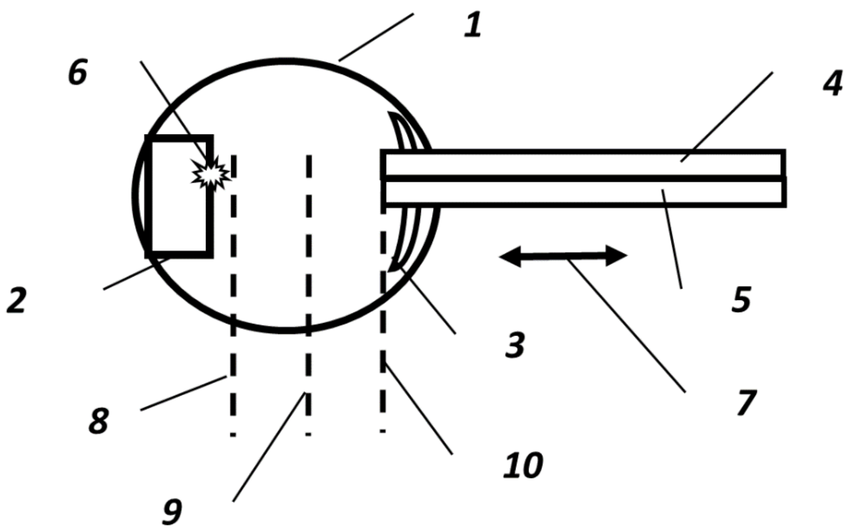

Figure 3. Scheme of the optical fibers position inside the eye: 1 - eye; 2 – lens capsule; 3 - retina; 4, 5, - optic fiber; 6 - area of action of laser radiation; 7 - direction of displacement of the distal ends of the optical fibers; 8, 9, 10 - the positions of the distal ends of the optical fibers: "behind the posterior capsule", "in the middle of the vitreous body" and "near the retina" in the region of the posterior pole of the eye

The position of the optical fiber inside the eye was monitored by indirect biomicroscopy with a 78 D lens.

Laser pulses of four energies (2.0 mJ; 3.0 mJ; 6.5 mJ; 13.7 mJ) were applied to the posterior capsule. We used the minimum values (2.0 mJ; 3.0 mJ), at which the capsule discision occurred, as well as the maximum possible value of the Yatagan-4M laser - 13.7 mJ and the average energy value between these indicators, which we took equal to 6.5 mJ. To determine the true value of the pulse energy, the pulses were calibrated, thus, the true values of the four types of pulse energy used were equal to 1.5 mJ, 2.1 mJ, 4.2 mJ, 8.5 mJ, respectively.

The pulses were concentrated in the posterior capsule of the lens, and the radiation propagating inside the eye was converted by high-speed photodetectors into electrical signals, which were recorded by a two-channel oscilloscope).

Statistical analysis was performed using StatTech v. 2.1.0 (Developer - StatTech LLC, Russia).

Quantitative variables were assessed for normality using the Shapiro-Wilk test (when the number of subjects was less than 50) or the Kolmogorov-Smirnov test (when the number of subjects was more than 50).

Quantitative variables following non normal distribution were described using median (Me) and lower and upper quartiles (Q1 – Q3).

Comparisons of three or more groups on a quantitative variable whose distribution differed from normal were made using the Kruskal-Wallis test and Dunn's criterion with Holm correction as a post-hoc method.

The direction and strength of the association between two quantitative variables were estimated using Spearman's correlation coefficient (if at least one variable does not follow a normal distribution)

A predictive modeling of a quantitative variable conditioning on other quantitative variables was developed using simple or multivariable linear regression.

Results

The results of the analysis of the pulses peak amplitude, depending on the pulse energy and the fiber position using high-speed photodetectors and the oscilloscope is presented in Table 1 and on the fig.4.

Table 1

Pulse amplitude depending on its energy and optic fiber position

Pulse energy and fiber position	Pulse amplitude (mV)			p
	Me	$Q_1 – Q_3$	n	
behind the PC 1,5 mj	42	29 – 46	8	< 0,001* $p_{\text{behind the PC 8,5 mj – behind the PC 1,5 mj}} = 0,044$ $p_{\text{behind the PC 1,5 mj – behind the PC 4,2 mj}} = 0,001$ $p_{\text{behind the PC 2,1 mj – behind the PC 4,2 mj}} = 0,008$ $p_{\text{behind the PC 8,5 mj – behind the PC 4,2 mj}} = 0,029$ $p_{\text{near the retina 1,5 mj – behind the PC 8,5 mj}} = 0,017$ $p_{\text{in the middle of the eye 8,5 mj – in the middle of the eye 1,5 mj}} = 0,027$ $p_{\text{near the retina 4,2 mj – in the middle of the eye 2,1 mj}} = 0,009$ $p_{\text{near the retina 8,5 mj – in the middle of the eye 4,2 mj}} = 0,004$ $p_{\text{near the retina 8,5 mj – near the retina 1,5 mj}} = 0,029$
behind the PC 2,1 mj	46	36 – 59	6	
behind the PC 4,2 mj	76	66 – 84	6	
behind the PC 8,5 mj	104	102 – 112	8	
in the middle of the vitreous body 1,5 mj	12	9 – 13	9	
in the middle of the vitreous body 2,1 mj	12	10 – 17	8	
in the middle of the vitreous body 4,2 mj	24	21 – 24	6	
in the middle of the vitreous body 8,5 mj	38	30 – 110	7	
near the retina 1,5 mj	25	24 – 42	7	
near the retina 2,1 mj	42	37 – 54	9	
near the retina 4,2 mj	62	56 – 83	9	
near the retina 8,5 mj	78	65 – 113	18	

* – differences are statistically significant (p <0.05)

According to the presented table 1, when comparing of peak pulse amplitude, statistically significant differences were revealed depending on pulse energy and fiber position (p <0.001) (applied method: The Kruskal-Wallis test).

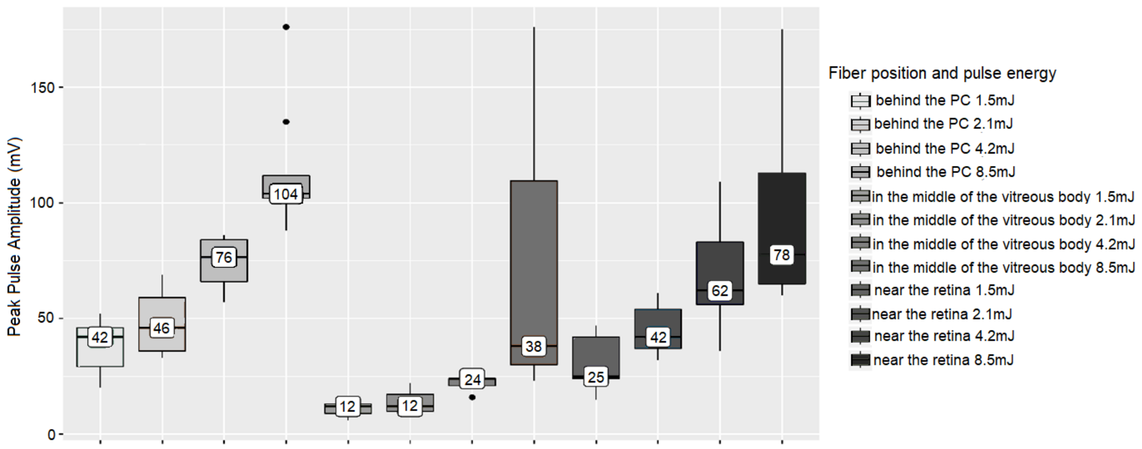

Figure 4. The amplitude of the pulse depending on its energy and the position of the fiber inside the eye

We performed a correlation analysis of the association between pulse energy and peak pulse amplitude.

Observed dependence of peak pulse amplitude from pulse energy is described by a linear regression equation:

$$Y_{\text{Peak pulse Amplitude}} = 9.46 \times X_{\text{Pulse Energy}} + 14.085$$

With an increase in the pulse energy by 1 mj, an increase in the peak pulse amplitude by 9.46 mV should be expected. The tightness of communication on the Chaddock scale is noticeable (ρ = 0.707) (p <0.001).

Discussion

Our research shows that a laser pulse in the eye can be measured with a high-speed photodetector, that the results are stable and reproducible (p> 0.05), the obtained pulses have the same configuration at all registration points. The peak pulse amplitude behind the posterior lens capsule and in the retina, when the pulse was applied to the posterior capsule, did not have statistical differences at each of the energy values (p> 0.05: p = 0.317 at 1.5 mj; p = 0.586 at 2.1 mj ; p = 0.662 at 4.2 mj; p = 0.066 at 8.5 mj). In this case, the peak pulse amplitude in the middle of the vitreous at pulses of 1.5mj, 2.1mj and 4.2mj is significantly less than the peak behind the posterior capsule and in the retina (p = 0.001 at 1.5mj and at 2.1mj; p = 0.002 at 4.2 mj). With pulses of 8.5 mj, the peak pulse amplitude in all positions did not have a statistically significant difference (p = 0.155).

An increase in the pulse energy leads to a linear increase in the peak of the pulse voltage, however, the pulses of 1.5 and 2.1 mj did not have a statistically significant difference between them (p = 0.076).

Under the action of a laser pulse (Fig.5), plasma is formed in the region of the posterior capsule (microexplosion effect), leading to local tissue destruction [14].

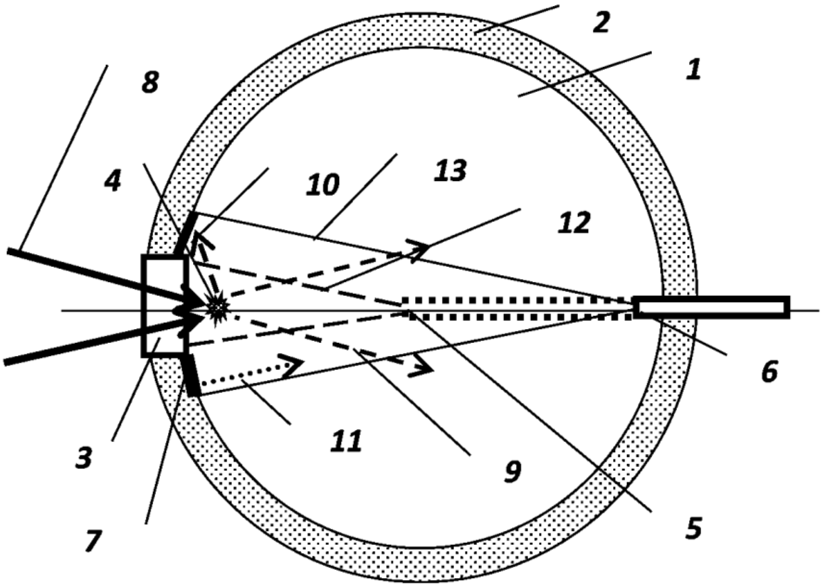

Figure 5. Distribution of laser radiation flow: 1 - eyeball; 2 - sclera; 3 - the pupil of the eye; 4 - breakdown in the posterior capsule; 5, - the position of the fiber "in the middle of the vitreous"; 6 - the position of the optical fiber "near the retina"; 7 - a section of the retina in the field of view of the optical fiber; 8 - influencing flow of laser radiation; 9 - the laser beam passed through the rear capsule; 10 - laser radiation flux scattered by the back capsule; 11 - laser radiation flux scattered by the retinal pigment epithelium; 12 - the field of view of the optical fiber in the position "in the middle of the vitreous body"; 13 - the field of view of the optical fiber in the position "near the retina"

When the distal end of the optical fiber is located "behind the posterior capsule" and "in the middle of the vitreous body", the main contribution to the amplitude of the recorded signal is made by the radiation transmitted through the posterior capsule. The difference in amplitude is due to the distance between the fiber and the focusing region of the laser beam. When the fiber is located "near the retina", then the main source of the recorded signal becomes laser radiation, diffusely scattered by the inner surface of the eye.

Conclusion: the pulse amplitudes behind the posterior capsule of the lens and at the retina, when the pulse is applied to the posterior capsule, have no statistical difference, this can be explained by diffuse scattering of laser radiation inside the eye by the inner surface of the eye. Using our experimental model, it is possible to calculate the peak of the pulse reaching the retina and use this data in further experiments and clinical practice.

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ВЛИЯНИЕ ТАБАКОКУРЕНИЯ НА ОСЛОЖНЕНИЯ У БЕРЕМЕННЫХ ЖЕНЩИН

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THE EFFECT OF SMOKING ON COMPLICATIONS IN PREGNANT WOMEN

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DOI: 10.31618/ESU.2413-9335.2022.4.101.1709

АННОТАЦИЯ

По данным ВОЗ Россия лидирует по количеству курящих женщин репродуктивного возраста. Курит около 30% работающих женщин. Среди беременных женщин табакокурение достигает 52 %, что является одной из причин увеличения частоты встречаемости осложнений беременности и плода, учащение самопроизвольных абортов. Изучение влияния никотина и других веществ, содержащихся в табачном дыме, позволило выявить, что курение приводит к гипоксии плода вследствие нарушения маточно-плацентарного кровообращения и повышенного образования карбоксигемоглобина в крови беременной женщины. В статье представлены результаты изучения влияния табакокурения на развитие осложнений у беременных женщин, страдающих артериальной гипертензией. В исследовании приняли участие 200 беременных женщин, из них 96 (48%) женщин курили. Применялись следующие опросники и анкеты: анкета мотивации отказа от курения (опросник Проскаха), анкета оценка степени никотиновой зависимости (тест Фагерстрема), шкала одышки mMRS» Среди курящих женщин 29 (30,2%) имели высокую и очень высокую зависимость, 31 (32,3%) среднюю зависимость, остальные беременные женщины имели умеренную и низкую никотиновую зависимость, при этом большинство 67 (69,7%) беременных имели высокую мотивацию к полному отказу от курения. Осложнения беременности значительно чаще диагностировались у курящих, чем у некурящих : преэклампсия у 78,3% курящих против 6,3% у некурящих, фетоплацентарная недостаточность у 71,6% и 9,5% соответственно, синдром внутриутробной задержки плода у 78,3% и 9,5% соответственно. Корреляционный анализ показал, что у курящих беременных женщин выявлена достоверная зависимость осложнений беременности от факта курения, стажа курения и наличия артериальной гипертензии