13. Raya-Povedano JL, Romero-Martín S, Elías-Cabot E, Gubern-Mérida A, Rodríguez-Ruiz A, Álvarez-Benito M. AI-based strategies to reduce workload in breast cancer screening with mammography and tomosynthesis: a retrospective evaluation. Radiology. 2021 Jul;300(1):57-65. doi: 10.1148/radiol.2021203555. 14. Shang Y, Sawa Y, Blyth BJ, Tsuruoka C, Nogawa H, Shimada Y, Kakinuma S. Radiation exposure enhances hepatocyte proliferation in neonatal mice but not in adult mice. Radiat Res. 2017 Aug;188(2):235–241. doi: 10.1667/RR14563.1.
15. Zubakha AB, Lihonenko OV, Chorna IO, Shumeiko IA, Storozhenko OV, Skotarenko TA, Yaroshenko RA. Combination of ultraviolet radiation of autologous blood, negative pressure wound therapy, and endolymphatic antibacterial therapy in the treatment of post-traumatic wound infections. World of medicine and biology. 2021;4(78):60–65; doi 10.26724/2079-8334-2021-4-78-60-65

Стаття надійшла 13.09.2022 р.

DOI 10 26724/2079-8334-2023-3-85-25-30
UDC 617.7-001.45-08-036

M.I. Badiuk, B.B. Zhupan[1], I.I. Khramov[1], O.O. Mykyta
Ukrainian Military Medical Academy, Kyiv
[1]National Military Medical Clinical Center "Main Military Clinical Hospital", Kyiv

MEDICAL AND SOCIAL FEATURES OF LASER EYE INJURIES IN MILITARY PERSONNEL OF THE DEFENSE FORCES OF UKRAINE

e-mail: badiuk@ukr.net

For the first time, an analysis of tactical and medico-social features of combat damage to the organ of sight in the Defense Forces of Ukraine servicemen from field tactical lasers was conducted using open-world sources of scientific information. The medical and tactical characteristics of admission of victims to specialized healthcare facilities are given, and complaints, medical history, and clinical features of laser injuries are revealed. It was noted that 2/3 of the lesions were monocular. The direct dependence of the severity of the lesion on the distance to the laser beam source was proved. Macular ruptures, manifested severe retinal lesions, and central or paracentral scotoma were noted. All patients with eye injuries underwent conservative treatment. In 25 % of cases, surgical interventions were performed. After treatment and rehabilitation, the servicemen underwent a military medical examination; 50 % remained fit to perform their military service duties.

Key words: laser lesions, eye, military personnel, retinal lesions, scotomas, field tactical lasers

М.І. Бадюк, Б.Б. Жупан, І.І. Храмов, О.О. Микита

МЕДИКО-СОЦІАЛЬНІ ОСОБЛИВОСТІ ЛАЗЕРНИХ УШКОДЖЕНЬ ОРГАНУ ЗОРУ У ВІЙСЬКОВОСЛУЖБОВЦІВ СИЛ ОБОРОНИ УКРАЇНИ

Вперше у відкритих світових джерелах наукової інформації проведено аналіз тактичних та медико-соціальних особливостей бойових ушкоджень органу зору у військовослужбовців Сил оборони України від польових тактичних лазерів. Наведена медико-тактична характеристика надходження постраждалих до спеціалізованих закладів охорони здоров'я, виявлено скарги, анамнез, клінічні особливості лазерних уражень. Відзначено, що 2/3 уражень були монокулярними Доведено пряму залежність тяжкості ураження від відстані до джерела лазерного променя. Тяжкі ураження сітківки очей проявлялись макулярними розривами, відмічались центральні або парацентральні скотоми. Усі пацієнти з ураженнями органу зору проходили консервативне лікування. У 25 % випадків проводились оперативні втручання. Після лікування та реабілітації військовослужбовцям було проведено військово-лікарську експертизу: 50 % військовослужбовців залишились придатними до виконання обов'язків військової служби.

Ключові слова: лазерні ураження, орган зору, військовослужбовці, ураження сітківки, скотоми, польові тактичні лазери

The study is a fragment of the research project: "Scientific substantiation of the standardization of the system of medical support of the Armed Forces of Ukraine in different operating conditions" code "Standard", state registration No. 0116U002816.

Eye injury and its consequences today remain one of the leading causes of blindness and professional disability of military personnel, especially in conditions of military conflict. The overwhelming number of combat ocular trauma of military personnel in the war in Ukraine from 2014 to the present day is caused by factors of conventional types of firearms (bullet and shrapnel wounds). Although the ocular surface area occupies less than 1 % of the total body surface, the frequency of combat injuries to the eyes and related structures reaches more than 8 %, with a clearly increasing trend. According to domestic experts, combat eye injuries in military personnel came out on top in the structure of causes of visual disability and accounted for 22.8 % of cases of primary disability. At the same time, 70.6 % of the visually impaired are young working-age people [2]. The standards and algorithms of the clinic, diagnosis, treatment and prevention of combat ocular trauma are well covered in the publications of scientists from other countries [3, 7, 9]. Modern national innovative methods of treatment are also proposed [1].

However, since the end of May 2016, the appearance of corneal flash burns as a result of the use of field tactical lasers has become a feature of combat ocular trauma of domestic servicemen during the Anti-Terrorist Operation (ATO) and the Joint Forces Operation (JFO). All such servicemen were injured while observing the enemy using optical means (binoculars, stereo tubes, etc.), which became a new challenge for domestic military medicine.

We did not find publications on the peculiarities of the biological effect of the laser on the eye among domestic scientists and scientific publications since damage to the retina by industrial or military lasers, in general, is a rare phenomenon. Scientific publications by experts from other countries regarding the coverage of the biological effect of the laser on the eye and the treatment and prevention of these injuries are also few. The latter relate to the coverage of accidental injury by industrial lasers [5, 10], the use of lasers in ophthalmology for therapeutic purposes [4] or minor injuries by laser pointers. Publications of cases of eye injuries caused by military laser systems are also relatively isolated, published more than 25 years ago and associated with violations of safety regulations [9]. Practical recommendations and cautions for handling military personnel with laser systems are even older, Lyon T. (1993).

In this, in general, insignificant scientific array, there are no publications of cases of the use of lasers for defeating and causing damage and maiming to military personnel who use optical devices in combat operations.

The purpose of the study was to highlight the specifics of the clinic, diagnosis, treatment and results of servicemen of the Defense Forces of Ukraine who suffered eye injury from exposure to field tactical lasers.

Materials and methods. Medical documentation (medical histories (health passports)), medical cards of inpatients (form No. 003/o), outpatient cards, transfer and discharge epicrises, conclusions of the Military Medical Commission) of military personnel with eye injuries from exposure to field tactical lasers from May 2016 to December 2019, who were treated in healthcare institutions of the Defense Forces of Ukraine: National Military Medical Clinical Center "Main Military Clinical Hospital (MMCH)", Military Medical Clinical Centers of the southern and central regions were selected as materials for conducting the study.

A total of 12 cases of laser damage were investigated. All patients were men aged 23 to 45 years. The average age was 35.3 years. Of the total number of cases, monocular lesions were registered in 8, and in 4 patients, both eyes were affected.

Laboratory and special hardware research methods were also carried out (visometry, biomicroscopy, ophthalmoscopy, optical coherence tomography of the retina (OCT) and computer perimetry according to program 30-2). Parameters of the functional state of visual analyzers were evaluated upon admission to healthcare institutions of the Defense Forces of Ukraine after a complex of treatment and military medical examination and after three months. All patients underwent conservative symptomatic treatment. In severe cases, the standard surgical treatment of macular rupture was performed by mobilising its edges.

Results of the study and their discussion. Upon admission, all patients complained of varying degrees of decreased visual acuity. At the time of the lesion, they usually noticed a bright flash of light, after which the vision of the affected eye instantly deteriorated. Servicemen with severe injuries (hemophthalmos and retinal tears) felt clicking and cracking in the area of the affected eye, which was accompanied by dizziness and pain.

In the anamnesis, all servicemen at the time of the defeat were observing using optical devices and were at a distance of 800 to 1300 m from the enemy. At the same time, the dependence of the severity of the patient's injuries on the distance to the enemy was monitored. Eye injury in military personnel at a distance of 1200–1300 m from the enemy was relatively light. As the distance to the laser beam source decreased, the severity of the lesions increased.

According to the time of arrival of the affected to the ophthalmological departments of the Medical Center of the Defense Forces of Ukraine, the latter were distributed: within 1 day, 50 % (6/12) of those affected arrived, within 2–3 days – 33.3 % (4/12), the rest of those affected by the laser were evacuated within 9–12 days – 16.7 % (2/12).

During the initial examination, the visual acuity of the affected eyes with maximum correction ranged from hand movement near the face to 0.9. According to the localization of the lesion, they were foveal 37.5 % (6/16), juxtafoveal 37.5 % (6/16), and extrafoveal 25 % (4/16). It should be noted that the damage pattern was different in the case of foveal damage. Both lesions of the temporal part of the foveal zone with an intact nasal part and severe lesions of the temporal and nasal areas of the foveal site, even with macular tears up to 1600 μm, were recorded, Fig. 1.

According to the static perimetry results, central or paracentral scotoma were noted in severe cases with macular tears (Fig. 1B) and their absence in patients with lesions of moderate severity (Fig. 1D).

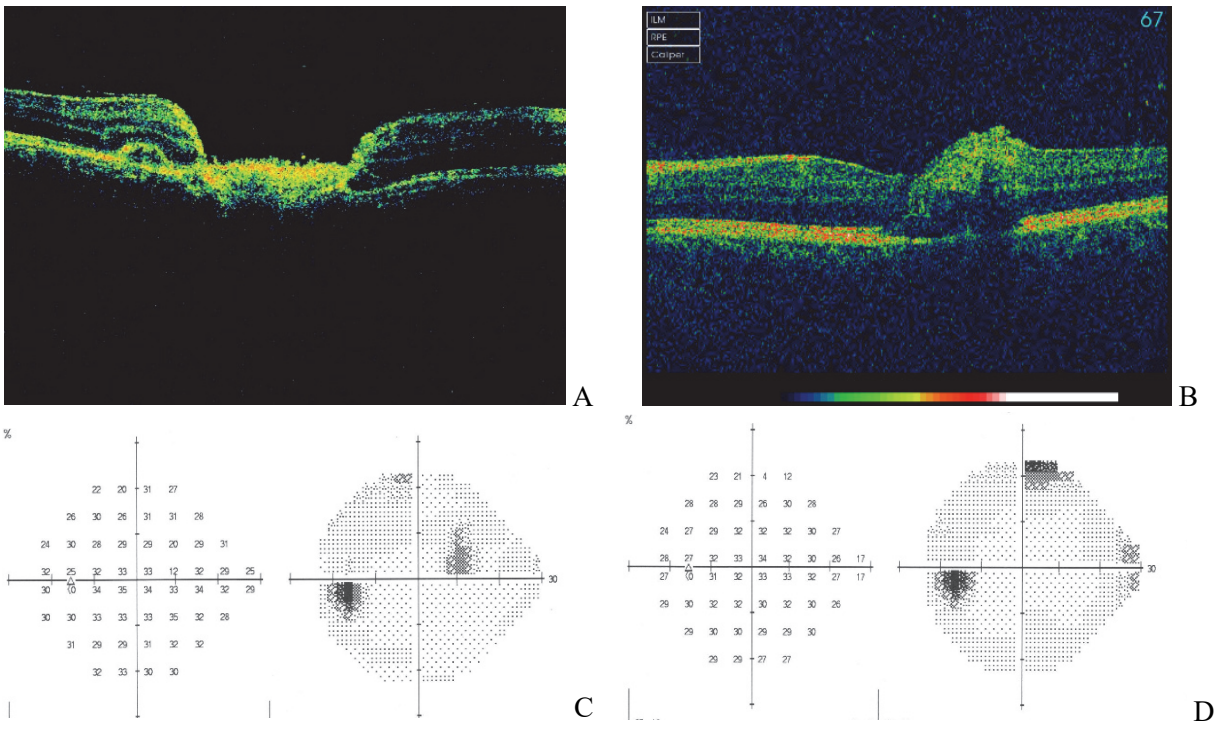

Fig. 1. Variants of retinal damage in ocular laser burns and perimetry indicators according to the program 30-2: A. Severe damage and macular rupture of the retina; B. Moderate damage; C. Macular rupture of the retina in the central area with edge retraction; D. Damage to the temporal part of the foveal zone.

It should be noted that severe injuries are associated with the close location of the serviceman relative to the laser – about 800 meters. Accordingly, visual acuity in patients with complete foveal damage was significantly worse. Visual acuity in foveal lesions was from 0.05 to 0.5 (0.23±0.19), in juxtafoveal lesions from 0.3 to 0.4 (0.35±0.05), in extrafoveal lesions from 0.7 to 1.0 (0.83±0.12), Table 1.

Table 1

Parameters of visual acuity depending on the location of retinal damage

Parameters	Foveal lesion	Juxtafoveal lesion	Extrafoveal lesion
Frequency of lesions, %	37.5	37.5	25
Visual acuity after the lesion	0.23±0.19	0.35±0.05	0.83±0.12
Visual acuity after 60 days	0.47±0.27	0.85±0.07	0.97±0.05

The parameter of decreased contrast sensitivity and median deviation (MD) was slightly changed in the affected eyes. This is especially noticeable in cases of bilateral damage. In all cases, the MD on the affected eye reached -2.8 dB, but it was not less than -1.0 dB on the intact eye. The severity of the lesion was also diagnosed ophthalmoscopically, where the foveal area was unchanged in the mildest cases, light regions of the central zone of the macula were visualized in moderate severity, and retinal pallor with visible tears and partial hemophthalmus in severe cases, Fig. 2.

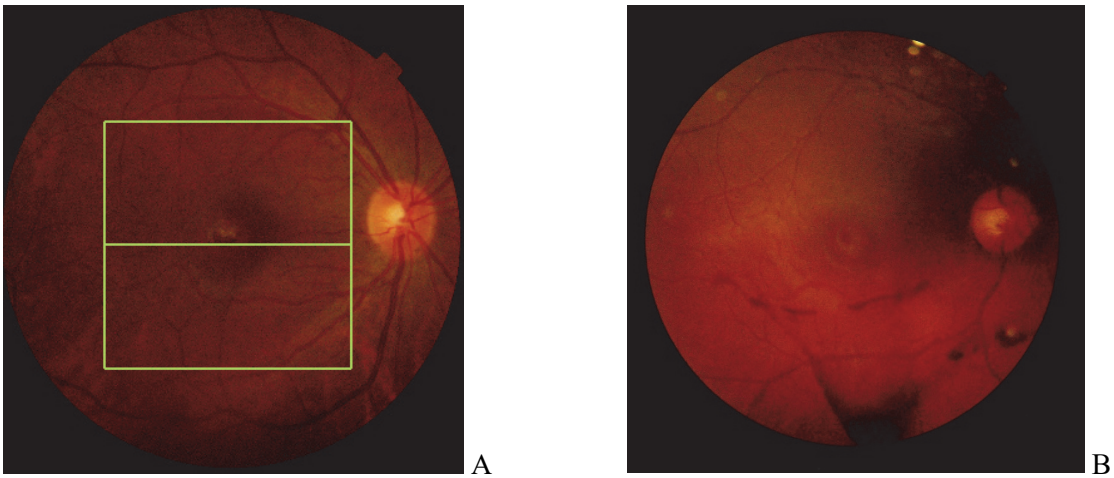

Fig. 2. Ophthalmoscopic picture of the fundus. A – visible pallor of the foveal zone and B – partial hemophthalmus with foveal damage.

Optical coherence tomography data differed depending on the severity of the lesion. In most cases, the pattern of inflammatory macular edema of the retina up to 270 μm with a violation of the architecture of the retina, which corresponded to the average degree of severity, prevailed. In severe lesions, macular tears of the retina were determined. No changes were detected in patients with mild lesions, or defects of the pigment epithelium up to 200 μm were determined. There was also a case of the formation of a macular tear during one month.

In one case, with a bilateral lesion, a central lesion in both eyes and an additional, less expressive lesion in the extrafoveal areas, unidirectional and at the same distance, was recorded, which may indicate pulsed laser operation with a specific radiation frequency. This damage can be explained by eye movement after initial exposure to a laser beam (Fig. 3).

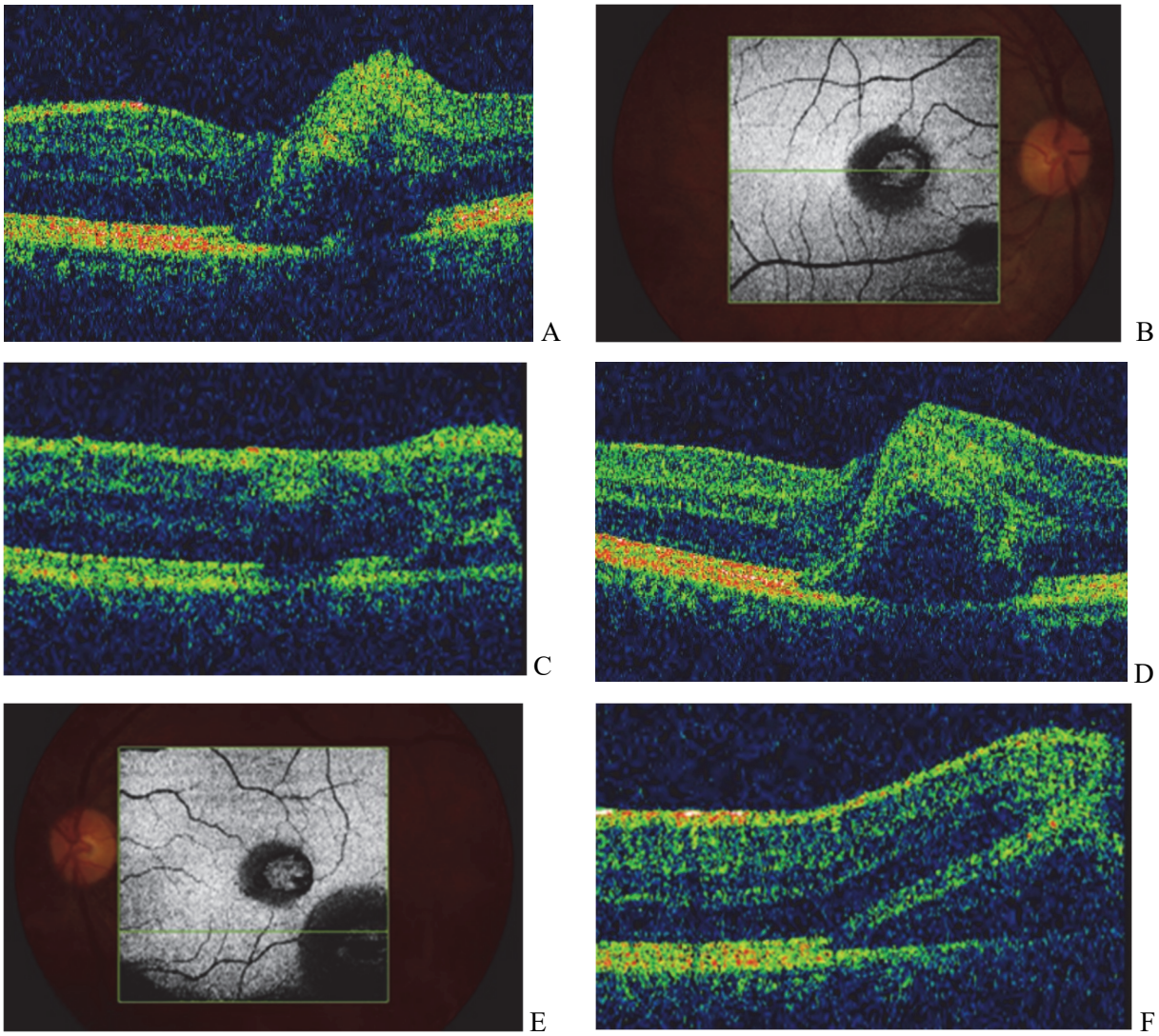

Fig. 3. Tomographic picture of primary and additional eye damage. A – Primary lesion of the foveal area of the right eye; B – Projection image of retinal lesions of the right eye; C – additional lesion of the extrafoveal area of the right eye; D – Primary lesion of the foveal area of the left eye; E – Projection image of retinal lesions of the left eye; F – additional lesion of the extrafoveal area of the left eye.

All patients with eye injuries underwent conservative symptomatic treatment, which included hormones, nonsteroidal anti-inflammatory drugs, antioxidants, agents that improve microcirculation, etc. In 25 % (4/16) of cases, patients underwent surgical interventions - closed subtotal vitrectomy, peeling of the internal boundary membrane with the plasticity of the macular area with the inner boundary membrane and endotamponade with a gas mixture. In one case, the surgical intervention was repeated. A CT scan of the retina of one of the patients before and after surgery is shown in Fig. 4.

It should be noted that in some cases, paramacular retinotomy and repair of the tear with an internal retinal membrane were also performed due to the rigidity of the edges of the macular tear. All patients who received surgical treatment had macular opening closure with local retinal atrophic changes in the central area.

When observing patients who received conservative treatment, a gradual improvement in visual acuity and positive dynamics were recorded according to retinal optical coherence tomography data, swelling in the affected area gradually decreased, and architecture was restored. After two months, as a rule, local atrophy of the retinal pigment epithelium and an atrophic area of the ellipsoid zone with a diameter of up to 200 μm were observed. The MD parameter of static perimetry remained almost at the same level – within -2.4 dB. Assessment of visual acuity of the affected eyes after treatment and two months after the injury showed the following results: foveal lesions from 0.06 to 0.9 (0.47±0.27), juxtafoveal – 0.7–0.9 (0.85±0.07), extrafoveal 0.9-1.0 (0.97±0.05). The average duration of treatment was 34.4 days.

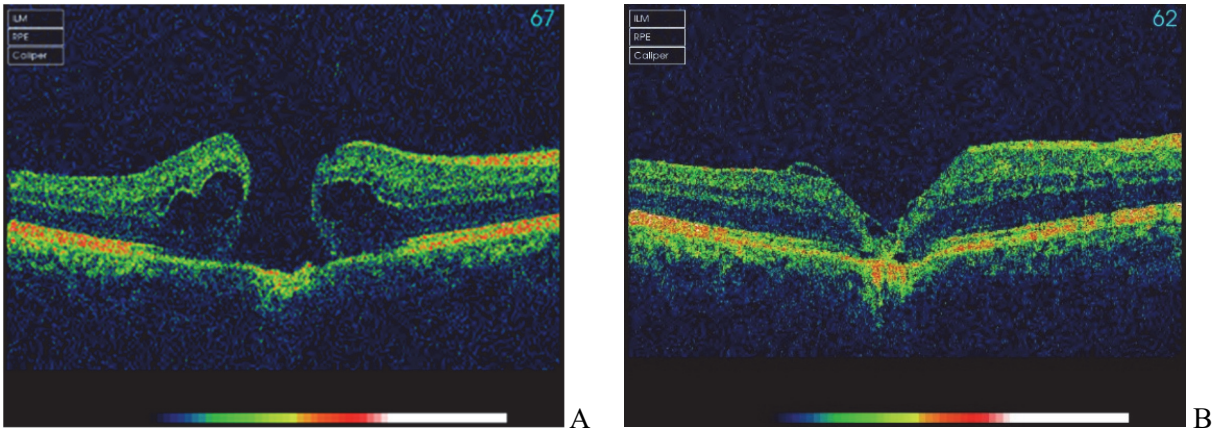

Fig. 4. Tomographic picture of the retina before and after surgery. A – Macular hole before surgical treatment and B – after surgical treatment.

After treatment and rehabilitation, all servicemen underwent a military medical examination, which, depending on the possibility of performing functional duties as assigned, showed the following results: 50 % (6/12) of military personnel remained fit for military service, 33 % (4/12) were limited fit, and 17 % (2/12) were unfit for military service.

According to scientific sources [8] and taking into account the laser beam's main properties, the latter's negative biological impact on the human organ of vision is aimed at two main groups of objects: the retina and the rest of the environment of the eye.

Therefore, there is a directly proportional dependence of the severity of the biological effect of the laser on the distance of the laser source, which actually forms the consequences of eye injury. In addition, the negative effect of the laser on the retina depends entirely on the characteristics of the wavelength spectrum and its range with the possibility of penetration through all the optical media of the eye, namely: the cornea, the anterior chamber, the lens and the vitreous body. The specified wave range includes the visible range with a length of 400 to 700 nm and waves of the near-infrared zone with a wavelength of up to 1400 nm. The range of dangerous radiation that does not affect the retina includes waves absorbed by the front tissues of the eye. This range includes ultraviolet radiation and part of the infrared range, with a wavelength over 1400 nm.

The use of optical devices (periscope, telescope, binoculars, optical sight, etc.) that, thanks to their light-concentrating properties, have the ability to increase the power of the laser beam entering the optical device, significantly increasing the danger of damage, are also negative features of injury to military personnel. With a hardware reduction of the beam diameter by 50 percent, the optical energy density of the beam increases squarely.

It should be noted that the use of lasers to damage the sight of servicemen in the conditions of hostilities is prohibited by UN conventions. The Prohibition of the use of lasers to damage the visual organ of military personnel in armed conflict is regulated by Protocol No. 4 of the UN Convention on Conventional Weapons of 1980 (as amended in 2003) [6], which prohibits the development of lasers designed to "cause irreversible blindness". This Protocol was signed by most countries, including the USA, Ukraine and Russia (1997) and Protocol No. 6 of the 1980 UN Convention on Conventional Weapons, which prohibits using Blinding Laser Weapons. The protocol prohibits using and transferring any weapon in question intended to cause permanent blindness.

Despite the international agreements ratified by Russia, the Russian military leadership considers it possible to develop and use lasers as a non-lethal means that blinds military personnel (mainly field commanders) and causes serious injuries.

Conclusions

1. The severity of eye injury by laser radiation in combat conditions directly depends on the distance between the laser source and the eye. As this distance decreases, the severity of the lesion increases proportionally.

2. When using optical devices that can increase the power of the light beam, the danger of laser damage increases. When the beam's diameter is reduced by hardware, the optical energy density of the beam increases proportionally, which is fully correlated with the severity of damage to the organ of vision. This requires further study of the problem of damage by tactical lasers for developing and implementing means of protection of optical devices.

3. Under the conditions of using laser beam generators in the pulse mode, there is a possibility of receiving several lesions of one eye simultaneously.

4. Patients with eye injury of mild and moderate degrees of severity need only conservative treatment. Severe irreversible eye injuries require complex surgical methods of treatment.

References

1. Stetsuk O, Shepitko K. Morfofunktsionalnyy stan hemomikrotsyrkulyatornoho rusla sytkivky pislya odnorazovoho vvedennya kriokonservovanoyi platsenty na tli hostroho eksperymentalnoho aseptychnoho retynitu u shchuriv. Svit medytsyny ta biolohiyi. 2019. № 1 (67). S. 190–194. DOI 10.26724/2079-8334-2019-1-67-190 [in Ukrainian].

2. Zhupan B, Lurin I, Medvedovs′ka N, Khramov I. Perspektyvy prohnozuvannya viddalennykh rezul′tativ likuvannya u patsiyentiv z boyovoyu travmoyu orhanu zoru. J.ophthalmol. (Ukraine) [internet]. 30, Cherven′ 2023 [tsyt. za 14, Serpen′ 2023]; (3): 34-7. dostupnyy u: https://ua.ozhurnal.com/index.php/files/article/view/18.[in Ukrainian].

3. Akıncıoğlu D, Küçükevcilioğlu M, Durukan A. Combat-related ocular trauma and visual outcomes during counter-terrorism urban warfare operations in Turkey. Ulus Travma Acil Cerrahi Derg. 2022; 28(5):648-653 https://doi.org/10.14744/tjtes.2021.25822.

4. Barone F, Amaral J, Bunea I, Farnoodian M, Gupta R, Gupta R, et al. A versatile laser-induced porcine model of outer retinal and choroidal degeneration for preclinical testing. JCI Insight. 2023 Jun 8;8(11):e157654. DOI:10.1172/jci.insight.157654.

5. Christodoulou E, Batsos G, Christou E, Gorgoli K, Parikakis E, Karagiannis D, et al. Long-Term Outcomes following Intravitreal Ranibizumab for Choroidal Neovascularization Related to Nd:YAG Laser Macular Injury: A Case Report. Case Rep Ophthalmol. 2023 Feb 17;14(1):68-74. DOI: 10.1159/000529297. eCollection 2023 Jan-Dec.

6. Convention on prohibitions or restrictions on the use of certain conventional weapons which may be deemed to be excessively injurious or to have indiscriminate effects. Adopted through 28 november 2003. Geneva. 67 p. https://www.icrc.org/en/doc/assets/files/other/icrc_002_0811.pdf.[nazva z ekranu].

7. Guven S. Verification of Ocular Trauma Score for Intraocular Foreign Bodies in Lethal-Weapon-Related Ocular Injuries. Military Medicine. 2020;185(7-8):1101-1105 https://doi.org/10.1093/milmed/usaa042.

8. Mainster M. Retinal laser accidents: mechanisms, managment and rehabilitation. J Laser Appl. 2000;123- 9Google ScholarCrossref.

9. Stuck B, Zwick H, Molchany J, Lund D, Gagliano D. Accidental human laser retinal injuries from military laser systems. In Laser-Inflicted Eye Injuries: Epidemiology, Prevention and Treatment. 1996, April Vol. 2674, p. 7-20).

10. Vlasov A, Denise S, Ludlow S, Coggin A, Weichel E, Stutzman R et al. Corneal and Corneoscleral Injury in Combat Ocular Trauma from Operations Iraqi Freedom and Enduring Freedom. Military Medicine, Volume 182, Issue suppl_1, March 2017, P. 114–119, https://doi.org/10.7205/MILMED-D-16-00041.

11. Wang Y, La T, Mason M, Tuten W, Roorda A. Case Report: Multimodal, Longitudinal Assessment of Retinal Structure and Function following Laser Retinal Injury. JCI Insight. Optom Vis Sci. 2023 Apr 1; 100(4):281-288. DOI: 10.1097/OPX.0000000000002004. Epub 2023 Feb 27.

Стаття надійшла 20.07.2022 р.