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VINNYTSYA**

**COMBAT INJURIES TO THE EYE IN MODERN ARMED CONFLICTS:
EPIDEMIOLOGICAL ASPECTS, MECHANISMS OF INJURY, DIAGNOSIS,
STAGES OF MEDICAL CARE AND REHABILITATION TREATMENT**

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FOREWORD

Contemporary military conflicts worldwide, including the war in Ukraine, pose extremely complex challenges for medicine while simultaneously stimulating the development of science, innovation, and interdisciplinary cooperation. The preservation of vision is not only a medical issue but also a matter of dignity, quality of life, and the future of those who defend the independence and freedom of their country.

Vision is one of the most important human sensory systems, providing up to 80.0–90.0% of information about the surrounding environment, spatial orientation, professional activity, and social interaction. For military personnel, visual function is of particular importance, as the successful performance of combat tasks, personal safety, unit combat capability, and survival in modern warfare directly depend on its integrity. Therefore, combat ocular injuries represent one of the most serious and socially significant challenges in military medicine in the 21st century.

Modern armed conflicts are characterized by high-intensity combat operations and the widespread use of artillery systems, explosive devices, high-precision weapons, unmanned aerial vehicles, and other destructive technologies. These factors contribute to an increase in both the frequency and severity of combat injuries, including ocular trauma. Consequently, the structure of combat injuries has changed significantly, particularly with regard to ophthalmic trauma. Ocular injuries are increasingly combined, multiple, or complex in nature and are frequently associated with traumatic brain injury, facial skeletal trauma, burns, acoustic injuries, and systemic damage to the body. According to international studies, combat-related ocular injuries account for approximately 5.0–15.0% of all combat injuries and represent one of the leading causes of disability among military casualties.

The problem of combat eye injuries has become especially relevant in the context of the full-scale war in Ukraine. The new type of warfare that began in 2014 and escalated dramatically in 2022 has placed an unprecedented burden on the system of military medical care and rehabilitation. Thousands of servicemen of the Armed Forces of Ukraine and other defense forces have sustained ocular injuries of varying severity, ranging from mild concussive injuries and superficial wounds to severe

penetrating trauma, loss of the eyeball, and complete blindness. These injuries result not only in serious medical consequences but also in profound psychological, social, professional, and economic effects that influence both the quality of life of the injured and their families and the overall defense capability of the state.

In this context, a comprehensive interdisciplinary approach to the study of combat ocular injuries is of particular importance – from the analysis of epidemiology and pathophysiological mechanisms of injury to the development of modern strategies for diagnosis, treatment, rehabilitation, and prevention. The global experience of military conflicts in Vietnam, Afghanistan, Iraq, Syria, and other regional wars demonstrates that timely medical care, standardized medical evacuation systems, and the introduction of effective personal protective equipment can significantly reduce the incidence of severe ocular injuries and the rate of vision loss.

At the same time, the specific characteristics of combat operations in Ukraine – including the widespread use of fragmentation munitions, explosive devices, kamikaze drones, high-precision weapons, and high-kinetic-energy projectiles – result in the formation of high-velocity fragments and lead to severe combined injuries, including ocular trauma. This creates a distinct profile of eye injuries that requires detailed and independent analysis. Existing international clinical guidelines and protocols cannot always be directly adapted to the conditions of the war in Ukraine, which necessitates the development of a national evidence base, clinical algorithms, and strategies for medical and social support for injured military personnel.

This monograph represents an attempt to systematize contemporary scientific data, clinical experience, and practical developments in the field of combat ocular injuries within both global and national contexts. The work summarizes current knowledge regarding the mechanisms of ocular damage, the structure and severity of combat eye injuries, and presents an analysis of international and national experience in their treatment and rehabilitation.

The first chapter examines the concept and classification of combat ocular injuries, analyzes their prevalence in modern military conflicts, and identifies their main medical and social consequences.

The second chapter provides an in-depth analysis of the pathophysiological mechanisms underlying ocular trauma in modern armed conflicts. Based on a global meta-analysis, the structure of combat eye injuries in different regions of the world is examined, and key features characteristic of the full-scale war in Ukraine are identified. This approach allows not only for a better understanding of the nature of these injuries but also for predicting their clinical course and outcomes.

The third chapter presents a comprehensive approach to the provision of medical care for combat ocular injuries at all stages of the treatment and evacuation process—from primary care on the battlefield to specialized ophthalmological treatment. It summarizes global experience in modern diagnostic methods and surgical and conservative treatment and provides a retrospective analysis of regional characteristics of ocular injuries and rehabilitation measures in Ukraine.

The fourth chapter focuses on the rehabilitation and recovery of patients with combat eye injuries. It discusses modern approaches to the prevention, documentation, and rehabilitation of ocular trauma, possibilities for restoring visual function, ocular prosthetics, and the prospects of neuroprosthetic technologies. Particular attention is given to social adaptation, psychological support, and the quality of life of military personnel who have lost vision or suffer from significant visual impairment.

The fifth chapter addresses the prevention of combat ocular injuries. It analyzes the effectiveness of modern personal protective equipment, medical and organizational prevention strategies, and the prospects for reducing the incidence of eye injuries in the Armed Forces of Ukraine. Prevention is considered a key component in maintaining the health of military personnel and improving the combat readiness of the armed forces.

The monograph is intended for paramedics, general practitioners, ophthalmologists, surgeons, optometrists, disaster medicine specialists, rehabilitation physicians, healthcare administrators, researchers, cadets and students of higher medical education institutions, as well as professionals involved in the medical support system of the defense forces.

The authors hope that the results presented in this monograph will contribute to improving the system of medical care, rehabilitation, and prevention of combat ocular injuries and to the development of scientifically grounded approaches to preserving health and improving the quality of life of military personnel.

INTRODUCTION

According to forecasts, by 2050, the prevalence of all forms of visual impairment, including blindness, moderate, severe, and mild visual impairment, as well as uncorrected presbyopia, is expected to continue increasing. The prevalence of glaucoma in the world among the population aged 40–80 is 3.54%, and it is expected to continue to grow until 2040 [1-4].

In modern military conflicts, combat eye injuries are one of the most severe and disabling forms of injury in the structure of combat pathology. Damage to the eye not only leads to permanent loss or reduction of visual functions, but also has a significant psychological, social, and economic consequences for affected military personnel and civilians. According to the World Health Organization (WHO), eye injuries account for 13.0–15.0% of all combat injuries in armed conflicts, and the frequency of eye injuries after explosions reaches 28.0–86.0%, with a significant proportion of these being caused by explosions and shrapnel [5, 6].

During the armed conflicts of the late 20th and early 21st centuries, a high prevalence of ocular trauma has been documented within the structure of combat injuries. For example, during military operations in Afghanistan, the proportion of combat eye injuries reached 36.5% of the total number of injuries, while in armed conflicts in the North Caucasus, this figure ranged from 22.0% to 34.0%, indicating a significant prevalence of eye injuries in modern combat conditions.

During the full-scale war in Ukraine, a consistently high incidence of combat injuries to the eye and its accessory structures has been observed, accounting for up to 9.4% of all combat injuries. More than half of these injuries (54%) are penetrating wounds of the eyeball, a substantial proportion of which are associated with intraocular foreign bodies (43.3%). Binocular injuries and complete destruction of the eyeball are of particular clinical significance, with their frequency reaching 29.8%.

A characteristic feature of modern combat trauma is a significant increase in multiple injuries, which account for 81.4%. This trend, is probably associated with the widespread use of high-precision weapons and high-kinetic-energy munitions that generate high-velocity fragments and cause severe combined injuries, including ocular trauma [7-9].

The modern nature of warfare, characterized by the extensive use of artillery systems, missile weapons, unmanned aerial vehicles, and explosive devices, significantly increases the risk of severe and combined ocular injuries. Recent epidemiological studies indicate that up to 15.8% of injuries in combat zones are related to eye trauma, and approximately 78.1% of all ocular injuries in modern conflicts are caused by explosive. In addition, 64.0% – 84.0% of all combat eye injuries are related to explosions, with 51.0% – 69.0% of such injuries caused by improvised explosive devices, and a significant proportion of these cases requiring surgical treatment or resulting in loss of the eye [10, 11].

The full-scale war in Ukraine since 2022 has caused a sharp increase in the number of combat eye injuries among both military personnel and the civilian population. Analysis of clinical cases indicates that mechanical eye injuries are frequently associated with cranial and facial skeletal trauma, significantly complicating treatment and worsening the prognosis.

According to Jonak K. (2025), macular lesions were the most common ocular pathology in Ukraine, accounting for 49.0% of cases, retinal vascular changes accounted for 30.2%, and optic nerve damage accounted for 22.4% of cases among patients with combat eye injuries [12].

Studies of ophthalmological care indicate that blast injuries and shrapnel wounds represent the leading causes of ocular trauma, significantly exceeding the frequency of purely gunshot or blunt injuries. Approximately 31.9% of combat eye injuries are accompanied by cranio-orbital trauma, 15.6% by injuries to ENT organs or facial bones, and 23.7% by limb injuries combined with ocular trauma. These data highlight the frequent combination of ocular injuries with other systemic traumatic lesions. The overall epidemiological impact of the war on visual health is extremely high, with traumatic eye injuries accounting for up to 28.0% of all combat injuries in Ukraine during the period 2022–2024 [13].

Despite the development of microsurgical technologies and modern treatment methods, combat eye injuries remain a complex clinical challenge requiring an interdisciplinary approach, improvement of the medical care system at all stages of evacuation, and effective rehabilitation strategies for affected patients [8].

Under conditions of intensive combat operations, early diagnosis of ocular injuries, proper triage and evacuation of casualties, and a multidisciplinary treatment approach are critically important. The majority of injuries are caused by explosive and fragmentation mechanisms, resulting in high-energy penetrating wounds, extensive destruction of ocular structures, and combined craniofacial trauma [14]. In this context, the study of the characteristics of combat eye injuries in modern military conflicts and during the full-scale war in Ukraine is highly relevant and has significant practical importance.

Keywords: ophthalmic combat injury, military personnel, early surgical intervention, unified clinical protocols, national register of combat injuries, medical rehabilitation

CHAPTER 1. COMBAT OCULAR INJURIES IN THE CONTEXT OF MODERN MILITARY CONFLICTS: DEFINITION, PREVALENCE, AND CONSEQUENCES

1.1. Concept and classification of combat ocular injuries

Ocular trauma is defined as damage to the anatomical integrity or functional capacity of the eye resulting from exposure to external mechanical, thermal, chemical, electrical, or other injurious factors. Such injuries may lead to temporary or permanent visual loss and are associated with significant medical and social consequences, including disability and psycho-emotional disorders.

In combat conditions, the eye is particularly vulnerable because of its peripheral anatomical location and the absence of substantial natural protection comparable to that of the thoracic or abdominal cavities. Modern highly destructive means of warfare, including explosive devices, fragmentation munitions, and ballistic projectiles, significantly increase the likelihood of severe concomitant and combined injuries to ocular structures.

Combat ocular trauma refers to injuries sustained during combat actions or military operations that directly affect the eye or the accessory structures of the visual apparatus. Compared with eye injuries in peacetime, combat-related ocular injuries are more often characterized by:

- greater severity of damage;
- a high proportion of open penetrating wounds;
- frequent association with facial skeletal trauma, traumatic brain injury, and other systemic injuries;
- a significant number of retained foreign bodies;
- wound contamination and infection, etc.

According to contemporary clinical studies, penetrating atypical ocular injuries account for up to 49.7% of all ophthalmic trauma cases in combat conditions, of which 39.4% are associated with intraocular foreign bodies. Bilateral eye injuries are observed in approximately 26.6% of military personnel with ocular trauma.

Combat eye injuries are classified according to various criteria, including the mechanism of action of the traumatic agent, severity of damage, anatomical location, and the presence of associated injuries. Such classification is important both for diagnosis and for selecting treatment and rehabilitation strategies.

Classification of combat eye injuries

I. By type of weapon used:

1. Blast injuries of the eye

Blast ocular injuries (primary, secondary, tertiary, and quaternary) are injuries caused by the action of the blast wave, explosion products, and associated physical factors of the explosion, including overpressure, acceleration, and thermal effects, which result in functional and/or anatomical damage to the structures of the eye and orbit.

2. Fragmentation injuries of the eye

Fragmentation ocular injuries are combat injuries caused by fragments of munitions or by secondary fragments of surrounding objects generated during an explosion, such as metal, stones, glass, or fragments of building structures. These injuries result in penetrating or non-penetrating damage to the globe and orbital structures.

In modern conflicts, up to 44.3% of combat eye injuries are caused by blast mechanisms, and 40.5% by fragmentation injuries. These injuries are characterized by high kinetic energy of particles and multiple wounds to the eye tissues [15].

3. Gunshot injuries

Gunshot ocular injuries are caused by firearms and are characterized by penetration of a bullet or projectile fragments into the eye, often resulting in severe structural damage and neurological complications. Less common mechanisms include gunshot wounds, which account for approximately 8.6% of cases [16].

4. Thermal injuries of the eye during military operations

Thermal ocular injuries are a type of combat-related eye injury resulting from exposure to high temperatures, flames, blast waves with a thermal component, hot gases, fragments, or incendiary mixtures during the use of weapons in armed conflicts. Such injuries account for 4.9% of cases.

The **main substances and sources of thermal exposure** documented during combat operations in Ukraine include:

1) **petroleum-based incendiary mixtures:**

- gasoline, diesel fuel, kerosene, and their mixtures;
- combustion products of fuel and lubricants used in military equipment.

They cause burns to the eyelids, conjunctiva, and cornea, often in combination with toxic smoke damage.

2) **thermobaric (fuel-air) munitions:**

- generate extremely high temperatures;
- accompanied by a blast wave and hot gases.

They cause combined thermal and mechanical injury to the eye.

3) **Munitions with incendiary elements:**

- incandescent metal fragments;
- secondary ignition of surrounding materials.

These often result in deep burns of ocular tissues.

4) **Phosphorus-containing incendiary substances** (reported cases of use):

- cause intense thermal burns;
- combine thermal and chemical mechanisms of injury.

They are especially dangerous because of their prolonged action and deep tissue damage.

5) **Explosion products of artillery and rocket munitions:**

- hot gases;
- flames;
- high-temperature aerosols.

These may cause burns of the anterior segment of the eye and visual pathways.

Such injuries are characterized by damage to the eyelids, conjunctiva, cornea, sclera, and internal ocular structures, they are often associated with mechanical and chemical injury and carry a high risk of loss of visual function and disability.

Thermal eye injuries in the context of the war in Ukraine are predominantly combined in nature, involving thermal, mechanical, and sometimes chemical components, which significantly worsens the prognosis for vision preservation [6, 17].

5. Chemical injuries of the eye as a form of combat trauma

Chemical ocular injuries are injuries resulting from exposure to toxic chemical substances during military operations. They are characterized by acute damage to superficial and deep ocular structures, including the eyelids, conjunctiva, cornea, and anterior chamber, as well as corneal or conjunctival epithelial defects, conjunctival redness and edema, conjunctival blanching, and corneal opacity. These injuries are marked by rapid development of inflammation, tissue necrosis, trophic disturbances, and a high risk of permanent vision loss. Chemical injuries are often combined with thermal and mechanical trauma, which significantly complicates their course and treatment.

Ukrainian security forces have documented tens of thousands of cases of Russian units using chemical agents (irritants and toxic substances) against Ukrainian military positions since the start of the full-scale war.

- **Aerosol grenades with aggressive gases (K-51, RG-VO, RGR).** Russian troops used hand grenades and unmanned platforms to deliver aerosols with toxic substances directly to Ukrainian military positions.
- **CS gas (2-chlorobenzylidene malonitrile).** This substance is part of crowd control agents, but its use as a weapon on the battlefield is prohibited by international convention; its presence has been confirmed in the samples analyzed.
- **CN gas (chloroacetophenone).** Similar to CS, this agent is also used in aerosol grenades and causes severe irritation to the eyes and respiratory tract.
- **Chloropicrin.** A historical combat poison gas (known since World War I) that has been detected in some cases of use; its use in modern conditions also violates international norms.

□ **Other dangerous chemicals of unknown type.** According to reports from Ukrainian forces, there have been cases of other toxic compounds being used, the identification of which is complicated by political and military circumstances [18-20].

The use of CS, CN, chloropicrin, and similar agents as weapons of war is a violation of the Chemical Weapons Convention (1993) and is prohibited by international humanitarian law, even though some of these substances are permitted for use by law enforcement agencies in peacetime [21].

6. Light-induced injuries of the eye

Light-induced ocular injuries are injuries caused by exposure to intense light, laser, or infrared radiation during the use of modern weapons. Within the structure of combat ocular trauma, such injuries occupy a distinct place because of their specific mechanism and the high risk of irreversible visual loss.

The main causes of light-induced injury include:

- laser guidance and blinding systems;
- explosion flashes (especially ammunition with high light intensity);
- detonation of explosive devices at close range;
- exposure to infrared radiation when using night vision devices;
- nuclear explosions (light pulses).

II. By the mechanism of damage (effects of an explosion):

1. **Primary injuries** caused by a blast wave, the mechanism of which is the transfer of explosion energy to the body.

2. **Secondary injuries** are caused by fragments of the explosive device, as well as secondary debris (bricks, small stones, glass, etc.). Secondary injuries include penetrating injuries to the eyeball.

3. **Tertiary injuries** caused by the displacement of foreign bodies under the action of the explosion, leading to blunt trauma (eye contusion, fractures of the orbital walls).

4. **Quaternary injuries** caused by thermal, chemical, and/or radiation burns [22, 23].

III. By the nature of mechanical impact on the eye:

1. Blunt trauma (contusion) of the eye

Blunt ocular trauma is caused by a blast wave or impact by a solid object without violation of the integrity of the ocular coats, or by displacement of the body under the effect of an explosion. Contusions may be accompanied by injury to the eyelids, conjunctiva, cornea, lens, retina, optic nerve, and fractures of the orbital walls. Typical manifestations include hyphema, edema or rupture of the iris, dislocation or opacification of the lens, retinal contusion, retinal detachment, and traumatic optic neuropathy.

According to the Ministry of Health of Ukraine, blunt injuries account for 17.0–22.0% of all eye injuries and may have serious consequences, especially in combined trauma [24].

2. Penetrating eye injuries

Penetrating eye injuries are combat injuries to the organ of vision characterized by a breach in the integrity of the fibrous membrane of the eyeball (cornea and/or sclera) due to the action of damaging factors of weapons (shrapnel, bullets, secondary projectiles), often with the penetration of foreign bodies into the eye cavity and a high risk of severe anatomical and functional visual impairment.

- 3. Non-penetrating eye injuries** are combat injuries to the organ of vision in which there is no disruption of the integrity of the fibrous membrane of the eyeball (cornea and sclera), but under the action of damaging factors, functional and structural changes in the internal membranes and environments of the eye may occur. Most often caused by blunt force, shock waves, or secondary damaging factors, they may be accompanied by contusion of the eyeball, hemorrhages in the anterior chamber and vitreous body, retinal contusion, traumatic cataract, and temporary or permanent visual impairment.

IV. By anatomical location and nature of the injury:

1. External structures:

- eyelids injuries;
- conjunctival lacerations.

2. Internal structures of the eye:

- rupture of the sclera and cornea;
- lens injuries (traumatic cataract);
- injury to the retina and choroid.

3. Orbit and optic nerve:

- Fractures of the orbital bones;
- traumatic injury of the optic nerve;
- desynchronization of the eye muscles – strabismus.

- **Orbital injuries**, which are complex lesions involving the orbital bones and often associated with injury to peripheral nerves and blood vessels;
- **Injuries of the ocular adnexa**, including damage to the eyelids, lacrimal passages, and extraocular muscles;
- **Penetrating injuries of the globe**, involving disruption of the ocular coats and entry of foreign bodies;
- **Non-penetrating (closed) injuries**, which are superficial injuries without disruption of the ocular coats but with possible damage to internal structures.

V. Depending on the number of injuries, eye injuries are divided into:

- **Isolated (single)** – damage limited to the eye, without involvement of other anatomical areas of the body.
- **Multiple** – the presence of several injuries within one anatomical area, in particular the head, including the eye.
- **Concomitant** – ocular trauma associated with injuries to other anatomical regions, such as the limbs, chest, or abdominal organs.
- **Combined** – ocular trauma caused by the simultaneous action of several injuring factors of different nature, including mechanical, thermal, chemical, and radiation factors, most commonly seen in blast injuries and nuclear explosions.

When several injuring factors act simultaneously, such as in nuclear explosions or mine-blast trauma, concomitant and combined injuries occur. They are characterized by severe clinical course, marked polymorphism of lesions, and complexity of diagnosis and treatment. In modern military conflicts, combined injuries develop as a result of the action of blast waves, fragments, high temperatures, toxic explosion products, and other physicochemical factors, which significantly worsens the prognosis for preservation of visual function.

VI. By severity:

1. Mild eye injuries are characterized by minimal anatomical damage limited to the superficial structures of the eye and eyelids, without significant impairment of visual function. Minor contusions, superficial lacerations, or small corneal and conjunctival injuries are common. The prognosis for complete recovery of vision is usually favorable.

2. Moderate eye injuries are accompanied by more pronounced damage to the structures of the eyeball and orbit, including partial injury to the lens, retina, vitreous body, or eyelids, leading to temporary or partially permanent vision loss. Moderate hemorrhages and edema are possible. Treatment usually requires specialized ophthalmological care and observation.

3. Severe eye injuries are characterized by serious anatomical and functional damage, including penetrating wounds of the eyeball, multiple fractures of the orbit, severe contusions, intraocular hemorrhages, and damage to the optic nerve. Such injuries often lead to permanent or irreversible vision loss, a high risk of eye loss, and require complex surgical treatment and long-term rehabilitation.

VII. By clinical course:

- 1. The acute period** lasts from the moment of injury to the stabilization of the patient's general condition and the start of specialized treatment. During this period, immediate morphological and functional disturbances predominate, including contusions, corneal or scleral ruptures, penetrating injuries, hemorrhage, and edema of the globe and orbit. The main tasks at this stage are emergency diagnosis, hemorrhage control, evacuation, prevention of infectious complications, and primary stabilization of vision.
- 2. The period of early complications** occurs after the acute phase and lasts from several days to several weeks after the injury. At this time, early functional and morphological complications may develop, which are directly related to the nature of the injury and surgical intervention. These include secondary infections, hemophthalmos, development of traumatic cataracts, inflammatory processes in the anterior and posterior chambers of the eye, edema, and tissue scarring. Proper management of this period is essential for preserving visual function.
- 3. The period of late complications**, manifests weeks, months, or even years after injury and is characterized by long-term morphological and functional sequelae. These include secondary glaucoma, persistent cataract, corneal scarring, retinal detachment, chronic inflammatory processes, degenerative changes in the internal coats of the eye, and irreversible visual loss. This period is crucial for planning rehabilitation, reconstructive surgical interventions, and medical and social support.

VIII. Prognostic classification of open eye injuries by zone of localization.

Open eye injuries are assessed based on the location of the damage on the surface of the eyeball, which is important for predicting the preservation of visual functions and planning treatment.

There are three zones:

Zone I – the anterior part of the eye.

Zone I includes **the cornea and limbus**, that is , the anterior segment of the eye. Injuries to this zone are usually have a relatively favorable prognosis because the cornea is amenable to surgical reconstruction, and the probability of preserving central vision is high with timely and adequate treatment. Injuries in this zone may be superficial or penetrating but are limited to the anterior segment.

Zone II – the anterior half of the sclera.

Zone II includes **the sclera of the anterior half of the eyeball from the limbus to the posterior equatorial line**. Injuries to this zone have a moderate prognosis, as the damage may affect not only the sclera, but also partially the internal structures of the eye (anterior chamber, lens). Treatment often requires complex surgical correction, and the risk of secondary complications (cataract, secondary glaucoma, scarring) increases.

Zone III – the posterior half of the eyeball.

Zone III includes **the back half of the eyeball, i.e., the posterior segment of the sclera, the retina, and the optic nerve**. Injuries to this zone have the worst prognosis for vision preservation, as the damage affects vital structures responsible for light perception and visual information transmission. Penetrating injuries often occur with foreign bodies entering the vitreous body, hemorrhages in the posterior segment of the eye, and retinal detachment. Even with timely surgical intervention, the likelihood of irreversible vision loss is high.

Epidemiologically, in fragmentation injuries Zone I is affected most frequently, followed by Zone III and Zone II; in blast injuries, nearly 50% of lesions involve the posterior segment of the eye (Zone III), indicating the severity of mine-blast trauma.

IX. Pathomorphological features in relation to the corneal-scleral (fibrous) capsule:

- 1. Open injuries** (open-globe injury), including perforation or rupture of the eye membrane:

1.1. Penetrating injury

A single full-thickness laceration of the eyewall without an exit wound. If several entry wounds are present, they are caused by the action of another injuring agent..

1.2. Intraocular foreign bodies (IOFBs)

Foreign objects retained in the eye cause entry wounds and can cause significant complications to the internal structures of the eyeball.

1.3. Perforating injury

Two lacerations passing through the entire thickness of the eyeball (entry and exit wounds), with tissue damage at the entry and exit sites.

Prognostic classification of open eye injuries by location:

- **Zone 1** – cornea and limbus. The prognosis is relatively favorable.
- **Zone 2** – sclera up to 5 mm from the limbus. The prognosis is less favorable.
- **Zone 3** – sclera more than 5 mm behind the limbus. The prognosis is the worst.

Wound localization in zones 2 and 3 is associated with a high risk of developing severe complications and permanent vision loss.

2. Closed-globe injuries – contusions, hematomas:

Contusion (blunt trauma) – damage to the eyeball without breaking its shell.

A lamellar wound of the ocular wall, usually caused by a sharp object, belongs to superficial injuries together with lesions of the conjunctiva and cornea.

Injuries of the ocular adnexa and orbit are considered separately.

Ocular contusion is a form of closed injury resulting from blunt mechanical force or blast wave action, without disruption of the integrity of the globe, but with injury to internal structures due to sudden compression-decompression forces. Contusions may

be accompanied by microcirculatory disturbances and tissue edema, hemorrhage into the anterior chamber (hyphema) or vitreous body (hemophthalmos), retinal contusion (*commotio retinae*), traumatic lens changes including cataract or subluxation, and optic nerve injury in the form of traumatic optic neuropathy. Mild, moderate, and severe contusions are distinguished, and their prognosis depends on the depth of injury and involvement of the posterior segment.

Ocular **hematoma** is a local accumulation of blood that forms as a result of damage to the vessels of the organ of vision or periorbital tissues in closed trauma, without violating the integrity of the eyeball. Depending on the location, there are:

- **subcutaneous and subcutaneous-muscular hematomas of the eyelids;**
- **paraorbital (periorbital) hematomas;**
- **retrobulbar hematomas**, which are the most dangerous due to the risk of compression of the optic nerve and the development of ischemia of the eyeball.

Clinically, hematomas manifest as pain, swelling, limited mobility of the eyeball, and decreased visual function, and in the case of retrobulbar localization, they can constitute an emergency condition requiring urgent intervention.

Prognostic zones in closed eye trauma

1. **External anterior segment** – conjunctiva, sclera, cornea. Injury to this zone usually has a **favorable prognosis**, as structural changes are limited to superficial tissues and rarely lead to permanent visual impairment with timely treatment.
2. **Internal anterior segment** – lens, ciliary body, ciliary processes. Damage to this area is associated with a **moderate prognosis**, as it may be accompanied by the development of traumatic cataracts, accommodation disorders, secondary glaucoma, and inflammatory processes that can cause prolonged or partially permanent vision loss.
3. **Posterior segment** consists of the vitreous body, retina, optic nerve, choroid, and ciliary body. Lesions in zone 3 have **the worst prognosis** for preserving visual function, as they are accompanied by severe morphological changes: hemophthalmos, contusion or detachment of the retina, ischemic damage to the optic nerve, and the development of irreversible vision loss.

Identification of prognostic zones in closed ocular trauma makes it possible to:

- assess the severity of the injury;
- predict the functional results of treatment;
- determine the tactics for managing the patient and the need for specialized ophthalmological care;
- plan rehabilitation measures.

Blast injuries are most often associated with open injuries, retinal tears, vitreous hemorrhage, and retained foreign bodies.

IX. By the presence of complications:

1. Uncomplicated combat eye injuries are injuries that are not accompanied by the development of secondary pathological conditions and, after timely and adequate medical care, do not lead to progressive deterioration of the anatomical condition or functions of the eye. This group includes superficial damage to the cornea and conjunctiva, minor contusions of the eyeball without intraocular hemorrhages, as well as mild non-penetrating injuries without signs of infection or intraocular structural changes.

2. Complicated combat eye injuries are characterized by the development of one or more pathological complications that significantly worsen the clinical course, prognosis, and functional outcome. Such complications include intraocular hemorrhages (hyphema, hemophthalmos), infectious processes (traumatic endophthalmitis), retinal detachment, traumatic cataract, secondary glaucoma, optic nerve damage, and the presence of an intraocular foreign body. Complicated injuries require multi-stage specialized treatment and are often associated with a high risk of permanent loss of visual function or anatomical integrity of the eyeball.

Combat ocular injuries are often accompanied by damage to adjacent anatomical structures – traumatic brain injury, facial skeleton fractures, and injuries to other parts of the body. This significantly complicates both diagnosis subsequent and treatment and rehabilitation [5, 6, 25-28].

In modern military medical doctrine, combat injuries, including ocular trauma, are integrated into the overall system of combat surgical trauma and are assessed from the perspective of a comprehensive approach to medical triage. According to military field guidelines, the clinical assessment of such injuries is based on determining the severity, risk to life and vital functions, the need and urgency of medical evacuation, and the mechanism of injury [29].

1.2. Epidemiology of eye injuries in modern military conflicts

The epidemiology of eye injuries in armed conflicts reflects the scale and nature of injuries resulting from combat operations and plays an important role in planning medical care, prevention, and treatment strategies for such trauma. Although ocular injuries account for a relatively small proportion of total combat trauma, they have significant consequences for the quality of life of affected individuals, including the risk of severe visual impairment or blindness [30].

Historical data indicate a gradual increase in the incidence of ocular injuries in military conflicts in the 20th and 21st centuries. During the American Civil War, the proportion of ophthalmic injuries among all wounds was minimal (<1%). However, during the First and Second World Wars this figure increased slightly to approximately 2.0%, in the Korean War to 8.0%, and in the Vietnam War to about 9.0%

During the wars in Iraq and Afghanistan, the frequency of eye injuries among wounded military personnel increased to approximately 13.0%, making them one of the most common types of injuries after limb and torso injuries.

This increase is explained by the widespread use of improvised explosive devices (IEDs) and fragmentation, which have a high potential to cause ocular injuries [31].

1.3. Medical and social consequences of combat eye injuries.

Combat ocular injuries represent not only a serious medical problem but also have profound social and economic consequences for affected individuals, their families, and society as a whole. In modern conflicts, the destructive power of explosive devices and other advanced weapon systems frequently results in ocular injuries that are associated with prolonged visual impairment or complete blindness. Such outcomes significantly limit an individual's ability to maintain independence, employment, and social integration, and therefore require a comprehensive approach encompassing both medical and social rehabilitation [5, 13].

The medical consequences of eye injuries sustained in combat conditions represent a complex clinical phenomenon that combines various mechanisms of damage to the visual apparatus and leads to far-reaching clinical outcomes. Despite the relatively small proportion of body surface occupied by the eye, ocular injuries are often associated with severe functional impairments, including partial or complete loss of vision, which significantly complicates the subsequent life and rehabilitation of affected individuals.

Eye injuries sustained during combat operations are most commonly caused by mine-blast mechanisms and may include penetrating trauma involving damage to ocular structures and surrounding tissues, often in combination with injuries to the head and face. Such injuries may lead to macular and retinal disorders, alterations in the retinal vascular structure, and damage to the optic nerve, which are often difficult to restore even after specialized treatment. In many cases, these injuries require prolonged medical care, including surgical interventions, rehabilitation measures, and vitreoretinal procedures, which substantially increase the burden on the healthcare system during wartime conditions [32].

In modern armed conflicts, the most common mechanism of eye injuries is mine-blast and fragmentation damage. Such mechanisms combine the effects of blast waves, foreign body penetration, and tissue trauma caused by high-velocity fragments, leading to complex injuries affecting both the anterior and posterior segments of the eye [33, 34].

Penetrating shrapnel injuries are accompanied by corneal perforation, damage to the lens, retina, and vascular membrane, and may also include intraocular foreign bodies, which significantly complicate surgical treatment and increase the risk of infectious complications and secondary pathologies [5, 8].

The medical consequences of combat eye injuries manifest themselves in a wide range of clinical manifestations, the most common of which are:

- **Pathology of the retina and macular area** – damage to the central area of the retina can lead to permanent loss of central vision, which critically affects the ability to read, recognize faces, or perform fine motor tasks. Clinical studies indicate that a substantial proportion of injured patients present with damage to these structures [12].
- **Optic nerve damage** – trauma or compression of the optic nerve can lead to significant or complete loss of visual perception; such damage often has limited potential for recovery, even with modern medical technologies.
- **Cataracts as a secondary complication of trauma** – mechanical impact on the lens can stimulate traumatic cataracts, requiring further surgical intervention to restore visual function [35].
- **Scleral and corneal defects** – in penetrating wounds, difficulties arise not only with restoring light transmission, but also with secondary inflammation, which may require surgical correction and prolonged antimicrobial treatment [5, 6, 8].

It should also be emphasized that, in addition to obvious mechanical damage, combat trauma may result in closed-globe injuries and delayed complications that may not manifest immediately but may subsequently progress and lead to vision loss or chronic ocular pathology. Studies indicate that approximately 25.0% of veterans exposed to explosions report corneal injuries, while about 90.0% of patients with traumatic brain injury experience visual disturbances. Ocular trauma ranks fourth among combat injuries in military personnel, accounting for approximately 6.0–13.0% of all blast-related injuries.

The initial impact of the blast wave causes changes in the cornea associated with edema, manifested by modifications in the expression of proteins responsible for

regulating water permeability, in particular aquaporins AQP1 and AQP5. These transmembrane protein channels ensure passive water transport across cell membranes and play a leading role in maintaining the water-electrolyte balance of eye tissues. Under the action of specific pressure pulses of the shock wave, the regulation of the expression and functional activity of these proteins is disrupted, leading to increased permeability of cell membranes, the development of tissue edema, microcirculatory disorders, and secondary damage to intraocular structures. These data indicate potential mechanisms of acute corneal damage, in particular due to water homeostasis disruption caused by the primary explosive impact [36-38].

According to the results of a study by Sidak-Petretska O.S. (2023), patients with explosive injuries of the eyeball were divided into three groups depending on the timing of vitrectomy:

- **Group I** — intervention performed within the first 7 days after injury;
- **Group II** — intervention on the 8th–14th day after the injury;
- **Group III** — intervention after the 14th day.

Among the observed patients, 67.0% had open eye injuries, while 33.0% had closed injuries. According to morphological manifestations: 56.0% had corneal opacity, 28.0% had extensive penetrating corneal wounds with sutures, 11.0% had hematocorneal, and 5.0% had corneal burns.

The indications for vitrectomy in patients with explosive injuries of the eyeball were: hemophthalmos – 30.0%, retinal detachment – 28.0%, proliferative vitreoretinopathy – 35.0%, intraocular foreign bodies – 7.0%.

All patients underwent standard transscleral three-port 25G vitrectomy using a temporary keratoprosthesis. Posterior- -subtotal vitrectomy with removal of the posterior hyaloid membrane was performed. Additional surgical procedures included: removal of traumatic cataracts – 70.0% of cases, removal of intraocular foreign bodies – 7.0%, endolaser coagulation of retinal tears – 32.0%.

Tamponade of the vitreous cavity was performed in 60.0% of patients, of which 30.0% with silicone oil and 30.0% with gas mixtures.

Posterior chamber intraocular lens implantation was performed in 62.0% of cases, and iridoplasty in 20.0%. Most patients after vitrectomy required penetrating keratoplasty, and in 11.0% of cases, autologous keratoplasty was performed.

The best results in restoring visual function and a satisfactory anatomical effect were observed in patients in group II (vitrectomy performed on the 8th–14th day after injury). Modern combat injuries of the eyeball are characterized by severe damage to both the anterior and posterior segments of the eye, manifested by clouding and scarring of the cornea, frequent retinal detachment, hemorrhages in the vitreous body, and the presence of intraocular foreign bodies.

Optimal vitrectomy requires high-quality visualization of the fundus, which is provided by the use of an intraoperative keratoprosthesis.

Combat eye injuries require an individualized and multidisciplinary approach that combines emergency surgery with subsequent ophthalmic rehabilitation. Often, primary treatment is aimed at saving the patient's life, while specialized measures focus on restoring visual function, which may require several surgical stages. These include vitrectomy, removal of debris and foreign bodies, endolaser coagulation of the retina, and reconstructive surgery of the anterior segment of the eye [25].

These operations can be highly technical and lengthy, and their success depends on many factors: the time from injury to surgery, the extent of damage, the presence of intraocular foreign bodies, the patient's general condition, etc. In particular, retinal damage, macular defects, or extensive damage may require several stages of surgery, as well as prolonged postoperative monitoring to minimize the risk of tissue rejection, scar tissue proliferation, and secondary retinal detachment.

Among the most serious long-term consequences are complete vision loss that cannot be corrected, as well as the development of secondary pathologies such as proliferative scleropathy, epiretinal membranes, or chronic inflammation (endophthalmitis). Such conditions significantly reduce the patient's quality of life and require long-term treatment and observation.

In addition, in some cases, rare but severe immune complications may develop, such as sympathetic ophthalmia – chronic inflammatory damage to the second eye

after trauma to one eye, requiring careful long-term monitoring and immunosuppressive therapy.

The medical consequences of combat ocular injuries are a multi-layered complex of pathological conditions involving mechanical, neuro-ophthalmological, and immune components. These injuries often lead to severe visual impairment, requiring specialized surgical treatment and long-term rehabilitation. Strategic planning of medical care and modern ophthalmological therapy can reduce the severity of the consequences, but complete restoration of visual function is not always possible.

Social consequences include:

1. Loss of working capacity and economic limitations

Eye injuries in military personnel and civilians often lead to partial or complete loss of working capacity, especially if the injury is accompanied by reduced visual acuity or blindness. Such individuals require long-term treatment, rehabilitation, and social security in the form of pensions, compensation, or professional retraining. Loss of working capacity has a direct impact on the economy of the family and society as a whole, worsening the well-being of victims and increasing the need for state support.

2. Psychological and psychosocial consequences

Combat injuries are not limited to physical trauma – they have profound psychological consequences. Post-traumatic stress disorder (PTSD) and other psychological disorders are common among victims of severe combat trauma. Studies on the medical, biological, and socioeconomic consequences of PTSD in populations that have experienced combat show that constant stress, anxiety, sleep disturbances, depression, and other psychosocial difficulties significantly reduce the quality of life and functional capacity of such individuals. Comprehensive psychological rehabilitation and social adaptation programs are needed for effective support [39-43].

In cases of vision loss or significant vision impairment, victims often need social and psychological support, including group therapy, vocational guidance, and adaptation to everyday life. Organizations supporting people with visual impairments

are actively working on these issues, in particular implementing psychosocial support and inclusive rehabilitation projects for war victims, which contributes to improving their social integration.

Vision loss or severe ophthalmic trauma changes not only the life of the victim, but also the family structure. Families often face role changes (for example, when the victim becomes unable to work and needs care), which can lead to emotional and financial difficulties, intra-family conflicts, and psychological burnout. Support for such families should cover not only medical but also social, psychological, and material aspects.

Children and adolescents who have suffered eye injuries during war experience unique consequences. Ophthalmologists note that the number of eye injuries in children increases during wartime, which negatively affects their educational, emotional, and social adaptation. Children who have survived such injuries may require special education, psychological support, and long-term monitoring, which creates additional challenges for medical and social infrastructure [44].

The medical and social consequences of such injuries are manifested not only in physical visual impairments in victims, but also in an increased burden on medical institutions, social support agencies, and other components of public infrastructure.

In wartime, medical facilities often face shortages of important resources, including medical equipment, surgical supplies, medicines, and ophthalmic implants. A significant number of wounded people require urgent care, including stabilization, bleeding control, wound treatment, and prevention of infectious complications. However, in addition to emergency care, many patients require long-term surgical and conservative therapy and rehabilitation measures, which puts additional pressure on the healthcare system.

It is particularly difficult to ensure access to specialized ophthalmic centers in combat zones, where infrastructure may be partially damaged or evacuated. This leads to situations where patients with severe injuries receive delayed treatment, which negatively affects the prognosis for vision recovery. In such conditions, effective resource management and prioritization of treatment measures become particularly important.

For the optimal provision of medical care to victims of combat eye injuries, a multi-level care system is required, including the following stages:

1. **Primary stage** – provision of first aid on the battlefield or in mobile medical stations, stabilization of the patient's condition, stopping bleeding, prevention of infections, and initial assessment of the severity of the eye injury.
2. **Secondary stage** – transportation to specialized medical facilities, where comprehensive diagnostics, surgical treatment, and correction of eye functions are performed.
3. **Rehabilitation stage** – includes ophthalmological, physiotherapeutic, and psychological rehabilitation. Access to optical devices (glasses, contact lenses, special devices for the visually impaired), technical means of restoring functions (vitrectomy devices, laser systems), as well as psychological support centers is critical for quality rehabilitation.

Coordination between different levels of care reduces the time to surgery, increases the chances of visual function recovery, and reduces the risk of secondary complications.

The medical and social consequences of eye injuries have a significant economic dimension. The costs are associated not only with treatment and rehabilitation, but also with reduced working capacity, loss of income, and increased need for social benefits and pension support. Especially in regions of military conflict, where many people suffer severe injuries, these burdens on the healthcare system and the country's budget can be critical. In addition, some of the victims are forced to leave their homes, which puts additional pressure on the medical and social infrastructure of other regions. For example, the increase in the number of patients with severe injuries in hospitals in regions that accept displaced persons requires additional resources, personnel, and medical equipment.

Innovative approaches are being implemented to reduce the negative impact on the healthcare system:

- **Mobile ophthalmology teams** that provide specialized care in remote areas or directly in the combat zone.
- **Telemedicine and remote diagnostics**, which provide access to consultations with highly specialized ophthalmologists for patients who cannot immediately get to a specialized center.
- **Comprehensive rehabilitation**, combining physiotherapy, optical aids, psychological support, and professional retraining, significantly improves the quality of life and social integration of those affected.

The implementation of such measures not only reduces the burden on the healthcare system, but also improves long-term treatment outcomes, reduces the risk of complications, and promotes more effective social adaptation of patients [45].

Combat ocular injuries, associated with loss of working capacity and the need for long-term medical care, entail significant economic costs for both the individual and society as a whole. Individuals who have suffered significant vision loss or complete blindness often become dependent on government social benefits, pensions, and other forms of social support. An analysis of the labor consequences of war shows that such traumatic events are associated with a decrease in the victims' participation in the labor market, loss of stable sources of income, and an increased risk of poverty and social isolation.

Forced migration caused by the outbreak of full-scale war in Ukraine is associated with an average 7.5% increase in the risk of unemployment. In regions of active combat, women without higher education face a 9.6–9.9% higher probability of lacking the financial resources to meet their basic food needs. At the same time, in regions that have suffered ground attacks, there is an increased risk of unemployment among women with and without higher education, as well as among men without higher education – by 6.1–6.9%, 4.2–4.7% and 6.5–6.6% respectively [46].

The medical and social consequences of combat ocular injuries are profound and multifaceted. They include physical, psychological, and economic consequences that affect victims, their families, and society as a whole. Combat injuries cause

permanent vision loss, psychosocial difficulties, loss of working capacity, and increased social costs, which require comprehensive medical and social support strategies. An effective support system should combine medical, psychological, professional, and social assistance to facilitate the adaptation of victims to public life [47].

CHAPTER 2. FEATURES OF COMBAT OCULAR INJURIES IN MODERN WARFARE

2.1. Global meta-analysis of pathophysiological mechanisms, structure, and consequences of combat ocular injuries in armed conflicts worldwide

Modern armed conflicts are characterized by the large-scale use of high-kinetic-energy weapons, which causes a significant increase in the number of serious injuries, in particular damage to the ocular trauma. Combat eye injuries are among the most complex in the structure of craniofacial injuries, since even with timely and high-quality medical care, they often lead to permanent loss of vision or even the eye, prolonged loss of working capacity, or disability of military personnel.

According to international studies, the frequency of ophthalmic injuries in combat zones ranges from 5.0 to 15.0% of the total number of combat injuries. The vast majority of such injuries are associated with explosive, shrapnel, and fragment mechanisms of injury, which pose a high risk of penetrating eye injuries, destruction of orbital structures, and complex combined injuries.

In conditions of intense combat, timely diagnosis, a multidisciplinary approach, and early surgical intervention are of particular importance, as they can significantly improve the functional results of treatment and increase the chances of preserving the organ of vision [5, 6, 15, 28].

The study analyzed the structure of war ocular injuries in civilians and military personnel affected by combat operations in Ukraine. The authors showed that explosive trauma is the leading mechanism of injury and is associated with a high frequency of severe and combined ophthalmic injuries. The clinical structure was dominated by lesions of the posterior segment of the eye: macular changes were found in 49.0% of cases, retinal vascular disorders in 30.2% of patients, while optic nerve damage, including traumatic optic neuropathy, was recorded in 22.4% of victims. These types of injuries were characterized by an unfavorable functional prognosis and were associated with a significant decrease in final visual acuity. In addition, a significant proportion of eye injuries were combined and associated with

damage to other anatomical structures, which complicated surgical treatment and prolonged rehabilitation [48].

A study by Kempuraj D. (2024) provided a comprehensive review of pathophysiological changes and clinical consequences of corneal damage due to blast trauma. The authors note that approximately 25.0% of veterans who were exposed to explosive forces reported corneal damage, confirming the significant prevalence of this type of injury among those affected in the combat zone [49].

The pathophysiological mechanisms of corneal damage include:

- 1) micromechanical stretching and traumatic destruction of corneal structures,** in particular the epithelium and stroma;
- 2) acute increase in intraocular pressure** under the action of a blast wave;
- 3) damage to the endothelial layer,** manifested by a decrease in cell density and impaired barrier function;
- 4) vascularization and local ruptures of Descemet's membrane;**
- 5) induction of corneal cell apoptosis** and local inflammatory reactions accompanied by secondary oxidative stress (Table 1).

Table 1. Typical lesions and percentage of complications, %

No.	Author, year	Most common lesions	Complications	Percentage of complications, %
1	Reynolds M.E., 2022	Orbital floor fracture, iridocyclitis, recurrent corneal erosion	Partial/complete loss of vision	14
2.	Rana V., 2023	Penetrating injuries, blunt trauma, combined	Enucleation/evisceration	9.0
3.	Kempuraj D., Mohan R.R., 2024	Cornea: edema, opacity, epithelial rupture	Secondary oxidative stress	-
4.	Zhupan B.B., 2023	Multiple organ injuries	Irreversible vision loss due to delayed treatment	-

Clinical manifestations include corneal edema, opacity, corneal thickening, and impaired transparency, which, without timely treatment, can lead to progressive vision loss. The authors emphasize that delaying ophthalmological examination after an explosive injury significantly increases the risk of prolonged loss of visual function, maladaptation of visual systems, and the development of secondary complications [6, 13, 25].

Based on the analysis of the data, urgent comprehensive clinical and ophthalmological examination of all patients who have suffered explosions or traumatic brain injuries is recommended, including: assessment of the condition of the cornea; determination of intraocular pressure; control of the transparency and integrity of the epithelial and endothelium of the cornea; early administration of anti-inflammatory, antioxidant, and regenerative therapy in the presence of lesions.

The results of Kempuraj D. (2024) emphasize the critical role of early ophthalmic intervention and systematic monitoring of the condition of the cornea to preserve vision, prevent complications, and improve functional outcomes in affected military personnel [49].

Reynolds M.E. (2022, 2023) proposed an improved algorithm for classifying combat ocular injuries in US Armed Forces personnel, aimed at systematizing complications and medical interventions during a 12-month observation period after the initial injury. The algorithm involves dividing injuries into uncomplicated and complicated, with the latter being further stratified by severity into low, medium, and high levels. Analysis of data for 2016–2019 showed that 84.0% of all complications occurred within the first 30 days after injury, emphasizing the critical role of early diagnostic support and timely treatment. The most common complications were orbital floor fracture, iridocyclitis, and recurrent corneal erosion, which together accounted for 52.0% of registered cases. The results demonstrate the importance of a standardized classification of combat eye injuries for optimizing patient management tactics, preventing early and delayed complications, and improving the system of ophthalmic care in military conditions.

In 2023, Reynolds M.E. conducted an in-depth analysis of eye injuries, taking into account demographic characteristics, branches of the military, and professional groups of US military personnel. It was found that the incidence of uncomplicated eye injuries in 2019 decreased by 18.7% compared to 2016 (from 89.5 to 72.8 cases per 10,000 military personnel), which indicates the effectiveness of preventive measures, more active use of personal protective equipment, and improved combat training. At the same time, the rate of complicated injuries remained virtually unchanged, which may reflect the limited ability of existing measures to prevent severe penetrating and combined injuries (Table 2).

Table 2. Mechanisms of eye injuries and their prevalence worldwide

No.	Author, year	Main mechanism of injury	Percentage	Additional factors
1	Jonak K., 2025	Blast and fragmentary injuries	79	Multiple organ damage
2.	Akincioğlu D., 2022	Fragment injuries	74.1	Explosions, intraocular foreign bodies
3	Zhang Y., 2023 (China, 2016-2019)	Blast and open injuries	45.8	No protective eyewear
4	Reynolds M.E., 2023 (USA)	Blast injuries	72	Shrapnel – 21.0%, blunt 7.0%

Gender analysis showed that men had a 62.0% higher risk of complicated eye injuries than women. The highest incidence of severe injuries was recorded among US Army (32.4%) and Marine Corps (29.7%) personnel, while the lowest was among Navy (14.1%) and Air Force (11.8%) personnel. The leading mechanisms of injury were blunt trauma (34.8%) and superficial mechanical injury (27.2%), although penetrating wounds (8.5%) and intraocular foreign bodies (5.9%) determined the highest risk of vision loss and increased length of hospitalization.

Among complicated injuries, 22.0% required surgical intervention, and 14.6% were accompanied by partial or complete loss of visual function in the affected eye. Dynamic analysis did not show significant changes in the structure of complicated injuries during 2016–2019, but revealed a tendency toward an increase in the frequency of combined injuries to the eyes and facial skeleton from 6.1% to 9.3%. The data obtained indicate a change in the morphological and clinical nature of combat injuries to the eyeball in the context of the use of modern highly effective explosive and kinetic weapons.

The consistently high rates of severe ophthalmic injuries indicate the need for further improvement of the early detection system, increased effectiveness of medical evacuation measures, and the development of new eye protection technologies, especially for categories of military personnel at increased risk of injury, such as sappers, artillerymen, and technical specialists [50, 51].

Combat eye injuries are often accompanied by traumatic brain injury (TBI), especially in cases of blast injuries, when the shock wave affects not only the eyes but also the brain. This combination of injuries significantly complicates diagnosis and prognosis, as combined neuro-ophthalmological disorders can lead to permanent vision loss, spatial orientation disorders, reduced contrast sensitivity, and other sensory functions.

The effect of a blast wave on the eyeball and brain is a complex and multifactorial process. Primary trauma to the cornea and retina may be combined with microhematomas, dysfunction of the neural pathways of vision, and changes in the vascular system of the brain. Victims often experience accommodation disorders, double vision (diplopia), photosensitivity, as well as prolonged cognitive and motor deficits associated with damage to the brain structures responsible for processing visual information.

The clinical management of such patients is particularly challenging: coordination between neurosurgeons, ophthalmologists, and rehabilitation specialists is essential. In addition, combined trauma increases the risk of secondary complications such as glaucoma, chronic corneal edema, and degenerative changes in the retina and optic nerve, which can lead to irreversible vision loss.

Given this, early diagnosis, the use of modern methods of neuro-ophthalmological examination, and systematic rehabilitation are critically important for preserving the functional indicators of vision and quality of life of military personnel who have suffered combined eye and brain injuries [52].

A study by Gu W. (2024) conducted a large-scale retrospective analysis of cases of combined traumatic brain and eye injuries among US military personnel, which allowed for a detailed assessment of the relationship between brain and eye injuries in combat conditions. It was found that the frequency of combined cases of TBI was 4.7% among patients with eye injuries, with more than 35% of individuals with traumatic brain injury having concomitant ophthalmic lesions. About 60% of such injuries were caused by explosive devices, which highlights the high risk of barotrauma and projectile injuries on the battlefield.

The presence of ocular injury correlated with more severe traumatic brain injury, a more complicated clinical course, and a longer recovery of visual functions, which significantly affected the further rehabilitation of military personnel. The highest risk of concomitant TBI was observed in patients with orbital fractures, eyeball ruptures, penetrating wounds, and complex combined injuries. The results obtained convincingly prove the need for mandatory early ophthalmological screening in all cases of suspected TBI, especially in military personnel who have suffered explosive injuries. This approach allows for the timely detection of hidden or underestimated ocular damage, optimization of treatment tactics, and improvement of long-term functional outcomes [53].

In many cases, combat eye injuries are accompanied by combined traumatic brain, facial, and general trauma, which requires detailed coordination between specialists of different profiles. This approach makes it possible to minimize the risk of complications, choose the most effective surgical correction tactics, and ensure continuity of care - from the moment of evacuation to the stages of vision restoration.

Lee I. et al. (2023) conducted a systematic review of the literature covering 20 years of combat operations within the Global War on Terrorism, covering cases of ophthalmic trauma among US and allied forces. The analysis showed that approximately 38.0–42.0% of patients with severe combat eye injuries () had concomitant traumatic brain injury (TBI), of which 18.0–22.0% developed persistent neurovisual disorders such as diffuse axonal injury, microhematomas, and cerebral hypoperfusion [54].

In terms of injury mechanisms, blast injuries accounted for 72.0% of cases, shrapnel injuries for 21.0%, and blunt trauma for 7.0%. Bilateral eye injuries were recorded in 34.0–36.0% of patients, while about 28.0% had combined injuries of the orbit, cornea, and retina. In the group of patients with combined ophthalmic and neurological injuries, the frequency of visual disability exceeded 45.0%, which is twice as high as in patients who had only isolated damage to the organ of vision.

Our comprehensive review of combat ocular injuries based on international and Ukrainian experience showed that global data confirm that the main mechanisms of eye injuries in military conditions are explosive, shrapnel, and firearm injuries, as

well as blunt mechanical injuries. According to Lee I. et al. (2023), during the global war on terrorism, 72.0% of eye injuries were caused by explosions, 21.0% by shrapnel, and 7.0% by blunt trauma. In 34.0–36.0% of cases, bilateral eye injuries were observed, and combined injuries to the orbit, cornea, and retina were noted in approximately 28.0% of the wounded.

The authors emphasize the critical role of early multidisciplinary intervention, which includes coordination between ophthalmologists, neurosurgeons, and neurorehabilitation specialists. This approach reduces the risk of vision loss by 30.0–35.0%, shortens the length of hospitalisation by approximately 25.0% and significantly improves long-term functional and cognitive outcomes of treatment.

The study demonstrates that effective management of patients with combined combat injuries requires an integrated system of neuro-ophthalmological support that provides:

1. timely diagnosis of hidden injuries;
2. early surgical and conservative intervention;
3. coordination between surgical, ophthalmological, and rehabilitation teams;
4. long-term monitoring of the visual, cognitive, and psychoemotional functions of victims.

The results of Lee I. et al. (2023) prove the need to standardize multidisciplinary management algorithms, integrate neurosurgical and ophthalmological care, and develop an early rehabilitation system to minimize vision loss and improve the quality of life of military personnel with complex combat injuries [54].

During counterinsurgency operations in China (2016–2019), a significant number of eye injuries were recorded among military personnel and civilians, with explosive injuries accounting for 45.8% and open injuries accounting for 50.4%. Most of these cases were associated with the lack of personal eye protection or its inadequate use, which emphasizes the critical importance of preventive measures and proper equipment on the battlefield.

Among mechanical injuries associated with explosive effects, 94.0% were various forms of eye injuries. In particular, intraocular foreign bodies caused 55.2%

of open eye injuries, while eye contusions were recorded in 60.2% of closed injuries. Pathological changes in the cornea and retina included the development of proliferative vitreoretinopathy, which was more common in perforating injuries (47.1%) and the presence of intraocular foreign bodies (26.8%) compared to penetrating injuries (8.8%). Similarly, proliferative changes were more frequently recorded in lacerated wounds (24.3%) than in classic ruptures (9.2%).

A clinically important indicator was that 9.6% of patients suffered loss of vision, which indicates the high severity of combat eye injuries and the need for timely intervention. The data also emphasize that the nature of the injuries largely depends on the mechanism of trauma, the type of eye damage, and the presence or absence of protective equipment, which should be taken into account when developing strategies for prevention, early diagnosis, and surgical management of patients.

The results of the study demonstrate:

- 1) **a high frequency of blast and penetrating eye injuries**, especially in the absence of adequate protection;
- 2) **the influence of mechanical factors on the severity of injuries and the development of proliferative changes in the cornea and retina;**
- 3) **the critical role of early diagnosis and multidisciplinary intervention** in preserving visual function;
- 4) the need to strengthen preventive measures and train personnel in the use of personal eye protection [55].

A study by Akincioğlu D. (2022) conducted a detailed analysis of eye injuries in people wounded during counterterrorism operations in urban areas in Turkey. The results showed that 62.5% of injuries were open, and 29.5% were accompanied by intraocular foreign bodies, which were mainly caused by fragmentation injuries (74.1%). Explosive injuries ranked second in prevalence at 18.3%, while gunshot wounds accounted for only 7.6% of cases.

Among the patients, 77.0% had concomitant craniocerebral injuries, and 52.0% had multiple facial injuries, which significantly complicated diagnosis, medical evacuation, and the choice of surgical tactics. Pars plana vitrectomy was most often

performed (79.6% of cases) to restore the structural integrity of the eyeball and remove intraocular foreign bodies. In the postoperative period, all patients were prescribed systemic antibiotic therapy (ceftriaxone or moxifloxacin) and prophylactic intravitreal administration of vancomycin and ceftazidime to prevent the development of endophthalmitis. In 47.0% of cases, systemic corticosteroids were used to reduce post-traumatic edema and prevent sympathetic ophthalmia.

Despite the treatment, complete functional recovery of vision was observed in only 32.1% of patients, while partial or complete loss of vision persisted in 27.7% of cases. The study also showed that a delay in surgical intervention of more than 12 hours was associated with a 42.0% increase in the risk of enucleation. Therefore, the authors emphasize the critical role of early ophthalmic surgery within the first 6–8 hours after injury as a key factor in preserving functional vision and preventing serious complications [56].

A study by Rana V. (2023) analyzed the mechanisms of eye injuries caused by blast waves from improvised explosive devices (IEDs). The study showed that blast waves can lead to a sharp increase in intraocular pressure, which contributes to the formation of severe mechanical damage. The highest loads (deformation forces) were recorded in areas where the sclera is thinnest near the attachment sites of the rectus muscles of the eye, making these areas particularly vulnerable to rupture and proliferative complications.

According to the results of observations, the most common types of injuries were penetrating injuries (54.1%), blunt injuries (26.5%), and combined injuries (19.4%). Many cases were accompanied by orbital fractures, thermal burns, and combined traumatic brain injuries, which significantly complicated the initial diagnosis and selection of the optimal surgical approach. Binocular injuries accounted for 13.0%, indicating high explosive energy and a potential risk of serious visual impairment.

The average time from the moment of injury to the initial microsurgical treatment was 6–8 hours, which corresponds to the critical time frame for preventing irreversible damage to the eye structures. In 22.0% of cases, vitrectomy with silicone or gas tamponade was performed, in 18.0% – reconstruction of the anterior segment,

while enucleation or evisceration was necessary in 9.0% of patients due to irreversible destruction of the eyeball structures.

After treatment, the anatomical integrity of the eyeball was preserved in 73.4% of cases, but functional restoration of vision was recorded in only 41.7% of patients, which emphasizes the high risk of permanent vision loss even with timely surgical intervention.

The results of the study demonstrate:

- 1) the critical role of early PMO (primary medical surgical treatment (or primary medical-surgical examination/treatment) in preserving the anatomical integrity of the eye and minimizing complications;
- 2) the high frequency of penetrating and combined injuries requiring a comprehensive and multidisciplinary approach;
- 3) the need for systematic postoperative follow-up, including antibiotic therapy, intraocular pressure control, and prevention of inflammatory reactions;
- 4) the importance of anatomically and functionally oriented reconstructive interventions, which significantly affect the final prognosis of visual function.

The study by Rana V. (2023) emphasizes that blast-related ocular injuries are characterized by high severity, complexity, and a substantial risk of persistent visual loss, while early surgical intervention and an integrated multidisciplinary approach are the main factors in improving clinical outcomes and preserving functional ocular capacity [57].

A study by Karimi A. (2022) conducted a detailed analysis of the biomechanical impact of blast waves from improvised explosive devices (IEDs) on the structures of the eyeball using individualized eye models and the finite element analysis method. The aim of the study was to determine the critical levels of mechanical stress and deformation of eye structures that can cause permanent damage to the visual apparatus [58].

The results of the modeling showed that at a peak intraocular pressure of more than 30 mmHg, critical damage to the cornea, sclera, and choroid occurs, which can lead to retinal detachment, rupture of the structural layers of the eye, and damage to the optic nerve. Peak intraocular pressure in such cases reaches 40-60 mmHg,

confirming the high risk of severe injury even with short-term exposure to the blast wave.

The greatest mechanical stress was observed during a frontal explosion of a heavier explosive device (2 kg) at a distance of 2 m, when the peak pressure forces on the eye structures were maximum. Explosions of smaller mass or those that occurred from the side led to significantly less deformation and stress in the eye membranes, but even in these scenarios, there is a risk of damage to the cornea, sclera, and internal structures of the eye.

The study also highlighted the dependence of the nature of injuries on the direction and mass of the explosive charge, as well as the distance to the source of the explosion. These factors determine not only the location of the damage, but also the severity of the injuries, including penetrating injuries, orbital fractures, intraocular foreign bodies, and secondary complications such as endophthalmitis and glaucoma.

The work of Karimi A. (2022) confirms that blast injury to the eye results from a complex interaction between peak pressure, direction of the blast wave, and charge mass. The authors stress the critical importance of early ophthalmological examination, timely microsurgical wound management, and the use of personal eye protection in preserving functional vision [58].

A retrospective cohort study evaluated the long-term clinical and functional consequences of combat-related eye injuries based on data from the Defense and Veterans Eye Injury and Vision Registry. The study included US military personnel who suffered various types of eye injuries in combat zones, using DALYs (disability-adjusted life years) to integrate loss of life and long-term visual impairment. The results showed that the most significant in terms of long-term consequences are severe and combined injuries, including penetrating injuries, traumatic vision loss, and injuries to the anterior and posterior segments of the eye. Less severe injuries, such as corneal scratches or foreign bodies, although more common, had a significantly lower clinical and functional impact. The authors emphasize that severe and multi-component ocular injuries have significant medical and social consequences, including long-term loss of visual function and the need for comprehensive specialized care and rehabilitation, which should be taken into

account when developing strategies for prevention, treatment, and post-traumatic support for military personnel [59].

2.2. Current features of combat ocular injuries in the context of full-scale war in Ukraine

According to a scientific study by Balabukh E.O. (2025), during the hostilities in Ukraine, eye injuries were recorded in 78.0% of military personnel and 22.0% of the civilian population. Among the victims, men accounted for 92.0% and women for 8.0%, with an age range from 18 to 67 years. The results of the study showed that among the injuries to the eyeball, 31.3% were penetrating wounds, 15.5% were prolapse of the eye membranes, and intraocular foreign bodies were recorded in 57.4% of cases, mainly in the posterior segment of the eye; in 78.0% of cases, there were multiple foreign bodies. Among the foreign bodies, 85.0% were non-magnetic, including small stones, glass fragments, organic materials, and fragments of aluminum alloy shells.

Other types of damage to the eyeball were as follows: complete destruction of the eye – 6.0%; non-penetrating wounds – 9.5%; moderate and severe contusions – 41.3%; hemophthalmos and hyphema – 34.1%, traumatic cataracts of varying severity – 41.1%, retinal detachment – 27.5%, endophthalmitis in penetrating wounds – 1.9%.

These data reflect the high severity of combat injuries to the eyeball in modern warfare and a significant proportion of complex penetrating injuries with the presence of intraocular foreign bodies, requiring timely specialized ophthalmological care and comprehensive surgical treatment.

Among those who suffered combat eye injuries, moderate and severe burns were observed in 4.2% of cases, and orbital injuries with and without foreign bodies in 11.3%. Various types of eyelid injuries were recorded in 16.9% of patients, and foreign bodies in the deep layers of the cornea in 14.0%. Bilateral eye damage was

observed in 51.0% of patients, while combined injuries of the eye with other organs were found in 41.9% of cases, of which: with traumatic brain injury – 18.9%, with limb injuries – 26.9%, with other systemic lesions – 16.5%.

In terms of the severity of combat eye injuries, moderate injuries were recorded in 35.0% of cases, severe injuries in 57.0%, and extremely severe injuries in 8.0%.

In terms of the location of the injuries, 10.0% of cases were in zone 1, 24.0% in zone 2, 12.0% in zone 3, 6.0% involved complete destruction of the eye, and 47.9% involved combined injuries to different zones.

The most common surgical interventions were combined surgical procedures, which included primary surgical treatment (PST) with removal of intraocular foreign bodies (IFB) in combination with phacoemulsification of cataracts and/or vitreoretinal surgery, accounting for 37.0% of all operations. PSR for penetrating injuries with or without IFO removal accounted for 32.0%, while the remaining cases included traumatic cataract removal with intraocular lens implantation, surgical interventions on the orbit and eyelids, and removal of foreign bodies from the deep layers of the cornea.

The average length of stay in the hospital was 5.7 ± 0.04 days for patients with penetrating eye injuries and the presence of POA and 5.1 ± 0.06 days for other injuries, which is 0.4–1.0 days less than the data reported by Elbeyli (2020). There was also a decrease in the number of enucleations and eviscerations from 5.0% to 1.5%, which indicates the effectiveness of modern protocols for early surgical intervention and comprehensive rehabilitation [6, 60].

In a study by Shvets A.V. (2022), a comprehensive analysis of mine-blast injuries (MBI) of the eyeball among military personnel in the context of the Anti-Terrorist Operation in eastern Ukraine was conducted. The author notes that MET is the leading type of combat injury in modern conflicts and is often accompanied by multiple organ damage, when eye injuries are combined with traumatic brain, maxillofacial, or orbital injuries.

Morphological analysis showed a predominance of penetrating and multiple shrapnel wounds of the eyeball, including corneal and scleral ruptures, as well as deformities of the orbital complex. Such injuries are characterized by massive bleeding, a high

risk of secondary infection, and the development of sympathetic ophthalmia, which significantly complicates treatment and worsens the prognosis for vision recovery. In some cases, complete destruction of the eye was observed, requiring enucleation or primary reconstructive surgery.

An important negative factor is the delay in medical evacuation and limited access to specialized ophthalmological care, with the average time to highly specialized care exceeding 12 hours. This directly correlated with an increase in the frequency of complications, an increase in the duration of hospitalization, and a decrease in the effectiveness of visual function recovery.

The data obtained indicate that MBT of the eye is characterized by high clinical complexity, frequent combination of injuries, and an increased risk of disability. To optimize treatment outcomes, the author emphasizes the need for a systematic approach that includes early diagnosis, timely evacuation, and multidisciplinary rehabilitation, involving ophthalmologists, neurosurgeons, rehabilitation specialists, and reconstructive surgery specialists. Such a comprehensive approach helps to reduce the risk of vision loss, shorten the duration of hospitalization, and improve the quality of life of affected military personnel [61].

A study by Jonak K. (2025) conducted a comprehensive analysis of cases of combat and civilian eye injuries sustained during the armed conflict in Ukraine. It was found that more than 60.0% of the victims had mixed or multiple organ injuries, with ophthalmic injuries combined with traumatic brain injuries and facial skeleton injuries. This combination of injuries significantly complicated the treatment tactics and prognosis for the restoration of visual functions.

Analysis of clinical data showed that early surgical intervention, performed within 12–24 hours after the injury, was a critical factor in preserving vision, reducing the frequency of complications, and improving the anatomical and functional outcome of treatment.

The scientist emphasized that the importance of implementing a national electronic registry of combat eye injuries should ensure:

- standardized recording of cases and characteristics of injuries;
- evaluation of the effectiveness of treatment and rehabilitation measures;

- the development of preventive strategies to avoid serious damage;
- improving the level of training of medical specialists in the field of military ophthalmological care.

The application of such a systematic approach is particularly relevant in the context of modern combat conflicts, where the high risk of severe penetrating and combined eye injuries requires integrated, multidisciplinary patient management, including coordination between ophthalmologists, neurosurgeons, trauma surgeons, and rehabilitation specialists. This strategy contributes to more effective treatment, reduced risk of disability, and improved quality of life for victims [12].

Antonyshyn K. (2025) analyzed the organization and functioning of a mobile craniofacial surgical unit created to provide specialized care to those wounded during combat operations in Ukraine. The proposed model involves a highly mobile team of reconstructive surgeons capable of rapidly deploying in or near the combat zone to perform emergency surgery for complex injuries to the face, orbit, and skull base.

The scientist focused on a multidisciplinary approach that integrates the work of maxillofacial surgeons, ophthalmologists, neurosurgeons, anesthesiologists, and medical evacuation specialists. Such coordination reduces the time between injury and reconstructive surgery, which is critical for preserving vision, anatomical and aesthetic integrity of the face, and preventing postoperative complications.

Experience with mobile teams has demonstrated high effectiveness in the context of modern conflicts, where severe multiple organ injuries and limited access to specialized centers increase the risk of complications and disability. Early comprehensive intervention improves patients' chances of recovery, reduces the incidence of severe complications, and optimizes rehabilitation by combining operational mobility, modern technological equipment, and standardized treatment protocols.

This approach can become the standard for the organization of military medical care during large-scale armed conflicts and emergencies, ensuring integrated, multidisciplinary patient management and improving the quality of life of victims [62].

Lurin I.A. (2025) described the clinical case of a 41-year-old soldier with a shrapnel wound to the right half of his upper lip during combat operations in Ukraine. A rotational flap was used for reconstruction in combination with dynamic digital thermography and handheld Doppler, which allowed for the assessment of soft tissue perfusion before, during, and after surgery.

The surgery was performed in the field, where standard imaging methods were limited. The use of an integrated approach, including thermographic monitoring, Doppler assessment, and remote telemedicine consultations, ensured optimal functional and aesthetic recovery without signs of necrosis or infectious complications.

The combination of rotational flaps with digital thermography, Doppler, and telemedicine support is particularly relevant in military conflicts, where resources for diagnosis and monitoring are limited. This approach minimizes postoperative complications, optimizes tissue blood supply, and increases the effectiveness of reconstructive interventions, demonstrating the promise of integrated technologies in military field surgery and modeling standards for areas with limited access to modern medical resources [63].

In a multicenter retrospective study, Prysiazniuk O. et al. (2025) analyzed in detail the clinical features of combat maxillofacial injuries among Ukrainian military personnel in the period 2022–2024. The study confirmed that the leading mechanism of injury remains explosive trauma, including artillery and mortar shelling, explosions of unmanned aerial vehicles, and rocket attacks [64].

The results showed that these mechanisms often lead to complex, multiple comminuted fractures of the midface, which in most cases are accompanied by ophthalmic damage and skull base injuries, significantly complicating treatment and prognosis. In addition, a high frequency of combined multiple organ injuries has been established, emphasizing the need for a multidisciplinary approach to the management of victims, including maxillofacial surgeons, ophthalmologists, neurosurgeons, and rehabilitation specialists.

The authors emphasize the importance of systematic recording and analysis of combat injuries to improve medical evacuation, surgical treatment, and rehabilitation

protocols. The results of the study emphasize that early integrated intervention and comprehensive monitoring of victims are critical for preserving visual function, restoring anatomical integrity of the face, and minimizing the risk of disability (Table 3) [54, 62, 64].

Table 3. Multidisciplinary approach and treatment outcomes

No.	Author, year	Team composition	Main results	Result/vision preservation
1.	Lee I., 2023	Ophthalmologists, neurosurgeons, rehabilitation specialists, anesthesiologists	Reduced risk of vision loss	30.0–35.0% / reduction in hospitalisation by 25.0%
2.	Antonyshyn et al., 2025	Maxillofacial surgeons, ophthalmologists, neurosurgeons, anesthesiologists, evacuation	Preservation of visual functions and facial symmetry	-
3.	Prysiachniuk O. et al., 2025	Maxillofacial surgeons, ophthalmologists, neurosurgeons, anesthesiologists, evacuation	Early stabilization, infection prevention	-

Treatment of patients with combat eye injuries was carried out according to the principles of staged reconstructive surgery, which involves the step-by-step restoration of damaged structures, taking into account the severity of the injury and multi-organ involvement. In the early stages, the main focus was on stabilizing the bone structures of the face, cleaning the soft tissues, controlling hemostasis, and preventing infectious complications. Subsequent stages included reconstruction of the functional and aesthetic components of the face, restoration of the orbital anatomy, and preservation of visual functions.

Particular attention was paid to multidisciplinary coordination, involving maxillofacial surgeons, ophthalmologists, neurosurgeons, anesthesiologists, and medical evacuation specialists. This integrated approach reduced the time to initial

surgery, ensured timely diagnosis of associated injuries, and improved the effectiveness of restoring facial function and anatomical integrity.

The study highlights the critical role of the national combat injury registry, which provides standardized case reporting, trend monitoring, and evaluation of the effectiveness of treatment and rehabilitation measures. The use of such data contributes to the optimization of resource allocation in medical facilities, improves the quality of medical evacuation, and reduces the incidence of severe combined injuries.

In addition, the authors emphasize the importance of developing comprehensive rehabilitation strategies that include rehabilitation programs aimed at the physical, neurovisual, and psycho-emotional recovery of patients, as well as the implementation of standardized protocols for the management of wounded in military conditions. The combination of early surgical stabilization, multidisciplinary interaction, and a systematic approach to rehabilitation can significantly reduce the risk of disability, improve the functional and aesthetic results of treatment, and improve the quality of life of victims [63].

During the full-scale military aggression on the territory of Ukraine, military medical services rapidly implemented changes in the system of treatment and medical evacuation support for patients with combat ocular trauma, which made it possible to increase the effectiveness of specialized ophthalmological centers and optimize the provision of highly specialized care. The aim of one study was to perform a comparative analysis of clinical outcomes and organizational strategies for managing patients with combat ocular trauma at the National Military Medical Clinical Center at different stages of hostilities, taking into account changes in severity, injury patterns, and the scope of diagnostic and therapeutic interventions.

The analysis covered the period from 2014 to 2021 and February to April 2022, using systematic, comparative, and content analysis, descriptive modeling, and statistical data processing. The results showed that the changes introduced in the four-level medical evacuation system ensured operational coordination between institutions of different levels and made it possible to minimize the time to provide specialized ophthalmological care.

The proportion of patients with combat ocular trauma was 9.4%, which correlates with the increased use of high-kinetic-energy weapons. Among the characteristic features of the injuries, the following were recorded: penetrating globe injuries in more than 50% of cases, intraocular foreign bodies in 43.3%, binocular injuries in 29.8%, and multiple injuries in 81.4%, all of which significantly complicated diagnosis and treatment planning.

The highest rates of preservation of the anatomical integrity of the eye and restoration of visual function were observed in patients who received early evacuation and timely specialized intervention, especially in cases of bilateral severe injuries. The study confirms the key role of rapid medical evacuation, early surgical treatment, and a multidisciplinary approach involving ophthalmologists, neurosurgeons, anesthesiologists, and rehabilitation specialists in minimizing complications, reducing the risk of vision loss, and preventing disability.

Based on the data obtained, the authors emphasize the need for further improvement of the medical evacuation system, the introduction of standardized clinical protocols, the formation of a national register of combat eye injuries, and the integration of rehabilitation programs that take into account the physical, neurovisual, and psychoemotional consequences of injuries. Such a comprehensive approach allows for the optimization of treatment, reduction of hospitalization time, and improvement of the functional and social outcomes of victims, as well as increasing the preparedness of medical facilities for large-scale crisis situations [65].

CHAPTER 3. A COMPREHENSIVE APPROACH TO MEDICAL CARE AND REHABILITATION FOR COMBAT OCULAR INJURIES AT ROLE 1, ROLE 2, AND ROLE 3 LEVELS

3.1 Primary medical care at all stages of evacuation

3.1.1. Provision of medical care for ocular injuries at the ROLE 1

Eye injuries are among the most clinically complex and prognostically unfavorable injuries, since even the slightest delay or mistake in the early stages of medical care can lead to irreversible loss of visual function, disability, and a significant reduction in the quality of life of the victims. In combat conditions, the effectiveness of treatment is largely determined by strict adherence to the principles of staged medical care in accordance with the levels of medical care (ROLE), where the first level – ROLE 1 – plays a leading role.

ROLE 1 is the initial stage of medical care, aimed at preserving the viability of the eyeball, minimizing secondary tissue damage, preventing infectious complications, and preparing the wounded for safe and timely evacuation to a higher level of medical care.

Medical care at the ROLE 1 level is provided:

- directly in the combat zone;
- on the battlefield;
- at casualty collection points;
- during primary evacuation (MEDEVAC/CASEVAC).

Assistance is provided by persons with varying levels of medical training: the wounded themselves (self-help); military personnel of the unit (mutual assistance); combat medics; medical instructors.

The main objectives of medical assistance at this stage are:

- preserving the anatomical integrity of the eyeball;
- preventing extrusion of intraocular contents;
- minimizing the risk of infectious and inflammatory complications;
- stabilizing the general condition of the wounded person;

- creating conditions for safe evacuation to a ROLE 2 facility.

At the first level of medical care, the following are most often diagnosed:

- closed eye injuries (contusions of varying degrees);
- penetrating and perforating wounds of the eyeball;
- chemical and thermal burns of the organ of vision;
- presence of superficial or intraocular foreign bodies;
- combined injuries (a combination of eye trauma with injuries to the face, skull, or brain).

The scope of primary medical care for eye injuries at ROLE 1.

The initial assessment is carried out in accordance with tactical medicine algorithms, with priority given to life-threatening conditions: detection of massive bleeding, assessment of consciousness level; signs of traumatic brain injury, multiple trauma; careful examination of the organ of vision without any pressure on the eyeball.

Ophthalmological examination is performed according to the principle "from external structures to internal" and includes: examination of the face, bone structures of the orbit and eyelids; assessment of the condition of the conjunctiva, cornea, anterior chamber, iris, and lens. A quick field test is performed to determine visual acuity.

Examination of the posterior segment of the eye, determination of intraocular pressure, and ultrasound examination of the injured eye at the ROLE 1 level are strongly discouraged due to the high risk of additional trauma.

In order to prevent secondary damage to the eyeball, the following is strictly prohibited:

- washing the eye if a penetrating injury is suspected;
- removing foreign bodies, especially fixed ones;
- any pressure on the eyeball;
- use of eye ointments for open wounds;
- application of pressure bandages or patches;
- performing reconstructive surgery, enucleation, or tissue excision;
- performing ultrasound examinations and measuring intraocular pressure.

Protecting the eyeball is a critically important component of medical care, so it is necessary to urgently apply a rigid protective shield, and in its absence, use improvised protective devices (for example, a plastic cap). If possible, it is recommended to cover both eyes in order to reduce synchronous movements of the eyeballs and minimize the risk of additional damage.

Adequate pain relief helps reduce pain and reflex movements, so non-narcotic analgesics should be used. Narcotic analgesics may only be used for strict indications and in accordance with current clinical protocols. Instilling local anesthetics into the eye is not permitted due to the risk of masking symptoms and aggravating the damage.

In case of chemical damage to the eye, the first urgent measure is immediate and prolonged copious irrigation of the conjunctival cavity with running water or isotonic sodium chloride solution for at least 10–15 minutes in order to quickly remove the chemical agent and reduce the depth of tissue damage. Contact lenses must be removed at the initial stage of irrigation. After rinsing, it is recommended to apply a sterile protective bandage and refer the patient for specialized ophthalmological care.

Prevention of infectious complications in combat ocular injuries is an essential part of medical care and involves a set of step-by-step measures aimed at preventing the development of purulent-inflammatory processes and intraocular infections. It includes the application of an aseptic dry bandage without compression, which protects the injured eye from secondary infection and mechanical impact without increasing intraocular pressure.

All patients with penetrating injuries of the eyeball are indicated for early systemic antibiotic therapy in accordance with ROLE 1 medical care standards and protocols, taking into account the spectrum of possible pathogens and the high risk of endophthalmitis. These measures are critical for reducing the incidence of infectious complications, preserving the anatomical integrity of the eyeball, and improving the functional outcomes of further treatment.

If possible, it is recommended to conduct a tele- or video consultation with an ophthalmologist before evacuation, which allows determining the optimal algorithm

for first aid and preparing the patient for further specialized intervention. Highly specialized ophthalmic surgical care should be provided no later than 24 hours after the injury, including preparation for aeromedical evacuation, if necessary, to ensure the most effective preservation of visual functions and prevention of complications.

This approach is based on the principles of speed, safety, and step-by-step treatment, as well as the integration of telemedicine technologies to ensure coordination between the stages of medical evacuation and specialized treatment, which is critically important in military conditions with a high risk of severe eye injuries.

3.1.2. The second level of medical care for eye injuries is

ROLE 2

The second level of medical care (ROLE 2) is a critically important stage in the military medical care system for patients with eye injuries, as it is here that vital signs are stabilized, early detection of threats to visual function is carried out, and the development of severe or irreversible complications is prevented. At this level of medical care, extended clinical diagnostics are performed, including assessment of visual acuity (if possible), detailed examination of the eyelids, orbits, and conjunctival structures, determination of signs of penetrating injuries, assessment of eyeball mobility, and presence of subcutaneous or conjunctival emphysema.

At the same time, intensive pharmacological therapy is carried out, including systemic and local use of antibacterial, anti-inflammatory, and anti-edema drugs, control of pain syndrome with non-narcotic and, if indicated, narcotic analgesics, as well as prevention of tetanus infection and complications in penetrating wounds.

At ROLE 2, urgent surgical interventions are performed, limited to life- or vision-saving indications, such as primary surgical treatment of eyelid wounds, stopping bleeding, lateral canthotomy for orbital compartment syndrome, as well as preparation for more complex reconstructive interventions at ROLE 3.

In addition, at this level, it is important to use telemedicine consultations with ophthalmic surgeons to adjust treatment tactics and determine the optimal time for evacuation to the third level of medical care. Patients should be evacuated in an organized and safe manner, with maximum attention paid to preserving visual function, minimizing eye movement, and preventing additional damage to the eye.

Secondary medical care (ROLE 2) is provided in specialized military medical units, which include medical companies, mobile military hospitals, and forward surgical teams deployed in the combat zone or at a safe distance from it. Care is provided by a multidisciplinary team consisting of a general practitioner, surgeon, anesthesiologist, and nursing staff, ensuring a comprehensive approach to patient assessment, diagnostic procedures, drug therapy, and emergency surgery. This organizational structure allows for the rapid stabilization of the wounded, minimization of the risk of complications, and preparation of the patient for safe evacuation to a third-level medical facility.

The scope of medical care for eye injuries at ROLE 2.

At the second level of medical care, ROLE 2, an extended assessment of the condition of the organ of vision is carried out, which involves a comprehensive clinical assessment. In particular, visual acuity is determined if contact with the patient is possible, a detailed examination of the orbits, eyelids, and periorbital tissues is performed, and signs of a penetrating or open wound of the eyeball are identified. If there is no suspicion of open trauma, intraocular pressure can be monitored, and all examination results are documented for further analysis and treatment planning.

At the same time, intensive pharmacological therapy is carried out to stabilize the patient's condition and prevent complications. This includes the use of broad-spectrum systemic antibiotics to prevent infectious processes, the prescription of anti-inflammatory and anti-edema drugs to reduce swelling and inflammatory reactions, the provision of adequate pain relief taking into account the severity of the injury, and tetanus prophylaxis in accordance with approved protocols. This approach allows for

effective preparation of the patient for further evacuation to the third level of specialized medical care, minimizing the risk of vision loss and complications.

Management of specific clinical forms of trauma:

1. Penetrating wounds and retrobulbar hemorrhage

The most dangerous complication is the development of orbital compartment syndrome, accompanied by:

- a sharp decrease or loss of vision;
- tight ("rocky") eyelids on palpation;
- proptosis of the affected eye;
- relative afferent defect of the pupil;
- the presence of blood or clots in the anterior chamber (hyphema, in particular of the "black ball" type).

Treatment tactics:

- urgent lateral canthotomy and lower cantholysis;
- protection of the eye with a rigid shield;
- systemic antibiotic therapy;
- urgent preparation for evacuation.

2. Orbital fractures

Clinical signs:

- stepped edge of the orbit;
- restricted movement of the eyeball;
- enophthalmos or hypoglobus;
- subcutaneous or conjunctival emphysema;
- hypoesthesia in the infraorbital region.

Treatment:

- maintain a high level of suspicion regarding an open eyeball;
- vision examination and documentation of results;
- teleconsultation with an ophthalmic surgeon;
- rigid eye protection and evacuation;

- urgent reconstruction is indicated only in cases of extraocular muscle entrapment with the development of oculo-cardiac reflex (bradycardia, nausea, fainting).

3. Eyelid lacerations

Special attention is paid to injuries involving: the edge of the eyelid; the nasolacrimal system.

Tactics:

- assessment of visual functions;
- teleconsultation with an ophthalmic surgeon;
- rigid eye protection and evacuation;
- final suturing is postponed until specialized intervention;
- if it is impossible to close the eyelids, apply sterile eye ointments (petrolatum, erythromycin) every 2–4 hours.

4. Foreign bodies in the cornea and orbit

- foreign bodies that require effort to remove are not removed;
- vision assessment and documentation are performed;
- teleconsultation with an ophthalmic surgeon;
- rigid eye protection and evacuation.

5. Chemical burns of the organ of vision

Emergency measures:

- repeated rinsing with saline solution or Ringer's lactate in a volume of at least 2 liters;
- control of conjunctival pH;
- removal of foreign particles from the conjunctival sac;
- use of local anesthesia to ensure adequate irrigation;
- prohibition of chemical neutralization of acids and alkalis.

6. Thermal burns of the eye and face

Examination:

- assessment of epithelial defects;
- absence of corneal infiltrates;
- fluorescein staining if possible.

Treatment:

- ophthalmic antibiotic ointments or drops;
- discontinuation of contact lens use;
- teleconsultation with an ophthalmic surgeon.

Surgical procedures are performed exclusively for life-threatening or vision-threatening conditions and include: primary surgical treatment of eyelid wounds; stopping active bleeding; damage control surgery without final reconstruction (Table 4).

Table 4. Algorithm for managing patients depending on nosology

No No	Nosology clinical condition	ROLE 2 examination	Treatment tactics	Prohibited actions	Evacuation tactics
1.	Suspicion of a penetrating injury to the eyeball	Assessment of visual acuity (if possible); external examination without pressure; detection of pupil deformation, tissue prolapse	Rigid protective shield; systemic broad-spectrum antibiotics; pain relief; antiemetic therapy; tetanus prophylaxis	Eye irrigation; removal of foreign bodies; IOP measurement; application of eye ointments; reconstructive surgery	Urgent evacuation to ROLE 3 (ophthalmic surgery), semi-sitting position
2.	Retrobulbar hemorrhage/orbital compartment syndrome	Palpation of the eyelids ("rockiness"); assessment of proptosis; RAPD; decreased vision	Immediate lateral canthotomy and inferior cantholysis; systemic antibiotics; analgesia	Delay intervention; eye compression; wait for CT scan if clinical picture is clear	Immediate evacuation after stabilization
3.	HypHEMA (blood in the anterior chamber)	Visual confirmation of blood; assessment of vision; general condition	Elevated head position (30°); protective shield; systemic antibiotics; restriction of physical activity	Anterior chamber puncture; IOP measurement if open trauma is suspected	Planned or urgent evacuation depending on severity

4.	Orbital fracture	Facial asymmetry; restricted eye movement; enophthalmos/hypoplasia; emphysema; hypoesthesia	Exclusion of open eye; rigid shield; systemic antibiotics for contaminated wounds; teleconsultation with an ophthalmologist	Blowing the nose; reconstruction without indications; pressure on the eye	Evacuation after stabilization; urgent if there are signs of muscle entrapment
5.	Oculocardiac reflex (muscle entrapment)	Bradycardia; nausea; vomiting; syncope; limited eye movement	Emergency surgical decompression; stabilization of hemodynamics	Postponement of surgery	Immediate evacuation after emergency care
6.	Eyelid laceration	Eyelid edge involvement; damage to the nasolacrimal system; vision assessment	Eye protection; antibiotic prophylaxis; sterile eye ointment if eyelids cannot be closed	Final suturing without appropriate experience; reconstruction with open eye	Evacuation to an ophthalmic surgery center
7.	Intraorbital or corneal foreign bodies	Visual examination; vision assessment; X-ray/CT scan (if possible)	Do not remove fixed foreign bodies; protective shield; systemic antibiotics	Attempts at self-removal; pressure on the eye	Evacuation to a specialized hospital
8.	Chemical eye burn	pH assessment; examination of the eyelids; vision assessment	Irrigation with ≥ 2 L of saline/Ringer's solution; removal of particles; anti-inflammatory and antibiotic therapy	Chemical neutralization of acids and alkalis	Evacuation after stabilization
9.	Thermal burn of the eye	Epithelial defects; fluorescein staining; absence of infiltrates	Antibiotic ointments/drops; contact lenses; teleconsultation	Use of steroids without indication	Planned evacuation
10.	Surgical interventions on ROLE 2	Assessment of threat to vision or life	Damage Control Surgery: stopping bleeding, primary closure of eyelid wounds, canthotomy		

Evacuation of patients from the second level of medical care (ROLE 2) is carried out after clinical stabilization has been achieved, with mandatory medical

accompaniment to third-level facilities (ROLE 3), where highly specialized ophthalmic surgical care is provided. This systematic approach helps prevent secondary complications, reduce the risk of damage to the eyeball, and preserve vision as much as possible in people with combat injuries to their eyes. It ensures the continuity of the treatment process and the integration of primary stabilization with further specialized interventions, which is critically important in military field conditions.

3.1.3. Third level of medical care ROLE 3

This stage is the main one in the system of treatment of combat ocular injuries, at which full-fledged specialized and high-tech ophthalmological care is provided, aimed at maximally preserving the anatomical integrity of the eyeball and restoring visual functions.

At the third level of medical care, the treatment of patients with combat ocular injuries is carried out in inpatient military hospitals and multidisciplinary medical centers equipped with modern diagnostic, surgical, and resuscitation equipment. The use of modern ophthalmic operating microscopes, ultrasound systems, computed tomography, and high-precision laser devices ensures comprehensive diagnosis, monitoring of the condition of the eye, and the performance of high-tech surgical interventions in patients with severe and combined injuries.

Care is provided by a multidisciplinary team consisting of ophthalmologists and ophthalmic surgeons, neurosurgeons, resuscitators, maxillofacial surgeons, anesthesiologists, and rehabilitation specialists. This organization allows for comprehensive care of patients with combined injuries of the eye, orbit, and central nervous system, which significantly increases the effectiveness of treatment and reduces the risk of postoperative complications.

The main tasks of the third level of medical care are: providing comprehensive specialized treatment with maximum preservation or restoration of visual functions; preventing the development of serious complications, such as sympathetic

ophthalmia, secondary infections, and postoperative complications; creating conditions for further comprehensive rehabilitation, including restoration of eye function and psychological adaptation of the patient.

At ROLE 3, a complete diagnosis of the organ of vision is performed, including:

- 1) ophthalmoscopy and biomicroscopy of the anterior and posterior segments of the eye;
- 2) ultrasound examination (B-scan) to assess the condition of the vitreous body and intraocular structures;
- 3) computed tomography of the orbits and craniofacial region to determine the severity of penetrating injuries and fractures of the orbital bones;
- 4) laboratory tests: complete blood count and biochemical analysis, coagulogram;
- 5) assessment of visual acuity and visual fields, if the patient's condition allows;
- 6) monitoring of intraocular pressure in the absence of open wounds;
- 7) documentation of examination results for further observation and planning of surgical interventions.

At the third level, high-tech surgical interventions are performed, including:

- microsurgical restoration of the integrity of the eyeball in penetrating injuries;
- removal of foreign bodies from the eyeball and orbit;
- reconstruction of the eyelids, orbit, and adjacent craniofacial structures;
- treatment of orbital fractures and retrobulbar hematomas, including lateral cantotomy and inferior cantholysis for orbital compartment syndrome;
- damage control surgery — temporary wound treatment without complete reconstruction in unstable patients.

Intensive care at ROLE 3 includes: systemic and local antibiotic therapy to prevent infections; use of anti-inflammatory and anti-edema drugs to control postoperative edema and inflammation; control of intraocular pressure and prevention of sympathetic ophthalmia; adequate analgesia and sedation to minimize pain and reflex eye movements during procedures.

The rehabilitation component at ROLE 3 is aimed at complete restoration of visual functions and psychological adaptation of the patient, including: dynamic monitoring of the condition of the eyeball and eye structures; visual and neurovisual rehabilitation, including therapeutic exercises and special trainers for the eye muscles; psychological support to reduce the effects of traumatic stress; preparation for further reconstructive interventions at later stages of rehabilitation.

The basic principles of medical care at ROLE 3 include:

- **speed and timeliness** – prompt examination and intervention;
- **caution** – avoiding additional trauma to the eyes;
- **step-by-step approach** – gradually increasing the intensity of treatment depending on the patient's condition;
- **minimal intervention in specialized treatment** – only urgent measures to stabilize the patient.

Timely and correct actions at ROLE 1 and ROLE 2 significantly increase the chances of preserving vision at ROLE 3 (Table 5) [66-70].

Table 5. Primary medical care for eye injuries at all stages of evacuation

No.	Criterion	ROLE 1 First level	ROLE 2 Second level	ROLE 3 Third level
1	Place of assistance	Battlefield, casualty collection point, primary evacuation	Medical company, mobile hospital	Inpatient military hospital
2.	Who provides assistance	Combat medic, paramedic, paramedic	Doctor, surgeon, anesthesiologist	Ophthalmologist, ophthalmic surgeon, specialists
3.	Main goal	Preserve the eye, prevent complications, rapid evacuation	Stabilization and prevention of complications	Specialized treatment and vision restoration
4.	Initial assessment	Examination without pressure on the eye,	Reassessment, clarification of diagnosis	Complete ophthalmological diagnosis

		identification of life-threatening conditions		
5.	Stopping bleeding	Aseptic dry dressing	Surgical hemostasis (if necessary)	Operative control of bleeding
6.	Eye protection	Hard protective shield, closure of both eyes	Continued eye protection	Postoperative protection
7.	Pain relief	Non-narcotic/narcotic analgesics (systemic)	Controlled pain relief	Comprehensive pain relief
8.	Foreign bodies	Do not remove	Do not remove (without indications)	Surgical removal
9.	Penetrating wounds	Bandage + shield, urgent evacuation	Antibiotics, preparation for surgery	Restoration of the integrity of the eyeball
10.	Chemical burns	Immediate rinsing for 10–15 minutes	Repeated rinsing, pH control	Specialized treatment of burns
11.	Drug therapy	Minimal (pain relief)	Antibiotics, anti-inflammatory drugs	Full course of therapy
12.	Surgical interventions	Not performed	Only for life-threatening conditions	Full ophthalmic surgery
13.	Evacuation	Immediate to ROLE 2	After stabilization to ROLE 3	Further treatment/rehabilitation
14.	Basic prohibitions	Do not press or wash in case of penetrating injury	Do not delay evacuation	—

3.2. Global experience in modern diagnostic support, surgical and conservative treatment of combat ocular injuries

Modern diagnostic equipment plays an extremely important role in the management of patients with ocular trauma. The widespread introduction of high-precision imaging methods, in particular computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US), as well as the use of endoscopic technologies and modern microsurgical equipment, allows for the most accurate assessment of the nature and depth of injuries. This, in turn, creates the conditions for timely planning of individualized treatment tactics and improvement of functional and anatomical outcomes.

Penetrating eye trauma caused by a blast wave is characterized by an extraordinary variety of clinical manifestations and can lead to damage to virtually all anatomical structures of the eye. In such cases, computed tomography is the method of choice and the main imaging tool, as it allows for rapid determination of the extent of damage to the eyeball, detection of intraocular and orbital foreign bodies, and assessment of the condition of the orbital bone structures and surrounding tissues.

Ultrasound examination of the eye is a fast, affordable, and reliable diagnostic method, especially in situations where clinical examination is limited due to clouding of the optical media. According to the literature, the sensitivity of ultrasound in detecting penetrating eye trauma reaches 99%, making it an extremely valuable tool in emergency ophthalmic practice.

Injuries caused by explosions are often accompanied by the entry of several foreign bodies of various origins and sizes into the eye, which significantly complicates the clinical picture and requires a comprehensive diagnostic approach. The combination of different imaging methods allows for the timely detection of all components of the injury, reduces the risk of complications, and enables the selection of the optimal surgical and postoperative treatment tactics.

Rehabilitation measures, including optical correction, physical therapy, and psychological support, are an integral part of returning military personnel to full activity [71, 72].

In Ukraine, as in many other countries affected by modern military conflicts, the hostilities of recent years have been accompanied by a sharp increase in the level of trauma among military personnel. This highlights the urgent need to introduce modern algorithms for the diagnosis, treatment, and rehabilitation of patients with combat ocular injuries. Early surgical intervention is particularly important, as it often determines not only the functional prognosis but also the viability of the eyeball itself.

At the same time, the effectiveness of treatment depends not only on the speed and technical perfection of surgical procedures. A multidisciplinary approach is a key factor in the successful management of such injuries. The coordinated interaction of ophthalmologists, neurosurgeons, otolaryngologists, maxillofacial surgeons, anesthesiologists, and specialists in reconstructive and plastic surgery allows for a comprehensive assessment of the patient's condition, timely detection of associated injuries, and determination of the optimal sequence of treatment measures.

A comprehensive study of global and Ukrainian experience in the management of combat ocular injuries, analysis of early surgical intervention tactics, and models of multidisciplinary care organization are prerequisites for improving the effectiveness of treatment for victims. This approach not only improves the immediate results of preserving the anatomical integrity of the eye, but also significantly affects the restoration of visual function, the return of military personnel to active life, and the improvement of their long-term quality of life.

Taking into account the best international practices – from the staged evacuation system and standardized protocols for providing care to modern methods of microsurgery and reconstructive interventions – makes it possible to optimize treatment strategies in the Ukrainian context. An important component is the creation of an effective model of interaction between ophthalmologists and related specialists: neurosurgeons, maxillofacial surgeons, otolaryngologists, anesthesiologists, and medical rehabilitation specialists. It is precisely this coordinated, multidisciplinary

work that ensures a comprehensive assessment of the severity of the injury, timely surgical intervention, and a reduction in the risk of complications, which is critically important in cases of combined injuries [73].

At the same time, the next stage is also important – rehabilitation, which includes optical correction, functional recovery, psychological support, and social adaptation. A systematic approach to analyzing available data and forming national standards of care based on it will significantly improve the quality of medical care and respond to the current challenges of military ophthalmic traumatology [74].

The role of early surgery and a multidisciplinary approach is highlighted in studies by Akıncioğlu D. (2022) and Rana V. (2023), which found that the time to primary surgery is a critical factor in preserving vision. A delay of more than 12 hours increases the risk of enucleation by 42%, while early intervention within the first 6–8 hours after injury significantly improves functional outcomes [56, 57]:

- 1) early surgical intervention and wound debridement;
- 2) systemic and local antibiotic therapy to prevent infectious complications;
- 3) use of anti-inflammatory therapy to reduce swelling and prevent sympathetic ophthalmia;
- 4) A multidisciplinary approach involving ophthalmologists, neurosurgeons, and reconstructive surgery specialists, especially in cases of concomitant craniofacial injuries (Table 6).

Table 6. Surgical intervention and time to surgery

No.	Author, year	Type of intervention	Time to surgery	Result / preservation of vision
1	Akıncioğlu D., 2022	Vitreotomy, anterior segment reconstruction	6-8	Functional recovery in 32.1%
2.	Rana V., 2023	Vitreotomy with silicone/gas, reconstruction	6-8 hours	Anatomical preservation 73.4%, functional preservation 41.7%
3.	Lurin I.A., 2025	Rotational flap, thermography, Doppler	7 days (after injury in field conditions)	Successful recovery
4.	Mulligan K., 2026	–	4-7 days	Improves vision, providing significant economic value to

				military personnel
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The study emphasizes that the time to specialized surgical intervention is one of the most important factors determining the clinical prognosis for combat ocular injuries. Delays in providing emergency ophthalmic surgery significantly increase the risk of serious complications, such as tissue necrosis, secondary infection, sympathetic ophthalmia, eyeball perforation, or loss of visual function. Prompt and timely intervention allows preserving the anatomical integrity of the eye, maintaining adequate tissue perfusion, and reducing the severity of postoperative edema and inflammation, which directly affects the restoration of visual acuity.

Early surgical treatment significantly improves the functional and social outcomes of victims, as the preservation of visual function allows them to maintain their working capacity, independence in daily life, and overall quality of life. This aspect is particularly relevant for military personnel, for whom visual impairment can lead to professional disability and long-term social maladjustment. Therefore, the integration of rapid evacuation, early diagnosis, and multidisciplinary surgical intervention is a key component of an effective system for treating combat eye injuries, capable of significantly reducing the risk of disability and improving long-term clinical and social outcomes [56, 57, 63, 75].

The work of Lurin I.A. (2025) notes that surgery was performed on the 7th day after injury in field conditions, reflecting the realities of delayed medical care in combat conditions. Rotational flaps were used to reconstruct the defect, and modern diagnostic techniques were used, including dynamic digital thermography and manual Doppler control of tissue perfusion, which ensured a high level of anatomical restoration of damaged structures. At the same time, the author emphasizes that the functional potential of vision remained limited due to the delayed nature of the surgical intervention and the specifics of the injury. This case demonstrates the effectiveness of an integrated technological approach to ensuring anatomical reconstruction in the field, while confirming the critical importance of early surgical treatment for maximum restoration of visual function [63].

In military personnel with combat ocular injuries, pars plana vitrectomy was most commonly used, performed in 79.6% of cases. The main goal of this intervention was to restore the anatomical integrity of the eyeball and remove intraocular foreign bodies, which is essential for preventing infectious complications and further progression of the injury.

In the postoperative period, all patients were prescribed systemic antibiotic therapy, mainly ceftriaxone or moxifloxacin, to prevent the development of infection. Additionally, in cases of high risk of endophthalmitis, prophylactic intraocular administration of vancomycin and ceftazidime was performed. To control post-traumatic inflammation and edema, systemic corticosteroids were used in 47.0% of patients, which also contributed to the prevention of sympathetic ophthalmia.

Despite the treatment, complete functional restoration of vision was achieved in only 32.1% of cases, while partial or complete loss of visual function persisted in 27.7% of patients. The analysis showed that a delay in surgical intervention of more than 12 hours was associated with a 42.0% increase in the risk of enucleation, emphasizing the critical role of early ophthalmic surgery within the first 6–8 hours after injury to preserve visual function and the anatomical integrity of the eyeball.

The data indicate that effective treatment of combat eye injuries should be based on a comprehensive approach that includes: early surgical intervention, especially in cases of penetrating injuries and the presence of intraocular foreign bodies; adequate antibiotic therapy combining systemic and local application of antibiotics; control of inflammation and edema, including the use of corticosteroids in certain cases; a multidisciplinary approach involving ophthalmic surgeons, neurosurgeons, maxillofacial surgeons, and specialists in anesthesiology and intensive care, which is especially important in cases of combined injuries to the craniofacial region and eyes; early rehabilitation of visual functions, including monitoring of intraocular pressure, control of secondary complications, and provision of psychological support to the patient.

The results of the study confirm that successful restoration of visual functions in military personnel with combat eye injuries requires the integration of early surgical intervention, systemic antibacterial and anti-inflammatory therapy, and

coordination of a multidisciplinary team, which minimizes the risk of disability and improves the quality of life of the wounded [8, 56, 57, 58, 63, 76].

Treatment of patients with combat ocular injuries was carried out in accordance with the principles of staged reconstructive surgery, which included early stabilization of bone structures, radical sanitation of soft tissues, and active prevention of infectious complications. The central component of this approach was multidisciplinary coordination between maxillofacial surgeons, ophthalmologists, neurosurgeons, anesthesiologists, and medical evacuation specialists, which reduced the time to primary surgery and ensured optimal functional outcomes.

In a study by Zhupan B.B. et al. (2023), a retrospective analysis of clinical data from patients with combat ocular injuries was conducted to identify the main factors affecting long-term functional outcomes and the prognosis for preserving the anatomical integrity of the eyeball. The authors note that timely referral for specialized ophthalmological care and early surgical intervention are critically important for minimizing the risk of irreversible damage and improving long-term treatment outcomes.

In particular, primary microsurgical treatment within the first 6–12 hours after injury was associated with a significant reduction in the incidence of endophthalmitis, secondary infection, and sympathetic ophthalmia. Conversely, a delay in specialized care of 12–24 hours increased the risk of irreversible damage to the structures of the eyeball, vision loss, and the need for enucleation.

The study also showed that the severity of the injury, the mechanism of injury (penetrating, blunt, or explosive), and the presence of concomitant traumatic brain injury are the main prognostic factors for clinical outcome. In this regard, to improve the effectiveness of treatment and rehabilitation measures, it is proposed to introduce specialized prognostic models that integrate clinical data, anatomical characteristics of the injury, the mechanism of injury, and the time interval from injury to surgery. The use of such models allows for the optimization of medical resource allocation, the prioritization of patients at high risk of complications, and the development of personalized treatment and rehabilitation protocols.

The study results emphasize that an integrated approach to the management of combat eye injuries, which includes early diagnosis, immediate surgical intervention, and the use of predictive models, is critical to minimizing long-term functional loss, improving the quality of life of victims, and reducing the risk of medical and social disability. In particular, timely provision of specialized care allows preserving the anatomical integrity of the eye, restoring visual functions, and shortening the period of long-term rehabilitation, which is especially important in combat conditions when access to highly specialized medical care is limited [8].

Effective treatment of military personnel with combat ocular injuries is impossible without a systematic multidisciplinary approach that involves the integrated coordination of ophthalmologists, neurosurgeons, anesthesiologists, rehabilitation specialists, and reconstructive surgery specialists. This approach allows for a comprehensive assessment of the severity of the injury, timely surgical treatment, and monitoring of the patient's general condition, as well as early restoration of visual functions and general physiological indicators.

A study by Lee I. (2023) showed that an integrated treatment strategy for combat eye injuries reduces the risk of irreversible vision loss by 30–35.0% and shortens the average length of hospitalisation by 25.0%, which significantly improves the effectiveness of therapy and optimises the use of medical resources. At the same time, a multidisciplinary approach reduces the frequency of secondary complications, including infectious processes, the development of sympathetic ophthalmia, and cognitive impairment in patients with combined craniocerebral and ophthalmic injuries.

In addition, this approach ensures early rehabilitation of functional and psycho-emotional indicators, which is a prerequisite for restoring the quality of life of victims. The integration of specialized treatment protocols, including early diagnosis, surgical intervention, and systematic rehabilitation, optimizes the management of severe combat eye injuries in modern armed conflicts and increases the effectiveness of medical evacuation systems.

The implementation of multidisciplinary protocols is a critically important component of modern ophthalmological practice in military conditions and determines the quality of long-term functional and social outcomes of treatment for patients with severe combat injuries to the organ of vision [54].

3.3. Regional characteristics of ophthalmic injuries, surgical treatment, and medical rehabilitation of military personnel: a retrospective analysis

The duration of hostilities on the territory of Ukraine has led to a significant increase in the number of severe injuries among military personnel, among which ocular trauma occupies a special place due to the high risk of irreversible vision loss and the development of permanent disability. Combat ocular injuries are characterized by complex pathogenesis, which includes a combination of mechanical, explosive, and infectious damage, accompanied by significant variability in clinical course and severity of combined injuries. This complicates the choice of the optimal treatment strategy and determines the high importance of timely and adequate medical care.

The relevance of the problem is exacerbated by the need for rapid clinical decision-making in conditions of limited resources, a multi-level medical evacuation system, and high-intensity combat operations. Early surgical intervention remains the main factor determining the possibility of preserving the anatomical integrity of the eyeball and functional vision, while delays in providing specialized care or insufficient coordination of treatment significantly increase the risk of serious complications, including endophthalmitis, sympathetic ophthalmia, and the need for enucleation.

At the same time, the effectiveness of managing patients with combat eye injuries depends on the level of specialization of medical care, the availability of modern diagnostic methods, and a clear multidisciplinary approach that involves the coordination of ophthalmologists, neurosurgeons, anesthesiologists, rehabilitation specialists, and reconstructive surgery specialists. The analysis of regional characteristics of combat ocular injuries and methods of their surgical treatment is

extremely important, as it allows identifying systemic problems in medical care, optimizing clinical algorithms, and improving the effectiveness of treatment and rehabilitation of military personnel in the context of modern armed conflict.

Studying the characteristics of combat ocular injuries and implementing integrated protocols for early diagnosis and specialized surgical treatment is critically important for improving the quality of medical care and preserving the functional capacity of patients [77].

The full-scale military invasion of Ukraine has highlighted significant systemic problems in the rehabilitation of military personnel who have suffered combat injuries. Despite the growing need for comprehensive restoration of physical, psycho-emotional, and social functions, the national rehabilitation system remains insufficiently structured, characterized by regional disparities, limited human resources, and a shortage of modern equipment and technological resources.

These shortcomings are particularly acute in patients with severe combined injuries, including trauma to the skull, facial skeleton, and organs of vision, who require long-term, phased, and multidisciplinary rehabilitation. The lack of unified clinical pathways and clear algorithms for coordination between medical, psychological, and social services significantly reduces the effectiveness of recovery, prolongs the period of hospitalization, and complicates the return of military personnel to active life and professional activity.

In this context, the development of a comprehensive, integrated rehabilitation system becomes particularly important. Such a system should be based on standardized protocols for multidisciplinary teams and ensure continuity of medical care from the acute phase of injury through the stages of restoration of functional abilities and social adaptation. These models involve a combination of physical, cognitive, and psychological rehabilitation, regular patient assessment, and flexible adaptation of programs to individual needs.

The development of integrated approaches to rehabilitation is a key condition for reducing disability, increasing the effectiveness of treatment and rehabilitation measures, and improving the quality of life of military personnel who have suffered in modern combat conditions. The creation of such systems also contributes to the

optimal use of available resources and increases the ability of the national medical service to respond quickly to the needs of victims in the extreme conditions of war.

In the context of modern military conflicts, improving the effectiveness of treatment for combat ocular injuries remains one of the priority tasks of military medicine. Of particular importance is the adaptation of international experience in early surgical intervention and the organization of multidisciplinary medical care to the real conditions of medical service provision in the Armed Forces of Ukraine.

Timely and well-coordinated interaction between ophthalmologists and related specialists, including neurosurgeons, maxillofacial surgeons, anesthesiologists, and rehabilitation physicians, makes it possible to significantly reduce the frequency of severe complications, achieve the best possible organ-preserving outcomes, and improve the functional prognosis in patients with combined combat injuries.

Equally important is ensuring the continuity of medical care, covering the entire spectrum of services: from primary tactical care on the battlefield and evacuation, through specialized surgical intervention, to the stages of restorative and functional rehabilitation.

Systematic analysis of existing clinical practices, the introduction of unified national treatment protocols, and standardization of patient pathways are key factors in reducing disability, increasing the effectiveness of medical care, and improving the quality of life of military personnel who have suffered combat-related ophthalmic injuries [55].

The relevance of the study is due to the significant increase in the number of severe ocular injuries among servicemen of the Armed Forces of Ukraine in the context of the active use of modern explosive weapons. Preserving visual functions is a prerequisite for successful further medical rehabilitation and effective social adaptation of the wounded. At the same time, insufficient standardization of treatment protocols and limited coordination of multidisciplinary teams emphasize the urgent need to implement modern, evidence-based strategies for providing medical care to military personnel with combat ocular injuries.

The study conducted an analytical review of clinical data on military personnel with combat ocular injuries, in particular, assessing the frequency of detection of

various pathological conditions in patients who underwent treatment in two different regions of Ukraine during active combat operations. (Table 7).

Table 7. Comparative analysis of the structure of ophthalmic injuries in military personnel, %

No.	Ophthalmic injuries	Purulent endophthalmitis	Traumatic cataract	Burns	Open wound	Foreign bodies	Eye contusion
1.	First sample (district hospital)	14.3	11.4	8.6	8.6	17.1	2.9
2	Second sample (regional hospital)	7.4	11.1	-	29.6	33.3	22.2

Among military personnel treated at the district hospital, the most common injuries were penetrating wounds to the eyeball with the presence of a foreign body inside the eye, accounting for 17.1% of cases, which highlights the high level of mechanical ocular trauma in combat conditions. In second place in terms of frequency was purulent endophthalmitis (14.3%), which probably reflects both a delay in seeking medical help and the complicated course of primary traumatic injuries. Traumatic cataracts were observed in 11.4% of cases, indicating the significant role of both blunt and penetrating injuries in the formation of severe secondary complications. Burns and open wounds of the eyeball had the same frequency – 8.6% each, while eye contusions were the least common, occurring in only 2.9% of cases.

Among military personnel treated at regional medical facilities, traumatic injuries to the organ of vision with a high risk of loss of visual function predominated. The largest proportion was injuries with intraocular foreign bodies (33.3%), which was almost twice the corresponding figure in the first sample. A

significant proportion of injuries were open wounds of the eyeball (29.6%), indicating more severe damage and a high level of penetrating injuries. Eye contusions occurred in 22.2% of cases, which contrasts sharply with the data from the first group and may reflect other mechanisms of injury. Traumatic cataracts in this sample were recorded at a frequency of 11.1%, which roughly corresponds to the indicator for the first group, while purulent endophthalmitis was observed much less frequently – in 7.4% of cases. No cases of eyeball burns were recorded in this group, which highlights the differences in the mechanisms of trauma between regions.

The data obtained indicate regional differences in the structure of combat ocular injuries. The first sample is characterized by a higher proportion of infectious complications, in particular purulent endophthalmitis, which may indicate a later appeal for medical help by patients or a complicated course of primary injuries. In contrast, the second sample shows a predominance of acute mechanical injuries, such as open wounds, contusions, and the presence of foreign bodies in the eye and orbit, reflecting the more severe nature of the trauma and the high risk of visual impairment.

These differences are likely due to a combination of factors, including the conditions of injury on the battlefield, the timeliness and availability of specialized ophthalmological care, and the specifics of patient routing to medical facilities.

Taking these regional characteristics into account is essential for developing differentiated strategies for the prevention, early diagnosis, and treatment of combat ocular injuries, as well as for optimizing medical care resources and improving the effectiveness of clinical work in different combat zones.

An analysis of the structure of surgical interventions in the two regions revealed significant differences in both surgical treatment tactics and the severity of ophthalmic pathology (Table 8).

Table 8. Comparative analysis of the structure of surgical interventions and differences in surgical treatment tactics, severity of ophthalmic pathology, %

No.	Surgical treatment	Evisceration of the eyeball	Surgical wound treatment	Removal of foreign body	Lens removal and lens implantation	Other
1.	First sample	14.3	14	20	11.4	40
2.	Second sample	6.25	46.9	21.9	9.4	15.5

Analysis of surgical care among military personnel with combat ocular trauma revealed marked differences between the regional groups. In patients treated in the district-level medical facility, the largest proportion consisted of other surgical interventions (40.0%), reflecting a broad range of operative procedures обусловuted by the diversity of clinical situations and the presence of combined injuries. Removal of ocular foreign bodies was performed in 20.0% of cases, which correlates with the high frequency of mechanical trauma in this patient group. Evisceration of the globe and surgical wound debridement were each recorded in 14.3% of cases, indicating both the severity of the primary injuries and possible delayed presentation for specialized care. Lens removal with intraocular lens implantation was performed in 11.4% of cases, which is consistent with the frequency of diagnosed traumatic cataract in this sample.

Among military personnel treated at regional medical facilities, primary surgical treatment of wounds was the most common procedure, performed in 46.9% of patients, indicating a high level of open and penetrating injuries to the eye that required immediate surgical intervention, including microsurgical repair. Removal of foreign bodies from the eye was recorded in 21.9% of cases, which is comparable to the indicator for the first group and confirms the prevalence of this type of injury in both regions. Lens removal with intraocular lens implantation was performed less

frequently, in 9.4% of cases. The proportion of eyeball eviscerations was significantly lower – 6.25%, indicating earlier patient referral and more effective organ-preserving treatment tactics. Other surgical interventions accounted for 15.5%, which is significantly lower than in the first sample.

Thus, the first sample is characterized by a higher proportion of radical operations, in particular eviscerations, and a wider range of non-standardized surgical manipulations, which may be due to the late arrival of patients and limited availability of specialized care. In contrast, the second sample shows a predominance of early microsurgical wound treatment, which is in line with modern organ-preserving tactics and reduces the risk of serious complications, secondary infection, and loss of visual function.

The results obtained emphasize the importance of taking into account regional characteristics of patient routing, the availability of ophthalmic surgical care, and the level of specialization of medical institutions when planning organizational and clinical measures aimed at optimizing the treatment and rehabilitation of military personnel with combat ocular injuries. This approach allows for improving the effectiveness of medical care, reducing the frequency of radical surgical interventions, and maximizing the chances of preserving the anatomical integrity and functional capabilities of the eyeball.

A correlation and association analysis was also performed to examine the relationships between the region where medical care was provided, the number and severity of ophthalmic injuries, and the nature of surgical interventions in patients with ocular trauma. The association between the type of ophthalmic intervention and the region of treatment was analyzed using Pearson's chi-square test and Cramer's V coefficient. A statistically significant association was established between these variables ($p < 0.05$), indicating the presence of regional peculiarities in the structure of ophthalmic surgical care. In particular, the first sample was characterized by a predominance of radical and highly specialized interventions, including globe evisceration, vitreoretinal, and reconstructive surgeries, whereas the second sample was dominated by primary wound debridement, foreign body removal, and other

minimally invasive procedures, consistent with the staged triage model of medical care delivery.

The correlation between the number of injuries and the type of operative intervention was assessed using Spearman's coefficient. A positive statistically significant correlation was identified ($p < 0.05$), indicating increasing invasiveness of surgical treatment with an increasing number of combined and multiple injuries. Isolated injuries to the organ of vision generally required minimal or minimally invasive surgical intervention, whereas combined and multiple combat injuries were associated with complex vitreoretinal and reconstructive procedures or radical interventions.

Analysis of the relationship between the severity of the injury and the extent of surgical intervention also showed a strong positive correlation according to Spearman ($p < 0.01$). Mild injuries to the organ of vision corresponded to the minimum scope of surgical treatment, moderate injuries – to organ-preserving and reconstructive interventions, while severe injuries complicated by infectious and inflammatory processes, destruction of the eyeball, or purulent endophthalmitis required radical surgical interventions, including evisceration. The results confirm the clinical validity of choosing the extent of surgical treatment depending on the severity and multiplicity of injuries, and also reflect the influence of regional factors on the structure of ophthalmic surgical care in combat trauma conditions.

CHAPTER 4. REHABILITATION AND RECOVERY OF PATIENTS WITH COMBAT EYE INJURIES

4.1. Prevention, accounting, and rehabilitation of combat eye injuries: modern approaches and national strategies

According to epidemiological studies by Mishra A. (2023), the creation of a unified registry of combat eye injuries is an important strategic step toward optimizing medical care in military conditions. Such a system allows for the centralized collection of data on damage to the organ of vision, ensures a unified classification of injuries, and enables the rational distribution of medical resources according to the severity of injuries and the needs of specific units [78].

The existence of a registry not only facilitates the analysis of the frequency and structure of ophthalmic injuries, but also makes it possible to predict the risks of injury depending on the type of combat missions, the weapons used, and the conditions of combat operations. Based on such data, standardized preventive measures can be developed, including: improvement and standardization of personal eye protection equipment; introduction of specialized training programs on safety and tactics in combat conditions; creation of protocols for early screening and evacuation of victims; and organization of systematic ophthalmological monitoring at the military unit level.

The introduction of such a registry allows for the formation of a prognostically oriented system for managing combat eye injuries, increasing the effectiveness of medical care, reducing the frequency of complications, and improving the functional recovery of military personnel:

- 1. Modernization and standardization of personal eye protection equipment,** including protective eyewear and shields, taking into account the mechanism of injury and exposure to explosive or kinetic factors.

2. **Implementation of training and education programs** aimed at raising awareness among military personnel about risks, rules for safe handling of weapons, and optimal tactics for action in combat conditions.
3. **Development of protocols for early screening and medical evacuation measures** to enable the timely detection of minor or hidden eye injuries and prevent the development of complications.
4. **Establishment of a preventive medical control system** at the unit level, including regular ophthalmologist examinations, vision assessment, and risk factor monitoring (Fig. 1).

Figure 1. Key strategic measures for the prevention of combat eye injuries.



Based on an analysis of current scientific sources, preventive and rehabilitative measures for military personnel with combat ocular injuries were systematized, and the expected clinical and functional effects of their implementation were determined (Table 9). Both primary measures for the prevention of injuries (modernization of personal protective equipment, training programs, protocols for early screening and medical evacuation, systematic medical monitoring) and secondary measures

(comprehensive medical and psychological rehabilitation, restorative ophthalmic surgery, physiotherapy procedures, and social adaptation. The expected outcome of such strategies is a reduction in the incidence of severe complications, optimization of functional restoration of visual functions, reduction in the duration of hospitalization, and increased effectiveness of integrated medical and social support programs for the wounded [78].

Table 9. Preventive and rehabilitation measures for eye injuries

No.	Author, year	Measures	Expected effect	Additional comments
1.	Mishra A. et al., 2023	Creation of an injury registry, standardization of classifications	Optimization of medical resources, prevention of severe injuries	Facilitates monitoring and planning
2.	USA and NATO	Use of protective eyewear, modification of training and combat protocols	Reduction in the frequency of eye injuries	Systemic preventive measures
3.	Ukraine	Telemedicine consultations, comprehensive monitoring, phased rehabilitation	Improvement of functional outcomes	Important for multiple organ injuries

By integrating such preventive measures with clinical treatment protocols and long-term rehabilitation strategies, it is possible to significantly reduce the incidence of severe combat eye injuries, increase the effectiveness of medical care, and improve functional outcomes in survivors.

The study by Lawry L.L. (2025) conducted a comprehensive qualitative assessment of the national rehabilitation care system in Ukraine in the context of ongoing military conflict, particularly with regard to military personnel with severe combat injuries. The study involved representatives of medical institutions, military personnel, patients with ophthalmic, craniofacial, and combined injuries, as well as specialists in physical and psychosocial rehabilitation. The results showed that the

national system remains fragmented and insufficiently integrated: there is uneven access to rehabilitation services in different regions of the country, a shortage of qualified specialists, limited availability of modern equipment, and a lack of unified clinical pathways and protocols for patient management.

One of the main problems is the lack of effectively formed multidisciplinary teams and insufficient coordination between medical, social, psychological, and rehabilitation services. This fragmentation significantly complicates the recovery process for patients with severe combined injuries, particularly head, facial skeleton, and eye injuries, which require comprehensive and phased treatment, including both acute surgical care and long-term functional and social rehabilitation [79].

Lawry L.L. (2025) emphasizes the critical need to establish a national network of specialized rehabilitation centers capable of ensuring continuity of care from the acute phase of injury to full social and professional reintegration of the patient. An important aspect is the standardization of clinical protocols and the implementation of evidence-based practices, which would reduce variability in treatment approaches, optimize resource utilization, and improve restoration of visual and physical functions.

The author emphasizes the need to develop modern training and retraining programs for rehabilitation specialists, taking into account the specifics of wartime and the intensity of combat injuries. Particular attention is focused on long-term rehabilitation strategies, which should cover not only physical recovery, but also psycho-emotional, cognitive, and social components. In particular, psychological support, correction of post-traumatic stress disorders, adaptation to everyday and professional stress, and social reintegration of wounded military personnel are priorities.

The results of the work demonstrate that the effective functioning of the national rehabilitation system in wartime requires a comprehensive, multidisciplinary approach, standardization of clinical pathways, and continuous medical support at all stages of treatment. The implementation of such models is critical to reducing disability rates, improving the quality of life of victims, and ensuring their full social and professional adaptation [79].

Mishra A. et al. (2023) conducted a systematic analysis of cases of combat eye injuries among Indian military personnel and justified the creation of a national registry of eye injuries in the Armed Forces. The authors emphasized the critical importance of implementing a centralized electronic database that would ensure standardized collection of information on all types of ophthalmic injuries, severity of damage, mechanisms of injury, and medical interventions performed [78].

According to their conclusions, the implementation of such a registry would allow several strategically important goals to be achieved:

1. **Improved epidemiological monitoring** – ensuring accurate and timely recording of cases of eye injuries in military units, allowing for the identification of high-risk groups and the determination of injury trends.
2. **Standardization of classification criteria** – introducing uniform approaches to assessing the severity of injuries and their classification, which facilitates the comparison of data between different military hospitals and units.
3. **Optimization of preventive measures** – use of data to improve the effectiveness of personal eye protection equipment, develop training programs and instructions for military personnel on safe behavior in combat conditions.
4. **Rationalization of medical resources** – systematized data contributes to more effective planning of surgical and rehabilitation care and optimal distribution of specialized equipment and personnel in military hospitals.
5. **Improving the quality of clinical decisions** – integrating registry data allows for the development of personalized treatment protocols, the prediction of risks of complications, and the timely application of organ-preserving and functionally oriented interventions.

The authors also emphasize that a centralized registry is a key element in integrating a multidisciplinary approach to the management of patients with combat eye injuries. Its use facilitates the effective coordination of ophthalmologists, neurosurgeons, rehabilitation specialists, psychotherapists, and other specialists, which not only increases the chances of preserving visual function and organ

preservation but also reduces the risk of developing long-term physical, psycho-emotional, and social complications.

Thus, the results of the study by Mishra A. et al. demonstrate that the creation of an integrated, digitized, and standardized registry of combat eye injuries is a strategically important step toward improving the effectiveness of medical care, improving preventive measures, and optimizing resources in the military medical system. Such a model could become the foundation for the formation of a unified national policy in the field of prevention, treatment, and rehabilitation of military personnel with severe ophthalmic injuries [78].

In the Ukrainian context, the introduction of telemedicine consultations, continuous comprehensive monitoring, and phased medical rehabilitation is of particular importance, as these are critical for patients with multiple organ injuries and complex combined injuries. The use of such approaches allows for increased treatment effectiveness, improved functional outcomes, optimized patient routing, and higher-quality recovery from combat ocular injuries.

The rehabilitation of military personnel with eye injuries should be viewed as a comprehensive recovery system that integrates medical, physical, psychological, social, and professional aspects. The goal of such a system is not only to restore anatomical integrity and visual functions, but also to ensure full social adaptation, improve quality of life, and restore the ability to engage in professional activities [80].

Medical rehabilitation in this system includes pharmacological treatment, physical therapy and physiotherapy techniques, surgical and restorative interventions, psychotherapeutic support, and other evidence-based methods. The rehabilitation process is based on the following key principles: patient-centeredness, timeliness, continuity and consistency, functional orientation, a multidisciplinary approach, and regular monitoring of the effectiveness of measures.

The current challenges of wartime necessitate the creation of specialized rehabilitation units for patients with visual impairments and the formation of a continuous system of care with the active participation of medical institutions, public organizations, and social institutions. Rehabilitation of visual functions is relevant not only for people with irreversible vision loss, but also for those who have the potential for recovery, with the aim of preventing disability and ensuring social integration [81].

In such a multidisciplinary model, the leading role should be played by an ophthalmologist who coordinates medical and rehabilitation measures. The further development of ophthalmic rehabilitation requires scientifically sound and evidence-based approaches, including the use of telemedicine, modern protocols for assessing visual functions, and adapted programs for physical, professional, and psychological rehabilitation [82].

Research results confirm the advisability of improving the medical evacuation system, standardizing clinical protocols, and introducing a national register of combat eye injuries as a tool for monitoring, resource planning, and developing preventive measures. Equally important is the development of comprehensive, continuous vision rehabilitation focused on restoring the functional, neurovisual, and psychosocial abilities of patients.

To improve the effectiveness of medical evacuation and rehabilitation services for patients with combat eye injuries in Ukraine, the following strategic measures should be implemented:

1. Improvement of the medical evacuation system:

- Ensure clear routing of patients from the site of injury to ROLE 2 and ROLE 3 medical facilities.
- introduce standardized protocols for the initial assessment, stabilization, and transportation of victims;
- Use telemedicine consultations for remote monitoring and optimal clinical decision-making during evacuation.

2. Standardization of clinical protocols and implementation of a national registry:

- develop and implement uniform national protocols for diagnosis, treatment, and surgical intervention for combat eye injuries;
- create a centralized electronic registry of combat eye injuries to monitor the prevalence of injuries, assess their severity, and analyze the effectiveness of treatment;
- Use registry data for strategic resource planning, risk forecasting, and preventive measures development.

3. Develop comprehensive and continuous vision rehabilitation:

- organize multidisciplinary rehabilitation teams that include ophthalmologists, rehabilitation specialists, psychologists, and vocational rehabilitation specialists;
- Ensure the integration of medical, physical, neurovisual, and psychosocial recovery methods.
- Implement individualized rehabilitation programs at all stages, from the acute period of injury to the patient's return to active social and professional life.

4. Integration of early surgical treatment and modern rehabilitation strategies:

- ensure timely surgical intervention within the first 6–12 hours after injury to maximize the preservation of visual function;
- maintain constant monitoring of the patient's condition and adapt rehabilitation measures in accordance with the progress of recovery;
- use evidence-based methods and modern technologies to improve the results of functional and psychosocial recovery.

4.2. Restoration of visual functions, prosthetics, and prospects for neuroprosthetics after combat trauma in the world and in Ukraine

In cases where the anatomical and functional integrity of the eyeball cannot be preserved due to severe trauma, infectious damage, or a tumor process, the indicated treatment method is enucleation followed by ophthalmic prosthetics. This approach is aimed not only at eliminating the pathological focus, but also at restoring the aesthetic symmetry of the face, reducing the psycho-emotional consequences of eye loss, and facilitating the patient's social adaptation.

Modern ocular prostheses are manufactured taking into account the individual anatomical characteristics of the patient, including orbital shape, iris color, prosthesis size, and mobility. Owing to the use of advanced materials and digital technologies, particularly three-dimensional (3D) modeling, a high level of aesthetic correspondence and wearing comfort can be achieved. The use of individually fabricated prostheses contributes to improved quality of life, psychological adaptation, and social integration of patients.

In terms of technical characteristics, ocular prostheses are divided into cosmetic and functional. Cosmetic prostheses perform mainly an aesthetic role, while functional prostheses may have elements of mobility or partial light sensitivity, depending on the preservation of surrounding tissues and the condition of the optic nerve. The choice of prosthesis type is determined by clinical indications and rehabilitation goals.

The effectiveness of treatment for patients with combat injuries to the organ of vision is based on adherence to basic clinical principles, which include:

- 1) **timely and accurate diagnosis of injuries**, which allows determining the scope of further interventions;
- 2) **maximum possible restoration of anatomical structures** aimed at preserving or reconstructing tissues;
- 3) **prevention of infectious complications and secondary pathological processes** that can worsen the prognosis.

The prospects for neuroprosthetics lie not only in improving the technologies themselves, but also in transforming approaches to the rehabilitation of patients with irreversible vision loss. Current developments are focused on improving the biocompatibility of implants, their long-term stability, and integration with the nervous system. Although neuroprostheses for vision currently have limited clinical application, they are considered one of the most promising areas for the restoration of visual functions in the future [83].

A separate promising area of development in modern ophthalmology is neuroprosthetics of vision. Scientific research is actively developing electronic visual prostheses, in particular retinal implants and so-called "bionic eyes," which are based on the principle of electrical stimulation of the retina or optic nerve. Such technologies are aimed at restoring residual visual functions by forming visual perceptions in patients with severe damage to the visual system.

Scientific research is actively developing neuroprosthetic vision devices, namely electronic "bionic eyes" and retinal implants, aimed at restoring residual visual functions. Current projects include technologies that use electrical stimulation of the retina or optic nerve to create visual perceptions. Although these technologies are not yet widely available, they offer hope for future restoration of function after severe damage.

Ocular prostheses are designed to restore the appearance of the eye and/or improve visual function after trauma, disease, or loss of the eye. Based on their functional purpose, they can be divided into **cosmetic and functional (neuro- and bionic) prostheses**.

I. Cosmetic eye prostheses

Cosmetic prostheses are mainly used to improve the aesthetic appearance after the loss of an eye. They do not restore vision, but they help restore the natural appearance and maintain the social confidence of patients.

The main types of cosmetic prostheses are:

1. Acrylic prostheses are custom-made from durable acrylic material, which ensures a comfortable fit and realistic reproduction of the color and shape of a healthy eye. They achieve a high aesthetic effect and improve the patient's appearance.

2. Glass prostheses are a traditional option that is less commonly used today. Glass eye prostheses provide a cosmetic effect, but are more fragile and less personalized than acrylic ones. The transition to acrylic models is due to their durability and the ability to more accurately reproduce the individual characteristics of the eye.

3. Prostheses with integrated movement are combined with residual eye muscles and allow the movements of a healthy eye to be imitated. Although they do not restore vision, such prostheses create a more natural appearance and improve the patient's social interaction.

II. Functional prostheses

Functional or neuroprostheses are designed to partially restore visual perception. They include:

1. Retinal prostheses are designed for patients with degenerative retinal diseases such as retinitis pigmentosa or macular degeneration. They stimulate the remaining retinal cells (e.g., ganglion cells) with electrical impulses, allowing for partial restoration of light perception and spatial orientation.

2. Cortical prostheses are used in cases of complete blindness due to damage to the optic nerve or cerebral cortex. These devices bypass the eye and directly stimulate the visual cortex, enabling visual information to be processed at the neural level.

3. Hybrid and experimental prostheses integrate multiple technologies, combining retinal implants with external devices. This improves visual recognition and spatial perception, opening up prospects for further development of functional rehabilitation [83].

At the same time, these technologies are mostly in the clinical trial stage and are not yet widely available for practical application. A systematic review by van Velthoven et al. (2022) emphasizes that modern visual neuroprostheses provide only limited restoration of visual perception, which necessitates realistic patient information, adherence to the principles of informed consent, and consideration of safety, accessibility, and long-term responsibility issues. The authors emphasize the importance of an interdisciplinary and ethically sound approach to the further implementation of neuroprosthetic technologies in clinical practice [84].

Fernandez E. (2018) highlights the current state of development of visual neuroprostheses designed to partially restore visual function in patients with severe blindness or degenerative retinal diseases. The main approaches include retinal implants, optic nerve stimulation, and cortical prostheses that provide electrical activation of residual neural structures of the visual pathway.

Clinical studies have shown that the use of such devices allows patients to perceive light, shapes, and spatial contours, but the resolution and detail of images remain limited. The main challenges include ensuring the biocompatibility of implants, the accuracy of stimulation, the adaptation of the cerebral cortex to the artificial signal, and the need for comprehensive rehabilitation of patients for maximum functional benefit.

The author emphasizes that further progress in the field of visual neuroprosthetics depends on the improvement of high-resolution stimulation technologies, the optimization of electrode interaction with neurons, and the integration of specialized rehabilitation programs aimed at increasing the adaptive potential of visual systems and improving the quality of life of patients [85].

In his review, Giansanti D. (2025) analyzed current advances in ophthalmic neuroprosthetics, which is considered an interdisciplinary field at the intersection of neuroscience, bioengineering, and information and communication technologies aimed at restoring visual function in patients with severe visual impairments. The author emphasizes that the new generation of visual neuroprostheses goes far beyond classical electrical stimulation, integrating artificial intelligence (AI) to process visual information, optimize stimulation patterns, and adapt devices to individual neural responses of patients. The use of AI significantly improves the functional effectiveness of neuroprostheses, particularly in object recognition, spatial orientation, and adaptation to dynamic environmental conditions [83].

Particular attention is focused on bioprinting as a promising technology for creating biocompatible structures that mimic retinal tissues and neural interfaces. This promotes more effective integration of implants with biological tissues, reduces inflammatory response, and enables a personalized approach to neuroprosthetics, which is critical for the long-term stability and functional effectiveness of devices.

The use of nanotechnology is also a key technological component in the modern development of neuroprostheses. Nanomaterials enable the creation of miniaturized electrodes with high conductivity and stimulation accuracy, reduce energy consumption, and increase the selectivity of interaction with neurons. This ensures more physiological signal transmission in the visual pathway and optimizes the integration of implants into the nervous system.

Therefore, Giansanti emphasizes that the combination of artificial intelligence, bioprinting, and nanotechnology forms a promising foundation for the creation of highly effective, personalized visual neuroprostheses capable of significantly improving the quality of life of patients with severe visual impairments and expanding the clinical possibilities of ophthalmic rehabilitation [83].

The study by Fernández E. (2005) examines in detail the development of a cortical visual neuroprosthesis as a promising approach to restoring visual perception in patients with complete blindness. The author focused on the role of brain neuroplasticity, emphasizing that the effectiveness of cortical prostheses largely depends on the ability of the cerebral cortex to adapt to artificial sensory information and form new neural connections in response to electrical stimulation.

The scientist justified the feasibility of direct stimulation of the visual cortex in cases where damage to the retina or optic nerve makes it impossible to use peripheral neuroprostheses. Studies show that even in patients with long-term blindness, the visual cortical areas retain functional potential that can be activated through neuroplasticity mechanisms.

The paper emphasizes that the successful implementation of cortical neuroprostheses is impossible without long-term and systematic training after implantation. The combination of electrical stimulation with adaptive training allows patients to improve their spatial perception, orientation in the environment, and overall functional outcomes.

Therefore, brain neuroplasticity is considered the main factor in the successful application of cortical visual neuroprostheses and should be taken into account in their further clinical development and integration into rehabilitation programs for patients with severe visual impairments [86].

The biocompatibility of implants is an important criterion for their clinical effectiveness and long-term functionality in the human body. It determines the ability of the implant material to interact with the biological system without causing toxic, immune, or inflammatory reactions and ensures stable integration with surrounding tissues.

A fundamental aspect of biocompatibility is the process that occurs at the **implant–host interface**. After implantation, plasma proteins are adsorbed onto the material surface, forming a bioactive layer that determines cellular behavior, including adhesion, proliferation, and differentiation. This process also regulates extracellular matrix formation and the response of surrounding tissues, which may be either favorable for integration or pathological, leading to inflammation or fibrosis.

The interphase interaction between the implant and tissue is critical for osteo- and tissue integration, as it determines the engraftment, stability, and durability of the implant. Biocompatibility includes not only the absence of acute toxicity, but also the minimization of corrosion, the prevention of the release of potentially harmful ions, and the maintenance of the mechanical stability of the material in the long term. Therefore, a high level of biocompatibility is a determining factor in the success of implantation technologies in modern clinical practice [87].

Materials widely used for the manufacture of medical implants include metals based on titanium and its alloys, high-tech ceramics, and some inert polymers. These materials are characterized by specific chemical and mechanical properties that determine their high biocompatibility, in particular: corrosion resistance, mechanical strength, stability in a biological environment, and the ability to undergo osseous integration, which is critically important for implants that interact with bone tissue.

Titanium and titanium alloys form a stable oxide layer on the surface, which significantly reduces corrosion processes and minimizes the activation of the body's immune response. Ceramic materials, on the other hand, are characterized by high bioinertness, chemical stability, and resistance in both soft and bone tissues, ensuring long-term functional integration of implants. The use of such materials allows for an optimal combination of mechanical reliability and biological compatibility, which is the basis for the long-term clinical success of implant procedures [88].

The assessment of the biocompatibility of medical implants is an integral part of their preclinical evaluation and is carried out using complex in vitro and in vivo models. In vitro studies include assessment of the cellular response to the material (adhesion, proliferation, differentiation, apoptosis), cytotoxicity, the effect of ions or degradation products on cell function, and the formation of an extracellular matrix on the implant surface. In addition, tests are conducted for corrosion resistance and stability in biological environments that simulate intra-tissue conditions.

In vivo studies provide an assessment of tissue integration and the body's response to the implant in a real anatomical context. Such assessments include: inflammatory and immune response, formation of a fibrotic capsule, osteo- or tissue integration, as well as long-term stability and functionality of the device. An important component is the assessment of local and systemic toxicity of the material, as well as its potential impact on adjacent organs and systems.

The standardization of biocompatibility assessment procedures is regulated by international standards (ISO 10993 – International Organization for Standardization – Biological evaluation of medical devices) – An international standard that defines procedures for the biological evaluation of medical devices, including tests for biocompatibility, cytotoxicity, immunological response, acute and chronic toxicity, as well as the evaluation of prolonged contact with human tissues . ISO 10993 consists of a series of parts (e.g., ISO 10993-5 – cytotoxicity test, ISO 10993-10 – irritation and sensitization tests, ISO 10993-12 – preparation of test specimens, etc.). ASTM – American Society for Testing and Materials (now ASTM International) – American standard that includes technical specifications and testing methods for materials and products, including medical implants; ASTM standards define the requirements for the mechanical properties, chemical composition, corrosion resistance, and biological safety of medical materials, which determine the minimum requirements for preclinical testing of medical devices. Performing such tests allows one to objectively determine whether the implant material is safe for introduction into the human body, minimizes the risk of toxic, immune, or inflammatory reactions, and provides optimal conditions for long-term integration and functioning of the implant.

A systematic approach to assessing biocompatibility is critical for improving the clinical effectiveness of implants, predicting their long-term stability, and minimizing complications after surgery [84, 88].

In the context of full-scale war in Ukraine, there has been a significant increase in the number of people with combat-related eye injuries, which raises the issue of developing state policy in the field of ophthalmological care and rehabilitation for veterans. State programs are aimed at ensuring the availability of highly specialized ophthalmic care, including eye prosthetics, for military personnel and civilians who have suffered injuries. In particular, victims are entitled to free diagnosis, treatment, and fitting of individual eye prostheses in healthcare facilities accredited by the Ministry of Health of Ukraine and the National Health Service of Ukraine as part of the medical guarantees program.

Along with state initiatives, charitable and cross-sectoral programs are actively implemented in Ukraine to provide specialized ophthalmological care for complex combat injuries, including damage caused by shrapnel and blast waves. For example, the project "Let's Restore Vision to the Defenders of Ukraine" provides free highly specialized diagnostics and treatment in a network of ophthalmological centers in different regions of the country. During the first year of the project, more than 1,900 veterans received professional ophthalmological care, demonstrating the effectiveness of cross-sectoral coordination and resource integration.

The synergy of state medical guarantee programs and targeted charitable initiatives creates a comprehensive platform for restoring vision in victims, contributing not only to the anatomical reconstruction of eye structures, but also to improving functional outcomes, quality of life, and social integration of military personnel and civilians who have suffered combat injuries to their eyes [89].

International medical missions are actively operating in Ukraine, focusing on reconstructive surgery of the face and eyes in military personnel who have suffered combat injuries. The cooperation of Ukrainian doctors with international specialists allows for highly specialized reconstructive interventions, including the manufacture and installation of individual eye prostheses for patients who have lost an eye.

One of the most active initiatives is the Face the Future Ukraine mission, which brings together experts in plastic and reconstructive surgery from Canada, the United States, and Ukraine to perform free comprehensive surgical procedures. During previous missions, reconstructive surgery was performed on more than 150 patients with mine-blast and other injuries to the face and neck. The scope of the procedures included eye socket reconstruction, bone fragment restoration, and preparation of patients for further prosthetics using individually manufactured bioengineered structures.

During the fifth mission in April 2025, 26 patients underwent comprehensive reconstructive surgery, including facial bone osteoplasty, nose plastic surgery, and preparation of the eye socket for prosthetics. This integrated approach allows for the restoration of the anatomical integrity of the face, improved aesthetic results, reduced need for repeat surgical interventions, and promotes the psychological and social adaptation of injured military personnel.

International cooperation in the field of reconstructive surgery and prosthetics ensures comprehensive restoration of the anatomical and functional parameters of the organ of vision and the face, which is critical for improving the quality of life and integration of military personnel into society after combat injuries [90].

A striking example of international cooperation in restorative ophthalmology and maxillofacial surgery is the *Vision for Ukraine* project, in which American and Ukrainian oculoplastic and maxillofacial surgeons jointly perform complex reconstructive interventions on the face and orbit. The use of custom-made titanium 3D implants ensures accurate restoration of bone structures, reproduction of natural facial contours, and optimization of symmetry, which significantly reduces the need for repeat surgeries.

This approach combines advanced three-dimensional modeling and engineering technologies with the extensive clinical experience of surgeons, allowing for highly effective functional and aesthetic restoration in military personnel with severe combat injuries. The use of 3D implants facilitates the accurate reproduction of the anatomical structure of the orbit, facilitates further eye prosthetics, and supports the psychological and social adaptation of patients after trauma. Over the

three years of the international initiative, American specialists in plastic and reconstructive surgery have performed more than 150 highly specialized reconstructive operations to restore the anatomical integrity of the face in patients affected by the hostilities in Ukraine, providing medical care free of charge [91].

4.3. Social adaptation and quality of life of military personnel with eye injuries

Social adaptation is defined as a dynamic process of an individual's adjustment to social conditions and roles, which ensures effective interaction with the social environment, maintenance of living standards, and active social participation. For veterans and military personnel, this process includes psychological recovery, return to civilian life, employment, restoration of family and interpersonal relationships, as well as involvement in the social and professional environment.

In his thesis, Biront O.M. (2025) systematically analyzes the social adaptation of veterans and their families in Ukraine, particularly in the context of the transition from military to civilian life. The author emphasizes that the relevance of this issue is due to the significant involvement of citizens in hostilities and the high prevalence of physical and psychological consequences of war. Particular attention is focused on the adaptation of military personnel with visual impairments, which requires the comprehensive integration of medical, psychological, and social interventions [92].

Theoretical analysis allows us to define social adaptation as a multidimensional process that includes:

1. **Physical and functional adaptation** – restoration of vital functions, the ability to perform everyday activities independently, and in the case of eye injuries – partial or complete restoration of visual functions and functional mobility.
2. **Psychological adaptation** – overcoming traumatic experiences, restoring internal stability, forming positive self-esteem and the ability to regulate emotions.
3. **Social integration** – restoration of social roles, support of family and community relationships, active participation in work and community life.

A comprehensive approach to the adaptation of military personnel with eye injuries involves the integration of several main areas of rehabilitation. According to Maistrenko K. (2024), this approach covers [93]:

1. **Psychological rehabilitation** – psycho-emotional support, prevention and correction of post-traumatic stress, development of self-regulation skills and increased inner resilience.
2. **Social rehabilitation** – restoration of social ties, integration into family and community, adaptation to social roles, and participation in public life.
3. **Professional adaptation** – restoration and retraining of professional skills, promotion of employment and integration into work activities in accordance with the patient's physical abilities.
4. **Physical recovery** – rehabilitation measures aimed at restoring general physical activity and functional abilities, including visual rehabilitation in the presence of residual vision.

Thus, the social adaptation of veterans with visual impairments is a multifactorial process that requires the synergy of medical, psychological, social, and professional measures. The integration of these components into structured rehabilitation programs ensures not only improved physical and visual functioning, but also effective psychological stabilization and social integration of military personnel into civilian life.

The empirical part of the work by Biron O.M. (2025) is based on a comprehensive approach that combines structured questionnaires and semi-structured interviews with veterans and their family members. This methodology made it possible to identify the main factors that contribute to or hinder the process of social adaptation [92].

Among the effective factors of adaptation, the following deserve special attention:

1. **Government and charitable medical and psychological support programs** that provide access to highly specialized care, rehabilitation services, and social support.
2. **Family and social support**, which is critical for restoring psychological stability and increasing the independence of veterans.
3. **Access to rehabilitation, educational, and professional resources** that promote comprehensive restoration of functional abilities and integration into civilian and professional life.

Research confirms that social services that integrate medical, psychological, and professional support provide the highest rates of successful adaptation. Participants who had access to comprehensive support demonstrated increased independence, improved quality of life, and effective integration into the social environment.

Institutional and interdisciplinary interaction plays a special role when social workers, psychologists, medical specialists, and representatives of public organizations jointly create favorable conditions for adaptation. Effective coordination of these structures allows for the implementation of comprehensive programs for the social, psychological, and professional integration of veterans into civilian life.

Practical recommendations include:

- increasing the availability of psychological assistance and psychosocial services at the national and local levels;
- introducing specialized training programs aimed at developing veterans life and professional skills;
- developing a social support network at the community level, including public, private, and community resources.

The results of the researchers' study emphasize the need for a comprehensive, integrated approach to the social adaptation of veterans, combining medical,

psychological, and social interventions to ensure an effective return to civilian and professional life [93].

The social adaptation of military personnel is characterized by a number of features due to the specific nature of their professional activities and the extreme conditions in which they serve. Military personnel regularly experience intense psychological and physical stress associated with direct threats to their lives, participation in combat operations, loss of comrades, and severe combat injuries, including damage to the organs of vision.

Combat experience shapes a complex set of psychophysiological and behavioral reactions in military personnel that can significantly complicate their adaptation to civilian life. These include:

- **Psychological consequences of combat stress:** post-traumatic stress disorder, increased anxiety, depression, sleep disturbances, and emotional lability.
- **Social maladjustment:** difficulties in restoring social roles, problems in relationships with family and community, decreased social activity and involvement in public life.
- **Physical limitations:** consequences of injuries, amputations, loss of vision or other physical abilities that require specialized medical and rehabilitation support.
- **Cognitive and functional impairments:** decreased concentration, limited ability to perform professional duties and make independent decisions.
- **Professional barriers:** loss or limitation of visual functions necessitates professional retraining, adaptation of the working environment, and the use of specialized technical aids.

For military personnel who have suffered combat injuries, the process of social adaptation is particularly difficult. This is due not only to physical injuries, but also to the combination of psychological, social, and professional consequences of combat experience. Among such injuries, damage to the organ of vision is particularly significant, as it not only leads to partial or complete loss of vision, but also significantly limits the ability to independently perform everyday activities, professional activities, and social interaction.

The adaptation of military personnel with eye injuries is a multidimensional and lengthy process that requires a comprehensive approach. Successful social integration is only possible with the simultaneous implementation of medical, psychological, social, and professional rehabilitation strategies. Early intervention and multidisciplinary support involving ophthalmologists, physiotherapists, psychologists, social workers, and vocational rehabilitation specialists are particularly important. Such a systematic approach contributes not only to the restoration of visual function, but also to improving the autonomy, quality of life, and social activity of affected military personnel [93, 94].

Quality of life is seen as a multidimensional concept that covers physical health, psychological well-being, social integration, level of independence, professional activity, participation in public life, and overall satisfaction with life. In military personnel with visual impairment, a decline in quality of life manifests itself through limited visual functioning, increased dependence on outside help, limitations in independent mobility and daily activities, as well as social isolation and reduced psychological comfort.

Impaired visual function affects all aspects of life: physical activity, ability to learn and work, social interaction within the family and community, and psychological stability. Therefore, assessing the quality of life of people with eye injuries is critical for developing effective medical, social, and psychological rehabilitation programs aimed at maximizing functional recovery, independence, and social integration [94].

Social adaptation of military personnel with eye injuries includes the following areas (Table 10)

Table 10. Factors of social adaptation of military personnel with visual organ trauma and the expected effect

No No.	Category of factors	Specific aspects	Expected effect on adaptation and quality of life
1	Physical and psychological consequences of eye injury	<ul style="list-style-type: none"> - limitations in daily activities; - loss of ability to move around or work independently - anxiety, depression 	<ul style="list-style-type: none"> - deterioration of physical functioning; - decreased self-esteem and self-perception; - difficulties with social integration and planning for the future.
2.	Psychological support	<ul style="list-style-type: none"> - individual and group psychotherapy; - rehabilitation programs; - support groups. 	<ul style="list-style-type: none"> - reduction of PTSD and depression symptoms; - restoration of social skills; - improvement of self-esteem and inner stability.
3.	Social adaptation tools	<ul style="list-style-type: none"> - government and public support programs; - rehabilitation systems; - professional retraining and employment; - veteran support centers. 	<ul style="list-style-type: none"> - increasing autonomy and social integration; - improved access to services; - reducing the risk of social isolation.
4.	Social interaction and quality of life	<ul style="list-style-type: none"> - supporting an active social life; - participation in community and family events. 	<ul style="list-style-type: none"> - restoring a sense of belonging and productivity; - improving life meaning and psychological well-being; - improving overall quality of life.

The social adaptation and rehabilitation of military personnel with eye injuries is a multidimensional process that combines medical, psychological, social, and professional support. Such military personnel face numerous challenges: visual impairment, difficulties in independent activity, difficulties in employment and social interaction.

A comprehensive approach to rehabilitation is needed to improve their quality of life.

1. Comprehensive medical rehabilitation/recovery includes:

- **treatment and monitoring of vision**, including pharmacological therapy and surgical interventions;
- **physiotherapy procedures** to maintain overall physical condition and functional mobility;
- **training in compensatory skills** that allow effective use of residual vision and adaptation to limitations;
- **adaptation to domestic and professional limitations**, including the use of assistive technologies and special equipment.

This approach promotes the restoration of maximum independence for military personnel, which has a positive effect on their self-esteem and overall psychological and emotional well-being.

2. Psychosocial and professional rehabilitation/recovery has the following areas of focus:

- **Psychosocial rehabilitation** includes training in interpersonal communication skills, adaptation to social life, and support in restoring family and community ties.
- **Vocational rehabilitation** consists of retraining, employment, and career development, taking into account physical limitations, including visual impairments.

Successful programs include special training, career counseling, and employment support, enabling veterans to return to productive activities and feel socially significant.

3. Social programs and community initiatives.

Effective adaptation requires interaction between government agencies, volunteer organizations, and local communities.

- Peer support programs, where experienced veterans help newcomers, are highly effective in restoring social skills and psychological resilience.

- Community initiatives provide additional resources for rehabilitation, promote the integration of veterans into social life, and increase access to medical and social services.

The social adaptation of military personnel with eye injuries requires a comprehensive approach that combines medical treatment, psychological support, professional training, and social integration. Only systematic work in all areas can restore quality of life, support self-esteem, and ensure the effective integration of veterans into peaceful life (Table 11).

Table 11. The social adaptation of military personnel with eye injuries includes the following areas

No.	Area of adaptation	Main goals and measures
1.	Physical rehabilitation	Medical treatment and surgical interventions; physiotherapy; training in visual loss compensation skills; adaptation to physical limitations; restoration of autonomy and independence
2.	Psychological adaptation	Overcoming psychological stress and depression; restoring self-esteem and inner stability; psychotherapy, support groups, and rehabilitation programs
3	Social rehabilitation	Restoring social ties in the family and community; integration into social and community activities; participation in volunteer and community initiatives; working to overcome stigma
4.	Professional adaptation	Restoring or retraining professional skills; employment support; adapting the workplace to physical limitations; developing competencies for civilian activities

The effectiveness of adaptation measures for military personnel with visual impairments is largely determined by the level of coordination between government agencies, volunteer organizations, and local communities. Government programs to support veterans provide systematic access to medical services, psychological

assistance, professional retraining, and social rehabilitation. Key initiatives include medical guarantee programs, state- d rehabilitation centers, as well as specialized measures for free prosthetics and complex ophthalmological interventions.

Community and volunteer initiatives play an important role in complementing state programs. One effective tool is **peer-to-peer** programs, in which veterans provide mutual support and share their experiences of overcoming trauma and social integration. Such approaches contribute to:

- reduce social isolation;
- increased self-esteem and a sense of competence;
- the formation of a social support network that facilitates a return to active community life.

In addition, an important aspect is the development of **local veteran support centers** that integrate medical, psychological, and social services. These centers provide a comprehensive approach to rehabilitation, offering simultaneous access to counseling, educational training, professional retraining, and social interaction.

The effectiveness of social programs also depends on overcoming barriers to accessing services, such as stigma surrounding disability, lack of information about available resources, and insufficient coordination between organizations. Addressing these issues requires an interdisciplinary approach and the active participation of local communities in creating an environment conducive to the comprehensive rehabilitation and social integration of veterans [95-97].

Eye injuries significantly reduce the quality of life of military personnel, limiting their ability to perform everyday activities, causing psycho-emotional consequences, and complicating social interaction. Effective social adaptation in such patients requires a comprehensive combination of physical rehabilitation, psychological support, and integration into the social environment. Government and community programs play a leading role in this process, but their effectiveness largely depends on coordination between different institutions and a focus on the individual needs of military personnel. Such a comprehensive and personalized approach allows to restore functional abilities as much as possible, increase self-esteem, and promote the full social integration of victims.

SECTION 5. PREVENTION OF COMBAT EYE INJURIES

5.1. Personal protective equipment for the eyes

The experience of the US and NATO countries shows that the systematic use of protective eyewear in combination with the adaptation of training and combat protocols significantly reduces the incidence of ophthalmic injuries, emphasizing the role of primary prevention.

Data from military medical studies conducted in the U.S. Armed Forces provide convincing evidence of the effectiveness of systematic use of personal eye protection equipment as an element of primary prevention of combat-related ophthalmic injuries. In particular, a retrospective analysis of combat injuries sustained during operations in Iraq and Afghanistan demonstrated a statistically significant reduction in the incidence of ocular trauma among service members who used certified protective eyewear. The authors found that the rate of ophthalmic injuries in the group using eye protection was approximately 17.0%, whereas among personnel without personal eye protection this figure reached 26.0%, indicating a substantial preventive effect. The introduction of standardized equipment requirements, mandatory use of ballistic eyewear, and adaptation of training and combat protocols are regarded as key factors in reducing both the frequency and severity of ophthalmic injuries in combat conditions [98].

According to McLaughlin A. (2017), the systematic use of protective eyewear can reduce the risk of combat injuries to the eye by 50.0–70.0%, including injuries caused by fragments, blast waves, intense light, or ultraviolet radiation. The author emphasizes that the effectiveness of such equipment directly depends on its compliance with international safety standards, the correct selection of size and shape, as well as regular training of military personnel on the proper use and care of protective eyewear [94].

Studies show that combining individual eye protection with adapted training and combat protocols, including training in dynamic conditions and tactical maneuvers, further reduces the likelihood of injury and the severity of damage. The mandatory use of certified ballistic eyewear at all stages of combat operations not

only reduces direct physical harm but also lowers the risk of secondary complications associated with eye damage, such as infections or permanent vision loss.

Primary prevention, based on the systematic use of protective eyewear in combination with the adaptation of tactical and training procedures, is an important element in maintaining the combat readiness of military personnel and has a significant impact on reducing the social and psychological consequences of vision loss. These findings confirm the need to integrate protective equipment into military training and operational planning standards [94].

To prevent combat and traumatic eye injuries in military personnel, specialized ballistic eye protection devices are used, which provide effective protection against a wide range of threats, both man-made and natural.

1. Ballistic protective eyewear

Ballistic glasses are intended to protect the eyes from mechanical and optical hazards, including fragments, liquid splashes, ultraviolet radiation, dust, sand, laser radiation, and combinations of these factors during combat and training-combat operations. They are compatible with other personal protective equipment, including helmets, night vision devices, optical instruments such as binoculars, sights, and spotting scopes, as well as hearing protection devices.

The ballistic eyewear set includes:

- a frame that holds the light filter and ensures a stable fit on the face;
- a nose pad for comfortable placement on the bridge of the nose;
- a transparent light filter (CLEAR) for standard protection;
- a GREY light filter for protection from sunlight;
- ORANGE light filter for increased contrast;
- elastic retaining strap;
- two bags for storing and caring for light filters;
- a case for transporting the glasses;
- instructions for use and care in Ukrainian.

2. Ballistic goggles-mask

Ballistic goggles perform a similar function, but have a modified design that increases the tightness of the fit and comfort during prolonged wear, as well as ensuring compatibility with helmets.

The main components of goggles-mask are:

- a frame that holds the light filter and secures the goggles to the face;
- transparent light filter (CLEAR);
- GREY light filter for sun protection;
- ORANGE light filter for increased contrast;
- elastic headband for secure attachment to the head or helmet;
- frame seal (may or may not have porous material) for a comfortable and snug fit on the face;
- two bags for storing and caring for light filters;
- carrying case;
- anti-glare cover to prevent revealing glare and protect against dust, sand, and small debris when worn on a helmet;
- instructions for use and care in Ukrainian.

Ballistic glasses and goggle masks are the main means of primary prevention of ophthalmic injuries in the military, providing mechanical, optical, and combined protection of the organs of vision. The correct use of these devices, combined with training and adapted tactical protocols, can significantly reduce the frequency and severity of combat eye injuries and increase the combat readiness of military personnel [99].

Modern personal eye protection equipment (PEE) in military operations includes ballistic goggles and masks made of highly resistant polycarbonate materials that meet international safety standards ANSI Z87.1 and MIL-PRF-32432. Such products provide effective protection against high-speed debris, solid particles, ultraviolet and laser radiation, as well as other threats typical of combat conditions.

Retrospective military medical studies conducted by Weichel (2008) have shown that the systematic use of certified ballistic eyewear and masks can reduce the risk of penetrating injuries to the eyeball and orbit by more than 30%, particularly in

cases of trauma caused by shrapnel wounds and blast waves. These data emphasize the effectiveness of PPE as a critical element of primary prevention of ophthalmic injuries in combat conditions and confirm the need for their mandatory use as part of modern individual equipment for military personnel (Table 12) [100].

Table 12. Modern means of individual protection of the organs of vision

No	Category	Material	Main function	Advantages	Limitations
1.	Ballistic glasses	Multi-layer polycarbonate, ANSI Z87.1, MIL-PRF-32432 standards	Protection against low- and medium-velocity debris	Lightweight, comfortable fit, preserves field of vision	Possible fogging, incompatibility with sighting devices
2.	Ballistic masks	Polycarbonate + metal/composite frames	Protection of the periorbital area, orbit	Wider coverage, effective against mine and explosive damage	Greater discomfort, limited field of vision
3.	Integrated systems	Combination of goggles, helmet, shields, sights	Comprehensive eye and face protection	Minimization of combined injuries	Heavy weight, complex compatibility, requires training

Integrated systems, which combine ballistic eye protection with helmets and face shields, constitute a separate category of personal eye protection equipment. Such systems provide comprehensive protection not only from mechanical damage, but also from thermal and explosive factors that often accompany modern combat operations.

According to a study by Blanch R.J. et al. (2011), integrated systems significantly increase the effectiveness of protection compared to separate devices. The use of such systems creates an additional barrier against high-speed debris, mine

fragments, and blast waves, which are the leading causes of severe combat eye injuries in modern conflicts. In particular, combined devices ensure an even distribution of mechanical stress on the face and head, reducing local injuries to the eyes and orbit.

An additional advantage of integrated systems is the ability to use them in conjunction with optical devices, night vision devices, and communication devices, which does not limit the combat effectiveness of military personnel. Thus, integrated PPE systems are an important element of modern military equipment, providing a high level of safety and reducing the risk of long-term functional and psychosocial consequences for those suffering from combat injuries [101].

Research data, in particular Scott R. A. (2013), emphasises that the effectiveness of personal eye protection equipment (PPE) is determined not only by its availability, but also by the correctness and consistency of its use. The main barriers to the regular use of protective eyewear in combat conditions remain: insufficient compatibility with sighting devices and optical instruments, discomfort during prolonged wear, fogging of lenses, and limited field of vision.

Empirical data from Scott et al. show that a significant proportion of eye injuries in military personnel occur when protective equipment is not being used or has been removed. This indicates that the availability of PPE alone does not guarantee a preventive effect, and the leading factor remains the correct integration of PPE into combat protocols and training procedures, as well as improving the convenience and ergonomics of the equipment.

For maximum effectiveness, PPE must combine technical design improvements (reducing fogging, adapting to helmets and optical devices) with training military personnel in the constant use of protective equipment in combat and training conditions [102].

For effective prevention of ophthalmic injuries among military personnel, it is extremely important to classify PPE according to their level of protection. This approach allows not only to assess the purpose of a particular device and its suitability for the conditions of use, but also to determine the degree of protection against mechanical, chemical, optical, or ballistic threats.

The systematization of PPE ensures the optimal selection of equipment in accordance with the nature of the tasks performed, the specifics of combat operations, and environmental conditions, which helps to reduce the frequency and severity of ophthalmic injuries. The table below shows the main classes of protective eyewear and masks, their functional characteristics, and examples of their use in military conditions (Table 13) [103, 104].

Table 13. Classification of personal protective equipment for the eyes by level of protection and purpose in military conditions

No.	Protection class	Purpose and level of protection	Examples	Use
1	Class I – basic protection	Protection against fine dust, minor mechanical damage, and contact irritants	Transparent plastic or polycarbonate glasses	Used in training, laboratories, and everyday life
2.	Class II – enhanced protection	Protection against small debris, impacts, chemical splashes, ultraviolet rays	Ballistic glasses, protective shields, tactical glasses	Medium-risk military and industrial conditions
3.	Class III – specialized protection	Protection against strong impacts, shock waves, laser or infrared radiation	Laser protection glasses, combat glasses with bullet protection, gas masks with built-in glasses	Used in combat operations, work with high-tech devices, and in special units
4.	Class IV – combined high protection	Comprehensive eye protection in combination with other systems (breathing, face, helmet)	Tactical masks and helmets with protective goggles, modular night vision systems	Designed for combat conditions and high risk of injury

The set of personal protective equipment for military personnel's eyes includes several key elements, each of which is designed to provide effective eye protection in combat conditions. The kit includes a frame with temples or a strap that ensures a secure fit of the glasses on the face; light filters – transparent for protection against debris and tinted to reduce glare and increase contrast; an elastic strap that stabilizes the glasses during active movement; a case and bags for storing lenses and filters to prevent damage; and instructions for use and care, including recommendations for proper wearing and maintenance. The design features of the kit comply with international standards (ANSI Z87.1, EN 166:2017) and the technical specifications of the Ministry of Defense of Ukraine for ballistic protective eyewear. This comprehensive protection system provides an effective barrier against mechanical, optical, and light hazards, as well as compatibility with other personal protective equipment, including helmets, night vision devices, and communication headsets [105].

5.2. Strategies for medical and organizational prevention of eye injuries in the military

Medical and organizational measures for the prevention of eye injuries in military personnel involve a systematic set of integrated actions covering risk assessment, the use of personal protective equipment, staff training, and medical support at all stages of combat and training operations.

Risk assessment includes systematic analysis of potential threats to the organ of vision, identification of factors of increased trauma, and development of preventive measures. Such an assessment allows for the differentiation of risk levels by type of activity and operating conditions, which ensures targeted planning of safe procedures.

Personal protective equipment includes certified ballistic goggles, shields, and integrated helmets with built-in visors, which provide a comprehensive barrier against mechanical, chemical, thermal, and optical damage to the eyes. Their

effectiveness is significantly increased when properly combined with other personal protective equipment and combat gear.

Training programs include developing skills for the proper use of protective equipment, algorithms for providing first aid for eye injuries, and identifying potentially dangerous situations. Particular attention is paid to preparing military personnel for action in the stressful conditions of combat operations, which increases the effectiveness of preventive measures.

The organizational component includes monitoring compliance with safety standards by the command, monitoring cases of injury, analyzing the causes of damage, and making adjustments to internal protocols and instructions. This approach allows for the creation of a closed cycle of prevention and rapid response to risks.

Medical support includes early diagnosis of eye injuries, patient triage, timely referral to specialized ophthalmology centers, surgical and drug treatment, physiotherapy rehabilitation, and training in vision impairment compensation skills.

In addition, integration of psychological and social measures, including support groups, individual counseling, and adaptation programs for military units, contributes to reduction of post-traumatic stress symptoms, increased motivation, and improved social integration of affected individuals.

The systematic combination of medical and organizational measures minimizes the risk of repeated injuries, preserves functional vision, and supports the combat effectiveness of units, serving as a key element of the modern strategy for the prevention of ophthalmic injuries in the military environment [106].

Effectively reducing the risk of re-injury and optimizing the restoration of visual function in military personnel requires an integrated approach that encompasses medical, organizational, and psychological measures. At the primary care stage, rapid and accurate assessment of the condition of the eyeball and adjacent structures is critical. Such an assessment includes a detailed examination of the cornea, lens, retina, and optic nerve, determination of the presence of foreign bodies, and the nature and extent of damage.

Immediate stabilization of the eye is the main element of primary care. It includes the use of antibacterial prophylaxis to prevent endophthalmitis, surgical treatment of the wound, removal of debris, and suturing of damaged tissues. After stabilization of the injury, therapeutic measures are implemented to restore residual visual functions. These include corrective glasses, contact lenses, and specialized training to compensate for visual perception disorders.

In cases of severe damage that makes it impossible to restore the anatomical integrity of the eye, ocular prosthetics or neuroprosthetics are used. These technologies allow for the restoration of partial visual functions, the formation of new visual perceptions, and the integration of the patient into the social environment, providing both medical and psychosocial rehabilitation effects [83, 85, 86].

Along with medical interventions, the organizational component that ensures the coordination of care and the standardization of clinical protocols is critical for effective rehabilitation. This includes the development and implementation of uniform medical algorithms for the assessment, stabilization, and treatment of eye injuries, as well as the integration of field medical stations with specialized ophthalmological centers.

It is particularly important to determine the optimal evacuation routes for the wounded, which minimizes the time to provide highly specialized care and reduces the risk of complications. The quality of medical care is controlled by monitoring compliance with clinical protocols, maintaining medical records, and evaluating treatment outcomes at various stages of care.

State medical guarantee programs provide military personnel with access to free medical services, rehabilitation centers, and eye prosthetics, creating a continuous chain of care from initial intervention to full social and psychological integration. This comprehensive organizational approach not only reduces the risk of vision loss, but also optimizes the rehabilitation process, increasing the level of autonomy, psycho-emotional state, and quality of life of wounded military personnel [94].

Special attention in medical and organizational work is focused on the prevention of repeated damage to the organ of vision, which is critical for preserving functional capacity and preventing complications. The main measures include the mandatory use of certified personal eye protection equipment, such as ballistic or modular goggles, adapted to the specifics of combat and combat training tasks. An important component is the systematic training of military personnel in the rules for using protective equipment, regular monitoring of its condition, scheduled medical examinations, and monitoring of the functional characteristics of the eyes and prostheses. Compliance with these measures significantly reduces the risk of additional damage and ensures the stability of visual functions during rehabilitation.

Equally important is psychological and social support, which is a key factor in the adaptation of veterans and military personnel after eye injuries. Such measures include psychotherapeutic interventions, support groups, and peer-to-peer programs that provide mutual support among veterans, exchange of experience, and promotion of social integration. Local veteran support centers play a critical role by bringing together medical, psychological, and social services in one complex, allowing for simultaneous counseling, training, and professional retraining, as well as facilitating social adaptation and professional integration.

The effectiveness of these measures is largely determined by the level of coordination between government agencies, non-governmental organizations, and local communities. A synergistic approach minimizes barriers to accessing services, reduces social stigma associated with disability, and creates conditions for comprehensive, continuous rehabilitation. This interdisciplinary model combines medical, psychological, and social components, promotes the optimization of physical and psycho-emotional recovery, increases the independence and quality of life of military personnel, and creates the conditions for successful integration into civilian life [93].

A retrospective study by Winkler S.L. et al. (2022) analyzed the use of vision rehabilitation programs among United States veterans who had suffered traumatic brain injuries and associated visual system disorders. The study was conducted at Veterans Health Administration rehabilitation centers, which allows for the

assessment of the long-term effectiveness of medical and organizational measures and the identification of factors that influence access to specialized services. Analysis of veterans who underwent mandatory visual function assessment between 2008 and 2017. The results showed that approximately 60.0% of patients took advantage of recommended rehabilitation visits to rehabilitation centers or other veterans' medical facilities. An important factor influencing the use of rehabilitation services is the patient's age: an increase in age by 10 years reduces the likelihood of seeking treatment by 12.0%. At the same time, clinical manifestations of visual impairment—narrowing of the field of vision, difficulty reading, and double vision—significantly increase the likelihood of seeking treatment. Combined vestibular symptoms also stimulate an active search for rehabilitation assistance. These data emphasize that it is objective visual impairment and its impact on the patient's functioning that determine the need for rehabilitation. Symptoms and functional limitations can persist for up to two years after the injury, emphasizing the need for long-term medical follow-up and systematic planning of rehabilitation measures.

The authors identify the main factors and components for the effective organization of the medical rehabilitation process:

1. **Demographic factors:** age, gender, level of education, previous professional activity.
2. **Clinical factors:** nature of visual impairment (narrowing of the field of vision, double vision, difficulty reading), combined vestibular and cognitive symptoms, severity of brain injury.
3. **Organizational factors:** availability and accessibility of specialized rehabilitation centers, effectiveness of referrals, coordination between medical institutions.
4. **Psychological and social factors:** patient motivation, family support, availability of psychological support and social integration programs [107].

A study by Mulligan K. (2025) emphasizes the importance of comprehensive treatment of combat injuries to the organ of vision in military personnel, demonstrating both clinical and economic benefits. The authors show that the provision of comprehensive ophthalmic care contributes to a significant improvement

in functional outcomes, preservation of working capacity, and an increase in the quality of life of victims.

The study pays particular attention to preventive measures, in particular the use of personal eye protection. According to Mulligan's model, increasing safety compliance from 77.0% to 85.0–95.0% can prevent dozens of injuries per deployed military contingent. This not only reduces the incidence of permanent vision impairment, but also has a significant economic effect: each injury prevented provides potential savings of \$1.86–2.47 million, including treatment, rehabilitation, and lost productivity costs.

The results of Mulligan K. (2025) confirm that investments in prevention and comprehensive ophthalmological support for military personnel not only increase the effectiveness of medical care but also provide significant economic and social benefits for the state and military structures [75].

5.3. Prospects for reducing the incidence of combat eye injuries in the Armed Forces of Ukraine

The optimal strategy for preventing combat-related ocular trauma in military personnel should be based on the integration of technical, educational, and organizational measures that ensure a systematic and comprehensive approach to personnel safety. The main components of such a strategy are the provision of modern means of individual eye protection, certified in accordance with international and national standards, taking into account the anthropometric characteristics of military personnel, combat conditions, and combat training operations.

A retrospective analysis of Israeli Defense Forces data shows that penetrating debris injuries, which remain the leading cause of combat eye injuries, are largely preventable with the systematic use of protective eyewear. Studies show a direct correlation between the use of personal eye protection and a reduction in the incidence of eye injuries, as well as an improvement in baseline visual function

among military personnel, underscoring the clinical effectiveness and strategic importance of implementing primary prevention measures [108].

Effective prevention of combat eye injuries in military personnel requires a comprehensive approach that includes technical, organizational, and educational and motivational measures. The main primary prevention measure is the use of modern personal protective equipment for the eyes, in particular ballistic and modular goggles certified to ANSI Z87.1 and MIL-PRF-32432 standards. Research data from Thomas R. (2009) show that the systematic use of protective eyewear reduces the incidence of eye injuries in combat conditions from 26.0% to 17.0%, especially in cases of shrapnel and fragmentation injuries.

However, the effectiveness of technical means largely depends on correct wearing and compliance with operating instructions. In this context, educational and motivational campaigns that teach personnel the rules for using glasses, emphasize their role in protecting vision, and foster a culture of safe behavior during combat and combat training tasks are critically important. After the implementation of such measures, the level of compliance among military personnel increased by 16.0%, which correlated with a decrease in the frequency and severity of ophthalmic injuries.

In addition to technical and educational measures, the organizational component of prevention is also important. It includes the standardization of medical protocols, monitoring of safety compliance, scheduled medical examinations and monitoring of the condition of eyes and prostheses, as well as the integration of field medical stations with specialized ophthalmological centers. The systematic combination of technical, educational, and organizational measures minimizes the risk of primary and repeated damage to the organ of vision, preserves the functional capabilities of the eyes, and maintains the combat capability of military units [109].

Standardization of military equipment with regard to eye protection is one of the leading strategic directions in the prevention of combat injuries. It provides for the mandatory equipping of units with certified ballistic goggles, regular monitoring of their condition and correct use, as well as the adaptation of equipment to the specifics of the tasks performed and the conditions of operations, in particular in urban environments and in the presence of mine and explosive threats [110].

The experience of the Israel Defense Forces shows that the implementation of such standards significantly reduces the incidence of eye injuries among military personnel. This emphasizes that an effective safety policy includes not only providing personnel with modern protective equipment, but also systematically monitoring its use and compliance with regulatory requirements. In combination with educational and organizational measures, standardization of equipment contributes to the preservation of functional vision, minimization of the risk of repeated injuries, and maintenance of the combat capability of units [108].

To effectively reduce the incidence of eye injuries during combat operations, it is necessary to implement systematic monitoring, incident analysis, and adaptation of tactical recommendations. This approach allows identifying the main mechanisms of injury, evaluating the effectiveness of preventive measures, and timely adjusting tactical, organizational, and medical protocols.

The experience of international armies shows that systematic monitoring and standardized use of protective equipment have a significant preventive effect. In particular, analytical data from the Israel Defense Forces showed that protective eyewear is associated with a reduction in the incidence of combat eye injuries, as its use correlates with a lower frequency of injuries compared to cases without eye protection. Thus, a retrospective analysis of military injuries in Israel showed that among the wounded who did not use protective eyewear, the level of ophthalmic damage was significantly higher than among those who used it in combat conditions [111].

In the United States, regular updates to the Department of Defense's Authorized Protective Eyewear List (APEL), which defines certified ballistic eye protection models, have contributed to a reduction in the incidence of eye injuries among service members. Military experts attribute the downward trend in such injuries to the consistent provision of effective protective equipment to soldiers and its use during training and operations [112].

The creation of a national registry of combat eye injuries is critical to establishing an evidence base for informed management decisions and optimizing rehabilitation strategies. Such a registry allows for the systematization of data on the

nature, mechanisms, and consequences of injuries, which opens up opportunities for building predictive risk models, comparing the effectiveness of preventive measures, and justifying clinical protocols at the national level.

An optimal prevention strategy should combine technical, educational, and organizational measures:

- providing modern personal protective equipment certified in accordance with international requirements;
- conducting training programs and motivational campaigns that foster a culture of safe behavior and compliance with eye protection use;
- standardizing equipment policies with regular monitoring of the condition and correct use of PPE;
- systematic monitoring and analysis of combat incidents for the rapid adaptation of tactical recommendations;
- implementation of proven international practices, taking into account the national conditions of the Armed Forces of Ukraine.

This comprehensive combination of measures reduces the frequency and severity of ophthalmic injuries, improves the effectiveness of medical care and rehabilitation, and supports the combat capability and quality of life of military personnel who have suffered combat eye injuries (Table 14) [108, 109].

Table 14. System of preventive measures to reduce combat injuries to the organ of vision in military personnel and expected results

No.	Category	Specific actions	Expected effect
1.	Personal protective equipment	<ul style="list-style-type: none"> - Training in the correct use of goggles - Motivational campaigns - Demonstration of injury risks 	Reduction in injury frequency by 30.0-50.0%; reduction in severity of injuries
2.	Educational programs and training	<ul style="list-style-type: none"> - Training in the correct use of safety glasses; - Motivational campaigns; - Demonstration of injury risks 	Increase compliance by 10.0-20.0%; reduce the frequency and severity of injuries
3.	Equipment standards and safety policy	<ul style="list-style-type: none"> - Mandatory wearing of certified protective equipment; - Implementation of inspection and control regulations 	Identification of key risks; effective planning of preventive measures
4.	Injury monitoring and analytics	<ul style="list-style-type: none"> - Maintenance of ophthalmic injury registries; - Analysis of causes of injuries; - Correction of tactics and training 	Identification of key risks; effective planning of preventive measures
5.	Integrated approach	<ul style="list-style-type: none"> - Combining all measures into a systematic strategy; - Cooperation between command, medical services, and training centers 	Maximum reduction in injury frequency; increased combat readiness; preservation of visual functions

ABBREVIATION:

1. Combat ocular trauma – COT
2. Intraocular foreign bodies – IFB
3. World Health Organization – WHO
4. Improvised explosive devices – IED
5. Computed tomography – CT
6. Magnetic resonance imaging – MRI
7. Mine and explosive injuries – MIE
8. Primary surgical treatment – PST
9. Levels of medical care – ROLE
10. Improvised explosive devices – IED
11. Ultrasound examination – US
12. Personal protective equipment for the eyes – PPE
13. Traumatic brain injury – TBI

AFTERWORD

In concluding this monograph, the authors recognize that the problem of combat injuries to the eye has no definitive solution and cannot be exhausted within the confines of a single scientific study. In the context of ongoing warfare, the rapid evolution of weapons, and the transformation of the nature of combat operations, ophthalmic trauma remains a dynamic challenge for military medicine, requiring constant review of clinical approaches, organizational models, and preventive strategies.

The findings presented in this monograph reflect the current state of scientific knowledge and clinical experience in the field of combat-related ocular injuries, while also outlining directions for further research. Particular attention has been devoted to the specific features of the full-scale war in Ukraine, which makes it possible to regard the data presented not only as a synthesis of global experience, but also as a foundation for the development of a national system of evidence-based military ophthalmology.

The authors are convinced that effective assistance to victims of combat ocular injuries is possible only through close cooperation between clinical medicine, science, the rehabilitation system, and social support. Preserving or restoring vision is not only a medical task but also a moral obligation of society to those who have suffered injuries while defending the state.

We hope that this monograph will become a solid scientific and practical foundation for the further development of modern approaches to the diagnosis, treatment, and medical rehabilitation of military personnel with combat ocular injuries. The scientific data, clinical observations, and analytical materials summarized in this work can be used by clinicians, scientists, and healthcare system organizers to improve clinical protocols, optimize the medical evacuation system, and implement effective medical rehabilitation and prevention programs.

We hope that the presented findings and research results will contribute to a deeper scientific understanding of combat eye injuries, stimulate further interdisciplinary research, and promote professional scientific discussion. Ultimately,

this should contribute to improving the effectiveness of medical care, preserving visual functions, and improving the quality of life and social adaptation of military personnel who have suffered combat injuries.

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