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Experience of providing eye care to the wounded at the NMMCC “Main Military Clinical Hospital” during the defense of Kyiv in February-April 2022

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Background: A full-scale Russian invasion of the territory of Ukraine required the military medical authorities to introduce corrections in the operation of the support system for treatment and evacuation of casualties with combat ocular trauma (COT). While the combat activities were taking place in Kyiv’s suburbs, the inpatient eye clinics of the city actively contributed to the provision of care to casualties.

Purpose: To examine the results of the managing decisions made on the introduction of corrections in the operation of the support system for treatment and evacuation of casualties with COT on the basis of the comparative analysis of the efficacy of medical care provided to casualties at the eye clinic of the National Military Medical Clinical Center “Main Military Clinical Hospital” (NMMCC “MMCH”).

Material and Methods: We presented the results of the analysis of (a) changes in the pattern and amount of treatment and diagnostic interventions provided to casualties in different time periods related to changes in the tactical combat situation and (b) transformation in the levels of provision of medical care to casualties with COT that took place due to the above changes. The structure of causes and locations of ocular and ocular adnexal injuries was calculated based on the aggregated data from medical papers related to treatment of combat casualties at the eye clinic of the NMMCC “MMCH” during 2014-2021 and February-April 2022. System, comparative and content analysis methods, descriptive modeling, statistical analysis and principal methods of treatment and diagnosis of eye disease were used as methods of the study.

Results: It was demonstrated that the urgent corrections introduced in the conventional four-level system of medical and evacuation support during combat activities in the metropolitan suburbs of Kyiv were timely and adequate. We reviewed the changes in the pattern of COT in different periods of combat activities on the territory of Ukraine and identified the issues requiring primary consideration in order to remove the shortcomings in the organizational support of the treatment and evacuation of casualties with COT.

Conclusion: First, the results of our comparative analysis of the advanced support system for treatment and evacuation of casualties under combat actions in aggravated tactical situations (particularly, during the defense of the metropolitan area of Kyiv), demonstrated the efficacy of the algorithms and standards recommended by NATO. Second, the front line advancing to the outskirts of the metropolitan area required making urgent managing decisions on introducing corrections in the classical four-level support system for treatment and evacuation of casualties (particularly, those with COT), which caused the NMMCC “MMCH” to unite and coordinate their care efforts with those of the special medical facilities of the metropolitan area of Kyiv. There were changes in the amount of eye care provided, with a change to level 3 and subsequently in the opposite direction to level 4, within a very short period, which did not cause difficulties for the military medical personnel. Third, combat actions at the outskirts of the metropolitan area of Kyiv resulted in an increase in the percentage of the wounded with combat-related injuries of the eye and adnexa to 9.4% of the total number of wounded, with more than half (54%) of them represented by penetrating injuries, particularly those with an intraocular foreign body (43.3%).

1

The percentage of binocular injuries and eye destruction increased to 29.8% and the percentage of multiple combat-related injuries to 81.4%, likely primarily due to wide use of high-kinetic-energy weapons with high-velocity fragments from explosive munitions of these systems having wide-area effects. Fourth, we found that treatment outcomes were better when casualties with COT (a) had an early single-stage evacuation to the destination point and (b) were timely provided with special care, which is especially important in bilateral severe eye injuries with a threat of irreversible visual function loss. Finally, the identified problems and shortcomings were caused primarily by impaired logistics of the support of treatment and evacuation of casualties, and shortage of medical staff (particularly, specialty doctors), medications and medical supplies, particularly at the territories which external communications were temporarily blocked.

Keywords:

combat ocular trauma, levels of the support system for treatment and evacuation of casualties

Introduction

The full-scale Russian invasion has become a challenge to the system of medical and evacuation support for the Armed Forces of Ukraine. The four-level system of medical and evacuation support based on the North Atlantic Treaty Organization (NATO) standards demonstrated high efficiency in armed conflicts such as Operation Iraqi Freedom in 2003–2011 in Iraq and Operation Enduring Freedom in 2001–2014 in Afghanistan, and its implementation in Ukraine began with the beginning of combat activities in the east of the country in 2014. With regard to casualties with combat ocular trauma (COT), this system included advanced components, with the measures determined to be of a key importance including: (a) shock management measures, application of an aseptic dressing on the injured area, and administration of antibacterial therapy topically and/or systemically, at levels 1 and 2, and (b) provision of tertiary treatment and diagnostic care including a set of diagnostic procedures (examination of the eye and ocular adnexa, visual acuity, biomicroscopy, ophthalmoscopy, computed tomography, light and color sensation, ocular ultrasound, perimetry, and optical coherence tomography (OCT)), eye surgery procedures (primary surgical treatment of wounds (PSTW), intraocular foreign body (IOFB) removal, wound repair, lid wound suturing, extraction of the crystalline lens and intraocular lens (IOL) implantation if indicated, vitreoretinal surgery, glaucoma surgery, reconstructive surgery of the ocular adnexa and orbit, surgical wound re-treatment, evisceration and enucleation), and postoperative treatment combined with in-patient rehabilitation of these patients, at levels 3 and 4 [1–4].

Recent studies on combat ocular injuries have demonstrated that, after treatment, inaccurate projection of light and blindness were found in 25–32% of eyes. Moreover, the percentage of eyes with visual acuity of 0.1 or lower after treatment for penetrating eye injury was as high as 75%, and evisceration or enucleation was performed in 8–12% of eyes with combat ocular injuries [5–11].

The increased severity of the combat situation in other regions of Ukraine with enemy's attempts to surround and

block Kyiv in February–April 2022 required making urgent managing decisions regarding optimization of classical four-level support system for treatment and evacuation of casualties at the outskirts of Kyiv. While the combat activities were taking place in Kyiv's suburbs, casualties with combat ocular and adnexal trauma were admitted to inpatient eye clinics of the city, which under these harsh conditions were temporarily used as the facilities of the second and third levels of the support system for treatment and evacuation [12].

In Ukraine, there have been no studies on the experience of providing care to casualties with COT with the assessment of the efficacy of the managing decisions made regarding an improvement in the support system for treatment and evacuation of casualties during combat actions at the outskirts of Kyiv, including a review of changes in the conditions of operation of NMMCC "MMCH" during the defense of Kyiv in February–April 2022, which makes this study important and relevant.

The purpose of the study was twofold: (1) to assess the experience of making managing decisions regarding an improvement in the support system for treatment and evacuation of casualties with combat ocular and adnexal trauma, and (2) to use comparative analysis to compare different periods of conducting combat activities on the territory of Ukraine (including the period of the defense of Kyiv in February–April 2022) with regard to changes in the pattern and amount of care provided to casualties at the eye clinic of National Military Medical Clinical Center "Main Military Clinical Hospital".

Material and Methods

The results of the analysis of changes in (a) the pattern and amount of treatment and diagnostic interventions in different time periods and (b) the level of support of evacuation of and care for casualties with combat-related ocular and ocular adnexal injuries, due to changes in the tactical situation (particularly, in the period of the defense of Kyiv in February–April 2022), were used as material for the study. The structure of causes and locations of ocular and adnexal injuries was calculated based on the aggregated data from medical papers related to treatment

of casualties at the Eye Clinic of the National Military Medical Clinical Center "Main Military Clinical Hospital" during 2014-2021 and February-April 2022. System, comparative and content analysis methods, descriptive modeling, statistical analysis and principal methods of treatment and diagnosis of eye disease were used as methods of the study. Variational statistics and Statistica 8.0 and Microsoft Excel 2007 (license CMPJ6-YBX7P-CJPKF-62GPW-F) software were used for statistical analysis.

Results

Під час аналізу результатів дослідження варто зупинитися на кількох його аспектах. This paper highlights the results of the study of the background to the improvement in the support system for evacuation and treatment of casualties with COT, with the description of the features of triage and treatment of COT in the setting of the eye clinic of the National Military Medical Clinical Center "Main Military Clinical Hospital" (NMMCC "MMCH"). At the next phase of the study, the analysis conducted allowed to generalize changes in the distribution and structure of COT by causative agent. At the final phase of the study, we reviewed the identified high-priority problems and shortcomings in the organization of support of evacuation of and care for casualties with combat ocular and adnexal injuries in different periods of combat activities.

Improving the support system for treatment and evacuation of casualties with combat ocular trauma in different periods of combat activities in the territory of Ukraine

The efficacy of the four-level system used by NATO has been demonstrated in numerous armed conflicts around the world, and, from the early days of combat, the standards and algorithms of this system have been used for providing medical care to service members of the Defense Forces of Ukraine. These standards state that, irrespective of wound location, level 1 care includes (a) first aid and first medical aid provided to the wounded, with the involvement of a paramedic and/or general practitioner, in the setting of a battalion aid station or brigade medical company (medical stabilization point), (b) triaging, and (c) the required treatment-and-diagnostic, resuscitation and stabilization measures, followed by waiting for the evacuation of the wounded to level 2.

Level 2 care includes qualified medical care (reception and triaging of, and provision of general surgery care for the wounded, and resuscitation and shock management measures, followed by waiting for the evacuation of the wounded to level 3) provided with the involvement of surgeons and traumatologists at a mobile hospital or a front-line hospital.

Level 3 care is important if a combat eye injury occurs, and includes specialty care (diagnostic assessment and required in-patient treatment of the wounded in order to return them to duty or to medically evacuate them to a higher level of care) in the setting of hospitals of territorial

hospital bases (THBs) of the Ministry of Health, regional Military Medical Clinical Centers (MMCCs) or the NMMCC.

Level 4 care includes high specialty care using advanced ophthalmological and eye surgery equipment for vitreoretinal and refractive surgery, tissue transplantation, highly complicated procedures, with the involvement of not only regional MMCCs, NMMCC, and special healthcare facilities and hospitals of THBs of the Ministry of Health, but also facilities of the National Academy of Medical Science (NAMS) of Ukraine (e.g., the Filatov Institute of Eye Disease and Tissue Therapy).

However, with the beginning of the full-scale Russian invasion, accompanied by a simultaneous abrupt increase in the area and scale of combat actions (attacks from the territory of Russian Federation, Belarus, and from the Black Sea) and rise in the intensity of these actions, with a risk of encirclement of as well as actual combat actions at the outskirts of the cities which were far behind the line before February 24, 2022, the background emerged to correct the operation of the above four-level system. It became urgently necessary to optimize triage of patients with ocular and adnexal trauma in accordance with the combat situation.

Particularly, during combat actions in the suburbs and at the outskirts of Kyiv, some Kyiv hospitals located close to the front line were providing care to the wounded with subsequent evacuation to the NMMCC "MMCH", and, in this way, functioned as Level 2 medical and evacuation support.

If the information on the wounded directed to the NMMCC "MMCH" was forwarded through means of communication, the logistics of the medical and evacuation support structure provided for preliminary general triage (involving the assessment of vital functions and, if required, ophthalmological examination). An eye examination of a patient with a severe and life-threatening condition was performed directly in the operating room, if (s)he required urgent surgery other than eye surgery; otherwise, this examination was performed in the intensive care unit. It was not uncommon that, in a patient with concomitant, severe injuries associated with ocular trauma, surgery was performed by a multidisciplinary team consisting of abdominal surgeons, vascular surgeons, maxillofacial surgeons, ophthalmologists and otorhinolaryngologists. On admission, an orbital computed tomography (CT) was done in the eye casualty having no life-threatening condition, to evaluate the globe and orbital integrity (whether the volumes of the eye chambers were maintained, the components within the eye were properly related to one another, and whether air bubbles were present within the eye (to exclude damage to the paranasal sinuses and orbital walls)), and visualize any intraocular or intraorbital foreign body or orbital wall fracture. The liberation of the route between Kyiv and Chernihiv was the next time period of a change in the combat situation in the outskirts of the city of Kyiv, with an abrupt increase

in the admission of patients with ocular complications to the NMMCC “MMCH”. The patients admitted to the Eye Clinic of the NMMCC “MMCH” in that period had a severe condition and various complications after they could not be provided with special care (particularly, eye care) at the healthcare facilities of the blocked city of Chernihiv for a long time due to adverse objective circumstances associated with the absence of power supply and lack of adequately trained personnel, medications and medical supplies. Of importance was the fact that, a certain shortage of staff ophthalmologists and eye surgeons emerged with the beginning of combat activities and due to forced displacement of civil population from the cities and towns of Kyiv and Chernihiv regions. Because this made provision of special eye care to military and civilian casualties difficult and sometimes impossible, urgent actions were required to manage complications of combat-related injuries in these casualties. Under these conditions, vast numbers of the wounded admitted to the NMMCC “MMCH” required further treatment, although an insufficient number of beds required evacuating many of them to a higher level (to healthcare facilities in the central and western Ukrainian regions and facilities of the NAMS of Ukraine for further medical care and treatment, eye surgery and military medical expert examination).

The Eye Clinic of the NMMCC “MMCH” has been functioning as a Level-3 facility to provide special medical care to the wounded from the early days of the war; however, (a) the proximity to the front line, (b) vast numbers of the wounded, and (c) the requirement for fast, adequate decisions on priorities and amount of surgery and the necessity of performing surgery in a multidisciplinary surgery team to be done during frequent air-raid alarms under threat of artillery shelling resulted in limited time and human capabilities available. It is in that time period that by far the most common surgical procedure was PSTW in the eye and adnexa (for IOFB removal) and wound closure (75.0%), followed by extraction of the crystalline lens and IOL implantation (10.0%), evisceration or enucleation (9.0%), and vitreoretinal surgery (6.0%). In that period of time, a delay in vitreoretinal surgery for COT was feasible due to insufficient time to perform this durable procedure. After having a short-time antibacterial and anti-inflammatory post-operative treatment, patients were evacuated for further treatment to MMCCs and military hospitals farther from the front-line, whenever possible.

After the enemy’s retreat from Kyiv, Chernihiv and Sumy, the distance from the NMMCC “MMCH” to the front line increased, and the eye service went back to functioning as a Level 4 facility providing tertiary eye care and rehabilitation.

Analysis of the distribution of casualties with combat ocular and adnexal trauma by causative agent

We compared two periods, the period of antiterrorist operation (ATO) and operation of united forces (OUF) (2014-2021) and the period of the full-scale Russian invasion and the attempted encirclement of Kyiv (February-

April, 2022) to identify the patterns of combat-related eye injuries related to these periods. There was an increase in the incidences of (a) penetrating injury with the presence of an IOFB and (b) binocular injury with destruction of the globe, likely due to active combat activities and wide use of high-kinetic-energy weapons (powerful long-range artillery systems, mortars, multiple rocket launchers, and ballistic and high-precision missiles with heavy warheads) by the enemy. Fragments from explosive munitions of these systems have a high velocity and large blast radius, and consequently, a great lethal force.

Eye cases represented 8.7% of the total number of wounded for the period of ATO/OUF (2014-2021). Penetrating ocular injuries represented almost half (49.7%) of all ocular injuries. Particularly, penetrating injuries with an IOFB and penetrating injuries without an IOFB accounted for 39.4% and 10.2% of all ocular injuries, respectively. In addition, 26.6% of ocular injuries were bilateral. Moreover, non-penetrating injuries of the eye and adnexa accounted for 48%, and eye destruction, for 2.4% of all ocular injuries.

During the period of ATO/OUF (2014-2021), combat-related eye injuries due to mine blasts were the most common (44.3%), followed by fragment injuries (40.5%), whereas combat-related bullet injuries (8.6%), burn injuries (4.9%) to the and blunt injuries (1.7%) were substantially less common. Although the percentage contribution of bullet injuries was relatively small, it should be noted that they are severe and can lead to death due to proximity to the brain and major head and neck vessels. There was an increase in the number and percentage of wounded with eye injuries with the beginning of the full-scale Russian invasion (February-April 2022), with almost tenth (9.4%) of the total number of wounded having a combat ocular and adnexal trauma. Penetrating ocular injuries represented more than half (54.0%) of all ocular injuries, with the percentage of penetrating injuries with an IOFB increasing to 43.3%. In addition, the percentage of binocular injuries and eye destruction increased to 29.8%.

Moreover, the proportions of combat-related eye injuries due to mine blasts and burn injuries increased to 46.7% and 6.3%, respectively, whereas the proportion of bullet injuries decreased to 7.1%, and we believe that these changes were caused by the intensity and defensive nature of combat actions with a more frequent use of explosive weapons. The above causes also led to an increase in the percentage of combat-related injuries of multiple systems from 77.2% to 81.4%.

Adapting the general principles of treatment of combat ocular and adnexal trauma to the conditions of actual combat actions

The first step in the treatment of a patient with COR was to perform primary surgical treatment of wounds including wound closure (early attempted removal of an IOFB, especially from the posterior segment, should be not harmful than delayed) and lid wound suturing. At this step,

it was important to prevent corneal damage from rubbing of the suture material in order to avoid the risk of corneal erosion and/or opacification with potential subsequent deterioration of visualization (especially in vitreoretinal surgery) at subsequent steps. This was achieved by placing suture nodes away from the cornea or applying a bandage soft contact lens (SCL). If the lens capsule was found to be damaged, the crystalline lens mass was to be removed from the anterior chamber. Evisceration or enucleation was performed in case of massive trauma with destruction of the globe. Antibacterial and anti-inflammatory therapy was administered postoperatively.

If required, surgical repeat surgical treatment of wounds, suture replacement, phacoemulsification of an opacified or damaged lens, iridoplasty, vitrectomy (for IOFB removal, vitreous hemorrhage, retinal detachment and/or other problems with the retina) with various temporal endotamponades were performed after evacuation of the wounded to higher levels of care. If it was not possible to perform complete treatment in a single-stage surgical procedure, surgeons considered to perform a multi-stage procedure. A temporary keratoprosthesis surgery was performed if the cornea was not transparent. Barrier laser photocoagulation was performed if required after vitrectomy or as a stand-alone procedure. If corneal melting occurred early after combat-related eye injury, a casualty was referred to the Filatov institute of Eye Disease and Tissue therapy for determining the feasibility of receiving corneal transplantation in the patient, particularly in the context of comprehensive reconstructive treatment for non-transparency and/or defective transparency of the central optic portion of the cornea. Treatment outcomes were better when eye casualties could have an early single-stage evacuation to the destination point with timely provision of special care, which is especially important in bilateral severe eye injuries with a threat of irreversible visual function loss.

In different periods of combat activities on the territory of Ukraine, during changes in the combat situation requiring an urgent optimization of the levels of the support system for treatment and evacuation of casualties, some issues for discussion and mistakes were identified with regard to providing medical care for COT.

Discussion

The flexibility of the support system for treatment and evacuation of casualties with combat ocular and adnexal injuries was undoubtedly beneficial. Some tactical mistakes made, especially in the period of combat actions at the outskirts of Kyiv, most often were associated with exceeding the required amount of medical care at Levels 1 and 2 of medical evacuation, especially when first medical aid was provided at special medical care facilities and units of the city. There were cases of improper medical record keeping with failures to make entries to specify the eye surgery procedure or to report the extent of surgery; most often, this was related to the wounded with destruction of the globe who had undergone tarsorrhaphy at Levels

1 and 2 of medical evacuation. In addition, with regard to the wounded with concomitant injuries associated with ocular injury, some of these wounded were not timely seen by an ophthalmologist, or changes in their visual functions were not ophthalmologically monitored because these patients were receiving surgical treatment at another (i.e., non-ophthalmological) special department, and their combat-related ocular injury was not timely detected due to various reasons.

Moreover, of note are technical mistakes made due to failure to observe the principles of primary surgical treatment of ocular and adnexal tissues with incorrect arrangement of tissues and/or suturing inappropriate tissues. There were cases of introduction of silicone into the eye with funnel retinal detachment having a non-flat retina, which made subsequent flattening of the retina almost an impossible task in these eyes. The experience that we have received and the problems that we have identified should be taken into account while planning support measures for evacuation and treatment of casualties during potential combat around a metropolitan city.

Conclusion

First, our comparative analysis of the flexible support system for treatment and evacuation of casualties under combat actions (particularly, during the defense of the metropolitan area of Kyiv), demonstrated the efficacy of the algorithms and standards recommended by NATO.

Second, the front line advancing to the outskirts of the city and changes in the combat situation in Chernihiv and Sumy regions required making urgent managing decisions on introducing corrections in the classical four-level support system for treatment and evacuation of casualties (particularly, those with COT), which caused the NMMCC "MMCH" to unite and coordinate their care efforts with those of the special medical facilities of the city. In addition, there were changes in the amount of eye care provided, with a change to level 3 and subsequently in the opposite direction to level 4, within a very short period, which did not cause difficulties for the military medical personnel.

Third, combat actions at the outskirts of Kyiv and in Kyiv region resulted in an increase in the percentage of the wounded with combat ocular and adnexal trauma to 9.4% of the total number of wounded, with more than half (54%) of them represented by penetrating injuries, particularly those with an IOFB (43.3%).

In addition, the percentage of binocular injuries and eye destruction increased to 29.8% and the percentage of multiple combat-related injuries to 81.4%, likely primarily due to wide use of high-kinetic-energy weapons with high-velocity fragments from explosive munitions of these systems having wide-area effects.

Fourth, we found that treatment outcomes were better when eye casualties (a) had an early single-stage evacuation to the destination point and (b) were timely provided with special care, which is especially important

in bilateral severe eye injuries with a threat of irreversible visual function loss.

Finally, there was a need for analysis and solution of the identified problems and shortcomings caused primarily by impaired logistics of the support of evacuation of and care for casualties, shortage of medical staff (particularly, specialty doctors), medications and medical supplies, particularly at the territories having temporarily blocked communications.

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