NATO STANDARD

AAMedP-1.9

INITIAL INVESTIGATION AND IMMEDIATE MANAGEMENT OF LASER EYE DAMAGE IN AIRCREW

Edition B, Version 1

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NORTH ATLANTIC TREATY ORGANIZATION

ALLIED AEROMEDICAL PUBLICATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

11 November 2019

1. The enclosed Allied Aeromedical Publication AAMedP-1.9, Edition B, Version 1, INITIAL INVESTIGATION AND IMMEDIATE MANAGEMENT OF LASER EYE DAMAGE IN AIRCREW, which has been approved by the nations in the Military Committee Air Standardization Board (MCASB), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 7165.

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4. This publication shall be handled in accordance with C-M(2002)60.

Zoltán GULYÁS
Brigadier General, HUNAF
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
FRA	Defects detected in the initial examination must lead to a consultation with a specialist in ophthalmology who will be the only one who can precisely assess the damage and decide whether the individual can return to duty. Early aeromedical evacuation to a facility specialized in ophthalmology can be required in the absence of a suitable field facility.
SVN	Flight personnel that suffered eye injury with laser will consult with specialist ophthalmologist. After consultation with specialist ophthalmologist, flight surgeon will decide about fly to fly/not fit to fly status of flight personnel.
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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

A laser (light amplification by stimulated emission of radiation) is a device that emits an intense narrow beam of light at discrete wavelengths which range from the near ultraviolet (invisible to the eye) through the color spectrum (visible) and into the far infrared spectrum (also invisible). The rapid growth of laser science and engineering has resulted in the increased use of lasers by the military. At present, laser range finders and target designators are used in force exercises, where accidental injury to the eye may occur. It is possible that in future engagements lasers will be used directly against our forces. Thus, their effects on the health and mission performance of our aircrews will be of particular concern. Laser energy outputs are sufficient to produce significant eye injury. Even at distances of a kilometer aircrews partially protected by windscreens and canopies are still at risk from near infrared and visible lasers. Other personnel, such as ground defence forces, are additionally at risk from ultraviolet and far infrared lasers.

1.2 PRINCIPLES OF LASER ENERGY

Laser light entering the eye through a 2-7 mm pupil to a retinal image about 5-30 microns in diameter can increase the retinal irradiance by a factor of at least 100,000 over that which is incident at the cornea. This relatively low-output laser can produce serious eye injury simply because the eye focuses the beam and increases the retinal irradiance. The use of light-gathering and magnifying optical instruments, such as binoculars, and other optical sighting devices increases the danger from exposures because they collect more of the laser light and further increase the ocular irradiance.

1.3 LASER EFFECTS ON VISION

1.3.1 Glare or Laser Dazzle

Visible laser light can interfere with vision even at low energies which do not produce eye damage. Exposure to CW or rapidly pulsed, visible laser light can produce a glare, such as that produced by the sun, searchlights, or headlights.

1.3.2 Flash Blindness and After-image

Visible laser light can also produce a lingering, yet temporary, visual loss associated with spatially localized after-effects, similar to that produced by flashbulbs. These after-effects can occur at exposure levels which do not cause eye damage.

a. **Flash Blindness**: One after effect, known as “flash blindness” is the inability to detect or resolve a visual target following exposure to a bright light.

b. **After-image**: The other after effect, often confused with flash blindness, is "after-image". After-images are the perception of light, dark, or coloured spots after exposure to a bright light. Small after-images, through which one can see, may persist for minutes, hours, or days. After-images are very dynamic and can change in colour ("flight of colour"), size, and intensity depending upon the background being viewed. It is difficult to correlate the colours of after-images with specific laser wavelengths. After-images are often annoying and distracting but are unlikely to cause a visual decrement.

1.3.3 Visual Loss from Damage

1. The wavelength of the laser determines which structure in the eye absorbs the radiation and, therefore, is at risk of damage. Visible lasers (and near-infrared) nearly exclusively affect the retina, while invisible lasers affect the cornea and/or the lens. Any laser damage can cause variable degradations in vision, dependent on the site and degree of damage.

a. **Corneal Damage**: Corneal damage may significantly degrade vision due to increased light scatter from opacities or due to gross rupture. In addition, iritis (intraocular inflammation), seen in association with corneal injuries, may cause photophobia, pain, and miosis (small pupil).

b. **Lens Damage**. Radiation absorbed by the lens increases the risk of a cataract developing later in life.

c. **Retinal Damage**: In the case of retinal damage, the severity of visual loss will depend upon the proximity and extent of the damage to the fovea. Functionally significant loss of vision usually occurs only if the burn directly affects the fovea. The expected minimum burn size (30-100 microns) for a low-power exposure to the parafoveal area may be expected to reduce vision to approximately 20/40 for high-contrast targets, but some reports detail greater visual acuity degradation and others report less. Nevertheless, a direct laser burn to the foveola would definitely alter vision. If the retinal damage includes haemorrhages, the visual loss may be more profound, as the blood may block the passage of light to uninjured portions of the retina.

2. Central visual field defects caused by damage to the posterior pole will be noticeable and may be distracting or disabling, depending upon whether the foveola is affected. These central defects can be detected and characterized quite accurately with a simple test – the Amsler Grid.

3. At operationally relevant distances, a laser's light energy is likely to affect both eyes, unless one eye is occluded or otherwise protected, because the laser beam's diameter, will be wider than the inter-pupillary distance. Laser pointers at short ranges usually cause injury in one eye because the beam is narrow and only one eye is exposed to the laser.

4. Of note, laser pointers have become inexpensive, and now often have power output of more than 50 mW. Therefore, such lasers are much more likely to cause damage at close ranges than classroom Class 3R or IIIa lasers with a max power output of 5 mW. For example, laser injuries in children and multiple laser lesions are becoming much more commonplace. Infra-red, green or blue light hand-held laser devices are the most dangerous wavelengths for the macular region; various macular injuries have been reported from focal outer retinal pigment epithelium disturbance at the macula, to full thickness macular hole.

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CHAPTER 2 MEDICAL MANAGEMENT OF COMBAT LASER EYE INJURIES

2.1 INITIAL AIRCREW EXAMINATION

All aircrew are at risk of laser exposure. It is therefore recommended that the Amsler Grid Test be included in the initial ophthalmic assessment of aircrew applicants, in order to document a baseline recording. It is also recommended that the Amsler Grid Test be performed when the aircrew member ceases to be employed in a laser risk environment. By using these “entry” and “exit” tests a time frame of possible laser eye damage may be established which would assist in future evaluations such as compensation claims.

2.2 POST-INCIDENT HISTORY

2.2.1 Potential Symptoms

Symptoms will vary depending upon the location and severity of injury. Patients may give a history of experiencing glare, flash blindness, decreased vision, pain, or any combination. When seen by medical personnel, they may continue to complain of after-images, blurred vision, photophobia, pain, or profound loss of vision. Obvious lesions, such as skin and corneal burns, and/or retinal burns and retinal haemorrhages make the diagnosis more certain, especially when accompanied by a history of seeing bright, coloured lights.

2.2.2 History

A full history should be ascertained using questions in Annex A.

2.3 POST-INCIDENT EXAMINATION

2.3.1 External Examination

The periocular tissue (lids and conjunctiva) and anterior segment (cornea, anterior chamber, and iris) of the eyes are evaluated on external examination. Laser injuries to the cornea will usually be limited to the area of the cornea within the palpebral fissure. Redness of the conjunctiva suggests ocular inflammation, possibly secondary to injury that may be external or internal. A small pupil in the inflamed eye suggests, but does not confirm, the diagnosis of intraocular inflammation (iritis). The anterior chamber should be examined for blood.

2.3.2 Snellen Acuity

A “standard” eye chart (for distance or near) is used to measure visual resolution in each eye. The 20/20 characters on the chart have a letter height which projects an angle of 5 minutes of arc on the retina with 1 minute of arc features which, it is assumed, must be seen to correctly read the letters. This procedure tests foveal vision.

2.3.3 Confrontation Visual Fields

Finger-counting confrontation visual fields can be accomplished by the examiner facing the patient (at 1 m) and each closing the opposing eye. The examiner then extends his hands to the sides where he can see them with his open eye. He then flashes different numbers of fingers in each quadrant and elicits the patient's response. The same procedure is accomplished on the opposite eye. This procedure may help to identify gross peripheral visual field defects such as might be caused by a large hemorrhage, if the patient is unable to see the fingers of the examiner.

2.3.4 Amsler Grid

The Amsler Grid is a printed grid on paper with a central spot, which is reproduced at Annex B. It is to be held 30 cm (12 in) from the eye and viewed monocularly by the patient, who must be instructed to focus on the central spot. It can be used to plot areas of retinal injury or vitreous haemorrhage in the posterior pole (central 20 degrees). The Amsler Grid is sufficiently sensitive that it can detect lesions as small as 50 microns. Each eye should be tested separately. The patient will report seeing visual distortion of the lines or a scotoma corresponding to the area of the posterior pole injured. The perceived visual field is upside-down and backwards to the corresponding retina, i.e., super temporal retinal defects will be "seen" by the patient in his inferonasal field. The foveola corresponds to the central point of the visual field. Abnormalities in testing may indicate old stable conditions or new retinal/vitreal pathology. Bilateral abnormalities in the same areas of the visual field support the diagnosis of a laser eye injury.

2.3.5 Ophthalmoscopy

Using the direct ophthalmoscope, the examiner should be able to obtain a clear and undistorted view of the posterior pole in undamaged or mildly damaged eyes. Poor visualization of the posterior pole can result from corneal or lens opacities or a vitreal haemorrhage. Pharmacologic dilation may be used to facilitate this examination.

2.4 SPECIAL TESTS

2.4.1 Fluorescein Staining

Fluorescein staining of the cornea will be helpful in detecting corneal epithelial defects in patients complaining of an ocular foreign-body or "scratchy" sensation. (It would be naturally washed out by tearing following application and does not interfere with the wound healing process.)

2.4.2 **Stereopsis**

An evaluation of stereopsis, if test equipment such as the VTA-DP test or the AO vectograph (distance measurements) or the Verhoeff apparatus or Randot Titmus (near measurements) is available, may give indirect evidence of retinal damage: the results are a good estimate of binocular visual function, as well as a test of foveal vision, as each eye must usually be at least 20/25 for an individual to pass.

2.4.3 **Colour Vision**

Colour vision testing is unlikely to play a significant role in the assessment of a significant laser injury because damage significant enough to affect colour vision would be expected to have produced a large central scotoma readily detectable by the Amsler grid. Nevertheless, it may be an adjunct to identifying a central retinal injury. When used, it should be capable of testing for both red/green and blue/yellow deficiencies, and each eye must be tested separately.

2.4.4 **Fictitious Visual Loss**

Some individuals may deliberately feign a nonexistent visual loss, while other may pretend that a condition is worse than it really is. Some individuals on the other hand, may deny the existence of a disability. In testing for total blindness (if monocular, you should cover the "good" eye), several simple objective tests can be done to demonstrate some vision. These include testing the pupillary reflexes; proprioception tests; and the optokinetic nystagmus test (drum or tape) where the reflex can seldom be suppressed. Any functional visual loss requires full assessment by an ophthalmologist.

2.5 **PHYSICAL FINDINGS**

1. It is likely that no clinical findings will be apparent if only subjective symptoms (glare, flash blindness, or after-images) occurred as the result of a non-damaging exposure, or if there is retinal damage or haemorrhage outside the fine vision area of the posterior pole; the latter may be asymptomatic and not seen with the direct ophthalmoscope. OCT images may be informative in case of apparently "normal" fundus exam and may also be useful for systematic classification of such retinal injuries. OCT findings may aid the early diagnosis and provision of advice on prognosis but also potential medical or surgical treatment.

2. Clinical findings due to damage may be variable and include the following: isolated, rows, or groups of retinal burns; retinal/vitreal haemorrhages; and superficial or deep burns of the skin and cornea.

2.6 TREATMENT

2.6.1 Corneal Injuries

Corneal injuries are not expected from visible-wavelength lasers: after seeing a visible-wavelength laser an abrasion from scratching the eye would be more likely than a corneal burn. However, the treatment of any corneal burn would include topical antibiotic ointment and an eye patch, with NSAIDs and mydriatics for pain relief. Steroids are not recommended since they may promote local infection.

2.6.2 Retinal Injuries

Of note, retinal injuries are usually painless. At present, the treatment for laser injuries to the retina/choroid is not well-defined. Ocular and oral corticosteroids have not been proven effective for the treatment of retinal burns or haemorrhages. The use of eye patches for retinal damage is discouraged. Patching deprives the patient of his residual vision which may be quite good. It also has the effect of magnifying the visual impairment to the aircrew member and increasing his dependence on others. Personnel with vitreal haemorrhages should be maintained at bed rest with their heads positioned so that the blood settles away from the visual axis, particularly for the first few days. Delayed or tertiary treatment of vitreous haemorrhage consists of vitrectomy and associated procedures, but only for those eyes that do not have adequate spontaneous absorption of the blood. For haemorrhages, retinal holes and severe retinal damage, anti-VEGF (Vascular Endothelial Growth Factor) or steroid injections are sometimes prescribed. A side effect of steroid injections is cataract formation. NSAIDS may be of value for treating and possibly promoting recovery for small laser retinal burns.

2.7 RETURN-TO-DUTY CRITERIA

1. An assessment of visual function and other findings, such as pain, should be made to determine how effective each individual will be to his unit. Personnel with best corrected visual acuities of at least 20/40 in the better eye and no worse than 20/400 in the other are returnable to duty. The specific duty they perform will be determined by the unit and the medical officer.

2. Aviators whose vision has been affected by a laser may remain at the front, but whether or not they perform aviation duties will be determined by the degree of vision loss, the extent of central visual field loss, whether the condition(s) is bilateral, the duties they are required to perform in the air, and the intensity of the engagement. Aviators with large contained retinal or vitreous haemorrhages should not fly, because the blood may shift and occlude the visual axis. The elective return of pilots to flight duty should be based on national standards, but the following short chart can serve as a general guide:

Better Eye	Worse Eye	Amsler Grid	Stereopsis	Mission
20/20	20/30	Abnormal one eye	Normal	All
20/25	20/30	Abnormal both eyes	Normal	Air to ground or transport
20/30	20/40	Abnormal both eyes	Abnormal	Emergency evacuation of aircraft in daylight

Table 1: Recommended Disposal

3. Other combinations of visual acuities are possible. The flight surgeon must use his best judgment, understanding the flying demands, in returning individuals with eye damage to flying duties. Aviators with 20/40 vision in their better eye should probably not be returned to flying duties. Even if reasonable visual acuity is retained, bilateral foveal injuries may result in small scotomas of operational relevance. Furthermore, laser injuries may cause a loss of confidence in a pilot with previously excellent vision.

2.8. PSYCHOLOGICAL IMPACT

1. The use of laser weapons has the potential for having a significant psychological impact on aircrew. Much of this impact can be alleviated by proper, well-directed education efforts. Care should be taken by the examiner to correctly diagnose laser lesions that are acute, as opposed to pre-existing retinal anomalies, lesions, or disease. When there are no visual problems, and no signs of damage, aircrew should be reassured that they are not expected to develop future problems as a result of sighting a laser.

2. Some laser effects are only temporary and non-injurious. Acute visual loss due to laser injury may improve with time, and injured personnel should be given that hope. In addition, they should be reassured that it is unlikely that they will lose all vision and be "blind." The chief source of expert knowledge and education for commanders and their aircrew members will be medical personnel, particularly flight surgeons, ophthalmologists, and optometrists. The flight surgeon should actively participate in education sessions designed to teach the aircrew about lasers, their effects, and methods of self-protection.

3. A laser attack has the potential for occurring as a total surprise. Steps must be taken before engagement to alleviate fears of "death ray" lasers and helplessness in the air or on the battlefield due to loss of vision. Use of protective goggles and visors appropriate to the threat must be emphasized, and aircrew should be reassured that the use of such devices will protect their eyes (at least against the anticipated wavelengths). Furthermore, aircrew should be reminded frequently to consciously resist the natural inclination to look into any laser beam encountered.

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ANNEX A MEDICAL DEBRIEFING FOR SUSPECTED LASER INCIDENTS

A.1. CIRCUMSTANCES

1. Did you see a bright light? How bright was it, like the sun, a full moon, or automobile headlights at night? Were there other light sources on the platform (such as running lights or navigation lights) and were they brighter or dimmer?

2. What was the colour(s) of the light? Was it uniform in colour? Did the colour(s) change during the exposure?

3. Did the light come on suddenly, and did it become brighter as you approached it?

4. Was the light continuous or did it seem to flicker? If it flickered, how rapidly and regularly?

5. For how long was the light on?

6. From what did the light emanate? Was it from an airplane, helicopter, tank, etc.?

7. How would you describe the brightness of the light? Was it equally bright in all areas or was it brighter in one area?

8. How far away was the light source? Was it moving?

9. At what time of the day did the incident occur?

10. What was the visibility? What were the atmospheric conditions - clear, overcast, rainy, foggy, hazy, sunny?

11. What was between the light source and your eyes - windscreen, glasses, head-up display, lenses, binoculars, filters, visors, or goggles? Describe them in great detail (for example, 2X binoculars, standard issue sun visor, prescription glasses, hazy windscreen). Were any of these things damaged or caused to malfunction by the light?

12. Did you try to move out of the light beam? What evasive manoeuvres did you attempt? Did the beam follow you as you tried to move away? How successful were you in avoiding it?

13. Was the light coming directly from its source or did it appear to be reflected off other surfaces? Did you notice multiple sources of light?

14. Did the light fill your cockpit or compartment? How wide was the beam at its source? How wide was the beam once it reached you?

A.2. POSSIBLE EFFECTS

1. How long did you look into the light beam? Did you look straight into the light beam or off to the side?

2. What tasks were you doing when the exposure occurred? Did the light prevent or hamper you from doing those tasks, or was the light more of an annoyance?

3. Were both eyes exposed? If not, describe the difference between the light exposures (for example, one eye was shielded or closed, or on the side away from the light beam). Describe any difference in the effects on either eye.

4. Were you startled or disoriented when the light appeared?

5. Was the light so bright that you had to blink or squint, close your eyes, or look away? Was the light painful? Describe the pain. For how long did the pain persist after the light exposure?

6. Was your vision affected while the light was on? How much of your visual field was affected? What types of things could you see or not see? Did you notice the colour of instruments or targets change? Did the changes to your vision remain constant or vary during the exposure? If the light source was mounted on a platform (aircraft, ground vehicle or building), how much of the platform was obscured? [Note: Recommend that the word "dazzle" not be used because its definition varies greatly; "glare" is the preferred word.]

7. Did your vision remain affected after the light was extinguished? If so, for how long and how did you estimate the time? How much of your visual field was affected? What types of things could you see or not see (watch, hand, altimeter, map, etc.)? Did you notice after-images ("spots before your eyes")? If so, how long did they last, what did they look like, and what were their size, shape and position in your visual field? Describe how your vision was affected 10 seconds after the light exposure ended, 30 seconds afterwards, 1 minute, 2 minutes, etc.?

8. Were there any lingering (hours or days) visual effects? If so, were the effects continuous or intermittent? Did you have problems reading or seeing in low-light conditions? How long until you were able to see normally again?

9. Did you notice any reddening, warming, or burns to your skin?

10. Describe the condition of your vision before the incident? Do you wear glasses? Are you taking any medications?

11. Did you seek medical attention following the incident? Where and when were you examined? Who performed the examination? Was the examiner an ophthalmologist or optometrist? What were the clinical findings?

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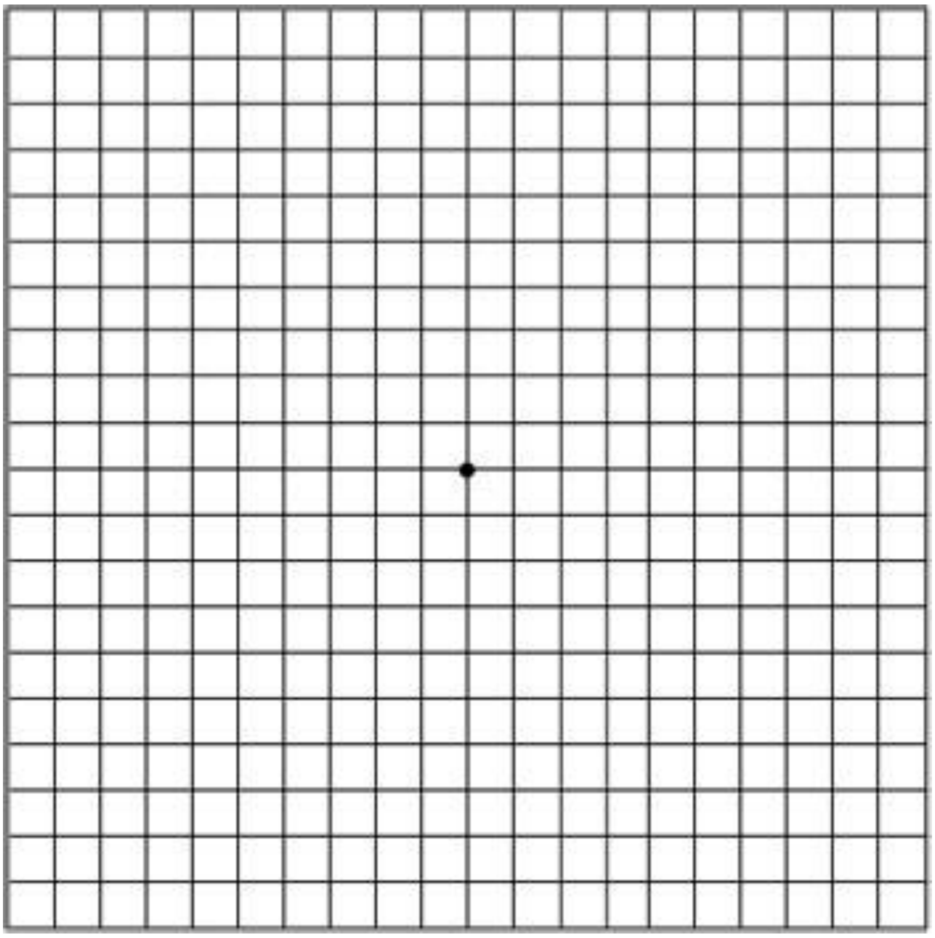
ANNEX B AMSLER GRID



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