IN DEPTH

CHEMICAL WEAPONS AND THEIR EFFECTS ON THE EYE AND VISION

Chemical weapons, developed and extensively used for disabling and often killing large groups of Service members during World War I, have caused more than one million casualties worldwide over the past 100 years. While not commonly used in modern warfare, the U.S. military continues to actively train Service members for chemical weapon attacks. Certain chemical agents, in the form of tear gas and similar irritating agents have become a routine part of crowd control. In recent years, the threat of chemical weapons, both as an instrument of war and of terrorism, has been pushed into the media forefront. Reports from the Iran-Iraq conflict during the 1980’s vividly describe the civilian and military casualties that ensued when the Iraqi government employed riot control agents (RCA), ortho-chlorobenzylidene malononitrile (CS), mustard gas and for the first time on the battlefield, the nerve agent Tabun which can kill within minutes, against Iranian targets. Additionally, during the late 1980’s, Iraq used mustard gas, Sarin and Tabun on the Kurdish city of Halabja which led to the death of almost 5,000 Iraqi Kurds; survivors sustained long-term health problems. Concerns about their use arose again during the Gulf War when it was known that the Iraqi government had enlarged its stockpile left over from the Iran-Iraq conflict. Reports from Japan describing the synthesis of and use of Sarin, VX and hydrogen cyanide gas by the terrorist group Aum Shinrikyo in the mid-90’s on civilian populations have provided further evidence of the devastating effects of these weapons. While chemical weapons have not been a factor during military actions in Afghanistan, recent events in Syria, where nerve gas was used against the civilian population, have made the world aware of their horrific effects. These events have been comprehensively illustrated by multiple media reports and photographic evidence, as well as by first-hand descriptions from survivors. The overwhelming evidence that chemical weapons, when available, may be used to further the aims of both terrorist and governments supports the continued need for: vigilance regarding possession and use of these agents; education...
regarding their use and effects on the body, including
the eye; and protective measures for the individuals
and populations they threaten.

Stockpiles Remain Despite Ban
Although 98 percent of UN member states have
signed the UN’s Chemical Weapons Convention
prohibiting the manufacture, stockpiling and use of
chemical and biological weapons,3, 4 stockpiles of
these weapons remain in places such as Syria and
North Korea. While both the U.S. and Russia have
active programs to destroy all such weapons, this
effort is still incomplete due to issues and costs
associated with transportation safety and completion
of an incinerator for weapon destruction. Disposal
continues to involve dumping at various deep ocean
sites. While generally safe and effective, there are
occasional reports of accidental recovery of these
weapons by fishermen.

Recognizing Signs and Symptoms of
Chemical Weapon Exposure
There are several chemical agent alarm kits that exist
to provide warning of a dispersed chemical agent.
However, these are not universally available, particu-
larly in civilian communities. For this reason it is
important to know the initial signs and symptoms of
chemical weapon exposure. The eye is particularly
vulnerable to these agents and is often where the first
indications of exposure are shown. The non-keratin-
ized epithelium of the conjunctiva and cornea rapidly
absorb chemical agents, particularly mustard gas and
other blistering agents or ocular irritants such as tear
gas. Immediate visual symptoms include pain, tearing, redness
and blurred vision.”

Following disgraces at the Abu
Ghraib prison, the U.S. military
changed its approach to the care
and treatment of detainees. These
changes included the medical services
provided to detainees, including
optometry. These services were trans-
ferr ed to Cropper Hospital and Camp
Cropper Theater Internment Facility
which was established in 2006 after
Abu Ghraib prison closed.

In this article, published in the
June 2012 issue of Military Medicine,
LTC Thomas White and LTC James
Elledge detail the demographics of the
Camp Cropper detainees, and the
Optometric services provided to them
between July 23, 2009 and May 11,
2010, by the 14th Combat Support
Hospital (CSH) Optometry Service.

White and Elledge’s data, which
were derived from the Armed Forces
Health Longitudinal Technology Appli-
cation -Iraq Theater (AHLTA-T)
electronic medical record, show that
the population served consisted
primarily of male Iraqi detainees. For
the majority of them the eye
examination they received at Camp
Cropper was their first ever visual and
ocular health examination.

Via AHLTA-T, White and Elledge
identified a total of 1,785 patient
cases. The patients were on average
33 years of age and most commonly
received a diagnosis of hyperopia.
The Optometry Service at Camp
Cropper had two rooms dedicated for
examination and treatment each
equipped with modern up-to-date elec-
tronic optometric lane examination
equipment. Detainees were provided
eyeglasses, eye medications and
referral for treatment of medical condi-
tions including ophthalmic surgical care.
If ophthalmic surgical care was
warranted, the detainee was flown in a
secure fashion (with medical and secu-
rity escort) to Air Force Theater Hospital
at Joint Base Balad for treatment.

The mission to provide compas-
sionate, caring and comprehensive
health care played a significant role in
helping to win the hearts and minds of
the detainees that passed through
Camp Cropper’s gates.
While the CDC notes that there are a number of categories of hazardous chemicals for which emergency preparedness and response is needed (Table 1), there are historically four primary classes of chemical weapons that have been used in warfare. These include: 1) vesicants (blistering); 2) nerve; 3) blood; and 4) choking agents, each with varying effects on the eye. The first two categories, vesicant and nerve agents, most frequently affect the eye. Blood and choking agents, however, do not have significant ocular effects.

Vesicants (blistering agents), such as sulfur and nitrogen mustards (e.g., mustard gas), lewisite and phosgene are all readily absorbed through the skin, conjunctiva, mucosa, lungs and gastrointestinal tract. These agents target cellular DNA and directly damage the skin, eye, and respiratory systems. Not surprisingly, the eyes are the organ most vulnerable and thus most severely affected. Although both lewisite and phosgene have not been extensively used in modern warfare, phosgene was widely used during WWI. Phosgene is a rapid irritant and when used in combination with other agents may cause a service member to remove their protective mask and be further exposed to a second agent. Mustard gas causes severe inflammation, pain, swelling and both permanent and temporary damage to conjunctival and corneal epithelium—similar to a thermal or acid burn. The resulting temporary or permanent loss of vision easily immobilizes entire armies rendering them ineffective as a fighting force. Typically, mustard gas exposure is not immediately apparent beyond mild skin and ocular

## CHEMICAL CATEGORIES

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**Table 1: CDC Categories of Hazardous Chemical Agents**

**Chemical Weapon Categories and Their Effects on the Eye**

Patients routinely turn to the internet for ophthalmic medical information and advice – it’s accessible, hassle free and cheaper than visiting a physician. But how understandable is the information that it provides?

M. R. Edmunds and colleagues at the University of Birmingham’s Birmingham and Midland Eye Centre in the U.K. shed light on this question in their article, “Readability Assessment of Online Ophthalmic Patient Information”. Their results are not promising. Edmunds and co-investigators evaluated on-line patient oriented information for 16 different ophthalmic conditions gathered from 160 web pages (approximately 10 per condition) identified using the Google search engine. After evaluating a range of readability characteristics - for example, illustrative material, the ability for visually impaired readers to magnify text, word count and other standard readability metrics (e.g., Flesch Reading Ease Score) - they concluded that none of the patient-centered web pages adhered to any of the readability guidelines of the U.S. Department of Health and Human Services (U.S. DHHS). U.S. DHHS recommends that health information be written at or below the sixth grade reading level.

Additionally, only 34 percent of web pages could be enlarged for visually impaired readers and only 59 percent of the pages contained illustrations to aid in the understanding of the material.

In sum, Edmunds et al. show that for most patients, ophthalmic medical information obtained from the internet needs significant modification, translation and guidance to be comprehended by patients and their families.
The ocular effects of mustard gas exposure can recur years after initial exposure, resulting in severe dry eye, inflammation, conjunctival scarring and vision loss from progressive corneal scarring. Visual rehabilitation in severe cases may require corneal transplantation. Mustard gas clings to clothing, buildings and trees, and can persist in a chemically-active state for weeks. This can result in injury to individuals not present at the time of the initial chemical attack. Specialized personal protective clothing and respirators are required for protection when chemical weapons are used, as these agents easily penetrate normal clothing and protective gear and are not filtered out by most respirators. It is essential to remove and destroy all clothing following contamination by chemical weapons and to decontaminate all surfaces contacted by gas. Evacuation from the exposure site is imperative. Treatment following gas exposure depends upon the extent of injury and includes supportive care, oxygen supplementation, ventilation assistance, burn care management in a dedicated burn unit, ophthalmic care (including topical and systemic antibiotics), topical and possibly systemic steroids and aggressive ocular lubrication. While aggressive ocular lubrication may or may not provide relief or treatment from the agent, it is highly recommended to copiously flush the ocular surface during the acute phase after exposure. This should be done continuously until a proper evaluation from an eye care professional can be obtained. Evaluation should be obtained immediately. Exposure to almost all chemical weapons warrants immediate emergency systemic and ocular care. Long term care of the affected eyes and adnexa may include: artificial tear lubrication including higher viscosity tears and gels; topical antibiotics; topical steroids; bandage contact lenses (in the case of corneal epithelial disruption); pressure patch; and topical cycloplegic agents in the case of miosis and/or ciliary spasm. Unlike most military units, the civilian population is usually not knowledgeable on the effects of chemical weapons, so it is important that first and second responders reach out to these vulnerable populations when attacks involving chemical weapons have been carried out.

“Nerve agents, such as Sarin gas (GB) or VX, are significantly more lethal than mustard gas.”

In this article published in the American Journal of Ophthalmology in December of 2013, Pauline Lim and her colleagues discuss a novel use of the PROSE scleral contact lens to help these persistent corneal epithelial defects heal. The acronym PROSE stands for “prosthetic replacement of the ocular surface ecosystem”.

Certain chronic diseases interfere with normal functions of the corneal epithelium, the top corneal layer that is exposed to the outer environment. Persistent corneal epithelial defects are those that fail to resolve. The PROSE scleral lens is a large contact lens that is individually customized according to scleral considerations as well as dimensions of a patient’s cornea. The large-fitting lens “vaults” over the front of the eye leaving an area or reservoir to be filled with specific eye medications or lubricants.

To fill the reservoir beneath the PROSE scleral lens and bathe the damaged cornea, Lim and her colleagues used one drop of a commercially available non-preserved moxifloxacin ophthalmic antibiotic solution to which they added sterile saline. The lens was worn day and night with the exception of one or two brief daily removals for cleaning and fluid exchange.

The average length of PROSE scleral lens treatment was 8.5 days. 17 out of 20 eyes (85 percent) re-epithelialized over the study period. This included 12 eyes in less than 7 days, 3 eyes in 8–14 days, and 2 eyes in more than 14 days. The PROSE scleral lens plus an ophthalmic antibiotic and saline solution appears to be a promising approach for the successful management of persistent corneal epithelial defects.

**BRIEF REVIEW**

**RAPID AND RELIABLE ASSESSMENT OF THE CONTRAST SENSITIVITY FUNCTION ON THE IPAD**


Home testing for vision is now a lot easier, thanks in part to Apple. In this article, Michael Dorr and colleagues at Harvard’s Schepens Eye Research Institute describe how they successfully adapted the standard contrast sensitivity (CSF) test into an efficient and easy to use mobile version on the iPad.

Vision is usually measured using letter acuity, most commonly with the Snellen eye chart, which features the iconic big “E”. Slow vision loss caused by eye-disease, however, is measured more accurately by the CSF test. As its name implies, the test measures how sensitive a person is to contrast.

Dorr and colleagues not only show that the iPad and classic CSF test results are indistinguishable, but also that the iPad version is more reliable.

iPad owners now have a useful and reliable app to test their vision and prevent and manage eye disease, along with email and angry birds.
Protecting Oneself Against Chemical Weapons

Nerve agents, such as Sarin gas (GB) or VX, are significantly more lethal than mustard gas and act by interfering with central nervous system functioning, causing neuromuscular paralysis which ultimately results in death from respiratory paralysis. Many of these agents have been developed from organophosphate insecticides and interfere with cholinesterase by irreversibly binding with acetylcholinesterase and preventing the breakdown of acetylcholine. Acetylcholine is a neurotransmitter that acts as a muscle stimulator. It results in continued, unremitting stimulation of the muscles. Death is usually caused by asphyxia. Exposure occurs through skin absorption, inhalation and ingestion. Unlike the blistering agents, nerve agents tend not to have direct permanent effects on the eye. However, extreme miosis or pinpoint pupil constriction (which can result in a reported “dimming of vision” due to lack of intra-ocular illumination), reduced visual acuity, light sensitivity, and eye pain are often the first signs of exposure to such agents. Prompt identification by becoming aware of these early signs and symptoms with subsequent action can ultimately lead to a significant decrease in loss of lives. Military units and individual troops are usually issued individual treatment kits for managing exposure to nerve agents. These kits include atropine, pralidoxime and diazepam provided as an individual dosage antidote kit to those who might become exposed. In addition to these chemical antidotes, treatment for exposed individuals includes mechanical ventilation, oxygen and suctioning of secretions. Evacuation from the exposure site and the removal and destruction of contaminated clothing are also essential for containing the effects of nerve agents.

Proper protection against and understanding of chemical weapons symptoms can help to minimize injury or death.”

Proper protection against and understanding of chemical weapons symptoms can help to minimize injury or death. Certain biological weapons, such as botulinum toxin, can be produced in aerosolized forms and may be initially confused with a chemical weapon, thus proper education and training are key for understanding appropriate response. Service members, despite being equipped with chemical alarm kits and protective equipment (e.g., protective masks, protective clothing) must

BRIEF REVIEW

EVOLUTION OF EYE-RELATED TERMS


In any culture, words come and go depending on their relevance and importance to understanding and communicating concepts and ideas relevant to the times.

In their paper, “Evolution and Impact of Eye and Vision Terms in Written English” S.G. Leffler, R. Schwartz, B. Stackhouse, Davenport and K. Spetzler examine the introduction of various eye-related terms into English language literature.

Using a list of 254 eye-related root strings, the authors examined Google’s extensive and publically available word frequency database created from the digitized records of scanned books, historical records, newspapers, and documents, to find eye-related words used between 1790 and 2008. They restricted their findings to words that had a usage frequency of no less than 0.00001% (when compared to the usage of all words during that particular period).

Highlights from their findings include the following:

• “Blind” was introduced in 1470 and initially referred to poor vision, until it came to mean absence of light perception in the 19th century
• Many words such as “strabismus”, “chemosis”, “mydriasis”, “myopia” and “staphyloma” did not appear until the 1870s
• Eye color was not commonly noted until the middle of the 1700s. Moreover, references to green and brown eye color only appeared around 1840-1860
• Until 1900, patients were seen by the “oculist”. It was only after 1900 that patients were seen by an “ophthalmologist”
• While “spectacles” were invented in 1200 the word itself did not appear until 1520, “glasses” in 1593, “eyeglass” in 1840 and “eyeglasses” in 1880.
• The development of the ophthalmoscope by Helmholtz in 1850 introduced many new words for describing previously unknown retinal and optic disc findings. In fact, the word “ophthalmoscope” was more frequently used than “otoscope” or “stethoscope” for over 60 years

Leffler and colleagues’ work highlight the many areas of uncharted and, up to now, unseen associations between the introduction of new terms and the then present historical and social environment, and contributes to the understanding of our own historical and intellectual development.
remain vigilant against the threat of chemical agents and be familiar with the early warning signs, including their effects on the eye. Additionally, they should be aware of important policies that strictly prohibit contact lens wear during basic training, field exercises, gas chamber exercises, deployments and/or combat (with exceptions for Air Force Personnel who have written authorization to wear contact lenses in combat). In deployed environments, it is important to remember that civilian populations are particularly vulnerable to the effects of chemical weapons, as these populations lack the necessary knowledge and equipment for protection and treatment. Whenever possible these vulnerable populations must be educated and protected along with our Service members.

REFERENCES


All links in this article were verified March 2014

ARE VISION IMPAIRMENT AND COGNITIVE IMPAIRMENT RELATED?