Medical Issues for NLT

Dr. Marten RISLING, MD
Exp.Traumatology unit,
Department of Defence Medicine,FOI
Retzius väg 8, B1:5, Karolinska institute
S-171 77 Stockholm,
SWEDEN

mrisling@gmail.com

GENERAL CONSIDERATIONS:

To date, non-lethal technologies have seen limited but effective use in military environment. For example, pepper spray has been employed to disperse angry mobs in domestic riot situations and rubber baton rounds have been used in the Bosnian peacekeeping missions. Non-lethal technologies are often used by law enforcement and corrections agencies to end domestic violence conflicts, prevent suicides, and to intervene in other threatening situations. However, the call for improved yet simple, effective technologies and weapons that provide a safe alternative to deadly force continues.

ENABLING A SPECTRUM OF RESPONSE:

If one envisions a terrorist/hostage situation, it is conceivable that the use of riot control agents, or directed energy, or a flash bang devices could quickly and temporarily disorient or disable all people in the crisis, allowing for the capture of the belligerents and safe recovery of hostages and innocents. Likewise, during a potential suicide crisis or threat, use of a blunt impact projectile or an electrical device could quickly and temporarily incapacitate the individual, preventing the suicide and potential harm to law enforcement officers and bystanders.

A spectrum of non-lethal responses must be made available for law enforcement, peacekeeping, counter-proliferation, anti-terrorism (both domestic and international), and the management of relations with rogue nations at all levels of conflict.

The wide spectrum or techniques that may be used and the variety of situations makes it very difficult to predict all possible medical effects of the NLT. It seems fair to assume, that medical effects of NLT in general, must be mild compared the lethal alternatives. However, it is possible that the threshold for use may be lower for NLT. For a safe use of NLT it is important to analyze the possible medical effects before the introduction of at new system. This has not been achieved in most cases. The millimeter wave project at US Air Force is an interesting exception to this role, since this system has been carefully evaluated in animal experiments and with human volunteers, and dose-response data provide a good background for safety-regulations.

INFORMATION ON MEDICAL EFFECTS OF NLT

For other systems, predictions of medical effects can partly to be made from case reports and experience with similar systems. Such data may also have been developed for setting safety-regulations. Safety-regulations are important to prevent a NLW to become a lethal weapon, e.g., as might occur with the inhalation of sedatives.

Reports on medical effects of NLW are hard to find in medical databases: In a search of the website http://www.ncbi.nlm.nih.gov/PubMed/ on Nov 30, 2003,

- Blunt injury – 155 articles indexed at Pub Med during the last 150 days (repeated search Sept 24, 2007 = 245, the last 180 days)
- Weapons – 105 articles indexed at Pub Med during the last 150 days (repeated search Sept 24, 2007 = 110, the last 180 days)
- NLW or non-lethal weapons – 0 articles (repeated search Sept 24, 2007 = 0, the last 180 days)

Thus, articles on specific medical effects of NLT/NLW are hard to find in traditional databases. However a lot of useful data, including medical reports, can be found on the ILEF (International Law Enforcement Forum) Less Lethal Weapons Database:

http://217.35.97.228/agencies.html

A large number of agencies (51 agencies, 24th of September 2007) have supplied data to this database. The International Less Lethal Weapons Database provides convenient online access to original source information regarding less lethal weapons and technologies. This Database is available to Government, Military, Law Enforcement and Research Agencies. Once fully populated, the database aims to be made publicly available with the goal of increasing the overall understanding and awareness of less lethal weapons and technologies.

Fig. 1. The LOGIN webside of the ILEF NLW database.

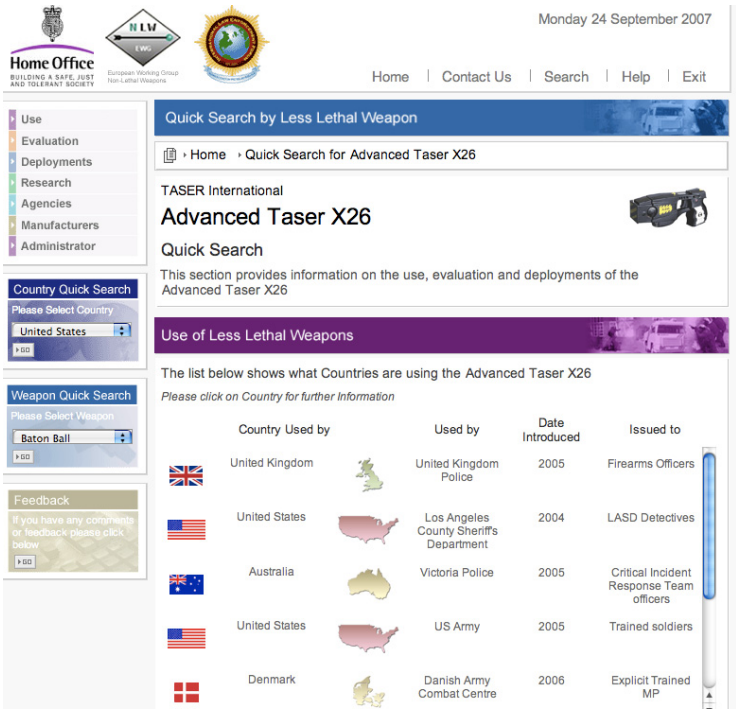

Fig.2. Reports on specfic NLT´s can be selected in the left column. In this example, Advanced TASER X26.

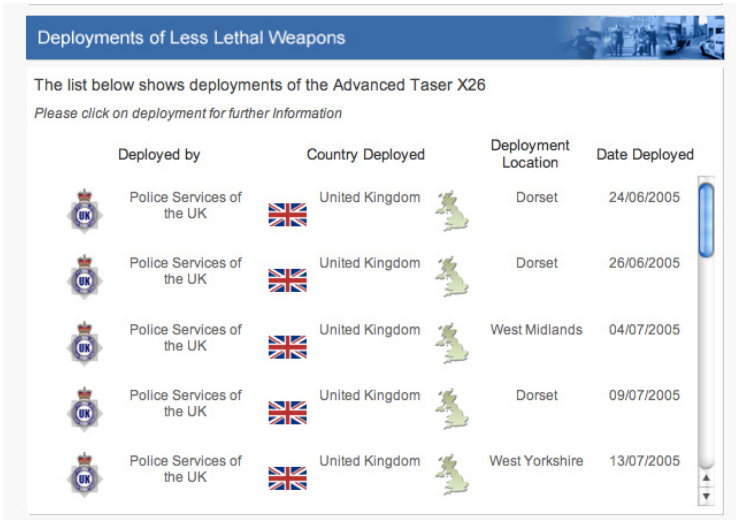

Fig.3. Data on actual deployment in contributing countries can be found. In this example, deployment of Advanced TASER X26 in the UK.

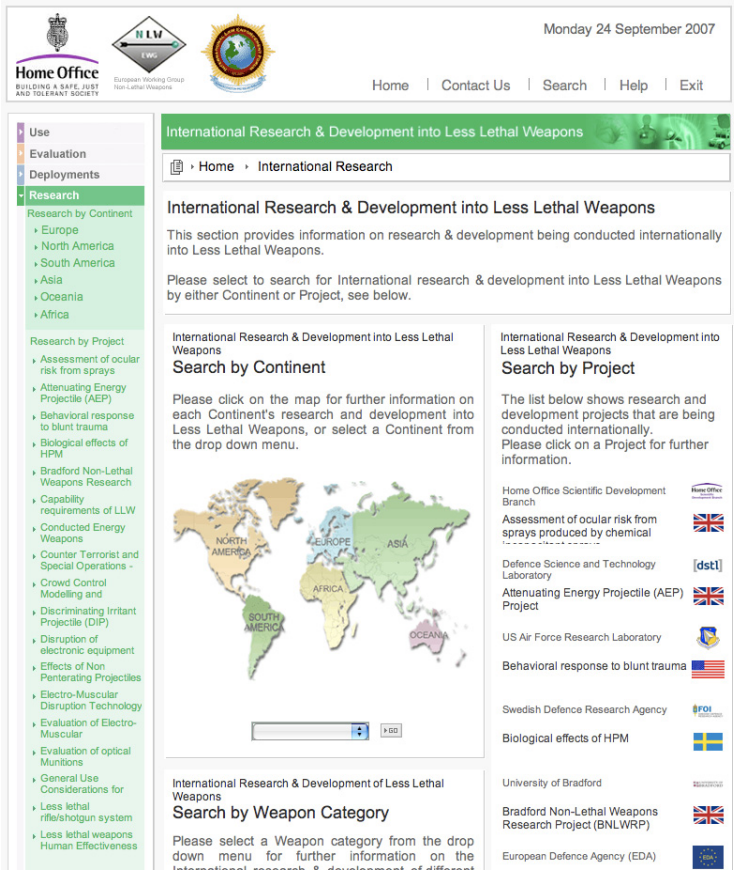

Fig. 4. The search page for research projects, on specific NLT or generic problem such as blunt impact.

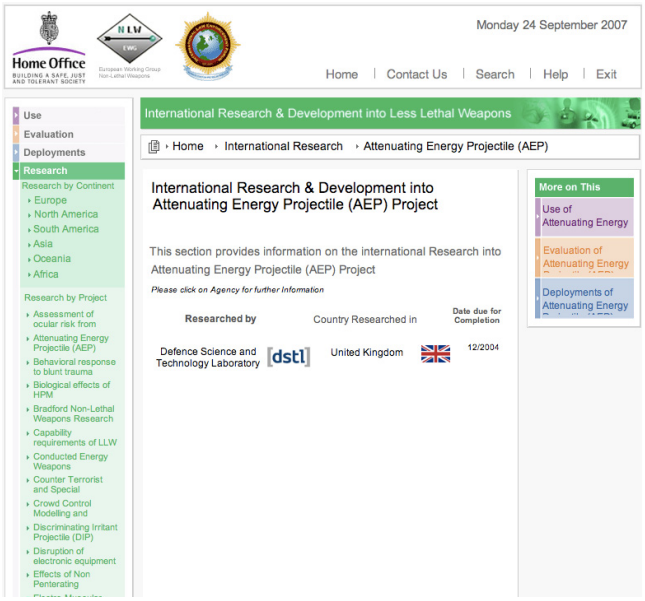

Fig. 5. Example of a search for the Attenuating Energy Projectile (AEP) project.

NEED FOR EVALUATION OF POSSIBLE MEDICAL EFFECTS OF NLT

Safety: The general purpose for medical analysis of different NLW techniques and scenarios is to increase safety and decrease injuries on targeted people (objects), bystanders and operators (personnel). Most non-lethal weapons have a graded effect (from no effect to lethal effect). Proper use can often be achieved after a combination of legal, operative and medical considerations.

Legal: An evaluation of effects and possible injuries is necessary to fulfill article 36 of Additional Protocol 1 to the Geneva Convention. The ICRC, which has a role as a guardian of the 1949 Conventions and their 1977 Protocols, has recently published a guide to the legal review of new weapons, means and methods of warfare (Lawand et al., 2006). It was concluded that a multidisciplinary approach, including wound ballistic analysis is needed. The review procedure is different in different countries (Daoust et al., 2002), but medical expertise is usually a component in the national panels.

Mechanisms: Some of the NLW techniques are based on well-known principles such as blunt impact or acoustic effects. However, other non-lethal weapons are based on new techniques such as microwaves or incapacitating electric shock with unknown biological mechanisms and effects. Basic medical research may be needed to evaluate the potential or possible hazards with such NLW´s. This research, which is technically complicated, is often conducted in organizations with experience from ballistic analysis.

CASE REPORTS GENERATE EMPIRICAL DATA

Analysis of medical data from case reports can generate important background information that is needed for development of revised rules of engagement and safer non-lethal weapons. The use of NLT´s at Police departments in different countries have generated a lot of experience on non-lethal systems such as Taser and kinetic blunt impact weapons. In order to collect statistical and comparable data it may be useful to develop protocols for documentation of the use of non-lethal weapons that are similar in different countries and for various NLT´s. It is important that such data includes material on possible injuries and relevant biodata (e.g. age) of the people exposed to NLT´s (including operators).

A collection of empirical data from actual use of non-lethal weapons is important and useful for well-known NLT techniques such as kinetic weapons and pepper spray. For this purpose it would be ideal to have standardized protocols for data collection. It is important to include detailed information on possible injuries as well as data on distance, velocity and type of impact. It is also essential to include controlled information on medical condition (e.g. cardiovascular disease or drug abuse).

EXPERIMENTAL DATA, INJURY CRITERIA

In order to define general mechanisms for effect it may be necessary to perform animal experiments, e.g. to identify possible injuries from new microwave weapons. Such experiments should have a focus on identification of dose-response effects, since non-lethal weapons in general have a graded effect. Dose-response curves have a key role for definition of thresholds for injury and to increase the safety while using NLT´s.

Valid injury criteria are vital for increased safety. As an example, criteria for skull fractures or neck injuries have an important role in car crash safety. The use of relevant injury criteria is imperative in the definition of valid protocols for collection of data from field use of non-lethal weapons and design of experiments that can generate data, which allow a comparison of different types of NLT´s.

Experiments on animals should be limited to reveal general mechanisms and for final testing of the validity of injury criteria. It is often not possible to extract sufficient data from clinical trauma cases due to

large variation of type of injury, variation in velocity and direction as well as age and size of injured patients. Many of these factors can be controlled in animal experiments. Data on physiological response, such as cardiovascular function or the interaction between the nervous system and other organs, are impossible to generate from experiments on cell cultures. However, cell cultures are very useful for dose-response experiments and toxicology.

Finite Element Analysis is a computer simulation technique used in engineering analysis. It can be used to solve biomechanical problems if correct biological data are present (Ueno et al., 1995; Viano et al., 2005). Such data include mechanical data of different types of tissue and exact models of the structure of the body that is analysed. Such models can be used to predict forces and their propagation in the body during an impact. Computerized models can also be used to predict heating in the body during exposure to microwaves. Also these models are dependent on solid basic biological data.

Injury Criteria: Biological data, enhanced by biomechanical computer analysis, can be used to generate useful injury criteria. At the moment, a limited number of injury criteria are available, for instance HIC (Head Injury Criterion), which is included in the requirements of the EURO NCAP to reduce head injuries in pedestrians (Petitjean et al., 2002). However, HIC is only an analysis of the risk for skull fracture after a frontal impact. No data on the risk for the soft tissue is included and HIC can therefore not be used to predict the risk for brain injury. Similar data for other soft organs such as liver and intestines are also lacking. It is obvious that enhanced injury criteria could be useful for risk analysis of kinetic blunt impact weapons. Injury criteria should be validated by careful analysis and simulation of clinical cases.

VALIDATION OF INJURY CRITERIA, TEST RIGS

Data based on validated injury criteria and computer models can be used to develop test rigs and dummies (such as car crash dummies) that could be used for mechanical testing of effects of kinetic non-lethal weapons. Dummies or phantoms can be used for tests of energy absorption of the head during exposure to mobile cell phones (Beard and Kainz, 2004). A model of the head is filled with a liquid with energy absorption properties similar to the human brain (European Standard EN 50361). However, this model is only validated for the waveforms and frequencies that are generated by cell phones. Waves from microwave weapons may generate other waveforms and induce non-thermal effects that can not be analysed with the aid of this phantom.

SOME COMMENTS ON SPECIFIC NLT

Riot Control Agents (RCA´s), e.g. tear gas and pepper spray, offer a well proven method for crowd control. There are, however, some issues to consider in the legal area. They are not allowed as a ‘method of warfare’. What this means in reality for the applicability of RCA´s should be further examined. When can EU troop for example be seen as performing ‘law enforcement’, and thus use RCA´s, and when must they be seen as performing ‘warfare’. This is interesting in the context of CMO´s, where there is naturally a mixture of these activities, with, in some cases, much focus on upholding law and order. Selectivity is a frequent problem. RCA´s can affect both bystanders and the operators. The sensitivity to pepper spray is individual, but significant effects can be observed in the majority of exposed individuals and the use of this NLT is widespread. The active substance *oleoresin capsicum* has been evaluated for possible toxic effects on the eye and airways (Busker and van Helden, 1998). It is however also important to observe possible toxic effects of carriers or solvents (Holopainen et al., 2003). Fatalities have been reported in the United States following the use of pepper spray. However, it has been concluded that it was not the pepper spray but rather other factors such as drugs that contributed to the cause of death (Busker and van Helden, 1998).

Audible optical systems, primarily flash/bang grenades, would have potential in crowd control situations as well as in incapacitating individuals and clearing facilities. More research into what really constitutes the effect – mainly the 'flash', mainly the 'bang', or a combination of the two – is needed. From a medical view it seems that some flash/bang grenades emit impulse noise close to the edge for effects on hearing threshold, but have a better safety margin with regard vision and smoke gas. It may be safer, and more effective, to expose with a longer series of bangs at a slightly lower sound level than one bang at a higher level.

Barrier systems include Airbag Stoppers, Microwire Systems, Nets, Rapid Barriers, and Temporary Fences, and have proven very effective when emplaced at the right time. However, all barrier systems have the potential of confining movement in such a way that vehicles can crash into them, or people can be crushed between them and a moving crowd. Temporary barriers that are rapidly emplaced are a particular problem because people could be hit, thrown back, fall, or get entangled in them; such barriers can also appear in unexpected locations, making the issues of crowd pressure more likely. Barriers, especially such that can be implemented fast, would be of great use against personnel (crowd control, denying area to personnel) as well as against materiel (denying area to vehicles). The technology is mature and the important thing is really developing clear rules governing their employment. Stoppers are, like barriers, a potent means to deny areas to vehicles or to disable and neutralise them. As with barriers it is important to have clear rules for their use, so as not to cause unnecessary danger to personnel.

Blunt impact devices are mainly for different kinds of 'policing'. As well as against personnel they may be used against vehicles (e.g. as paint balls hitting the windscreen of a car). Use against vehicles may, however, mean a risk for lethal effect since a car crash may be caused. The medical aspects of systems like the 'baton rounds' have been studied for a long time, resulting in fewer casualties today than was the case before. There is little medical research on the human effects of blunt impact NLT. Some problems can be predicted from earlier experience and prevented by correct use. Data from studies on effects of Behind Armour Blunt Trauma (BABT) and in sports-incurred injuries may be relevant. Skin penetration, mild brain injury, eye injuries, bleeding in internal organs, contusions, and shock can be anticipated, depending on the area and energy of the impact. Unclear definitions make it difficult to compare effects of different types of non-lethal trauma. Repeated mild trauma is a current problem in several medical specialties, such as neurology and sports medicine. Some aspects of repeated mild trauma are discussed in Annex L. Additional information can be found in the report of HFM-024 (RTO-TM-022) "Blunt Trauma Induced by Non-Lethal Weapon Kinetic Projectiles" found through http://www.rta.nato.int/Pubs/RDP. Descriptions of the experiences from use of kinetic weapons in riot control and law enforcement in Northern Ireland can be found at the Northern Ireland office web site. http://www.nio.gov.uk/. The North Ireland experience with impact weapons shows that it is possible to reduce the number of eye and head injuries with good training and well-defined safety regulations.

DIRECTED ENERGY SYSTEMS

Laser Systems are widely used in weapon systems for range finding, detecting, and pointing. Their frequencies are fixed and mostly well known, so that eye protection with special goggles is possible. Laser weapons have been developed for use against sensor systems, anti-optical equipment and, at very high intensities, to burn metal structures and destroy weapon systems. They can easily affect the eyesight of persons. The need to pay attention to new laser weapons to be sure they do not violate international humanitarian law has already been codified in Article 36 of the 1977 First Additional Protocol to the 1949 Geneva Conventions. Current technology provides the possibility for small lightweight lasers that are dangerous for eyesight over distances of kilometres. Laser eye protection is frequency specific and because of easy to alter frequencies (tuneable lasers) there is no fully effective protection that soldiers could wear. It should be emphasized that with repetitively pulsed laser weapons there is a high probability of multiple lesions induced in the victim's eyes. With very short-pulsed lasers (nanoseconds or less),

haemorrhages may be large and thus visually important even if impacts are in the periphery. Immediate blinding, forcing mission abortion, and permanent blindness may be the result. Blindness is exceptionally debilitating, even when compared with the worst of other injuries. No cure is possible and even long-term prognosis with improvements of ophthalmic surgery is very poor. The awareness of blindness-causing weapons would establish fear, anxiety, and extreme mental problems in soldiers on the battlefield. Sudden blindness, most likely with no other injury, will be psychologically very disturbing for the victim as well as for his fellows. The soldier's morale will be affected. Even the rumour of that laser weapons may be used may result in inactivity, mission abortion, or desertion; people will not knowingly risk their eyes. Protection measures. The need for adequate vision in a life-threatening situation is, of course, vital to the soldier. Avoidance of looking into a laser is not possible for physiological reasons. If some kind of light or flash might be noticed in darkness, the eyes automatically will try to focus the source. Closing the eyelids is too late to avoid the laser energy from immediately damaging the retina, the papillo-macular bundle, or the fovea centralis (the central area of vision) without causing pain. Observation of enemy positions by periscopes or other optical systems will not protect against laser radiation – indeed, it may actually increase the energy received by the retina. Technical or electronic high-speed shutters are too slow for laser pulses. Eye-safe goggle systems for soldiers and aircrews are possible only against known, fixed-frequency laser systems with near-monochromatic bands. For protection purposes, specially designed bandstop filters may be used without degrading visual performance significantly, but to be effective the threat wavelengths would need to be determined. However, tuneable lasers can work at any wavelength and an effective filter would have no visible transmission and therefore completely impair vision.

Microwave and radio frequency systems. The effects of human exposure to microwaves range from direct thermal effects causing pain to the untested possible effects of microwaves used in anti-materiel systems. The possible medical effects induced by the use microwaves in non-lethal weapon systems are difficult to evaluate, in spite of extensive research and wide use of cell phones and wireless phones. The available scientific evidence does not show any health problems associated with using wireless phones, yet, as with the health effects of any agent, **absolute** safety can never be proven. Wireless phones emit low levels of radiofrequency energy (RF) in the microwave range while being used. They also emit very low levels of RF when in the stand-by mode. Whereas high levels of RF can produce health effects by heating tissue, exposure to low-level RF that does not produce heating effects causes no known adverse health effects. RF based non-lethal weapons include high power pulsed microwaves (HPM) and the 94GHz ADS system. The ADS system is based on biological thermal effects, while HPM systems have no known biological antipersonal effects. The ADS system has been extensively tested with regard to both desired and possible undesired effects. So far, no other weapon system has been tested with such a systematic approach in order to establish safety margins and rules for use. HPM systems are being tested in several labs in different countries to identify possible biological side effects. No effects that could have health consequences have been revealed, so far, and the effects that have been claimed to occur at low levels (so-called non-thermal levels) have been difficult to replicate when adequate controls and accurate dosimetry are employed.

Stun weapons from TASER Incorporated are used by a large number of police forces. A number of user reports have been published at the TASER website (www.taser.com). Currently, military use is not widespread. Medical risks include cardiovascular disturbances, penetration injuries (skin and eye), and fall injuries. Reported fatalities have been attributed to pre-existing drug abuse or cardiovascular illness. A few studies on experimental animals have been conducted.

GENERAL PROBLEMS IN THE ANALYSIS OF THE MEDICAL RESPONSE TO MILD TRAUMA

Unclear definitions: The importance in defining terms when assessing the effects of mild trauma is illustrated by the studies on mild brain trauma in American football (Pellman, 2003; Pellman et al., 2004; Viano et al., 2007). It is also possible that genetic differences can be of importance for the susceptibility

for mild trauma. The presence of an apolipoprotein E (APOE) epsilon 4 allele may be a risk factor for the severity of the consequences of head trauma, both short-term and long-term (Caulfield, 1999).

It is important to consider the psychological response to NLTs as well as the physiological and physical response. The course of posttraumatic stress disorder (PTSD) in populations directly exposed to terrorist attacks is of major importance in the post-9/11 era (North et al., 2004). Because no systematic diagnostic studies of the most highly exposed individuals of the 9/11 terrorist attacks have yet been done, the Oklahoma City bombing remains a unique opportunity to examine PTSD over time in high-exposure terrorist victims. Almost half of the survivors directly exposed to the blast reported developing problems with anxiety, depression, and alcohol, and over one third of these survivors reported Posttraumatic Stress Disorder (PTSD). Similar symptoms may occur after exposure to NLT, such as Flash Bang grenades, but appear to be difficult to access in experimental studies.

COLLECTION OF AFTER-ACTION MEDICAL DATA

While laboratory data and models are useful in predicting the medical effects of NLT, there is no substitute for human effects data collected soon after an action in which NLT have been used. We suggest that NATO develop after-action data collection forms that are implemented along with new NLWs. After-action medical recording and reporting procedures should become an integral part of the fielding of any new NLW.

REFERENCES

Beard BB, Kainz W. 2004. Review and standardization of cell phone exposure calculations using the SAM phantom and anatomically correct head models. Biomed Eng Online 3(1):34.

Busker RW, van Helden HP. 1998. Toxicologic evaluation of pepper spray as a possible weapon for the Dutch police force: risk assessment and efficacy. Am J Forensic Med Pathol 19(4):309-316.

Caulfield TA. 1999. The law, adolescents, and the APOE epsilon 4 genotype: a view from Canada. Genetic testing 3(1):107-113.

Daoust I, Coupland R, Ishoey R. 2002. New wars, new weapons? The obligation of States to assess the legality of means and methods of warfare. IRRC 84(846):345-363.

Holopainen JM, Moilanen JA, Hack T, Tervo TM. 2003. Toxic carriers in pepper sprays may cause corneal erosion. Toxicology and applied pharmacology 186(3):155-162.

Lawand K, Coupland R, Herby P. 2006. A Guide to the Legal Review of New Weapons, Means and Methods of Warfare Measures to Implement Article 36 of Additional Protocol I of 1977. International Committee of the Red Cross http://www.icrc.org/Web/eng/siteeng0.nsf/html/new-weapons-publication-190106.

North CS, Pfefferbaum B, Tivis L, Kawasaki A, Reddy C, Spitznagel EL. 2004. The course of posttraumatic stress disorder in a follow-up study of survivors of the Oklahoma City bombing. Ann Clin Psychiatry 16(4):209-215.

Pellman EJ. 2003. Background on the National Football League's research on concussion in professional football. Neurosurgery 53(4):797-798.

Pellman EJ, Powell JW, Viano DC, Casson IR, Tucker AM, Feuer H, Lovell M, Waeckerle JF, Robertson DW. 2004. Concussion in professional football: epidemiological features of game injuries and review of the literature--part 3. Neurosurgery 54(1):81-94; discussion 94-86.

Petitjean A, Lebarbe M, Potier P, Trosseille X, Lassau JP. 2002. Laboratory Reconstructions of Real World Frontal Crash Configurations using the Hybrid III and THOR Dummies and PMHS. Stapp Car Crash J 46:27-54.

Ueno K, Melvin JW, Li L, Lighthall JW. 1995. Development of tissue level brain injury criteria by finite element analysis. J Neurotrauma 12(4):695-706.

Viano DC, Casson IR, Pellman EJ. 2007. Concussion in professional football: biomechanics of the struck player--part 14. Neurosurgery 61(2):313-327; discussion 327-318.

Viano DC, Casson IR, Pellman EJ, Zhang L, King AI, Yang KH. 2005. Concussion in professional football: brain responses by finite element analysis: part 9. Neurosurgery 57(5):891-916; discussion 891-916.