Lethality of Taser Weapons

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On April 28, 2004, police responded to a disturbance in Montgomery County, Maryland. Eric Wolle, a 45-year old 6-foot-4, 275-pound mentally ill man, had become agitated at the sight of a car delivering Chinese take-out food parked in front of his house. He pushed his elderly mother aside and ran out of the house, apparently believing the car carried agents coming to take him away. Wolle reportedly had not been taking his prescribed medications. The police found him in a nearby back yard, wielding a large machete-type knife, screaming that the police would never take him alive. Wolle ignored the officers' commands to get down on the ground and was subsequently hit with a Taser, though he continued to struggle with the officers. After being "tased" a second time, he dropped to the ground, still wrestling with police; shortly thereafter, he lost consciousness. The officers immediately began administering Cardio Pulmonary Resuscitation (CPR) but were unable to revive him, and he was taken to an area hospital, where he was pronounced dead. Seven officers were placed on administrative leave pending an investigation and autopsy results.

The preliminary autopsy report found that the suspect died of cardiac arrhythmia in a setting of acute psychosis and had a blood alcohol content of 0.18. The final autopsy report confirmed the cause of death as cardiac arrhythmia in the setting of acute psychosis during restraint, and the death determined to be a homicide. Other contributing factors were alcohol intoxication and a markedly enlarged heart with scarring in the heart muscle. The medical examiner concluded that the Taser did not contribute to Wolle's death.

Nearly one year later, and after approximately 100 Taser-related in-custody deaths, I was asked by a law enforcement agency to opine on the lethality of a weapon characterized by the manufacturer as "less-than-lethal" or "non-lethal." Following a review of the available documents and uncovering important technical errors on the part of the manufacturer, I concluded that the device, although likely to be less lethal in many cases than a conventional handgun projectile, was indeed capable of killing.

This paper discusses these errors, and identifies fallacies in the manufacturer's claims when contrasted to fundamental electrical engineering principles and affirmed technical standards governing electric shock and electrocution.

Keywords: Taser, Cardiac Arrhythmia, Electrocution, Shock, Lethal, in-custody deaths, homicide, Medical Examiner, Autopsy, Electrical Engineering, Standards.

Taser Technology

The Taser M26 is a hand-held electronic stun gun which fires two tethered electrically conductive barbed darts. The fishhook like darts are designed to penetrate up to two inches of the target's clothing or skin and deliver high-voltage electrical pulses through thin, flexible electrical conductors. The Taser M26 was developed by Taser International, an Arizona-based company, and introduced into service in late 1999. It supplies 26 Watts of power (compared to 7 Watts of earlier models) and discharges 50,000 Volt electrical pulses designed to interfere with the subject's central nervous system, causing uncontrollable, rapid contractions of muscle tissue, resulting in instant collapse.

In May 2003, Taser International introduced a new model, the Taser X26, which is 60% smaller and lighter than the M26 but has the same voltage and, according to the manufacturer, an incapacitating effect that is 5% greater than the M26. Both fire two darts up to a distance of 21 feet and are programmed to provide five-second pulse trains. The darts are propelled by gas-filled cartridges that can be replenished if subsequent discharges are required. Both models include laser sights to facilitate aiming; however, accuracy suffers greatly with increasing distance between the Taser and the target, resulting in a dart spread of about two feet at a distance of twenty-one feet. These devices include an integrated black-box recording feature to record the time and date of each firing.

Both the M26 and the X26 can also be used as simple stun guns, to apply electric shocks in direct contact with the subject. The manufacturer claims that the M26 and X26 are "safer" alternatives to many conventional weapons and that the electric power supplied by these devices is incapable of causing permanent injury or death.

Published characteristics of the Taser M26:[1]

Voltage at Output:	50,000 Volts (50 kV)
Peak Current:	18 A
Current at Output:	162.48 mA (RMS) Average
Current at Output Range	100 to 500 mA
Repetition Rate:	2 to 40 pulses per second
Pulse width duration:	10 µs to 100 µs
Output Pulse Energy:	1 to 3 J
Body Impedance Reference:	1000 Ohms

The deployment and use of Tasers have received widespread criticism, particularly in cases where these devices are used on young children, the elderly, pregnant women, mental patients, and the physically ill, in circumstances where the individuals' conduct would not normally be considered an immediate threat to police or others. In one notable case occurring on May 2004, a police officer from South Tucson, Arizona, used a Taser on nine-year-old girl runaway from a home for severely emotionally disturbed children. According to reports, the child was already handcuffed with her hands behind her back and sitting in the back of a police car when the Taser was used as an officer struggled to put her into nylon leg-restraints.[2]

Selected Case excerpts of Taser Related Deaths and Incidents [*]

- On 7 February 2005, a 14-year-old boy went into cardiac arrest after police used a stun gun to subdue him. More than a day after the incident, the boy remained

[*] For a comprehensive accounting of Taser-related deaths, the reader is encouraged to review the report prepared by Amnesty International: Excessive and lethal force, Amnesty International's concerns about deaths and ill-treatment involving police use of tasers.

unconscious at Children's Memorial Hospital. Cook County Public Guardian Robert Harris questioned why police used a Taser on the boy, a ward of the state who was living at a residential treatment center. [3]

- In 2002, the City of Chula Vista, California, paid $675,000 to settle a damage claim in the case of Cindy Grippi, a woman, six-months' pregnant, who lost the baby she was carrying after she was shot with a Taser. [4]

- James Borden, aged 47, died in Monroe County Jail, Indiana, on 6 November 2003, after being stunned at least six times with an M26 Taser. The autopsy report gave cause of death as consistent with "cardiac dysrhythmia, secondary to hypertrophic cardiomyopathy, pharmacological intoxication and electrical shock", with manner of death listed as "accidental". [5] After the "tasing," the officer noted that James Borden was no longer responsive and his face was discoloured. An ambulance was called and attempts at resuscitation failed. He was pronounced dead upon arrival at the hospital.

- Eddie Alvarado, aged 32, died in June 2002 in Los Angeles after being tased five times while handcuffed behind his back. The autopsy report states that "According to the history, the decedent exhibited violent and irrational behaviour. He was observed to have seizure activity and collapsed prone on the floor". Cause of death was given as "sequelae of methamphetamine and cocaine use, status post restraint, including taser use." [6] The coroner also noted a "temporal relationship" between restraint, taser application and his cardiopulmonary arrest but found the manner of death "undetermined." [7]

- Glenn Richard Leyba, aged 37, died in Glendale, Colorado in September 2003. According to a report on the case by the District Attorney's office, paramedics arrived at Leyba's apartment after his landlady called for an ambulance, and found him "laying face-down, rolling from side to side … making moaning and whimpering sounds". A police officer twice used her taser on him as a stun-gun when he failed to respond to attempts to roll him over and became "physically resistant". The police report stated that the second stun mode discharge "increased his level of agitation".

The same officer then fired taser darts into Leyba's back, resulting in Leyba "moaning, screaming and 'flailing' his legs – increasing his level of physical agitation. It did not, however, gain Mr Leyba's compliance." Altogether, Leyba was tased at least five times, after which he "stopped all physical resistance" and was handcuffed behind his back. The report states: "while being wheeled to the ambulance, the paramedics noticed that Mr Leyba's skin color was grayish, that he had stopped breathing, and that he had no pulse." Efforts to resuscitate him were unsuccessful and he was pronounced dead at the hospital. The coroner determined cause of death as "cardiac arrest during cocaine-induced delirium." [8]

- Roman Gallius Pierson, aged 40, died in October 2003 after being tased in Yorba Linda, California. Police had responded to reports that a disturbed man had been running in and out of traffic. According to press reports, Pierson had run into a gas station and was rubbing ice onto his face, complaining of being hot and thirsty. When the police arrived, he was shot with a taser when he ignored an order to lie down on the pavement. Pierson was tased again when he began "grappling with police." He went into cardiac arrest at the scene and died at the hospital.[9]

Skin Effect, Depth of Taser Current Flow in Human Tissue and Impacts upon the Human Fetus

The initial safety review of the Taser, performed by Dr. Robert Stratbucker of Taser International claimed that that high frequency current delivered by the Taser couldn't cause injury to internal organs or to a fetus because of *Skin Effect* and *Faraday Shield* phenomena.[10]

The theory holds that high frequency current cannot pass deep into human tissue, and that electric current conduction occurs only at the tissue surface.

In his review of the "Advanced" Taser, Taser proponent Anthony Bleetman adopts this same theory. Bleetman addresses the protections provided to the uterus and fetus via the Faraday Shield, and discussed how this high frequency phenomenon prevents direct conduction into nerves and muscles.[11] Similarly, other Taser proponents also argue that the fetus is safe from harm because of the Faraday Shield effect. [12]

Skin Effect phenomenon describes a condition where conductor current distribution is not homogeneous across the conductor cross-sectional area because of magnetic field response related to conductor impedance.[13] The area through which the charge carriers flow is referred to as the skin depth. At DC or zero Hertz, charge carriers are evenly distributed throughout a conductor cross-section, and distribution varies with increasing frequency. In high frequency power and signal transmission, applications, addressing skin effect phenomena requires substantive engineering consideration to compensate for decreased conductor cross-sectional area; often resulting is solutions applying alternate conductor geometries. In these cases, conductor circumference is the factor used in determining conductor ampacity and not conductor cross-sectional area. For instance, high-power arc furnaces are often supplied high-frequency current through water-cooled copper piping since only the conductor circumference is useful in conducting current. [14] Coaxial cable and *Litz* wire[†] [15] are also used to mitigate against the effects of skin effect in applications involving the transmission of high-frequency (e.g., radio-frequency, radar and microwave wave-guides, etc.)[16]

J.P. Reilly[17] relies on Oliver Heaviside's description for computing skin depth for a material of arbitrary conductivity and provides the following equation:

$$\sigma = \frac{1}{2\pi f\left\{\left(\frac{\mu\varepsilon}{2}\right)\left[\sqrt{1+\left(\frac{\sigma}{2\pi f\varepsilon}\right)^{2}}-1\right]\right\}^{\frac{1}{2}}}$$

where:
σ = Skin depth or depth of current penetration in the conductor
$\mu = \mu_0\, \mu_r$ is the magnetic permeability of the material

[†] Litz is derived from the German litzendraht meaning woven wire. Litz wire is a conductor system constructed of individually insulated wires braided so individual wires alternate through various cross-sectional locations along its length as a means of reducing impacts of skin effect. *GMC Electrical Engineering Archives*

$\varepsilon = \varepsilon_o \, \varepsilon_r$ is the dielectric permittivity of the material
$f =$ is the frequency of the current induced in a material

With respect to biological materials, Reilly concludes that only when the frequency is well above 10 MHz that skin depth becomes a significant consideration in most cases, and that for frequencies below 10 MHZ, a magnetic field will readily pass through biological material with negligible differences between the internal and external magnetic fields.

However, the Taser M26 does not deliver output waveform frequencies approaching or exceeding 10 MHz. Although the steep-wave front discharge identified in the Taser output waveform may be treated as a high-frequency component, the pulse-width of the M26 discharge ranges from 10 μs to 100 μs, or frequencies between 100 kHz to 10 kHz (i.e., 1/pulse-width). Therefore, the Taser M26 discharge waveform current frequency is at best two orders of magnitude below what is needed to consider skin effect phenomenon.

There is no indication that either Stratbucker or Bleetman performed any research or tests to verify limited current flow depth in biological materials to confirm their theories of skin effect and no impact to deep tissue. However, the mathematics and relations are apparent, and we can conclude that the 100 kHz frequency component of the Taser waveform discharge would flow uniformly throughout biological tissue.

The finding that Taser current can indeed penetrate deep into human tissue has important implications with respect to the opinions of Taser proponents regarding susceptibility of the fetus to a Taser discharge.

L. Mehl offers convincing evidence that the fetus is more vulnerable to electric shock than the mother, and identifies many cases where the mother exhibited no symptoms following low-voltage shock incidents; however, the effects manifested in devastating consequences to the fetus.[18] Mehl concludes that the current provided by the Taser is well within the range at which fetal injury would occur, particularly in the first trimester, and raises ethical questions regarding criteria for Taser use on women of childbearing age.

M.A. Cooper recommends that obstetric consultation be obtained for all pregnant patients, subject to electro-shock and regardless of any symptoms at time of presentation, particularly second and third trimester patients to be considered high risk and receive continual fetal monitoring, while first trimester patients should be informed of risk for spontaneous abortion.[19]

Despite the manufacturer's assertions that the Taser current cannot penetrate into the body because of skin effect, Bleetman does identify one case where a miscarriage occurred following a Taser shock administered to a pregnant woman. In this case, Bleetman recommends caution with "tasered" pregnant patients. [20]

Contrast of Taser M26 Performance to IEC 479 and Underwriters Laboratories (UL) Limits for Ventricular Fibrillation

It is notable that a certain Taser International prepared graph recurs in several Taser documents and in product safety reviews performed by others in addressing Taser lethality and Taser margins of safety. [21] Purportedly, the graph contrasts relative proximity of Taser M26 and Taser 34000 current-pulse-width plots to UL and IEC 479 limits for ventricular fibrillation. Taser International does not identify which UL standard they applied in their graph, however, in the footnote of the Taser document, Taser states that the UL standard addresses periodic pulse trains and is *"directly applicable to pulse wave devices like the Sticky Shocker."* However, Underwriters Laboratories denies ever having produced any such standard or promulgating any standard applicable to the stun gun or Taser-like devices and it is believed that Taser International may have instead misapplied the provisions of UL 69 governing electric fence controllers. Following Taser use by the Miami-Dade police on a six year old boy and twelve year old girl, UL's electric shock researcher, Walter Skuggevig, confirmed the inappropriateness and the irrelevancy of UL 69 provisions to the Taser, and affirmed that UL never tested or evaluated the Taser device for safety, and UL does not certify the Taser as safe.[22] A training officer for the Putnam County Sheriff's Office said he originally believed the Taser was indeed certified by UL following a seminar given by Taser International; however, when informed that the Taser had never been reviewed by UL, he felt that he had been mislead by the manufacturer.

Notwithstanding the inapplicability of UL 69 to the Taser, in regard to tests initiated by the Consumer Product Safety Commission (CPSC) in 1976 using a weaker Taser model, Dr. Theodore Bernstein states: [23]

"Taser output energy per pulse is somewhat higher than the allowable output for an electric fence"

- and -

" .. the Taser pulse occurs 13 times per second compared to the once per second for the fence. The power into the load is 13 times greater for the Taser output than for the electric fence. These results indicate that the Taser output is more hazardous than an electric fence output."

Bernstein emphasizes the importance pulse repetition has on electric safety and states that the hazard in the output would be increased if the pulse repetition rate should increase or the amplitude of the output increased.

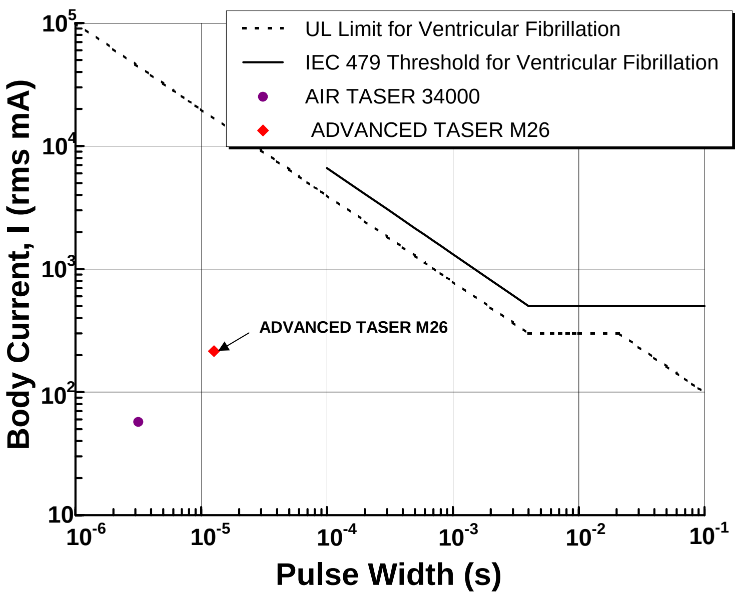

Figure 1 – Taser graph packaged with Taser marketing material delineating un-reproducible curves and invalid claims for the Taser M26 when compared to UL and IEC standards.

Similarly, Taser does not identify which of the three set IEC 479 standards were used in their formulation of a basis for their graph; however, the Taser graph could not be reproduced upon close review and analysis of each of the three subject IEC standards.

However, graphs in IEC 479-1 show a better than 50% likelihood for ventricular fibrillation to occur when a 100 *mA* AC current is sustained from left hand to feet for a period of five seconds, and at the Taser M26 published current of 162 *mA* rms, the same probability for ventricular fibrillation can result in as little as one second.

Taser disputes similarity of Taser current waveform to AC sinusoidal waveforms addressed in IEC 479-1 because of pulse-width differences between the claimed 10 *µs* to 100 *µs* Taser M26 pulse-width and the 50/60 Hertz sinusoidal waveforms addressed in IEC 479-1. Koscove notes lack of any experimental data on the clinical effects of a train of damped sinusoidal waves as a function of pulse frequency, pulse duration, amplitude, current and frequency. [24] However, Reilly does produce data resulting from experiments with dogs showing that the ventricular fibrillation threshold occurs at a peak current of 15 *mA* +/- 4.3 *mA* for single DC pulse of 1 *ms* duration. Reilly notes, as does Bernstein, that oscillatory stimuli can significantly enhance the biological response that might otherwise result from a single pulse, and that the fibrillation threshold falls steadily with the increasing number of pulses. Reilly also shows the VF threshold to fall by a factor of thirty with train of six pulses. Although the Taser M26 pulse width of 100 *µs i*s one order of magnitude smaller than the 1 *ms* pulse width used by Reilly in his dog experiment, the Taser M26 peak current of 18 Amperes is three orders of magnitude larger than Reilly's 15 *mA* model. Given this information and the 40 pulses-per-second capability of the Taser M26, it is unreasonable for claims of "non-lethality" with the Taser M26.

In their published output energy computations, Taser incorrectly assumed body impedance values of 1000 ohms [25] - a figure that is correct only when considering skin contact (i.e., non-penetrating) connection and a circuit path from hand to hand, or from hand to feet. Such a circuit path with the Taser device is not likely, and instead, the impedance value Taser should have used instead is about 13 ohms – corresponding with a circuit path from sternum to abdomen. [26]

Additionally, in the 1976 CPSC evaluation of a weaker energy predecessor to the M26, Bernstein identifies how the fishhook like barbs of the M26 would likely incur local trauma, serving to increase the effective area of the barb, and therefore decreasing resistance to a value as low as 200 ohms.

Reduction of the resistance figure has important implications regarding the credibility of Taser's claims regarding safety, since current is determined by the ratio of voltage over impedance or

$$I = \frac{E}{Z}$$

showing that: holding voltage (E) constant, as impedance (Z) decreases, current (I) must therefore increase, therefore increasing risk of VF.

Other Tests and Findings

In earlier experiments with pigs and using earlier stun-gun devices exhibiting weaker energy levels than the Taser M26, Roy concludes that the stun gun is *"far from benign"* and for devices applied directly to the heart, a charge transfer of 3 $\mu C/cm^2$ to 4 $\mu C/cm^2$ will cause cardiac stimulation while a charge transfer of 34 $\mu C/cm^2$ will result in ventricular fibrillation. Pulse width for the stun gun devices tested by Roy are ≤ 20 μs and shorter than the pulse width intervals claimed by Taser International in their U.S. Patent for the M26 (i.e., up to 100 μs). However, Taser International's claims relating charge transfer and ventricular fibrillation conflict sharply with Roy's findings.[27] The claims made by Taser International describes a twenty-two to thirty times increase in the VF threshold for 40 kg and 52 kg pigs (1056 $\mu C/cm^2$ and 1440 $\mu C/cm^2$, respectively) representing about thirty one to forty-two times more charge than observed by Roy to induce ventricular fibrillation.

For these earlier devices, Roy asserts that pump failure and cardiac arrhythmia can occur when stun-gun devices are applied directly to the chest, and pacemaker leads can act as a secondary winding of a transformer – providing an excellent pathway for the fibrillatory current.[28]

It is noteworthy that the stun-gun devices tested by Roy introduce current to the skin and do not penetrate into tissue, as do the fishhook-like barbs of the Taser M26. Surface area for barbs penetrating moist human tissue is substantively larger than pointed non-penetrating electrodes in contact with skin, therefore, it is reasonable to expect greater electrical conductivity with the Taser barbs since skin impedance no longer presents a resistive obstacle to Taser M26 current.

Medical Examiner Findings in Taser-Related Deaths and Delayed VF Effects of Electric Shock Incidents

Death by electrocution is difficult to conclude in low energy circumstances, and in such cases, electrocution is ruled as the cause of death when there is a report of electrical connection, and all other reasonable possibilities have been ruled out. Determining electrocution in high-energy incidents is somewhat simpler, owed to the presence of severe burns and carbon-arc tracking of tissue. In most all of the low energy electrocutions addressed by this author, if an electrical connection has been established, and no other evidence of physical trauma was present, the medical examiners often ruled death by electric shock, irrespective of any latent condition, illness, drugs or alcohol later found in the patient. Although such factors can exacerbate the effects of electric shock, the primary cause of death in all these other cases is ruled as electrocution.

Nevertheless, in many Taser-related deaths there appears to be a tendency to imprudently rule the Taser out as a contributory factor, and point to other factors. In many cases, and without benefit of first hand knowledge, the manufacturer quickly discounts any possibility that their product could have caused a death, while offering troubling statements such as "*they would have died anyway.*"

In several Taser M26 related death cases, Taser International's Medical Director, Dr. Robert Stratbucker ruled out the Taser M26 as cause of death based upon reported time delay between the application of the Taser and the deaths. Stratbucker stated: "The only plausible cause of death from electrical injury not leaving tell-tale skin lesions – clearly not present in any of the cited cases – is ventricular fibrillation, a fatal disturbance of heart rhythm which ensues immediately upon shocking the heart with greater-than-threshold, non-Taser-like electric current pulses. Specifically, if the Taser output were to cause cardiac arrest, it would be immediate." [29]

One former Los Angeles medical examiner tasked with investigating a Taser-relate death indicates that Los Angeles pathologists were under pressure from law-enforcement agencies to exclude the Taser as the cause. In this case, the ME described the performance of an autopsy in the presence of six upper-level law enforcement agents who were confrontational and argumentative in their attempts to persuade the ME that death was caused by drowning in a few inches of water. The ME was not permitted to visit the scene of the incident, and he concluded that the Taser was indeed the cause of death. His supervisor later mischaracterized the cause of death as cocaine related rather than identify Taser involvement. [30]

Research does identify appreciable risk of late ventricular fibrillation in injuries involving the passage of current through the thorax [31] and myocardial biopsy findings of patchy myocyte necrosis and fibrosis. Jensen identifies eight to twelve hour delays in the onset of symptoms for three patients who sustained electric injuries with current passing through the thorax. [32] Jensen described the resulting ventricular arrhythmias as severe and long lasting, and in two of the three patients, ventricular tachycardia or ventricular fibrillation or both occurred, and in one patient, ventricular parasystole developed. Jensen recommends that patients who sustain injuries in which the current passes through the thorax should be monitored for 24 hours; while patients presenting unexpected arrhythmias should be questioned about previous electrical injury.

Jensen indicates the heart could be damaged following the passage of current through the thorax – resulting in heart complications, including ventricular fibrillation some time after exposure.

From these findings, we can conclude that unnecessary or experimental shocking of individuals with the Taser M26, or any stun gun weapon, should not be performed. This restriction of use includes the termination of police department policies to require officers to first be *Tased* before being given authorization to use Tasers. This latter practice provides no added value to officer training, while incurring substantive and unnecessary risk to officers. According to Taser International, there have been many thousands of police officers subject to exemplar *Tasing* as a means of training and certain members may have unknowingly incurred permanent heart damage. There is no indication that medical follow-ups were later performed to evaluate Taser after-effects or damage these individuals may have sustained.

Fish and Geddes believe the Taser to have more impact upon the body than stun gun weapons, since the electrode spacing for the Taser can be wider than the fixed electrode width of the stun gun.[33] It is more likely that such spacing between barbed electrodes will encompass and involve the heart region, particularly with increasing distance between gun and target. The Taser M26 and X26 offer relatively poor accuracy – with the lower barb projectile directed about 11 degrees below the axis of the upper barb. This results in an electrode barb spread of about two feet at a firing distance of twenty-one feet. However, the manufacturer identifies the optimum distance as between seven to ten feet – resulting in a barb spread of eight to twelve inches – still sufficient spacing to possibly involve the heart.

Taser Aftermath

Cooper recommends all patients with evidence of electrical shock injury or significant surface burns undergo laboratory tests, including complete blood count (CBC), electrolyte levels, serum myoglobin, blood urea nitrogen (BUN), serum creatinine, and urinalysis. Cooper recommends that cardiac enzyme levels be interpreted with care when diagnosing myocardial infarction in the setting of electrical injury since peak CK level is not indicative of myocardial damage in electrical injury because of the large amount of skeletal muscle injury, and that all patients sustaining an electrical injury should receive cardiac monitoring and an ECG despite the source voltage.[34]

Dr. Zian Tseng, a San Francisco cardiologist that routinely stops the heart using electric current as a precursor to implanting electric defibrillators believes Tasers to be potentially dangerous. Tseng likens Taser use to a game of *Russian Roulette*, since the Taser current may strike during the heart's vulnerable period. Tseng recommends that police carry automatic electronic defibrillators as a precaution, a recommendation that Mark Kroll of Taser International admits to be a good policy.[35]

Discussion

The Taser can serve a useful role in law enforcement; however, it should not be touted as a harmless device that can be used without consequences or risk, especially when used on children, the elderly, or those who may not be at optimum health. Without doubt, the Taser M 26 can kill and may have already killed many. In the opinion of this author, such deaths were unnecessary and a direct result of the manufacturer's misinformation about the product. Several studies promoting Taser safety apparently relied heavily on the erroneous information and propositions supplied by Taser International (e.g., Skin Effect, Faraday Shield, applicability and use of UL 69 and IEC 479 etc). Therefore, the conclusions made in these studies are unsound, and the conclusions resulting from those studies must be reconsidered.

The following criteria for law enforcement and government agencies is recommended:

- The Taser M26 and similar weapons should only be used in circumstances where a failure to act is likely to result in severe injury or death to either the officer, the patient, or to others, and no other force alternative is feasible. Police should be informed that the Taser can indeed kill, and therefore be given the opportunity to exercise informed and appropriate judgement.

- Electro-shock weapons should never be used as a routine means to control an unruly individual where other, less lethal means can be effective, and law enforcement agencies will need to develop and provide officer training programs to help officers understand Taser risk through development of appropriate response strategies.

- Agency policies that mandate exemplar officer *Tasing* as a means of training for authorization to use the Taser should cease immediately since such a requirement adds little to officer knowledge or ability to use the Taser while incurring unnecessary risk to officers.

- Police officers and others who have been *Tased* should seek medical evaluation to determine possibility of injury to the heart.

- Where Tasers are used, officers should aim for a target area such as to minimize exposure of the upper chest area , such as to target the lower abdomen and upper legs.

- Multiple Taser weapons should never be used, and where Tasers are ineffective, the officer should defer to other means of acquiring compliance, including chemical sprays.

- Officers authorized to use Tasers should also carry and be trained in the use of automatic electronic defibrillator devices and other fundamental resuscitation devices, and be prepared to use such devices following a Tasing.

- Tased patients should receive immediate follow-up evaluation by medical personnel prior to further legal processing.

- Public availability of Tasers and other electro-shock weapons should be subject to the same oversight presently given to other classes of deadly weapons and federal, state and local regulations and ordinances should be developed to control deployment and use of electro-shock weapons.

The technological advantages attributed to Tasers and similar devices have caused some users to ignore legitimate concerns about permanent injuries resulting from use of the device. Nevertheless, there is a growing body of forensic evidence, coupled with a discrete analysis of the device's engineering limitations, suggesting that national guidelines for the use of Tasers and stun guns by law enforcement are needed to prevent unnecessary deaths and permanent injuries. It is both the intention and hope of this author that the issues raised in this paper will stimulate a broader dialogue in the scientific community to scrutinize the use of these types of devices by law enforcement entities.

References

1. United States Patent No. 6,636,412 B2, October 21, 2003
2. Associated Press, 1 June 2004
3. Chicago Sun Times, February 9, 2005
4. Union Tribune, Amy Oaks, 29/29/2002
5. KTH TV Little Rock Arkansas, Liz Massey, 4/12/2004
6. Department of Coroner, Los Angeles, California, Autopsy Report for Eddie R. Alvarado, 15 June 2002.
7. Arizona Republic, Robert Anglen, 6/18/2004
8. Rocky Mountain News, Huntley, Sarah Huntley, 10/2/2003
9. KABC TV, Los Angeles, 10/8/2003
10. Bleetman, A., Steyn, R. (2003). The Advanced Taser: a Medical Review
11. Bleetman, A. Steyn, R., Lee, C Introduction of the Taser into British policing. Implications for UK emergency departments: an overview of electronic weaponry. Emerg Med J. 2004, 21:136-140
12. Valdez v. Farmon et al. U.S. District Court, Eastern District of California, No. CIV S-89-0939 DFLGGHP. 1991.
13. Mei, S., Ismail, Y.I., Modeling Skin Effect with Reduced Decoupled R-L Circuits, International Symposium on Circuits and Systems, 2003, ISCAS '03 Proceedings, IEEE Press.
14. Mendis, S.R., Gonzales, D.A., Harmonic and Transient Overvoltage Analysis is Arc-Furnace Power Systems, IEEE Transactions on Industry Applications, Vol.28, No. 2, March/April, 1992, IEEE Press
15. Tourkhani, F; Viaroughe, P., Accurate Analytical Model of Winding Losses in Round Litz Windings, IEEE Transactions on Magnetics, Vol. 37, Issue 1, 2001, IEEE Press
16. Van Deventer, T.E.; Katehl, P.B.; Cangellaris, A.C.; High Frequency Conductor and Dielectric Losses in Shielded Microstrip, Microwave Symposium Digest, 1989, IEEE Press
17. Reilly, J.P. (1998). Applied Bioelectricity, From Electrical Stimulation to Electropathology. Springer
18. Mehl, L., Electrical Injury from Tasering and Miscarriage. Acta Obstet Gynecol 1992; Scand 1992; 71; 118-123.
19. Cooper, M., (1995). Emergent Care of Lightning and Electrical Injuries, Seminars in Neurology, Volume 15, Number 3, September 1995.
20. Bleetman, A. Steyn, R., Lee, C Introduction of the Taser into British policing. Implications for UK emergency departments: an overview of electronic weaponry. Emerg Med J. 2004, 21:136-140
21. Taser International, Advance Taser M26, Less-Lethal EMD Weapon.

22. Experts dispute data on stun guns: Taser International said its weapons were a safe way to subdue children, but some researchers say more study is needed. Miami Herald, December 5, 2004

23. Analysis of Dr. Theodore Bernstein to CPSC BES, dated 12 February, 1976.

24. Koscove, Eric M. The Taser Weapon: A New Emergency Medicine Problem, Annals of Emergency Medicine. December 1985

25. Letter from Carleton University to Taser International, Inc. dated 14 February, 2000 regarding Advanced Taser M26 , authored by Robert G. Harrison, Adjunct Research Professor.

26. IEC 479-1 Effects of Current on Human Beings and Livestock, Part 1, General Aspects, 1994-09 (Figure 2)

27. Cardiac Safety of TASER Stimulation, Power Point Presentation prepared by Mark Kroll, retrieved from http://www.taser.com on 2 January 2005.

28. Roy OZ, Podgorski AS. Tests on a shocking device – the stun gun . Med Biol Eng Comput. 1989 Jul;27(4):445-8.

29. Reported in Taser International News Bulletin, Topic: In-Custody Deaths, February 2002.

30. Allen, Terence B. Discussion of "Effects of the Taser in Fatalities Involving Police Confrontation", Journal of Forensic Science.

31. Orme, S, Channer, KS Tachycardia following low-tension electrocution, *Postgrad Med J* 1999;75:439-441 (July)

32. Jensen PJ, Thomsen, PE, Bagger JP, Norgaard A, Baandrup U. Electrical injury causing ventricular arryhythmias. Br Heart J 1987;57:279-283

33. Fish, Raymond M; Geddes, Leslie A. Effects of stun guns and tasers. The Lancet, Volume 358, September 1, 2001

34. Cooper MA, Timothy Price, Rosen's Emergency Medicine - Concepts and Clinical Practices, 5th Edition.

35. San Francisco Chronicle, Heart Expert warns about using Tasers, UCSF doctor says jolt can interrupt pumping of blood. January 5, 2005-02-15