BASIC INVESTIGATIONS

Cardiovascular and Physiologic Effects of Conducted Electrical Weapon Discharge in Resting Adults

Jeffrey D. Ho, MD, James R. Miner, MD, Dhanunjaya R. Lakireddy, MD, Laura L. Bultman, MD, William G. Heegaard, MD, MPH

Abstract

Objectives: The TASER is a conducted electrical weapon (CEW) that has been used on people in custody. Individuals occasionally die unexpectedly while in custody, proximal to the application of a CEW. In this study, the authors sought to examine the effects of CEW application in resting adult volunteers to determine if there was evidence of induced electrical dysrhythmia or direct cellular damage that would indicate a causal relationship between application of the device and in-custody death.

Methods: Human subjects (N = 66) underwent 24-hour monitoring after a standard CEW application. Blood samples were collected before and after exposure and again at 16 and 24 hours after exposure. A subpopulation (n = 32) had 12-lead electrocardiography performed at similar time intervals. Blood samples were analyzed for markers of skeletal and cardiac muscle injury and renal impairment. The electrocardiograms were read by a cardiologist blinded to the study. Data were analyzed using descriptive statistics.

Results: There was no significant change from baseline at any of the four time points for serum electrolyte levels and the blood urea nitrogen/creatinine ratio. An increase in serum bicarbonate and creatine kinase levels was noted at 16 and 24 hours. An increase in serum lactate level was noted immediately after exposure that decreased at 16 and 24 hours. Serum myoglobin level was increased from baseline at all three time points. All troponin levels measured were <0.3 ng/mL, except for a single value of 0.6 ng/mL in a single subject. This subject was evaluated, and no evidence of acute myocardial infarction or disability was identified. At baseline, 30 of 32 electrocardiograms were interpreted as normal. The two abnormal electrocardiograms were abnormal at baseline and remained the same at all four time points.

Conclusions: In this resting adult population, the TASER X26 CEW did not affect the recordable cardiac electrical activity within a 24-hour period following a standard five-second application. The authors were unable to detect any induced electrical dysrhythmias or significant direct cardiac cellular damage that may be related to sudden and unexpected death proximal to CEW exposure. Additionally, no evidence of dangerous hyperkalemia or induced acidosis was found. Further study in the area of the in-custody death phenomenon to better understand its causes is recommended.

ACADEMIC EMERGENCY MEDICINE 2006; ■:■■–■■

Keywords: TASER, in-custody death, electrocardiogram analysis, serum analysis, conducted electrical weapon

From the Department of Emergency Medicine, Hennepin County Medical Center (JDH, JRM, LLB, WGH), Minneapolis, MN; and Department of Cardiology, Cleveland Clinic and Hospital (DRL), Cleveland, OH.

Received November 25, 2005; revisions received January 3, 2006, and January 6, 2006; accepted January 6, 2006.

Supported in part by TASER International (Scottsdale, AZ), manufacturer of the conducted electrical weapon in question. Drs. Ho, Miner, Bultman, and Heegaard serve as external consultants to TASER International.

Address for correspondence and reprints: Jeffrey D. Ho, MD, Department of Emergency Medicine, Hennepin County Medical Center, 701 Park Avenue South, Minneapolis, MN 55415. Fax: 612-873-4904; e-mail: hoxxx010@umn.edu.

The TASER (TASER International, Scottsdale, AZ) is a conducted electrical weapon (CEW) available for law enforcement and civilian use. It is designed to subdue or repel agitated or violent individuals. It has come under scrutiny by national and international media and human rights organizations because there have been deaths of persons in custody following its application.[1,2] Most deaths in police custody occur when no CEW has been applied.[3] However, a causal association has been suggested.[4–6]

Current theories about this association include production of immediate fatal arrhythmias or some type of subacute, delayed cardiac or other organ system damage that manifests itself as sudden death at a later time.

doi: 10.1197/j.aem.2006.01.017
ISSN 1069-6563
PII ISSN 1069-6563583

In this study, we sought to examine the effects of a CEW application in resting adult volunteers to determine if there was evidence of induced electrical dysrhythmia or direct cellular damage that would indicate a causal relationship between the application of the device and in-custody death (ICD).

METHODS

Study Design

This was a prospective observational study of resting adult volunteers recruited at a TASER International training course in April 2005. The institutional review board of Hennepin County Medical Center approved the study. Subjects provided informed consent before enrollment.

Study Setting and Population

This study was performed with volunteer subjects. As part of their training course, they were to receive a five-second CEW application as required by the course curriculum. All adult subjects (age older than 18 years) were eligible for enrollment. They did not have to participate in the study as a requirement for successful course completion, but declining to participate in the study did not absolve them from receiving the CEW application. The application consisted of a five-second application with projectile darts powered by the TASER X26 model CEW (TASER International) (Figure 1).

Study Protocol

Before undergoing the CEW application, 32 of the 66 subjects were randomly selected to also undergo a baseline electrocardiographic evaluation. Random selection of these subjects was made by taking the next subject in line when an electrocardiography machine became available. All subjects had blood drawn before the CEW application for baseline laboratory analysis for electrolytes, serum markers of skeletal and cardiac muscle injury, and renal function. All subjects completed a medical questionnaire for the purpose of gathering additional medical information for descriptive reporting. The descriptive data points gathered for all subjects included age, gender, medical history, current medications, and significant exertion within the 24 hours before the study.

The CEW application consisted of a standard TASER X26 deployment of probes made from a distance of approximately 7 ft. The subject faced away from the deploying instructor and was supported by assisting personnel per the manufacturer's training recommendations. When the CEW was deployed and muscular incapacitation was achieved, the support personnel would allow the subject to begin to fall to the ground and would assist them to the ground in whichever direction they were falling. The CEW was allowed to run for a standard five-second cycle. On completion of the application, the probes were removed, the probe entry points were disinfected, and adhesive bandages were applied if needed.

Immediately following the CEW application, all subjects underwent repeat venipuncture. This was performed again at 16 and 24 hours after the application. Similarly, the electrocardiography subgroup underwent additional electrocardiography at the same time intervals.

Collected blood samples were analyzed for troponin, myoglobin, lactate, potassium, glucose, blood urea nitrogen, creatinine, and creatine kinase levels. Venipuncture was performed by an independent laboratory organization (Laboratory Corporation of America, Phoenix, AZ) using certified phlebotomists and routine venipuncture practices. After each venipuncture, the specimens were labeled and transported according to the laboratory standard for analysis at an off-site facility. Analysis was performed using standard assays and laboratory instruments (Abbott Diagnostics, Abbott Park, IL).

The subjects selected to participate in the 12-lead electrocardiographic evaluation were connected to cardiac monitors (Medtronic, Minneapolis, MN). The leads were placed in standard configuration on the chest wall, arms,

Figure 1. Cutaway image of TASER X26 conducted electrical weapon. Photograph courtesy of TASER International.

and legs. The computer assessment function was turned off to prevent printing of the assessment on the electrocardiogram to ensure unbiased evaluation. The electrocardiograms were sent to a blinded, independent cardiologist in random order and individually evaluated for abnormalities.

Data Analysis

Data were entered in an Excel (Microsoft Corp., Redmond, WA) database for analysis. Data analysis was performed using Stata 6.0 (Stata Corp., College Station, TX). Descriptive statistics were used when appropriate. The percentage change from baseline laboratory values is presented with 95% confidence intervals (95% CI). Changes were considered insignificant when the confidence interval crossed zero.

RESULTS

A total of 66 subjects were enrolled (65 men and one woman), with a mean (±SD) age of 40.3 (±6.8) years (range, 29–55 years). No eligible subjects were excluded from participation. The mean (±SD) body mass index was 28.4 (±3.5) kg/m^2 (range, 21.1–36.8 kg/m^2). Of the 66 subjects, 51 (77.3%) reported no significant medical history, six (9.1%) reported a history of known hypertension, and six (9.1%) reported hypercholesterolemia. Additionally, one subject reported previous myocardial infarction with triple coronary artery bypass grafting and significant coronary artery disease. One subject also reported a history of congestive heart failure (currently well controlled), another reported a history of a transient ischemic attack two years prior, and one subject reported type 2 diabetes mellitus (Table 1). There were eight reports (12.1%) of a significant family history of coronary artery disease (close relative with early onset of disease). There were also 17 reports (25.8%) of strenuous physical exertion on the day of study enrollment. The strenuous physical exertion described was typical of an exertional aerobic workout or anaerobic weight lifting.

Laboratory results are shown in Table 2. There was no significant change from baseline for serum electrolyte levels and the blood urea nitrogen/creatinine ratio. An increase in serum bicarbonate and creatine kinase levels was noted at 16 and 24 hours. An increase in serum lactate level was noted immediately after exposure that decreased at 16 and 24 hours. Serum myoglobin level was increased from baseline at all three time points. The troponin I levels were all <0.3 ng/mL, except a single value of 0.6 ng/mL in a single subject at the 24-hour post-exposure period. This subject was evaluated in a hospital by a cardiologist, and no clinical evidence of acute myocardial infarction was identified and no evidence of cardiac disability was demonstrated. The troponin I value returned to normal within eight hours of its reported elevation. The subject was never symptomatic and continued a regimen of daily aerobic exercise after the hospital evaluation without difficulty.

Thirty of the 32 electrocardiograms were interpreted as normal. The two abnormal electrocardiograms remained the same at all four time points (one was left ventricular hypertrophy, and one was an occasional sinus pause). No other abnormalities were noted.

Table 1
Summary of Subject Medical Histories

Medical History		*n*	Percentage of Total
Past history	None	51	77.3
	Hypertension	6	9.1
	Hypercholesterolemia	6	9.1
	Mitral valve prolapse	2	3.0
	Hypothyroidism	1	1.5
	Congestive heart failure	1	1.5
	Previous myocardial infarction	1	1.5
	Cerebrovascular disease	1	1.5
	Asthma	1	1.5
	Diabetes	1	1.5
	Gout	1	1.5
Medications	None	52	78.8
	Statin	6	9.1
	Antihypertensive	6	9.1
	Aspirin	6	9.1
	Thyroxine	2	3.0
	Glipizide	1	1.5
	Allopurinol	1	1.5
	Nitroglycerin	1	1.5
Family history	None	44	66.7
	Coronary artery disease	8	12.1
	Diabetes	9	13.6
	Other*	13	19.7

* All other reported conditions (hypertension, hypercholesterolemia, stroke, abdominal aortic aneurysm, implanted cardiac pacemaker, rheumatoid arthritis, various cancers).

DISCUSSION

Conducted electrical weapons are considered to be an intermediate weapon by law enforcement agencies (intermediate weapons are those devices that generally can induce subject compliance due to pain or incapacitation and are a level above empty-hand control techniques but less than deadly force). Examples of intermediate weapons include devices such as aerosolized chemical irritants, impact batons, and projectile beanbags. TASER is a brand name (acronym for Thomas A. Swift Electric Rifle) of CEW. The terms "TASER device" and "CEW" are often used interchangeably because, at the time of this writing, there are no other CEW manufacturers that have brought products to market. Currently, TASER International manufactures two law enforcement models (X26 and M26) and three civilian models (X26^c, M18, and M18L). The X26 is the latest generation and the most popular model currently in use and was the model used in this study. It is considered to be a nonlethal weapon under the definition set forth by the U.S. Department of Defense.[7]

The X26 is programmed to deliver a roughly rectangular pulse of approximately 100-microsecond duration with about 100 μC of charge at 19 pulses per second for five seconds.[8] The peak voltage across the body is approximately 1,200 V, but the weapon also develops an open-circuit arc of 50,000 V to traverse clothing in cases where no direct contact is made. The average current is approximately 2.1 mA. It uses compressed nitrogen to fire two metallic darts up to a maximum of 35 ft with a

Table 2
Summary of Serum Analysis for Study Subjects

	Baseline	Time 2	Time 3	Time 4
Glucose (mg/dL)				
Mean	94.5	98.5	92.1	101.6
SD	13.8	16.5	22.6	19.4
Range	56–137	44–161	51–185	69–151
% Change (95% CI)		4.9 (−1.1, 8.6)	−1.0 (−7.6, 5.6)	7.6 (−0.5, 14.8)
BUN (mg/dL)				
Mean	16.5	16.5	16.9	17.2
SD	4.5	4.4	4.1	3.5
Range	9–31	9–29	11–31	11–28
% Change (95% CI)		−0.7 (−2.8, 1.4)	−5.3 (−10.2, 0.4)	−5.4 (−11.0, 0.2)
Creatinine (mg/dL)				
Mean	1.1	1.1	1.1	1.1
SD	0.16	0.15	0.13	0.14
Range	0.7–1.5	0.7–1.4	0.7–1.4	0.7–1.5
% Change (95% CI)		−1.0 (−2.5, 0.5)	2.1 (−0.7, 4.8)	−1.4 (−5.3, 2.6)
BUN/creatinine ratio				
Mean	15.1:1	15.0:1	16.0:1	15.3:1
SD	3.5	3.5	3.7	2.9
Range	9–24:1	9–27:1	9–26:1	11–25:1
% Change (95% CI)		0.0 (−2.2, 2.2)	8.1 (3.4, 12.9)	4.7 (−0.2, 9.5)
Sodium (mmol/L)				
Mean	138.8	138.9	137.4	137.8
SD	2.2	2.2	1.9	2.4
Range	135–148	134–147	134–142	134–145
% Change (95% CI)		−0.1 (−0.4, 0.2)	1.0 (0.5, 1.4)	0.7 (0.2, 1.1)
Potassium (mmol/L)				
Mean	4.1	3.9	4.5	4.2
SD	0.3	0.4	0.4	0.3
Range	3.5–5.0	3.3–4.9	3.7–5.7	3.2–5.2
% Change (95% CI)		4.1 (1.9, 6.4)	−8.7 (−11.7, −5.6)	−2.2 (−4.6, 0.1)
Chloride (mmol/L)				
Mean	100.3	99.9	101.1	101.0
SD	2.1	2.0	2.5	2.7
Range	96–106	95–109	96–108	96–108
% Change (95% CI)		0.4 (0.0, 0.8)	−0.7 (−1.4, 0.0)	−0.6 (−1.3, 0.0)
Bicarbonate (mmol/L)				
Mean	22.6	22.0	24.6	23.8
SD	1.9	2.1	2.1	2.3
Range	19–26	18–27	19–29	18–29
% Change (95% CI)		2.4 (0.4, 4.3)	−9.1 (−11.8, −6.3)	−5.0 (−7.2, −2.8)
Calcium (mg/dL)				
Mean	9.9	9.9	9.9	9.9
SD	0.3	0.3	0.3	0.3
Range	9.3–10.7	9.0–10.6	9.2–10.7	9.1–10.6
% Change (95% CI)		0.3 (−0.4, 0.9)	−0.4 (−1.0, 0.3)	0.1 (−0.8, 0.9)
Creatine kinase (U/L)				
Mean	185.1	184.1	221.6	242.3
SD	99.4	99.8	143.9	170.5
% Change (95% CI)		0.9 (−0.5, 2.2)	−23.9 (−38.1, −9.8)	−32.2 (−49.3, −15.0)
Range	71–479	60–484	50–806	52–909
Troponin I (ng/mL)				
Mean	0	0	0	0
SD	0	0	0	0
Range	0	0	0	0
% Change (95% CI)		0	0	0
Lactate (mg/dL)				
Mean	15.8	24.7	18.3	19.8
SD	5.7	7.6	6.8	6.7
Range	7–44	9–45	7–36	9–37
% Change (95% CI)		−66.9 (−80.8, −53.0)	−22.3 (−35.1, −9.5)	−30.8 (−43.6, −17.9)
Myoglobin (ng/mL)				
Mean	32.4	45.5	42.9	51.3
SD	15.1	27.1	22.4	29.8
Range	11–100	15–167	18–130	17–61
% Change (95% CI)		−34.1 (−57.4, −10.7)	−36.3 (−47.3, −25.6)	−64.0 (−89.4, −38.6)

Percent change is from baseline.

predetermined angled rate of spread. It is capable of transmitting an electrical impulse through two cumulative inches of clothing. When it makes adequate contact and the darts are of adequate separation, it causes involuntary contractions of the regional skeletal muscles that render the subject incapable of voluntary movement. If the darts are fired at very close range and do not achieve adequate separation, full muscular incapacitation may not be achieved, and the device is then used to encourage certain behavior through pain compliance. Additionally, the TASER device has electrical contact points at its tip that are approximately 1.5 inches apart. These contact points may be touched to a subject during discharge of the weapon and are also considered a pain compliance technique because the separation is not adequate to cause a full, involuntary contraction of muscles.

It has been theorized that CEWs have been associated with several sudden and unexpected subject deaths while in law enforcement custody. This ICD phenomenon is not new, and similar phenomena have been described in psychiatric literature dating back to the mid-1800s.[9] Over the years, there have been attempts to link ICD with single causative factors, such as use of chemical irritants (e.g., pepper spray), restraint and positional asphyxia, structural cardiac abnormalities, or use of illicit stimulant medication.[10–22] Many of these links have been questioned, disproved, or found to be absent.[23–29] This has generated more questions than answers in the search for a common cause.

One theory that has gained some recent popularity has been that of the condition of excited delirium and metabolic acidosis.[30] The described features of excited delirium syndrome include agitation, incoherence, hyperthermia, paranoia, inappropriate and often violent behavior, constant motion, and feats of incredible strength. This syndrome is closely associated with sudden, unexpected death.[19,29] It is believed that precursors to this condition are chronic, illicit stimulant abuse, presence of certain mental health conditions, and also use of certain mental health medications. It is believed that the state of excited delirium sets the stage for the subject to enter a metabolic acidosis condition, and this can be profound.[31] If left untreated, the subject will become acidotic to a point that is not compatible with life and will experience a cardiorespiratory arrest. Surveillance data seem to correlate this type of behavior with those at highest risk for an ICD event.[3]

However, another more recent theory is that of the TASER-induced ICD (TIICD). It is a perception by many that because a CEW incapacitates through the generation of electricity, it is somehow causing death, presumably from an electrically induced fatal arrhythmia. There have been media sources that have incorrectly compared CEWs with the electric chair used in capital punishment, although the electrical current specifications for each are markedly different.[32] If the TIICD theory is correct, it would be expected that electrically induced fatal arrhythmias would be inducible in the laboratory setting. This has not been the case, and there is evidence to show that the current, available CEW output would need to be increased to a minimum of 15 times its current setting to reliably induce ventricular fibrillation in a 60-lb animal.[33] This same study showed that animals with heavier masses required even greater outputs. Additionally, there have been instances when persons of small stature have experienced a CEW deployment without evidence of sudden death.[34,35] Collectively, these data do not support the theory of a CEW-induced fatal arrhythmia as the cause of ICD events.

If TIICD were to occur in real life, it would be expected that any induction of arrhythmia would be instantaneous and result in instantaneous collapse and cardiac arrest. However, in a surveillance of eight months of ICD events in the United States, only 27% of ICD events were associated with occurrence proximal to application of a CEW, and in none of these cases did the person collapse instantaneously after the application.[3] There have been two other data sources that seem to counter the TIICD theory. The first was a small study by Levine et al. that measured cardiac rhythm strips before, during, and after CEW application on a pool of volunteers. The conclusion was that the CEW application did nothing to create an abnormality on the observed rhythm strip.[36] The second and more compelling set of data comes from the training classes conducted by CEW manufacturer TASER International. These classes have delivered more than 100,000 CEW applications to participants with no reported collapses, cardiac arrests, or fatalities.[8] Additionally, the results of our study do not support this theory.

There has been one report in a letter to the editor of a medical journal of a case of ventricular fibrillation after exposure to a CEW.[37] Upon review of the paramedic field report, the subject received a CEW application because of apparent threatening behavior toward a police officer during a prolonged, agitated state. The subject was successfully subdued but found to be in cardiorespiratory arrest approximately 14–23 minutes after the CEW application. We believe that this case is very similar to every other described in the literature in which the ICD event occurs proximal to CEW exposure but collapse is not instantaneous. We believe that the facts of this case report do not support an electrically induced dysrhythmia.

Because the TIICD theory does not seem to be consistent with an instantaneously induced catastrophe, it has also been theorized that perhaps the application of the CEW somehow causes a more insidious, longer-term problem that manifests itself minutes or hours after the event. It is hypothesized that this could take the form of a silent myocardial event. It is also thought that perhaps the CEW application could induce rhabdomyolysis that has been associated with an excited delirium condition.[38] Because of this theory, we undertook this project.

Using standard laboratory analyses and electrical cardiac monitoring devices, we were unable to demonstrate a significant change from baseline in standard serum electrolyte values of the test subjects after application of the CEW. Of note, it is theorized that an association between CEW application and ICD is due to a possible induced hyperkalemia from cellular damage and necrosis. Our findings do not support this, and the mean serum potassium value actually decreased slightly immediately after CEW exposure. Additionally, we did not demonstrate any decrease in serum bicarbonate levels that would lead to a suggestion of induced acidosis.

With regard to serum markers of muscle injury such as creatine kinase, lactate dehydrogenase, and myoglobin,

we did demonstrate increased levels after CEW exposure. These findings were not unexpected based on previous literature demonstrating elevated levels of skeletal muscle damage markers for at least 48 hours following an exertional event.[39] We consider these CEW data to be a baseline with regard to resting human subjects. A possible consideration is that in subjects who experience an ICD event, there may be a connection between their hypermetabolic and presumed acidosis state (due to fleeing, fighting, stimulant use, and so on) and the application of CEWs. This possible connection has not yet been shown or disproved and remains as an area requiring further investigation.

The single subject with the slight elevation of troponin I level was initially concerning. All of this subject's troponin levels remained within the normal range (laboratory reference normal is 0.0–0.4 ng/mL) except for the single level drawn at 24 hours after CEW exposure. This level was 0.6 ng/mL. It should be noted that this subject was a very fit and athletic individual and had performed a rigorous aerobic workout regimen without difficulty about three hours before the CEW exposure. Despite being asymptomatic and feeling well, he was immediately taken to a hospital where he underwent admission and extensive cardiac evaluation from a group of consulting cardiologists. His initial troponin level at the hospital was drawn within eight hours of his elevated level and was 0.1 ng/mL. His inpatient evaluation included a treadmill stress test (Treadmill Myoview test utilizing standard Bruce protocol with a double product of 24,335 achieved) and a rest/adenosine-augmented stress gated tomographic myocardial perfusion study utilizing Tc99m radiopharmaceutical injection. The results of both tests were interpreted as normal. There were several explanations offered as possible causes by the consulting cardiologists. These included laboratory error, delayed clearance of troponin related to subject baseline physiology, or idiopathic and indeterminate etiology. There was agreement that there was no indication of myocardial damage or ischemia, and the subject was allowed to return to regular duty without limitations.

LIMITATIONS

Previous studies conducted on CEWs have used police volunteers as study subjects. The criticisms surrounding this type of sampling have focused on the perceived health of the study population. It has been stated that persons in the police profession have above-average health and fitness when compared with other members in society. Therefore, studies based on this population might be biased. The same criticism could be brought forward in this study. However, we collected the health histories of all of the volunteers and found that a surprising number of the volunteers had significant health problems as previously outlined. Based on this, we believe that this study population encompasses volunteers with health issues not unlike the general population. Additionally, the mean body mass index calculated for the study group places them in the "overweight" category for American adults. We acknowledge that the study population did not have a diagnosed mental illness condition and did not have an apparent history of illicit stimulant abuse. Both of these conditions are recognized to be present in a high percentage of subjects who experience an ICD event.[3,40] However, we also recognize that a real-time study of this population is unlikely to meet any protections required for human subject studies in this country.

Another limitation to this study is that the population sampled was considered to be at rest. This is unlike the population that meets the profile at high risk for an ICD event.[3] We recognize this but believe that these baseline data make an important contribution to this area of study, and we recommend that further study be conducted with other types of sample populations to determine associative risk, if any.

An additional criticism of this project might be that the study subjects received only a five-second application from the CEW. We recognize that there are occasional reports of multiple applications or prolonged exposures to CEWs, but we designed the study around the most common time exposure reported. The period of five seconds was used because the manufacturer's collected data suggest that a majority of field applications (67%) are for five seconds or less.[8]

CONCLUSIONS

In this resting adult population, the TASER X26 CEW did not affect the recordable cardiac electrical activity within a 24-hour period following a standard five-second application. We were unable to detect any induced electrical dysrhythmias or significant direct cardiac cellular damage that may be related to sudden and unexpected death proximal to CEW exposure. Additionally, we did not demonstrate evidence of dangerous hyperkalemia or induced acidosis. We recommend further study in the area of the ICD phenomenon to better understand its causes.

References

1. American Civil Liberties Union. Citing deaths in police custody, ACLU of Colorado calls for limits on use of electroshock weapons. ACLU Library, Feb 26, 2004. Available at: http://www.aclu.org/CriminalJustice/CriminalJustice.cfm?ID=15167&c=15. Accessed Nov 1, 2005.
2. Amnesty International. Excessive and lethal force? Amnesty International's concerns about deaths and ill-treatment involving police use of TASERs. Amnesty International Library, Nov 30, 2004. Available at: http://web.amnesty.org/library/index/engamr511392004. Accessed Nov 1, 2005.
3. Ho JD, Reardon RF, Heegaard WG. Deaths in police custody: an 8 month surveillance study [abstract]. Ann Emerg Med. 2005; 46(Suppl):S94.
4. Berenson A, Demands rise for tighter oversight on use of stun guns. New York Times. Feb 17, 2005:A24.
5. Anglen R. Taser safety claim questioned. Arizona Republic, Jul 18, 2004. Available at: http://www.azcentral.com/specials/special43/articles/0718taser-main18.html). Accessed Nov 1, 2005.
6. Anglen R. 73 cases of death following stun gun use. Arizona Republic, Oct 12, 2004. Available at: http://

www.azcentral.com/specials/special43/articles/0915taserlist16-ON.html. Accessed Nov 1, 2005.
7. Anonymous. Department of Defense Directive 3000.3 Policy for Nonlethal Weapons. United States Department of Defense. Jul 9, 1996. Available at: http://www.dtic.mil/whs/directives/corres/pdf/d30003_070996/d30003p.pdf. Accessed Nov 1, 2005.
8. TASER training video and information disk, version 12. Scottsdale, AZ: TASER International, Nov 2004.
9. Bell L. On a form of disease resembling some advanced stages of mania and fever, but so contradistinguished from any ordinary observed or described combination of symptoms as to render it probable that it may be overlooked and hitherto unrecorded malady. Am J Insanity. 1849; 6:97–127.
10. American Civil Liberties Union of Southern California. Pepper spray update: more fatalities, more questions. Pepper Spray Update, Jun 1995. Available at: http://www.aclu-sc.org/attachments/p/Pepper_Spray_New_Questions.pdf. Accessed Nov 1, 2005.
11. Stratton SJ, Rogers C, Brickett K, Gruzinski G. Factors associated with sudden death of individuals requiring restraint for excited delirium. Am J Emerg Med. 2001; 21:187–91.
12. Eckart RE, Scoville SL, Campbell CL, et al. Sudden death in young adults: a 25-year review of autopsies in military recruits. Ann Intern Med. 2004; 141: 829–35.
13. Maron BJ, Roberts WC, Epstein SE. Sudden death in hypertrophic cardiomyopathy: a profile of 78 patients. Circulation. 1982; 65:1388–94.
14. Ross DL. Factors associated with excited delirium deaths in police custody. Mod Pathol. 1998; 11: 1127–37.
15. Reay DT, Fligner CL, Stilwell AD, Arnold J. Positional asphyxia during law enforcement transport. Am J Forensic Med Pathol. 1992; 13:90–7.
16. O'Halloran RL, Lewman LV. Restraint asphyxia in excited delirium. Am J Forensic Med Pathol. 1993; 13: 289–95.
17. O'Halloran RL, Frank JG. Restraint asphyxia. Am J Forensic Med Pathol. 2000; 21:420–2.
18. O'Halloran RL, Frank JG. Asphyxial death during prone restraint revisited: a report of 21 cases. Am J Forensic Med Pathol. 2000; 21:39–52.
19. Wetli CV, Mash D, Karch SB. Cocaine-associated agitated delirium and the neuroleptic malignant syndrome. Am J Emerg Med. 1996; 14:425–8.
20. Karch SB, Stephens BG. Drug abusers who die during arrest or in custody. J R Soc Med. 1999; 92: 110–3.
21. Pestaner JP, Southall PE. Sudden death during arrest and phencyclidine intoxication. Am J Forensic Med Pathol. 2003; 24:119–22.
22. Ruttenber AJ, Lawler-Heavner J, Yin M, Wetli CV, Hearn WL, Mash DC. Fatal excited delirium following cocaine use: epidemiologic findings provide new evidence for mechanisms of cocaine toxicity. J Forensic Sci. 1997; 42:25–31.
23. United States Department of Justice, Office of Justice Programs, National Institute of Justice. The effectiveness and safety of pepper spray. Research for Practice, Apr 2003. Available at: http://www.ncjrs.gov/pdffiles1/nij/195739.pdf. Accessed Nov 1, 2005.
24. Chan TC, Vilke GM, Clausen J, et al. The effect of oleoresin capsicum "pepper" spray inhalation on respiratory function. J Forensic Sci. 2002; 47:299–304.
25. Chan TC, Vilke GM, Neuman T, Clausen JL. Restraint position and positional asphyxia. Ann Emerg Med. 1998; 32:116–8.
26. Chan TC, Vilke GM, Neuman T. Reexamination of custody restraint position and positional asphyxia. Am J Forensic Med Pathol. 1998; 19:201–5.
27. Chan TC, Neuman T, Clausen J, Eisele J, Vilke GM. Weight force during prone restraint and respiratory function. Am J Forensic Med Pathol. 2004; 25:185–9.
28. Kornblum RN, Reddy SK. Effects of the TASER in fatalities involving police confrontation. J Forensic Sci. 1992; 37:956–8.
29. Glatter K, Karch SB. Positional asphyxia: inadequate oxygen, or inadequate theory? Forensic Sci Int. 2004; 141:201–2.
30. Di Maio TG, Di Maio VJM. Excited Delirium Syndrome Cause of Death and Prevention, ed 1. Boca Raton, FL: Taylor & Francis, 2006.
31. Hick JL, Smith SW, Lynch MT. Metabolic acidosis in restraint-associated cardiac arrest: a case series. Acad Emerg Med. 1999; 6:239–43.
32. Anonymous. Taser packs potent but brief punch of electricity. USA Today. Jun 3, 2005:A13.
33. McDaniel WC, Stratbucker RA, Nerheim M, Brewer JE. Cardiac safety of neuromuscular incapacitating defensive devices. PACE. 2005; 28(Suppl):S284–7.
34. United Press International. Police use stun gun on 6 year old. The Washington Times. Nov 12, 2004. Available at: http://washingtontimes.com/upi-breaking/20041112-111756-3329r.htm. Accessed Nov 1, 2005.
35. Police review policy after tasers used on kids. CNN, Nov 15, 2004. Available at: http://www.cnn.com/2004/US/11/14/children.tasers/). Accessed Nov 1, 2005.
36. Levine SD, Sloane C, Chan T, Vilke G, Dunford J. Cardiac monitoring of subjects exposed to the TASER [abstract]. Acad Emerg Med. 2005; 12(Suppl 1):71.
37. Kim PJ, Franklin WH. Ventricular fibrillation after stun-gun discharge [letter]. N Engl J Med. 2005; 353: 958–9.
38. Ruttenber AJ, Mcanally HB, Wetli CV. Cocaine-associated rhabdomyolysis and excited delirium: different stages of the same syndrome. Am J Forensic Med Pathol. 1999; 20:120–7.
39. French DN, Kraemer WJ, VanHeest JL, et al. Physiological damage and stress of a competitive NCAA division 1 football game. Med Sci Sports Exerc. 2003; 35(Suppl):S320.
40. Pollanen MS, Chiasson DA, Cairns JT, Young JG. Unexpected death related to restraint for excited delirium: a retrospective study of deaths in police custody and in the community. CMAJ. 1998; 158:1603–7.