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Clinical Reviews

EMERGENCY DEPARTMENT EVALUATION AFTER CONDUCTED ENERGY WEAPON USE: REVIEW OF THE LITERATURE FOR THE CLINICIAN

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☐ **Abstract—Background: Conductive energy weapons (CEWs) are used daily by law enforcement, and patients are often brought to an emergency department (ED) for medical clearance. Study Objectives: To review the medical literature on the topic of CEWs and to offer evidence-based recommendations to Emergency Physicians for evaluation and treatment of patients who have received a CEW exposure. Methods: A MEDLINE literature search from 1988 to 2010 was performed and limited to human studies published from January 1988 to January 20, 2010 for English language articles with the following keywords: TASER, conductive energy device(s), electronic weapon(s), conductive energy weapon(s), non-lethal weapon(s), conducted energy device(s), conducted energy weapon(s), conductive electronic device(s), and electronic control device(s). Studies identified then underwent a structured review from which results could be evaluated. Results: There were 140 articles on CEWs screened, and 20 appropriate articles were rigorously reviewed and recommendations given. These studies did not report any evidence of dangerous laboratory abnormalities, physiologic changes, or immediate or delayed cardiac ischemia or dysrhythmias after exposure to CEW electrical discharges of up to 15 s. Conclusions: The current medical literature does not support routine performance of laboratory studies, electrocardiograms, or prolonged ED observation or hospitalization for ongoing cardiac monitoring after CEW exposure in an otherwise asymptomatic awake and alert patient.** © **2011 American Academy of Emergency Medicine**

☐ **Keywords—conductive energy weapons; TASER; emergency department; treatment**

INTRODUCTION

Use of conducted energy weapons (CEWs) such as the TASER (TASER International Inc., Scottsdale, AZ) includes delivery of a series of brief electrical pulses, which result in pain and muscular contractions. The pulses may be delivered via a pair of sharp metal probes fired from the device, commonly referred to as "probe mode," or by direct contact with the front of the device, commonly referred to as "drive stun" or "touch stun" mode.

Current practice in managing patients who present to the Emergency Department (ED) after being exposed to a CEW varies from place to place and by individual practitioners. Some hospitals have the practice of admitting all patients who were exposed to a TASER to the hospital for overnight telemetry monitoring, whereas other systems allow Emergency Medical Services providers to remove the darts in the field and the police take the patient directly to jail without ever going to an ED.

This article seeks to review the medical literature on the topic of CEWs and to offer evidence-based recommendations to Emergency Physicians for evaluation and

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treatment of patients who have received a CEW exposure. The clinical question being asked was: Do patients who present to an ED after a CEW exposure need any specific radiographic or laboratory evaluation or any specific monitoring based solely because a CEW was used? This work was done at the request of and published as a position statement by the American Academy of Emergency Medicine Clinical Guidelines Committee.

MATERIALS AND METHODS

This was a structured review of the literature on the topic of CEWs. A literature search of the National Library of Medicine's MEDLINE database's PubMed system was performed and limited to studies published from January 1988 to January 20, 2010 written in the English language. Keywords used in the search were: TASER, conductive energy device(s), electronic weapon(s), conductive energy weapon(s), non-lethal weapon(s), conducted energy device(s), conducted energy weapon(s), conductive electronic device(s), and electronic control device(s). After searching the articles found from these key word parameters, the Reference sections were also reviewed for additional articles.

Studies included for the final review were limited to randomized controlled trials, clinical trials, prospective and retrospective cohort studies, and meta-analyses in human subjects. Case reports, case series, and general review articles were not included for the selection criteria for formal rigorous review. The final list of all of the articles was assessed independently by two emergency medicine physicians to determine the classification of the article and deem whether appropriate for formal review.

Each of the articles selected underwent a Grade of Evidence Review. Each of the selected articles was subjected to detailed review by all three authors. The level of the evidence was assigned a grade using the definitions as noted in Table 1 and were based on reference focus, specific research design, and methodology.

Each of the selected articles was also subjected to detailed review and assigned a Quality Ranking based on a critical assessment with regards to quality of the design and methodology. This included Design Consideration (e.g., focus, model structure, presence of controls) and Methodology Consideration (actual methodology utilized). The definitions of the Quality Ranking scores are included in Table 2.

Independent review of the articles as well as discussion and joint review by the authors was undertaken to answer the clinical question. The references were sorted into 3 categories: supportive, neutral, and opposed. A table was constructed to assign the supportive references to the appropriate location using both the Grade of Evidence and the Quality of Evidence.

Finally, recommendations were made based on the review of the literature and assigned a level of recommendation, which are defined in Table 3.

RESULTS

The findings of the original key word search in MEDLINE are noted in Table 4 under the column "# ALL references." Combining these references resulted in 140 unique articles on CEWs. From these original 140 articles, the Reference sections were also reviewed, and no further novel articles were identified. It was noted that not all articles that were captured with these key words involved CEWs, which is why there were 145 articles found using the key words "conductive electronic devices" but only 140 unique articles identified on the topic.

Studies included for the final review were limited to randomized controlled trials, clinical trials, prospective and retrospective cohort studies, and meta-analyses. The numbers of references yielded by the various search parameters are included in the column labeled "final review" in Table 1. There were a total of 20 articles deemed appropriate for intensive critical review based on their suspected relevance to the clinical question (1–20). These 20 articles include: randomized controlled trials (n = 2), prospective controlled trials (n = 2), prospective cohort studies (n = 13), and retrospective cohort studies (n = 3) (Table 5).

Table 6 includes the Grade of Evidence and the Quality of Evidence for each of the articles reviewed. The references were sorted into three categories: supportive, neutral, and opposed. All were supportive; none were classified as neutral or opposed.

Recommendation 1: Cardiac Monitoring and Electrocardiogram Screening after CEW Use

Level of recommendation: Class A. The current human literature has not found evidence of immediate or delayed cardiac ischemia or dysrhythmias after CEW exposures

Table 1. The Definitions of the Grades of Evidence of the Articles

Grade A	Randomized clinical trials or meta-analyses (multiple clinical trials) or randomized clinical trials (smaller trials), *directly* addressing the review issue
Grade B	Randomized clinical trials or meta-analyses (multiple clinical trials) or randomized clinical trials (smaller trials), *indirectly* addressing the review issue
Grade C	Prospective, controlled, non-randomized, cohort studies
Grade D	Retrospective, non-randomized, cohort or case-control studies

Table 2. The Definitions of the Quality Ranking Scores of the Articles

Ranking	Design Consideration Present	Methodology Consideration Present	Both Considerations Present
Outstanding	Appropriate	Appropriate	Yes, both present
Good	Appropriate	Appropriate	No, either present
Adequate	Adequate with possible bias	Adequate	No, either present
Poor	Limited or biased	Limited	No, either present
Unsatisfactory	Questionable/none	Questionable/none	No, either present

of up to 15 s. *Therefore, the medical literature does not support routine performance of electrocardiograms (ECGs), prolonged ED observation, or hospitalization for ongoing cardiac monitoring after CEW exposure in an otherwise asymptomatic awake and alert patient with a short duration (< 15 s) of CEW exposure.*

Studies have looked for dysrhythmias during and immediately after CEW use (1,11–14,19,20). There have been no reports of ectopy, dysrhythmia, QT prolongation, interval changes, or other ECG changes immediately after CEW use. Additionally, studies have looked at delayed monitoring findings and there have been no changes in ECGs 60 min or longer post CEW use (13,17,20).

Studies have also looked at serial troponin levels as a marker of cardiac injury or ischemia. A number of studies have looked at troponin levels at 6 h post CEW activation, and all levels except one have been normal (12,13,15,20). The one study that showed elevated troponin was on a healthy young male subject who received a 5-s TASER activation (13). The troponin I values all were < 0.3 ng/mL, except a single value of 0.6 ng/mL at the 24-h draw, which had been normal at the 16-h draw, and returned to normal within 8 h of the reported elevation. The subject was evaluated at the hospital by a cardiologist and showed no evidence of myocardial infarction or cardiac disability. 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 Tc99 m radiopharmaceutical injection. The results of both tests were interpreted as normal.

Echocardiograms during CEW use have also shown no abnormalities during activation to suggest electrical capture or structural cardiac damage (3,11).

Recommendation 2: Laboratory Testing after CEW Use

Level of recommendation: Class A. The current human literature has not found evidence of dangerous laboratory abnormalities or physiologic changes after CEW exposures of up to 15 s. *Therefore, the medical literature does not support routine performance of laboratory studies, prolonged ED observation, or hospitalization for ongoing laboratory monitoring after a short duration of CEW exposure (< 15 s) in an otherwise asymptomatic awake and alert patient.*

Studies have not shown any clinically significant changes in electrolyte levels or renal function in subjects with up to 15-s CEW activations (9,13,18,20). There have

Table 3. Definitions for Recommendations

Level of Recommendation	Criteria for Level of Recommendation	Mandatory Evidence
Class A Recommended with outstanding evidence	• Acceptable • Safe • Useful • Established/definitive	• Level A/B grade • Outstanding quality • Robust • All positive
Class B Acceptable and appropriate with good evidence	• Acceptable • Safe • Useful • Not yet definitive	• Level A/B grade lacking • Adequate to Good quality • Most evidence positive • No evidence of harm
Class B 1	• Standard approach	• Higher grades of evidence • Consistently positive
Class B 2	• Optional or alternative approach	• Lower grades of evidence • Generally, but not consistently, positive
Class C Not acceptable or not appropriate	• Unacceptable • Unsafe • Not useful	• No positive evidence • Evidence of harm
Class Indeterminate Unknown	• Minimal to no evidence	• Minimal to no evidence

Table 4. All English-language Articles Found with the Following Search Parameters

Search Parameter	# All References	# Final Review
Conductive electronic devices	145	0
TASER	137	15
Conductive energy devices	113	4
Conductive electronic device	112	0
Conductive energy device	87	4
Electronic weapon	70	8
Electronic weapons	54	8
Conducted energy weapons	32	6
Non-lethal weapons	30	0
Non-lethal weapon	22	0
Electronic control devices	12	0
Electronic control device	11	0
Conducted energy weapon	4	1
Conductive energy weapon	3	3
Conductive energy weapons	3	3
Conducted energy device	0	0
Conducted energy devices	0	0

been mild but clinically insignificant elevations in lactate levels with CEW activations. However, these have been demonstrated to be of a smaller magnitude relative to other forms of physical exertion with a similar duration (8,10,12,13,18,20).

Acid base status has been evaluated and has not shown any significant pH shifts for a 5-s CEW activation (13,18,20). Similar findings with mild transient pH shifts were noted in CEW use for longer durations of application up to 15 s (9).

Recommendation 3: Evaluation after Use of CEW in Drive Stun or Touch Stun Mode

Level of recommendation: Class B. For patients who have undergone drive stun or touch stun CEW exposure, medical screening should focus on local skin effects at the exposure site, which may include local skin irritation or minor contact burns. This recommendation is based on a literature review in which thousands of volunteers and individuals in police custody have had drive stun CEWs used with no untoward effects beyond local skin effects.

As above, routine ECG, cardiac monitoring, laboratory testing, or other forms of evaluation specific to the electrical component of short-duration CEW use are generally unnecessary.

Recommendation 4: Evaluation after Use of CEW in Probe Mode

Level of recommendation: Class B. For patients who have undergone probe mode CEW exposure, medical screening should focus on probe penetration sites, potential injuries due to muscle contractions, and potential trauma due to falls. CEW probes may strike the eyes, or penetrate skin and nearby superficial structures such as vessels, nerves, and bones. Muscle contractions due to the CEW may produce spinal compression fractures and other soft tissue injuries. Falls may occur from loss of muscular control and protective reflexes, resulting in blunt trauma. Literature review indicates that significant injuries due to this mechanism are rare, occurring in $<0.5\%$ of real-world deployment in subjects (2,16).

As above, routine ECG, cardiac monitoring, laboratory testing, or other forms of evaluation specific to the electrical component of short-duration CEW use are generally unnecessary.

DISCUSSION

CEWs are commonly used by police as an intermediate force option. Civilian models of CEWs are also available to the public. Patients may be brought to EDs for medical evaluation after CEW exposure. The primary goal in conducting this literature search was to identify whether routine monitoring, ECG, with or without laboratory tests are necessary for a patient who presents after receiving an electrical discharge from a CEW.

Our evaluation considered both techniques in which a CEW can be used. They are the drive or touch stun mode, and the probe mode. In the drive stun mode, the tip of the device is placed in contact with the subject and locally conducts energy across the two probes that are present on the tip of the device. This mode typically causes local painful stimuli. The other technique is the "probe mode," which uses two sharp metal darts that are shot from a distance into the subject or the subject's clothing, causing energy to arc a greater distance across the two probes. If there is enough of a probe spread, generalized muscle contraction, sometimes termed "neuromuscular incapacitation," is produced. This may result in the subject falling if he or she is in a standing position. There are case reports of injuries sustained directly from the darts, such as ocular, skull, or genital penetration (21,22). Other case reports of spinal compression fractures, presumably from intense muscle contractions of the back musculature in subjects with osteopenia, have been documented (23,24). There are no studies demonstrating the effects on pregnant women, so physicians will need to make clinical decisions on the need for fetal assessment and monitoring based on the type of CEW use, location, and patient presentation.

As noted above, the literature review for this clinical guideline focused on studies that involved rigorous methodologies to evaluate the physiologic effects of CEWs in humans. We did not include specific case reports or case series which in and of themselves cannot support any causal connection between CEWs and physiologic changes. We also did not include animal studies, which

Table 5. Details of the 20 Reviewed Articles

List #	Article Information	Grade	Quality	Design, Size
1	Bozeman WP et al. Immediate cardiovascular effects of the Taser X26 conducted electrical weapon. Emerg Med J 2009	C	Good	Prospective cohort (n = 28)
2	Bozeman WP et al. Safety and injury profile of conducted electrical weapons used by law enforcement officers against criminal suspects. Ann Emerg Med 2009	D	Good	Retrospective cohort (field use) (n = 1201)
3	Dawes DM et al. Echocardiographic evaluation of TASER X26 probe deployment into the chests of human volunteers. Am J Emerg Med 2010	C	Good	Prospective cohort (n = 10)
4	Dawes DM et al. Electrical characteristics of an electronic control device under a physiologic load: a brief report. Pacing Clin Electrophysiol 2009	C	Good	Prospective cohort (n = 9)
5	Dawes DM et al. 15-Second conducted electrical weapon exposure does not cause core temperature elevation in non-environmentally stressed resting adults. Forensic Sci Int 2008	C	Good	Prospective controlled trial (n = 32)
6	Dawes D et al. The neuroendocrine effects of the TASER X26: a brief report. Forensic Sci Int 2009	B	Good	Prospective randomized controlled trial (n = 52)
7	Eastman AL et al. Conductive electrical devices: a prospective, population-based study of the medical safety of law enforcement use. J Trauma 2008	D	Adequate	Retrospective cohort (field use) (n = 426)
8	Ho JD et al. Prolonged TASER use on exhausted humans does not worsen markers of acidosis. Am J Emerg Med 2009	C	Good	Prospective cohort (n = 38)
9	Ho JD et al. Lactate and pH evaluation in exhausted humans with prolonged TASER X26 exposure or continued exertion. Forensic Sci Int 2009	B	Good	Prospective randomized controlled trial (n = 40)
10	Ho JD et al. Absence of electrocardiographic change after prolonged application of a conducted electrical weapon in physically exhausted adults. J Emerg Med 2009	C	Good	Prospective cohort (n = 25)
11	Ho JD et al. Echocardiographic evaluation of a TASER-X26 application in the ideal human cardiac axis. Acad Emerg Med 2008	C	Good	Prospective cohort (n = 34)
12	Ho JD et al. Respiratory effect of prolonged electrical weapon application on human volunteers. Acad Emerg Med 2007	C	Outstanding	Prospective cohort (n = 52)
13	Ho JD et al. Cardiovascular and physiologic effects of conducted electrical weapon discharge in resting adults. Acad Emerg Med 2006	C	Outstanding	Prospective cohort (n = 66)
14	Levine SD et al. Cardiac monitoring of human subjects exposed to the taser. J Emerg Med 2007	C	Good	Prospective cohort (n = 105)
15	Sloane CM et al. Serum troponin I measurement of subjects exposed to the Taser X-26. J Emerg Med 2008	C	Good	Prospective cohort (n = 66)
16	Strote J et al. Conducted electrical weapon use by law enforcement: an evaluation of safety and injury. J Trauma 2009	D	Adequate	Retrospective cohort (Field use) (n = 1101)
17	VanMeenen KM et al. Cardiovascular evaluation of electronic control device exposure in law enforcement trainees: a multisite study. J Occup Environ Med 2010	C	Good	Prospective cohort (n = 118)
18	Vilke GM et al. Physiologic effects of the TASER after exercise. Acad Emerg Med 2009	C	Outstanding	Prospective controlled trial (n = 25)
19	Vilke GM et al. Twelve-lead electrocardiogram monitoring of subjects before and after voluntary exposure to the Taser X26. Am J Emerg Med 2008	C	Good	Prospective cohort (n = 32)
20	Vilke GM et al. Physiological effects of a conducted electrical weapon on human subjects. Ann Emerg Med 2007	C	Outstanding	Prospective cohort (n = 32)

Table 6. Supportive Evidence (Article # Referenced)

Quality/Grade	A	B	C	D	E	F
Outstanding			12, 13, 18, 20			
Good		6, 9	1, 3, 4, 5, 8, 10,11, 14, 15, 17, 19	2		
Adequate				7, 16		
Poor						
Unsatisfactory						

There were no neutral or opposed references.

are often more limited in scope and have questionable applicability to clinical human findings.

Recommendations in this review are limited to CEW exposure durations of 15 s or less. This reflects the exposure durations commonly used in the existing human literature and will apply to the large majority (> 90%) of subjects against whom CEWs are used by police officers. Although several reports have included exposure durations of 20–45 s and have not demonstrated concerning cardiac or physiologic effects, collectively this small body of literature is inadequate to support guidelines on medical screening after longer duration exposures. Therefore, until confirmatory studies of adequate power are available, clinicians should use their own judgment regarding the need for screening tests in this population.

It is important to point out that these recommendations focus solely on the issue of CEWs and their physiologic effects on humans. Clinical evaluation and testing may very well be warranted when evaluating patients after CEW application, not due to the CEW exposure, but as a result of the patient's underlying condition such as alcohol or drug intoxication, altered mental status, physical exhaustion, excited delirium, or psychiatric conditions that precipitated the application of the CEW in the first place.

CONCLUSIONS

The current human literature has not found evidence of dangerous laboratory abnormalities, physiologic changes, or immediate or delayed cardiac ischemia or dysrhythmias after exposure to CEW electrical discharges of up to 15 s. Therefore, the current medical literature does not support routine performance of laboratory studies, ECGs, or prolonged ED observation or hospitalization for ongoing cardiac monitoring after CEW exposure in an otherwise asymptomatic awake and alert patient.

Testing for cardiac conduction abnormalities or injury, or other physiologic effects of CEWs may be appropriate in individual cases based on medical history such as history of cardiac disease or symptoms like chest discomfort, shortness of breath, or palpitations suggestive of cardiac issues, pain suggesting muscle contraction injuries, or prolonged CEW exposure > 15 s. Coexisting conditions like intoxication, prolonged struggling, altered mental status, or symptoms of excited delirium syndrome may also be present in patients exposed to CEWs, although the CEW does not seem to be the precipitating factor. Presence of these findings should prompt additional evaluation or treatment of the underlying condition as clinically warranted.

For CEW activations in the probe mode, patients should be screened for injuries related to the dart penetration or surface burns due to CEW use, as well as injuries associated with falls and muscle contractions. Among patients who had a CEW activation in drive stun or touch stun mode, evaluation should focus on skin manifestations, which are typically limited to surface burns, also called signature marks.

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ARTICLE SUMMARY

1. Why is this topic important?

Conductive Energy Weapons (CEWs) are used daily by law enforcement and patients are often brought to Emergency Departments (ED) for medical clearance.

2. What does this review attempt to show?

The clinical question being asked was: Do patients who present to an Emergency Department after a CEW exposure need any specific radiographic or laboratory evaluation or any specific monitoring based solely because a CEW was used?

3. What are the key findings?

These studies did not report any evidence of dangerous laboratory abnormalities, physiologic changes, or immediate or delayed cardiac ischemia or dysrhythmias after exposure to CEW electrical discharges of up to 15 seconds.

4. How is patient care impacted?

There might be more efficient use of the emergency department and ICU beds.