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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 emergency departments (EDs) for medical clearance. Objective: Our aim was 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 2018 was performed and limited to human studies published from January 1, 1988 to November 1, 2018 written in English 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: Two hundred and sixty-three articles on CEWs were screened and 37 appropriate articles were rigorously reviewed. Evaluation and treatment recommendations are presented. 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, electrocardiography, or prolonged ED observation or hospitalization for ongoing cardiac monitoring after CEW exposure in an otherwise asymptomatic awake and alert patient.**

☐ **Keywords—conductive energy weapons; TASER; electronic weapons; systematic review**

Clinical Practice Paper approved by the American Academy of Emergency Medicine Clinical Guidelines Committee.

INTRODUCTION

Use of conducted energy weapons (CEWs), such as the TASER, includes delivery of a series of electrical pulses, which result in pain and muscular contractions. The electrical pulses can be delivered by a pair of metal probes propelled from the device, commonly referred to as "probe mode," or by direct contact with the end of the device, commonly referred to as "drive stun" or "touch stun" mode.

Clinical practice managing patients who present to the ED after being exposed to a CEW are varied. This article reviews the medical literature on the topic of CEWs and offers evidenced-based recommendations to emergency physicians for evaluation and treatment of patients who have received a CEW exposure. The clinical question is: Do patients who present to an ED after a CEW exposure require any specific radiographic or laboratory evaluation or any specific monitoring because of the use of a CEW itself? This work was done at the request of and published as a position statement by the American

Academy of Emergency Medicine (AAEM) Clinical Guidelines Committee. The original AAEM Guidelines on this topic were published in 2011 (1). This article will update findings from that article to include more contemporary literature.

MATERIALS AND METHODS

This study is 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 1, 1988 to November 1, 2018 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 keyword 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 articles was assessed independently by two emergency physicians to determine the classification of the article, and deem whether it was appropriate for formal review.

Each of the articles selected underwent a Grade of Evidence Review (grades A, B, C, or D). 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 (Outstanding, Good, Adequate, Poor, or Unsatisfactory) based on a critical assessment with regard to quality of the design and methodology. This includes Design Consideration (eg, focus, model structure, and presence of controls) and Methodology Consideration (ie, 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. Finally, recommendations were made based on the review of the literature and assigned a level of recommendation (class A, B, C, or indeterminant), which are defined in Table 3.

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

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

RESULTS

The findings of the original keyword search in MEDLINE are noted in Table 4. Combining these references resulted in 263 unique articles on CEWs. From these original 263 articles, the reference sections were also reviewed, and no further novel articles were identified. The numbers of references yielded by the various search parameters are included in Table 4. There were a total of 37 articles deemed appropriate for intensive critical review based on their suspected relevance to the clinical question. These 37 articles are briefly described in Table 5 and include: randomized controlled trials (n = 2), prospective controlled trials (n = 2), prospective cohort studies (n = 28), and retrospective cohort studies (n = 5).

The vast majority of studies (n = 30) received an evidence grade of C (prospective, controlled, non-randomized, cohort studies); 5 studies were grade D, and 2 studies were grade B. No studies were determined to reach the A grade level (randomized clinical trial or meta-analysis directly addressing the review issue). All but three of the studies were determined to be Good or Outstanding in terms of quality, as determined by the reviewers.

Based on this analysis, the following recommendations were formulated as classified by level of recommendation/evidence (A, B, C).

Recommendation 1: Cardiac Monitoring and Electrocardiography 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 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.

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

Studies have looked for dysrhythmias during and immediately after CEW use (2–10). There have been no reports of ectopy, dysrhythmia, QT prolongation, interval changes, or other ECG changes immediately following CEW use. Additionally, studies have looked at delayed monitoring findings and there have been no changes in ECGs up to 60 min or longer post CEW use (3,7,11).

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 troponin level have been normal (3,4,7,12). The one study that showed elevated troponin was on a healthy young male subject who received a 5-s TASER activation (3). The troponin I values were all < 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. More recent studies have measured troponin initially and at 24 h; no clinically significant elevations were found (9,10,13–15).

Echocardiograms during CEW use have also shown no abnormalities during activation that suggest structural cardiac damage (5,9,10,14–17). Due to the proximity to the myocardium, probes inserted in the anterior chest are at highest risk of inducing cardiac capture. There have been 66 human subjects who have had continuous monitoring during anterior chest wall probe placement; no cases of ventricular fibrillation (VF) were induced and one case of capture was recorded (18). This case occurred with an experimental CEW device model, which was never manufactured or released for commercial use (9).

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 (3,7,10,13,19–21). There have 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 (3,4,7,10,13–15,20–28).

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 B1	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. Search Parameters for All English Language Papers Found

Search Parameter	All References, n	Final Review, n
Conductive electronic devices	1608	0
Taser	327	13
Conductive energy devices	994	2
Conductive electronic device	965	0
Conductive energy device	649	2
Electronic weapon	1169	5
Electronic weapons	955	5
Conducted energy weapons	102	4
Non-lethal weapons	55	2
Non-lethal weapon	52	0
Electronic control devices	20,296	0
Electronic control device	16,365	0
Conducted energy weapon	128	1
Conductive energy weapon	10	2
Conductive energy weapons	9	2
Conducted energy device	1140	0
Conducted energy devices	1463	0

There have been three studies of humans, with a total of 241 patients, examining the rise of creatine kinase (CK) levels with CEW use (10,11,29). While there were small rises in CK, none were clinically significant. Of note, those subjects that were found to have a rise in CK were often found to have broken study protocol and performed strenuous exercise immediately after CEW exposure and prior to blood sampling 24 h after exposure.

Acid–base status has been evaluated and has not shown any significant pH shifts for a 5-s CEW activation (3,7,20,25). Similar findings with mild transient pH shifts were noted in CEW use for longer durations of application up to 15 s (10,13–15,19,21,28).

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.

Table 5. Details of the 37 Reviewed Articles

List No.	First Author, Year (Reference)	Grade	Quality	Design
1	Bozeman, 2009 (2)	C	Good	Prospective cohort (n = 28)
2	Bozeman, 2009 (30)	D	Good	Retrospective cohort (field use) (n = 1201)
3	Bozeman, 2012 (40)	D	Good	Retrospective cohort (field use) (n = 178)
4	Criscione, 2014 (41)	C	Adequate	Prospective cohort (n = 32)
5	Dawes, 2010 (16)	C	Good	Prospective cohort (n = 10)
6	Dawes, 2010 (42)	C	Good	Prospective cohort (n = 9)
7	Dawes, 2010 (14)	C	Outstanding	Prospective cohort (n = 30)
8	Dawes, 2010 (15)	C	Outstanding	Prospective cohort (n = 16)
9	Dawes, 2008 (24)	C	Good	Prospective controlled trial (n = 32)
10	Dawes, 2009 (43)	B	Good	Prospective randomized controlled trial (n = 52)
11	Dawes, 2011 (21)	C	Outstanding	Prospective cohort (n = 53)
12	Eastman, 2008 (44)	D	Adequate	Retrospective cohort (field use) (n = 426)
13	Gardner, 2012 (45)	D	Good	Retrospective cohort (field use) (n = 100)
14	Havranek, 2015 (17)	C	Good	Prospective cohort (n = 26)
15	Ho, 2012 (46)	C	Good	Prospective cohort (n = 31)
16	Ho, 2010 (13)	C	Good	Prospective cohort (n = 66)
17	Ho, 2011 (9)	C	Good	Prospective cohort (n = 53)
18	Ho, 2009 (22)	C	Good	Prospective cohort (n = 38)
19	Ho, 2009 (19)	B	Good	Prospective randomized controlled trial (n = 40)
20	Ho, 2011 (23)	C	Good	Prospective cohort (n = 25)
21	Ho, 2008 (5)	C	Good	Prospective cohort (n = 34)
22	Ho, 2007 (4)	C	Outstanding	Prospective cohort (n = 52)
23	Ho, 2006 (3)	C	Outstanding	Prospective cohort (n = 66)
24	Ho, 2013 (25)	C	Good	Prospective cohort (n = 37)
25	Ho, 2014 (10)	C	Good	Prospective cohort. (n = 10)
26	Kroll, 2018 (27)	C	Good	Prospective cohort (n = 31)
27	Levine, 2007 (6)	C	Good	Prospective cohort (n = 105)
28	Moscati, 2010 (28)	C	Good	Prospective cohort (n = 22)
29	Scherr, 2016 (47)	C	Good	Prospective cohort (n = 71)
30	Sloane, 2008 (12)	C	Good	Prospective cohort (n = 66)
31	Stopyra, 2017 (48)	C	Good	Prospective cohort (n = 4)
32	Strote, 2010 (31)	D	Adequate	Retrospective cohort (field use) (n = 1101)
33	Vanmeenen, 2013 (49)	C	Good	Prospective cohort (n = 23)
34	Vanmeenen, 2010 (11)	C	Good	Prospective cohort (n = 118)
35	Vilke, 2009 (20)	C	Outstanding	Prospective controlled trial (n = 25)
36	Vilke, 2008 (8)	C	Good	Prospective cohort (n = 32)
37	Vilke, 2007 (7)	C	Outstanding	Prospective cohort (n = 32)

As mentioned, 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 and 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 (30,31).

As mentioned, 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 a force option. Civilian models of CEWs are also available to the public. Patients may be brought to the ED 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 end 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 metal probes that are propelled 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, termed as *neuromuscular incapacitation*, is produced. This may result in the subject falling if he or she is in a standing position. Traumatic brain injuries are probably the most serious result of these falls (32). Rarely, direct traumatic injuries occur, including ocular, skull, or genital penetration (33–35). Other case reports of spinal compression fractures, presumably from intense muscle contractions of the back musculature in subjects with osteopenia, have been documented (36,37). Very rarely, patients will be injured by serious burns associated with CEW use; these will be obvious and examination will guide treatment (38). There are no rigorous 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.

There has not been a documented case of CEW-induced lethal VF that has withstood close scrutiny; whether it is theoretically possible is controversial and beyond the scope of this review (18,39). For the case of this review, one should note that if a dysrhythmia is going to be induced, the dysrhythmia should happen at the time of the CEW discharge, not in delayed fashion (39). Thus, providers evaluating a patient exposed to a CEW who now has a reassuring examination can be confident that the patient will not develop a delayed dysrhythmia; and testing and monitoring specifically for this possibility is unnecessary.

As noted, 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 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. This reflects the exposure durations commonly used in the existing human literature and applies to the large majority of subjects against whom CEWs are used by police officers. While 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, 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 because of the CEW exposure, but as a result of the patient's underlying condition, such as alcohol or drug intoxication, excited delirium syndrome, altered mental status, physical exhaustion, 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 or concerning 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 abnormalities or injuries may be appropriate in individual cases based on clinical presentation, such as a history of cardiac disease or suggestive symptoms like chest discomfort, shortness of breath, or palpitations. Similarly, penetrating and blunt trauma as a consequence of CEW exposure should prompt further evaluation for traumatic and musculoskeletal injuries as 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.

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 appear to be the precipitating factor. Presence of these findings should prompt additional evaluation or treatment of the underlying condition as clinically warranted.

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