Immediate cardiovascular effects of the Taser X26 conducted electrical weapon

W P Bozeman, D G Barnes, Jr, J E Winslow, III, J C Johnson, III, C H Phillips and R Alson

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ABSTRACT

Study objectives: To evaluate the immediate cardiac and cardiovascular effects of Taser X26 conducted electrical weapon (CEW) exposure in human volunteers, including heart rhythm, rate and blood pressure.

Methods: Volunteer police officers participating in CEW training and testing each underwent a 5, 3 and 1 s exposure to the Taser X26 CEW. Continuous electrocardiogram (ECG) monitoring was performed before, during and after each exposure. Blood pressures were measured at rest before and within 1 minute after each exposure. Paired sample t-test analysis and confidence interval calculations were performed.

Results: 84 Taser exposures were monitored among 28 subjects (24 men, four women) with an average age of 34 years (range 24–46, SD 5.6). No cardiac dysrhythmias or aberrantly conducted beats were seen. Mean heart rate increased by 10.9 beats per minute (bpm) (95% CI 8.2 to 13.7) from 121.7 to 132.6 (p<0.001). The QRS and QTc cardiac intervals did not change significantly. Mean blood pressure increased from 138.6/82.8 mm Hg at rest to 145.8/85.6 mm Hg after the standard 5-s CEW discharge.

Conclusion: CEW exposure produced no detectable dysrhythmias and a statistically significant increase in heart rate. Overall, Taser CEW exposure appears to be safe and well tolerated from a cardiovascular standpoint in this population. This study increases the cumulative human subject experience of CEW exposure with continuous ECG monitoring and includes 28 full 5-s exposures.

The Taser is a conducted electrical weapon (CEW) used by an estimated 12 000 of the 18 000 law enforcement agencies in the USA, as well as numerous law enforcement agencies in the UK and other countries. These CEW (fig 1) are intended to incapacitate violent or dangerous suspects without causing serious injury by delivering a series of electrical pulses that produce pain and muscular tetany. The devices fire two sharp metal probes propelled by compressed gas. The probes remain connected to the device by thin insulated wires, which allow the delivery of 19 electrical pulses per second. Each pulse lasts approximately 100 μs and delivers a small electric charge (0.36 joules for the X26 model), at high voltages. The standard discharge duration is 5 s, although this may be terminated early or repeated by the operator. An estimated 640 000 human exposures have occurred in field deployments and volunteer settings since the modern device’s introduction in 1999. Thousands of police officers are trained in its use yearly; most are voluntarily exposed to its discharge as part of their training.

CEW have been associated with lower injury rates in both suspects and officers when compared with alternative police force options such as hand-held impact weapons, irritant sprays and police dogs. Numerous police agencies have reported overall reductions in officer injuries, suspect injuries and uses of lethal force after the implementation of CEW. However, concerns remain regarding the overall safety of CEW, and particularly the possibility of cardiac dysrhythmias related to the electrical current of the CEW.

The purpose of this study was to elucidate further the possible dysrhythmogenic and cardiovascular effects of a commonly used CEW, the Taser model X26. We also evaluated the possibility of a dose–response relationship related to the duration of discharge. We hypothesised that CEW exposure would not produce dysrhythmias, but would produce a hypertensive/tachycardic response with a dose-dependent change in heart rate.

METHODS

Study participants included adult police officers participating in their law enforcement agency’s training and testing process for the Taser model X26 CEW. As part of the training and testing process each officer voluntarily underwent three exposures to the Taser discharge including a 5, 3 and 1 s exposure in that sequence. The CEW discharge was applied using alligator clips secured to light gym clothing with varying probe locations and spacing according to the agency’s evaluation protocol. For medical study purposes each subject provided demographic information and underwent electrocardiogram (ECG) monitoring and vital sign measurement. The institutional review board approved the protocol and informed consent was obtained from each subject before study participation.

Continuous three-lead ECG monitoring was performed immediately before, during and after each exposure to the CEW (Lifepak 10; Medtronic, Inc, Minneapolis, Minnesota, USA). Investigators printed and analysed a lead II rhythm strip. Any dysrhythmias or aberrantly conducted complexes were noted. Heart rates and standard ECG intervals (PR, QRS, QT and QT corrected) were measured using calipers approximately 5 s before and after each CEW discharge.

Oscillometric blood pressure measurements were obtained at rest just before exposure and approximately 60 s after each Taser exposure (Lifepak 12; Medtronic Inc). Blood pressures were compared at rest and after the initial 5-s exposure to assess the
haemodynamic response to a standard Taser “dose” compared with the pre-exposure state.

Data were entered and analysed using standard spreadsheet software (Microsoft Office Excel 2003 SP2). Descriptive and comparative statistical analysis was performed using commercial software (InStat 3.06; GraphPad Software Inc, San Diego, California, USA). Numeric means were compared using non-parametric Wilcoxon rank sum testing.

RESULTS
A total of 84 CEW exposures was monitored in 28 subjects. The subjects included 24 men and four women with an average age of 34 years (range 24–46, SD 5.6). Average weight was 183 lb (range 119–225, SD 27) and average body mass index was 26.3 (range 20.4–31.4, SD 2.76).

No abnormal cardiac dysrhythmias or aberrantly conducted beats were detected. Normal sinus rhythm or sinus tachycardia was seen before and after each exposure. Cardiac rhythm during the CEW discharge was typically obscured by the electrical noise produced by the weapon, although an underlying rhythm at a similar rate as before and after the shock was discernable through the noise in several cases. (fig 2).

The overall mean heart rate increased from a baseline of 121.7 to 132.6 beats per minute (bpm), an increase of 10.9 bpm (95% CI 8.2 to 13.7, p < 0.0001; table 1.) When grouped by exposure times a trend towards a dose–response was seen, with heart rates increasing by 9.7, 11.1 and 12.3 bpm for the 1, 3 and 5-s CEW exposure times, respectively. These increases are statistically significant compared with each group’s own pre-exposure baseline. However, when compared between exposure times the confidence intervals for the increases overlap, indicating a lack of statistical significance between the groups.

Comparison of standard cardiac intervals shows a decrease in the mean PR interval compared with baseline. There was no significant change in the QRS or QTc durations (table 2).

Mean blood pressure increased from 138.6/82.8 mm Hg at rest to 145.8/85.6 mm Hg within one minute after the standard 5-s CEW exposure (table 3). The small increase in systolic blood pressure of 7.14 mm Hg reached statistical significance (95% CI 0.1 to 14.2, p = 0.05), whereas the change in diastolic blood pressure did not (95% CI –1.1 to 6.7, p = 0.15).

DISCUSSION
CEW are currently carried and utilised in the majority of the 18 000 law enforcement agencies in the USA and in growing numbers of agencies in the UK and elsewhere.1 Their use has been associated with decreased injury rates in both officers and suspects, and injuries associated with their use are typically minor.4 6 Although proponents point out that no cardiac deaths have been conclusively documented in an estimated 640 000 human uses, concerns remain regarding the possibility of deleterious cardiac effects from CEW use, and the role of CEW in some deaths in police custody remains unclear.3 5

In this study, 84 consecutive CEW exposures were performed under continuous electrocardiographic monitoring. The results show an increase in heart rate and systolic blood pressure. This makes physiological sense as CEW exposure is a painful stimulus and is likely to elicit an adrenergic outflow. Interestingly, a baseline tachycardia of just over 120 bpm was seen, probably reflecting adrenergic outflow in anticipation of the upcoming CEW exposure. Some of the concerns regarding CEW have involved their possible contribution to deaths in custody as part of a hypermetabolic or acidotic state. Our data showing an increased heart rate and blood pressure do indicate that CEW place the body under an increased metabolic demand. It is possible that this increased metabolic demand in combination with stimulant drugs and/or physiological effects of fleeing from or struggling with police could contribute to anaerobic metabolism. However, studies to date of CEW exposure in humans after exercise have not demonstrated additional dangerous metabolic effects from CEW discharge.7 8

No dysrhythmias or abnormally conducted beats were observed in any of the CEW exposures. This suggests that CEW are unlikely to induce dysrhythmias in similar populations of healthy individuals. This is in concordance with previous research and the empiric experience with training and field exposures to date. These field exposures include criminal suspects, who have an unknown but presumably higher incidence of comorbid conditions and substance abuse than the police and public volunteers.
Ours is only the second study to evaluate cardiac rhythm before, during and after CEW impulse delivery in humans. The single previous report included 105 human volunteers exposed to a variable duration (mean 5.0 s) CEW discharge while undergoing continuous cardiac monitoring. This study also demonstrated an increased heart rate, with no induced dysrhythmias. A limitation of that study is that only a small number of patients underwent the full 5-s (or standard “dose”) CEW discharge. With our data, we confirm these findings and add to the cumulative experience of CEW exposures with continuous ECG monitoring, including 23 additional full “dose” (5-s) exposures.

A statistically significant decrease in the PR interval was noted. This is normal and consistent with the observed increase in heart rate. Neither the QRS duration nor the QTc were significantly changed. The limited literature available on the subject seems to indicate that subjects who have no ECG changes after receiving an electrical shock have a very low chance of later developing an arrhythmia. Human and animal studies have been largely reassuring regarding the overall safety of CEW. Several investigators have examined metabolic and cardiac markers after standard and prolonged CEW exposure in humans, without evidence of dangerous effects. Respiratory inhibition, possibly contributing to respiratory acidosis, was suggested in preliminary animal research. However, follow-up studies with both standard and prolonged CEW exposures have shown this not to be the case in humans. Similarly, 12-lead ECG performed before and after CEW exposure have not suggested ischaemia or other dangerous events.

Several escalating dose studies in swine models have demonstrated considerable cardiac safety margins of CEW. Standard CEW output had to be multiplied 15–48 times to induce ventricular dysrhythmias in one study, and the presence of cocaine increased the fibrillation threshold by 1.5 to twofold in another. However, other animal studies have produced discordant results, showing ventricular capture and fibrillation using standard Taser X26 CEW discharges. These finding reinforce concerns of possible direct dysrhythmic effects, but whether these conflicting findings in animal studies can be extrapolated to humans is currently speculative. Swine are generally recognised as good surrogates for human physiology, but are known to have lower fibrillation thresholds than humans. As illustrated by the respiratory inhibition seen with CEW in swine but not humans, assessments in humans are required for confirmation of conflicting results seen in animal models. This study is one step towards such assessments of cardiac safety.

**Limitations**

Limitations of this study include the small size and the population of police volunteers studied. Volunteers were predominantly young men, in overall good health. This population may not reflect suspects who undergo CEW exposure in the field. Studies of deaths in police custody have found a high proportion of illicit drug use, which could not be reproduced in this setting.

Importantly, the electrical noise of the CEW discharge typically obscures the underlying ECG waveform during the time of the discharge. This limits investigators’ ability to assess for possible transient dysrhythmias or myocardial capture during CEW discharge using unfiltered surface ECG recordings. However, it does not hinder the ability to assess for sustained dysrhythmias. In several cases the underlying cardiac rhythm could be discerned during the discharge, and in all of these the rate was consistent with that before and after CEW exposure.

The method of manually measuring ECG intervals limits the accuracy of measurements. The single previous study that included measurement of cardiac intervals during CEW exposure found poor interrater reliability of cardiac interval measurements. This was not reassessed in this study. Other factors that may occur in real-world police interactions were not reproduced in this volunteer study. These include pre-existing metabolic acidosis from fleeing or fighting police, structural heart disease and other comorbidities.

**CONCLUSION**

Standard CEW exposures appear to be cardiovascularly well tolerated in this population. No dysrhythmias occurred. An increase in heart rate and a small increase in systolic blood pressure can be expected in response to CEW exposure.

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**Competing interests:** None.

**Ethics approval:** The institutional review board approved the protocol.

**Patient consent:** Obtained.

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**Table 1** Changes in heart rate (mean values in beats per minute)

<table>
<thead>
<tr>
<th>CEW exposure duration</th>
<th>Pre-exposure</th>
<th>Post-exposure</th>
<th>Change</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All exposures (n = 84)</td>
<td>121.7</td>
<td>132.6</td>
<td>10.9</td>
<td>8.2–13.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5 s (n = 28)</td>
<td>119.4</td>
<td>131.7</td>
<td>12.3</td>
<td>5.7–18.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3 s (n = 28)</td>
<td>121.6</td>
<td>132.6</td>
<td>11.1</td>
<td>6.6–15.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1 s (n = 28)</td>
<td>123.1</td>
<td>132.8</td>
<td>9.7</td>
<td>6.7–12.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

**Table 2** Measured PR, QRS and QTc intervals (mean values in ms)

<table>
<thead>
<tr>
<th>All exposures n = 84</th>
<th>Pre</th>
<th>Post</th>
<th>Change (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR</td>
<td>133.3</td>
<td>127.4</td>
<td>−6.0 (−8.6 to −3.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>QRS</td>
<td>88.8</td>
<td>90.0</td>
<td>0.2 (−1.5 to 2.0)</td>
<td>0.839</td>
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<tr>
<td>QTc</td>
<td>446.5</td>
<td>450.1</td>
<td>3.6 (−4.2 to 11.4)</td>
<td>0.503</td>
</tr>
</tbody>
</table>

**Table 3** Changes in blood pressure (mean values in mm Hg) with 5-s CEW exposure (n = 28)

<table>
<thead>
<tr>
<th>Blood pressure</th>
<th>Pre-exposure</th>
<th>Post-exposure</th>
<th>Change (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic</td>
<td>138.6</td>
<td>145.8</td>
<td>7.1 (0.1–14.2)</td>
<td>0.05</td>
</tr>
<tr>
<td>Diastolic</td>
<td>82.8</td>
<td>85.6</td>
<td>2.9 (−1.1–6.9)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

CEW, conducted electrical weapon.
REFERENCES