Cardiovascular Safety Profile of Electrical Stun Guns (TASER-X26): Effects of Cocaine Intoxication on Induction of Ventricular Fibrillation

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• None of the authors have any kind of conflict of interest with TASER International.
Background:

• Electrical stun guns, a.k.a neuromuscular incapacitation devices (NMIDs), are increasingly used by law enforcement personnel over traditional lethal and non-lethal weapons. From here onwards we will use TASER synonymous to NMID.

• A frequently employed model (TASER X-26, TASER® International, Scottsdale, AZ) delivers high voltage-low current electrical energy to the body, causing transient neuromuscular disruption with incapacitation.

• The safety of these devices is under intense scrutiny with several deaths being claimed to be related to its use.
Background:

• Violent subjects who pose a threat to law enforcement officers are often intoxicated from illicit drugs such as cocaine, phencyclidine and amphetamines.
• Cocaine has a variety of cardiac effects including potential proarrhythmic effects.
• Arrhythmogenic effects of TASER when applied to the body surface at varying proximity to the heart and orientations along the cardiac axis are not clearly understood.
• The interplay of cocaine and TASER current on the induction of arrhythmias is not known.
Objective:
• To determine vulnerability for VF induction by a TASER at varying locations on the body surface with and without cocaine
Methods & Materials

• Animals: A total of 13 anesthetized adult pigs

• Stun gun: TASER® X26 is a 26-watt pistol-like device that shoots two tethered darts and delivers up to 6000 volts (typical output about 1500 volts) of peak electrical potential at 19 rapid pulses per second over 5 seconds. Arcing voltage (50,000 volts) is strictly “open-circuit”. The average net current is < 2 mA (19 X 100 μC) & Energy per pulse is about 70 mJ with an output power < 1.5 W = 19 pps • 70 mJ.
TASER-X26 and the modified current waveform

Current waveform characteristics at x1, x5, x10, and x30 of the standard discharge from TASER X-26. The waveform of the standard pulses has a duration of about 100 µs and a net delivered charge of about 100 µC at standard output. Variations of the current waveform with increased output are shown in this figure. Due to effects of the transformers in the output stages in front of the capacitors, there is both an increase in pulse duration and peak current.

TASER X26 Current Waveforms

- x1
- x5
- x10
- x30
Experimental protocol

VF vulnerability to application of TASER current at multiples of standard outputs @ 5 paired-dart positions:

1. Sternal notch (SN) – point of maximum cardiac impulse (PMI) (Position-1),
2. SN – supra-umbilical region (Position-2),
3. SN – infra-umbilical region (Position-3),
4. side to side across the chest (Position-4)
5. upper to mid posterior region (Position-5).

Cocaine infusion:

In 5 pigs, high dose cocaine was infused intravenously at 8 mg/kg over 30 minutes. Plasma cocaine and benzoylecgonine levels 30 minutes after infusion were 557 ± 280 U/L and 462 ± 123 U/L.
Results

Differences in VF vulnerability at the 5 tested positions

Comparisons of the five positions for MinVFIM and MaxSM (p<0.001, Friedman test). The symbols †, *, and + indicate paired comparisons where p > 0.05 by the Wilcoxon test. All other paired comparisons had p< 0.05.
VF induction:

At the standard strength of TASER current no fatal ventricular arrhythmias were noted at any of the five tested positions.

However, at higher strengths of TASER current (approx. 4x) Ventricular fibrillation could be induced at Position-1, while it took up to 40X the TASER current to induce VF at position-5.

This shows that the front of the body is more vulnerable for VF induction than the back of the body at significantly higher strengths of TASER current.

The VF vulnerability decreased by at least 1.5 to 2 fold after cocaine infusion.
<table>
<thead>
<tr>
<th></th>
<th>B-MaxSM</th>
<th>C-MaxSM</th>
<th>p</th>
<th>B-MinVFIM</th>
<th>C-MinVFIM</th>
<th>p</th>
<th>B-VFT</th>
<th>C-VFT</th>
<th>p</th>
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<tbody>
<tr>
<td>P1</td>
<td>4.2±1.10</td>
<td>8.6±6.88</td>
<td>0.192</td>
<td>8.0±2.74</td>
<td>15.0±10.00</td>
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<td>P2</td>
<td>12.0±7.58</td>
<td>28.0±4.47</td>
<td>0.030</td>
<td>20.0±10.00</td>
<td>38.0±4.47</td>
<td>0.037</td>
<td>14.5±9.59</td>
<td>33.0±4.47</td>
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<tr>
<td>P3</td>
<td>22.0±8.37</td>
<td>50.0±18.71</td>
<td>0.009</td>
<td>32.0±8.37</td>
<td>60.0±18.71</td>
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<td>27.0±8.37</td>
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<tr>
<td>P4</td>
<td>30.0±7.07</td>
<td>48.0±17.89</td>
<td>0.070</td>
<td>40.0±7.07</td>
<td>58.0±17.89</td>
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<tr>
<td>P5</td>
<td>38.0±4.47</td>
<td>60.0±14.14</td>
<td>0.011</td>
<td>48.0±4.47</td>
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<td>0.011</td>
<td>43.0±4.47</td>
<td>65.0±14.14</td>
<td>0.011</td>
</tr>
</tbody>
</table>
Physiology behind our observations

- Na+ channel blocking + hypersympathetic = Arrhythmia (Cocaine)
- Cocaine + substrate = Arrhythmia (Substrate includes – myocardial ischemia, infarct, metabolic abnormalities, artificial infusion of catecholamines etc)
- Cocaine in the absence of an appropriate substrate may not be arrhythmogenic and contrarily, may exert significant Na+ (class-Ia, Ib) channel blocking effect like quinidine, procainamide, lidocaine, disopyramide and mexiletine increasing VF thresholds

Limitations

• Findings may not apply to the diseased heart (potential substrate for sustained ventricular tachycardia).
• Cocaine may interact differently in the presence of a substrate.
• Presence of other substances of abuse could interact differently.
Public health implications

• A standard 5-second stun gun application is unlikely to cause life-threatening arrhythmias, at least in the normal heart irrespective of the position of application.

• Avoidance of anterior chest as a target site would greatly reduce any concern for induction of fatal ventricular arrhythmias.
Conclusions

• Standard discharge from a TASER X-26 weapon did not induce VF at any of the five tested locations and cocaine increased the safety margin by 50-150% above the baseline safety margin.

• Applications away from the cardiac axis and cardiac apex have higher VF safety margins than those close to it.