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Electrical Parameters of Projectile Stun Guns

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Abstract — **Projectile stun guns have been developed as less-lethal devices that law enforcement officers can use to control potentially violent subjects, as an alternative to using firearms. These devices apply high voltage, low amperage, pulsatile electric shocks to the subject, which causes involuntary skeletal muscle contraction and renders the subject unable to further resist. In field use of these devices, the electric shock is often applied to the thorax, which raises the issue of cardiac safety of these devices. An important determinant of the cardiac safety of these devices is their electrical output. Here the outputs of three commercially available projectile stun guns were evaluated with a resistive load and in a human-sized animal model (a 72 kg pig).**

I. Introduction

Electronic stun guns are hand-held weapons with two electrodes on the end, which are held against the subject to directly apply the electric shock. Projectile stun guns (PSGs) extend the range of application of these electric shocks, by shooting two barbed electrodes towards the torso of the subject to be subdued, which trail wires back to the hand-held device to conduct the electricity from the device to the subject. Frequently one or both of the electrodes lodge in the thorax of the subject. Any application of electricity to the thorax raises the concern that the electrical stimulation will induce ventricular fibrillation (VF) in the subject, which is a potentially lethal cardiac arrhythmia.

Commercially available PSGs include the Taser M26, the Taser X26 (both from Taser International, Scottsdale, AZ), and the Stinger S200 (Stinger Systems, Tampa, FL). These devices have been shown to be capable of incapacitating humans, but they do so with very different electrical waveforms and shock amplitude (See figs 1a, 1b, & 1c at right). Safety studies of each of these devices have been published [1-3]. However, there have also now been several studies that have demonstrated that the two Taser devices are capable of cardiac stimulation [4-7]. In addition, an implanted pacemaker in a Taser subject recorded two high ventricular rate episodes, which corresponded to applications of a Taser device [8]. Another case report observed VF in a subject shortly after a Taser exposure [9].

A recent paper reported finding media reports of 422 deaths linked in the press to the application of a Taser device, in the time period from 2001 to 2008 [10]. This group sought medical records on all of these deaths, and received records on 200 subjects. Of this total, 118 decedents (59%) were found to have collapsed within 15 minutes of the application of the Taser device. This study goes on to find that ventricular fibrillation was only observed in 4 of the 56 decedents for whom an initial cardiac rhythm was available, which does not support electrically induced ventricular fibrillation as a mechanism of these sudden deaths. However, the temporal proximity of collapse after Taser application suggests the possibility that the two events may be related through a mechanism that is not yet understood.

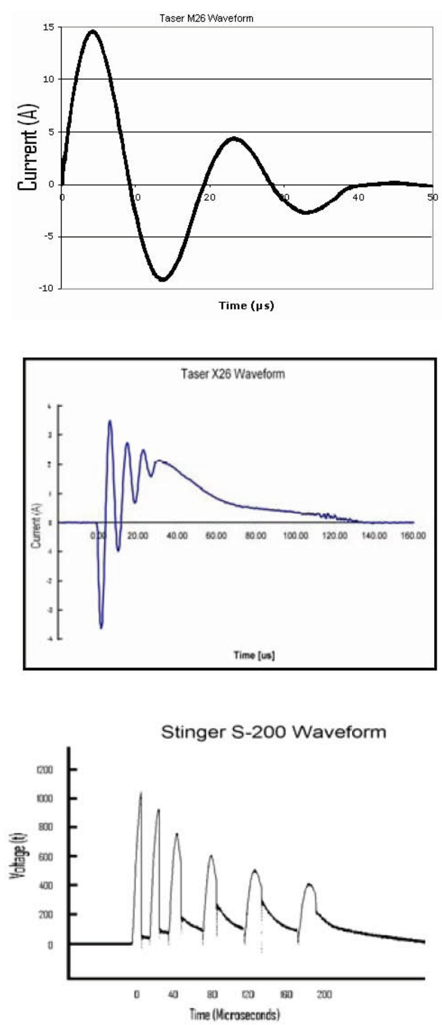

Figure 1 Pulse from Taser M26, Taser X26, and Stinger S200 (top to bottom). Note change in amplitude and time scale in figures.

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It is likely that any adverse effects of these devices, including potential cardiac stimulation, will be determined by their electrical output, in particular the current delivered, the pulse repetition frequency, and the individual pulse waveform and duration. Therefore, the purpose of this study was to characterize the electrical output of these three PSGs in both a resistive model and in a human-sized animal model.

II. Methods

Study 1 - The three PSGs were applied to a 430 ohm non-inductive resistor. The voltage across the resistor and the current through the resistor were captured on a digital oscilloscope with the use of high voltage probes and an inductive current probe (Model 2877, Pearson Electronics, Palo Alto, CA). From these tracings, the other electrical parameters were measured and/or calculated.

Study 2 – This study was approved by the Institutional Animal Care & Use Committee. A 72 kg pig was anesthetized and placed in dorsal recumbency on an insulated table. The darts from the stun gun being studied were applied in each of the following orientations: Side to Side across the heart (S-S), Sternal Notch to Xiphoid (SN¬X), and Sternal Notch to Umbilicus (SN-Umb). One of the probes from the stun gun was fed through an inductive current probe, which was then connected to a digital oscilloscope (Model 3014B, Tektronix, Beaverton, OR). Each stun gun was applied to the pig in each of the three orientations, while recording the current waveform that actually flowed into the pig. The peak and rms current were then measured and/or calculated.

III. Results

Study 1 -The electrical parameters observed when the PSGs were applied to the resistive load are shown in the table below (Table 1). Due to possible variation with battery status, we used the following published values for the pulse repetition frequency in our calculations: M26 – 17 pps, X26 – 19 pps, and S200 – 17.5 pps.

Table 2: Results from Study 1.

	Taser M26	Taser X26	Stinger S200
Energy/pulse (J)	0.565	0.084	0.053
Power (W)	10	1.59	0.92
Current pk (A)	15.6	4.0	2.14
Current rms (mA)	153	61	47
Voltage pk (V)	6320	1520	864
Voltage rms (V)	63	26.2	19.7

We found that the S200 delivered substantially less of each of the measured electrical parameters than either the X26 or the M26. For example, the S200 delivered 63% of the energy/pulse of the X26, and less than 10% of the energy/pulse of the M26. The X26 delivered a peak current almost twice that of the S200, and the M26 delivered a peak current more than 7 times that of the S200. The X26 delivered a rms current 30% higher than the S200, while the M26 delivered a rms current more than 3 times that of the S200.

Study 2 - The current parameters measured and calculated when the PSGs were applied to the 72 kg. pig are shown in the following table (Table 2). In this study, we used the same values for the pulse repetition frequency of the three devices as in study 1. The following abbreviations were used for the three orientations of the PSG probes: Side to Side across heart – S-S; Sternal notch to Xiphoid – SN-X; Sternal notch to umbilicus – SN-Umb.

Table 1: Results from Study 2.

Device	Orient.	Current Pk (A)	Current rms (mA)
S200	S-S	1.96	43.1
S200	SN-X	1.88	40.1
S200	SN-Umb	2.12	40.5
X26	S-S	3.48	51.2
X26	SN-X	3.40	56.7
X26	SN-Umb	3.64	53.3
M26	S-S	14.6	147
M26	SN-X	15.3	137
M26	SN-Umb	15.3	145

The peak current of the X26 was approximately 75% higher than the peak current of the S200. The peak current of the M26 was approximately 7 times the peak current of the S200, and 5 times the peak current of the X26. The rms current delivered by the X26 was approximately 28% higher than the rms current delivered by the S200. The rms current delivered by the M26 was more than 3 times the rms current delivered by the S200 and about 2.5 times the rms current delivered by the X26.

IV. Discussion

Law enforcement officers encounter potentially violent subjects on a routine basis. Many of these subjects are under the influence of alcohol or other mind-altering drugs. When encountering such a subject, officers are often justified in the use of their firearms, with a high probability that the subject will be left seriously injured or dead. A variety of non-lethal weapons have been developed to give law enforcement officers options in dealing with these subjects, including pepper spray, rubber bullets, bean bag rounds fired from shotguns, night sticks, launchable nets, stun guns, and projectile stun guns (PSGs). However, subjects continue to die in custody, which causes the law enforcement community to continually look for better and safer ways to deal with these violent subjects.

PSGs are among the most recent additions to the non-lethal options available to law enforcement officers to control violent offenders. They have many attractive features over the other non-lethal weapons, including: an approximate 20 foot range that allows the officer to utilize the PSG at a safe distance; PSGs cause involuntary muscle contraction that is not dependent on the subject feeling pain; and the desired effects of the PSGs terminate when the electrical shock is terminated.

The Taser M26 and X26 have now been applied to hundreds of thousands of human volunteers during training, and are reported to have been used on humans in the field more than 600,000 times worldwide [11]. However, organizations such as Amnesty International have criticized the in-custody deaths that are associated with the use of the Taser devices [12]. Association does not prove causation, but many people still have concerns about the safety of these devices.

Of particular concern in the present climate is how best to quantify and describe the magnitude of the electrical shocks that are delivered by PSGs. As described above, the peak currents for the tested devices range from 2.1 to 15.6 A. However, some have made the argument that delivered charge is the only important electrical parameter, and this logic has led them to describe the Taser X26 output as having an average current of 1.9 mA (instead of a peak current of 4.0 A) [13]. In a letter to the editor in response to this article, one reader remarked "To say that 1.9 milliamperes is the average current available from a Taser X26, while nominally and technically correct, completely understates and misrepresents the electrical output from these devices" [14].

It may be that the electrical incapacitation effects of these PSGs are better predicted by some other electrical descriptor, such as the magnitude of the peak or rms currents delivered, than they are by the magnitude of the average currents delivered. It is also possible that different features of a PSG could be best predicted by different electrical descriptors. For example, pain might be best predicted by one electrical parameter such as the peak current; incapacitation might be best predicted by another electrical descriptor such as the rms current; and the ability to pace the heart might be best predicted by another electrical descriptor, such as average current. Each of these features of PSGs needs to be studied further.

Absent compelling research to the contrary, describing the output of a PSG only as the average current would appear to be counterproductive to understanding the beneficial and potential harmful effects of these devices. In the present study, the electrical output of these devices was quantified using units of measure that have historically been used to describe waveforms such as those that are generated by these PSGs.

This study found that the Stinger S200 delivered substantially less of each of the relevant electrical parameters, than either the M26 or the X26. The X26 was also found to deliver less of each of the electrical parameters than the M26. By delivering less energy, power, current and voltage, the S200 could prove to be a safer device than either of the Taser devices. However, these devices will need to be tested in future studies, before any safety conclusions can be drawn.

V. Conclusion

The Stinger S200 was found to deliver less energy, power, current, and voltage than both the Taser M26 and X26 when applied to a resistive load. The S200 was also found to deliver less peak and rms current than the M26 and X26 when applied to a human-sized pig.

VI. Limitation

The study presented here was conducted using a Stinger S200 that was provided to the author by Stinger Systems in January, 2008. The author has reason to believe that the presently available Stinger S200 generates a different electrical output than the one tested here. If the output of the S200 has indeed changed, then these studies would need to be repeated with a present model for a valid comparison. In addition, further animal and human trials need to be performed to see if these observed differences in electrical output translate into meaningful differences in parameters such as pain, ability to incapacitate, cardiac stimulation, or safety.

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