C22 Analysis of Electrical Activation of Nerve and Muscle by TASERs

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The goal of this presentation is to increase understanding of the basic principles of skeletal muscle activation, as well as the evoking of strong sensations including pain, via TASER stun guns.

This presentation will serve the forensic community through theo- retical analysis of the activation of nerve and muscle by TASERs. Rattay's "activating function" approach, along with knowledge of strength-duration time constants of excitability for skeletal muscle and nerve has been used to predict the electric field gradient levels needed for activation of each tissue type by TASER pulses.

The high-voltage, low-charge, brief pulse-width stimulus train applied by the latest generations of TASER stun guns is intended primarily to strongly activate skeletal muscle contraction (thus disabling the target individual through incapacitation of their ability to move and to stand), while secondarily also eliciting strong sensations of pain and/or exhaustion. The TASER X26, for example, delivers a somewhat complex "shaped" stimu- lation waveform that to a first approximation appears as a pseudo monophasic (half sinusoid) pulse of about 50 to 100 µsec duration about every 50 msec (delivering peak currents that can range over several Amps but with only about 50 µC of charge delivered).

In general, skeletal muscle activation by electrical stimulation is elicited by excitation of á-motor neurons which innervate such muscle fibers. This fact often comes as a surprise, in that skeletal muscle cells are themselves excitable. Skeletal muscle excitability, however, is less than that of motor neuron cells in that both rheobase and chronaxie values of skeletal muscle are higher than those of the myelinated nerve axons which innervate them. Therefore, immediately adjacent to TASER dart locations it is possible that skeletal muscle fibers may be "directly" stimulated but any significant distance away from the darts it is expected for skeletal muscle to be "indirectly" activated through its nervous innervation. Sensations of discomfort and pain in response to TASER stimuli are expected to result from a host of sensory nerve fiber types, to some extent dependent upon the specific locations of TASER dart attachment to the body (as well as the specific tissues located between and near the darts in what might be called the "capture" zone of the darts where excitable cells are activated).

From both efficacy (in terms of efficiently activating skeletal muscle between and near the darts) and safety (in terms of activating skeletal muscle with a wide safety margin in comparison to corresponding current levels that would be needed to excite or fibrillate the heart) viewpoints, analysis indicates that the TASER X26 stimulus pulse is a well designed stimulus. This is because:

- The timing of the X26 stimulus pulse is on the order of the strength- duration time constant τ (and chronaxie) for electrical excitation of the α motor neuron fibers which innervate and control the contraction of skeletal muscle, making it an effective stimulus in terms of pulse duration. It appears likely that reflex activation of additional skeletal muscle response may also occur through excitation of motor afferent myelinated nerves. Skeletal muscle not contained within the "target" zone of the TASER darts may also be activated if motor afferent or efferent nerves are stimulated which then innervate more distant musculature (as in the instance where nervous structures within or entering/leaving the spinal cord might be excited).
- The timing of the X26 pulse is also likely to result in widespread excitation of cutaneous myelinated nerves responsible in normal function for senses of touch, pressure, vibration, etc. Given the modest separation of the timing of the X26 pulse in comparison to the time constant values for excitation of the type III Aδ myelinated nerve fibers responsible for "sharp" pain (τ equal to about 650 µsec) as well as for activation of C fibers responsible for dull or aching pain (τ equal to about 500-600 µsec), one can conclude that activation of nerves responsible for perception of pain (at least in normal sensation) would certainly be higher if the X26 pulse were increased in duration. C fibers also have notably higher thresholds (in terms of predicted rheobase electric fields necessary to stimulate) than myelinated motor or sensory nerve fibers.

An important safety concern of the TASER technology is to insure that stimulation of the heart does not occur, which could cause life-threat- ening arrhythmias or cardiac arrest. The low-charge and in particular brief pulse-width nature of TASER stimuli applied through darts which have contacted the torso are inherently protective against such cardiac events (i.e. because current needs to penetrate deep within the torso to reach the heart itself, and because stimulus pulse-widths needed to activate the heart are longer in duration than those needed to stimulate skeletal muscle or nerve).

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