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Brief Reports

CARDIAC STIMULATION WITH ELECTRONIC CONTROL DEVICE APPLICATION

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☐ **Abstract—Background: Electronic control devices (ECDs) are weapons used to incapacitate violent subjects. Subjects have died suddenly after ECD application, but because cardiac dysrhythmias have been inconsistently observed during ECD application in animals, the cause for death is uncertain. Objectives: The objective was to identify the factors contributing to cardiac stimulation during ECD application detected by transesophageal echocardiography. Methods: Four Yorkshire pigs were anesthetized, paralyzed with vecuronium, and restrained in a supine position. A GE 6T echo probe was placed in the esophagus to directly visualize left ventricular function. M-mode echocardiography was used to estimate heart rate. Two dart locations, chest and abdomen, were assessed. ECD applications were delivered from one of five commercially available devices (Taser X26, Singer S200 AT, Taser M26, Taser X3, and Taser C2) in random order to each pig, four times in each orientation. Results: Cardiac stimulation, characterized by multiple PVCs or the sudden increase in ventricular contraction rate during application, did not occur with abdominal dart location. With chest dart application in small pigs, cardiac stimulation occurred with all ECDs except with the Taser X3 ($p < 0.0001$). In large pigs, cardiac stimulation occurred only during chest application of the S200 AT (chest vs. abdomen: 207 beats/min, vs. 91 beats/min, $p < 0.0001$). Conclusion: Cardiac stimulation occurs during ECD application in pigs, and is dependent upon subject size, dart orientation, and ECD. The Taser X3 did not result in cardiac stimulation in small or large pigs.** © **2014 Elsevier Inc.**

☐ **Keywords—TASER; electronic control device; cardiac stimulation; stun gun; dysrhythmia**

INTRODUCTION

Electronic control devices (ECDs) are electrical devices used by both law enforcement officials and citizens to incapacitate violent subjects. ECDs function by shooting two barbed probes into the subject's skin or clothes. The probes are connected to the device by conductive wires, which deliver a series of rapid pulses of high-voltage electrical shocks that cause involuntary muscle contraction to subdue the subject. ECDs are emerging as one of several intermediate-force options available to law enforcement officers as an alternative to firearms. As of March 31, 2011, there have been an estimated 1.27 million uses of ECDs by law enforcement officers (1). Prior studies have found that the use of ECDs results in a decrease in injury rates among both criminals and police officers (2,3).

Due to the delivery of electrical shocks to the thorax, concern has been raised that fatal cardiac dysrhythmias may result from ECD application. Over 400 deaths have been associated with their use from 2001 to 2008, but the exact cause of death is unclear (4). The induction of ventricular dysrhythmias has not been consistently observed in animal studies and it remains uncertain if cardiac stimulation occurs during ECD application in humans (5–8). Due to this, a number of other explanations for the ECD-associated deaths have been proposed. These include metabolic or electrolyte abnormalities, and excited delirium syndrome, which is described

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as agitation, incoherence, hyperthermia, and violent behavior (9).

During experimental ECD application in animals, detection of cardiac stimulation has been challenging. Surface ECG tracings become saturated with electrical and motion artifact during ECD discharge, which complicates the detection of heart rate or cardiac rhythm. Transthoracic echocardiography has been used in some studies of ECD cardiac stimulation, but offers limited windows with further degradation of image quality due to chest muscle contraction. We hypothesized that ECD-induced cardiac stimulation could be detected and quantified better with transesophageal echocardiography (TEE). We further hypothesized that if cardiac stimulation did occur, it would vary depending on subject size, dart location, and the characteristics of the various waveforms of commercially available ECDs.

METHODS

This study was reviewed and approved by the appropriate Institutional Animal Care and Use Committee. Pigs were selected for the study due to their use in past studies of cardiac stimulation by ECDs (5–8).

Five commercially available ECDs, the TASER M26, TASER X26, TASER X3, TASER C2 (all from TASER International, Scottsdale, AZ), and the Stinger S-200AT (Stinger Systems, Tampa, FL) were tested during these experiments. The devices tested were supplied to the investigators by the Oakland Police Force, along with a grant to partially fund this study. These devices differ in output waveform, pulse duration, and amplitude (Figure 1, waveforms of each ECD). Each ECD was applied individually to a 400-Ω resistor to capture the images shown in Figure 1, and to allow us to assess the differences in output waveform.

Four Yorkshire pigs: Group 1 (n = 2, 25 ± 0 kg) and Group 2 (n = 2, 69.4 ± 1.6 kg) were anesthetized, paralyzed with vecuronium, and restrained in a supine position. A femoral artery was cannulated to allow the monitoring of arterial blood pressure, and to allow collection of arterial blood samples. Arterial blood gas and electrolytes were monitored every 30 to 40 min, and corrected to maintain them within normal limits. A GE 6T echo probe was placed in the esophagus to directly monitor cardiac function, mitral valve function, and to assess heart rate during ECD application. Two dart locations, a chest orientation and an abdominal orientation, were assessed (Figure 2). In the chest orientation, two darts were placed subcutaneously to maximal depth (12 mm), with one dart 4–7 cm right of the sternal notch and one dart 7–10 cm left of the umbilicus. In the abdominal orientation, the darts were positioned 7–10 cm lateral to each side of the umbilicus.

Each ECD was applied in random order to each pig, four times in the same orientation separated by at least

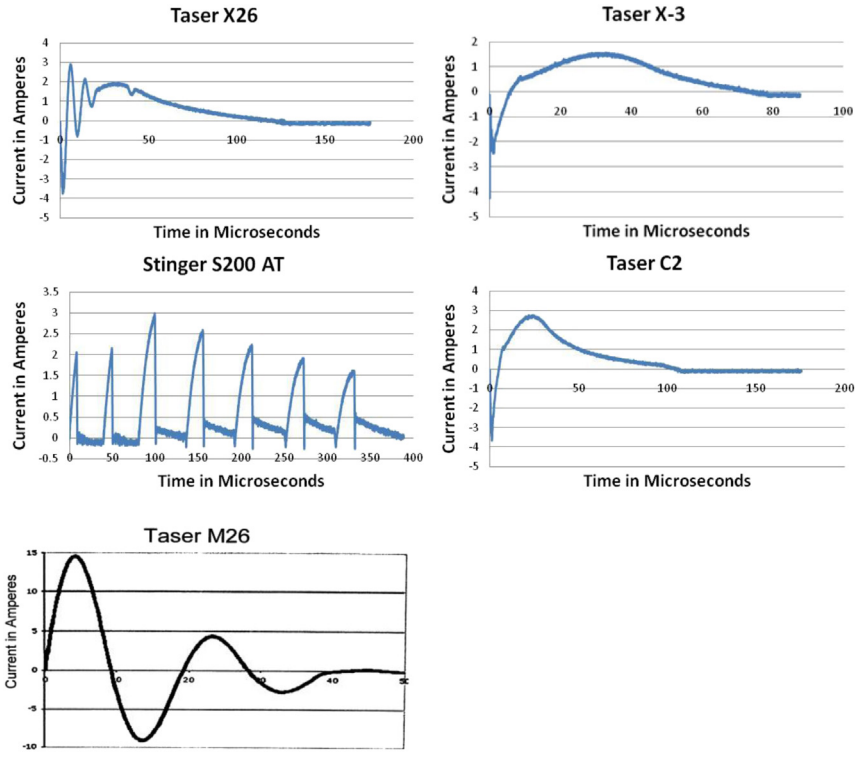

Figure 1. Waveforms of each electronic control device.