

# **Medical Examiner Collection of Comprehensive, Objective Medical Evidence for Conducted Electrical Weapons and Their Temporal Relationship to Sudden Arrest.**

Michael A. Brave, M.S., J.D.

Steven B. Karch, M.D., FFFLM, FFSSoc

Mark W. Kroll, Ph.D., FACC, FHRS

Michael A. Graham, M.D.

Charles V. Wetli, M.D.

# Disclosures

- Mr. Brave is an employee of TASER International, Inc. (TASER), TASER's primary PMK (Person Most Knowledgeable), a TASER Master Conducted Electrical Weapon (CEW) Instructor, and legal advisor to the TASER Scientific and Medical Advisory Board (SMAB) and TASER Training Advisory Board; and Manager/Member (owner) of LAAW International, LLC.
- Drs. Karch and Wetli previously retained as consultants/expert witnesses for TASER.
- Dr. Kroll is a paid consultant/expert to TASER, and a member of the TASER SMAB and Corporate Board.
- Dr. Graham is a member of the TASER SMAB, and a paid consultant/expert to TASER.
  - All authors are frequent expert witnesses for law enforcement.

# Very Brief Background

- Involved in reviewing and analyzing > 350 Law Enforcement Officer (LEO) contact temporal related deaths (Arrest-Related Deaths (ARDs))
  - (to my knowledge) more than anyone else
- Monitor medical, scientific, electrical, engineering, animal, FEM literature
- Certified as instructor in all LEO common field-use force options
- Designated expert in > 200 civil/criminal cases
- Presented > 400 force-related presentations

# Very Brief Background

- Involved with electroshock weapons (ESW) since 1984
  - Conducted Electrical Weapons (CEWs)
- Multiple ESW/CEW instructor certifications
- TASER International, Inc. (TASER):
  - National/International Litigation Counsel
  - Member of Training Advisory Board
  - Member of Scientific & Medical Advisory Board
  - Designated Person Most Knowledgeable (PMK)
- Presented > 100 CEW-related presentations
  - in U.S., Canada, U.K., Mexico, Panama, & Austria

# Basics:

- Typical Medical Examiner (ME) will have < 1 Conducted Electrical Weapon (CEW) temporal Involved Arrest-Related Death (ARD) in career.
- Proper collection and documentation of all available evidence is imperative to reasonable medical conclusions.
- Important to have literature support for opinion held to a reasonable degree of scientific certainty.
  - Current literature incomplete, inconsistent and contradictory

# **TASER CEW**

## **Electricity 101**

# TASER CEW Electricity 101

## **TASER X26 CEW** (basic electrical parameters)

- ~ 19 (18.3) pulses per second, each pulse is ~
  - 0.00001 coulombs (C) or 100 microcoulombs ( $\mu\text{C}$ )
  - 0.00001 seconds (s) or 100 microseconds ( $\mu\text{s}$ )
  - 0.1 joules (J)
- ~ 53 milliseconds (ms) between pulses
  - No delivered charge for 99.8% of a second

# TASER CEW Electricity 101

## TASER X26 CEW (basic electrical parameters)

- Power Source: a battery of two 3 V cells
- Wire: insulated 127 microns (0.000127 m)
- XP Darts: 13 millimeters (mm)

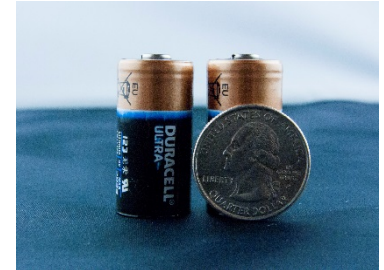




# TASER CEW Electricity 101

**TASER X26 CEW** Power Source: battery of two 3-V cells (CR123)

Duracell CR123 cells



- 3 volts
- used in some digital cameras (e.g. Nikon® F6)
- each battery provides 195+ 5-s discharges
- at 19 pulses per second (PPS) x 195+ discharges = 18,525+ pulses per battery

**Thus, battery of 2 3 V cells providing  
18,525+ pulses,  
how big can a pulse be?**

# TASER CEW Electricity 101

**TASER X26 CEW** (Wires – 127 microns (0.000127 m))

Cartridge wires:

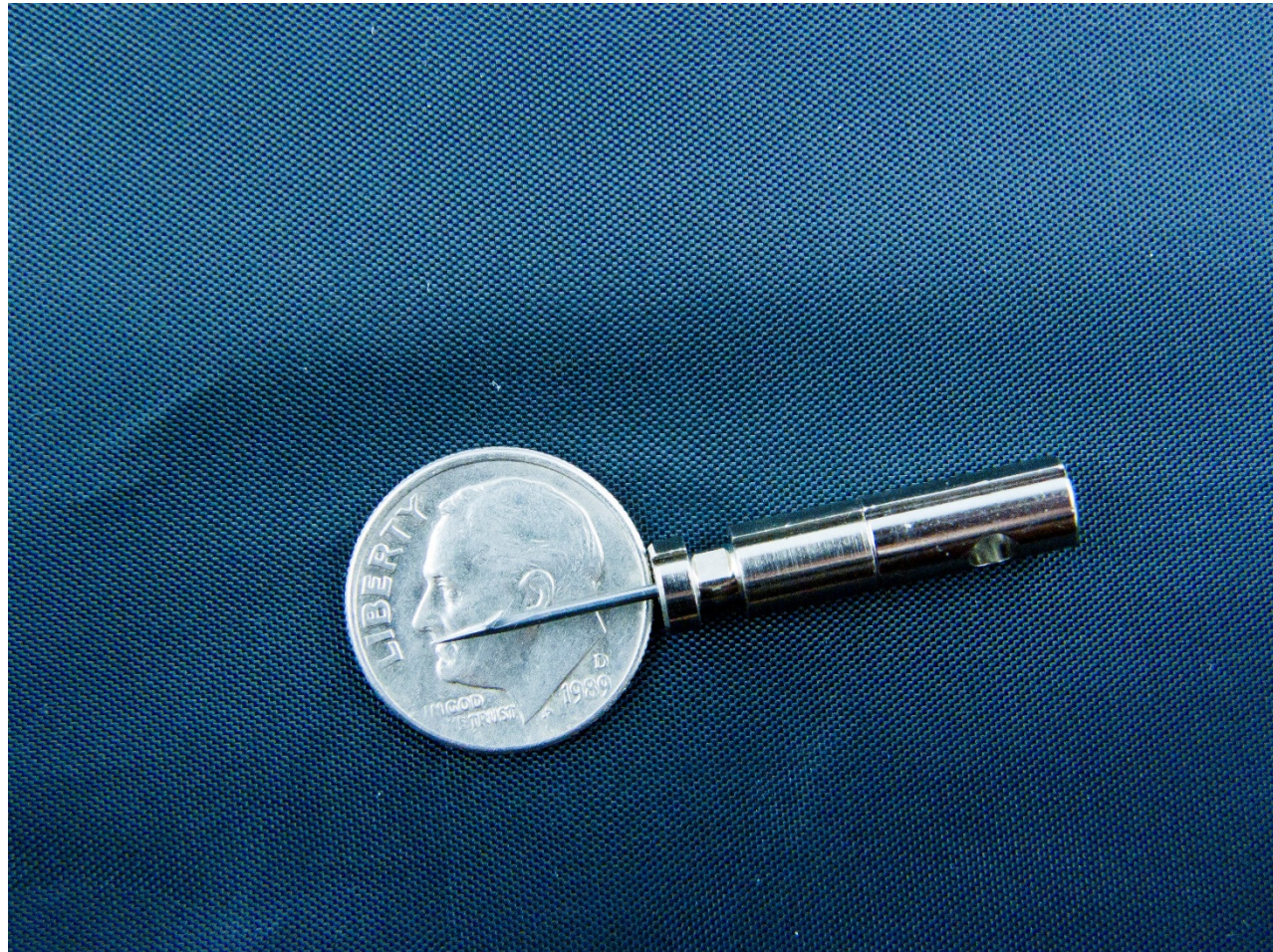
- smaller than some human hair
- ~ 2 pounds break strength
- these wires not automobile jumper cables





# TASER CEW Electricity 101

**TASER X26 CEW** (XP Darts – 13 mm (0.013 m))



# Electricity 101 – Charge (coulombs)

**Charge** – is given in the unit coulomb (C)

Minimum transthoracic pacing thresholds:

Subjects	Minimum pacing thresholds
Adults	1,680 - 4,000 microcoulombs ( $\mu\text{C}$ )
Pediatrics	1,160 - 3,920 microcoulombs ( $\mu\text{C}$ )

~ 12 x - Capture to VF Safety Margin

(Which is why emergency room doctors are not concerned with inducing VF when they attach a transthoracic pacemaker.)

# Electricity Concepts – Energy (joule)

## What Is a “joule”?

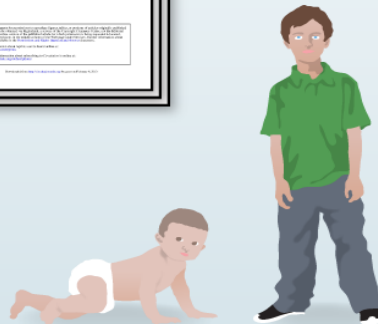
“joule”: International system of units measurement of energy (mechanical, electrical, or thermal) describing the energy delivered in a single pulse.



Automated External Defibrillator (AED):  
Delivers **360 joules**



– Pediatric Defibrillator  
Energy Analogy American  
Heart Association current  
Pediatric Advanced Life  
Support (PALS) Guidelines



Infants & Children:  
**2–10 joules/kilogram**



TASER X26:  
Delivers up to about  
**0.1 joule**

# Electricity Concepts – Energy (joule)

## Pediatric Advanced Life Support Guidelines



### Infants & Children

2–10 joules/kilogram



Infant

Child

### Example

5 kg (11 lb) Infant



10–45 joules have been found effective **“with negligible adverse effects”**



# Electricity Concepts – Energy (joule)

## Pediatric Advanced Life Support Guidelines (2010)



Pediatric Defibrillator  
Energy Analogy American  
Heart Association current  
Pediatric Advanced Life  
Support (PALS) Guidelines

It is acceptable to use an initial dose of **2 to 4 J/kg** (Class IIa, LOE C), but for ease of teaching an initial dose of 2 J/kg may be considered (Class IIb, LOE C). For refractory VF, it is reasonable to increase the dose to 4 J/kg (Class IIa, LOE C). Subsequent energy levels should be at least 4 J/kg, **and higher energy levels may be considered, not to exceed 10 J/kg** or the adult maximum dose (Class IIb, LOE C).

# Theoretical & Actual CEW CoD

## Theoretical Mechanisms

- Electrocution (cardiac)
- Respiratory insufficiency
- Pain response leading to cardiac arrest
- Physiologic/metabolic derangements caused by CEW-induced muscle contractions:
  - acidosis
  - rhabdomyolysis

## Actual Mechanisms

- Fall trauma (~ 15 cases)
- Ignition of flammable substances (~ 7 cases)



# No Clinically Significant Biochemical or Physiologic Changes

- No clinically significant biochemical or physiologic changes<sup>1</sup>
- In probe mode (with at least 12” probe spread) muscle contractions are 46% of voluntary maximum.<sup>2</sup>
- Impact on acidosis less than prolonged exertion.<sup>3</sup>

1. Pasquier, M., Electronic Control Device Exposure: A Review of Morbidity and Mortality, *Annals of Emergency Medicine*, May 2011. Vilke GM, Bozeman WP, Chan TC., Emergency Department Evaluation after Conducted Energy Weapon Use: Review of the Literature for the Clinician, *The Journal of Emergency Medicine*, In Press, Corrected Proof. Position Paper Approved by the American Academy of Emergency Medicine Clinical Guidelines Committee.
2. Sweeney J. Theoretical Comparisons of Nerve and Muscle Activation by Neuromuscular Incapacitation Devices. *Conf Proc IEEE Eng Med Biol Soc.* 2009;1:3188–3190.
3. Ho J, Dawes D, Cole J, et al. Lactate and pH evaluation in exhausted humans with prolonged TASER X26 exposure or continued exertion. *Forensic Sci Int.* Sep 10 2009;190(1-3):80–86. Vilke G, Sloane C, Suffecool A, et al. Physiologic Effects of the TASER After Exercise. *Acad Emerg Med.* Aug 2009;16(8):704–710. Five (5) year NIJ study: Laub, J., Study of Deaths Following Electro Muscular Disruption, National Institute of Justice, May 2011

# Electrocution

**Controversial:** Induction of ventricular fibrillation (VF) or “electrocution.”

- Theoretically possible with perfect probe placement in extremely thin individual.<sup>1</sup>

- 12 published case reports.<sup>2,3</sup>

  - Detailed review of case-specific facts casts doubt on many, if not all, of these opinions.

  - Included a case where the probes missed the subject

  - Published rebuttals

- Investigation: Discern initial pre-resuscitation recorded cardiac rhythm

1. Kroll MW, Lakkireddy D, Rahko PS, Panescu D. Ventricular fibrillation risk estimation for conducted electrical weapons: critical convolutions. *Conf Proc IEEE Eng Med Biol Soc.* 2011;33:271-277.

2. Zipes DP. Sudden cardiac arrest and death following application of shocks from a TASER electronic control device. *Circulation.* May 22 2012;125(20):2417-2422.

3. Kroll M, Lakkireddy D, Stone J, Luceri R. TASER<sup>®</sup> Electronic Control Devices and Cardiac Arrests: Coincidental or Causal? *Circulation.* 7 Jan 2014;129:93-100.

# VF Threshold Small Swine vs. Humans

❑ 30 kg swine (Dennis/Walter) had VF induced.<sup>1,2</sup>

❑ Swine are 3 times as sensitive as humans

❑ VF threshold proportional to  $W^{.437}$

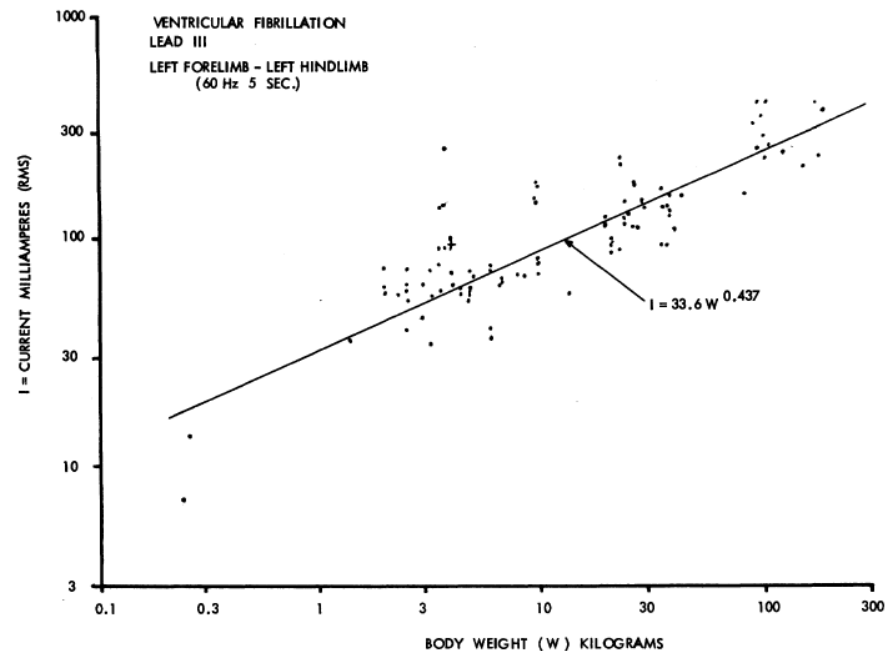
❑ Use square root for simplicity

❑ These swine correspond to human weighing:

❑  $17.3 \text{ kg} = 30 \text{ kg} \div \sqrt{3}$

❑ Equivalent to 38 lb human

1. Dennis AJ, Valentino DJ, Walter RJ, et al. Acute effects of TASER X26 discharges in a swine model. *J Trauma*. Sep 2007;63(3):581-590.
2. Walter RJ, Dennis AJ, Valentino DJ, et al. TASER X26 discharges in swine produce potentially fatal ventricular arrhythmias. *Acad Emerg Med*. Jan 2008;15(1):66-73.



# VF can be Induced in Small Swine

- VF has never been induced in swine in human field-use conditions
- Out of 745 myocardial capture events there were 6 instances of VF
- Webster: Probe tip has to be within 6 mm of the heart.<sup>1</sup>
  - DTH (Dart-To-Heart distance) is critical.
- Swine are 3 times as sensitive to electricity as humans
  - Translates to 2-3 mm DTH for humans.<sup>2-4</sup>
- Probe anterior to sternum is not “close” since sternum is an electrical insulator.<sup>5</sup>

1. Wu JY, Sun H, O'Rourke AP, et al. Taser blunt probe dart-to-heart distance causing ventricular fibrillation in pigs. *IEEE Trans Biomed Eng.* Dec 2008;55(12):2768-2771.
2. Brave MA, Lakkireddy D, Kroll M, Panescu D. Studies Using Small Swine May Exaggerate Electrical Safety Risks. *Conf Proc IEEE Eng Med Biol Soc.* 2014;36:in press.
3. Walcott GP, Kroll M, Ideker RE. Ventricular Fibrillation: Are Swine a Sensitive Species? . *manuscript under review.* 2014.
4. Kroll MW, Lakkireddy DR, Stone JR, Luceri RM. TASER electronic control devices and cardiac arrests: coincidental or causal? Supplement. *Circulation.* Jan 7 2014;129(1):On Line Supplement..
5. Panescu D, Kroll M, Iverson C, Brave MA. The Sternum as an Electrical Shield. *Conf Proc IEEE Eng Med Biol Soc.* 2014;36:in press.

# Short Checklist for CEW Electrocutation

- DTH distance  $\leq 4$  mm
  - Alternatively, body mass  $< 17$  kg
  - Sternum or bone not shielding heart

# CEW Dart-to-Heart (DTH) Distances

Dart to Heart Distance For **VF**



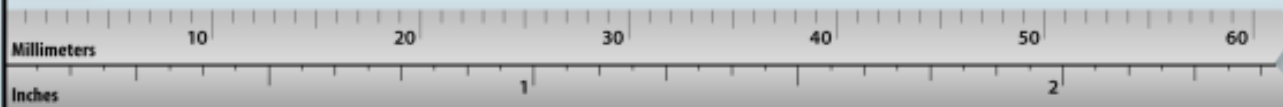
Dime  
(17.91 mm)



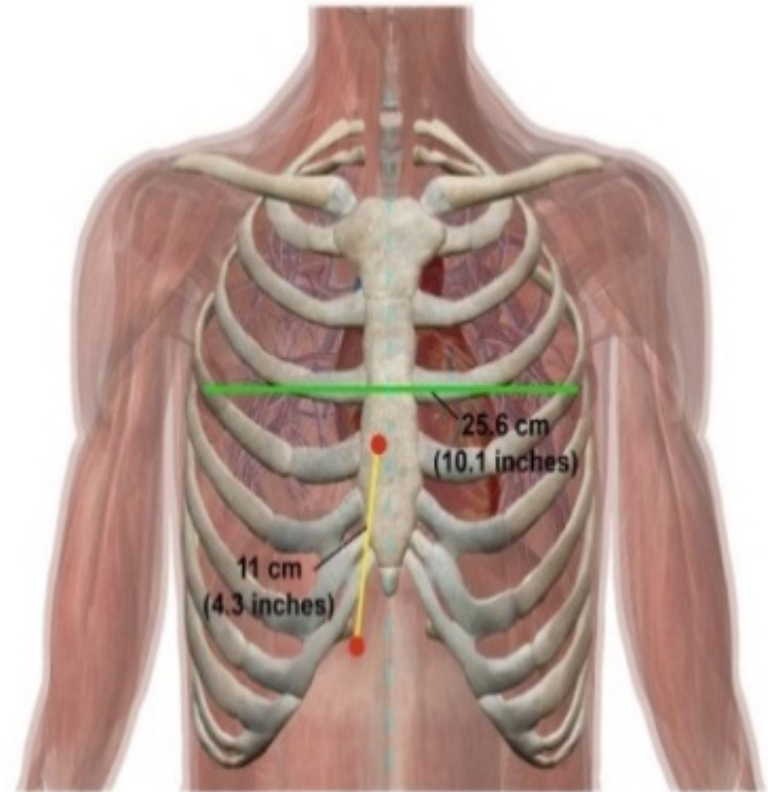
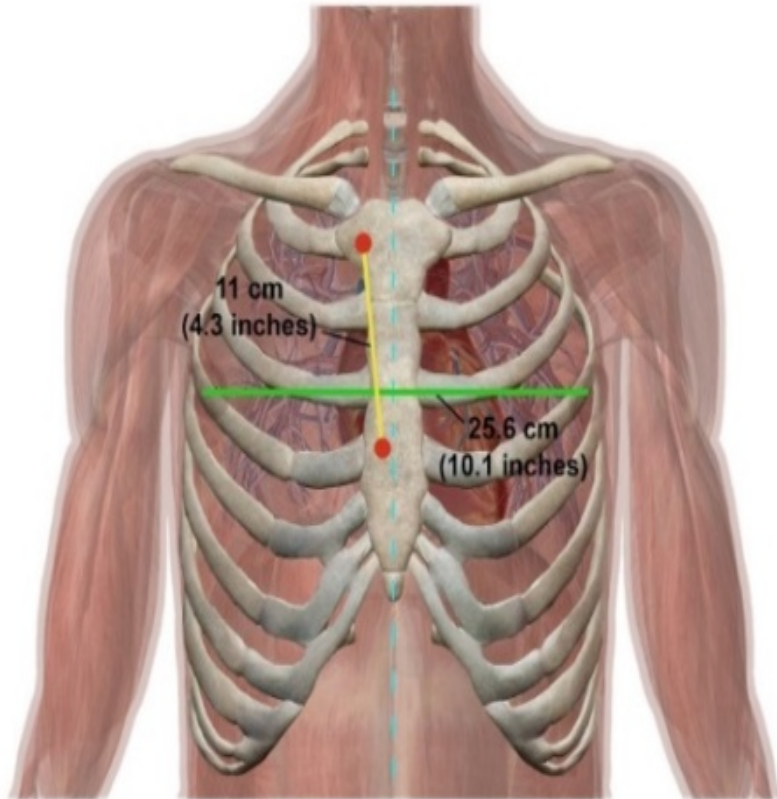
**2-8 mm**  
**VF**  
Pigs



**4 mm**  
"Theoretical" Risk of  
**VF**  
Humans



# Examples of DTH Analysis



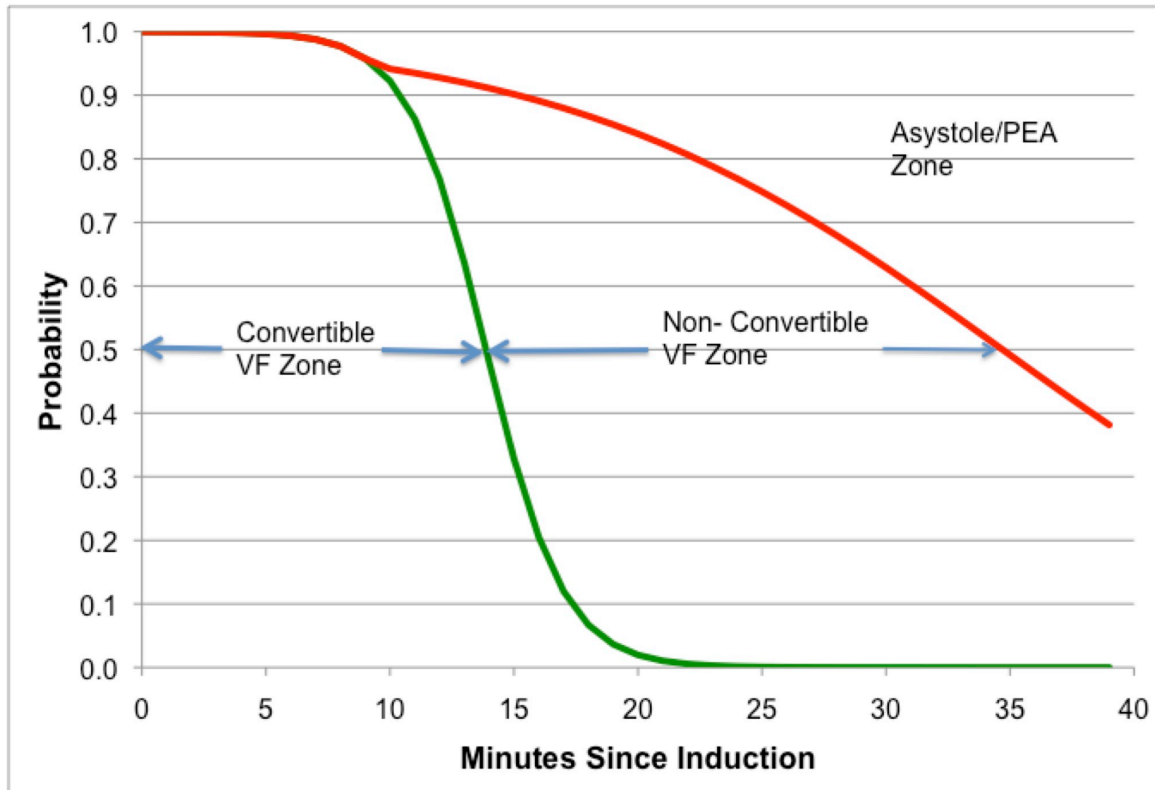
# Short Checklist for CEW Electrocutation

- Presenting rhythm of VF
  - Not asystole or PEA
- Defibrillation attempted within 14 minutes expected to be successful
- Pulse is instantly lost
- Blood pressure 0 in 3 seconds
- Normal breathing  $\leq$  60 seconds
  - Agonal breathing  $\leq$  6 minutes



# Electrically-Induced VF

- Typically successfully defibrillated within 14 minutes with any CPR.<sup>1</sup> Almost always within 10 minutes.
- Deteriorates to asystole/PEA at about 32 minutes.<sup>2</sup>



1. Kroll MW, Fish RM, Calkins H, Halperin H, Lakkireddy D, Panescu D. Defibrillation success rates for electrically-induced fibrillation: hair of the dog. *Conf Proc IEEE Eng Med Biol Soc.* 2012;34:689-693.
2. Kroll MW, Walcott GP, Ideker RE, et al. The stability of electrically induced ventricular fibrillation. *Conf Proc IEEE Eng Med Biol Soc.* 2012;34:6377-6381.

# Vital Signs

- Pulse is lost instantly with VF.
  - False-negative pulse findings are common,
  - False positives are not.<sup>1</sup>
- After a cardiac arrest, normal breathing ceases in 12 to 60 seconds.<sup>2, 3</sup>
  - Some subjects will have agonal breathing for a total of 6 minutes.<sup>4</sup>

1. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. *Resuscitation*. Dec 1996;33(2):107-116.

2. Haouzi P, Ahmadpour N, Bell HJ, et al. Breathing patterns during cardiac arrest. *J Appl Physiol*. Aug 2010;109(2):405-411.

3. Zuercher M, Ewy GA, Otto CW, et al. Gasping in response to basic resuscitation efforts: observation in a Swine model of cardiac arrest. *Crit Care Res Pract*. 2010;10(36):1-7.

4. Clark JJ, Larsen MP, Culley LL, Graves JR, Eisenberg MS. Incidence of agonal respirations in sudden cardiac arrest. *Ann Emerg Med*. Dec 1992;21(12):1464-1467.

# Electrocution Red Herrings

- Immediate collapse after CEW application:
  - CEW is ***supposed*** to cause a postural collapse to stop aggression.
- Nonresponsiveness:
  - A sternal rub response is often blunted by the presence of alcohol, illegal drugs, psychotic break, and endorphins from the struggle.
- Long-duration application:
  - Electricity does not build up like poison.<sup>1</sup>
  - Electrocution happens in 5 seconds or generally does not.<sup>2</sup>

1. Kroll MW, Fish RM, Lakkireddy D, Luceri RM, Panescu D. Essentials of low-power electrocution: established and speculated mechanisms. *Conf Proc IEEE Eng Med Biol Soc.* 2012;34:5734-5740.

2. Kroll MW, Panescu D, Hinz AF, Lakkireddy D. A novel mechanism for electrical currents inducing ventricular fibrillation: The three-fold way to fibrillation. *Conf Proc IEEE Eng Med Biol Soc.* 2010;32:1990-1996.

# Diagnosis of Exclusion

Erroneous for 4 reasons:

- ARD is a well-recognized syndrome often with no clear single pathological mechanism.<sup>1, 2</sup>
- The majority of ARDs do not involve a CEW.<sup>2, 3</sup>
- CEW satisfies all relevant safety standards.<sup>4, 5</sup>
  - including those for electric fences
  - inclusion should be questioned
  - exclusion favored.
- Swine data suggests that the risk is limited to humans  $\leq 38$  lbs.

1. Pollanen MS, Chiasson DA, Cairns JT, Young JG. Unexpected death related to restraint for excited delirium: a retrospective study of deaths in police custody and in the community. *CMAJ*. Jun 16 1998;158(12):1603-1607.
2. Southall P, Grant J, Fowler D, Scott S. Police custody deaths in Maryland, USA: an examination of 45 cases. *J Forensic Leg Med*. May 2008;15(4):227-230.
3. Ho JD, Heegaard WG, Dawes DM, Natarajan S, Reardon RF, Miner JR. Unexpected arrest-related deaths in america: 12 months of open source surveillance. *West J Emerg Med*. May 2009;10(2):68-73.
4. Nimunkar AJ, Webster JG. Safety of pulsed electric devices. *Physiol Meas*. Jan 2009;30(1):101-114.
5. Panescu D, Nerheim M, Kroll M. Electrical Safety of Conducted Electrical Weapons Relative to Requirements of Relevant Electrical Standards. *Conf Proc IEEE Eng Med Biol Soc*. 2013;35:5342-5347.

# Conclusions

- CEWs can contribute to death by:
  - Causing uncontrolled falls
  - Igniting flammable fumes
- CEW-induced VF (electrocution) is a theoretical possibility
  - Actual occurrence is controversial; rare, if any, instances
  - Animal studies suggest that the risk would be restricted to thin person, precordial probe, short probe-heart distance, immediate onset of VF
- CEW-induced changes in pH, lactate, and other markers are comparable to that induced by exercise of the same duration
  - No evidence of dangerous respiratory or metabolic effects  
CEW discharges up to 45 seconds
  - No clinically significant biochemical or physiologic changes

Backup

# The Pain Contribution Speculation

**The CEW allegedly caused great pain and this led to increased catecholamines, which caused the death.**

- There have been over 1.9 million CEW training applications — all painful — and there have been no deaths.
- Cardiac arrest in someone with an otherwise normal heart is not induced from the pain associated with severe back problems, headaches, broken bones, childbirth, or kidney stones.
- People can faint (from other mechanisms than physiologic derangements) from pain but they do not die.
- Most ARD subjects are well anesthetized from alcohol, illegal drugs, schizophrenic psychosis, or the endorphins from the struggle.
- The over 1.9 million CEW officer trainees did not have any anesthesia.

# Necessary, not Sufficient, CEW Electrocutation

## Diagnostic Criteria (all must be simultaneously satisfied)

	<b>Criteria</b> (all must be satisfied)	<b>Cutoff Value</b>
1	CEW deployed in probe mode	Must be present
2	Successful delivery of electrical charge	Must be present
3	Conductive electrical path to the heart	Must be present
4	Lung not between electrode and heart	Must be present
5	Short DTH (Dart-to-Heart) distance	≤ 6 mm (millimeters) DTH
6	Cardiac capture ratio [BMP (beats per minute)]	2:1 capture ratio (550 BPM)
7	Immediate loss of pulse (no pulse after VF)	Any
8	Loss of consciousness (LOC)	≤ 20 seconds
9	Cessation of normal breathing	≤ 60 seconds
10	Presenting cardiac rhythm	Ventricular Fibrillation
11	Cessation of agonal breathing	< 6 minutes
12	≤3 Defibrillation attempts restoring rhythm	≤ 10 minutes
13	Deterioration of VF to asystole	≤ 21 minutes



## **No Evidence of Dangerous Respiratory or Metabolic Effects with CEW Discharges Up to 45 Seconds**

“A rapidly evolving body of literature has examined a range of physiologic and cardiovascular effects of conducted electrical weapon exposure in human volunteers (Table 6). These studies, which include articles and published preliminary reports in abstract form, demonstrate no evidence of dangerous respiratory or metabolic effects using standard (5-second), prolonged (15-second), and extended (up to 45-second) conducted electrical weapon discharges.”

“Other studies of conducted electrical weapon exposure in combination with exercise designed to simulate the physiologic effects of fleeing from or struggling with police demonstrate changes in pH, lactate, and other markers comparable to that induced by exercise of the same duration.”

1. Bozeman, W.P., Hauda, W.E., Heck, J.J., Graham, D.D., Martin B.P., Winslow, J.E. 2009. Safety and Injury Profile of Conducted Electrical Weapons Used by Law Enforcement Officers Against Criminal Suspects. *Annals of Emergency Medicine*. Volume 53, Issue 4, Pages 480–489, April 2009. Five (5) year NIJ study: Laub, J., Study of Deaths Following Electro Muscular Disruption, National Institute of Justice, May 2011.

# Non-Firearm Arrest-Related-Death

~ 1.5 Uses of Force (UoF) per 100 contacts

~ 1 (non-firearm) ARD per 500-1000 UoF

~ 1 detention (jail) death per 700 detainees

Average LEO involved in < 1 ARD in career.

ARD is a well-recognized syndrome often with no clear single pathological mechanism.<sup>1, 2</sup>

The majority of ARDs do not involve a CEW.<sup>2, 3</sup>

1. Pollanen MS, Chiasson DA, Cairns JT, Young JG. Unexpected death related to restraint for excited delirium: a retrospective study of deaths in police custody and in the community. *CMAJ*. Jun 16 1998;158(12):1603-1607.
2. Southall P, Grant J, Fowler D, Scott S. Police custody deaths in Maryland, USA: an examination of 45 cases. *J Forensic Leg Med*. May 2008;15(4):227-230.
3. Ho JD, Heegaard WG, Dawes DM, Natarajan S, Reardon RF, Miner JR. Unexpected arrest-related deaths in america: 12 months of open source surveillance. *West J Emerg Med*. May 2009;10(2):68-73.

# Conducted Electrical Weapon (CEW) Basics

- About 4.63 million human CEW exposures
  - 2.73 million human field CEW exposures
  - 1.9 million training CEW exposures

# CEW Dart-to-Heart (DTH) Distances

## Dart to Heart Distance For **Capture & Release**



Dime  
(17.91 mm)

**25.2 mm**  
Max Capture & Release  
Pig

**16.7 mm**  
Capture & Release  
Human

