TASER® Conducted Electrical Weapons: Physiology, Pathology, and Law
TASER® Conducted Electrical Weapons: Physiology, Pathology, and Law
The below-listed authors have a material, financial, or other relationship with a related business or other entity whose products or services may be discussed in, or directly affected in the marketplace by, this manuscript. This relationship is specified in the author's chapter.

Jeffrey D. Ho
Mark W. Kroll
Ronald Moscati
Robert F. Reardon
Donald M. Dawes
James D. Sweeney
Robert A. Stratbucker
TASER® Conducted Electrical Weapons: Physiology, Pathology, and Law
# Contents

1  **Conducted Electrical Weapons: A User's Perspective.**  
   Greg Meyer  

2  **The Scientific History**  
   Robert A. Stratbucker  

3  **Conducted Electrical Weapons and Resolution of Use-of-Force Encounters**  
   Charlie Mesloh, Mark Henych, and Ross Wolf  

4  **Nonlethal Weapons: The Broader Context.**  
   Peter J. Cuenca and John G. McManus  

5  **Transcutaneous Muscle Stimulation.**  
   James D. Sweeney  

6  **Current Flow in the Human Body.**  
   Dorin Panescu and Robert A. Stratbucker  

7  **Animal Studies.**  
   John G. Webster  

8  **CEW Research Models: Animal and Human Studies.**  
   Theodore C. Chan and Gary M. Vilke  

9  **Cardiac Arrhythmias.**  
   Derek J. Dosdall and Raymond E. Ideker  

10 **Electrocardiographic Effects of the CEW.**  
   Jeffrey D. Ho  

11 **Serum and Skin Effects of CEW Application.**  
   Jeffrey D. Ho
12 Echocardiographic Effects of the CEW ................. 153
   Robert Reardon

13 Rhabdomyolysis ........................................... 163
   Ronald Moscati and Samuel Cloud

14 Effects of CEWs on Respiration ......................... 167
   Donald M. Dawes

15 Neuroendocrine Effects of CEWs ....................... 179
   Donald M. Dawes and Mark W. Kroll

16 Electroporation of Cardiac and Nerve Cells ............ 187
   Vadim V. Fedorov, Leonid Livshitz, Geran Kostecki
   and Igor R. Efimov

17 Eye and Head Injuries .................................... 201
   S. Robert Witherspoon, Andreas K. Lauer
   and Jonathan L. Marinaro

18 CEW Effects with Illegal Stimulant Intoxication ....... 211
   Patrick Tchou

19 Alcohol and the CEW ...................................... 219
   Ronald Moscati and Jeffrey D. Ho

20 Conducted Electrical Weapons and Implantable Cardiac
   Devices .................................................. 223
   Subba Reddy Vanga, James L. Vacek, Loren Berenbom
   and Dhanunjaya R. Lakkireddy

21 Risk Management and the CEW ............................ 235
   Greg Bingham

22 The New York City Experience ............................ 241
   Michael D. White and Justin Ready

23 Impact of CEW and Other Types of Force and Resistance on Officer
   and Suspect Injuries ..................................... 257
   Michael R. Smith, Robert J. Kaminski, Jeffrey Rojek,
   Geoffrey P. Alpert, and Jason Mathis

24 Field Statistics Overview ............................... 283
   James E. Brewer and Mark W. Kroll
Contributors

Geoffrey P. Alpert  University of South Carolina, Department of Criminal Justice and Sociology

Loren Berenbom  Clinical Assistant Professor; Director, Electrophysiology, Mid America Cardiology, University of Kansas Hospital

Greg Bingham  Oakland, CA Police Department (Ret.), gkcglb@aol.com

Michael A. Brave  LAAW International, Inc., TASER International, Inc., brave@laaw.com

James E. Brewer  jamesbrewer@wcta.net

Theodore C. Chan  Department of Emergency Medicine, University of California, San Diego Medical Center, tchan@ucsd.edu

Samuel Cloud  Department of Emergency Medicine, SUNY at Buffalo, Erie County Medical Center, New York, USA

Peter J. Cuenca  Department of Combat Medic Training, Department of Emergency Medicine, Brooke Army Medical Center

Donald M. Dawes  Department of Emergency Medicine, Lompoc District Hospital, Lompoc, CA, donalddawes@aol.com

Vincent J.M. Di Maio  Chief Medical Examiner (retired), Bexar County (San Antonio), Texas, vincent_dimaio@yahoo.com

Theresa G. Di Maio

Derek J. Dosdall  Department of Biomedical Engineering, University of Alabama, Birmingham, Alabama, USA, djd@crml.uab.edu

Igor R. Efimov  Department of Biomedical Engineering, Washington University, igor@wustl.edu

Michael A. Evans  AIT Laboratories, maevans@aitlabs.com
Vadim V. Fedorov  Department of Biomedical Engineering, Washington University, igor@wustl.edu

Joshua Gunn  AIT Laboratories, JGunn@aitlabs.com

Mark Henych  Advanced Research Solutions, Estero, FL

Jeffrey D. Ho  Department of Emergency Medicine, Hennepin County Medical Center, University of Minnesota Medical School, Minneapolis, MN, USA, hoxxx010@umn.edu

Raymond E. Ideker  Departments of Medicine, Biomedical Engineering, and Physiology, University of Alabama-Birmingham, Volker Hall B140, 1670 University Blvd, Birmingham, AL 35294-0019, USA, rei@crml.uab.edu

Robert J. Kaminski  University of South Carolina, Department of Criminal Justice and Sociology

Steven B. Karch  Consultant Pathologist and Toxicologist, Berkeley, California, skarch@sonic.net

Geran Kostecki  Department of Biomedical Engineering, Washington University in St. Louis

M. Scott Kriger  AIT Laboratories

Mark W. Kroll  University of Minnesota, Biomedical Engineering, mark@kroll.name

Dhanunjaya R. Lakkireddy  Clinical Assistant Professor and Staff Electrophysiologist, Mid America Cardiology, University of Kansas Hospitals, Suite G600, 3901 Rainbow Blvd, Kansas City, KS 66160, USA, dlakkireddy@mac.md

Andreas K. Lauer  Casey Eye Institute, Department of Ophthalmology, Oregon Health & Science University, Legacy Hospitals, lauera@ohsu.edu

Leonid Livshitz  Department of Biomedical Engineering, Washington University in St. Louis

Jonathan L. Marinaro  Trauma Critical Care, Departments of Surgery and Emergency Medicine University of New Mexico Health Sciences

Deborah C. Mash  Department of Neurology, Miller School of Medicine, University of Miami, dmash@med.miami.edu

Jason Mathis  University of South Carolina, Department of Criminal Justice and Sociology

John G. McManus  Department of Emergency Medicine, Brooke Army Medical Center, john.mcmanus@amedd.army.mil

Charlie Mesloh  Florida Gulf Coast University, cmesloh@fgcu.edu
Greg Meyer  Captain, Los Angeles Police Department (Ret.), gregmeyer@earthlink.net

Ronald Moscati  Department of Emergency Medicine, SUNY at Buffalo, Erie County Medical Center, moscati@buffalo.edu

Dorin Panescu  Chief Technical Officer with NewCardio, Inc., Santa Clara, CA, dpanescu@NewCardio.com

John G. Peters  President and Founder, Institute for the Prevention of In-Custody Deaths, Inc., john@ipicd.com

Justin Ready  Department of Sociology, John Jay College of Criminal Justice, 899 Tenth Ave, New York, NY 10019, jready@jjay.cuny.edu

Robert Reardon  Department of Emergency Medicine, Hennepin County Medical Center, rfreardon@gmail.com

Jeffrey Rojek  University of South Carolina, Department of Criminal Justice and Sociology

Michael R. Smith  University of South Carolina, mrsmith@gwm.sc.edu

Robert A. Stratbucker  Faculty, University of Nebraska, Colleges of Medicine and Engineering (Ret.), rstratbucker@cox.net

Samuel J. Stratton  Professor, University of California, Los Angeles School of Public Health and the David Geffen School of Medicine at the University of California, Los Angeles; Medical Director, Health Disaster Management/Emergency Medical Services Orange County Health Care Agency, strattos@ucla.edu

James D. Sweeney  Department of Bioengineering, Florida Gulf Coast University, jsweeney@fgcu.com

Patrick Tchou  Cleveland Clinic, Section of Cardiac Electrophysiology and Pacing, Department of Cardiovascular Medicine, The Heart and Vascular Institute, tchoup@ccf.org

James L. Vacek  Director of Cardiovascular Research, The Center for Cardiovascular Scholarship, Mid America Cardiology, The University of Kansas Hospital

Subba Reddy Vanga  St. Luke’s Hospital, Chesterfield, MO 63017, USA

Gary M. Vilke  Department of Emergency Medicine, University of California, San Diego Medical Center, CA, USA, gmvilke@ucsd.edu

John G. Webster  Department of Biomedical Engineering, University of Wisconsin, webster@engr.wisc.edu
Charles V. Wetli  Chief Medical Examiner and Director of Forensic Sciences, Suffolk, County, NY (retired); Clinical Professor of Pathology, SUNY at Stony Brook (retired), thanatopsis888@yahoo.com

Michael D. White  School of Criminology and Criminal Justice, Arizona State University, mdwhite1@asu.edu

S. Robert Witherspoon  Casey Eye Institute, Department of Ophthalmology, Oregon Health & Science University, Devers Eye Institute, Legacy Hospitals, witherss@ohsu.edu

Ross Wolf  University of Central Florida, American Military University
Introduction

Seldom has a technology had such rapid adoption as the TASER® conducted electrical weapon (CEW). We all think of mobile phones and their rapid adoption but the compound average growth rate of mobile phone penetration over the past 10 years was 5.2% while that of the CEW was an astounding 84%. It is now the standard nonlethal tool for the majority of the law enforcement agencies in all of the English speaking countries and has rapidly spread to 45 countries worldwide.

Along the way there was an enormous collision of confusions. The interaction with law enforcement for the average citizen is the meek acceptance of a traffic ticket. Thus, we have no personal experience with the difficult challenge facing a police officer when taking a resistant subject into custody. Or, when controlling a psychotic person needing help for a medical emergency. For centuries before the CEW the primary tools were the clubs which are now euphemistically referred to as batons. Secondly, the total understanding of electricity for the average citizen is that it is something useful that comes out of sockets in the wall but that it is very dangerous and it should not contact the body. Finally, there is no appreciation of the difficult problem of arrest-related deaths which now take 800 lives annually in North America alone.

This collision of confusions is now being confronted by a rapidly growing body of science. Nearly a dozen animal and human studies of CEWs are now performed per year. Unfortunately, all of this scientific data has never been put together nor has it been combined within the context of the law enforcement use-of-force requirements and the difficult problems of arrest-related deaths. Thus, we recognized that there was a need for a standard reference to deal with these issues.

The book begins with the background of the history of CEWs both from a user and a scientific perspective. Captain Greg Meyer was a senior researcher for the innovative Los Angeles Police Department in use-of-force techniques and writes the user history. Dr. Stratbucker was well known for early research on defibrillation and was a medical pioneer in the study of CEWs. Dr. Mesloh

TASER® is a registered trademark of TASER International, Inc.
follows up with the background of police use-of-force and Dr. McManus covers the broader context of nonlethal weapons and the directions for the future.

Dr. James Sweeney – who is well known for his work in electrical transcutaneous muscle stimulation to help paralysis victims – explains transcutaneous muscle stimulation. Dr. Panescu – a recognized authority in the flow of electrical current through the human body – explains exactly where the CEW current does and does not flow.

The central and critical portion of the book covers the issue of possible side effects. We begin with the chapter of Dr. Webster, a prominent authority in biomedical engineering, who writes on animal models that have been used to study these devices. Dr. Chan has participated in about a dozen human studies of CEWs and other police tools. He wrote the important chapter on bridging the human and animal data as there are areas in which the animal and human data disagree. Dr. Ideker is the internationally recognized expert on lethal cardiac arrhythmias and writes on that topic. Dr. Ho follows up with chapters on the electrocardiographic and blood serum effects. Dr. Reardon covers the important topic of echocardiographic monitoring of the heart during CEW applications. The possibility of kidney damage from rhabdomyolysis is covered in the chapter by Dr. Moscati. Dr. Dawes discusses the effects on human respiration in one chapter and neuroendocrine effects in another. Dr. Moscati covers the effects with alcohol intoxication.

Dr. Efimov – world recognized authority on electroporation (direct electrical damage to cells) – contributed the chapter on electroporation and possible nerve damage while Dr. Lauer covers the issue of facial and head injuries including the eye. A common concern is the possible dysynergy with illegal drugs and that is covered by Dr. Tchou who is a senior cardiac electrophysiologist with the Cleveland Clinic. A common concern with the public is the possible interaction with a pacemaker or implantable defibrillator and Dr. Lakireddy – who has researched this issue – presents the facts in his chapter.

The law enforcement need and the field experience are covered in three chapters by experienced police officers and law enforcement researchers. The chapter by Sgt. Bingham deals with risk management issues in a large police department. The field results in New York City are covered by Dr. White and the data in two other cities is covered by Dr. Smith. Statistician Brewer then presents the statistical evidence surrounding other common questions.

The important issues of the in-custody death are covered in the chapter by Dr. Stratton. Dr. Karch explains the cardiac effects of illegal stimulants. Dr. DiMaio covers the issue of excited delirium. The in-custody death creates great challenges for a medical examiner and the issue of toxicology is also covered by Dr. Evans’ chapter while the brain analysis is covered by Dr. Mash who pioneered the techniques of brain analysis for excited delirium deaths. Dr. Wetli – who coined the modern term of “excited delirium” – provides a pathology checklist.
Finally, the legal issues loom very large in this case since the CEW is an electrical device that interacts daily with law enforcement. Michael Brave penned the chapter on CEW law and Dr. Peters covers the complicated issue of the meaning of science and logic in the courtroom.

Because of his scientific background in the use of electrical stimulation for medical devices Mark was invited to join the TASER International board in 2003 and there got his first exposure to the challenges faced by police. Jeff recognized a need for more scientific studies in this area and was able to secure grants from TASER to do the first formal human studies.

As opposed to the pacemaker and implantable defibrillator industry we have an unusual situation where one manufacturer dominates an area of technology. Thus we had a special challenge to find authors with the maximum amount of independence and minimal connections to TASER in order to keep the scientific credibility at its highest level. That had to be balanced with the fact that many of the top authorities in this area became so by working cooperatively in some cases with the primary manufacturer. As it is often put, we could not cross the sometimes thin line between independence and ignorance. We think we have achieved the right balance between knowledge and objectivity. Only one of the 50 authors is an employee of TASER International, and the majority have derived no consulting income from them. Dr. Sweeney, Dr. Stratbucker, and Dr. Kroll are on the Scientific and Medical Advisory Board.

To keep the scientific rigor at its highest level we also took the unusual step of having the chapters peer reviewed. Almost every chapter was anonymously reviewed by one to three experts in the field. This was done in addition to careful review by the coeditors.

We have dramatically different backgrounds. Jeff is a board certified emergency physician and a licensed law enforcement officer. Mark is a scientist who studied the use of electrical stimulation for therapy. What we have in common is a career dedication to saving lives especially those in emergency situations. Neither of us expected to be involved with TASER CEWs but our involvement has now reached the ultimate level of commitment as we have both experienced the amazing effects of this weapon. Thus, we joined that special club of over 1.6 million people that know what it feels like to have your body briefly controlled by special electrical waveforms. We hope you enjoy reading this book as much as we have enjoyed putting it together.