Chapter 24
Field Statistics Overview

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We now have enough years of experience and enough CEW deployments to answer many of the common statistical questions that arise. This chapter will deal with the following questions:

1. How many human beings have experienced a CEW exposure?
2. What is the net impact on officer and suspect injuries?
3. Is there any truth to the common perception that multiple CEW exposures are more dangerous?
4. How often is the CEW blamed as a cause of death in an arrest-related death?

24.1 Total Human Exposures

24.1.1 Field Usage Exposures

Previous publications have reported the field usage for various law enforcement agencies [1,2]. We sought to calculate the overall usage from local usage rates and detailed CEW sales data.

Reports of law enforcement CEW usage were gathered from web searches. These covered 187 reports from 118 unique agencies for the years 1986–2008. A total of 156 reports were from the United States (83%) with the remainder coming from Canada. The reporting period duration for an agency ranged from 6 weeks to 6 years with a mean of 1.03 ± 0.53 years. The reports covered departments with 10–40,000 officers with 2–3847 TASER CEWs deployed in a department.

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A CEW field use was defined as either a drive-stun or barb-launched application or attempted application. Brandishing, arcing, or laser painting were not counted for this analysis. A total of 22,160 field uses were reported. The usage rate per CEW varied significantly with departments (1.2 ± 2.1) with the pattern of use following a log normal distribution (m = 1.2, μ = 1.08). Most of that variation encountered was due to different deployment levels with an impressive correlation of $r^2 = 0.72$ as seen in Fig. 24.1.

The deployment level is the number of CEWs divided by the number of sworn officers. Full patrol officer deployment is typically found at a deployment level >0.75. This is explained by the fact that not every sworn officer is issued a CEW as they are not all active patrol officers.

$$\text{DL(deployment\_level)} = \frac{\text{number\_of\_CEWs}}{\text{number\_of\_sworn\_officers}}$$

If DL was >75% it was then set to 0.75 (75%).

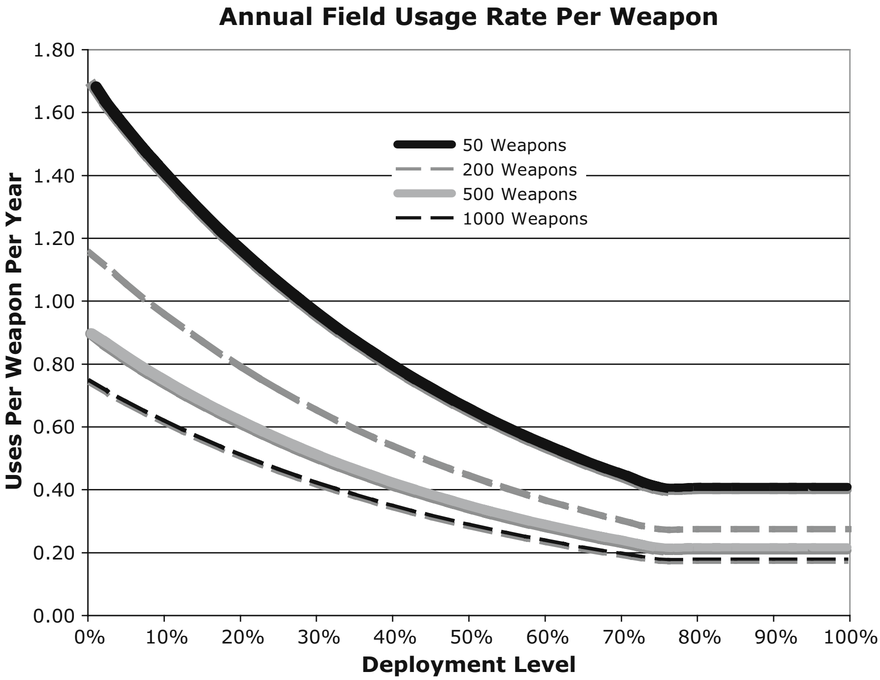

Fig. 24.1 Low deployment departments have much higher usage rates per CEW as officers in these departments are called out to many different situations while officers in full deployment departments have individual CEWs

The predicted annual usage rate per CEW was then given by:

$$\mathrm{Log}_e(\text{usage rate}) = 1.6009 - 1.9047\ \mathrm{DL} - 0.2746\ \log_e(\text{number of CEWs})$$

For example (see Fig. 24.1), in a city that has few CEWs and issued only to the SWAT unit, each of those devices will be called on often and they will be used, on average, about 1.7 times per year. The more officers equipped with CEWs the lower the usage rate, which drops to a rate of 0.2–0.4 per year per CEW depending on the number of CEWs issued.

There was no difference between usage rates in the United States versus Canada nor was there any apparent correlation between the year reported and the usage rate.

This model of usage rate versus deployment rate was then utilized on a TASER CEW sales database of 7617 agencies covering 219,970 CEWs. This database included department size, number of CEWs owned, and deployment level. The model gave an average annual usage rate for each CEW of 0.550 ± 0.008. Each CEW in law enforcement hands was used once every two years, on average, across all departments.

The TASER sales history was then integrated over time from Q1 2000 to 30 June 2008 and yielded 1,102,254 "CEW years" with 606,395 field uses. These numbers did not include those of the 150,000 CEWs in civilian hands (since 1993). They also do not include the large number of noncontact uses including brandishing, arcing, and laser "painting."

24.1.2 Training Exposures

In summer 2007 a survey was sent to all TASER CEW certified instructors. A total of 2082 surveys were completed which covered 106,637 TASER CEWs. This is about 30% of the devices then fielded with law enforcement and thus the survey has unusually high statistical confidence. Instructors were asked about their training policies and the number of human training exposures per CEW.

As can be seen in Fig. 24.2, the most common law enforcement department policy decision was to encourage the law enforcement officer to receive a training CEW exposure. The second most common policy was to make the training exposure mandatory. The *least* common policy was to forbid an exposure (5.4%). Note that the percentages were calculated from the individual instructor responses. Since larger departments had multiple instructors, this method gave an estimate of the number of officers subject to a given policy.

Using the responses from the responding 2,082 certified instructors, we found a weighted mean of 2 (1.98) human training exposures per CEW. The reason this number was >1 was that in low deployment departments many officers share a CEW. A statistical "bootstrap" technique with 1,500 samples of 1,581 data each was used to estimate the confidence limits on this training exposure rate. The 95% confidence limits were 1.85–2.12.

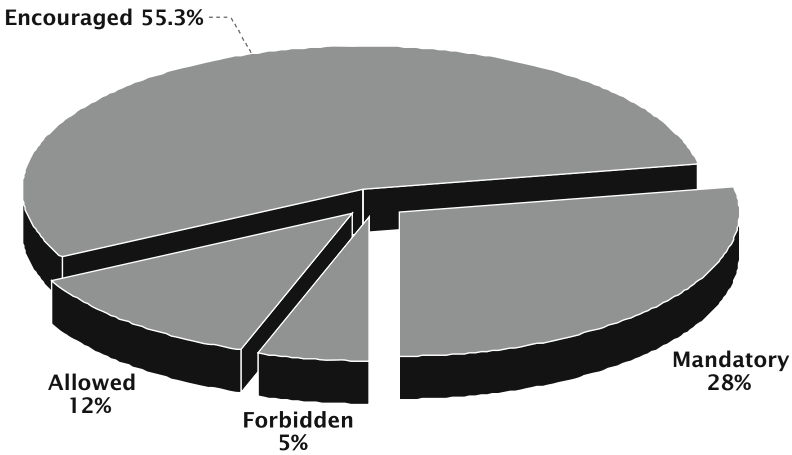

Fig. 24.2 Distribution of officer training policies

The mean response date to the survey was September 18, 2007. The mean calculated training hits given for officer turnover was 4.62% per year. This was 1.17% per quarter.

An estimated 378,731 CEWs were fielded by June 30, 2008. This number multiplied time 1.98 gives 749,175 CEW training exposures. Adding in 1.17% per quarter for turnover exposures gave an estimate of 758,385 training exposures with confidence limits of ±53,000.

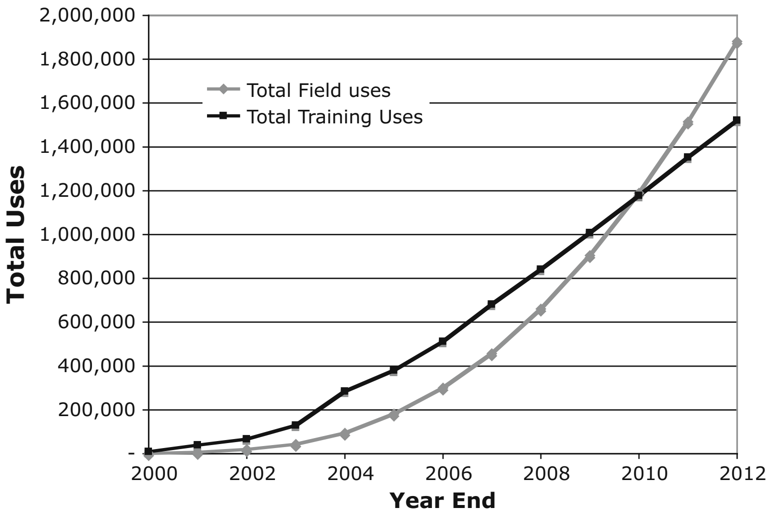

Fig. 24.3 Total field and training exposures. The numbers up to mid-2008 were based on actual CEW deployments while the remaining were based on conservative sales estimates

The total human exposure estimates are shown in Fig. 24.3. Note that the field uses are expected to exceed the training uses by 2010. The reason for this is that training exposures are primarily driven by new deployments and thus are approximately proportional to new sales. However, field uses are driven by the total number of CEWs in the field and thus are predicted by the aggregate number of deployed units. Since this, in turn, is the aggregate number of sales we would hypothesize a quadratic fit to the year, which was the case ($r^2 = 0.9988$). One factor that could influence this analysis, in the future, is the actual need for field usage. There is substantial evidence that the behavioral abnormalities that lead to CEW usage are a function of the illegal street-based drug supply. If this drug supply should expand or contract, field usage could increase or decrease accordingly.

24.1.3 Impact on Officer and Suspect Injuries

Recent publications have demonstrated the low rates of injury from CEW usage [1,3,4]. To establish the average agency results we performed a broad search for reports relating CEW introduction to officer and suspect injuries.

24.1.4 Officer Injuries

The results are shown in Table 24.1. There were 25 law enforcement agencies reporting data. The year of maximum deployment was compared to a baseline year. The baseline year was typically the year before. However, in cases of gradual deployment the baseline year was the latest year with no CEW deployment. The postdeployment year ranged between 2002 and 2007. The number of CEWs in the departments was 54–1444 (mean 456 $\pm$ 446).

The reported officer injury rate reduction ranged from 20% to 100%. The injury reduction statistics were weighted by the number of CEWs. The weighted mean injury reduction was 63%. The 95% confidence bounds were 55–72%. There was no univariate or multivariate correlation between the injury rate reduction and the year or number of CEWs in the department.

24.1.5 Suspect Injuries

The results are shown in Table 24.2. There were data from nine agencies. Both the postdeployment (comparison) year and the number of CEWs are shown. The comparison years were 2004–2005 and the number of CEWs was 205–2569.

The injury reduction ranged from 24% to 82%. These were weighted by the number of CEWs. The weighted mean injury rate reduction was 64%. The 95% confidence bounds were 52–75%. There was no univariate or multivariate

Table 24.1 Officer injury reductions with number of CEWs and post deployment year. The weighted mean injury rate reduction was 63% (55–72% confidence limits)

Location	CEWs	Postdeployment year	Injury reduction (%)
Austin, TX	1144	2004	50
Cape Coral, FL	243	2004	93
Charlotte, NC	1444	2004	59
Cincinnati, OH	1221	2004	56
Columbus, OH	205	2005	23
Concord, CA	71	2006	65
El Paso, TX	869	2007	86
Garner, NC	56	2004	20
Glenn County, CA	54	2006	100
Leon County, FL	203	2004	65
Long Beach, CA	1108	2005	25
Maui, HI	413	2007	77
Minneapolis, MN	128	2006	75
Oakland County, MI	410	2004	100
Omaha, NE	96	2005	47
Orange County, FL	1344	2002	80
Peel Regional, OT	64	2004	37
Putnam County, FL	129	2005	86
Sarasota, FL	220	2006	65
South Bend, IN	275	2004	66
Topeka, KS	147	2003	46
Toronto, ON	630	2006	100
Ventura County, CA	538	2007	72
Queensland, Australia	493	2007	40
Wichita, KS	308	2006	46

correlation between the injury rate reduction and the year or number of CEWs in the department.

It is interesting to note that CEW deployment appeared to help suspects (64 $\pm$ 11% injury rate reduction) and law enforcement officers (63 $\pm$ 8% reduction) equally.

Table 24.2 Suspect injury reductions. The baseline for Phoenix was August 2001–August 2002. Mean suspect injury rate reduction was 64% (52–75%)

Location	TASER CEWs	Post deployment year	Injury reduction (%)
Austin, TX	1144	2004	82
Cape Coral, FL	243	2004	68
Charlotte, NC	1444	2004	79
Cincinnati, OH	1221	2004	35
Columbus, OH	205	2005	24
Lynchburg, VA	40	2007	58
Maui, HI	413	2007	48
Peel Regional, OT	205	2005	47
Phoenix, AZ	2569	2004	67

There were several limitations to this analysis. The data were self-reported (often without independent quality control) and covered varying deployment years.

24.2 Are Multiple Exposures More Dangerous?

A commonly heard hypothesis is that multiple or prolonged CEW exposures may be more dangerous. A limit of three CEW "hits" was proposed as a safe limit [5]. A large body of 292 media-linked death cases, in which the number of exposures was ascertainable, were analyzed to see if there was any statistical support for this hypothesis.

A total of 267 autopsies were obtained, and police records or media accounts were analyzed for the remaining 25 cases. The results are shown in Fig. 24.4. It can be seen that 85% of fatalities were preceded by three exposures or less. Over 75% of the deaths involved only one or two exposures. The distribution of the number of CEW exposures was then compared to the exposure distribution for 3200 CEW exposures of the Royal Canadian Mounted Police (RCMP) [6]. These distributions were fitted to a Gumbel-Gompertz model and then were compared. Main and secondary distribution lobes, including the tail, showed no differences (log-rank $p = 0.48$). We concluded that there appeared to be no correlation between the number of exposures and the mortality rate.

Thus, there does not appear to be any basis for the baseball-reminiscent "3-strike" rule of no more than three CEW discharges. Even if there was an identifiable pathology associated with a fourth exposure, enforcing this "baseball" rule would affect only 15% of cases. In these 15% of cases, officers would

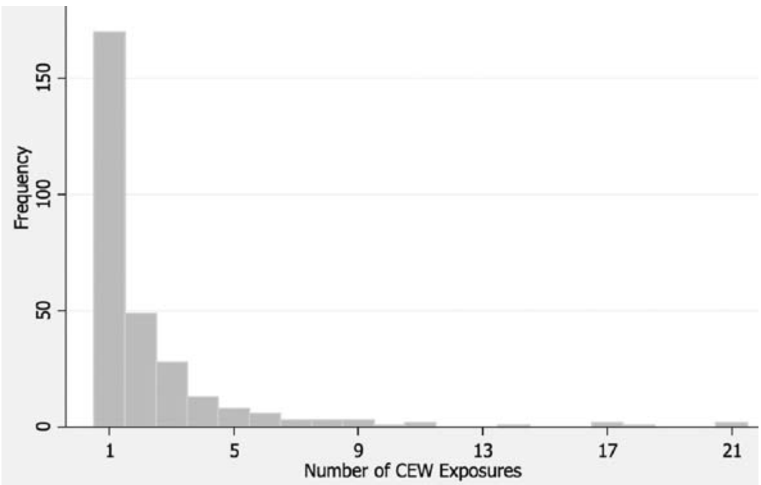

Fig. 24.4 Frequency of various numbers of exposures in 292 reported deaths

then be forced to switch to alternatives such as OC spray, baton strikes, prolonged physical struggle, or firearm discharge. Based on the demonstrated increased injury rates with these alternatives overall injury rates would likely increase.

These conclusions are supported by the recent human data with exposures out to 45 seconds [7] and animal data with exposures out to 30 minutes [8].

24.3 How Often Is the CEW Blamed as a Cause of Death?

The arrest-related death (ARD) is an phenomenon that occurs about 800 times per year in North America. This number is estimated from a population-based adjustment from the 700 annual ARDs found in the 47 reporting states of the USA [9]. These deaths include both criminal suspect arrests and attempts to control someone in order to render medical assistance. In the 700 annual ARDs a CEW was used in 1.8% (12) of the cases. The results of smaller studies (eliminating firearm cases) have demonstrate that CEWs, such as the TASER® X26, had been used during approximately 30% of ARDs in the United States [10,11]. As more law enforcement agencies adopt these devices the percentage will increase.

The medical examiner (ME) is under great pressure when investigating an ARD. They must be impartial in spite of great media and advocacy pressure (especially in the case of an ethnic minority death). Adding to the pressure has been the controversy and paucity of scientific literature regarding these tools. This was also true with chemical irritant aerosols, "hog-tying," carotid neck holds, and restraint "asphyxia." Finally, advocacy groups have always been slow to acknowledge exculpatory scientific evidence, even after it has been published in the peer-reviewed literature. For example, both Amnesty International and the American Civil Liberties Union (ACLU) have still not withdrawn their previous "concerns" regarding alleged deaths following the use of oleresin capsicum (OC) spray [12,13].

Although the use of CEWs was often temporally associated with the occurrence of ARD, medical examiners cited the device as the primary cause of death in five cases (This is now down to four cases as a judge ordered a medical examiner to correct her autopsy in one of these cases.) [14] If the time frame was expanded going back to 1983, and included cases where the CEW was listed as one of several causes of death, the total rises to 12. Twelve cases (out of nearly 1.4 million uses) give the devices a death rate of less than one in 100,000.

Since electrical current does not linger or accumulate in the body, some medical examiners have, in the past, erred on the side of including the CEW as a contributory cause of death, even though they had no explanation for how it could have caused or contributed to the death. Since electrical current does not accumulate in the body, we hypothesized that, as more peer-reviewed data were published, medical examiners would be able to make more accurate judgments about the causes of death.

ME autopsy report accuracy has been previously explored [15–18] as well as clinical autopsy accuracy [19–21]. We decided to explore the rate of ME errors with ARDs with usage of CEWs.

24.3.1 Possible Areas for Confusion

24.3.1.1 Electrocution

"Electrocution" is the term first coined to describe the government's execution of a convicted criminal by use of electricity. Today the term "electrocution" is more broadly used to describe the induction of a cardiac arrest by the application or exposure to electrical shock. This has been theorized as a mechanism by which a TASER CEW, could, allegedly, kill a person. If electrocution – by electrical stimulation – does occur, death is immediate and occurs within seconds. This is distinct, for example, from the results of a high power shock such as lightning strike, which may will cause long term damage including myocardial necrosis [22,23]. Electrical stimulation effects do not linger or build up in the body like a poison beyond the first few seconds [24–32].

The electrical induction of ventricular fibrillation (VF) has recently become one of the best scientifically researched causes of death. Paradoxically, this has been due to the surgical implantation of lifesaving implantable cardioverter defibrillators (ICDs). About 500 times per day a cardiac electrophysiologist will intentionally use electrical current to induce a cardiac arrest to test an ICD device immediately following its insertion [33,34].

From this experience with over 1,000,000 such intentionally induced cases of cardiac arrest in the cardiac cathertization laboratory, certain facts have been medically and scientifically established beyond question:

a. VF is either induced or not induced within 1–5 seconds of current application [30,32,35].
b. Asystole or PEA (pulseless electrical activity) is never induced [36].
c. The cardiac pulse disappears immediately [37].
d. The patient loses consciousness within 5–15 seconds [37].
e. A sufficiently strong defibrillation shock within the first one minute following VF – either internal or external – restores a cardiac sinus rhythm 99.9% of the time [38].

24.3.1.2 Long Duration Shocks

The regulations of both the International Electrotechnical Commission (IEC) [39,40] and Underwriters Laboratories (UL) regulations recognize that electrocution either happens in the first few seconds or does not occur [41]. Currents that will not induce VF in a few seconds will not induce VF in 1 minute as shown in Fig. 24.5 taken from Chilbert [41].

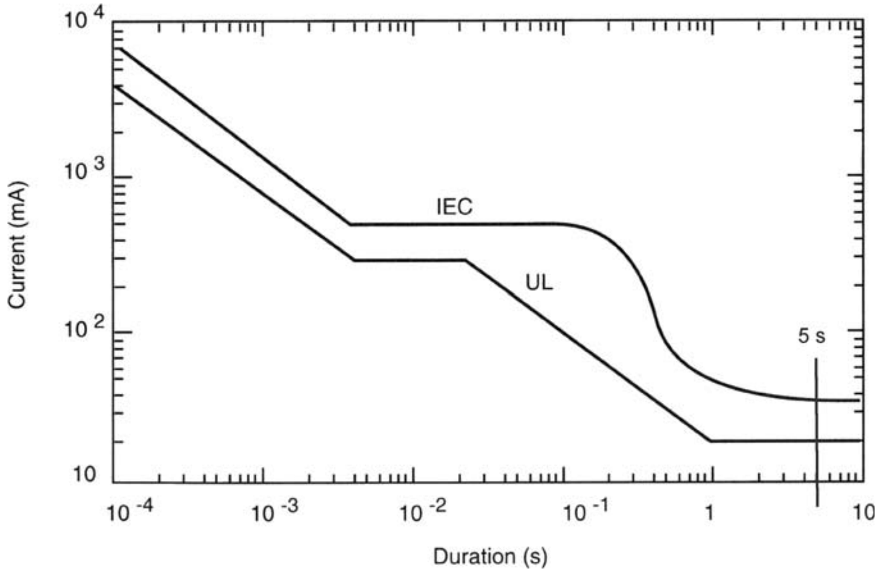

Fig. 24.5 The level of electrical current to induce ventricular fibrillation does not decline after a few seconds

Animal studies going back to the 1930s showed that the risk of inducing VF did not build up (increase) after a critical exposure time of a few seconds. These studies have found that the critical exposure time ranged over 0.8–5.0 seconds [24,26–29,42]. Based on these animal results above, Beigelmeier and Lee calculated that this critical time to induce fibrillation ranged from 2 to 5 seconds for humans due to the fact that humans have lower heart rates than experimental animals [26,27].

When TASER probes were buried under the skin of small pigs (50 kilograms), with a barb over the most sensitive part of the heart [43], experimenters found no difference in the ability of either a 5-second or a 15-second X26 application to induce ventricular capture (24/25 vs. 28/28, p = NS by Yates-corrected χ^2). Due to the differences in thoracic geometry, bilateral passage of current through the heart, as occurred in the pigs, would almost certainly be impossible in humans because of insulation provided by the lungs. Also, any vulnerable side-to-side orientation would be very rare since the CEW barbs are launched in a vertical plane. See Chapter 8 for further discussion of the swine–human differences.

One human study found that connecting a 9-volt cell directly to the inside of the heart induced VF within 3 seconds in the majority of patients [32]. An intracardiac human study found that the current duration required to cause fibrillation (at a 96% success rate), with a small steady direct current (DC), was 3.8 ± 1.4 s [30].

24.3.1.3 Effects of Electrical Current on Breathing

Due to the routing of the phrenic nerves it is extremely difficult to electrically induce respiratory paralysis in the human [44]. The phrenic nerve derives from the C3–C5 cervical plexus and the point of closest passage of these nerves to the skin is just above the clavicle, near the sternocleidomastoid muscle. The left and right phrenic nerves travel through the center of the thorax passing just on the margins of the heart on the way to enervate the left and right hemidiaphragm muscles. The nerves are surrounded by the highly insulative lungs throughout this passage, thus making them very insensitive to external electrical currents. Indeed, when electrical devices are used to stimulate the phrenic nerve (as in a paraplegic), surgical insertion of the electrodes is required, and they must be wrapped directly around the nerve to have any positive effect. As discussed in the chapter by Dawes on breathing effects, it does not appear that CEWs interfere with human breathing. This is true for applications across the chest [45–47] and for "drive-stun" applications focused over the trapezius muscle near the phrenic nerves [48].

24.3.1.4 Drug Dysynergies

As discussed in the chapters of Karch, Tchou, and Evans, chronic abuse of stimulants – such as cocaine – can do permanent damage to the heart and lead to an arrhythmic death without any electrical stimulation. Thus, there has been speculation that the acute usage of stimulants may also exacerbate the risk of electrocution. In fact, the opposite has been found to be typically true [49,50]. For example, cocaine intoxication is a strong sodium channel blocker and actually makes it more difficult to induce VF electrically [51–53]. This has recently been confirmed with actual TASER X26 waveforms [54]. With cocaine intoxication the safety margin rose significantly and was almost doubled for barbs near the heart. The occasional cocaine abuser with the syndrome variously referred to as excited delirium (a subgroup of the population likely to receive a Taser discharge) were usually found to be in asystole [11,36]. The appearance of this rhythm disorder remains unexplained, but it may be of central origin. Thus the induction of VF was irrelevant in these cases.

24.3.1.5 Autopsy Analysis

We performed extensive searches for the years 2001–2006 to find cases of an ARD with any mention of a CEW usage. Once they were identified, written requests were made for the associated autopsy reports.

Any material failure to appreciate the scientific facts regarding electrocution was scored as an error. This included ignoring any of the following: (1) a delayed collapse, (2) failure of immediate defibrillation, or (3) a non-VF rhythm. Other errors were counted if the report reflected hypotheses not supported by known literature. These included: (1) blaming the CEW for

Table 24.3 Scored autopsy errors in decreasing order of frequency [55]

Scored error	Rate of finding
Delayed collapse ignored	16
Nebulous equivocal comment such as "could not be ruled out"	16
Non-VF rhythm ignored	13
Failure of defibrillation ignored (includes cases where a non-VF rhythm was noted by paramedics)	9
Discharge duration or parity stressed	9
Drive-stun mode ignored	8
Assumed drug-CEW dysynergy	6
"Straw" comment	6
Cardiac damage blamed on CEW	4
Impaired respiration assumed	2

myocardial physical changes [23], (2) inclusion of a unsupported innuendo or a nebulous equivocal comment (e.g. "we were unable to eliminate the role" of the CEW), (3) assuming prolonged CEW applications were more dangerous than other restraint techniques, (4) speculating that CEWs impaired breathing, (5) presumption of a lethal synergy between stimulant drug intoxication and the CEW, and (6) use of the CEW only in the "drive stun" mode since this involved current passing between 2 very close electrodes and did not create any major organ involvement. Finally, the use of an unscientific lay term such as the metaphoric "last straw" or "pushed over the edge" was scored as an error (Table 24.3).

24.4 Results

We obtained 301 autopsies and summaries covering deaths occurring between January 1, 2001 and December 31, 2006. Between the autopsies and the summaries obtained, we believe that we were able to analyze the findings of almost ARDs in which a ME might have cited the CEW.

There were 39 cases (9.4%) where the autopsy report listed the CEW as a possibly contributory or as an "unknown" factor. The listing rate declined from 33% in 2001 to 3.3% in 2006 ($r^2 = 0.73$, $p = 0.031$ for linear fit) as seen in Fig. 24.6. Autopsy reports were reviewed for these cases and errors were tabulated. The decedents were primarily male (38 M/1 F) with mean age 35.0 $\pm$ 10.9 years (median = 32) which was consistent with other reported ARD data [9,11,56].

We found a mean of 2.9 $\pm$ 1.3 scored errors per autopsy report with a range of 1–6. This error rate declined steadily over time as seen in Fig. 24.7 ($p = 0.002$, $r^2 = 0.33$). We performed a multivariate analysis for predictors of the error rate. Suspect age, date of death, body mass index, heart mass, suspect

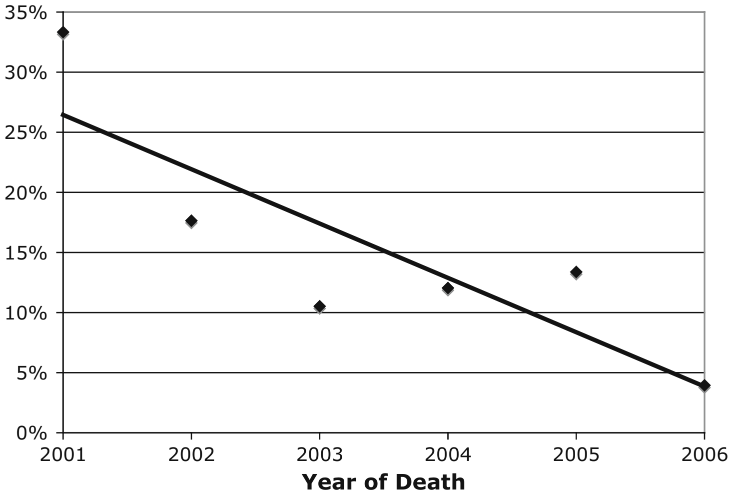

Fig. 24.6 The rate at which medical examiners mentioned a CEW as possibly contributing to a CRD declined significantly over the study period

mass and height, and race were analyzed. The only multivariate predictors found to be significant covariates were date-of-death ($p = 0.034$) and race of subject ($p = 0.028$). Black subject autopsies had slightly higher error rates averaging an additional 0.80 ± 0.30 (SEM) errors per report. Hispanic subject autopsies had slightly lower error rates averaging 0.98 ± 0.38 (SEM) less errors

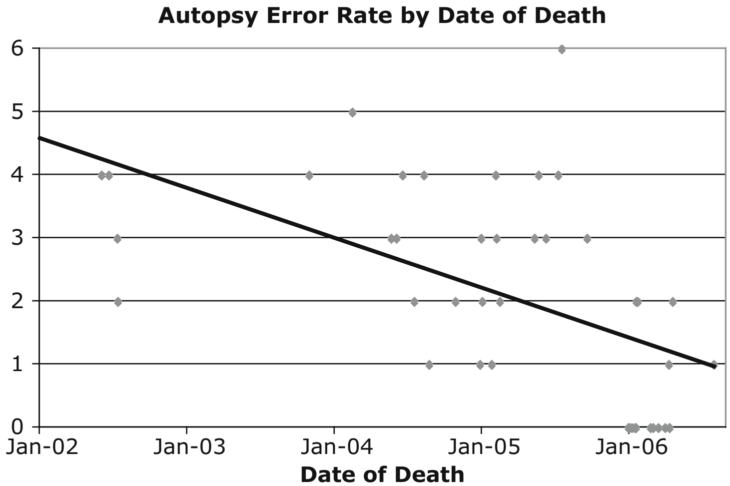

Fig. 24.7 The scored error rate fell significantly from 3.5 per autopsy in 2002–2004 to a rate of 1–2 in 2006

per report. This effect of race was also significant as a univariate predictor of error rate by ANOVA ($p = 0.047$).

The rate at which medical examiners mentioned CEWs as possibly contributing to a ARD went from 33% in 2001 to 10% in 2003. It appeared that the rapid acceptance of these devices by law enforcement agencies began to increase their temporal association with ARDs in the media. This appeared to affect a few medical examiners as the rate of mention began to level off somewhat (p = NS) to 13% in 2005. During 2005 and 2006, numerous peer-reviewed publications and conference presentations addressed the speculated safety concerns regarding these devices [1,2,45–47,57–81]. In addition, published books addressed the critical issue of excited delirium [82,83]. These factors may explain the fall in the mentions of CEW contribution to a ARD. The rate that the CEW was mentioned (as possibly contributory) fell to 3.3% by 2006.

24.5 Conclusions

About 1,400,000 human beings have received CEW exposures as of July 2008. Statistical analysis showed that many of the urban myths surrounding the use of CEW were false. The adoption of these devices has demonstrated a reduction in both suspect and officer injuries. There was no evidence that longer exposures were more dangerous. Presently, medical examiners rarely suggest a link between a CEW exposure and the death of a suspect.

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Calculations for Uses and Saves 2011-2012

						SAVES	SAVES
Year Ending	2008	2009	2010	2011	2012	2011	2012
Total Field uses	660,942	904,772	1,189,366	1,514,681	1,880,706	5.40%	5.40%
Total Training Uses	840,608	1,007,617	1,178,044	1,351,891	1,521,149		
Total (Field + Trn)	1,501,550	1,912,389	2,367,410	2,866,572	3,401,855		
Per month	16,964	20,319	23,716	27,110	30,502		
	13,285	13,917	14,202	14,487	14,105		
Per day	557	668	779	891	1,002		
	436	457	467	476	463		
Field uses							
Jan	474,343	681,261	928,488	1,216,476	1,545,184	65,690	83,440
Feb	491,307	701,581	952,205	1,243,585	1,575,686	67,154	85,087
Mar	508,270	721,900	975,921	1,270,695	1,606,188	68,618	86,734
Apr	525,234	742,219	999,637	1,297,805	1,636,690	70,081	88,381
May	542,197	762,538	1,023,353	1,324,914	1,667,192	71,545	90,028
Jun	559,161	782,857	1,047,069	1,352,024	1,697,694	73,009	91,675
Jul	576,124	803,176	1,070,785	1,379,133	1,728,196	74,473	93,323
Aug	593,088	823,496	1,094,502	1,406,243	1,758,698	75,937	94,970
Sep	610,052	843,815	1,118,218	1,433,353	1,789,200	77,401	96,617
Oct	627,015	864,134	1,141,934	1,460,462	1,819,702	78,865	98,264
Nov	643,979	884,453	1,165,650	1,487,572	1,850,204	80,329	99,911
Dec	660,942	904,772	1,189,366	1,514,681	1,880,706	81,793	101,558

Note: the number is for Dec 31 of the listed year

76,913	Saves as of Aug 20, 2011	49	New Saves/Day	29.5	Minutes Between Saves
1,424,316	Field Uses as of Aug 20, 2011	904	Field Uses/Day	2	Minutes Between Uses