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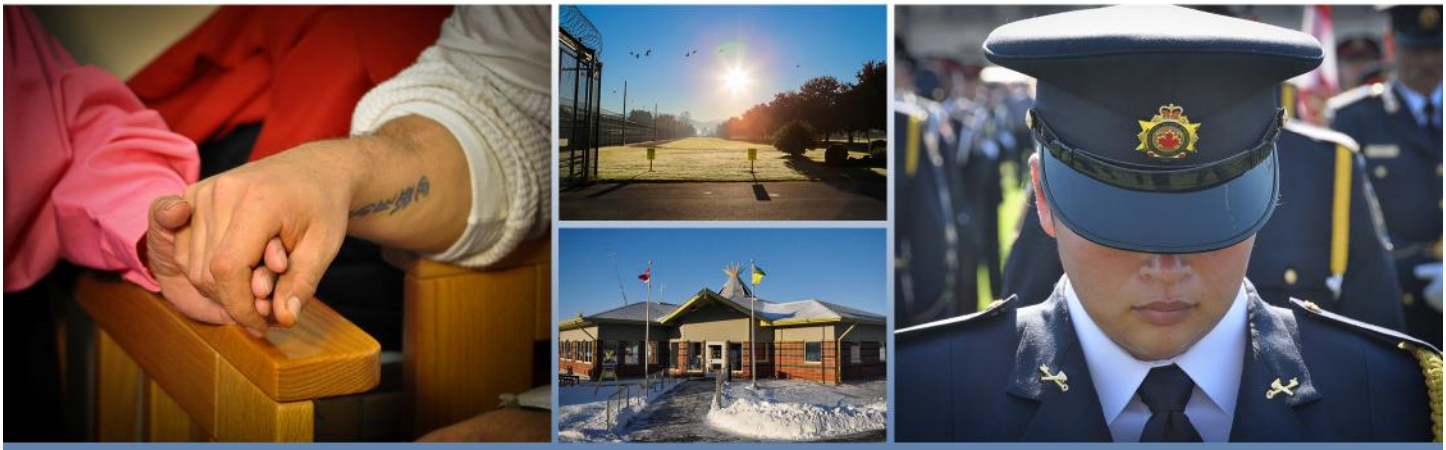

RESEARCH REPORT

Injuries and Deaths Proximate to Oleoresin Capsicum Spray Deployment: A Literature Review

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Injuries and Deaths Proximate to Oleoresin Capsicum Spray Deployment: A Literature Review

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Executive Summary

Key words: *OC spray, oleoresin capsicum, effectiveness of OC spray, injuries*

The primary goal of this literature review was to assess research (both published and unpublished) related to injuries and deaths proximate to Oleoresin Capsicum (OC) spray deployment. A search of several databases and search engines produced 22 documents that were deemed relevant for the review.

Existing research makes it clear that OC spray is now commonly used across a variety of settings, including law enforcement and corrections. Research has also demonstrated that the impact of OC spray will vary as a function of numerous factors, including: its concentration, its physiochemical properties, the deployment device used, and a range of subject (e.g., clothing) and environmental (e.g., weather) factors.

A number of studies have examined the operational effectiveness of OC spray (i.e., to control resistant subjects). Some of these studies have included injuries (to the subject and to the person deploying the spray) as outcome variables. This research demonstrates that OC spray is often effective and it is typically associated with decreased odds of both subject and "deployer" injury. This finding is relatively consistent across jurisdictions and conditions. Although there are exceptions, when OC-associated injuries do occur, they consistently appear to be relatively minor.

Other research focuses more specifically on the nature of injuries that are associated with the use of OC spray. Most of the specific injuries reported in the literature are relatively minor and individuals targeted by OC spray rarely seem to require serious medical attention. It appears to be very uncommon for OC-associated injuries to have a long-term, negative impact on the affected individual. The vast majority of reported injuries involve eye and skin irritation or pain, altered vision, corneal abrasions, and respiratory symptoms.

A number of documents also examined deaths that appear to be associated with the deployment of OC spray. Based on the evidence cited, OC spray is rarely associated with serious harm or death. However, when OC spray is used proximate to a subject's death, common themes are present. In the majority of reported deaths associated with OC spray exposure, the subject appears to be: male, combative, intoxicated (by drugs and/or alcohol), placed in a prone maximal restraint position, and have pre-existing health conditions (most commonly asthma, obesity, and/or cardiovascular disease). Very rarely in the studies we cited was OC spray deemed a contributory or sole cause of death; instead, medical practitioners point to various combinations of these pre-existing factors.

The literature review identified several factors that appear to be commonly associated with the deployment of OC spray. These include: the presence of Excited Delirium Syndrome (ExDS), positional asphyxia (especially related to hobble or hog-tie restraint positions), pre-existing health conditions such as asthma and obesity, and drug use (most commonly, psychostimulants such as cocaine).

The vast majority of research we reviewed is plagued by limitations that make it difficult to establish a causal link between OC spray and injuries and/or death. These limitations include: a lack of details related to what was done in a study and why it was done, small sample sizes, a lack of information regarding potential confounds, the reliance on ambiguous and/or potentially invalid outcome measures, experimental designs that are not suited for establishing causal links, a lack of relevant control groups, and infrequent and/or short-term follow-up periods. Given these concerns, one must be cautious when speaking to the nature of the relationship between OC spray and injuries or deaths.

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Introduction

This literature review was undertaken at the request of Correctional Service Canada (CSC). The primary goal of the review was to assess research related to injuries and deaths proximate to Oleoresin Capsicum (OC) spray deployment. The review includes the following sections:

1. A description of OC spray, the physiological mechanisms by which OC spray is meant to achieve its intended effects, and factors that can influence the effectiveness of OC spray.
2. A review of research related to the operational effectiveness of OC spray, when that research has also examined injuries or deaths.
3. A review of research related to specific injuries and deaths, which are potentially associated with OC spray deployment.
4. A review of research pertaining to factors associated with OC spray and injuries or death.
5. Concerns with existing OC spray research, which need to be taken into account when considering the potential implications of research reviewed in (2) to (4).

Methodology

In order to identify material for this literature review, the following databases and search engines were utilized: PsycINFO, PubMed, Google Scholar, and Carleton University's electronic library catalogue, which houses a large number of academic journals. Keywords used to facilitate the searches included: "oleoresin capsicum spray", "oc spray", "pepper spray", "oleoresin capsicum vapor", "oc vapor", "pepper vapor", "chemical agents", "death", "injury", "health", "effectiveness", and all combinations of these terms.[1] We also contacted specific individuals who conduct research in relevant fields to determine if they had access to material that was not found through formal searches. Finally, the reference sections of all identified material were also examined to determine if extra material needed to be collected.

Any published or unpublished material pertaining to potential injuries or deaths in encounters where OC spray (or any variant of it) was deployed were retrieved and scanned to ensure relevance to the topic of the literature review. To be considered relevant for inclusion in this literature review, the material had to describe potential injuries or deaths associated with the deployment of OC spray. We defined this broadly to include studies related to the effectiveness of OC spray in operational settings; so long as injuries or deaths were included as a variable of interest in those studies (these reports typically did not specify the nature of any injuries). Reports related solely to the effectiveness of OC spray (e.g., in resolving use of force [UoF] encounters) were not included in the review, nor did we include in our review any animal studies,[2] even if the focus was on injuries/death, or studies where variants of OC spray were used for reasons other than to subdue or otherwise control a subject (e.g., when pepper spray was used as a form of treatment).

Of course, any material that was encountered, which was deemed classified, was not included in

[1] We attempted to include literature in our review that spoke to injuries or deaths associated with the use of OC vapor. OC vapor is similar to OC spray, but because the particles are finer than those found in OC spray, OC vapor is likely to have a more immediate and intense effect. While we could identify several sources that described OC vapor, and its use in operational settings (e.g., from manufacturer websites, like safariland.com), we could not locate any research related to injuries or deaths proximate to the deployment of OC vapor.

[2] We made one exception to this. One article cited below, in the section on drug use, included animal experimentation in addition to a review of 26 human deaths that occurred after exposure to OC spray. We only discuss the component of that study related to human deaths.

the report.

Using these inclusion and exclusion criteria, our search resulted in 9 reports that could be included in the section dealing with operational effectiveness (and injuries and/or death), 7 reports that could be included in the section dealing with specific injuries, and 6 reports that could be included in the section dealing with deaths.

What is OC Spray and How Does It Work?

OC spray is often used as a pain compliance technique to control subjects when they are being actively resistant or assaultive. In addition to being used for private purposes (e.g., for self-defense), OC spray is also frequently used in military, law enforcement, and correctional settings. OC spray contains the active ingredient, oleoresin capsicum (Yeung & Tang, 2015), which can be produced synthetically, but is also a naturally occurring substance found in peppers (National Institute of Justice; NIJ, 1994). Oleoresin capsicum relates to a group of compounds known as capsaicinoids. There are five different types of capsaicinoids that have the same base structure, but slight variations that alter their individual effects. The two most powerful capsaicinoids are capsaicin and dihydrocapsaicin, which typically account for 80% to 90% of the total pepper spray concentration (Smith & Greaves, 2002). Typically, OC sprays range from 1% to 15% in concentration, with public safety agencies typically relying on sprays with higher concentrations than sprays sold commercially (Vilke & Chan, 2007).

OC spray typically acts on sensory nerves in the periphery of the body, the respiratory tract, and the skin (Smith & Stopford, 1999; Toprak et al., 2015). OC spray has both direct irritant and neurogenic inflammatory effects (Smith & Stopford, 1999). Neurogenic inflammation specifically results from the sprays action on peripheral neurons, which triggers the release of a neurotransmitter that ultimately causes dilation of blood vessels (vasodilation) and the severe sensation of pain (Smith & Greaves, 2002). The elicited effects of OC spray are thought to be instantaneous and short-term. Specifically, it can cause irritation to the eyes (resulting in redness, burning, tearing, and involuntary blinking), skin, and mucous membranes (Vilke & Chan, 2007). Exposure to the respiratory tract can also cause tingling, coughing, gagging, shortness of breath, and transient laryngeal paralysis (Steffee et al., 1995). Laryngeal paralysis occurs when the larynx (“voice box”) does not open or close properly.

Various factors contribute to the effectiveness of OC spray (Yeung & Tang, 2015). For

example, concentrations of OC spray can vary greatly (e.g., between 5%-15% for law enforcement) and this can influence the clinical consequences of being sprayed (Haas, Whipple, Grant, Andresen, Volpe, & Pelkey, 1997). The exact concentration of OC spray will, to a certain extent, be unpredictable because OC is a product extracted from peppers, and peppers will naturally have different concentrations of capsaicinoids (Smith & Greaves, 2002). As it is the responsibility of these capsaicinoids to elicit the chemical's effects, different peppers may result in slightly different irritant profiles. The physiochemical properties of the solvent used in OC spray can also have an impact on its effectiveness. Most OC sprays not only contain capsaicinoids, but also carbon dioxide, nitrogen, or isobutane, which act as propellants to disperse the chemical from the delivery device (Jett, 1997). Some of the propellants themselves have been noted to potentially produce adverse cardiac, respiratory, and/or neurologic effects (Smith & Stopford, 1999).

Other factors that impact the effectiveness of OC spray include the specific device that is used to deploy the spray [3] and a wide range of environmental and subject factors. The device used to deliver the spray ultimately influences the size of the dispersed particles, which in turn affects their ability to penetrate the membranes and airways of the target (Yeung & Tang, 2015). The delivery device will also determine whether the user is able to target specific areas of a subject's body with enough of the spray to have the intended effect. Environmental and subject factors that influence the effectiveness of OC spray, alone or in combination with the other factors outlined above, include variables such as temperature, wind, distance, and potential barriers like clothing and/or eye protection (Karch, 2011).

The Operational Effectiveness of OC Spray and Associated Injuries

A number of studies have examined the operational effectiveness of less-lethal UoF options, including OC spray. As indicated above, these studies were only included in this review if the research also examined how the use of OC sprays potentially related to injuries and/or deaths. None of the studies provided detailed descriptions of the types of injuries received by the suspects in this research or the person deploying the spray (police officers in these studies), but generally these studies suggest that OC spray typically decreases the likelihood of suspects and officers being injured, and that it results in relatively minor injuries when injuries do occur (with

[3] Noted delivery devices are liquid sprays, powder, or aerosolization (Yeung & Tang, 2015).

very few, but notable exceptions).

Edwards, Granfield, & Omnen (1997)

Edwards and his colleagues (1997) examined the effectiveness of OC spray deployed during incidents encountered by officers in the Baltimore County Police Department. During the study period, officers used OC spray in 194 incidents (20 of which involved animals). In the vast majority of these cases (90%), OC spray was deemed effective by the officers. When examining data related to assaults on police officers before and after the introduction of OC spray in this agency, the total number of officer assaults was substantially lower in the post-OC spray period. Only 11% of the officers who deployed OC spray during an encounter reported being injured, and most of these injuries were minor. Only 8% of suspects who were sprayed received injuries, and all of these were minor (requiring no hospitalization). Comparing these percentages to the percentages of injuries occurring in the pre-OC spray period, the authors concluded that OC spray had a positive effect on reducing officer and suspect injuries.

Lumb & Friday (1997)

Lumb and Friday (1997) conducted a study using data collected from a police agency in Concord, North Carolina. The data covered the time period from July 1992 to December 1993. The researchers examined a range of issues related to UoF encounters where OC spray was deployed. Their data included a 6-month period before OC spray was implemented as an option for police officers in Concord, a 6-month period during its use, and a 6-month period after usage was suspended. While officer injuries were found to increase during the period where OC spray was authorized, no injuries occurred to either suspects or officers (with one exception) when OC spray was deployed; every instance of injury occurred when physical force was used by an officer.

Morabito & Doerner (1997)

Morabito and Doerner (1997) examined a variety of factors related to the use of OC spray in the Tallahassee Police Department (Florida). The study specifically examined a time period in which OC spray was being transitioned from being treated as the equivalent to an impact weapon (Level 4 use of force) to a UoF option that was deemed equivalent to hands-on tactics, such as

punches and kicks (Level 3 use of force). Analyses were conducted at both levels of force. It was found that OC spray resulted in minimal, relatively minor injuries to officers and suspects. The severity of injuries associated with OC spray was lower than that found for other impacts weapons that could be used at Level 4 and other physical contact techniques that could be used at Level 3.

Bowling & Gaines (2000)

Bowling and Gaines reviewed officer and subject injuries before and after OC spray implementation in the Charlotte-Mecklenburg Police Department (CMPD), Winston Salem Police Department (WSPD), and North Carolina State Highway Patrol (SHP). They extracted data from varying time periods between 1975 and 1999 depending on the information available from each police department. Data was extracted from Worker's Compensation and Medical Only Claim files for SHP, the UoF database for CMPD, and an Injury database for WSPD. Data collected included subject and officer injury, use of excessive force complaints, and arrest or UoF data. Notably, SHP did not record subject injury. Analyses revealed that CMPD and WSPD demonstrated 20% and 30% reductions in subject injury, respectively, following the implementation of OC spray. Following a similar trend, two of the three agencies similarly demonstrated a reduction in officer injury following OC implementation: CMPD demonstrated a 45% reduction in officer injury and WSPD demonstrated a decline in officer injury by 1% each month. SHP found no significant effect of OC. These findings suggest that the implementation of OC spray in two of the three agencies was associated with a reduction in both officer and subject injuries.

Smith, Kaminski, Rojek, Alpert, & Mathis (2007)

Smith and his colleagues (2007) collected data from two police agencies to examine the use of conducted energy devices (CEDs) on officer and subject injuries. In one of these agencies (Richland County Sheriff's Department), their data also allowed them to examine the effect of OC spray on officer and subject injuries. This analysis examined 467 UoF reports related to incidents that occurred between January 2005 and July 2006. A relatively small number of suspects and officers were injured in these cases (78 suspects and 46 officers) and the majority of injuries were minor (consisting of bruises, abrasions, and lacerations). Using logistic regression analysis to identify predictors of officer and suspect injuries, the researchers determined that the

use of OC spray was not related to officer injuries, when holding a number of other variables related to force and resistance constant. In their analysis of suspect injury, on the other hand, the use of OC spray was related to a reduction in the odds of suspect injury. After controlling for all other levels of force and resistance, the use of OC spray reduced the odds of an injury occurring to a suspect by almost 70% (odds ratio [OR]=0.31, p=.046).

MacDonald, Kaminski, & Smith (2009)

Macdonald and his colleagues (2009) set out to examine the effect of less-lethal weapons, including CEDs and OC spray, on injuries to police officers and civilians involved in UoF encounters. The researchers analysed 24 380 UoF incidents that occurred between 1998 and 2007 across 12 police departments in the US. Approximately 39% of the UoF incidents resulted in an injury to the suspect, whereas approximately 14% of officers were injured. The suspect injury rate was lower than the sample average when the police officers involved in the encounter deployed OC spray. More specifically, OC spray was deployed in 23% of cases, resulting in 22% of suspects being injured (and 14% of officers). If a police department in their sample had a defensive OC spray policy (restricting officers to defensive use only), the suspect and officer injuries rates were approximately 38% and 14%, respectively. When controlling for a range of case attributes, the odds of suspect injury was reduced by 69% when OC spray was deployed (OR=0.31; 95% confidence interval [CI]=0.28, 0.33), whereas officer injuries increased when OC spray was used (OR=1.42; 95% CI=1.29, 1.58). For comparative purposes, suspect injuries were reduced by 65% with the use of CEDs (OR=0.35; 95% CI=0.32, 0.38) and no relationship was found between CED use and officer injury.

Additional Studies

A number of other studies were selected for inclusion in this section, but could not be retrieved in hard copy or electronic form in time for them to be included in this literature review (only abstracts could be retrieved). Accounts of these studies taken from other sources indicate that they report: (1) reduced injuries to suspects and officers when OC spray became available to officers in Portland, Oregon (Gauvin, 1995), (2) very low rates of officer and suspect injuries during OC spray deployments in Connecticut (e.g., none were reported in the 360 uses of OC spray examined by Nowicki, 1993), and (3) lower rates of injury from OC spray than from other "more conventional" types of force, such as punches, kicks, and baton use (as found by Meyer,

1992 in his analysis of incidents in Los Angeles).

Summary

In general, the deployment of OC spray appears to be quite effective according to the studies cited above. In addition, studies demonstrate that, when OC spray is deployed, it is typically associated with decreased odds of both subject and officer injuries. This finding is relatively consistent across jurisdictions and conditions. Instances do exist where the deployment of OC spray appears to be unrelated to injuries, but we could only identify one study where OC spray appeared to be associated with an increase in injuries (in this case, the increase was to officer injuries). Overall, when OC-associated injuries do occur, they consistently appear to be relatively minor.

Specific Injuries Proximate to OC Spray Deployment

Unlike the research cited above, which focused primarily on the operational effectiveness of OC spray and treated associated injuries as secondary, other research has examined specific injuries that may occur proximate to the deployment of OC spray. Consistent with the previously cited research, the available research on this topic suggests that OC spray is rarely associated with serious, long-lasting injuries.

Watson, Stremel, & Westdorp (1996)

Watson and colleagues (1996) examined 81 emergency department patients that had been exposed to OC spray by officers of the Kansas City Police Department between June 1991 and June 1994 (representing approximately 10% of all individuals who had been sprayed by the police during this time period). None of the patients required hospitalization due to OC spray toxicity, but several injuries were reported, some being relatively serious. The most common symptoms were eye irritation, including burning (56%) and redness (40%). Symptoms related to dermal burning and redness were also common (40%). More serious injuries included altered vision (9%), corneal abrasions (9%), and various respiratory symptoms (7%). Two of the 12 patients with asthma presented with respiratory symptoms (wheezing), in comparison to four of the remaining 69 patients. While this indicates that patients suffering from asthma reported with higher rates of respiratory symptoms (17%) than those without asthma (6%), it is worth noting the sample size of asthmatics was quite small. In addition, the wheezing presented in the

asthmatics resolved without treatment and the authors concluded that pre-existing asthma does not elevate one's risk of adverse pulmonary effects if they are OC sprayed.

Stopford (1996)

Stopford (1996) examined 6 000 correctional officers who were exposed to OC spray during their training between 1993 and 1995. Of the 6 000 officers whose data were analyzed, 61 of them (1%) required medical treatment. For these 61 officers, the most common symptoms were eye irritation (46%), chest symptoms (33%), headaches (26%), hypertension (18%), nose, eye, and/or throat symptoms (11%), and skin effects (8%). Of the 61 officers who sought medical attention, 8 of them (13%) had symptoms that lasted longer than one week (including eye problems, chest problems, and headaches).

Criminal Justice Commission and Queensland Police Service (1999)

This research relates to a trial that was set up to test the effects of OC spray. The study involved the Queensland Police Service in Queensland, Australia. There were 35 incidents involving the application of OC spray in the study (7 of these incidents involved the use of OC sprays on attacking dogs). Of the 28 incidents that involved people there were 37 deployments of OC by a police officer (and 3 recorded uses involving no deployment). The OC spray was rated as very disabling (effective) for the majority of cases. There were few reported injuries by the individuals who were sprayed. Most of the subjects received no injuries at all during the incident. Of those that did report injuries, the majority occurred prior to contact with the police (e.g., received during fights or self-harm leading up to police involvement). None of the officers that deployed OC spray indicated that subjects suffered from severe respiratory difficulties because they were sprayed, but two officers reported that subjects experienced temporary breathing difficulties. No officers reported that they themselves suffered serious injuries related to to OC spray deployment.

Zollman, Bragg, & Harrison (2000)

Similar to Stopford's (1996) study, this study involved police cadets who volunteered to be exposed to OC spray during training. In total, 47 police cadets participated in the study. All of these subjects were examined before being OC sprayed, 10-minutes after exposure, and 1-hour after exposure (11 of the subjects were also examined 1-week after exposure). The visual acuity

of the participants was not found to vary before and after (1-hour) exposure. Corneal sensitivity, however, was greatly reduced from pre-test to post-test. Punctate epithelial erosions were found in 21% of the sample at 1-hour post exposure, but no corneal abrasions were found. All of the subjects reported significant pain, blurring of vision, and tearing at 10-minutes after exposure, but these symptoms improved at 1-hour post-exposure. At 1-week post exposure, no corneal abnormalities were observed.

Brown, Takeuchi, & Challoner (2000)

In a similar study to that reported by Watson et al. (1996), Brown and his colleagues (2000) reported on 100 in-custody adults who were exposed to OC spray (with a 10% concentration) by the police over a 3-year period between 1994 and 1996. By relying on the individuals' medical records, reported injuries were categorized. The most common symptom amongst the subjects was red or blood shot eyes (38%). A further 7% experienced corneal abrasions. The researchers note that 52% of the individuals examined had concomitant drug or alcohol use and 44% experienced acute traumatic injuries unrelated to the OC spray.

Oh, Yong, Ponampalam, Anantharman, & Lim (2010)

This paper by Oh and colleagues (2010) reported on civilian secondary exposure to OC at an urban shopping centre. Thirteen people presented with a range of symptoms to the emergency department (11 immediately following exposure and two additional patients 5-hours later, after their symptoms had resolved). The most common symptoms among the patients were: eye irritation (69.2%), throat discomfort (61.5%), nausea (30.8%), cough (30.8%), chest discomfort (23.1%), shortness of breath (15.4%), skin irritation (15.4%), vomiting (15.4%), sneezing/runny nose (15.4%), and giddiness (7.7%). All of these symptoms resolved and it was concluded that the effects of OC were both brief and self-limiting, with no long-term or permanent effects, or tissue damage.

Kearney, Hiatt, Birdsall, & Smollin (2014)

In a large scale study, Kearney and his colleagues (2014) examined all human exposure cases to pepper spray that were reported to a poison control centre between 2002 and 2011. After applying their inclusion criteria, their sample consisted of 3 671 cases. Out of these cases, 294 subjects (6.8%) experienced injuries that required a medical evaluation; none of the cases

resulted in death. The more serious injuries could be categorized as those effecting the eyes (53.8%), the respiratory system (31.7%), and the skin (17.7%). Factors related to more severe outcomes related to the use of OC spray in the context of law enforcement training (OR=7.39, 95%CI=2.98, 18.28), the use of OC spray for intentional incapacitation (OR=3.02, 95%CI=1.80, 5.06), and in the context of law enforcement for suspect or crowd control (OR=2.45, 95%CI=1.42, 4.23).

Summary

Most of the specific injuries reported in the studies cited above were relatively minor and those targeted by OC spray rarely seem to require serious medical attention. It appears to be very uncommon for OC-associated injuries to have a long-term, negative impact on the affected individual. The vast majority of reported injuries involve eye and skin irritation or pain, altered vision, corneal abrasions, and respiratory symptoms. An additional symptom identified in one study was punctate epithelial erosions (damaged tissue of the cornea).

Deaths Proximate to OC Spray Deployment

The section summarizes the current literature related to deaths that may be potentially related to OC spray use (with the exception of deaths directly identified as involving Excited Delirium Syndrome [ExDS], which will be described separately in the associated factors section below).

Grandfield, Omnen, & Petty (1994)

An attempt was made by Grandfield and his colleagues (1994) to identify in-custody deaths that followed the use of OC spray between August 1990 and December 1993 in the United States. The authors identified cases through news media services, a review of material from California Peace Officer Standards and Training (POST), and the American Civil Liberties Union of Southern California, and word of mouth with International Association of Chiefs of Police (IACP) members. Thirty incidents were identified from across 13 states. All individuals were male and a majority of the incidents involved: combative and bizarre behavior, a struggle with police, alcohol and/or drug intoxication, and restraint techniques. In the vast majority of cases, OC spray was generally considered ineffective (60% of cases) or partially effective (23%). A definitive cause of death was determined by reviewing incident reports from law enforcement

agencies and coroner or medical examiner records. Of the 30 cases, only 22 had complete data, which allowed for the cause of death to be determined. For these 22 cases, 18 (81%) were concluded as positional asphyxia with drugs and/or disease also acting as contributing factors. Three of the remaining four cases (14%) were determined to be caused by cocaine, and the final case (5%) was deemed to be caused by cocaine and disease. OC spray was not discussed as a factor leading to death in any of the cases.

American Civil Liberties Unions of Southern California (1995)

Twenty-six incidents, occurring between January 1993 and May 1995, were identified by the American Civil Liberties Unions of Southern California (1999) where individuals in custody died after being exposed to OC spray by the police. The cases all involved men exhibiting combative or irrational behaviour. Nearly all of the cases involved a struggle (96%) and most involved drug and/or alcohol intoxication (85%). Multiple sources were used to confirm the cause of death. Of the 24 cases where complete data was available, OC spray was not cited as the official cause of death in any of the cases, although pepper spray was viewed as a potential contributing factor when used on certain individuals (e.g., those suffering from asthma, especially when certain restraint techniques were used). Primary causes of death included suicide and drugs, with a number of contributing factors being highlighted, including restraint practices and positional asphyxia (see below).

Steffee, Lantz, Flannagan, Thompson, & Jason (1995)

Steffee and colleagues (1995) examined two in-custody death case studies that involved OC spray with full autopsies. They attempted to determine whether OC caused the deaths or was a contributory factor. The first case involved a 53-year old male with cardiovascular disease and a history of syncopal episodes (fainting). The male was exhibiting bizarre, disruptive, and threatening behaviour. The male was sprayed twice, officers handcuffed him, and rinsed his eyes with saline. At no point did the individual complain of breathing problems or appear to be in respiratory distress. The male once again became aggressive and then he collapsed. He was resuscitated and transported to hospital, but unfortunately entered a vegetative state. Ultimately, the cause of death was deemed “complications of a sudden life-threatening event due to atherosclerotic cardiovascular disease” (p. 186).

The second case examined by Steffee and colleagues (1995) involved a 24-year old male

who was 73 inches tall and weighed 308 pounds with a vague clinical history of asthma. The male was resisting arrest for disorderly conduct. The interaction resulted in the male being sprayed 10 to 15 times (not all sprays hit the man's face). A struggle occurred, with the male on the ground in a prone position. Two sets of handcuffs were used to restrain the male due to his "large frame". This male did complain of difficulty breathing. Another altercation resulted in him being placed in a prone position for a second time. He was placed in the back of a police vehicle on his side and left alone for several minutes. When the officers returned, the male was unresponsive. Autopsy did not reveal any traumatic injuries and no histological changes indicated that asthma was a cause of death. Toxicological analysis revealed that the individual was under the influence of alcohol. The cause of death was noted as "asphyxia due to bronchospasm precipitated by pepper spray" (p. 187). The forensic pathologists felt OC may have played a role due to the lack of symptoms prior to exposure, the difficulty breathing after exposure, and the fact that this difficulty was not restricted to restrained positions as the male was sitting upright while complaining. Additional to OC exposure, the following additional factors were noted as playing a role in his death: "repeated exposure to capsaicin, physical exertion and excitement during the course of a struggle with law enforcement officers, underlying pulmonary disease in the form of follicular bronchitis and bronchiolitis, acute alcohol intoxication, aspiration of stomach contents, and physical restraint during transport" (Steffee et al., 1995, p. 187).

Petty (2004)

A review of 73 cases was undertaken by Petty (2004) where OC spray was applied during confrontations of subjects with law enforcement. Ten of the cases were excluded due to limited details or further investigation identifying that OC spray was not actually involved. The 63 remaining cases were split into categories based on their characteristics. The first category contained those with a clear cause of death with three sub-categories identified as drugs alone (n = 12), drugs and disease in combination (n = 4), and positional asphyxia (n = 7). The second category related to cases that were considered "jumbled" and contained subsets with the cause of death identified as confrontational situations and drugs (n = 23), confrontational situations and disease (n = 5), and confrontational situation, drugs, and disease (n = 4).4 The third category was considered "odd balls," which consisted of six cases that did not fit into any of the other

categories. Finally, category four consisted of cases where the cause of death was due to asthma (n = 2). Only five cases in the sample reported difficulty breathing. The author notes that unless there is difficulty breathing, or death ensues directly after OC application, then OC cannot be considered to have directly caused death. Ultimately, this report concluded that there was no evidence that OC spray use in confrontations with law enforcement was responsible in part or totality for the death of subjects. However, this may not be the case when the individual has pre-existing asthma.

Niemcunowicz-Janica, Ptaszynska-Sarosiek, & Wardaszka (2009)

Niemcunowicz-Janica et al. (2009) report on a case study of a male sitting in his car that refused to leave when asked by officers. The male was sprayed with OC through his window. Shortly after being exposed to OC, the male got out of his car very aroused. Police were able to handcuff the male and they placed him on the ground where he collapsed. Toxicological analyses did not reveal the presence of drugs or alcohol. The autopsy revealed severe emphysema, and it was concluded that exposure to OC could have resulted in the swelling of the male's larynx, ultimately leading to his death by suffocation.

Toprak, Esroy, Hart, & Clevestig (2015)

Toprak and his colleagues (2015) completed a review of deaths associated with the use of [4] riot control agents (RCAs) to assess how an individual's existing pathology can influence their autopsy conclusions. Through a search of PubMed/MEDLINE and Web of Science, they identified 10 lethal cases where RCAs were identified as the main or a contributing factor of death. Of these 10 cases, seven included OC alone and one included OC used in combination with CS (tear gas). The review concluded that RCA-related death typically involves several factors, including pre-existing medical conditions (e.g., asthma, cardiovascular disease), drug use (e.g., stimulants like cocaine and methamphetamine), excited delirium (also referred to as ExDS; see below), and the prone maximal restraint position. Furthermore, despite two individuals presenting with a history of asthma, only one of those two demonstrated histological findings consistent with asthma. It is important to note the limitations of the review were that full

[4] The term "confrontational situation" is applied in place of positional asphyxia because these cases in category 2 are not as well defined.

autopsies were only available in five of the 10 cases and that the methodologies used to complete the autopsies were not consistent. The authors concluded that deaths involving RCAs are quite rare.

Summary

Based on the evidence cited above, OC spray deployment is rarely associated with serious harm or death; however, when the chemical agent is used proximate to a subject's death, common themes appear to be present. In the vast majority of reported deaths associated with OC spray exposure, the subject is male and combative. Furthermore, in the majority of cases, the deceased is intoxicated (by drugs and/or alcohol), placed in a prone maximal restraint position, and has pre-existing health conditions (most commonly, asthma, obesity, and/or cardiovascular disease). Very rarely, in the studies cited above, was OC spray deemed a contributory or sole cause of death; instead, medical practitioners point to various combinations of these pre-existing factors. The potential role that these factors play in OC-associated injuries and deaths will be discussed below.

Additional Associated Factors

A review of the current literature reveals a set of factors that appear to be commonly associated with the deployment of OC spray. Included among these associated factors are: ExDS, positional asphyxia, pre-existing health conditions, and drug use.

ExDS

ExDS has been described as "a state of extreme mental and physiological excitement, characterized by extreme agitation, hyperthermia, hostility, exceptional strength and endurance without apparent fatigue" (Morrison & Sadler, 2001, p. 46). A majority of individuals characterized by ExDS are violent (66%; Hall et al., 2013) and they frequently end up interacting with police because of their aggressive behaviour. Often, such encounters are characterized by a non-compliant subject, who is often intoxicated, under the influence of drugs, or suffering from a mental health issue. The police frequently have to rely on a range of UoF intervention options in these cases (Baldwin, 2014), which would be expected to increase the chance of injury on the part of the subject and officer. There have been cases where these subjects have died suddenly and unexpectedly; in these instances, autopsy does not reveal a definitive cause of death (Vilke et

al., 2012).

A number of studies have demonstrated that the deployment of OC spray occurs in cases involving ExDS, and in some of these cases, the subject ends up dying. For example, Ross (1998) examined 61 case reports of in-custody deaths in the US where ExDS was identified as a primary factor. Most of the deaths occurred within 1-hour following the encounter. The presence of drugs was common in these cases. The causes of death were most often drug-related, due to positional asphyxiation during restraint, or the result of cardiorespiratory arrest. Nine of the 61 cases involved the use of OC spray, but none of the autopsies identified OC spray as a contributing factor to death. A similar pattern of results was reported by Pollanen, Chiasson, Cairns, and Young (1998), O'Halloran and Frank (2000), and Stratton, Rogers, Brickett, and Gruzinski (2001); in each case, OC spray was used prior to a number of deaths involving subjects suffering from ExDS, but in none of the cases was OC spray identified as a contributory or sole factor in the deaths of these individuals.

Positional Asphyxia

Positional asphyxia refers to cases where a person, because of the bodily position they are placed in, is unable to use normal and accessory muscles to move air in and out of their lungs (Petty, 2004). Positional asphyxia is, on occasion, associated with OC spray. One position that has been heavily criticized as being a contributor to sudden death is the "hobble" or "hog tie" positions. Both positions involve tethering the wrists to the ankles behind the subject's back, but the latter position involves less distance between the tethered restraints (Neuman, 2006). In these positions, the diaphragm may be unable to expand to allow for proper oxygenation (Robison & Hunt, 2005), which can result in injuries or deaths under certain circumstances.[5]

Few studies have examined the association between OC spray and positional asphyxia.The only study we could identify was conducted by Chan, Vilke, Clausen, Clark, Schmidt, Snowden, and Neuman (2001). They ran a randomized, cross over, controlled laboratory study with 34 volunteers from a law enforcement training academy. The goal of the study was to assess the effects of OC spray inhalation on respiratory function. Subjects were exposed to either OC or a placebo spray in either the sitting or hobble position. The study

[5] To ensure the subject's safety, it is typically recommended that he or she is turned on their side to decrease breathing difficulty when restrained used the hobble or hog tie positions.

revealed no impact of OC spray in the sitting condition. In contrast, subjects in both the OC and placebo group experienced restricted pulmonary functioning in the restrained position, but neither were out of normal range. Of relevance to the next section on pre-existing health conditions, the study also demonstrated that a history of lung disease, asthma, smoking, or inhaler use did not affect functioning in either position.

Pre-existing Health Conditions

Several pre-existing health conditions also appear to be associated with the use of OC spray in cases involving injuries or deaths. Asthma is arguably the condition that has received the most attention given that it has the potential to act as a risk factor. While some studies have examined this factor in the context of real-world encounters, most research has been conducted in well-controlled medical studies. Generally, research suggests that, while some asthmatics do react negatively to capsaicin, many react in a way that is similar to healthy subjects. In addition, when differences are found between healthy and unhealthy subjects, the disparities often relate to relatively minor symptoms, such as coughing.

In one of the studies discussed above, Watson and his colleagues (1996) evaluated emergency department admissions due to OC spray. The findings of this study demonstrated that 17% of individuals with a history of asthma complained of wheezing in comparison to 6% of those patients without asthma who complained of other respiratory symptoms. Few differences were also found between asthmatics and non-asthmatics in a study conducted by Collier and Fuller (1984). They compared the effect of OC inhalation using healthy volunteers and mild asthmatics. No differences were found between the groups in terms of cough responses. In addition, none of the subjects reported shortness of breath and the capsaicin caused no changes to FEV1 values (a measure related to forced expiration of air from the lungs). Doherty, Mister, Pearson, and Calverley (2000) also compared cough responses across subjects with severe asthma, chronic obstructive pulmonary disease (COPD), or no illness. Asthmatics and COPD subjects were equally sensitive to capsaicin, and both exhibited an increased cough reflex compared to healthy subjects. Finally, Hathaway, Higenbottam, Morrison, Clelland, and Wallwork (1993) examined airway narrowing among asymptomatic asthmatics and normal controls in response to inhaled capsaicin. Under half of the 17 asthmatics exhibited airway narrowing, indicating that not all individuals with asthma are equally affected by OC. None of

the normal subjects responded in this way. All subjects coughed in response to capsaicin.

Another pre-existing health condition often discussed in the context of OC spray is obesity (Granfield et al., 1994; Stratton et al., 2001; Toprak et al., 2015). The physical exertion involved in a struggle with public safety professionals results in the release of norepinephrine and epinephrine through sympathetic nervous system activation as part of the fight or flight response. This elevation results in high levels of physiological arousal and stress, which may disproportionately affect individuals who are obese given the strain already placed on their hearts. If further stress is placed on an obese individual, serious injuries or death may occur. This additional stress may be caused by putting the individual in certain restraint positions or through the use of OC spray, both of which may restrict already reduced airflow.

Despite how frequently obesity is discussed in the literature, we could identify only one study that examined how OC spray interacted with body weight. In the same study described above, Chan and his colleagues (2001) included an analysis of body weight. Recall that subjects in this study were exposed to either OC or a placebo spray in either a sitting or hobble position. According to the researchers, they found "no evidence of additional restrictive pulmonary dysfunction in seven overweight subjects in the sitting or…restraint position with OC or placebo exposure" (p. 4). However, the researchers cautioned against putting too much weight on this finding given that the sample size was extremely small, and none of the subjects were morbidly obese.

Drugs

Drugs, especially psychostimulants like cocaine, have also been implicated in cases of death proximate to OC spray deployment. Drugs are thought to play a multifaceted role in rendering an individual more likely to experience sudden death. For example, many drugs increase the likelihood of abnormal rhythms ultimately disrupting heart function (Petty, 2004) by constricting blood vessels, elevating heart rate, raising blood pressure, and increasing body temperature (Granfield et al., 1994). The effects of these drugs in highly stressful encounters can have serious consequences, even in isolation, let alone when they are present in combination with pre-existing health conditions, like obesity, which may also result in additional stress on the heart (Granfield et al., 1994). Of course, we also have to be very concerned when drugs are combined, given that injuries and sudden deaths are probably more likely in these scenarios

(Wetli, 1993).

While a number of researchers have identified cases where death is associated with both drug use and the deployment of OC spray (e.g., Mash et al., 2009), very few studies speak directly to the role of drug use as a risk factor in cases involving spray deployment. In one of the few studies that does, Mendelson et al. (2010) examined whether cocaine use increases the lethality of capsaicin. Their study consisted of two parts: (1) experimentation with mice and (2) a review of 26 autopsy and police reports of cases where death occurred after exposure to OC spray (only the human component will be discussed here). The average age of the subjects that died was 36 years and all were male. Sixty-two percent of the sample had a pre-existing medical condition (including cirrhosis, schizophrenia, psoriasis, and coronary and artery stenosis). Seventy-nine percent of the sample died within 1-hour of when they were exposed to OC spray. Common causes of death included drug intoxication (42%), heart failure (22%), positional asphyxia (8%), and wounds (8%). Blood toxicology reports indicated that most subjects were under the influence of drugs at the time of their death, primarily methamphetamine or cocaine. Taken together, the animal experiment and the retrospective analysis of the human death cases, led the authors to conclude that their findings "support the idea that exposure to OC spray in cocaine-intoxicated individuals potentiates cocaine lethality" (p. 33).

Concerns with Existing OC Spray Research

Despite the fact that a reasonable amount of research has examined potential links between the use of OC spray and suspect (and officer) injuries and deaths, the vast majority of studies (if not all of them) are plagued by limitations that render them incapable of establishing a clear causal link between OC spray use and any adverse events. Thus, it would be premature to draw any conclusions about the potential role of OC spray in any reported injuries or deaths that occur during interactions with the police (or with any other public safety professional).
For the sake of space and brevity, we will not describe the limitations associated with each of the studies we have cited. Instead, we will highlight more general limitations that characterize research in this area. Many of these issues have been raised in previous reviews related to the safety implications of OC spray, and we draw heavily on the work of Broadstock (2002) in this section. Key limitations of research in this area include:

- Like many studies, reports of research in this area often lack sufficient detail, particularly in

relation to methodological issues. This prevents the reader from fully understanding what was done by the researchers, why it was done that way, and whether the approach to the research poses any potential problems (with respect to drawing conclusions or making generalizations from the data).

- The vast majority of research in this area is limited by small sample sizes and some of it is limited to case studies. This likely restricts the representativeness of the data collected. In part, sample sizes are limited by virtue of the fact that UoF occurs relatively rarely in North America, with the deployment of OC spray obviously occurring even less frequently. It is also often difficult to collect high quality data in this area, either because public safety agencies do not house appropriate data or because that data is deemed too sensitive to share with researchers.
- Very rarely is data provided in the studies regarding potential confounds, despite the many factors that are known to impact the effectiveness of OC spray (and presumably any symptoms, injuries, or deaths related to its deployment). It is uncommon, for example, to have access to information related to the deployment device, the distance at which the subject was sprayed, the concentration of the OC spray that was used, the frequency of sprays, environmental factors (e.g., weather conditions), subject characteristics (e.g., pre-existing diseases), etc. Without such information, it is impossible to determine what the link might be between OC spray and injuries or death.
- Outcome measures, including autopsy reports and other forms of testimony, are often used in these studies to establish what occurred in an encounter and what ultimately led to a subject's injuries or death. Most of the outcome measures that are used have not been validated and are known to be problematic (e.g., include vague statements regarding cause of death; Broadstock, 2002).
- Experimental designs that would allow one to determine whether causal linkages exist between OC spray and injuries or death are not used in existing studies, nor are relevant control groups typically relied on to carefully establish the effects of OC spray (e.g., similar subjects that have not been exposed to OC spray).
- Follow-ups are usually infrequent and rarely adequate for establishing the rate at which symptoms and/or injuries subside after exposure to OC (if they do in fact subside). Relatedly, it is unusual to be provided with baseline data, which would allow researchers to

more accurately establish the role that OC spray plays in any injuries or deaths that occur in encounters.

- There is also some evidence that the same cases (e.g., of in-custody deaths) are used across multiple reports, although this is often not made explicit. To the extent that this is occurring, it is possible that certain patterns of results may become exaggerated (i.e., leading one to believe that a widespread pattern exists, whereas the true pattern is less discernible).

Conclusions

The majority of research we reviewed suggests that OC spray is relatively safe and typically decreases the likelihood of injury, for both the subject and the person deploying the spray. That being said, there is always the potential for harm when using any sort of UoF intervention option, and evidence suggests that OC spray definitely occurs proximate to both injuries and deaths. In the vast majority of these cases, the deployment of OC spray has not been deemed a contributory or sole factor in causing the injuries or death. Other factors, such as other UoF intervention options or various subject characteristics (e.g., drug use) are more commonly at the root of those outcomes. When OC spray does cause injuries, the damage is usually minor and not long-lasting. Of course, this will vary as a function of many factors, including the OC concentration used and various environmental and subject variables (e.g., wind, distance, clothing, etc.). There is also some evidence that certain factors, including ExDS, positional asphyxia, pre-existing health conditions, and drug use, are associated with OC spray, and injuries or deaths, in some cases. While it is tempting to see some of these variables as risk factors that directly amplify the negative effects of OC spray, it is very difficult when relying on the data that currently exists to establish the exact nature of any relationships between OC and these factors. Further research is still required to resolve this issue.

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