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Injuries and deaths proximate to oleoresin capsicum spray deployment: A literature review

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Abstract
This literature review assessed research related to injuries and deaths proximate to oleoresin capsicum (OC) spray deployment. Our review of 22 relevant documents suggests that OC spray is often effective and is typically associated with decreased odds of both subject and "deployer" injury. When OC-associated injuries do occur, they consistently appear to be relatively minor. When OC spray is used proximate to a subject's death, common themes are present. Given the limitations of the research in this area, one must be cautious when speaking to the nature of the relationship between OC spray and injuries or deaths.

Keywords
Oleoresin capsicum spray, pepper spray, in-custody injuries, in-custody deaths

Introduction

Police officers are inevitably faced with people who pose a threat to themselves or to others. Officers must therefore have access to effective intervention strategies to manage these individuals and eliminate, or at least reduce, the harm they can cause. The use of less-lethal intervention options is one approach for temporarily incapacitating violent individuals while minimizing the risk of long-term consequences (Bertilsson et al., 2017). Currently, police officers working in North America are equipped with various less-lethal options, with oleoresin capsicum (OC) spray being a common tool found on most officers' duty belts (Canadian Police Research Centre, 2004; Gabor, 2009; Reaves,

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2010). While rates of OC spray deployments vary substantially from jurisdiction to jurisdiction (Hall and Votova, 2013; Wittmann, 2018), it appears to be a frequently used intervention option in some sites (e.g. MacDonald et al., 2009).

What is OC spray?

OC spray is generally considered a less-lethal weapon that is used by officers as a pain compliance technique to control subjects who are being actively resistant, assaultive, or threatening grievous bodily harm to themselves, a member of the public, or the officer (Kiedrowski et al., 2015). OC spray contains the active ingredient oleoresin capsicum (Yeung and Tang, 2015), which can be produced synthetically, but is also a naturally occurring substance found in peppers (National Institute of Justice (NIJ), 1994). OC relates to a group of compounds known as capsaicinoids. There are five different types of capsaicinoids that have the same base structure but vary slightly in ways that alter their individual effects. The two most powerful capsaicinoids are capsaicin and dihydrocapsaicin, which typically account for 80–90% of the total OC spray concentration (Smith and Greaves, 2002). Typically, OC sprays range from 1% to 15% in concentration, with law enforcement agencies typically relying on sprays with higher concentrations than those sold commercially (e.g. for self-defence; Vilke and Chan, 2007).

OC spray typically acts on sensory nerves in the periphery of the body, the respiratory tract, and the skin (Toprak et al., 2015). OC spray has both direct irritant and neurogenic inflammatory effects (Smith and Stopford, 1999). Neurogenic inflammation specifically results from the spray's action on peripheral neurons, which triggers the release of a neurotransmitter that causes dilation of blood vessels and a severe sensation of pain (Smith and Greaves, 2002). The effects of OC spray are thought to be instantaneous and short-term, primarily causing irritation to the eyes, skin, and mucous membranes (Vilke and Chan, 2007). Exposure to the respiratory tract can also cause tingling, coughing, gagging, shortness of breath, and temporary paralysis to the larynx (i.e. voice box; Steffee et al., 1995).

Factors influencing the effectiveness of OC spray

Various factors contribute to the effectiveness of OC spray (Yeung and Tang, 2015). Some of these factors relate to the spray itself. For example, concentrations of OC spray vary greatly and this can influence the consequences of being sprayed (Haas et al., 1997). Furthermore, other substances included in the spray (e.g. carbon dioxide, nitrogen, isobutene) that act as propellants for dispersing the chemical can potentially produce adverse cardiac, respiratory, and/or neurologic effects (Smith and Stopford, 1999). Additional factors, such as the device that is used to deploy the spray, can influence the size of the dispersed particles, which in turn affects their ability to penetrate the membranes and airways of the subject (Yeung and Tang, 2015). Depending on the mode of deployment (e.g. cone, fog, or stream pattern) the maximum effective range and precision of OC spray can also vary (Heal et al., 2010).

Environmental and subject factors have also been demonstrated to influence the effectiveness of OC spray, alone or in combination with the factors outlined above.

Relevant environmental factors include temperature, wind, distance, and potential barriers like clothing and/or eye protection (Karch, 2011). OC spray is generally found to be less effective for incapacitating subjects with increased distances between the officer and the subject (Bertilsson et al., 2017), presumably because the amount of spray required and the risk of missing the target area both increase with distance. Additionally, wind can cause cross-contamination (i.e. when an officer experiences the effects of OC spray). In terms of subject characteristics, Bertilsson and colleagues (2017) reported that OC spray was less effective for incapacitating older subjects, based on self-reported effectiveness ratings provided by the deploying officer, whereas Kaminski et al. (1999) found a non-linear relationship between OC spray effectiveness and age (again, based on self-reported effectiveness ratings provided by the deploying officers). More specifically, in Kaminski et al.'s study, OC spray was deemed most effective on the youngest (i.e. between 14 and 21) and oldest (i.e. between 38 and 66) subjects in their sample. Research examining the influence of alcohol intoxication on OC spray effectiveness appears to be mixed. Some research suggests that intoxicated individuals are more susceptible to the effects (e.g. Kaminski et al., 1999), while other research suggests otherwise (e.g. Edwards et al., 1997).

Concerns with the use of OC spray

Despite the widespread availability of OC spray and its use in the policing context, there has been controversy surrounding the potential health risks associated with exposure, such as corneal and vocal cord damage, and potential carcinogenic and mutagenic effects (Kaminski et al., 1999). Furthermore, some organizations have suggested that OC spray is a contributing factor to in-custody deaths, given that numerous individuals have died while in police custody shortly after OC spray deployment (e.g. American Civil Liberties Union of Southern California, 1995). These concerns have resulted in numerous reviews of existing research in an attempt to determine whether the use of OC spray has the potential to result in serious injuries and/or deaths to subjects. Generally, these reviews have determined that OC spray is relatively harmless and typically causes only minor injuries, if any harm is caused at all (e.g. Broadstock, 2002; Haar et al., 2017; Vilke and Chan, 2007).

Broadstock (2002), for example, examined seven studies and found that medical intervention was not commonly required after exposure to OC spray. Additionally, when serious injuries and/or death did occur, OC spray was not identified as a causal factor (although Broadstock indicates that limitations of the reviewed research would make it difficult to establish causality in any case). Likewise, Vilke and Chan (2007) reviewed the medical literature regarding the use of less-lethal technology, including OC spray. They similarly concluded that, despite reports of hundreds of thousands of exposures, there appears to be no evidence of long-term health effects associated with OC spray exposure. Moreover, in cases where death occurred following exposure to less-lethal technologies, other potential causes were also present (e.g. drug intoxication). Finally, Haar et al. (2017) examined 31 studies and found that the majority (98.7%) of individuals exposed to a chemical irritant (OC spray or tear gas) fully recovered. Consistent with the findings from previous reviews, the majority of injuries were minor and predominantly affected the skin, eyes, and cardiopulmonary system. When severe injuries were reported, it was frequently related to the deployment mechanism of the chemical irritant (e.g. the canister of the chemical munition causing traumatic injury to the head and neck).

While each of these previous reviews contributes to our understanding of OC spray and its potentially harmful consequences, the reviews are limited in various ways. For example, one of the reviews is unpublished (Broadstock, 2002) and therefore has not undergone peer review. In addition, two of the reviews are now somewhat dated (Broadstock, 2002; Vilke and Chan, 2007) and may not reflect current research findings or contemporary policing practices with respect to the use of less-lethal technologies, such as OC spray. Furthermore, some of the reviews do not speak to the factors that may be important to consider when trying to establish whether OC spray has a harmful affect. Vilke and Chan (2007), for instance, do not focus on the quality of the studies they reviewed or speak to the specific types of injuries suffered by subjects, and Harr et al. (2017) do not focus on the full range of potential outcomes that might be associated with OC spray (e.g. injuries and deaths). Moreover, Harr et al.'s (2017) review took a broad approach by examining the effects of various interventions (e.g. OC spray and tear gas) in settings that go beyond policing; this makes it somewhat difficult to determine the effects of OC spray within a policing context.

Given these issues with existing reviews, and the lack of reviews in this area more generally, we believe there is value in conducting a comprehensive, up-to-date review of literature that focuses specifically on the potentially harmful effects associated with OC spray deployments in settings that are relevant to police officers.

The current study

The primary goal of the current literature review was to examine published and unpublished research related to injuries and deaths proximate to OC spray deployment to determine the degree to which concerns regarding the use of this intervention option are warranted. A secondary goal of the review was to examine whether additional factors exist in cases where injuries and death did occur following OC spray deployment to determine what other factors might contribute to injuries and/or deaths. A final goal of the review was to consider the quality of existing research that examines injuries and death proximate to OC spray deployment to determine how cautious readers need to be when reviewing this literature and drawing conclusions (e.g. about the causal effect of OC spray with respect to injuries and deaths).

In line with these goals, the review is broken into the following sections:

1. A review of research pertaining to the operational effectiveness of OC spray, when that research has also examined injuries or deaths.
2. A review of research pertaining to specific injuries, which are potentially associated with OC spray deployment.
3. A review of research pertaining to deaths, which are potentially associated with OC spray deployment.

4. A review of research pertaining to additional factors that have been 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 (1) to (4).

Methodology

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 house 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 whether they had access to material that was not found through formal searches. Finally, the reference sections of all identified material were examined to determine whether 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). Our review did not include any animal studies,[2] even if the focus was on injuries or death, or studies where variants of OC spray were used for reasons other than to subdue or otherwise control a subject (or to simulate these events, such as in a training context). For example, studies examining the impact of OC spray when it was used as a form of treatment were not included in our review.

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

The operational effectiveness of OC spray and associated injuries/deaths

A number of studies have examined the operational effectiveness of less-lethal use of force 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 spray potentially related to injuries and/or deaths. None of the studies discussed in this section provided detailed descriptions of the types of injuries received by the subjects or the officer deploying the spray.

The earliest study we identified was conducted by Edwards et al. (1997) who examined the effectiveness of OC spray deployments 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 deploying officers.[3] 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, potentially because of the availability of OC spray as an intervention option. More importantly for our purposes, only 11% of the officers who deployed OC spray during an encounter reported being injured, and most of these injuries were minor. Additionally, only 8% of subjects who were sprayed reportedly received injuries, and all of these were considered minor (and did not require hospitalization).

Around the same time as the Edwards et al. (1997) study, Lumb and Friday (1997) collected data from a police service in Concord, North Carolina. Lumb and Friday focused on a time period between July 1992 to December 1993, which included a 6-month period before OC spray was implemented, 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 subjects or officers (with one exception) when OC spray was deployed; instead, every instance of injury occurred when physical force was used by an officer.

Using a similar methodology to the previous two studies, Bowling and Gaines (2000) reviewed officer and subject injuries before and after OC spray implementation in three American police services—Charlotte-Mecklenburg Police Department (CMPD), Winston Salem Police Department (WSPD), and North Carolina State Highway Patrol (NCSHP). Analyses revealed that in CMPD and WSPD, 20% and 30% reductions in subject injury were observed, respectively, following the implementation of OC spray (data were not available for NCSHP). Following a similar trend, officer injuries also decreased in all agencies following OC implementation. More specifically, CMPD and NCSHP both demonstrated a significant reduction in officer injury (45% and 50%, respectively). Similarly, WSPD observed a decline in officer injury by 40%. However, once multivariate analysis were conducted, the introduction of OC spray was either not significantly related to injuries (NCSHP and WSPD) or reduced the number of use of force events, which in turn reduced injury rates (CMPD).

Examining a slightly different issue, Morabito and Doerner (1997) focused on a time period in the Tallahassee Police Department in which OC spray was transitioned from being treated as the equivalent of an intermediate weapon (e.g. baton; level 4 force) to an option comparable to hands-on tactics (e.g. punches and kicks; level 3 force). Analyses were conducted at both levels of the use of force continuum to determine how injuries resulting from OC spray compared to injuries resulting from other intervention options at the same level. The researchers found that OC spray resulted in minimal, relatively minor injuries to officers and subjects. Furthermore, the severity of injuries associated with OC spray was lower than alternative intermediate weapons and physical control techniques.

More recently, Smith et al. (2007) collected data from two American police services—Miami-Dade Police Department (MDPD) and Richland County Sheriff's

Department (RCSD)—to examine the use of various intervention options on officer and subject injuries. In one of these services (RCSD), the researchers examined the effect of OC spray on officer and subject injuries. This analysis examined 467 use of force reports related to incidents that occurred between January 2005 and July 2006. A relatively small number of subjects and officers were injured in these cases (78 subjects and 46 officers) and the majority of injuries were minor (consisting of bruises, abrasions, and lacerations). Using regression analysis to identify predictors of officer and subject 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 subject injury, on the other hand, the use of OC spray was related to a reduction in the odds of subject injury. More specifically, after controlling for all other levels of force and resistance, the use of OC spray reduced the odds of an injury occurring to a subject by almost 70% (odds ratio = 0.32).

Similarly, Macdonald et al. (2009) examined the relationship between the use of less-lethal weapons and injuries to officers and subjects. The researchers analyzed 24,380 use of force incidents that occurred between 1998 and 2007 across 12 police services in the United States. Overall, approximately 39% of the use of force incidents resulted in an injury to the subject, whereas approximately 14% resulted in injuries to officers. However, the subject 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 subjects being injured and 14% of officers. If a police service in the sample had a defensive OC spray policy (i.e. restricting officers to defensive use only), subject injury rates were slightly lower than the sample average at approximately 38%; however, officer injury rates were consistent with the sample average at 14%. When controlling for a range of case attributes, the odds of subject injury was reduced by 69% when OC spray was deployed (odds ratio = 0.31; 95% CI = 0.28, 0.33), whereas officer injuries increased when OC spray was used (odds ratio = 1.42; 95% CI = 1.29, 1.58). For comparative purposes, subject injuries were reduced by 65% with the use of conducted energy devices (odds ratio = 0.35; 95% CI = 0.32, 0.38) and no relationship was found between conducted energy devices and officer injury.

We experienced difficulties retrieving copies of three additional studies that met our inclusion criteria. However, based on accounts of these studies taken from other sources, they appear to support the view that OC spray is generally a safe intervention option. For example, Gauvin (1995) found that subject and officer injuries decreased when OC spray became available to officers in Portland, Oregon. Similarly, Nowicki (1993) reported very low rates of officer and subject injuries during 360 OC spray deployments in Connecticut, while Meyer (1992) demonstrated that in Los Angeles lower injury rates were associated with OC spray use compared to other forms of force, such as punches, kicks, and baton use.

To summarize, 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. While instances do exist where the deployment of OC spray appears to be related to injuries, as will be demonstrated, we only identified one study where OC spray appeared to be associated with an increase in injuries (in this case, the increase was to officer injuries; Macdonald et al., 2009). 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. For example, in a recent large-scale study, Kearney et al. (2014) examined all cases involving human exposure to pepper spray that were reported to a poison control center 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 which 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 involving more severe outcomes related to the use of OC spray in the context of law enforcement training (odds ratio = 7.39; 95% CI = 2.98, 18.28), law enforcement use for subject or crowd control (odds ratio = 2.45; 95% CI = 1.42, 4.23), and the use of OC spray for intentional incapacitation (odds ratio = 3.02; 95% CI = 1.80, 5.06).

Other research has examined the impact of OC spray within these specific settings, particularly in a training context and when OC spray has been used specifically for subject control in operational settings. These studies are reviewed next.

OC spray in training

Consistent with the increased risk for adverse outcomes reported by Kearney et al. (2014), some training agencies have banned OC spray exposure for officers in training (McLaughlin, 2007). In contrast, many agencies still provide their officers with the opportunity to be exposed to OC spray during training to prepare them in case of accidental exposure through cross-contamination in the field. This appears to be a valid justification, given that approximately 27% to 50% of OC deployments by police officers result in cross-contamination to other officers (Adang and Mensink, 2004; Bertilsson et al., 2017; Crime and Misconduct Commission, 2005). Additionally, officers whose training includes OC spray exposure report that it helped them maintain composure after being cross-contaminated in the field (Hogan, 2006 as cited in McLaughlin, 2007). Two studies we reviewed examined the use of OC spray in the training context.

While not specifically focused on OC spray use in police training, Stopford (1996) examined 6,000 correctional officers who were exposed to OC spray during their training between 1993 and 1995. Only a small proportion of these officers (1%, $n = 61$) required medical treatment. For these 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 those who required medical attention, eight (13%) had symptoms that lasted longer than 1 week (including eye problems, chest problems, and headaches).

In a similar study, Zollman et al. (2000) examined 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 their exposure to OC spray, 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. However, corneal sensitivity was greatly reduced from pretest to posttest. 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 postexposure. At 1-week postexposure, no corneal abnormalities were observed.

OC spray for subject control

As discussed above, police officers are equipped with OC spray as an intervention option for subject control. Some studies have examined injuries that occurred as a consequence of OC spray deployment in this context by examining cases where symptoms warranted hospital evaluation,[4] as well as all deployments by a police service during a trial period.

Watson et al. (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 burning and redness of the skin 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 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 preexisting asthma does not elevate one's risk of adverse pulmonary effects if they are OC sprayed.

In a similar study, Brown et al. (2000) reported on 100 adults who presented to a hospital jail ward emergency room due to exposure 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 among the subjects was red or bloodshot 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.

The implementation of OC spray by the Queensland Police Service as an intervention option for subject control was examined by the Criminal Justice Commission and Queensland Police Service (1999). There were 35 incidents involving the application of OC spray in the study (7 of these incidents involved the use of OC spray on attacking dogs). Of the 28 incidents that involved people, there were 37 deployments of OC by a police officer (some incidents involved multiple deployments). 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 who 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 OC spray deployment.

To summarize, consistent with research cited in the previous section on OC spray effectiveness, the available research that has specifically focused on injuries associated with OC spray deployments suggests that most of the injuries that are experienced are relatively minor and rarely seem to require serious medical attention. Indeed, 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; Zollman et al., 2000).

Deaths proximate to OC spray deployment

This section summarizes all 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). All of the studies examined in-custody deaths related to police use of OC spray, but on varying scales.

Large-scale studies

Granfield et al. (1994) attempted to identify all 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 and the American Civil Liberties Union of Southern California, and word of mouth with International Association of Chiefs of Police 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 police services 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[5] 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.

Petty (2004) further examined 73 cases where OC spray was applied during confrontations of subjects with police officers. 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 subcategories 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 ($n = 4$).[6] 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 preexisting asthma.

The American Civil Liberties Unions of Southern California (1995) conducted a similar review to the one conducted by Granfield et al. (1994), but it focused on individuals who died in custody after being exposed to OC spray by the police in California between January 1993 and May 1995. They identified 26 incidents, all involving men exhibiting combative or irrational behavior. Nearly all cases involved a struggle (96%) and drug and/or alcohol intoxication (85%). Furthermore, 25% of the sample were under the influence of lethal doses of drugs. Multiple sources were used to confirm the cause of death. Of the 24 cases where complete data were available, OC spray was not cited as the official cause of death in any of the cases, although it 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, which were used in 50% and 25% of cases, respectively (see below for more details on these factors). Interestingly, OC spray was reported as not effective in all cases.

Another, more recent study by Toprak et al. (2015) reviewed deaths associated with the use of 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 tear gas. The review concluded that RCA-related death typically involves several factors, including preexisting medical conditions (e.g. asthma, cardiovascular disease), drug use (e.g. stimulants like cocaine and methamphetamine), excited delirium (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 autopsies were only available in 5 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.

Case studies

Some studies provided detailed descriptions of one or two cases. While these might not be useful for generalizing to the broader population of individuals who have been exposed to OC spray, they provide a more in-depth explanation of factors that they may have contributed to an individual's death.

Steffee and colleagues (1995) examined two in-custody deaths that involved OC spray with full autopsies. They attempted to determine whether OC spray caused the deaths or if it 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 behavior. 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 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 individual's face). A struggle occurred, with the male being put 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. The autopsy did not reveal any traumatic injuries and no histological changes indicated that asthma was the 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 factors were noted as playing a role in his death:

> Repeated [versus single] 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: 187)

More recently, Niemcunowicz-Janica et al. (2009) reported on a case study of a male sitting in his car who 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 and died. 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.

To summarize, based on the evidence cited above, OC spray deployment appears to be 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. For example, in the 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 preexisting 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 preexisting factors. The potential role that these factors play in OC-associated injuries and deaths will be discussed next.

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, which may contribute to whether subjects experience injuries and/or deaths. Included among these associated factors are ExDS, positional asphyxia, preexisting health conditions, and drug use.

Excited delirium syndrome

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 and Sadler, 2001: 46). The 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 behavior. Often, such encounters are characterized by a noncompliant subject, who is frequently intoxicated, under the influence of drugs, or experiencing a mental health crisis. The police frequently have to rely on a range of use of force 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, autopsies do not typically 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 United States where ExDS was identified as a primary factor. Most of the deaths occurred within 1 hour following the encounter, in these cases the presence of drugs was common. 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 et al. (1998), O'Halloran and Frank (2000), and Stratton et al. (2001); in each case, OC spray was used prior to a number of deaths involving subjects exhibiting 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 is, on occasion, associated with OC spray exposure. 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 and Hunt, 2005), which can result in injuries or deaths under certain circumstances.[7]

Few studies have examined the association between OC spray and positional asphyxia. The only study we could identify was conducted by Chan et al. (2001) who used a randomized, crossover, controlled laboratory study with 34 volunteers from a police training academy. The goal of the study was to assess the effects of OC spray inhalation on respiratory function. Participants were exposed to either OC or a placebo spray in either the sitting or hobble position. The study revealed no impact of OC spray in the sitting condition. In contrast, subjects in both the OC and placebo groups experienced restricted pulmonary functioning in the restrained position, but neither were out of normal range. Of relevance to the next section on preexisting health conditions, the study also demonstrated that a history of lung disease, asthma, smoking, or inhaler use do not affect functioning in either position.

Preexisting health conditions

Several preexisting 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 (e.g. Chan et al., 2001). In addition, when differences are found between healthy and unhealthy subjects, the disparities often relate to relatively minor symptoms, such as coughing.

Few differences were found between asthmatics and non-asthmatics in the earliest study we could find on the topic. Specifically, Collier and Fuller (1984) 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). In a similar study, Hathaway et al. (1993) found some minor effects related to asthma. They 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. However, none of the control participants responded in this way despite all participants coughing in response to capsaicin. These findings are consistent with that of Watson and colleagues (1996) who evaluated emergency department admissions due to exposure to OC spray. Some minor differences were observed between asthmatics and a comparison group with 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. Most recently, Doherty et al. (2000) compared cough responses across participants with severe asthma, chronic obstructive pulmonary disease (COPD), or no illness. Compared to participants in the control group, those with asthma and COPD were equally sensitive to capsaicin, however, both exhibited an increased cough reflex.

Another preexisting health condition often discussed in the context of injuries and/or death proximate to 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 additional stress is placed on an obese individual, serious injuries or death may occur. More specifically, placing the individual in certain restraint positions or experiencing the effects of OC spray may restrict already reduced airflow or place additional stress on an already compromised heart.

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 participants 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 confidence in this finding, given that the sample size was extremely small, none of the subjects were morbidly obese, and the participants did not engage in strenuous exercise prior to being sprayed.

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 (Mittleman and Wetli, 1987 as cited in Granfield et al., 1994).

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 OC spray exposure. 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 (as previously mentioned only the second 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 preexisting medical condition (including cirrhosis, schizophrenia, psoriasis, and coronary artery disease). Consistent with findings regarding ExDS (Ross, 1998), the majority (79%) of the sample died within 1 hour after exposure 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 subject (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 relevant work of Broadstock (2002) in this section. Key limitations of research in this area include

1. 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).

2. The vast majority of research in this area is limited by small sample sizes and, as highlighted above, 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 limited reliance on use of force tactics in North America, with the deployment of OC spray thus 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 are deemed too sensitive to share with researchers.
3. Related to the above limitation, and compounding the issue of representativeness, is the fact that much of the research to date has been conducted in particular police jurisdictions, mostly in the United States. It is not currently clear whether results from the cited studies generalize across jurisdictional boundaries, especially because OC spray may be used differently in different sites (e.g. with respect to concentrations or delivery mechanisms).
4. 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, the frequency of sprays, environmental factors, subject characteristics, and so on. Without such information, it is difficult to determine what the link might be between OC spray and injuries or death.
5. Outcome measures, often extracted from 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 these sources of information have not been validated for this purpose and are known to be problematic (e.g. include vague statements regarding cause of death; Broadstock, 2002).
6. Experimental designs that would allow one to determine whether causal linkages exist between OC spray and injuries or death are rarely 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).
7. 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 during encounters.
8. 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).

Conclusion

Despite concerns related to the fact that injuries and deaths have occurred proximate to OC spray deployment, the majority of research reviewed above suggests that this intervention option is relatively safe and typically decreases the likelihood of injury, for both the subject and the officer deploying the spray. While there is always the potential for harm when any force is used by a police officer, the deployment of OC spray appears to rarely cause *serious* injuries and it has not been directly linked to subject death. Indeed, injuries that are commonly associated with OC spray tend to be minor and not long-lasting, and when death occurs proximate to OC spray deployments, other factors appear to play a more significant role in explaining the death (including ExDS, positional asphyxia, preexisting health conditions, and drug use). 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. Relatedly, we are also unable to speak to the relationship between the various factors related to OC spray (e.g. concentration, mode of deployment, organizational policy regarding the use of OC spray, etc.), the effectiveness of OC spray, and related health outcomes. Further research, which is not plagued by the sorts of the methodological issues described above, is required to resolve these issues.

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Notes

1. We also 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.
3. Although tangential to the current review, given our focus on injuries and deaths proximate to OC spray deployments, it is important to point out that the reported effectiveness of OC spray

by Edwards and colleagues (1997) is quite high (i.e. 90%) relative to other research on the topic. For example, Mesloh et al. (2008) analyzed 4,303 use of force reports collected between 2000 and 2005 from two police services and discovered that OC spray was effective in 64% of deployments, which was more effective than baton (45%) and takedowns (41%), but less effective than conducted energy devices (CEDs; 69%). Other studies have revealed that the effectiveness rate of OC spray ranges from between 70.7% (Kaminski et al., 1999) and 73.8% (Brandl and Stroshine, 2017). Differences in effectiveness may relate to operational factors, such as the OC concentration used in a particular jurisdiction or the type of dispersal pattern (e.g. Haas et al., 1997), but they may also reflect differences in how "effectiveness" is defined by researchers (e.g. see Adang and Mensink, 2004).

4. An interesting study, which speaks to OC-related injuries but is unrelated to the use of OC spray in policing, was conducted by Oh et al. (2010). This study reported on civilian secondary exposure to OC at an urban shopping center. 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.
5. 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).
6. The term "confrontational situation" is applied in place of positional asphyxia because these cases in category 2 are not as well defined.
7. 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 using the hobble or hog tie positions.

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