Health Hazards of Pepper Spray

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Oleoresin capsicum (OC) is an oily extract of pepper plants of the genus *Capsicum*. Each year, millions of pounds of capsicum are imported into the United States, primarily from India, Japan, Africa and Mexico. It is used as a spice in salsa, chili, curries, and hot sauces; as a pharmacologic agent in topical anesthetic and analgesic creams; and as the principal active ingredient in OC spray, or "pepper spray," used by police and others as an antipersonnel agent. OC extract consists of a complex mixture of fat soluble phenols known as capsaicinoids; capsaicin (*trans*-8-methyl-*N*-vanillyl-6-nonenamide) and dihydrocapsaicin, the most potent homologues, make up 80-90% of the total. Capsaicinoid content determines the "hotness" of the extract. The Table depicts the relative hotness of three popular edible peppers and capsaicin as measured in Scoville units (the greatest dilution of pepper extract that can be detected by the human tongue).[1-3]

The capsaicinoid content of extracts used in pepper sprays varies widely among manufacturers, from 1.2% to 12.6%. Since the concentration of extract in pepper sprays also varies (5-15%), the potential risks associated with capsaicinoid exposure may vary by as much as 30-fold among brands of OC spray.

Depending on brand, an OC spray may contain water, alcohols, or organic solvents as liquid carriers; and nitrogen, carbon dioxide, or halogenated hydrocarbons (such as Freon, tetrachloroethylene, and methylene chloride) as propellants to discharge the canister contents.[3] Inhalation of high doses of some of these chemicals can produce adverse cardiac, respiratory, and neurologic effects, including arrhythmias and sudden death. The health effects of solvents and propellants are beyond the scope of this article, but they too need to be considered in evaluating potential hazards and effects of exposure to specific brands of OC spray.

During the past decade, OC sprays have become popular with law enforcement and corrections personnel as nonlethal deterrent agents. But there is no real scientific basis for the claim that OC sprays are relatively safe. In fact, a number of reports have associated serious adverse sequelae, including death, with legitimate use, as well as misuse and abuse, of these sprays.

Table. Relative "hotness" of edible peppers and capsaicin*

Source	Scoville heat units (HPLC**)
Jalapeno pepper	5,000
Cayenne pepper	2,500-25,000
Habanero pepper	85,000-200,000
Pure capsaicin	15,000,000
OC (10%)	1,500,000

*Adapted from Steffee et al[3]
**high-performance liquid chromatography

In this article, we review the acute and chronic effects of exposure to capsaicin and OC spray, summarize the occupational health risks of exposure to OC spray during training, review actions taken in the state to address these concerns, and present recommendations to prevent unwanted effects as these sprays become more widely used for personal protection, law enforcement, and corrections-related activities.

Health Effects of Capsaicin

The characterization of capsaicin was begun in the 1940s by the Hungarian pharmacologist Nicholas Jancso. From his work and others', we have learned that capsaicin acts directly on peripheral sensory nerves and not on motor nerves. It has

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been used to probe the biologic function of C-fibers and the role of pain receptors (nociceptors) in human physiology. It provides a unique pharmacologic tool for studying the human cough reflex and other airway reflexes. It alters the neurophysiology of sensory neurons in the airway mucosa by inducing the release of tachykinins or neuropeptides like substance P and neurokinin A. These induce neurogenic inflammation in airway blood vessels, epithelium, glands, and smooth muscle, leading to vasodilation, increased vascular permeability, neutrophil chemotaxis, mucus secretion, and bronchoconstriction.[4-7]

The chemical tear gas agents chloroacetophenone (CN) and o-chlorobenzylidene malononitrile (CS) produce primarily irritant effects, but exposure to OC causes both irritation and neurogenic inflammation. Exposure to OC spray may occur through skin or eye contact, or inhalation. Once inhaled, it can be expectorated or ingested. With acute exposure, there is rapid onset of constitutional symptoms including nausea, fear and disorientation.

The ill effects of OC. Dermal exposure to OC spray causes tingling, intense burning pain, swelling, redness, and, occasionally, blistering (capsaicin alone causes redness and pain, but not vesiculation). A severe dermatitis, called "Hunan hand," is found in people who process chili peppers in Mexico. Capsaicin amplifies inflammation by releasing substance P from the skin and nasal mucosa. Multiple exposures of skin or mucous membranes over a period of seconds or minutes exaggerate the response. Capsaicin augments allergic sensitization and worsens allergic dermatitis. Exposure may diminish sensitivity to heat- or chemical-induced pain, thus increasing the risk and severity of skin burns. Capsaicin powerfully stimulates heat receptors, causing reflex sweating and vasodilation, and activates hypothalamus-mediated cooling; this dual effect increases the risk of hypothermia if victims are decontaminated with cold water on cold days.[3,7,8]

Respiratory responses to OC spray include burning of the throat, wheezing, dry cough, shortness of breath, gagging, gasping, inability to breathe or speak (due to laryngospasm or laryngeal paralysis), and, rarely, cyanosis, apnea, and respiratory arrest.[3]

Nasal application of capsaicin causes sneezing, irritation, and reflex mucus secretion.[9] Its inhalation can cause acute hypertension (similar to ammonia inhalation), which in turn can cause headache and increase the risk of stroke or heart attack. Animal studies show various and sometimes profound reflex effects on respiratory and cardiovascular function. These include apnea, airway edema and constriction, systemic vasodilation, hypotension, bradycardia, and sometimes atrioventricular blockade and even asystole.[8-10]

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Respiratory effects. Capsaicin-sensitive nerves play an important role in cough, airway reactivity and inflammation. Like other airway irritants, aerosolized capsaicin stimulates the human cough reflex via sensory nerve endings supplied by afferent, unmyelinated C-fibers.[10,11] In one study, 13 of 22 chili workers exposed to capsaicinoids complained of rhinorrhea and cough, even at concentrations lower than 1μg/m^3.[4] Another study of hot pepper workers and controls found that inhalation of dilute, nebulized capsaicin caused reproducible, dose-dependent cough in both groups without inducing tachyphylaxis or significant decrease in baseline pulmonary function in either group.[4] Other studies have demonstrated that capsaicin causes contraction of human bronchial smooth muscle in vitro[12] and transient (<1 min) dose-dependent bronchoconstriction in vivo (a 20-50% increase in airway resistance at doses that do not induce cough).[9,13] There was no difference in duration or magnitude of bronchoconstriction in normal subjects, smokers, and asthmatics; the mechanism has not been clearly elucidated, but it is felt to be mediated either through substance P (acting directly or indirectly) or through vagal reflex bronchoconstriction caused by stimulation of C-fibers.[13] No cases of occupational asthma due to capsaicin have been reported, and it is important to point out that not all asthmatics are sensitive to its bronchoconstrictive effects.[3,14]

In addition to precipitating bronchoconstriction, which could manifest as acute asthma, OC spray exposure may increase the risk of laryngospasm and respiratory arrest. Two persons with asthma and one with chronic bronchitis developed respiratory arrest following OC spray exposure during arrest. Respiratory arrest also occurred in another person with a respiratory infection who was sprayed repeatedly.[3,10,15] Direct contact of capsaicinoids with the vocal cords has caused laryngospasm lasting 45 seconds. In addition, laryngospasm, laryngeal and pulmonary edema, chemical pneumonitis and respiratory arrest have occurred after intentional and accidental OC spray inhalation by children.[16,17]

In rodents, capsaicin-induced release of substance P stimulates mucus secretion, increases vascular permeability in the lungs, and exacerbates pulmonary inflammation associated with respiratory infection. Capsaicin exposure in the face of respiratory infection may increase vascular permeability 60-fold. Exposure during *Parainfluenza* infection causes a 3- to 5-fold increase in neurogenic inflammation of the airways, and, during *Mycoplasma pulmonis* infection, a 30-fold increase in neurogenic plasma extravasation that may last for several weeks. Unfortunately, there are no similar studies in humans.[5]

Chronic low-dose exposure to capsaicinoids is associ

Police using pepper spray to control demonstrators. Photo by Bernie Eng, Saginaw News, Saginaw, Michigan.

ated with chronic respiratory symptoms and illness. Chili grinders chronically exposed to *Capsicum* develop rhinorrhea, sneezing, cough, weight loss, burning skin (especially when they sweat), and bronchoconstriction. Symptoms are more severe early in employment and tend to decrease with time or when exposed to pepper plants containing less capsaicin. Paprika workers exposed to capsaicinoids may develop hemoptysis, severe chronic bronchitis, pulmonary fibrosis, and bronchiectasis. The chronic pulmonary effects occur in workers who break open the capsicum fruits and not the grinders, and so the etiologic factor may be a fungus (*Mucor stolonifer*) which infests the fruits.[18,19] The chronic effects of low-dose inhalation exposure to OC spray are not known with certainty.

Eye symptoms. Common ocular symptoms associated with OC spray exposure include redness, swelling, severe burning pain, stinging, conjunctival inflammation, lacrimation, blepharospasm and involuntary or reflex closing of the eyelids. In the rat, application of 1% capsaicin to the eye causes neurogenic inflammation and loss of reaction to chemical and mechanical stimuli for up to a week. In humans, superficial anesthesia and loss of the blink reflex may lead to corneal abrasions from contact lenses or foreign bodies. Capsaicin disrupts the epithelial layer of the cornea, so persons with impaired corneal integrity (from exposure keratitis, keratomalacia, or recurrent corneal erosion) are more susceptible to severe ocular effects than those with normal corneas. Ocular exposure to OC should be treated by flushing for at least 15 minutes with water.[3,7,20]

Gastrointestinal effects. Capsaicin is principally used

throughout the world as a spice. It provides a burning sensation while eating that does not necessarily end in the mouth. Chemical irritation can produce a sensation of warmth along the entire gastrointestinal tract; high doses may cause painful burning in the esophagus, stomach, abdomen, even anus.[7]

Animal and human epidemiologic studies suggest that chronic chili pepper consumption may be involved in a number of chronic diseases and may be a significant risk factor for gastrointestinal malignancy. Chronic oral administration of capsaicinoids to hamsters is associated with liver fibrosis, necrosis, and cirrhosis, and damage to the kidney glomeruli. Humans who eat lots of chili peppers reportedly have an increased risk of liver cirrhosis. Capsaicin irritates the stomach, which increases acid secretion and gastric motility and may cause hematemesis. Chronic ingestion of capsaicinoids and peppers is associated with an increased incidence of stomach ulcers in both humans and animals.[7,8,21]

Capsaicin is weakly mutagenic in the Ames test, and a co-carcinogen in rats, enhancing gastric carcinogenesis. Ten percent of mice exposed to capsaicin developed duodenal cancer, versus 0% of those not exposed. A study in Mexico found that consumers of chili pepper had a more than 5-fold increase in risk of gastric cancer (age- and sex-adjusted odds ratio of 5.49; 95% CI 2.7-11.1) compared to nonconsumers; high-level consumers had an odds ratio of 17.11 (95% CI 7.8-37.6). In India and other Southeast Asian countries, eating of chili peppers is associated with oral submucosal fibrosis, a precancerous condition of undetermined etiology.[7,22-24]

A health benefit? Capsaicin may have some beneficial effects. In mice, it produces dose-dependent prolongation of bleeding time and is a more potent inhibitor of platelet aggregation than either aspirin or indomethacin. In Thailand, ingestion of capsicum is associated with increased fibrinolytic activity and hypocoagulability, resulting in higher antithrombin III and lower plasma fibrinogen levels. These may explain the lower incidence of thromboembolic disease in Thai people.[7]

Occupational Risks of OC Exposure

Based on a favorable 1989 FBI report[25] and anecdotal reports of safety and efficacy, many law enforcement and corrections agencies chose OC sprays as a "less than lethal" deterrent, alternative to impact weapons and tear gas. OC was alleged to be effective in apprehending persons who, because they were extremely agitated, mentally ill, or under the influence of alcohol or drugs, might not feel the irritant effects of tear gas, but would be incapacitated by the inflammatory effects of OC. In 1993, however, the US Department of Labor warned that OC spray posed significant health risks to exposed employees, that it could cause unpredictable, severe adverse health outcomes, and that it should not be intentionally sprayed on the skin, eyes, or mucous membranes of employees during training.[26]

In 1995, additional questions were raised about the safety and effectiveness of OC sprays. A conflict of interest investigation by the FBI Academy Firearms Training Unit in Quantico, VA (which had produced the earlier, favorable report on OC sprays) revealed that one of their researchers had received $57,500 from the manufacturer and distributor of Cap-Stun, a widely used brand of OC spray. The agent pled guilty to a felony violation of federal conflict of interest law.[27]

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Challenge to training exposure. Some law enforcement and corrections officers began to challenge training policies requiring that they be sprayed in the face with OC to learn its effects. Concern about pain and potential adverse effects led those involved to ask, "We don't need to get shot to know what a bullet does, so why do we have to be sprayed to know what OC does?"[28] A challenge to mandatory exposure in North Carolina took the form of a lawsuit seeking an injunction against the NC Department of Corrections, arguing that pepper mace training is "dangerous," extremely painful, and a violation of the right to due process. Lacy H. Thornburg, U.S. District Court Judge for Western North Carolina (who was North Carolina Attorney General when the policy mandating full exposure to OC spray during training was written), dismissed the case, stating that pepper mace training did not deprive the plaintiff of due process under the 14th Amendment. The decision was appealed, and in 1996 the US Court of Appeals reversed Judge Thornburg's decision.[29]

In 1996, the Division of Epidemiology of the NC Department of Health and Human Services and the Occupational Safety and Health Section of the NC Department of Labor began an investigation of training practices involving intentional exposure to OC spray. Based on a compliance inspection, observation of a training session, detailed review of various training programs, the medical literature, and Occupational Safety and Health Administration (OSHA) activities outside of NC, they concluded that exposure to OC spray during training constituted an unacceptable health risk. A review of reported injuries found that 61 of approximately 6000 officers directly exposed to OC spray during training

experienced adverse effects (eye irritation, eye burns and abrasions, dyspnea, asthma attacks, nasal irritation, acute hypertension, severe headaches, chest pain and loss of consciousness) sufficiently severe to require medical attention. In 9 cases, effects (headaches, corneal abrasions and asthma) lasted for more than a week. (W Stopford, unpublished data).

NC Medical Society Resolution. In 1997, delegates to the North Carolina Medical Society's Annual Meeting adopted a resolution calling for the NC Commissioner of Labor to send guidelines for the safe use of capsaicin spray to law enforcement organizations, the Secretary of the NC Department of Crime Control and Public Safety, and the NC Attorney General. In April 1998, Dr. Ronald H. Levine, then State Health Director, and Harry Payne, the Commissioner of Labor, sent an advisory letter outlining the health and legal concerns associated with the use of OC spray, and recommending that exposure during training be discontinued. The advisory further outlined several measures to reduce the chance of serious injury, should organizations choose to continue exposure training. These included (1) substituting indirect exposure (spraying a wall faced by the trainee or spraying above the trainee's head) or wearing face shields or chemical goggles if direct exposure is used; (2) providing emergency showers and eyewash stations; (3) screening employees to identify and exempt from exposure those with health conditions that might be exacerbated by exposure to OC spray; (4) having medical personnel present during training to render first aid and other medical treatment if necessary; and (5) compliance with OSHA's Hazard Communication (29 CFR 1910.1200) and Personal Protective Equipment (29 CFR 1910.132) standards during each OC spray training course.[30]

Discussion

Serious adverse health effects, even death, have followed the use of OC sprays. These sprays should be regarded as poisons or weapons and kept away from children and teenagers.[17] The risks of OC spray use by adults for self defense has not been studied, and its effectiveness as a crime deterrent is unknown.

The dangers. Hot peppers and sauces have been agents of child abuse[7] and OC spray has been used in a juvenile detention center for corporal punishment and psychological control. Use of OC to inflict pain is abusive and may cause emotional sequelae.[31] At least one court has ruled that pepper spray should be used only when absolutely necessary to incapacitate dangerous youth "in situations which are reasonably likely to result in injury to persons or injury to a substantial amount of valuable property."[32]

Historically, Japanese police used the *metsubishi*, a lacquer or brass box, to blow pepper dust into the eyes of persons they sought to apprehend.[3] Today, more than 2000 public safety agencies now use some form of pepper spray to subdue and arrest aggressive and violent persons.[31] Law enforcement publications suggest that most who are sprayed suffer relatively minor, transient effects, and that serious adverse effects are uncommon.

Because there have been few controlled clinical studies of the human health effects of pepper spray marketed for police use, some physicians have surmised that pepper spray is not inherently lethal or dangerous.[33] A retrospective review of 81 cases of OC exposure seen in the emergency department of Truman Medical Center, Kansas City, MO, and representing about 10% of total instances of spraying by the Kansas City Police Department over three years, found no significant ocular or pulmonary effects. Burning and redness of the eyes and exposed skin were the most common symptoms; there were corneal abrasions in 7 and respiratory symptoms in 6 patients, but none required hospitalization. Interestingly, 12 of the 81 had a history of asthma, but their respiratory symptoms were similar to the other 69. Five patients presented with shortness of breath or wheezing; 2 had a history of asthma (their wheezing resolved without treatment), and 3 had no apparent predisposing factors (and also did not require treatment).[34]

Despite the encouraging findings from Missouri, since 1993 over 70 in-custody deaths have involved the use of OC spray during arrest efforts.[2] A review of 30 such deaths occurring in 13 states[35] and another of 26 deaths occurring in California[15] found that positional asphyxia (usually associated with hog-tying the arrestee), drug intoxication (with ethanol, cocaine, methamphetamine, or phencyclidine), pre-existing cardiovascular or respiratory disease, obesity, neuroleptic malignant syndrome, and other conditions caused or contributed to almost all deaths. Exposure to OC spray was not judged to be a precipitating cause in any case, but its use before death was not mentioned in 10 of the California cases, and there is concern that its potential role was not adequately considered in some of the others.

A 1993 death in North Carolina (a 24-year-old man with pre-existing florid bronchiolitis/bronchitis and cardiomegaly found at autopsy) was attributed to "asphyxia due to bronchospasm precipitated by pepper spray" by the attending pathologist and the NC Chief Medical Examiner. This highly publicized and controversial case and another involving, but not attributed to, OC spray have been presented in an article that details the pathologic, toxicologic, and other evidence needed to establish whether OC spray is unrelated, contributory, or causative of death in such cases.[3]

Avoiding unnecessary exposure. Many law enforcement and corrections agencies now prohibit the practice of spraying trainees directly in the face with OC. Based on reports of ocular damage, bronchospasm, pulmonary edema, laryngospasm, respiratory arrest, and death following OC expo-

sure, it is reasonable to conclude that exposure during training, particularly repetitive, direct facial spraying of individuals at increased risk, may cause serious adverse effects and possibly even death. Occupational exposure during training is not advised, and those organizations that continue to use OC spray should avoid direct exposure and screen out and exempt entirely all employees at increased risk for adverse effects (those with pre-existing allergies to peppers, with corneal disease, hypertension, heart disease, respiratory infections, bronchitis, asthma or a history of airway reactivity following irritant exposures, and cigarette smokers). Some people, such as instructors in law enforcement, may have repetitive, low dose exposure to OC spray, but the effects of such chronic exposure are unknown.

The proper role of OC. Despite training-related hazards, field-use data by police departments in Baltimore, Portland ME, and Winston Salem indicate that properly used OC can be effective and provide additional safety to enforcing officers. In many instances it may reduce injuries to officers as well as to arrestees (such as fractures, traumatic brain injury, or gunshot wounds, which sometimes result when physical force or impact weapons are required). The use of OC may thus lessen complaints about use of excessive force, and civil liability and injury-related costs to governmental agencies. We believe that OC spray should remain in the armamentarium of law enforcement and corrections officers who ultimately must decide, based on standard operating protocols, when and which deterrents ought to be used in a given situation. It is important to remember that subjects who are highly aggressive, agitated, intoxicated, or suffering from mental illness may have altered perception of and response to pain, and consequently may not be affected by—or may even become enraged after—being sprayed. When OC spray is used, officers must decontaminate those sprayed as soon as possible, continuously monitor them for evidence of serious adverse effects, and seek medical attention immediately if potentially life-threatening symptoms develop.[28]

The Consumer Product Safety Commission regulates the labeling of OC spray as a hazardous substance under the Federal Hazardous Substance Act. A prominent and conspicuous warning stating the principal hazard, precautionary measures to take when using the product, and first aid measures to be used should appear on the spray. These sprays can be readily purchased via the Internet, and most states place little or no restriction on their purchase. Many buyers do not know enough about the potential hazards of accidental or deliberate misuse and most never receive any training other than the most primitive instructions ("Point and spray!"). Anecdotal, research, and clinical data on the adverse effects of OC sprays are now sufficient to say that the hazards of these products ought to be more objectively and thoroughly evaluated and more clearly communicated. ❐

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