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the EXCHANGE

ASPR
ASSISTANT SECRETARY FOR PREPAREDNESS AND RESPONSE

TRACIE
HEALTHCARE EMERGENCY PREPAREDNESS INFORMATION GATEWAY

Foreword:

Preparing for and Responding to Chemical Incidents

Many readers already know about ASPR's National Health Security Strategy (NHSS). Objective 2 of the NHSS Implementation Plan is to "Protect the nation from the health effects of emerging and pandemic infectious diseases and chemical, biological, radiological, and nuclear (CBRN) threats." Under this objective lie four focus areas—accompanied by actions and end-states—that can help our many partners and stakeholders better prepare for and respond to CBRN threats:

1. Continue efforts to improve early detection of emerging and potential pandemic infectious diseases.
2. Rapidly identify, develop, produce, and make available safe, effective medical countermeasures (MCMs).
3. Maintain the capacity to produce enough vaccines and other necessary MCMs to provide protection from pandemic influenza and CBRN agents that represent a strategic health security threat to the nation.
4. Support [state, local, tribal, and territorial] authorities' efforts to stock, and rapidly obtain, distribute, dispense, administer, and monitor the safety of MCMs.

Whether a chemical incident is accidental (e.g., a chlorine spill as a result of a derailed train) or intentional (e.g., a nerve gas poisoning on a busy subway), responder, patient, and population safety are key to a successful response. Along those lines, ASPR recently worked with other federal partners on a White House National Security Council working group formed to help the emergency response community identify, plan for, and respond to a fourth-generation agent (FGA) incident and bolster overall chemical preparedness efforts. Links to the resources that resulted from this collaboration can be found on the HHS Chemical Hazards Emergency Medical Management (CHEMM)'s website. The articles in this issue of *The Exchange* highlight lessons learned (from the responder and practitioner perspectives), recent experiences abroad, and updates to federal initiatives that align with the four focus areas.

As a former Deputy Assistant Secretary at the U.S. Department of Homeland Security, Countering Weapons of Mass Destruction (WMD) Office, and as the current Director of Emergency Management and Medical Operations at ASPR, I fully embrace ASPR's mission to save lives and protect Americans from 21st century threats, including WMDs. ASPR provides proven, operationally focused resources and templates to our stakeholders through several channels, including ASPR TRACIE. Our resources are developed or reviewed by subject matter experts who have direct experiences with planning for and responding to disasters or public health emergencies. We encourage you to access ASPR TRACIE-developed resources and our CBRN Resource Page. Please share your own promising practices, lessons learned, or questions about chemical incidents with us so others may learn from your experiences. As always, we welcome your feedback.

Jon Greene, Director
Emergency Management and Medical Operations, HHS ASPR

Welcome to Issue 9!

In this issue of *The Exchange*, we discuss planning, response, and lessons learned specific to chemical incidents. ASPR TRACIE interviewed subject matter experts from the federal government, a healthcare provider, and a fire chief to learn more about emerging threats and past and current challenges in chemical incident response. We hope that these real-life experiences shared by your colleagues across the nation help you plan (and adjust existing plans) for chemical incidents. Please visit our resource page on chemical/ biological/ radiological/ nuclear incidents and our Chemical Hazards, Pre-Hospital Patient Decontamination, Hospital Patient Decontamination, and Responder Safety and Health Topic Collections.

We have spent the last year updating our 57 Topic Collections and we continue to respond to a variety of requests for technical assistance. Your feedback is what makes us successful—please contact us with comments, questions, technical assistance needs, and resources to share. We look forward to our continued collaboration!

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At a Glance

What's New With ASPR?

A lot has happened in the months since our last issue of *The Exchange* (which focused on supporting hospital surge) was published. In October, the Biomedical Advanced Research and Development Authority (BARDA) announced they were exploring "Lung-on-a-Chip Technology in Developing Chemical Injury Treatments," allowing researchers to better "understand injuries caused by inhaled chlorine gas, a potential national security threat, and to develop treatments for those injuries." They also recently announced a licensed vaccine for the prevention of smallpox and monkeypox and their sponsorship of the development of a novel therapeutic to treat smallpox infections. BARDA is also working to advance novel technology to meet the need for platelets after a nuclear detonation and advance development of an investigational Ebola treatment. ASPR's Medical Reserve Corps Program Office recently developed Training Community Members to Respond, a guide that includes information on specific curricula, instructor requirements, and links to training materials and education resources. This blog describes how emergency responders can protect themselves from compassion fatigue, burnout, and posttraumatic stress disorder and includes a link to ASPR TRACIE's newly released responder self-care modules. Another blog highlights the progress made in Puerto Rico and the U.S. Virgin Islands in the past two years with a focus on collaboration between ASPR's Division of Recovery and the Puerto Rico Department of Health. Visit the ASPR homepage and blog to learn more about how ASPR is working to strengthen the nation's ability to prepare for, respond to, and recover from emergencies.

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Next Generation Nerve Agents: Symptoms, Treatment, and Lessons Learned

In March 2018, a father and his adult daughter collapsed on a park bench in Salisbury, United Kingdom. After ruling out other causes (e.g., opioid overdose), clinicians decided that they were likely suffering from the effects of being exposed to a nerve agent. Eventually, the agent was determined to be a novel nerve agent: Novichok, a fourth generation agent (FGA). In September 2019, ASPR TRACIE interviewed Susan Cibulsky, PhD, a Senior Policy Analyst with ASPR and Mark Sutter, MD, with the Department of Homeland Security's / Countering Weapons of Mass Destruction Office, who have both studied the incident and met with some of the responders and clinicians responsible for treating these patients. Together with other federal and non-governmental partners, they have worked to develop scientific and clinical materials to help responders and providers prepare for, recognize, and treat FGA-exposed patients.

John Hick (JH): What are key differences between fourth generation agents and other nerve agents in terms of both physical characteristics and clinical presentation?

Susan Cibulsky (SC): The FGAs are low volatility liquids like VX, but with even lower vapor pressure than VX. The relatively long delay between exposure, from dermal contact, and initiation of symptoms is one big difference between the FGAs and other nerve agents. It can be hours—even days—before symptoms begin. It takes time for the substance to be absorbed through the skin. This is part of the reason that the progression of symptoms may be different than for other nerve agents. In the U.K., the patients did not initially show many signs of nerve agent exposure (consistent with the mnemonics) that we expect. For example, they did not exhibit bronchorrhea or have difficulty breathing.

Mark Sutter (MS): I think you have to interpret their clinical presentation in the world of synthetic opioids, synthetic cannabinoids, and the various novel psychoactive substances that we see. While these patients eventually presented a more cholinergeic picture, it was significantly delayed. They had miosis (pinpoint pupils), but without the other overt immediate SLUDGE or DUMBBELS symptoms. If we think about the epidemiology of the "found down" or unresponsive presentations, providers likely assumed these patients resembled someone who had been using one of these novel substances rather than someone exposed to Novichok.

One thing I noted from the discussion with the providers is the need to rely on the basics and keep differential diagnosis open. In the first 24-48 hours after FGA poisoning, optimal outcome is dependent on meticulous

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Nerve Agent Mnemonics

Patients may demonstrate a combination of:

SLUDGE – Salivation, Lacrimation, Urination, Defecation, Gastrointestinal upset, Emesis

and

DUMBBELS – Defecation, Urination, Miosis/Muscle weakness, Bronchospasm/ Bronchorrhea, Bradycardia, Emesis, Lacrimation, Salivation/Sweating

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supportive care. Healthcare providers used universal precautions to protect themselves. This highlights a best practice when facing an unknown situation. We don't necessarily have to know the substance, but we must rely on the basics.

JH: It seems like if there is one physical differentiator, this is an agent that is extremely environmentally persistent. The good news is it's less likely to off-gas, and inhalation isn't a huge risk, but contact is.

MS: Yes, the environmental persistence and delayed onset of symptoms are both very important for preparedness.

SC: In addition to their low volatility, they are highly water soluble but not readily degraded by water. They can be spread easily, as was seen in the UK. This represents a cross-contamination risk for responders.

JH: What were the dominant symptoms the patients presented with?

SC: Both patients had small pupils, slow heart rates, and a decreased level of consciousness on initial presentation.

MS: One patient had bradycardia, and the other patient's heart rate was on the lower side of normal. They were described as staring off into space—in almost an altered, postictal (post-seizure) state. This presentation of bradycardic and not responding to commands had first responders initially thinking they had overdosed on opioids. In retrospect, the patients did have some cholinergic symptoms at the scene, but I don't know how easy those were to recognize. Responders in this area were previously notified to be on the lookout for fentanyl analogs. The big thing providers noted was lack of pulmonary edema. Both patients had clear lungs, and did not demonstrate any airway or breathing difficulties.

SC: It is so important to leave open differential diagnosis, and keep in mind what the environment outside of the medical scene was like. How did they get to the bench? Who were they? That is one of the things that turned the course of the events—one of the law enforcement officers knew that the male had been a Russian spy and informed the hospital.

JH: As time went on, did pulmonary issues or hemodynamic consequences increase?

SC: There were no issues with their airways. They did receive tracheostomies, but much later.

MS: Yes, the tracheostomies were for prolonged intubation—not because of airway failure. On arrival, a key finding was lactic acidosis. Lactates were at 5 and 13 millimoles per liter. Their pH levels were around 7.1 or 7.2, with a bicarb of 14. They were unresponsive, acidotic, had small pupils, and were eventually intubated and provided supportive care. While this could at first be presumed as post-seizure lactic acidosis, the lack of rapid clearance of the lactate made it clear that this was not only from a seizure. The fact that this

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After the 2018 incidents in the U.K. involving an FGA, the White House National Security Council convened a federal interagency working group to identify and develop resources to help the emergency response community prepare for and respond to a similar incident. While FGAs share similar characteristics with other nerve agents, FGAs also pose several unique challenges in terms of toxicity, detection, persistence, and potential for delayed onset of symptoms. Four resources were developed to address these characteristics and challenges and provide tailored guidance to various segments of the emergency response community:

- Safety Awareness for First On-Scene Responders Bulletin
- Reference Guide
- Pre-hospital Medical Management Guidelines
- Hospital Medical Management Guidelines

These are all located on CHEMM's Fourth Generation Agents page.

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persisted kept the differential diagnosis open.

JH: Did the physicians try atropine to control the bradycardia?

MS: Yes, and the patients responded well to atropine.

JH: How long did the hemodynamic issues and other effects last?

MS: They were intubated in the emergency room, and were started on fluid resuscitation and initially, the providers were still treating them as though they had overdosed on opioids, even though when they look back, there were some things that didn't fit. They got bradycardic overnight—one got to a heartrate of 12—but they did respond to atropine. The nurses noticed that the sheets were wet due to intense sweating, so they changed them overnight, yet neither patient ever became febrile. On the first night, the ICU physician actually considered a cholinergic-type poisoning, but the absence of pulmonary symptoms (i.e., edema) led him away from that diagnosis.

They didn't get extubated for weeks, as sometime in the first 24 hours of the hospital course, they became hemodynamically unstable and needed vasopressors.

JH: What worked as far as treating their blood pressure issues?

MS: They went on a vasopressor and fluids, and they also became markedly hypernatremic (i.e., their electrolytes were significantly imbalanced), with a sodium of 157 and potassium of 2.5. Basically, clinicians went into general supportive care mode, then once they realized who the patients were, they started different types of testing and treatment, to include administering atropine and 2-PAM (pralidoxime chloride). The clinicians who cared for the patients believed that 2-PAM helped with hemodynamic stability. It wasn't administered early because the diagnosis hadn't been made; 2-PAM was started somewhere in the 24-40 hour range. In these cases, Salisbury's delayed use of pralidoxime was judged to be clinically effective by the treating physicians and should be considered even if significant time after the exposure has elapsed.

The patients received pralidoxime and also parenteral scopolamine subcutaneously every eight hours (because there were no pulmonary secretions to which to titrate; they did scheduled dosing). Clinicians also used atropine boluses as needed to correct slow heart rates. The clinicians noticed that pralidoxime improved the patients' hemodynamic stability and urine output. But we need to caveat this—the patients were still getting supportive care. There are still a lot of theories about the medication having effects outside of just regenerating cholinesterases, but animal studies don't show consistent data that they improve hemodynamics with general carbamates or organophosphates. So the reliability of pralidoxime to make a difference is unclear based on literature with cholinesterase inhibitors in animal studies, but the clinicians who cared for these patients felt that it improved their hemodynamics.

JH: There's relatively little downside to repeat dosing of 2-PAM. It's known to cause some hypertension—is that possibly the effect they were observing?

MS: We aren't sure. There has been a lot of postulated theory that there are nicotinic receptor effects, including in the kidney, and that may be what contributed to the improved urine output. Did pralidoxime stimulate these receptors? The mechanism is still unknown. Their urine output improved, and that is what the clinicians noted.

JH: What else have we learned about patient treatment?

SC: In this case, the treatment was very prolonged, so the hospital went through large amounts of drugs.

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MS: While these were prolonged hospitalizations and the cumulative dosage was significant, we weren't seeing these 50 or 100 mg atropine usages in short time frames. Something else to note: the U.S. doesn't currently have parenteral scopolamine, so I don't know how we would make adjustments. When we talk about hospital preparedness, it is important to note these issues; we can't hang our hats on these amounts based on so few actual patient experiences.

JH: So what are some alternate preparations or formulations that are already available and could be used if needed?

SC: Ophthalmic atropine can be used sublingually if it's available as the concentration is high.

MS: If you look at the [paper published on contingency countermeasures](), you have other anticholinergics (e.g., Atropine [1% Ophth 5gtt SL] or Cyclopentolate [1% Ophth 20gtt SL] or Glycopyrrolate [0.4mg IV/IM/IO]). These are all options, as are inhalers (e.g., Ipratropium inhaler [4-6 puffs] OR Tiotropium inhaler [2 capsules]).

Dosing on these is going to be a challenge because if you are using a sublingual route, and the patient is experiencing significant salivation, you may have to compensate with higher dosing or possibly preparing the patient by placing a cotton ball under their tongue to blot the saliva before administering the medicine. If

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we take a step back from FGAs and just talk about nerve agents in general, you really need to factor in how much drug is absorbed sublingually. ASPR's Biomedical Advanced Research and Development Agency (BARDA) is planning a study of the ophthalmic atropine product to determine pharmacokinetics and bioavailability with sublingual administration.

The more complex the drug pharmacology, the more side effects you'll need to anticipate. If we think the patient was exposed to a nerve agent and seizure activity is possible, we try to stay away from drugs that have a wide range of central nervous system effects. The bottom line is we have no data, so we ideally stay away from those types of drugs.

JH: Benzodiazepines have historically been discussed as both anti-seizure medications and to help manage the psychological effects of earlier generations of nerve agents. Should this still be considered?

MS: I would use the benzodiazepines first across the board.

SC: Midazolam is now FDA approved for status epilepticus. It's rapidly absorbed after intramuscular injection, making it easy to use in the field and mass casualty situations.

JH: Was any decontamination done on the patients once the providers realized what they were dealing with?

MS: Yes—the first thing to remember is these patients developed significant sweating during the first hospital day. The sheets were changed, and they received traditional patient hygiene while in the ICU. Based on agent detected from skin swabs, on Day 10 of hospitalization, the palms of their hands were treated with Reactive Skin Decontamination Lotion (RSDL). This was repeated on Day 16. Skin-measured levels appeared to drop after each RSDL application. It's another lesson that we learned—delayed RSDL use still removed the agent.

JH: For those who do not stock RSDL, would soap and water still be effective?

SC: Yes, soap and water will work, but healthcare providers need to be careful about the water runoff - they need to try to contain it and avoid contact with it as much as possible.

JH: Did any providers experience negative health effects from treating these patients?

SC: No, fortunately their use of universal precautions was effective. ■

Organophosphate and carbamate pesticide exposures are common and can present the emergency department with challenges including provision of safe decontamination and supportive care and specific treatment. The 2017 Annual Report of the American Association of Poison Control Centers' National Poison Data System indicates that Poison Control Centers were consulted in 2017 on three fatal cases and:

- 2,326 case mentions of "Organophosphate Insecticides Alone;"
- 35 "Organophosphate Insecticides in Combination with Carbamate Insecticides;" and
- 493 "Organophosphate Insecticides in Combination with Non-Carbamate Insecticides."

Chemical Hazards: Preparedness and Response Tools

As threats to national security emerge and evolve, ASPR, CDC, and other federal partners are collaborating to help prepare and protect our communities. In this article, Susan Cibulsky, PhD, a Senior Policy Analyst with ASPR and Susan Gorman, PharmD, MS, Associate Director for Science and Science Branch Chief for Strategic National Stockpile, ASPR discuss tools and resources that can help emergency responders and healthcare providers learn more about and respond to chemical incidents involving industrial chemicals, chemical warfare agents, and emerging threats.

John Hick (JH): What are some of the gaps you see in chemical incident preparedness on the community level?

Susan Gorman (SG): I don't think chemical preparedness gets the same level of attention as biological preparedness. In general, communities conduct fewer exercises and awareness activities on chemical incidents. And yet, the breadth of chemicals that can be released is much larger than the biological threats we are preparing for, and there are not many antidotes for all the chemicals that can pose a threat.


Photo courtesy of Strategic National Stockpile.

Susan Cibulsky (SC): There is also more of a burden on local communities because in many cases chemical incidents proceed rapidly and the acute health effects can be seen in a very short period of time (minutes to hours). There is not enough time for the federal government to move resources long distances to participate in the initial response. Generally speaking, local communities bear the responsibility to respond on their own.

Nerve agent antidotes are needed very soon after an exposure, before Strategic National Stockpile (SNS) delivery can take place. State and local governments had limited or no chemical/nerve agent antidote stocks. Hospitals carried very limited supplies of treatments for nerve agent exposures. Nerve agent antidotes are costly and have variable shelf lives (not an easily sustainable resource).

The CHEMPACK program was created in 2002 to address these issues and:

- Provide, monitor and maintain a nationwide program for the forward placement of nerve agent antidotes.
- Provide state and local governments a sustainable resource and improve their capability to respond quickly to a nerve agent incident; and
- Ensure storage of antidotes under conditions that allow their shelf lives to be extended.

Taken from https://chemm.nlm.nih.gov/chempack.htm#provisions

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JH: And because of that, some federal resources need to be pre-deployed. Can you comment a bit on CHEMPACK? Have the plans received the attention/ exercises or other things that other mass casualty or biological plans have? How do you see it moving forward and what do communities have to do to integrate CHEMPACK in their pre-hospital response plans?

SG: CHEMPACKs are forward deployed throughout the U.S. We worked with each state and territory early on to give them a chance to choose the number and types of CHEMPACKs they wanted based on the population-related budgets they received. States also got to choose where the CHEMPACKs would be placed in conjunction with the Strategic National Stockpile. They may be housed in different locations. We did not dictate to them how they need to use or integrate them. We wanted them to integrate them in their all hazards or HAZMAT response plans in ways that would best serve their communities, so this may differ widely throughout the U.S.

For example, in Georgia, the GA Poison Center is the hub for any requests for CHEMPACKs. In a nerve agent or organophosphorus incident, a call would be placed to the center and they would quickly locate the nearest CHEMPACK, connect the affected area to that location, and help make transport arrangements.

Consequently, they do their own exercising. There is no national exercise program for CHEMPACK containers; we want their exercises to complement their local response plans. We do have a few training containers that states can request; these containers have replica cases of materials participants can break down.

It's incumbent on local areas to exercise their plans and ensure that these types of steps are clear.

JH: How have CHEMPACK contents changed recently, and do you anticipate more changes?

SG: We recently added midazolam to the CHEMPACK containers—the hospital containers now have some diazepam multi-dose vials and some midazolam (Seizalam) multi-dose vials, as well as atropine and pralidoxime vials. The EMS containers primarily hold auto injectors (either Mark 1 kits, Antidote Treatment-Nerve Agent, Autoinjector [ATNAA], or pralidoxime autoinjectors, as well as different types of atropine auto injectors) plus all have midazolam multi-dose vials. Due to some manufacturing challenges in the U.S., we were able to import atropine auto injectors from Israel.

Hospital containers no longer have auto injectors in them. The autoinjector quantities were backfilled to include additional multi-dose vials of pralidoxime, atropine, and diazepam. There are

RELATED RESOURCES

The 2nd edition of PRISM decontamination guidance is provided in three volumes:

1. Strategic Guidance
2. Tactical Guidance
3. Operational Guidance

The "Algorithm Suggesting Proportionate Incident Response Engagement" (ASPIRE), a decision-aid for PRISM, was created to help identify the need for patients exposed to chemical agents to undertake wet decontamination.

The Wireless Information System for Emergency Responders (WISER) can also help responders in HAZMAT incidents.

ASPR TRACIE's Pre-Hospital Patient Decontamination and Hospital Patient Decontamination Topic Collections contain additional resources, including OSHA's Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances.

Learn more about your state Poison Control Centers.

AskRail allows qualified responders to access information on hazardous train cargo being transported through their communities.

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no other major changes anticipated for the program at this time.

SC: CHEMPACK still only contains medical countermeasures for nerve agents and other organophosphorus compounds. But in another recent change to the Strategic National Stockpile (SNS), Silverlon was approved by the FDA for treating cutaneous injuries as a result of sulfur mustard exposure. Silverlon had already been stockpiled in the SNS burn blast kits to treat thermal burn injuries; this new FDA approval expands the product's utility.

JH: Going back to the concept of "all response is local," one of the issues that comes up a lot is effective pre- and hospital decontamination. Can you talk about the PRISM documents and how they were developed?

SC: Primary Response Incident Scene Management, or PRISM, guidance is based on several years of research funded and overseen by BARDA. The recommendations are evidence-based and centered on the goal of decontaminating people as quickly as possible. EMS engages the patients themselves and instructs them on moving away from the site, removing their clothing, and doing some dry decontamination with any type of absorbent material. This can all be accomplished before specialized decontamination equipment arrives and is set up. PRISM work has shown that clothing removal and dry decontamination can remove most of the contamination if done correctly. This approach is applicable to a wide variety of chemicals and exposure scenarios, making patient decontamination a broad spectrum medical countermeasure.

JH: That's really important—it's the first time we have had data that supports that clothing removal and dry decontamination is effective. And sometimes wet decontamination is not possible in a pre-hospital environment based on climate, the amount of time and resources available, and the like. If you have some dry decon kits and clothes for people to change into, it can minimize injury and exposure to both the patients and first responders. What about hospital-based issues with HAZMAT incidents?

SC: The PRISM guidance can be incorporated at hospitals as well—as we've learned, many patients will likely go directly to hospitals without first being evaluated or decontaminated at the scene. Hospitals need to plan to receive potentially contaminated patients. They can establish areas for dry decontamination to initiate the process while simultaneously setting up their triage, wet decontamination, and evaluation systems. In the guidance that ASPR and the Department of Homeland Security published prior to PRISM, we also emphasize that field responders and hospitals should plan and train together to ensure a common approach. Knowing each other before an incident and having confidence in the pre-hospital decontamination that has already been done is invaluable.

JH: Can CHEMPACKs be used to treat an incident of organophosphate exposure—regardless of whether it's an accident or a terror incident—in the event that the local stock of antidotes is insufficient? And once a container is opened, what happens next?

SG: Yes. The containers are federally owned, but locally managed. They are monitored for temperature so that the contents may be placed into the federal shelf life extension program to extend the life of the product. Local officials in charge of the CHEMPACKs do not have to ask federal permission to open the container once the local supply of antidotes has run out. Once the door is opened, the SNS will receive a notification alarm, but at that point, they can take out the contents and distribute them to the field and/ or to hospitals as needed. After the incident is over, SNS is responsible for replacing

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Photo courtesy of Strategic National Stockpile.

the content of the CHEMPACK (pending availability of product and funds) and resealing the container. The CHEMPACK training containers do not hold actual product. They just have empty cases; training auto-injectors are not included.

JH: Have CHEMPACKs been used in response to any incidents?

SG: No, they have not yet been used.

JH: Do you keep track of CHEMPACK exercises, or how often the training materials are used?

SG: The training containers with the empty cases are not often requested, and unless we are invited to participate in the exercises, we do not track them. We do participate in state-level exercises for various threats; if a request comes in, we do our best to support it.

JH: It's certainly incumbent upon local jurisdictions to make chemical preparedness a priority. Toxic industrial chemicals are a matter of significant concern from both an accidental and intentional standpoint. Can you both discuss the guidance available for these types of incidents?

SG: It's important for communities to know what they have in their location and conduct a hazard risk analysis to know what to be prepared for. For example, if they know that trains carrying chlorine traverse their community, they could better prepare for a related incident. While SNS is not a first response mechanism, we do have materials we could use to provide backup and resupply should the local cache run out (e.g., airway management supplies and ventilators that could be used for pediatric and adult patients).

SC: It is so important to conduct these analyses to identify risks unique to each community. Communities should be familiar with their nearest poison control center –they can always reach out to poison control for medical treatment advice.

Check out ASPR TRACIE's Hazard Vulnerability Assessment Topic Collection and our Evaluation of Hazard Vulnerability Assessment Tools for related resources.

JH: From a planning standpoint, some communities have very active local emergency planning committees, but integrating the healthcare coalition can also be beneficial and help members understand the risks, hazards, and assets available to the community.

SG: Yes, and I would strongly encourage state and local planners to find out where their CHEMPACKs are and what the plans are to access them. I would also encourage them to use the CHEMM website for planning and information-gathering purposes.

SC: Engaging with law enforcement and other public safety agencies can help the healthcare community (and the community at large) stay informed about emerging chemical threats and hazards. For example, we are in the midst of an opioid public health crisis and large amounts of highly potent illicit drugs are easily accessible to the public. New variants of such drugs are continuously being synthesized for illicit purposes. Staying vigilant and aware can help us prepare for and manage the effects of these and other threats to our nation's health. ■

The Effect of Chemical Incidents on Hospitals:

An Interview with Stephen Grant, MD, Lexington Medical Center

For more information, access these reports:

- Collision of Norfolk Southern Freight Train 192 With Standing Norfolk Southern Local Train P22 With Subsequent Hazardous Materials Release at Graniteville, South Carolina January 6, 2005
- Public Health Consequences from Hazardous Substances Acutely Released During Rail Transit

At 2:39 a.m., on January 6, 2005, Graniteville, SC was the scene of a deadly train derailment. Three chlorine tankers derailed and one ruptured, releasing between 46 and 90 tons of chlorine. In this interview with ASPR TRACIE, Dr. Stephen Grant described the initial chaos in the emergency department and how the medical response was managed in this incident that led to 9 fatalities, 554 people receiving treatment at hospitals, and 75 admissions.

John Hick (JH): Take us back to that night—describe the hospital and staffing when the crash occurred.

Stephen Grant (SG): At the time of the incident, Aiken Regional Medical Center was undergoing reconstruction. We had 180 beds, which included 14 emergency department (ED) beds and five express beds. That night, we had 141 inpatients and one ICU bed available. We didn't have any decontamination areas—that

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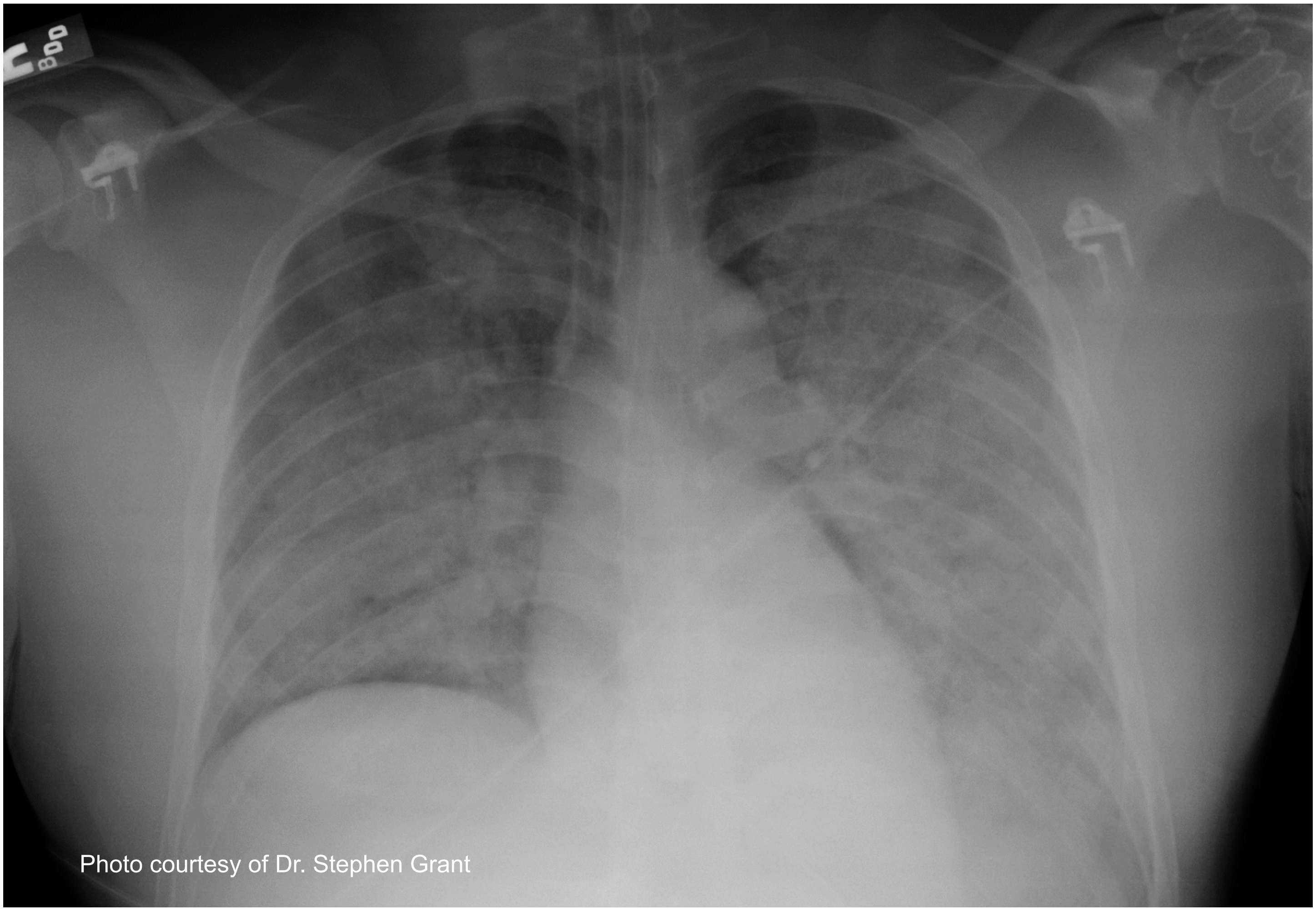
Photo courtesy of Dr. Stephen Grant

was part of the construction. We had one overnight doctor, five ED nurses, a few technicians, and two respiratory therapists working. I was called in to assist and stayed until about 4:00 the next afternoon.

JH: How were staff first notified about the incident?

SG: About 15 minutes after the derailment, the ED received the call from Aiken County Dispatch/ Emergency Medical Service (EMS). Patients showed up within minutes—many of them self-evacuated—and the ED very quickly became a scene of mass confusion. Patients complained of burning eyes and throats, chest discomfort, and shortness of breath. At first, we didn't know what toxin or chemical we were dealing with. The initial report listed sodium nitrate, and later we were told it was methanol. A lot of time was wasted because of this miscommunication—those on the scene actually knew it was chlorine, but it took a while for that message to reach the ED.

JH: How did you manage that many patients with respiratory symptoms?

SG: It was 2005, and we didn't have the pulse oximetry capacity we have now, but we brought what we had into the ED. That was the line we drew —if people had low O2 levels, they were brought into the ED. The other patients were parked in the triage waiting room area. The traditional treatment for chlorine gas exposure is

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decontamination, oxygen, bronchodilators, and mechanical ventilation as needed. At first, it was difficult to decide between who to intubate versus who to provide humidified oxygen. After a couple of hours, we got a call from Lexington Medical Center (where I currently work), as they started to receive patients. They were using inhaled sodium bicarbonate and found that it was easing symptoms and preventing patients from needing intubation. It's important to note here that there are no controlled studies on treating this type of patient, so like much of the toxicology literature, it's a matter of case reports and conjecture. In this instance, it relieved patients' symptoms.

We didn't perform formal decontamination at first—we didn't have the people or the supplies for that. Once the police arrived, they helped set up a barrier and decontamination area across the street, on the USC Aiken campus. Aiken Public Safety and EMS hosed patients down and gave them scrubs, then sent them over if it was determined they needed further treatment.

We also didn't formally register our patients. In fact, we probably treated patients who were never registered. We used paper-based triage and lab slips and hard copies of X-rays.

JH: Did you run into issues with capacity specific to the number of intubated patients and critical care resources you needed?

SG: We called a trauma alert and that freed up capacity. Canceled same-day and elective surgeries, freeing up 20 beds. The post-anesthesia care unit (PACU) became our satellite intensive care unit (ICU). PACU was staffed by pulmonologists and hospitalists and held intubated and sicker patients. Pediatricians, internists, and day surgery nurses treated non-acute cases in the day surgery area. Express care beds were used for secondary triage/observation.

We found that once patients were stabilized, the anesthesiologist could manage the ventilators and respiratory issues until we got patients to the PACU. We had pediatricians handle more mild exposures as they would treat a patient with asthma. By 4:00 P.M. (a little more than 12 hours after the crash), 24 patients were admitted—they all either had beds or were in the PACU.

JH: We know that chlorine can have delayed effects—did you see patients who deteriorated?

SG: Yes, we had a second surge of patients over the next two days with mild to moderate symptoms.

> "Nine persons, including the train engineer, died from chlorine gas inhalation as a result of the accident. Of the eight civilians who received fatal injuries, six were employees of Avondale Mills facilities to the west and north of the accident site, one was a truck driver at one of the plant facilities to the west of the site, and one was in a residence south of the site."
>
> National Transportation Safety Board Railroad Accident Report RAR-05/04

Several re-presented with hypoxia and pulmonary edema that was not present initially. Thankfully, they all did well. No patients were admitted after the first day and after day 4, the number of patients steadily declined.

JH: Did you have all of the ventilators you needed?

SG: Yes, and because we cancelled other procedures, we were able to use surgical ventilators, too.

JH: How did you manage patient transport?

SG: We actually mobilized school buses for transport—they were stationed at the decontamination

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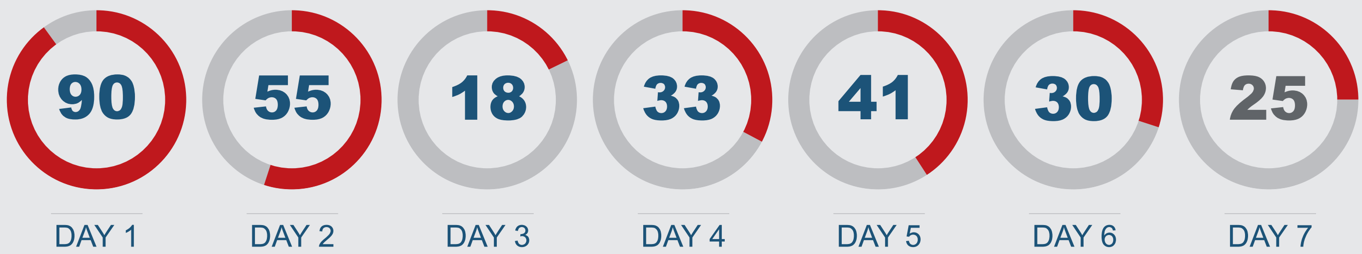
CHLORINE PATIENT ED NUMBERS (AIKEN):



center across the street (pre-established in our county disaster plan) and took patients to other hospitals (who had advance notice and were ready to take patients into ED). With enough notice, one hospital was able to provide rows of wheelchairs and had oxygen ready for incoming patients.

JH: Was your hospital in danger of needing to evacuate?

SG: While we were put on alert for the possibility, the wreck happened in a valley, there was very low wind, and we were located on a hill.

JH: Is there anything you would have done differently?

SG: Looking back, I can say I would have put an ED representative, like a charge nurse, at the command center. Communication was challenging. We did not know it was purely chlorine and nothing else for a couple of hours. There were four chemicals on the train.

JH: Have the patients been followed to see if they exhibit delayed respiratory effects?

SG: Yes, the Division of Acute Disease Epidemiology and the regional and county offices of the South Carolina Department of Health and Environmental Control worked with the Centers for Disease Control and Prevention to examine the effects of exposure and determine who was at risk for long-term effects. It is hard to define damage without baseline data—if your lungs are initially damaged, they won't improve. This was a very healthy population to begin with—there was a low number of smokers, for example. I did some research on people who had been exposed to chlorine gas during World War I, and it appears as though the intensity of the exposure is related to the chronicity of the scarring. ■

The Effect of Chemical Incidents on First Responders:

An Interview with Bruce Evans (MPA, NRP, CFOD, SEMSO), Fire Chief, Upper Pine River Fire Protection District

A massive leak of liquefied chlorine gas created a dangerous cloud over the city of Henderson, NV, in the early morning hours of May 6, 1991. Over 200 people (including firefighters) were examined at a local hospital for respiratory distress caused by inhalation of the chlorine and approximately 30 were admitted for treatment. Approximately 700 individuals were taken to shelters, and between 2,000 and 7,000 individuals were evacuated from the area. ASPR TRACIE interviewed Chief Bruce Evans (who was a firefighter-paramedic at the time of the incident), asking him to share his experiences and highlight how the fire and emergency response to chemical incidents has changed over the years.

Corina Solé Brito, ASPR TRACIE (CSB): Can you please share your experience in Henderson and other related incidents, how you think the field has changed since then, and what you think the future holds?

Bruce Evans (BE): I am fortunate to have lived through two major incidents that have culminated in U.S. Fire Administration technical reports. When I was 21, I left Central Iowa to be a paramedic in Las Vegas in 1985. Just a few years later, I was involved in my first large-scale incident: the PEPCON explosion. PEPCON was a rocket fuel plant that supplied propellant used for the space shuttle program. This explosion sent a shock wave over the entire Las Vegas Valley, blew out windows that were miles away, and created a small, multicolored mushroom cloud on the south end of the valley. The Professional Golfers' Association (PGA) was also in town, so there were satellite trucks and news trucks present. At that time, the rudimentary cell phone network was overwhelmed very quickly; this was my first experience with not being able to communicate with a supervisor. I didn't know what chemicals were in that cloud, or how many fatalities or injuries from flying debris were to be expected. The hospital—a small, critical access hospital at the time—became overwhelmed with the walking wounded. That was a "chaos event," and the type that most large departments hadn't

Access these U.S. Fire Administration Technical Reports for more information on these incidents:

- Fire and Explosions at Rocket Fuel Plant
- Massive Leak of Liquefied Chlorine Gas

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dealt with. At the time, Henderson Fire Department did not have paramedics as part of their team—after this incident, they decided to increase their level of care, and I was recruited to serve on that fire department.

Fast forward to 1991, when the largest leak of liquefied chlorine in U.S. history took place, also in the Las Vegas suburbs, at the Pioneer Chlor Alkali Company. Late that night, we (Henderson Fire) got a call to assist some firefighters from Clark County Fire Department who were at the company's gate. Our two communications centers ultimately decided that Clark County should respond first, since the facility—while it was essentially an "island" surrounded by the residential area of Henderson—was technically in the county's jurisdiction. At first, people were only reporting a strong smell of chlorine, so members of the first engine company, an ambulance, and a battalion chief vehicle pulled up to the gate without their air packs on. One of the captains later said he thought it was odd that the security personnel in the guard shack were wearing gas masks.

Pioneer Chlor Alkali was storing liquefied chlorine in tanks, and after crews had serviced the tanks, they had left some water in an elbow area of a pipe. When they recharged the tanks, the chlorine mixed with the water and basically formed almost pure hydrochloric acid, which burned right through the pipe. Because it was at an elbow, at a 90-degree angle, you couldn't get a patch on it. Nearly 90 tons of liquid chlorine spilled, then aerosolized at more than 300 times its volume.

As soon as the Clark County firefighters got out of the firetruck, they were immersed in and overcome by a cloud of extremely high parts per million of chlorine. Chlorine is a respiratory irritant that can cause non-cardiogenic pulmonary edema, and when it mixes with moisture—either in your airway or areas where

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you might be sweating, like your armpits or groin—it turns into hydrochloric acid and burns what it comes in contact with. When we arrived (wearing our air packs), we rescued eight people; as a firefighter-paramedic at the time, I remember very vividly seeing the battalion chief coughing up blood. Everyone had mucus running out of their eyes and noses, and their eyes were burning. We tried to decontaminate them as quickly as possible and get them to the hospital for treatment.

We returned to the command post, and this is when I learned a specific lesson. A command officer showed up and started making some questionable decisions that ultimately lead to the injury of more firefighters. The officer chose to send a few firefighters into the facility in a pickup truck to try to put a patch on the leaking container. The two members from the HAZMAT team were allowed to don Level B protection suits (Tyvek and an air pack). In this day and age, I would never let anyone go into a situation like that without a Level A suit.

When these two firefighters returned about 15 minutes later, jumped out of the truck, and started stripping off their clothes, I remember seeing how the chlorine had penetrated through their Tyvek suits. Most firefighters wear a navy blue t-shirt and navy blue pants. The chlorine had seeped through the Tyvek suits and bleached their shirts, turning them pink where the zippers were. It is extremely warm in those suits, and you essentially create your own humidity when you wear one. The gas reacted with the sweat in their armpits and groin areas, burning any skin that had perspiration on it. We had to strip them down and perform a field decontamination (i.e., rinse them with the fire hose) and transport them to the hospital.

We came back to the command post a second time, and I learned another lesson. The plant official, the expert on chlorine, arrived and told us we were too close to the spill and instructed us to move further away. I remember listening to him advise the incident commander, who replied, “Well, chlorine is heavier than air; it should travel downhill and we should be safe here.” About 20 minutes later, the cloud was so large that it overtook the command post and we had to evacuate and very hastily move to another staging area. Just 10 minutes later, the cloud grew even larger and overtook us again. We rescued four more firefighters who had been overcome by the fumes, and once again, the scene became chaotic.

At that point, I decided to take the four injured firefighters to another hospital farther away from the primary access hospital that we normally use. After we dropped them off, we sat in our truck and listened to the radio, waiting for someone to gain control over the scene. About an hour later, we heard that there was a strong incident commander in place, making good decisions, so we returned to the scene. Overall, we sent about 45 firefighters to the hospital.

Once the sun came up and the heat dissipated the chlorine, you could see this massive, green cloud sitting over most of the (evacuated) community. Within a couple of days, all of the trees were completely defoliated. Once the incident was deemed complete, the crews that performed most of the rescues reported to the hospital to be checked out. We realized the chlorine had off-gassed from patients and some of the firefighting equipment and actually pitted the stainless steel in the back of our ambulances.

Even though we wore our air packs while we treated patients in the ambulances, we all got a fairly significant dose of chlorine. The hospital that we went to had a TOMES database and they also called Poison Control, explaining that they were treating firefighters who had inhaled chlorine gas. At that time, the TOMES database and the Poison Control operator told the physicians to nebulize bicarbonate. We all sat in the emergency room (ER) with nebulizers, inhaling bicarbonate solutions.

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This was not the correct treatment plan. Simple chemistry shows that when you mix an acid in a base, it is going to give off heat, creating an exothermic reaction. So as we inhaled that nebulizer bicarbonate based on the directions given to the ER doctors by the Poison Control center, we all wound up with low-level respiratory burns. Most of us ended up with reactive airway disease, and it was probably seven or eight years before I could get my lung capacity up to where I could stop using an inhaler. One of my colleagues who had an underlying asthma condition was off work for almost two years, in a worker's compensation situation, while trying to get his lung capacity to the point where he could wear an air pack again.

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) later came in and highlighted the errors that were made and made recommendations for future work. Based on these results, and to reduce the pending fines (levied based on a NIOSH investigation into prior training, equipment provided, and other related factors), the International Association of Firefighters sent a team in from Phoenix and trained everyone in the department up to the HAZMAT operations level under the NFPA Standards 472 and 473, and covered how to operate in a Level A suit and perform decontamination. Additional research on our part found that the treatment protocol in the TOMES database used by the Poison Control operator at the time was based on one study conducted on only eight patients. Based on the lessons we have learned from other incidents over the years and the advancement of HAZMAT medicine, the guidance has changed significantly.

After that incident, I wanted to have the knowledge to be able to politely refuse an order or point out to an incident commander that their instructions might be unnecessarily putting people at risk. In 1994, the National Fire Academy began offering a new class called "Advanced Life Support Response to Hazardous Materials Incidents." Instructors taught one week of organic and inorganic chemistry followed by another week of toxicology. I took the inaugural course and I've been on the instructor cadre for this class for 20 years.

Subsequently, I had a long conversation with the director of the local Poison Control center, and we agreed they would look into their protocols and update them based on this experience. Now they know to use normal saline to dilute and stabilize the chlorine.

CSB: You said your health effects lasted 7-8 years. Can you share more about the health effects for other firefighters who responded to this incident?

BE: A lot of people who were injured were lucky enough to be moved into administrative and training positions. Ultimately, everyone returned to work. The battalion chief I mentioned earlier who was in non-cardiogenic pulmonary edema returned for about six months and then retired. After nearly two years, the firefighter-paramedic who had an underlying asthma condition returned to work and was able to finish his career.

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CSB: Did the event overwhelm the healthcare facilities? Was the hospital evacuated?

BE: This event absolutely overwhelmed the small community hospital located a quarter of a mile from the facility. Not only did we flood that facility with patients, but it was located downwind from the leak. If this were to happen now, we would evacuate the hospital, but it remained operational throughout the event. We had done shelter-in-place drills with the local schools, where they would shut down their HVAC systems, duct tape classroom doors, and put plastic sheeting around the entrances to the buildings. The schools were much more prepared than the hospital was for dealing with a chemical leak. I don't think zoning permits would allow a chemical facility like that to be built anywhere near a residential area today.

Of course today, hospitals are required to go through these types of drills. And when the hospital was remodeled several years ago, they incorporated lessons learned from the incident and added outside decontamination facilities close to the ambulance entrance and built double-door systems to enable them to isolate the ER. The Joint Commission has done a fantastic job encouraging hospital preparedness. With ASPR's help and after 9/11, hospital administrators understand that self-evacuated patients—some who may be contaminated with chemical or weaponized materials—can show up at the ER without any EMS involvement, and are preparing for these scenarios.

CSB: What else "keeps you up at night?"

BE: There is a human condition, or a protective factor, that makes us feel like things can't ever be that terrible, that terrible incidents like this can't happen. While we don't want to believe that humans can cause other humans harm, I feel like we still must focus on and prepare for the worst case scenario. We can learn a lot from the Israelis who unfortunately have vast experience in these types of incidents. EMS providers in Israel generally are allowed to take their vehicles home with them, allowing them to quickly respond in a vehicle that can transport a patient. In the article Health and Medical Response to Active Shooter and Bombing Events, we discuss the benefit of pre-designed response matrices which are programmed to assign a set of resources to specific incidents.

On a related note, I think one of the things we are losing sight of in traditional medicine is the "rule out." For a long time, physicians were taught to start by assuming the worst case scenario to cover all of their bases. This is being lost now, when providers are being pushed to stick to time-related metrics and make quick treatment decisions.

CSB: Do you have any final thoughts to share with our readers?

BE: After 9/11, first responders were supposed to be trained to the HAZMAT operations level, because the awareness level doesn't include the decontamination piece. But so many departments still only train to the awareness level and this is a challenge with private ambulances serving about 40% of the country. All of our ambulances at Upper Pine contain one five gallon bucket that holds two Tyvek (Level B) suits that can be paired with self-contained breathing apparatus to function as Level B equipment, an adapter hose, dish soap, and gloves—if responders encounter something in the field, they can quickly decontaminate.

Chemicals are evolving. Look at organophosphates, look at fentanyl. Bad actors involved with "street chemistry" are getting "better" at what they do. Including the basics of chemical awareness and response in continuing education programs can both increase responder resilience and readiness for the next asymmetrical incident. ■

Chemical Challenges

Contributed by John L. Hick, MD, Senior Editor for ASPR TRACIE, Hennepin Healthcare (Minneapolis)

In the late 1990s and early 2000s we focused tremendous energy on preparing for acts of chemical terrorism. Detection technology, decontamination trailers, personal protective equipment (PPE) purchases, CHEMPACK deployment, and significant education, training, and exercising advanced our communities' preparedness, capabilities, and resilience. In many jurisdictions, this preparedness has faded over time. Training has languished, equipment has been discarded or isn't kept up, CHEMPACK plans aren't operationally grounded and haven't been recently tested, and providers don't know how to recognize toxidromes or provide specific treatment.

Yet these threats have not diminished – in fact, the use of fourth generation nerve agents in several recent international incidents demonstrates that their development and use are ongoing. The accidental or intentional release of toxic industrial chemicals such as chlorine can also pose a major threat to populations as our contributors have highlighted.

HAZMAT incidents demand immediate action to contain the event, decontaminate victims while protecting staff and the facility, and provide appropriate treatment. Our readers may have perceived that sometimes, appropriate treatment still isn't clear based on the available evidence as noted with the use of sodium bicarb nebulizers mentioned in two articles in this issue. Benefit may be confined to those with lower concentration inhalations, or less pre-existing lung damage, but it's hard to do research on these types of therapies. Fortunately, most HAZMAT events result in a limited number of injuries, but the potential is there to rapidly overwhelm a community's medical capacity.

Healthcare coalitions are uniquely positioned to discuss, develop, and exercise the resources and policies specific to chemical events and must do so in the interest of community protection and provider safety. A few things to consider are:

- **Assess community threats.** Involving the Local Emergency Planning Committee (these have variable degrees of activity and participation) can be helpful in assessing threats and building public-private channels of communication and information sharing with industry and transportation partners.

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- **Offer access to provider education resources and sources of information.** CHEMM, WISER, AskRAIL, poison control centers, and other sources should be easily accessible and used. EMS and emergency department providers must be able to recognize the basic toxidromes (including cholinergic) and treat them.
- **Ensure effective information sharing.** Information sharing is critical in the early phases of an incident; making sure that the information available to and gathered by the HAZMAT responders is passed along to hospitals can help with agent identification and treatment. Plume information is also critical to making sheltering and evacuation decisions and ensures that any hospitals, long-term care, or other medical facilities in the affected area have as much warning and duration/concentration information as possible.
- **Prioritize PRISM guidance.** PRISM guidance should be used to adjust pre-hospital and hospital decontamination to emphasize "dry" decontamination, reserving "wet" decontamination for more heavily contaminated patients who have already disrobed and well-controlled incidents with a limited number of survivors.
- **Prepare for self-transported patients.** Hospitals should understand the pre-hospital capabilities for gross vs. technical decontamination as well as EMS capabilities at HAZMAT scenes (e.g., available PPE and role in the decontamination and treatment process) that may affect care of arriving patients. The hospital must be prepared for significant numbers of victims to bypass EMS; many of these patients will not require any significant medical care but will require triage for decontamination and treatment. OSHA's Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances provides excellent guidance for hospital decontamination programs. Trained staff must always be available to initiate a decontamination response.
- **Ensure that CHEMPACK plans are fully operational.** Assets must be accessible 24/7 by trained personnel who know what is in the containers, how they are to be distributed to the field/ within the hospital, and how assets are to be moved to other facilities/agencies as needed. Providers need to know what auto-injectors are in their packs (as there is variability), how to administer them, and how to dose them.
- **Plan for patient redistribution.** Hospitals should have a plan for redistribution of casualties and, when necessary, request of additional assets (e.g., ventilators) from federal stockpiles to support a major chemical response.
- **Jurisdictional collaboration is key.** Public health, public safety, and environmental protection agencies must agree prior to an incident on their roles for such functions as: evacuation orders, sheltering, safe return to evacuated areas, environmental monitoring, public messaging, and evaluation of effects on the population.

Chemical preparedness has taken a backseat to mass violence and biologic planning in recent years but the issues presented in this *Exchange* are no less pressing. Healthcare coalitions can facilitate local (and regional) discussions and plan scaled exercises to test the systems and resources in their community against realistic scenarios so that when an event happens, we are ready to provide an effective response that keeps our providers and facilities safe while efficiently sorting, decontaminating, and treating patients. ■

RECOMMENDED RESOURCES

TECHNICAL RESOURCES

After publishing our 57th comprehensively developed Topic Collection in August 2018, we began working with subject matter experts to refresh these resources. Our most recently refreshed Collections are: Emergency Operations Plans/Emergency Management Programs; Incident Management; Recovery; Continuity of Operations, and Volunteer Management. We continue to revise Collections; check back often. You can also learn more about rating, commenting on, and saving resources to your dashboard in this short tutorial.

ASSISTANCE CENTER

We encourage readers to access our summary of responses to select technical assistance (TA) requests. We have responded to TA requests for Biological, Chemical, and Radiological Resources; Chemical Hazard Spills; First Receiver Personal Protective Equipment (PPE) Screening Resources; and Level C Personal Protective Equipment (PPE) Resources for Pre-Hospital Healthcare Providers. For assistance navigating the Assistance Center, check out this tutorial.

INFORMATION EXCHANGE

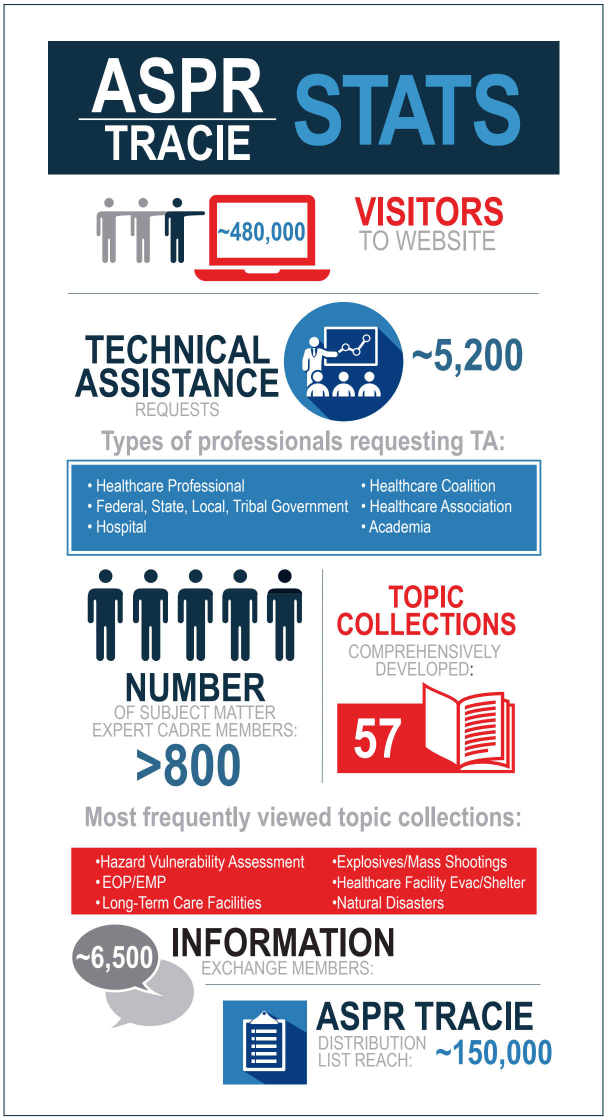
Register for the ASPR TRACIE Information Exchange, where you can share your opinions and resources with us and your colleagues. Already have an account? Simply log in and share your feedback! Need help registering for the Information Exchange? Access our quick tutorial.

ASPR TRACIE:

Your Healthcare Emergency Preparedness Information Gateway

The Exchange is produced by the Office of the Assistant Secretary for Preparedness and Response (ASPR) Technical Resources, Assistance Center, and Information Exchange (TRACIE). Through the pages of *The Exchange*, emergency health professionals share firsthand experiences, information, and resources while examining the disaster medicine, healthcare system preparedness, and public health emergency preparedness issues that are important to the field. To receive *The Exchange*, visit https://asprtracie.hhs.gov/listserv and enter your email address.

ASPR TRACIE was created to meet the information and technical assistance needs of ASPR staff, healthcare coalitions, healthcare entities, healthcare providers, emergency managers, public health practitioners, and others working in disaster medicine, healthcare system preparedness, and public health emergency preparedness. The infographic illustrates ASPR TRACIE's reach since launching in September 2015.



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