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Evaluation of Children Removed From a Clandestine Methamphetamine Laboratory

Penny Grant, MD

The illicit manufacturing and use of methamphetamine continues to be a significant and growing problem in the United States. Children are often found in homes where this activity is occurring and are affected by it on many levels. This article will provide background information on the manufacturing of methamphetamine, including classes of chemicals involved; hazards inherent to the manufacturing process and its effects on those living in a clandestine laboratory; and the approach to children found in these homes and their medical care. The focus will be on care in the acute settings with the introduction of a protocol for evaluation and follow-up of these patients.
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Amphetamines are stimulants that affect both the central and the sympathetic nervous system. Amphetamine was first synthesized in 1887. It was first commercially available in 1931 as the nasal spray Benzadrine, a racemic form of amphetamine [1]. The first amphetamine tablet appeared in 1937 and was used to treat narcolepsy. Because of its euphoric and stimulating as well as its appetite-suppressing effects, amphetamine use became widespread during the 1930s and 1940s and was used by foreign armies in World War II [2].

In the late 1970s, drugs similar to amphetamines began to appear. Methamphetamine is the *n*-methyl homologue of amphetamine. This structure decreases the polarity of the molecule and allows for better penetration of the blood-brain barrier. Methamphetamine releases dopamine from vesicular storage pools into the cytoplasm, where it is oxidized to form reactive oxygen species and neurotoxic quinones that are thought to cause neurite degeneration [3]. Biker gangs began manufacturing methamphetamine primarily from precursors including phenyl-2-propanone—the P2P method.

The Controlled Substance Act of 1970 regulated the manufacture of methamphetamine, restricting its availability. Manufacturing via another method, ephedrine reduction, began to occur in trailer parks and mobile homes and was more commonly found in rural areas [4]. Methamphetamine comes as a powder resembling granulated crystals or as a rock form, "ice," which is the smokable version that came into use in the 1980s [5]. Methamphetamine can be smoked, snorted, orally ingested, or injected. The drug's "rush" results from the release of high levels of dopamine into the brain, which is almost instantaneous if smoked or injected and occurs within 5 minutes if snorted and 20 minutes if orally ingested [6].

Data from the National Drug Intelligence Center's National Drug Threat Survey, published in 2005, indicates that state and local agencies now identify methamphetamine as their greatest drug threat (39.6%) surpassing cocaine, marijuana, heroin, or 3,4-methylenedioxymethamphetamine [7]. The 2006 National Drug Threat Assessment notes that methamphetamine availability is stable in long-established markets such as the Pacific, Southwest, and West Central regions while becoming increasingly available in the Great Lakes, Northeast, and Southeast regions [8]. In the Midwest,

Child Advocacy and Protection Program, Dartmouth-Hitchcock Medical Center, Lebanon, NH.

Reprint requests and correspondence: Penny Grant, MD, Montefiore Hospital-Albert Einstein College of Medicine, New York, NY. (E-mail: p.grant@montefiore.org)

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makeshift "mom and pop" laboratories produce relatively small amounts of methamphetamine for personal use or to sell to close friends and family. Synthesis methods are relatively simple, and no expertise in chemistry is needed. Methamphetamine producers often obtain their recipes from the Internet, friends, or inmates when imprisoned. To avoid law enforcement officials, laboratories have become quite mobile. It is not uncommon for a single batch of methamphetamine to be produced in several stages, with each stage occurring at a different location. Clandestine laboratories are found in cars, garages, trailers, homes, motel rooms, and rural areas [4]. Laboratories capable of producing greater than 10 lbs of methamphetamine, or "super laboratories," are more common in California, many controlled by California- and Mexico-based criminal groups [7]. According to the National Clandestine Laboratory Seizure System, methamphetamine laboratory seizures have increased steadily since 1999. Seizures have decreased in some western states but have increased in eastern states [7]. Decreased domestic production of methamphetamine has a resulted from an increased regulation of the sale of precursor and essential chemicals. However, these decreases have been offset by increased production in Mexico, which can ensure a steady supply to established US markets and facilitate the distribution of methamphetamine eastward [8].

According to the United States Drug Enforcement Administration, from fiscal year 2000 through the first quarter of 2005, more than 15000 children were reported as being affected in clandestine laboratory-related incidents. The term *affected children* is defined as a child being present and/or evidence that a child lived at a clandestine laboratory site. Of course, this total reflects only those instances where law enforcement was involved [9].

Manufacturing Methods and Risks

Methamphetamine manufacturing commonly starts with pseudoephedrine, the precursor, and requires the combination and addition of several other household chemicals as reagents. The classes of chemicals used include acids; bases; organic solvents; as well as lithium, red phosphorus, or iodine, depending on the method of synthesis. One method of manufacturing uses red phosphorus or hypophosphorous acid and iodine. Another method, commonly found in agricultural communities, uses anhydrous ammonia and lithium. Methanol, toluene, acetone, Coleman fuel, freon, and trichloroethane are just a few of the organic solvents that can be used in the synthesis of methamphetamine [10].

Organic solvents have known toxicities, including damage to the liver and bone marrow, or may be carcinogens. Inhalation of solvents such as toluene can cause respiratory irritation and central nervous system (CNS) depression or excitation and carries risk for aspiration [11]. Acids such as sulfuric, phosphoric, or hydrochloric and bases such as sodium hydroxide are 2 other classes of chemicals used in clandestine laboratories. Dermal exposure to acids can cause severe burns. Ingestion of acids or bases can cause esophageal burns, and inhalation can cause pulmonary edema and chemical pneumonitis [12]. Inhalation of chemical vapors can cause nausea, dizziness, headache, anxiety, and lethargy [13]. Iodine crystals, if inhaled, can lead to respiratory distress and mucus membrane irritation and, if ingested, can cause a corrosive gastritis [12]. Phosphine gas may be produced using the red phosphorus method, with effects including ocular irritation, nausea, stomach pain, headache, shortness of breath, and potential fatal respiratory and hemodynamic effects [14]. Literature on its adverse effects generally addresses industrial exposures among grain fumigators from the use of aluminum or zinc phosphide. The deaths of 3 individuals who were cooking methamphetamine in a motel room in California were determined to be due to inhalation of phosphine gas. Pulmonary edema appears to be the primary physical evidence of phosphine poisoning [15]. Anhydrous ammonia is usually found in agricultural communities for use as a fertilizer. When liquid anhydrous ammonia is released, it forms a dense gas that travels along the ground rather than dispersing upwards into the air, increasing the potential for exposure to children. Symptoms of exposure include eye, nose, and throat irritation; dyspnea; wheezing; chest pain; pulmonary edema; skin burns; vesiculation; and frostbite [16]. The different classes of chemicals and their major adverse effects are listed in Table 1.

Hazards From the Laboratory Environment

The most significant health risk related to the production of methamphetamine is acute injury secondary to massive chemical exposure via inhalation and contact to the skin and eyes. Thus, when a clandestine laboratory is raided, the law enforcement team wears personal protective equipment (PPE). In a retrospective cohort study of chemists and clandestine laboratory investigation teams in Washington State, most exposures in methamphetamine laboratories were via inhalation [17]. Most of these exposures occurred with chemicals dispersed via leaks, spills, fires, explosions, or uncontrolled reactions, with an increased risk of becoming ill during the active or ongoing chemical reaction (part of the manufacturing process). Reported symptoms included headache, sore throat, nose irritation, cough, breathing difficulty, eye irritation, skin burn/irritation, dizziness, chest pain, abdominal pain, and lung damage [17].

Table 1 Chemical components of methamphetamine laboratories and their attendant risks.

Chemical Class	Method of Exposure	Adverse Effects
Ammonia; liquid, anhydrous	Inhalation	Eye, nose, throat irritation, dyspnea, chest pain, pulmonary edema
	Dermal	Skin burns, vesiculation, frostbite
Acids and bases	Inhalation	Pneumonitis, pulmonary edema
	Topical exposure	Caustic burns
	Ingestion	Gastric perforation, esophageal damage with later strictures, nausea, vomiting
Solvents	Inhalation and ingestion	Liver and kidney damage, respiratory irritation, CNS effects, aspiration, headache
Iodine	Inhalation	Respiratory distress, mucus membrane irritation
	Ingestion	Corrosive gastritis
Phosphorus	Ingestion	Gastrointestinal irritation, liver damage, oliguria
Red phosphorus		Flammable
Potential: phosphine gas	Inhalation	Ocular irritation, nausea, headache, fatal respiratory effects

A report from the participating states in the Hazardous Substances Emergency Events Surveillance (HSEES) system from 1996 to 1999 noted 112 methamphetamine-associated events with 155 persons injured [18]. Of those injured, 51% were first responders including police officers, emergency medical technicians, firefighters, and hospital employees. Injuries were only described for the first responders, and no children were included in this report. These injuries included respiratory irritation (cough), breathing difficulty, throat irritation (54.1%), and eye irritation (10.8%). Of those injured, 77.2% were treated and released. Of the 84.8% of first responders whose PPE status was known, 85.1% were not wearing PPE at the time of injury. Of the 36 events causing injuries to first responders, 33.3% involved anhydrous ammonia, and 30.6% involved hydrochloric acid. In 33 of the 36 events for which the type of release was known, 57.6% involved air emissions, 30.3% involved fires, and 21.2% involved explosions.

From January 1 through June 30, 2004, 1,791 methamphetamine associated events were reported to the HSEES system with 558 events resulting in 947 persons injured. The 2 most common substances associated with injury were ammonia and hydrochloric acid. Injuries included respiratory irritation (39%), headache (26%), eye irritation (8%), and burns (8%). Of victims, 29% were treated at hospitals and not admitted, 7% were admitted, and 1% died. Of the 1,544 known event locations, 55% occurred in private households and 10% involved explosions [19]. One hundred sixty-four ammonia theft events with the intention of methamphetamine production, resulting in 85 persons injured, were reported to the HSEES system from January 1, 2000, through June 30, 2004. Of the reported injuries, 62% were due to respiratory irritation and 17% were from eye irritation, with 56% of the victims requiring treatment at a hospital without need for admission [16].

Horton et al [20] conducted an analysis of 519 methamphetamine-related emergency events in the HSEES database, with release of at least 1 chemical involving children from 1996 to 2001. Eight known events involving 13 injured children with ages ranging from 3 months to 17 years were reported. Three children sustained trauma, and 4 sustained respiratory irritation. Three children were hospitalized. The children who were affected were exposed via volatilization (2), spill (2), volatilization/spill (2), fire (1), and fire/explosion (1). Four exposures involved anhydrous ammonia with subsequent respiratory symptoms in 3 children. The other exposures were to toluene, lye, and solvents with symptoms including headache, gastrointestinal problems, chemical burns, and skin/eye irritation. One acid exposure led to chemical burns. Ether exposure because of an explosion/fire led to respiratory irritation and associated trauma. Of these events, 5 occurred in a private residence: 3 houses, 1 apartment building, and 1 duplex [20]. These exposures and their effects are summarized in Table 2.

Methamphetamine Exposure

Methamphetamine stimulates both the central and the peripheral nervous system. Systemic effects of methamphetamine use in adults involve the cardiovascular, psychiatric, neurologic, metabolic, musculoskeletal, and gastrointestinal systems. Symptoms include hypertension, tachycardia, hallucinations, irritability, mydriasis, hyperpyrexia, hyperactivity, nausea, vomiting, and diarrhea