High-Pressure Hand Injection Injuries Caused by Dry Cleaning Solvents: Case Reports, Review of the Literature, and Treatment Guidelines

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A previously unreported subset of high-pressure injection injuries, namely those involving solvents used in the garment dry cleaning industry, is presented. Dry cleaning solutions contain isoparaffinic hydrocarbons, methoxypropanol, and dichlorofluoroethane. Although these solvents have limited potential for systemic toxicity, severe local toxicity causing tissue necrosis often results in loss of the injured digit. Proper treatment includes prompt surgical exploration, careful débridement and irrigation, intravenous antibiotics, and in selected cases, high-dose systemic corticosteroids. (*Plast. Reconstr. Surg.* 111: 174, 2003.)

High-pressure injection injuries to the hand are uncommon but have potentially devastating consequences, including significant functional loss, and result in amputation in 21 percent to 48 percent of cases.[1,2] Despite recommendations that these accidents be treated as limb-threatening injuries,[1] their initial innocuous appearance often results in a delay in seeking medical attention, inadequate treatment by the primary-care physician, and lack of appropriate and timely surgical consultation. Most cases are work-related and involve industrial grease, oil, hydraulic fluid, or paint guns.[1,3] We present a previously unreported subset of high-pressure injection injuries—those of solvents used in the garment dry cleaning industry.

Case Reports

Five patients with confirmed dry cleaning solvent high-pressure injection injuries were identified during a chart review of all hand injuries at Bellevue Hospital during a 4-year period. Three of these patients were initially evaluated by a physician outside of our institution and were treated and discharged without formal surgical exploration. These patients presented late in their course and subsequently had worse outcomes. One case resulted in amputation of the injected digit.

Case 1

A 38-year-old man, who injected his left ring finger with dry cleaning fluid and was discharged from another hospital with a prescription for cephalexin, was admitted 3 days later with a swollen and ischemic digit, marked edema, and pus draining from the injection site, which was located dorsally over the proximal interphalangeal joint. He underwent incision and drainage of the digit and release of the digital vessels. Pus was found extending from the extensor hood to the dorsum of the hand stopping just distal to the extensor retinaculum. The flexor sheath, distal interphalangeal, proximal interphalangeal, and metacarpophalangeal joints were not involved. He was treated with intravenous antibiotics but 2 days later was reexplored for unrelenting and intense digital edema and further erythema. Pus and necrotic tissue found in the area previously explored was drained and débrided. He was eventually discharged but returned with progressive tip necrosis and two episodes of cellulitis over the next 8 weeks. He agreed to amputation when his necrotic finger demarcated at the proximal interphalangeal joint level.

Case 2

A 48-year-old woman injected her left index finger pulp with dry cleaning fluid. The next day, a physician irrigated the injection site, and she presented a day later with a diffusely swollen digit accompanied by extreme tenderness and pain

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with active and passive movement. Exploration of the digit revealed small pockets of pus, the culture of which grew *Staphylococcus aureus* and enterococcus. The flexor sheath was not involved. Necrotic tissue was débrided and she was treated with intravenous antibiotics. She was eventually discharged without need for further intervention.

Case 3

A 30-year-old man injected the pulp of his right index finger with dry cleaning fluid known to contain isoparaffin, hydrocarbons, and dichlorofluoroethane. The same day, he underwent drainage, débridement, and irrigation of the digit distal to the distal interphalangeal joint. After 3 days of elevation and intravenous antibiotics, he developed progressive pain, edema, and erythema of the digit and underwent further drainage of pus and débridement. An irrigation catheter was left in the wound, and 2 days later repeat débridement was preformed because of persistent edema and ongoing signs of necrosis. The flexor sheath was not involved, and culture of the pus failed to grow any organisms.

Case 4

A 35-year-old man who injected his left index finger with dry cleaning fluid containing isoparaffinic hydrocarbons, methoxypropanol, and dichlorofluoroethane was evaluated and discharged without treatment from an outside institution. He presented to our Emergency Department the same day with a painful, swollen, and indurated digit, which was immediately irrigated and débrided in the operating room. Postoperatively, he was treated with intravenous antibiotics and did not require further intervention.

Case 5

A 38-year-old man presented 17 hours after injecting the volar surface of his left middle finger with dry cleaning fluid containing isoparaffinic hydrocarbons, methoxypropanol, and dichlorofluoroethane. The affected digit was tender and swollen. Operative irrigation and débridement revealed tissue necrosis but no pus or involvement of the tendon sheath. He was treated with intravenous antibiotics and did not require further intervention.

DISCUSSION

In large published reviews of high-pressure injection injuries, the typical patient is a young male with injury to the nondominant index finger.[1,2,4] Initial symptoms are minimal and findings are not very startling. Hours later, significant swelling, discoloration, and pain occur.[3] The initial symptoms often lead to a delay in treatment, which contributes to the severity of the injury and consistently worse outcomes.

Mechanisms of injury include direct tissue necrosis resulting from the toxic effects of the injected substance,[5] high pressure generated by the injection gun (up to 69,000 kPa),[3] and ischemia resulting from tissue distension.[6] The amount of toxic material injected, the presence of secondary infection, and delay in proper treatment will determine the final outcome of these injuries.[7] Findings of a cool or poorly perfused digit on initial assessment resulted in amputation in all cases in one series.[1] Typically, paint and paint thinner injuries have much worse outcomes than grease gun injuries.[1,2,4,6,8]

In the garment dry cleaning industry, accidental systemic toxicity usually results from inhalation of solvents, most often perchloroethylene.[9] In our series, patients were exposed to several other solvents by high-pressure injection as opposed to inhalation. In three of the five patients, the solvents were known to be isoparaffinic hydrocarbons, methoxypropanol, and dichlorofluoroethane. Isoparaffins are branched aliphatic hydrocarbons of varying lengths used to manufacture paints, charcoal lighter fluids, polishes, and cleaners. They are colorless translucent liquids at room temperature and do not have a strong odor. Isoparaffins have very low systemic toxicity in humans by oral, dermal, or inhalational exposure and only cause slight to moderate dermal irritation in animals and humans in occluded patch tests.[10] Methoxypropanol is a colorless liquid used as a solvent, and it also has a low systemic toxicity. Chronic dermal exposure with methoxypropanol on rabbits produced a mild transient irritation. Inhalational exposure of humans to 1000 parts per million caused irritation of the eyes, nose, and throat and signs of central nervous system impairment.[11] Dichlorofluoroethane is a colorless gas classified as a Freon and is used as a refrigerant, aerosol propellant, and solvent.[12] Sniffing halogenated hydrocarbons has been reported to cause sudden death from cardiac arrest.[13] Animal studies have demonstrated the mechanism to be sensitization of the myocardium to epinephrine.[14]

Although most hand injection injuries involve grease or paint, a series of Freon injection injuries to the hand has been reported.[15] These patients injected themselves with hexafluoroethane, a gaseous Freon. They were managed conservatively without operation, and all had resolution of symptoms within 7 days. In contrast, our patients all underwent incision, drainage, and débridement, and two required secondary explorations. The success of conservative treatment of Freon injection cases may be because of the low injection pressure or to the less damaging effects of Freon compared with other hydrocarbons.

Injection injuries involving paint or grease typically leave pigmented solvents in the tissues

that are easily identified and removed. The solvents involved in our series of patients were either colorless liquids or a gas, making visual identification and complete removal difficult. Because of the small amounts injected into the tissues, cardiac and central nervous system toxicities are unlikely.

Use of systemic corticosteroids to decrease inflammation in high-pressure injection injuries is controversial. Although there are no proper controlled studies addressing high-pressure injection injuries, there is a theoretical risk of infection associated with high-dose systemic steroids, especially in the presence in necrotic tissue and compromised blood supply, as seen in these patients. However, Lewis[1] supports steroid use, arguing that these organic chemicals tend not to support bacterial growth and infections are not a major problem. A prednisone taper starting at 40 mg per day has been reported to promptly and significantly attenuate the tissue response to the toxic effects of injection injuries in two patients.[16] Likewise, a regimen of hydrocortisone followed by prednisone has been attributed to improved outcomes.[2]

Based on the conclusions of previous reports and our own observations, the following guidelines are suggested for optimal treatment of dry cleaning solvent high-pressure injection injuries:

1. Early medical evaluation, including radiographic studies.
2. Prompt surgical consultation. Patients treated properly within 10 hours of injury had much better outcomes than those treated in a delayed fashion.[6]
3. Administration of tetanus prophylaxis and intravenous antibiotics.
4. Elevation and splinting before and after surgical exploration. Do not use cooling packs to control edema because their use may further compromise tissue perfusion.
5. Surgical exploration using general anesthesia or axillary block. Digital and local blocks may contribute to tissue edema and are associated with worse outcomes.[6]
6. Use of an extremity tourniquet to establish a bloodless operative field after exsanguinating the arm by elevation. Esmarch bandage exsanguination may cause further spread of the injected toxins into tissue planes or compartments.[1]
7. Wide surgical exploration, including decompression of tissue compartments, débridement of nonviable tissue, and high-volume saline irrigation. Particular attention should be directed toward fluid tracking around neurovascular bundles; flexor tendon sheaths are less likely to be involved.[17]
8. Wound cultures when appropriate to direct antibiotic therapy.
9. Consideration of leaving the wound open, with a planned "second look" operative irrigation and débridement.
10. Consideration of early amputation of a cool or poorly perfused digit.[1]
11. If edema is significant, consideration of administering 100 mg of hydrocortisone intravenously every 6 hours until improvement is observed. Change to 25 mg of oral prednisone daily and taper over 3 to 5 days. Restart hydrocortisone if edema, erythema, or pain worsens.[2]
12. Frequent postoperative reassessment and return to the operating room if indicated.
13. Early postoperative hand therapy to maximize functional outcome.

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