High-Pressure Paint Gun Injection Injury to the Palm

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Abstract

High-pressure injection injuries often have a misleadingly benign presentation. However, it is important to recognize the potential surgical urgency and long-term sequelae associated with these injuries. We present a case of paint gun injection to the palm and review the literature on high-pressure paint injection injuries. The 3 factors most important for the fate of the limb are material type, injection pressure, and injury site. The immediate use of antibiotics and tetanus prophylaxis, with or without steroids, is indicated. Urgent debridement in the operating room is imperative and can decompress the neurovascular structures and flexor tendon sheath by removing the irritating agents. Reported overall amputation rates have been as high as 30%.

Case Report

A 33-year-old right-hand–dominant bridge painter presented to the emergency department (ED) 2 hours after an injection injury to the right palm. The patient had been cleaning a high-pressure paint gun when it discharged an unknown amount of water-based paint, causing immediate pain in the right hand. The patient's hands were washed with soap and water and a bandage was applied.

The patient presented in no apparent distress, with a small puncture wound over the A1 pulley of the long finger and paint visible in the wound (**Figure 1**). Minimal tenderness was present distally over the proximal phalanx of the index and long fingers. There was full active range of motion (ROM) of the long finger throughout all joints. Hand radiographs showed radiodensity in the intermetacarpal space between the index and long fingers (**Figures 2A, 2B**).

In the ED, initial management consisted of administration of cephalexin and tetanus toxoid, irrigation with normal saline, limited debridement of visible paint, and wound dressing. Then, within 4 hours of presentation to the hospital, the patient was brought to the operating room for irrigation and debridement.

A tourniquet was inflated on the upper arm after gravity exsanguination. A volar Bruner incision was made to extend the traumatic wound in the palm and over the proximal phalanx of the long finger. Paint was found in the soft-tissues of the palm in the area of the A1 pulley and flexor tendon sheath, extending to the base of the proximal phalanx. The paint enveloped the neurovascular bundles circumferentially.

We removed most of the foreign material but could not extract minute amounts of paint deep to the neurovascular structures. Neurolysis of the radial digital nerve of the long finger and the ulnar digital nerve of the index finger was performed. The flexor tendon sheath was not violated by the foreign material. After repeat irrigation with normal saline (**Figure 3**), a Penrose drain was placed in the wound to allow for drainage, and the incision was closed with nylon sutures.

After surgery, the hand was immobilized in a short arm splint and elevated in a Carter pillow. Antibiotic prophylaxis, which had been started before surgery, was continued with cephalexin and ampicillin/sulbactam. The patient was neurovascularly intact throughout but had limited ROM because of pain. On postoperative day 1, the Penrose drain was pulled. On postoperative day 2, irrigation and debridement were repeated in the operating room to reassess the viability of the tissue in the injury site. Minimal fatty necrosis was noted in the zone of injury, and this tissue, along with a small amount of paint, was debrided.

The hospital course was uneventful and on postoperative day 4, the patient was discharged home with instructions to continue ampicillin/sulbactam for 1 week and to work on digital ROM. At first follow-up, 7 days after surgery, the wound was dry, and there was no evidence of erythema. The patient noted paresthesias along the radial border of the long finger, without motor deficits. The sensation was intact to light touch, and capillary refill occurred in less than 2 seconds. Active flexor digitorum superficialis and profundus function were intact. We referred the patient for hand therapy to improve ROM and strength.

During the most recent follow-up visit, 4.5 months after injury, the wound was fully healed. The digit had full active ROM. Metacarpophalangeal joint ROM was 0° to 90°, proximal interphalangeal joint ROM was 0° to 90°, and distal interpha-

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Figure 1. Benign appearance of patient's traumatic injection site.

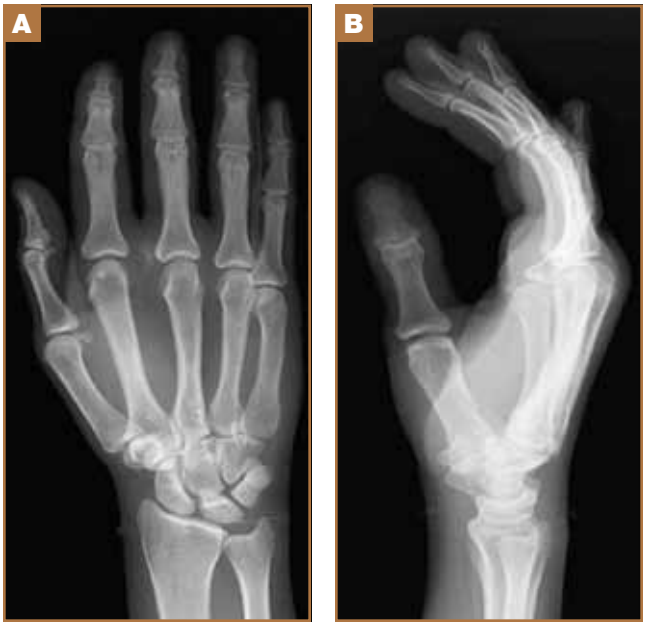

Figure 2. Anteroposterior (A) and lateral (B) radiographs of injured hand show radiodense material in injection site.

langeal joint ROM was 0° to 65° (**Figures 4A, 4B**). Two-point discrimination was between 4 and 5 mm on both the radial and ulnar aspects of the index and long fingers. There was no tenderness over the surgical incision or flexor sheath. The patient returned to work 2 weeks after the injury—beginning with light duty and progressing to full duty, without limitations, within 2 weeks.

The patient provided written informed consent for print and electronic publication of this case report.

Discussion

High-pressure injection injuries, first described by Rees[1] in 1937, accounted for about 1 in 600 hand injuries at the time.[2] Descriptions of paint gun injections date back to a 1963 case report by Workman.[3] Given the limited number of these injuries, the variability in materials injected, and the inability to prospectively examine treatment options, most of the literature on this injury consists of case reports and small retrospective series. A search of the 1966 to 2003 literature found 435 cases of high-pressure injection injuries distal to the elbow; 431 of these patients were male, and mean age was 35 years.[4] These injuries most often affect the nondominant index finger metacarpal, with the middle finger next in frequency, and the forearm last.

High-pressure paint sprays often operate around 3000 psi[5] (range, 700-7000 psi[6]). Injuries most often occur when injectors are being cleaned or when nozzles are being unblocked; during these activities, outflow pressure is increased to a value higher than that listed.[4] Although the belief that injuries from pressures above 7000 psi eventually result in amputation[7] has been disproved, higher pressures usually mean larger volumes of injected material and larger zones of injury. Injections under 1000 psi are associated with amputation rates of 19%, compared with 43% at higher pressures.

The type of material injected is the most important prognostic factor. Water and air injections, even at high pressures, do not require surgery. Antibiotics and observation can often lead to full recovery of ROM.

In stark contrast, paint is generally considered the most toxic injection material. It is composed of more than 40 raw materials in 3 categories: solvents, transport vehicles, and pigment. Solvents and transport vehicles are designed to evaporate, and pigment is the major visible component.[8] Oil-based paints are associated with a 58% amputation rate; modern paints are often latex-based and associated with a much lower amputation rate of 6%.[4] According to animal studies, a potential downside of latex is that acrylic latex and titanium dioxide increase the risk of infection.[9] Viscosity is another factor, as more-viscous paints disperse less,[10] potentially minimizing the zone of injury.

Histologically, paint causes an acute neutrophilic inflammatory exudate and tissue edema.[8] Myelin sheaths are dissolved by agents in paint, causing local anesthesia. Observation of later stages of injury show repair, with muscle regeneration surrounding the necrotic foci, and fibrohistiocytic proliferation. One case report details a spindle cell fibrohistiocytic proliferation with pigmented areas mimicking a giant cell tumor of the tendon sheath[8]; the refractory elements visible were probably talc, a mineral in pigments added for a matte finish of the paint.

The injection site is another important factor to consider. In palm injections, more material can be dispersed, leading to less ischemic injury. When wax was injected into cadaver palms, the palmar aponeurosis produced a lateral spread of material. However, with the superficial and deep palmar spaces separated from the thenar and hypothenar spaces, the radial and ulnar bursae remained uninvolved.[11] Trajectories perpendicular to bone or to a rigid pulley deflect material laterally to the neurovascular bundle. Injections over joints can penetrate the thin underlying pulley and enter tendon sheaths. High-pressure injections have even tracked proximally up the axilla

Figure 3. Residual paint just radial to flexor tendon after initial debridement.

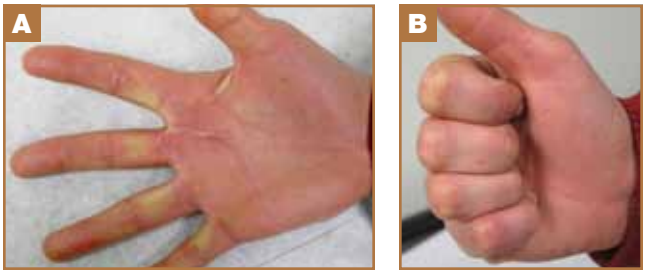

Figure 4. Full active extension (A) and flexion (B) at 4-month follow-up.

into the mediastinum and contralateral upper extremity.[2]

Injury presentations are misleadingly benign. Often the entry wound is a small skin defect producing little pain. Swelling from the foreign material, as well as inflammation, is delayed. Blood flow is compromised by material irritants and by increased pressure, causing vasospasm and vessel thrombosis. Involved digits presenting late are often mottled, swollen, and numb to varying degrees.[6] It is important to check the initial radiographs for proximal spread of radiopaque material or radiolucency from material or air.[4]

Initial treatment should consist of intravenous antibiotics and tetanus prophylaxis. Mirzayan and colleagues[12] found 47% of wound cultures to be positive, with more than half growing gram-negative bacteria, indicating broad-spectrum coverage. Beyond these 2 measures, the need for additional interventions before operative management remains controversial. Animal studies have shown that steroids decrease the severity of the initial inflammation.[9] Theoretical disadvantages of steroid administration, such as increased positive cultures or infections, have not been found.[2,4] Heparin administration to reduce perfusion[2] and use of a stellate ganglion block to decrease sympathetic vasoconstriction[10] have been advised, but these recommendations are not evidence based.

Operative debridement should be undertaken urgently. According to a review of reports in which time to surgery was noted (N = 166 patients),[4] surgical intervention for injection with organic solvents (eg, paint) undertaken within 6 hours of injury was associated with an amputation rate (38%) significantly lower than that associated with intervention after 6 hours (58%) and with no intervention within a week (88%). However, there was no correlation between delayed surgery and amputation rates when all injection injuries were included.

Guidelines for operative management include the following:

- Irrigation with normal saline or lactated Ringer's (organic solvent irrigation can increase tissue damage);
- Exploration of wounds under general anesthesia (digital nerve blocks and other forms of local anesthesia can further ischemia);
- Exploration in a bloodless field to maximize visualization (but no use of an Esmarch bandage to exsanguinate, as it can propagate the spread of foreign material);
- Excision of all fat and fascia involved (but no removal of paint from around the neurovascular bundle);
- Allowing intact tendon sheaths to remain closed to prevent secondary tenosynovitis;
- Subtotal resection with preservation of essential pulleys, if indicated, in cases of violated tendon sheath; and
- Leaving wounds open immediately postoperative and revisiting operating room for later skin grafting when healthy clean tissue bed is available, or closing wounds over a drain while elevating them.[5,6,10,13]

Outcomes in studies are often limited to subjective, unquantified reports. One of the largest series detailing hand function after high-pressure injections discussed 19 cases, detailing decreased grip strength and a 25% decrease in 3-point pinch strength.[14] Distal interphalangeal joint contractures, pulp atrophy, late skin necrosis requiring skin graft, distal phalanx bone resorption, and osteoporosis have all been reported as sequelae. In several reports, loss of ROM, which depends on location, was unquantified. In 1 case, stiff interphalangeal joints inhibited gripping function to the point that the patient requested amputation.[10] However, the more mobile thumb with its multiplanar ROM at the carpometacarpal joint can better compensate for stiff metacarpophalangeal and interphalangeal joints. This likely explains the lower amputation rate with injection injuries to the thumb versus other digits, but it is speculative as indications for amputation are not well documented in the literature.

Conclusion

High-pressure paint injection injuries require urgent treatment with antibiotics, tetanus toxoid, and surgical debridement. The most important prognostic factors are the type of material injected, injection pressure, and injury site—none of which can be altered by the treating physician. Whether there is a role for additional measures, such as steroids, heparin, and stellate ganglion blocks, remains unclear. Although prospective studies are unavailable, a review of case reports and small series is valuable in guiding treatment of these injuries. Despite the controversies that exist among the various treatment rec-

ommendations, it is clear that a high degree of suspicion for severe injury and provision of timely and aggressive treatment is indicated for high-pressure injection injuries.

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