



First Hand News

Topics in Upper Extremity Care

A publication of the Christine M. Kleinert Institute for Hand and Microsurgery, Inc.

High-Pressure Injection Injuries

High-pressure injection injuries to the hand are not common but occur with enough frequency and the consequences of missing them are so serious, that all emergency and primary care physicians must be able to diagnose them. The potential severity of these injuries requires a prompt response and urgent disposition of these patients to a hand surgeon.

Incidence of these injuries has risen with increased use of high-pressure injection guns in the industrial setting. The first case of a high-pressure injection gun injury was reported in 1937, but since that time, use of this equipment has become much more prevalent. High-pressure injection guns are used for painting, lubrication, cleaning, and mass farm animal vaccinations. Materials injected with these devices may include water, paint, paint thinners, grease, oil, plastic, vaccines, or cement.

These spray guns produce such high pressures that, even without direct skin contact, significant injury can occur. A pressure of 100psi can break the skin, and pressures from these injection guns can exceed three hundred times that pressure.

Epidemiology

These injuries occur most frequently in a work setting, and are generally due to operator inexperience. The patient usually reports that the injury occurred after being exposed to the high-pressure jet while cleaning an obstruction from the equipment. The typical patient is male, 35 years old, and a manual laborer who has worked with the equipment for less than six months. More than 75% of these injuries involve the non-dominant hand, usually the index finger followed by the middle finger and palm. Any bodily area can be injured, but when digits are effected, their limited capacity to allow tissue expansion tends to produce more devastating injuries.

Mechanism of Injury

Three types of industrial equipment are responsible for most of these injuries: grease guns, spray guns, and diesel injectors. Over half (57%) of high-pressure injection injuries are caused by grease guns. The emission pressures reached by the grease creates a propulsive force of 5,000 to 10,000psi.

High-pressure spray guns are responsible for 18% of injection injuries. They deliver material like paint, lacquer, semi-fluid cement, hydraulic fluids, and solvents (i.e. paint thinners, turpentine and gasoline). They can generate pressures between 3,000 and 7,000psi. The automobile industry uses these spray guns widely.

Diesel fuel injectors generate pressures between 2,000 to 12,000psi. These injuries usually occur during testing or servicing of an engine. They account for 14% of high-pressure injection injuries.

Injection injuries can also be caused by a variety of other sources, such as defective lines and valves. Pneumatic hoses, hydraulic lines, grease boxes, and oilrig drilling devices all pose dangers.

Objectives

After reading this issue you should be able to:

- **LIST** key historical features and physical examination findings associated with high-pressure injection injuries of the hand.
- **DESCRIBE** the key prognostic factors for high-pressure injection injuries of the hand.
- **DISCUSS** the indications for diagnostic testing and preoperative treatment.
- **DESCRIBE** the surgical treatment for these injuries and the long term implications.

Tissue Injury

Several factors effect the extent of tissue injury in high-pressure injection injuries to the hand. These include type of material, amount of material, anatomic location of the injection, and velocity of the injected material.

Type of material injected is the most important prognostic factor. This greatly effects tissue inflammatory response, resulting in fibrosis that may occur during healing. Oil-based paints and paint thinners can generate significant early inflammatory responses that may lead to severe fibrosis. Amputation may ultimately occur in as many as 70% of these injection injuries. However, these materials also have antibacterial properties.

Grease gun injuries, on the other hand, create a lesser inflammatory response, unless a bacterial infection is super-imposed. This leads to a higher incidence of fibrosis, oleomas, and draining sinuses.

The volume of material injected determines the degree of mechanical distention, and thus the extent of arteriovenous circulation impairment. Significant edema results from these injuries and also contributes to compromised circulation. The exact mechanism for vascular supply interference is unclear; digital vasospasm, venous obstruction, digital artery compression from tissue distention, or massive thrombosis from volatized oil have been proposed. This may result in chemical inflammatory response and vascular impairment that eventually results in tissue necrosis and potentially super-imposed bacterial infection.

The anatomic location of injection is critical. The site of tissue penetration determines where material will disperse within the digit and hand along fascial planes, flexor tendon sheaths, and subcutaneous tissue. The unique anatomy of the hand and digits contributes to variability. For example, distal interphalangeal (DIP) and proximal interphalangeal (PIP) flexion creases are entry points for the flexor tendon sheath. Because tendon sheaths of the index, middle, and ring fingers end approximately at the metacarpalphalangeal (MCP) joint, material injected at the DIP and PIP flexion creases remains within these digits. However, the tendon sheaths of the thumb and small finger extend into the radial and ulnar bursae. Therefore, material injected at the DIP, PIP and IP flexion creases has the potential for retrograde extension of material into the forearm, and could result in compartment syndrome, carpal tunnel syndrome, or ulnar nerve compression in Guyon's canal.

Velocity of the material contributes to potential tissue injury indirectly, as a result of material dispersion. The higher

the velocity and the more injection material dispersion, the potential increase in tissue damage.

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Clinical Presentation

The initial presentation of a patient with a high-pressure injection injury is usually benign and subtle. This may lead to mismanagement or minimizing the patient's complaints. Initially, the patient may have minimal complaints and physical signs of injury. There may not be an obvious break in the skin, or a benign looking pinhole sized puncture site may be present with only minimal symptoms. However, several hours later, the effected digit may become increasingly more painful, swollen, and pale.

These injuries are generally classified into three stages at presentation. The acute phase includes the first four to six hours post injury. Signs at this stage may include swelling, anesthesia, and vascular insufficiency. The injected material may drain from the puncture site, and significant edema may occur. If not treated properly, tissue ischemia and necrosis can occur within four to twelve hours. Vascular compromise will result in a pale, numb digit. On rare occasions, injected materials may be systemically absorbed; and with solvent injuries, the inflammatory reaction can produce lymphangitis, lymphadenitis, and fever.

The intermediate stage includes development of oleomas throughout the tissue and at the injection site. These nodular tumors are created from the foreign body tissue reaction produced by injected material. Fibrosis frequently occurs with a loss of function, although these growths may remain dormant for a number of years.

The late stage includes skin breakdown overlying the oleoma. This may result in ulceration and draining sinuses that may become infected.

Patients usually present in the acute stage within several hours of injury. A detailed history must be obtained to determine the exact time of injury and type of material injected. A thorough physical examination must be done to determine neurovascular status.

Treatment

The key to managing these patients properly is prompt recognition, realization of the severity of injury, initiation of aggressive treatment, open wound management, and immediate referral to a hand surgeon. Antibiotic prophylaxis should be started. Patients must be prepared for the operating room, and are generally admitted into the hospital.

Radiographs help determine the extent of dispersion and requirements for surgical exploration and debridement. Lead-based paints appear as radiopaque soft tissue densities. Non-lead based paints may appear as subcutaneous emphysema, and grease may appear lucent.

Pain management is usually necessary because these injuries become quite painful after their initial painless presentation. Use of parenteral analgesia is encouraged. Brachial plexus and stellate ganglion blocks may be performed. Local and digital blocks are absolutely contraindicated as they may contribute to increased tissue pressure and potential compromise of tissue perfusion.

Surgical incisions are made to decompress the effected tissue and perform an extensive exploration. All areas infiltrated by injected material must be exposed, and foreign material and all necrotic tissue must be debrided. Particular care must be taken in areas that contain the neurovascular bundles. Copious irrigation with normal saline is indicated to help reduce fibrosis and scarring. The wounds are either closed loosely with Penrose drains, left open to heal by secondary intention, or closed with delayed skin grafts or flap covers.

A high incidence of gangrene occurs with these injuries, depending upon the site of injection, type of injected material, and time to treatment. In fact, many result in surgical amputation of the digits. If debridement is not conducted within six to ten hours, serious complication rates increase.

Paints and paint solvents lead to a higher incidence of amputations. Studies show that 84% of digits can be salvaged by using open wound treatment techniques, and as many as 60% return to normal function.

Prophylactic broad-spectrum antibiotics are indicated. They are not routinely recommended for grease gun injuries unless super-imposed infection occurs.

Use of steroids is controversial. They are recommended for cases that have a severe inflammatory response, delay in treatment, or for systemic symptoms.

Suggested Readings

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Case Presentation

History of Present Illness

The patient is a right-hand dominant, 41-year-old male. The injury occurred when the patient stopped to clean the high-pressure paint gun he was using, and inadvertently struck his left middle finger. The material injected was a water-based paint. He reported to his supervisor, who sent him directly to the emergency department for care.

Emergency Department Note

The emergency department triage nurse was unaware of the potential severity and initially misclassified the patient as non-urgent. Fortunately, the emergency physician evaluated the patient promptly, and an appropriate treatment plan was initiated.

Past Medical History

The patient was previously fit and well, took no regular medication, and had no known allergies. His tetanus status was unknown. He was a regular smoker of ½ pack per day, and was appropriately starved for surgery.

Physical Exam

Left hand – middle finger

- Puncture wound ulnar side
- DIP crease - volar surface
- Digit swollen, erythematous
- Decreased sensation to tip
- Adjacent digits – within normal limits

Examination revealed an innocuous appearing puncture wound on the volar surface of the left middle finger, overlying the DIP joint crease slightly to the ulnar side (photograph 1 and 2). A bead of white paint was visible at the wound site.

The finger had minimal swelling and good capillary refill, but showed decreased sensation at the tip. The adjacent digits appeared normal and had normal two-point discrimination.



Photograph 1



Photograph 2

Emergency Department Treatment

- Hep lock
- Td 0.5
- Hand radiograph
- IV cephazolin 1 gram
- NSAID pain medication IM

The patient was given tetanus toxoid immunization and a hand radiograph was taken. A Hep lock was established, 1 gram intravenous cephazolin was given, and a non-steroidal anti-inflammatory drug was given IM as pain medication.

Radiographs

Plain radiograph revealed subcutaneous opacity on the volar surface, extending proximally to the level of the PIP joint and distally into the pulp of the finger (photograph 3).



Photograph 3

Operating Room Treatment

- Patient taken to operating room
- Anesthesia

After initial assessment in the emergency department by the hand surgeon, the patient was transferred to the operating room. General anesthesia was induced and an upper arm tourniquet was applied. Intraoperative photographs were taken during the surgery for documentary and educational purposes. The arm was exsanguinated using an Esmarch bandage, and the tourniquet was inflated to 250 mmHg.

The puncture wound was excised. Exploration was carried out, using modified Brunner incisions with broad based flaps. The blood supply was radially based at the site of the injection in case of local compromise of the ulnar neurovascular bundle (photograph 4).



Photograph 4

The skin flap was raised at subcutaneous level. Extensive local infiltration of soft tissue found white paint clearly visible proximally down to the level of the PIP joint. Although the flexor sheath was coated in paint, there was no penetration through the sheath. The ulnar neurovascular bundle had been directly injected with paint at the level of the DIP joint. The nerve was 50% divided, with paint infused distally along the length of the nerve (photograph 5). Paint extended across the mid-line, surrounding the radial neurovascular bundle.



Photograph 5

Debridement of the wound involved excision of all tissue involved in paint, but with preservation of the neurovascular bundles and the flexor sheath. Little pulp fatty tissue remained on the ulnar side of the finger distally to the DIP joint at the end of the debridement. The ulnar digital nerve was repaired after the debridement of paint from the fascicles. The wound was thoroughly irrigated with saline, the tourniquet was deflated, and the skin flaps were inspected for viability. The wound was closed loosely, and the hand immobilized in a volar forearm-based hand splint.

After 48 hours, the dressing and drains were removed. Programmed whirlpool treatments and active mobilization were initiated. The patient was encouraged to stop smoking.

Once the wound healed, anti-edema measures were introduced. With hand therapy, the patient regained good range of motion. However, the patient continued to have pain along the ulnar side of the digit, with tenderness and a positive Tinel's sign at the site of the repair.

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Discussion

High-pressure injection injuries may be devastating, sometimes resulting in digital amputations or loss of hand function. The patient's history and employer may indicate the severity of the injury, but too often, others underestimate it. Initially, there may only be minimal signs and symptoms despite a digit threatening injury. Recognition of the problem should result in immediate referral to a hand surgeon and preparation of the patient for the operating room. Only occasionally can these injuries be treated conservatively, and an experienced hand surgeon should make this decision.

The outcome of the injury is dependent on the site of injection and type of material injected, together with prompt and appropriate management. Steroids, antibiotics, and tetanus immunization may be required. Operative management involves aggressive and early debridement of involved tissues, with delayed wound closure. Hand therapy is invariably required for rehabilitation and restoration of hand function. Even with prompt treatment, some cases are likely to result in amputation, particularly if there is vascular compromise at presentation. Where digits are preserved, a deterioration in hand function is still common.

About First Hand News

First Hand News is the education journal of the Christine M. Kleinert Institute (CMKI). The CMKI is a center for hand care research and education. The CMKI includes Research and Education in the areas of Hand Care, Hand and Microsurgery, Physical Therapy, Rehabilitation, and Injury Prevention.

The CMKI is affiliated with Kleinert Kutz Hand Care Center at Jewish Hospital in Louisville, Kentucky.

If you have any patient care questions, Kleinert Kutz can be contacted 24 hours a day, seven days a week at (502) 561-4263 or toll free 1 (800) 477-4263.

About the Authors

Raymond G. Hart, MD, MPH is a Board Certified Emergency Physician and Director of Research at the Christine M. Kleinert Institute.

Ms. Gillian Smith, MBB (Ch), FRCS (Ed), FRCS (Plast) is a Hand Surgery Fellow from Birmingham, England.

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To earn credit, read the First Hand News carefully, answer the questions below, submit your completed quiz for grading, and obtain a passing score (minimum of 75%). Each quiz may be submitted only once for credit and must reach First Hand News within one year after publication.

QUESTIONS

Please circle the letter that corresponds to the single, most appropriate answer for each of the following questions.

- High-pressure injection injuries of the hand are caused by all of the following except:
 - spray guns
 - diesel injectors
 - garden hoses
 - grease guns
- There are several key components that determine tissue injury in high-pressure injection injuries to the hand. The following include:
 - type of material injection
 - amount of material injected
 - the anatomic location of the injection
 - all of the above
- The following statements about high-pressure injection injuries of the hand are true except:
 - radiographs are not generally helpful in these cases
 - immediate referral to hand surgery is indicated
 - open surgical management is required
 - prophylactic antibiotics are generally begun on these cases
- The following statement is the most accurate concerning the surgical management of high-pressure injection injuries of the hand:
 - these injuries rarely result in amputation of the digit
 - surgical incisions are made to decompress the tissue and allow for extensive exploration
 - the injected material is generally localized and easily excised
 - local and digital blocks are the anesthesia of choice in these cases

OBJECTIVES

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- DISCUSS the indications for diagnostic testing and preoperative treatment.
- DESCRIBE the surgical treatment for these injuries and the long term implications.

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Excellent	Good	Fair	Poor
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Christine M.
KLEINERT INSTITUTE
for HAND AND MICROSURGERY, INC.

225 Abraham Flexner Way
Suite 850
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