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Understanding High-Pressure Injection Injuries

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Introduction

A high-pressure injection (HPI) injury is a hazard that can result in tissue damage, amputation, or at worst, death. HPI injuries are rare, usually occurring in the hand, with an estimated incidence of one in 600 hand injuries presenting to an emergency care unit.[1] HPI injuries are characterized by a small puncture wound that is often underestimated by physicians and patients. The injected substance leads to extensive tissue damage and sometimes to loss of the limb. Large surgical hand centers have on average 1–4 injection injury treatments every year.

Most HPI injuries are industry-related, and the preponderance are from grease guns, spray guns, and diesel injectors. Other guns that reportedly cause such injuries include paint guns, concrete guns, and plastic injectors. Grease is the material injected most often, followed by paint.[2] Water, wax, paint thinner, cement, plastic, oil, and hydraulic fluid have also been reported.[3]

In order to breach the human skin, the ejection pressure has to be at least 100 pounds per square inch (psi),[4] while most high-pressure guns and injectors reach pressures of 2,000-12,000 psi.[5] The average age of patients with an injection injury is approximately 36 years, with the majority being male. Several factors determine the severity of the injury. The type and amount of injected material seem to be the most important factors determining the severity of the injury.[6] The most common cause of an HPI injury is using hands or fingers to detect leaks. It is important to understand that HPI injuries demand immediate treatment.

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[1] Bekler, H., Gokce, A., Beyzadeoglu, T., & Parmaksizoglu, F. The surgical treatment and outcomes of high-pressure injection injuries of the hand. *J Hand Surg Eur Vol*. Aug 2007;32(4): 396.

[2] Jebson, P.J., Sanderson, M., Rao, V.K., & Engber, W.D. High-pressure injection injuries of the hand. *Wis Med J*. Jan 1993;92(1): 13.

[3] Pai, C.H., Wei, D.C., & Hou, S.P. High-pressure injection injuries of the hand. *J Trauma*. Jan 1991;31(1): 111.

[4] Weltmer, J.B. Jr, & Pack, L.L. High-pressure water-gun injection injuries to the extremities. A report of six cases. *J Bone Joint Surg Am*. Sep 1988;70(8): 1221.

[5] Hart, R.G., Smith, G.D., & Haq, A. Prevention of high-pressure injection injuries to the hand. *Am J Emerg Med*. 2006;24: 73–76.

[6] Lewis, H.G., Clarke, P., Kneafsey, B., & Brennen, M.D. A 10-year review of high-pressure injection injuries to the hand. *J Hand Surg* [Br]. Aug 1998;23(4): 479-81.

Importance of Recognizing High-Pressure Injection Injuries

The puncture wound is small, inconsiderable and not distinct. Initially the toxic substance causes edema and ischemia and later, the combination of mechanical and chemical factors leads to compartment syndrome and consequently to fibrosis, adhesions, necrosis (see Figure 1), and secondary contractures and ulcerations, apart from the risk of systemic intoxication (acute renal failure, air embolism).[7]

The seemingly innocuous initial clinical presentation of injection injuries, with a narrow puncture wound and mild symptoms and signs, leads to their underestimation not only by the patient, but also by the physicians.[8] This leads to extension of the tissue damage, development of compartment syndrome and finally to functional disability of the limb, or even to amputation, while the patient's life may also be at risk.[9]

Figure 1. HPI injury presenting with edema, ischemia and tissue necrosis.[10]

The severity of injury and consequently the prognosis depend on the toxicity, density, and velocity of the injected substance, the pressure of the appliance, the anatomy and distensibility of the injection site, the possible secondary infection and the interval between injury and treatment.[11] Amputation rate ranges between 16% and 48% and can even reach 80% in injection injuries by paint solvents.[12] The amputation risk is lower if wide surgical debridement occurs within 6 hours of injury.[13]

Prompt and correct diagnosis is crucial for the reduction of the catastrophic results. Due to their potential morbidity, injection injuries are characterized as "the most urgent of all

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[7] Gutowski, K.A., Chu, J., Choi, M., & Friedman, D.W. High-pressure injection injuries caused by dry cleaning solvents: case reports, review of the literature, and treatment guidelines. *Plast Reconstr Surg.* 2003;111: 174–177.
[8] Hart, R.G., Smith, G.D., & Haq, A. Prevention of high-pressure injection injuries to the hand.
[9] Cristodoulou, L., Melikyan, E.Y., Woodbridge, S., & Burke, F.D. Functional outcome of high-pressure injection injuries of the hand. *J Trauma.* 2001;50: 717–720.
[10] Fluid Power Safety Institute.
[11] Vasilevski, D., Noorbergen, M., Depierreux, M., & Lafontaine, M. High-pressure injection injuries to the hand. *Am J Emerg Med.* 2000;18: 820–824.
[12] Schoo, M.J., Scott, F.A., & Boswick, J.A. High-pressure injection injuries of the hand.
[13] Hogan, C.J. & Ruland, R.T. High-pressure injection injuries to the upper extremity: a review of the literature. *J Orthop Trauma.* 2006;20: 503–511.

emergencies of the hand."[14] Physicians must be aware of the emergency nature of this condition, and must regard all patients who report digital injection as potential amputees at the time of the injury[15] and refer them to the appropriately specialized hospital. Almost all of these injuries require expeditious surgery, and nonsurgical treatment is exceptional.[16] Usually multiple procedures are needed and late reconstruction of the salvaged digit may include the use of flaps to restore good quality pulp tissue to the index finger.[17] Antimicrobial therapy, including tetanus prophylaxis and use of anticoagulants, is recommended, whereas the use of steroids is controversial.[18] Patients and their relatives should be informed of the nature and severity of this injury. Wide surgical exploration, including decompression of tissue compartments, debridement of nonviable tissue and high-volume saline irrigation under general or regional anesthesia is recommended, whereas digital blocks should be avoided.

It is suggested that education of high-risk population and of healthcare workers in the use of high-pressure equipment would help to reduce the number of these injuries.[19] These seemingly innocuous injuries should not be underestimated but instead, should alert physicians, so that their destructive consequences are limited.

Why High-Pressure Injection Injuries Occur

High-pressure injection injuries result from the inappropriate operation of equipment that achieves ejection pressures of their contents sufficient to breach the human skin.[20] The majority of the HPI injuries affect the non-dominant index finger and occur usually due to inexperience in operating the high-pressure equipment, inappropriate use, insufficient training, carelessness, fatigue at the end of the shift, or rupture of the equipment.[21]

The most common cause of an HPI injury is using hands or fingers to detect leaks. Even thick leather gloves offer little protection against a highly pressurized, extremely concentrated stream of hydraulic fluid. Under normal operating conditions, a pinhole-size leak can propel the fluid at more than 600 feet per second.

Once the high-pressure material penetrates the skin, it opens up a number of possibilities for damage. Most obvious is the injection of dangerous substances into the bloodstream, such as corrosives or poisons. Most injuries of this type are from high-pressure grease guns. High-pressure paint guns and diesel injection follow a very distant second and third. Other materials include water, wax, paint thinner, cement, plastic, oil, and hydraulic fluid.

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[14] Ebelin, M. High pressure injection accident of the hand. *Rev Prat.* 1994;44: 2461–2463.
[15] Vasilevski, D., Noorbergen, M., Depierreux, M., & Lafontaine, M. High-pressure injection injuries to the hand. *Am J Emerg Med.* 2000;18: 820–824.
[16] Smith, G.D. High pressure injection injuries. *Trauma.* 2005;7: 95–103.
[17] Pai, C.H., Wei, D.C., & Hou, S.P. High-pressure injection injuries of the hand.
[18] Fialkov, J.A. & Freiberg, A. High-pressure injection injuries: An overview.
[19] Hart, R.G., Smith, G.D., & Haq, A. Prevention of high-pressure injection injuries to the hand.
[20] Smith, G.D. High pressure injection injuries. *Trauma.* 2005;7: 95–103.
[21] Valentino, M., Rapisarda, V., & Fenga, C. Hand injuries due to high-pressure injection devices for painting in shipyards: circumstances, management, and outcome in twelve patients. *Am J Ind Med.* 2003;43: 539–542.

Treatment

High-pressure injection injuries can be extremely dangerous if treatment is not rendered quickly. Due to the potential for internal tissue damage, amputation may be the only option, especially if treatment is delayed for more than six hours, due to hidden gangrene or tissue necrosis or injected material spreading into other areas of the body. Depending on the type of material injected and extent of the damage, the specific treatment can vary widely.

In some cases, the injection can be treated like any other puncture wound. In others, surgery may be required to remove the injected material, such as paint, from the body or repair damage to the underlying tissue. The most important thing to remember is that the amount of pain felt at the time of the injury is a poor indicator of how much damage has been done. The true extent of the damage is never obvious in these cases.

Since the injured tissue is susceptible to bacteria, an antibiotic is often prescribed to prevent secondary infections. The damaged tissue and injection material will be immediately removed under anesthesia, in a procedure called debridement. The medical team may also need to decompress the injury area by cutting the skin areas open to relieve the swelling pressure and release the toxic chemicals injected (see Figure 2). This can result in substantial wound areas. Further debriding may be necessary as the surrounding tissue becomes involved over the next couple of days. The medical team may also need to treat you for any acute reactions to the chemicals injected.

Figure 2. An HPI injury decompressed by cutting open the skin.[22]

Amputation is often unavoidable, especially in injuries to the fingers. Paint and paint thinner cause the most amputations, with estimates as high as 48 percent of these type injuries ending in amputation. Even if amputation is avoided, the finger or toe may be too stiff to be usable. Other complications can include infection, permanent contraction of the injured digit, and chronic pain. Physical and occupational therapy will be critical after the initial injury treatment to help restore as much use as possible to the injured area.

[22] Fluid Power Safety Institute

Full recovery is often unusual, especially if treatment is delayed. In many cases, the quality of treatment does not seem to greatly influence the outcome.[23] Prevention is, therefore, of great importance. The education of workers, particularly those at risk, allied to the development of safer equipment, is the best way to achieve this.

Preventing Injuries

This type injury is completely preventable. A high index of suspicion and early aggressive therapy are necessary to minimize the risk of a disastrous outcome associated with many of these injuries. Sufficient attention must be given to the prevention of such traumas. Preventative measures should include a targeted safety program for equipment users, engineering improvements in gun and hose design, economic incentives, and workplace legislation.

To avoid HPI injuries, it is important to inspect equipment thoroughly to ensure that there is no damage, such as cracking or holes. Safety attachments, such as leak detectors, are standard on many types of high-pressure equipment, but they must be inspected as well to make sure that they are working properly. Never attempt to locate a high-pressure leak by passing your hand over the equipment to feel for the leak, and always wear the protective equipment designed for the job.

Although these types of injuries are not common, according to the Fluid Power Safety Institute, "Over 99 percent of the people who service, repair, and troubleshoot hydraulic systems have been subject to the exact dynamics that trigger a high-pressure injection injury. However, the 'liquid bullet' either missed or deflected off its target."[24] That means just about everyone who uses an airless sprayer has created the perfect set of circumstances that could have led to this injury and the potential loss of limb.

Poor skills, not poor employees, are the root cause of most accidents associated with high-pressure injection injuries. There is no tool more effective at eliminating poor skills and hence, work-related accidents, than *training.*

Conclusion

The use of high-pressure injection equipment has increased dramatically in recent years. Many combustion engines are now equipped with fuel-injection systems designed to improve performance. Both industrial and casual home users operate high-pressure equipment, such as grease guns, paint sprayers, and washers. These devices usually eliminate labor-intensive activity and reduce the amount of time needed to complete various tasks. HPI equipment such as airless paint sprayers, high-pressure grease guns, and fuel-injection apparatus constitute a serious safety hazard resulting in significant morbidity.

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[23] Scott, A.R. Occupational high-pressure injection injuries: Pathogenesis and prevention. *Occup Med (Lond).*1983; 33: 56-59.

[24] Fluid Power Safety Institute

In HPI injuries, prompt recognition, diagnosis and aggressive early treatment are essential to avoid a poor outcome. Patients should be informed about the severity of their injury, its potential complications, and the multiple surgical procedures that may be required for a satisfactory functional result. Successful management of these cases involves awareness of the impending problem and rapid referral of the patient to an emergency department and to a competent orthopedic or plastic surgeon.

HPI injuries involving grease and paint are considered surgical emergencies, whereas HPI injuries with other substances require careful clinical evaluation and/or surgical intervention. Full recovery is unusual, especially if treatment is delayed. In many cases, the quality of treatment does not seem to greatly influence the outcome. Prevention is, therefore, of great importance. The education of workers, particularly those at risk, allied to the development of safer equipment, is the best way to achieve this.

Preventative measures should include a targeted safety and health program for equipment users, engineering improvements in gun and hose design, economic incentives, and workplace legislation. Supervisors and employees should remember that there is no tool more effective at eliminating poor skills and hence, work-related accidents, than *training.*

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