

High-Pressure Injection Injuries to the Foot: A Case Report of 2 Patients

Christopher Gerzina, MD¹, Joash Suryavanshi, BS²,
and Jerry Grimes Jr, MD¹

Abstract

Background: High-pressure injections injuries to the extremities can result in significant disability, including amputation of the affected limb. Proprietary mixtures associated with drill mud and hydraulic fracking leads to frequent encounters with varied materials. The physician needs to be aware of the effect of these materials when inadvertent exposure occurs. Injected toxic materials cause extensive soft tissue inflammation and destruction. This puts the foot at risk not only to the cleaning fluid used, generally water, but any contaminant on the boot at the time of injury. This case report is the first known case report involving injection with drill mud contaminant and describes 2 oil field injuries resulting in the gross deep contamination of the foot from a high-pressure washer injury.

Case Report: Two patients, a 46-year-old man (patient 1) and a 29-year-old man (patient 2) sustained high-pressure injection injuries to the foot. These patients underwent treatment with immediate broad-spectrum antibiotics and emergent irrigation and debridement on arrival to the treating facility. Neither patient underwent amputation of the affected extremity as a result of their injuries and achieved a full recovery and return to work.

Conclusion: High-pressure injection injuries are operative emergencies. Treatment should include tetanus prophylaxis, neurovascular monitoring, broad-spectrum antibiotic coverage, emergent operative debridement for toxic materials. Despite the toxic nature of the injection injuries, aggressive treatment can improve the chance of salvage in these industrial injuries.

Keywords: trauma, injection, foot and ankle, industrial injury

Introduction

High-pressure sprays of liquid are commonly used in industrialized settings. However, these sprays can sometimes malfunction leading to injection injuries of the extremities or face. Various previous reports on the effects of injuries secondary to high-pressure injections on the abdomen, face, spine, hand, and foot have been reported in the literature.^{6,8,12,22,24} The material injected is one of the primary contributors to the patient outcomes after injury, and the previously reported literature is scarce in regards to injections in industrial settings.^{11,21} Industrial settings often have particularly noxious contaminants and this is especially true in oil fields, although injection injuries involving river water have also been reported involving aggressive contaminants.^{5,23} Petroleum-based products are commonly associated with injection injuries in oil fields, but more exotic materials such as clay, heavy metals, and radioactive substances have also been reported.²⁵ Proprietary mixtures

associated with drill mud and hydraulic fracking leads to frequent encounters with varied materials. The physician needs to be aware of the effect of these materials when inadvertent exposure occurs.

Injected toxic materials cause extensive soft tissue inflammation and destruction. Recommended treatment is generally immediate irrigation and debridement and removal of the foreign material.^{4,14} It may be difficult in industrialized setting

¹ Department of Orthopaedic Surgery & Rehabilitation, Texas Tech University Health Sciences Center, Lubbock, TX, USA

² Department of Medical Education, Texas Tech University Health Sciences Center School of Medicine, Lubbock, TX, USA

Corresponding Author:

Joash Suryavanshi, BS, Department of Medical Education, Texas Tech University Health Sciences Center School of Medicine, 3601 4th St Stop 6238, Lubbock, TX 79430, USA.

Email: joash.suryavanshi@ttuhsc.edu



to determine exact composition of the material. This is especially true when the high-pressure device is used to clean equipment in the less than controlled setting of the oil field. The composition of the cleaning fluid as well as the substances being removed has to be considered. Amputation is a common result of injections with petroleum-based products.²⁴

Injection injuries in the foot are infrequently reported. The pressure reported to penetrate work boots is relatively low, 2000 PSI, compared to the pressures in common use, which range from 600 to 12 000 PSI.¹⁸ This puts the foot at risk not only to the cleaning fluid utilized, generally water, but any contaminant on the boot at the time of injury. This case report describes 2 oil field injuries resulting in the gross deep contamination of the foot from a high-pressure washer injury.

Case Report

Case 1 involves a 46-year-old man (patient 1) who used a commercial pressure washer at an unknown pressure in the oil field to remove drilling mud and other debris from the equipment. This equipment was contaminated with drilling mud, diesel, and other drilling site-related materials. It was unknown what fluid was in the pressure washer. The dorsal aspect of his left foot was sprayed with the pressure washer. The transfer of the patient to a tertiary referral center took 16 hours. On arrival, the patient had a white count of 22 700, a C-reactive protein of 5.9, and an erythrocyte sedimentation rate of 16. Physical examination revealed a 3×4-mm opening at the base of the fourth metatarsophalangeal joint on the dorsal side. Erythema over the dorsal lateral aspect of the foot extended from the toes to the ankle. The opening was draining a serous fluid smelling of petroleum. Radiographs showed a radiopaque material in the subcutaneous tissues both dorsal and plantar aspects of the foot (Figure 1). Treatment was broad-spectrum intravenous antibiotics and emergent irrigation and debridement in the operating room.

Two longitudinal dorsal incisions, with a 3-cm skin bridge, exposed a large amount of gray material that smelled of petroleum with the consistency of toothpaste. A Bruner incision was made on the plantar aspect of the foot under the injection site exposing more of the gray material. The wounds were copiously irrigated with 6 liters of normal saline containing castile soap. The tissues appeared viable. Debridement at this time did not extend into the toes, and fluoroscopy was not used during the debridement. Radiographs after the first debridement showed a significant amount of retained material (Figure 2). Two days later, the patient was taken to the operating room for a second irrigation and debridement. Necrotic subcutaneous tissue and residual gray debris were found extending into the third and fourth digits and throughout the plantar fat pad. The plantar and dorsal incisions were irrigated with 3 L of normal saline with castile soap. The foot was splinted to prevent an equinus contracture. A third debridement encountered purulent



Figure 1. Radiographs showing radio-opaque subcutaneous material in the dorsal and plantar aspects of the foot.



Figure 2. Persistent retained radio-opaque material after the initial irrigation and debridement procedure seen on radiographs.

material but little foreign material. A wound vacuum closure device was applied to the dorsal surface because of skin loss about the injection site. Eight days after initial debridement, the wounds were closed with a split-thickness skin graft dorsally. Radiographs at that time showed little foreign material.

Patient followed up over the course of the next 6 months. Healing was complicated with a superficial infection at 3 months with wound cultures growing *Staphylococcus aureus* and *Klebsiella oxytoca*. The infection was resolved after a course of oral antibiotics. At 6 months postoperation, the wound and graft site had healed, and the patient's pain managed with nonopioid medications. Custom foot beds were recommended to accommodate the loss of soft tissue on the plantar foot. Figure 3 shows the clinical appearance of the foot at final follow-up.



Figure 3. Clinical appearance of the foot at the final follow-up.

Case 2 involves a 29-year-old man (patient 2) who sustained commercial pressure washer injury with an unknown pressure to his left foot on accidentally injecting himself while trying to free his boot from mud in an oil field. The pressure washer was fed with well water, but the contents are unknown. The area of injury was contaminated with debris, mud, and other drilling site materials. The dorsal aspect of his foot in the first web space sustained a small puncture wound. Transfer to the treating center took approximately 20 hours. On arrival, the patient had a white blood cell count of 10 320. Radiographs showed a radiopaque material in the soft tissues in the dorsum of the foot at the level of the first metatarsal (Figure 4). Treatment was broad-spectrum antibiotics in the emergency department and emergent irrigation and debridement in the operating room.



Figure 4. Radio-opaque material seen at the level of the first metatarsal seen on radiographs of patient 2.

The wound was explored in the operating room. The area of injury was explored, and no purulence was noted. At this time, the wound was curetted to the level of bone and thoroughly irrigated with 6 liters of normal saline. The tissues appeared viable and the wound was loosely approximated with nylon sutures. The patient was discharged 3 days later on oral amoxicillin clavulanate (Augmentin) for 14 days.

The patient followed up in clinic 4 weeks after discharge. Sutures were removed and the wound was well healed without signs concerning for infection. The patient was instructed on signs and symptoms of infection and voiced understanding. No further clinical encounters were documented with the patient.

Discussion

Patient 1 was exposed to an unknown industrial mix of materials at an oil field drilling site. When asked about the material, the personnel accompanying the patient reported drill mud, diesel, and heavy metals. The material was reported to have a pH of 10. The radiographs showed a radiopaque material in both the dorsal and plantar soft tissues of the foot. At both the first and second debridement, a strong petroleum smell was noted. The soft tissues were severely affected by the foreign material, with extensive necrosis. This may be due to the petroleum or caustic components. The material spread widely in the dorsal and plantar soft tissues as demonstrated by the initial radiograph. It does appear that the extent of the foreign material spread was not fully explored at the first debridement. It is possible that the lack of fluoroscopy and lack of sufficient exposure during

the initial debridement contributed heavily to the subsequent need for multiple trips to the OR for this patient. This is evident by the radiographs taken after the initial debridement. There was a vigorous inflammatory reaction with a large inflammatory exudate although the patient's white count, and C-reactive protein were not particularly elevated.

Patient 2 had a similar exposure with a pressure injection injury at an oil field with an unknown mixture of chemicals and additives. Radiopaque material was confined in the dorsal subcutaneous tissue of the foot. The initial emergent operative debridement was sufficient to remove the foreign material and debride the affected tissue, which contributed to the relatively uneventful hospital stay and subsequent discharge.

The previously published reports of injection injuries outcomes ranges from benign to amputation. The extent of the soft tissue injury, the material injected, the time to debridement, and injection pressure are key factors in the outcome of the injury.¹ Urgent operative debridement is key in reducing the impact of the injected materials. Debridement within 6 hours is recommended.^{1,14} Petroleum distillates have been reported to have a worse prognosis and should always trigger immediate operative intervention.¹⁴ Despite the use of a surfactant, such as castile soap, patient 1 required 2 debridements to remove the petroleum products. It is often necessary to repeat the debridement to remove all the foreign material and necrotic soft tissue. Cultures are often positive

in injection injuries, but have not shown a correlation to outcome.¹ Literature review has shown negative pressure wound therapy being used with positive outcomes to apply a base for subsequent skin grafting, which is consistent in the outcome seen in this patient.¹⁷

High-pressure injection injuries in the foot with water only have been previously reported, with 2 patients who sustained an amputation to the affected digit after minimal debridement at index procedure.²⁴ The injection of normal saline under high pressure did not appear to cause significant soft tissue reaction, whereas the mechanical effects of the injection contribute to the majority of the tissue destruction in similarity to high pressure missiles.^{10,20} The cases we reported underwent extensive debridement at index procedures without eventual amputation, although the injuries sustained were both high-pressure injections coupled with toxic materials. It is possible that the extensive debridement these patients received contributed to the lack of amputation as a part of their treatment course.

The unique aspect of these cases is the setting. The recent spread of hydraulic fracking has seen extensive spread of oil drilling in the United States. This is exposing a larger section of the workforce to the chemicals used in the industry. In this case, the patient was known to be exposed to petroleum products and drill mud. Drill mud is a viscous liquid used in the drilling process. The mud circulates through the well, cooling the drill bit, removing debris generated by the drilling process, preventing the influx of gas and crude oil, and supporting the sides of the well to prevent collapse. The composition of the drill mud varies according to manufacturer propriety blends, but commonly includes such materials as barium sulfate, hematite, zinc chromate, organic amines, formaldehydes, esters, hydrated lime, diesel, phenol, and caustic soda. It is often strongly alkaline and highly poisonous.^{13,19} The organic components and the alkaline pH are both recognized as risk factors for amputation after injection injury because of their toxicity to skin.²⁶

The drill sites are often in remote locations. Transportation to tertiary treatment centers can result in delay in treatment. Patient 1 required 16 hours to transport to the treating facility, whereas patient 2 reached the treating facility in roughly 20 hours after injury. The delay in treatment is a known risk factor in amputation after injection injuries.^{1,7} As the chemicals break down the tissues, inflammatory mediators are released. The resulting swelling can increase the pressures within compartments already compressed by foreign material. Compartment syndrome can result from the initial injection owing to volume of material or can develop from the body's reaction to the insult.^{2,15}

The technique of fracking has been extensively covered in the media. Fracking is a technique of injecting fluids under very high pressure to access the hydrocarbons trapped in shale formations. The injected fluids are often a proprietary blend by the manufacturer, and it is difficult to discern their exact composition. However, literature has shown that a mixture of nonpolymeric and polymeric compounds such

as cellulose, starch, xanthan gum, guar gum, polyanionic cellulose (PAC), and carboxymethyl cellulose in conjunction with bentonite are commonly used to reduce environmental impact and decrease cost.^{9,16,25} A literature search found no reports of injection injuries from fracking fluid. The mechanism of fracking makes a direct injection injury to an extremity during fracking extremity unlikely. Exposure to these materials is more likely when servicing or cleaning equipment in oil fields.

In conclusion, high-pressure injection injuries are operative emergencies. Treatment should include tetanus prophylaxis, neurovascular monitoring, broad-spectrum antibiotic coverage, emergent operative debridement for toxic materials, and fasciotomies if compartment syndrome is a concern.^{1,3} Tissue injury from the mechanical injury of the injection can be compounded by the materials exposed. The materials in the oil field are particularly toxic, and the physician should have a low threshold for operative exploration of injection injuries sustained in the oil field. If the injury is sustained in a remote location, transport to a treating facility should be expedited. Despite delays in treatment and the toxic nature of the injection injuries, aggressive treatment can improve the chance of salvage in these industrial injuries. After reviewing the differences in these 2 cases, we highly recommend the use of fluoroscopic imaging in the operating room if foreign material is retained in the soft tissue as well as a more extensive debridement in order to thoroughly debride the injured soft tissues when necessary.

Ethical Statement

Ethical approval for this study was waived by TTUHSC Lubbock/Odessa Institutional Review Board because as presented, these case studies do not appear to meet the definition of research; therefore, IRB review is declined.



Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. ICMJE forms for all authors are available online.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Joash Suryavanshi, BS,  <https://orcid.org/0000-0002-3347-2093>
Jerry Grimes Jr, MD,  <https://orcid.org/0000-0003-4238-5861>

References

1. Amsdell SL, Hammert WC. High-pressure injection injuries in the hand: current treatment concepts. *Plast Reconstr Surg.* 2013;132(4):586e-591e.
2. Bean B, Cook S, Loeffler BJ, Gaston RG. High-pressure water injection injuries of the hand may not be trivial. *Orthopedics.* 2018;41(2):e245-e251.

3. 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.* 2007;32(4):394-399.
4. Booth CM. High pressure paint gun injuries. *Br Med J.* 1977; 2(6098):1333-1335.
5. Borenstein TR, Johnson JP, Cohen B, Kane P. High-pressure injection to the great toe with river water. *R I Med J (2013).* 2015;98(11):38-41.
6. Bussewitz B, Littrell S, Fulkert K, VanCourt R. High-pressure water injection of the foot with associated subcutaneous emphysema: a case report. *J Foot Ankle Surg.* 2010;49(4):399.e15-399.e20.
7. Christodoulou L, Melikyan EY, Woodbridge S, Burke FD. Functional outcome of high-pressure injection injuries of the hand. *J Trauma.* 2001;50(4):717-720.
8. Chu FY, Wu KC, Lin HJ. Craniofacial high-pressure air injection injury. *Ann Emerg Med.* 2007;49(1):113-115.
9. Clark RK. Applications of water-soluble polymers as shale stabilizers in drilling fluids. In *Advances in Chemistry.* Washington, DC: ACS Publications; 1986:213.
10. De Beaux JL. High-pressure water jet injury. *Br Med J.* 1980; 280(6229):1417-1418.
11. Dietz JW Jr, Goodrich JA, Brown WB. Acinetobacter calcoaceticus foot infection secondary to high-pressure injection injury: a case report. *Foot Ankle.* 1988;8(4):216-222.
12. Gao X, Wu QH, Chen WS, et al. An unusual high-pressure injection injury involving the cervical spinal cord. *J Bone Joint Surg Br.* 2011;93(8):1140-1142.
13. Gardner R. Overview and characteristics of some occupational exposures and health risks on offshore oil and gas installations. *Ann Occup Hyg.* 2003;47(3):201-210.
14. Hogan CJ, Ruland RT. High-pressure injection injuries to the upper extremity: a review of the literature. *J Orthop Trauma.* 2006;20(7):503-511.
15. Kennedy J, Harrington P. Pneumomediastinum following high pressure air injection to the hand. *Ir Med J.* 2010;103(4):118-119.
16. Kerunwa A, Gbaranbiri BA. Evaluation of local viscosifiers as an alternative to conventional Pac-R. *Advances in Petroleum Exploration and Development.* 2018;15(1):1-8.
17. Marinovic M, Bakota B, Spanjol J, et al. High pressure injection injury of the foot: a role of negative pressure wound therapy. *Injury.* 2013;44(suppl 3):S7-S10.
18. Mrvos R, Dean BS, Krenzelok EP. High pressure injection injuries: a serious occupational hazard. *J Toxicol Clin Toxicol.* 1987;25(4):297-304.
19. Occupational Safety & Health Administration, US Department of Labor. Oil and gas well drilling and servicing eTool. <https://www.osha.gov/SLTC/etools/oilandgas/drilling/drillingfluid.html>. Accessed February 16, 2015.
20. Ramos H, Posch JL, Lie KK. High-pressure injection injuries of the hand. *Plast Reconstr Surg.* 1970;45(3):221-226.
21. Reiner MM, Khoury WE, Mackel A, Ehredt DJ, Razzante MC. Reconstruction after osteomyelitis of the midfoot from high-pressure washer injury. *J Foot Ankle Surg.* 2017;56(6):1305-1311.
22. Sarwar U, Javed M, Rahman S, Wright TC. Digital high-pressure injection injury: the importance of early recognition and treatment. *BMJ Case Rep.* 2014;2014:bcr2013203206.
23. Schoo MJ, Scott FA, Boswick JA Jr. High-pressure injection injuries of the hand. *J Trauma.* 1980;20(3):229-238.
24. Shea MP, Manoli A 2nd. High pressure water injection injuries of the foot: a report of two cases. *Foot Ankle.* 1993;14(2):104-106.
25. Tollefson J. Secrets of fracking fluids pave way for cleaner recipe. *Nature.* 2013;501(7466):146-147.
26. Yano K, Hata Y, Matsuka K, Ito O, Matsuda H. Experimental study on alkaline skin injuries—periodic changes in subcutaneous tissue pH and the effects exerted by washing. *Burns.* 1993;19(4):320-323.