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CASE REPORT

High-pressure injection injury with concrete to the hand and forearm

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ABSTRACT

High-pressure injection injuries to the upper extremities are uncommon yet serious, particularly when they involve substances such as concrete. These injuries, frequently occurring in industrial environments, can lead to substantial tissue damage and functional impairment. A 24-year-old male patient who incurred a high-pressure concrete injection injury to his left hand and forearm while employed at a construction site was admitted. The injury, originally seeming minor, involved concrete penetration into the thenar region and extended through the forearm, resulting in significant damage to muscles, tendons, and nerves. The immediate medical care comprised immersion of the injured arm in warm water, administration of intravenous antibiotics, and tetanus prophylaxis, succeeded by rapid debridement in the operating room. Through a series of surgeries, comprising sequential debridements and reconstructive interventions, hand function of the patient was acceptable regarding the occupational return. Radiographic imaging was essential in evaluating the severity of injury and informing surgical choices. Preoperative radiological clarification of the extension of the upper extremity to the anatomical regions with high pressure is of utmost importance in determining the location and size of the surgical incision to remove the vital initial debridement and cement from the anatomical regions as much as possible. This case highlights the significance of prompt identification, assertive treatment, and sequential surgical procedures in high-pressure injection injuries. The necessity for proactive workplace safety protocols and heightened awareness of the potential severity of these injuries is underscored. We believe that this case report enhances the comprehension of the difficulties and problems associated with treating high-pressure concrete injection injuries to the upper extremities.

Keywords: Debridement, forearm, hand, high-pressure injection injury, reconstruction.

Hand injuries are common in daily emergency surgery routine and are mostly caused by work accidents.[1,2] High-pressure injection injuries to the hand are uncommon, and those to the forearm with concrete have been documented only once; yet, they are regarded as a serious clinical entity and typically considered a surgical emergency.[3] Since its initial description in 1925 in German and 1937 in English, the incidence of these injuries has progressively escalated alongside the rising prevalence of high-pressure industrial machinery.[4,5] A pressure of 100 psi can penetrate the skin, whereas high-pressure industrial machinery operates at pressures ranging from 2,000 to 20,000 psi, potentially inflicting significant harm even without direct contact with the skin or upper extremity protective gear. The severity of those injuries was frequently underestimated due to the initial innocuous appearance of the wound and a lack of widespread awareness regarding the seriousness of such injuries. Even when such cases are recognized

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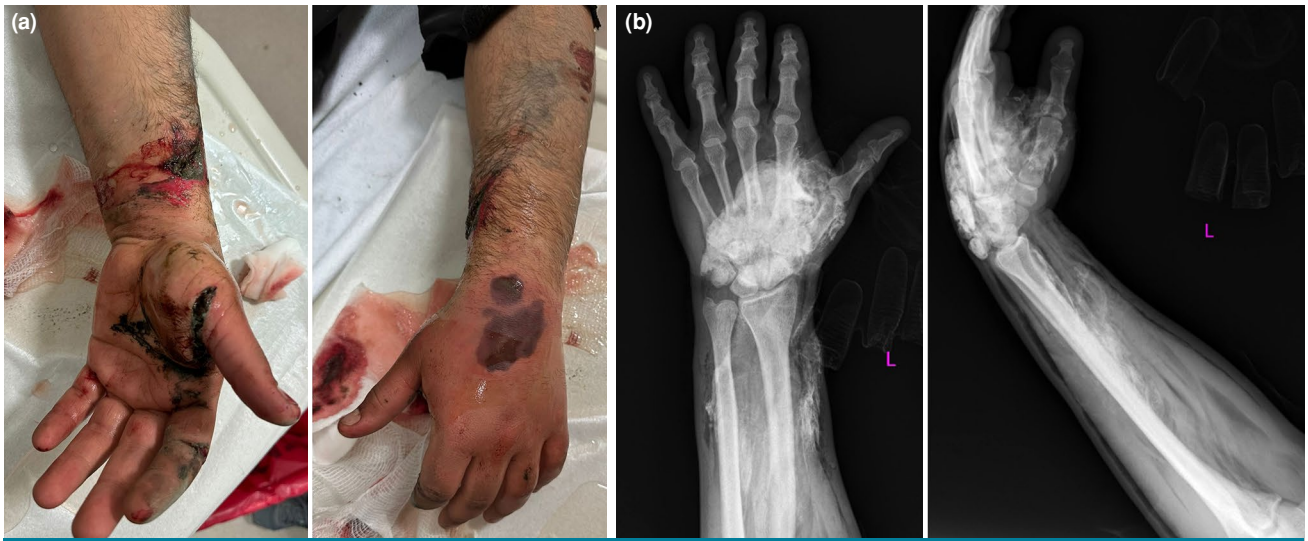

FIGURE 1. Preoperative views. **(a)** Clinical appearance of the injury just after emergency department administration. **(b)** First X-ray graphs of the left hand and forearm.

and treated early, devastating sequelae can still occur.

The damage after high-pressure injection injuries is thought to result from multiple processes. These include tissue distention leading to a pressure accumulation which surpasses hydrostatic pressure, thereby restricting tissue perfusion akin to compartment syndrome; chemical injury inflicted by the substance, resulting in tissue damage and an inflammatory response; and the probable occurrence of infection.[6] Standard plain radiographs can aid in evaluating the distribution of the injected substance, which may manifest as air in the soft tissue or as radiopaque in other instances.[7]

This type of occupational injury is the result of the injection of various substances, as described previously in the literature, including wax grease, hydraulic oil, cement, paint, and solvents.[8] In this article, we report a case of high-pressure concrete injection injury to the hand, which extends through the forearm. The case presents clinical and therapeutic data on an exceptional phenomenon, aiming to share the whole surgical process and its management.

CASE REPORT

A 24-year-old right-handed non-smoker, without comorbid disease, 176 cm tall and 78 kg in weight, male presented to the Emergency Department (ED) after injecting concrete into the thenar region of his left hand during his night shift at a construction site. The patient was administered an injection into the left hand and subsequently directed the device away, resulting in a spray that reached 10 meters across the field. The upper extremity below the elbow was immersed in a basin of warm water immediately following the orthopedic consultation in the ED after the X-ray radiographs were obtained. He was administered intravenous prophylactic antibiotics and a tetanus toxoid at the ED. The physical examination revealed a 2-cm laceration on the thenar region, extending radially into the first web space and through the forearm. The patient

VIDEO 1. Concrete pressing machine (noticed the pressure).

had an inability to adduct and/or oppose the thumb, was unable to abduct the index finger, and demonstrated diminished thumb flexion along with restricted active flexion of all fingers due to acute pain. All digits exhibited pink coloration at the tips, accompanied by diminished sensitivity in all digits. Radiographs revealed concrete within the first and second web gaps and extending through the forearm (Figure 1, Video 1).

The patient was transported to the operating room roughly 60 min following ED admission and underwent extensive debridement in an effort to excise all wet concrete. During the initial procedure, the first interosseous and thumb adductor muscles sustained significant damage and were subjected to debridement. Concrete encased both digital nerves of the thumb and index finger, extending to the palmar dermis. The nerves remained undamaged. Following the excision of all discernible cement and necrotic tissue, wound cultures were obtained, pathological specimens were maintained, a fasciotomy of the forearm was executed, and the wound was left exposed. The patient received debridement six times every other day, and the Esmarch bandage was not used to avoid exsanguination, which could have driven injected material further along tendon sheaths and neurovascular bundles of the upper extremity

FIGURE 2. Clinical and surgical images of the patient in chronological order during consecutive debridements. **(a)** Intraoperative clinical appearance of the hand after the initial surgical debridement. **(b)** Intraoperative clinical appearance of the forearm after the initial surgical debridement. **(c)** Intraoperative clinical appearance of the soft tissue defects on the dorsum of the hand and forearm after three radical debridements. **(d)** Intraoperative clinical appearance of the soft tissue defects and primary closure of the wounds. **(e)** Preoperative clinical appearance of the hand after debridements and closure of the soft tissue defects.

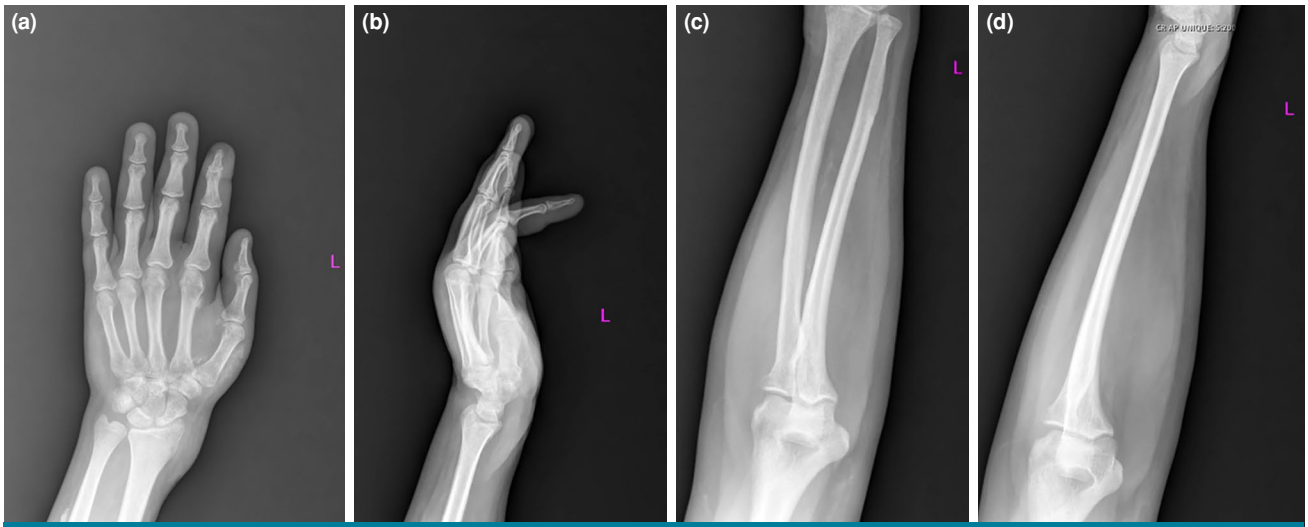

FIGURE 3. X-ray graphs of the patient's left hand and forearm after a consecutive debridement period of time, which show that there is no cement residue left. **(a)** AP radiological view of the forearm. **(b)** AP radiological view of the hand. **(c)** Lateral radiological view of the forearm. **(d)** Lateral radiological view of the hand.
AP: Anteroposterior.

commencing with the initial surgical operation (Figure 2). Cultures revealed an identifiable Bacillus species, and pathological investigation of intraoperative materials demonstrated necrotic tissue and significant inflammation. During the six debridement sessions conducted every other day following carpal tunnel release, the residual cement solidified and was removed until the control X-ray radiographs exhibited no radiopaque areas (Figure 3). A 2.0×3.0-cm area of palmar skin was necrotic and was resected, and the wound after consecutive operations closed with secondary healing. After consecutive debridement surgeries, which all were performed under regional block anesthesia, one month later, reconstructions of the thumb with tendon transfers and the first dorsal metacarpal flap for interphalangeal and metacarpophalangeal joints' contracture was performed. Nine months after the injury and three months after the last surgical procedure, the patient regained his left-hand functions but was unable to abduct the thumb. Thirty degrees limited extension at the metacarpophalangeal joint and 15° at the joint of the thumb. Despite rigorous therapy, thenar region sensibility was not fully regained. On the other hand, n. medianus and n. ulnaris sensation areas on the hand did not cause any complaints. At the final follow-up, injured-side wrist range of motions, extension 40, flexion 35, and radial and ulnar deviation 10 and 15 degrees, respectively, and clinical views of hand motions are presented in Video 2.

The initial and ongoing therapy of the patient included routine laboratory monitoring of C-reactive protein (CBC), serum electrolytes, renal and liver function tests, inflammatory markers (CRP and erythrocyte sedimentation rate [ESR]), and serum calcium levels. These values showed no major systemic abnormalities during hospitalization. The early postoperative phase showed modest leukocytosis (maximum white blood cell [WBC]: 12,300/mm^3) and increased CRP (14.2 mg/L), indicating an immediate inflammatory response

VIDEO 2. Final clinical and functional appearance of the hand.

to soft tissue injury and surgical procedures. Serial debridements and infection prevention gradually stabilized these values. Serum creatinine, liver enzymes, and electrolyte levels, including calcium, were within reference limits, and chemical absorption from concrete did not cause systemic toxicity or organ dysfunction.

We realize that systemic toxicological screening for calcium hydroxide or trace heavy metals (e.g., aluminum, magnesium) was not performed to detect concrete-derived chemicals in the circulation. The limited harm, lack of systemic symptoms (e.g., changed mental status, renal impairment, or electrolyte imbalance), and lack of clinical suspicion for systemic absorption influenced this conclusion. Due to the caustic potential and high alkalinity of the wet cement, the acid-base status and calcium levels were constantly monitored during the intraoperative period and did not change.

In addition, the internal medicine department was consulted early postoperatively to assess systemic toxicology and monitor infection indicators and wound-related systemic inflammatory responses. They agreed with the surgical team that systemic toxicity was improbable and advised clinical observation and supportive care without diagnostic toxicology. Infection indicators and metabolic and electrolyte stability during many surgeries were their main duties. A written informed consent was obtained from the patient.

DISCUSSION

High-pressure injection injuries to the upper extremities are uncommon and provide distinct diagnostic and treatment issues, particularly while utilizing materials like concrete. This case underscores the need for immediate recognition and aggressive management due to the deceptively benign appearance of the initial presentation and the potential for extensive underlying damage.

An injection injury from concrete likely entails a chemical burn and a high-pressure component. The majority of concrete in Türkiye comprises calcium oxide, silicon dioxide, and trace quantities of iron, aluminum, potassium, magnesium, and sulfur oxides.[9] Upon the addition of water, the pH may reach levels as high as 12 to 13 due to the creation of calcium hydroxide. Calcium hydroxide denatures proteins, much like a lye burn, and would persist in causing damage until diluted, neutralized, or removed,[10] An exothermic reaction may result in thermal injury, which can be diminished by promptly immersing the affected area in a basin of warm water following a high-pressure concrete injection injury.

One notable aspect of this case is the extensive spread of concrete from the hand into the forearm, a phenomenon rarely described in the literature. The mechanism of injury with pressures likely facilitated the deep penetration and distribution of the material, necessitating serial debridement and eventual reconstructive procedures. Radiographic imaging played a critical role in assessing the extent of concrete dissemination, corroborating previous studies advocating for early imaging to guide surgical planning and also being sure that there was no remnant of the concrete. Sirinoglu et al.[7] reported a case about the late presentation of a case of high-pressure cement injection to the hand at the level of the metacarpal bones, indicating that serial radiographs were so essential before, between, and after debridement surgeries.

The management involved multiple debridement sessions to remove necrotic tissue and residual cement. The requirement for six consecutive debridements underscores the importance of staged surgical interventions in preventing further tissue damage and optimizing outcomes. Similar to other reports, early fasciotomy was crucial in preventing compartment syndrome and preserving circulation.[11]

The location of the injury is also significant in evaluating the prognosis. Kaufman's cadaver investigation demonstrated that the dispersion of the injected substance is contingent upon the varying densities of the encountered tissues.[12] The status of the thenar region as the most expansible portion of the hand led to increased dispersion of the concrete along anatomical planes extending to the forearm, complicating both the injury and its treatment.

Despite timely intervention and comprehensive management, the patient experienced persistent functional deficits, notably limited thumb abduction and partial sensory loss in the thenar region. These findings are consistent with other reports indicating that functional recovery after high-pressure injection injuries can be incomplete, even with optimal surgical care.[13-18] The use of tendon transfers and flap coverage contributed to the restoration of function, highlighting the value of reconstructive techniques in managing such complex injuries.

It is crucial that personnel receive comprehensive training that adheres to international standards. This includes not only technical skills, but also awareness of the risks associated with high-pressure equipment,[17] We would stress the importance of optimal working hours and conditions to reduce fatigue and enhance focus, thereby minimizing the likelihood of human error. The use of appropriate safety gear must be mandatory, and we would advocate for the continuous development of safety systems in hazardous machinery, ensuring they account for potential human errors. We would propose the implementation of structured safety protocols that are regularly reviewed and updated based on new data and technologies.[17,18]

In conclusion, this case further highlights the importance of occupational safety measures and the need for heightened awareness of the severe consequences associated with high-pressure injection injuries. Early recognition, prompt surgical intervention, and a multidisciplinary team experienced in reconstructive microsurgery remain the cornerstones of management to mitigate long-term morbidity.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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