

# High-pressure injection injury of the hand

## Abstract

Hand injuries due to injection of substances by high-pressure industrial devices is a pathology which the family doctor may have to face. These are rare lesions (0.025-0.25% of the hand injuries) that mostly affect the first finger of the non-dominant hand. Apparently benign but with high risk of substantial long-term morbidity, undervalued many times. Mistakes in the initial management of these injuries can cause serious functional sequelae and amputations. The aim of this article is to review and summarize the main concepts of etiopathogenesis, diagnosis, treatment and prognosis of these lesions, as well as the lines of action in their prevention, in order to raise awareness among health personnel for the need to administer a quick and aggressive treatment in the first hours, to avoid complications and consequences so important that they can reach 48% of finger amputations. (Medical action need be standardized). Since the three main prognostic factors are the characteristics of the injected substance (type, amount, pressure and temperature), the anatomical area damaged and the time elapsed between the accident and the start of treatment, it is evident that early treatment determines the result. It is the only factor that the physician can change. Prevention is probably the issue to address to achieve the challenge of reducing the final consequences as much as possible.

**Keywords:** high-pressure injection injury, hand, prognostic factors, finger amputations, hand injuries, etiopathogenesis, diagnosis, hyper pressure, gun, injectors, compressed air, oxygen, helium

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## Introduction

The injuries by high-pressure injection of substances are infrequent (0.025-0.25% of the injuries of the hand) but are however extremely dangerous as a result of the serious affects that they produce, being able to limit the future function of the affected limb. Despite being infrequent injuries, the primary care physician who carries out his activity in emergency services must be aware of them, without underrating their apparent lightness and requiring the assessment of specialists because the absence of emergency treatment can make the lesion evolve towards a state of irreversible sequelae. Since Rees<sup>1</sup> in 1937 first recorded and described a case of this type in written literature, we have witnessed a progressive increase in the use of high pressure systems in the industrial sector, a medium in which these injuries are mostly present, although the improvement and greater awareness of the correct use of PPE (personal protective equipment) in the last decades make their incidence proportionally lower. Nonetheless, injuries produced by the injection of a liquid or gaseous substance, generally in the pulp of the index finger of the non-dominant hand, come from a high pressure system (gun, injectors) that develop an output pressure of the material from 140 to 700 Kg / cm<sup>2</sup> and a speed exceeding 300 m/sec., which is sufficient to overcome the primary protection cutaneous barrier and harm deeper structures. There are many substances that can be involved in this type of work accidents, of two main types, fluids (gas oil, paint, brake fluid, water, grease-oil, polyurethane, ...) and gas (compressed air, oxygen, helium, ...), the most frequent being grease and oil, followed by painting.<sup>2</sup>

## Physiopathology

The pathophysiological mechanism is based on three factors: mechanical effect, hyper pressure and chemical irritation.<sup>3,4</sup> The mechanical lesional effect that every particle in motion, with its corresponding kinetic energy, produces when impacting soft tissues, especially the ones with noble structures, such as vessels and nerves, can even cause a rupture of tendons, as reported by Costas-Chavarri.<sup>5</sup>

The hyper pressure that the injection of any substance produces on relatively inextensible anatomical areas such as the hand, can cause a vascular blockage effect that can lead to ischemia and compartment syndrome. The chemical irritation reactivates the injection of foreign substances in our body, such as the formation of olegranulomas secondary to the injection of fats, formations that according to Vinogradoff<sup>6</sup> could evolve towards malignization, or necrosis of the subcutaneous cellular tissue by dissolving the lipids in the presence of industrial solvents.

## Anatomical area

Regarding the anatomical lesional area, the injection occurs more frequently in the fingers, affecting more to the palm of the non-dominant hand, and within these the second, followed by the first and third, being there a greater incidence in the volar zone than the back, area in which there is a greater risk of spreading the substance injected by the presence of the tendon sheath.

## Diagnosis

The diagnosis must be mainly clinical, supported by the different diagnostic means. Unfortunately, these are relatively unknown and undervalued lesions, and in the first hours there may be no more signs than a punctate wound from which a small amount of the injected liquid or blood can emanate, which gives it an appearance of apparent benignity. Subsequently there is edema, pallor or cyanosis, local anesthesia and a progressive functional limitation, which in the absence of emergency treatment can evolve to a necrosis and infection at 24-48 hours. We should be alert about the possible establishment of a primary compartment syndrome (due to the high pressure caused by the injection of a gas or fluid) or secondary syndrome (due to the toxic effects of the injected substance)<sup>7</sup> Complementary diagnostic means are of great help, the realization of a conventional radiological study (evaluation of radiopaque material, gas) being necessary (Figure 1); the magnetic resonance would provide an adequate valuation of the tissue damage and degree of propagation of the material injected.



**Figure 1** Finger paint injection.

### Treatment

The treatment should always be an emergency treatment, generally surgical, except for some cases of air or water injection. The time elapsed from the injection of the substance to the treatment should be reduced to the maximum, this being an aspect on which the medical and paramedic personnel can act directly. The surgical treatment will always be rendered under anesthesia, preferably with long-term brachial plexus blockage and ischemia without expression of the affected area, to avoid the spread of the injected substance. It should involve extensive debridement and washing, trying to remove all the injected substance and necrotic tissues (Figure 2), decompression of the neurovascular structures and closure without tension (or delayed closure), using coverage with flaps before the exposure of tendinous and neurovascular structures.<sup>8</sup> Perioperative treatment requires adequate tetanus and antibiotic prophylaxis, combining a cefazolin and an aminoglycoside, such as cefazolin and tobramycin. The use of corticosteroids (methylprednisolone) in a single dose in the emergency department is useful. Early physiotherapy is essential to minimize the risk of fibrosis and help functional recovery of the limb, always supported by an adequate analgesia regimen. Smoking must be prohibited. Though injuries by injection of air and water at high pressure should not be underestimated, in some cases one can initially adopt an expectant attitude. The properties of the high pressure system, including the source of water and its temperature, should be considered, as well as the functional state of the limb, wound characteristics, neurovascular status and attention to possible compartment syndrome. If the examination is favorable, it is possible to opt for hospital observation, elevation of the limb and the pharmacological prophylaxis mentioned above. In case of any warning sign, surgical treatment should be carried out according to the criteria already explained. The authors recommend the algorithm proposed by Verhoeven<sup>9</sup> for this type of injury, which protocolizes the action from the place of the accident to the different phases of hospital treatment, considering the type of substance injected.

### Prognosis

The prognosis of these injuries will depend on the affected area (worse on the fingers, since they are less distensible areas than the hand), the type of material injected (paints, solvents and brake fluid are of worse prognosis), temperature, quantity and degree pressure, as

well as the time elapsed between the injury and the start of treatment (the higher it is, the worse the prognosis).



**Figure 2** Finger X-ray: plumb paint.

### Prevention

Prevention is a fundamental aspect in the management of this type of accident, given that, as we have said, these are injuries with a high rate of complications and sequelae, the type of substance and the characteristics of its injection, being aspects more related to industry than to medicine.

### Discussion

The family doctor must know these lesions and have an action procedure like the algorithm proposed by Verhoeven.<sup>9</sup> It is very important that the injured is immediately transferred to an emergency unit, where the doctor will take into account the characteristics of the product used and the industrial injection system, assess the state of the hand and general condition of the patient and decide the attitude to follow with the support of the orthopedic surgery specialist. The injury-treatment interval, in which an adequate coordination between the paramedical and medical team (since the accident warning is given, the transfer to the hospital center is properly carried out and a specific specialized protocol is applied) significantly reduces the degree of final sequelae, emergency surgical debridement being known to reduce the risk of amputation.<sup>10</sup> Although the use of corticosteroids is under discussion<sup>11</sup> the authors recommend the use of i.v. of 250 mgr. of prednisolone diluted in 100 ml of saline solution in a single preoperative dose, there being no evidence that its use in the acute phase increases the risk of infection or the incidence of amputation,<sup>10</sup> avoiding an acute inflammatory response to the fluid injected. Unfortunately, even after an early and adequate treatment, the complications and sequelae are frequent and important: tissue necrosis (Figure 3), infection, fibrosis that evolve towards rigidities, digital atrophy and complex regional pain syndrome, the most feared one being the compartment syndrome. The digital amputation rate after these injuries is 48%,<sup>12</sup> reaching 100% when the substance is injected at a pressure higher than 500 kgr/cm<sup>2</sup>, according to the review carried out by Schnall.<sup>13</sup> Remember that amputation is not only carried out by the appearance of complications such as necrosis or infection, but also by the presence of a stiff finger, which sometimes, especially in manual workers,<sup>14</sup> can become annoying and even cause subsequent accidents when handling industrial machinery. However, the main complication is the initial underestimation of the

lesion, which leads to a delay in treatment and a greater number of sequelae,<sup>15</sup> so an adequate initial medical action is crucial. Prevention is the Gold Standard in the management of these injuries, based on three actions: the continuous training of workers who handle these systems of injection of substances, the investigation of substances which are more water soluble and less harmful to the organism, and the improvement in Individual protection equipment and development of industrial safety devices (automatic stop in emergency situations, automatic unblocking, ...) in compliance with labor legislation.<sup>16</sup> The accurate treatment of these lesions has its limitations in terms of the final result of the functionality of the hand, so it is necessary that medical science and industry continue to work together to reduce the aggression and sequelae of this type of accidents.



**Figure 3** Index finger pulp necrosis.

## Conclusion

Lesions of the hand due to high-pressure injection are apparently mild lesions in the first hours, which can evolve towards severity with important and perhaps irreversible sequelae. The general practitioner should know this pathology, be alert and act quickly with an adequate assessment of the local and general state of the patient, consider the characteristics of the injected substance and request urgent help from the qualified surgeon for its rapid treatment, since the final functional state of the hand will depend on it.

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## Conflict of interest

The author declares there is no conflict of interest.

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