Hand Injuries Due to High-Pressure Injection Devices for Painting in Shipyards: Circumstances, Management, and Outcome in Twelve Patients

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Background Injuries due to high-pressure injections are frequently underestimated occupational accidents, which may have disabling outcomes.

Methods The occupational injuries logbooks of two shipyards were examined. Twelve accidents due to the utilization of high-pressure equipment were reported. Data were obtained by reviewing the employers’ logbooks and hospital records.

Results Contaminants were epoxy paint and stucco, paint solvent, hydraulic and industrial oil. In three cases, the palm was injured and the fingers in nine. In 91% of cases, the accident occurred in the last 2 hr of the work shift. Mishandling (n = 9) and rupture of the high-pressure equipment (n = 3) were the causes. Mean time to medical treatment was 42.5 hr (SD 56.0). Ten workers were permanently disabled.

Conclusions Prompt surgical intervention with debridement and decompression was done in two workers, who healed completely. The ten patients who were not treated immediately eventually experienced a high rate of disability and five of them also suffered amputation. Am. J. Ind. Med. 43:539–542, 2003. © 2003 Wiley-Liss, Inc.

KEY WORDS: occupational injuries; hand injuries; shipyard; spray painting; high-pressure equipment; wound management

INTRODUCTION

High-pressure injection devices have a wide range of industrial applications when painting, cleaning, greasing, and degreasing of large surfaces and optimal application of substances are required.

This type of equipment can produce pressures of 600–12,000 pounds/square inch (psi) [O’Reilly and Blatt, 1975; Hayes and Pan, 1982], delivering paint, solvent, water, and air at a speed comparable to the muzzle velocity of a rifle (Fig. 1). The substance penetrates into the skin through a minute entry wound and rapidly spreads through the tissues. The resulting lesions, first described by Rees [1973], affect most often the index finger [Pai et al., 1991] of the hand that is not operating the apparatus (non-dominant hand). The generally tiny entry wound is too frequently underestimated [Mrvos et al., 1987; Peters, 1991] and many of these lesions evolve unfavorably [Mrvos et al., 1987; Peters, 1991] and may produce permanent functional impairment and disability.

A typical use of high-pressure injection equipment is hull painting in shipyards. We examined the occupational

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injury logbooks of two naval painting firms operating in two shipyards (one on the Adriatic and the other on the Tyrrhenian sea) to study the evolution, management, and outcome of these distinctive injuries so that a suitable, effective emergency protocol might be developed for the occupational health physician.

MATERIALS AND METHODS

From January 1973 to October 2000, 12 cases of lesions due to high-pressure jets were entered in the occupational injuries logbooks of two naval painting firms.

All cases were monitored by the Italian national insurance body for occupational injuries (INAIL), which recognized permanent disabling outcomes in ten cases.

Subjects were 12 males, mean age 39.7 years (SD 6.8), with a mean seniority in naval painting of 16.4 years (SD 7.2). All had been assigned to the same job for at least 5 years. At the time of the accident, nine were using an airless paint sprayer and three high-pressure grease guns. None had previously experienced similar accidents.

RESULTS

In 11 (91%) of these cases, the accident occurred in the last 2 hr of the work shift, but no correlation was found with shift number (morning, afternoon, or night).

In nine cases, the accident was attributed to carelessness by the worker, who had forgotten to turn off the compressor (which was producing 5,000 psi) after completing the job. Three (25%) workers were injured as they descended the scaffolding holding the gun; six (50%) inadvertently turned the apparatus on during maintenance or cleaning operations.

In three cases (25%), the accident was due to the rupture of the high-pressure pipe or of the pipe–gun joint.

Data regarding age, operation performed at the time of the accident, lesion site, substance injected, time to first medical intervention, type of treatment, and outcome are reported in Table I.

Hospital treatment was delivered at the Orthopedics Departments of the nearest hospital (Ancona and Savona).

All lesions involved the hands. All workers were right-handed. There were 10 (83.4%) lesions of the left hand. In nine cases (75%), the fingers were injured: the index finger in eight cases (66.6%) and the thumb in one (8.4%).

The contaminants injected were epoxy paints or solvents in eight cases, hydraulic oil in two, and industrial oil and epoxy stucco in the remaining two. The solvents were xylol and tetrachloroethylene base. The epoxy paints contained oil distillate, turpentine, and toluene as catalyst. In two cases, they also contained barium salts (cases 10 and 11) and in one tar (case 8). Stucco contained epoxy resin.

All these substances have a marked irritating action on tissues, in particular, the paint and solvent injections produced a strong inflammatory reaction with formation of necrotic areas.

Eight (66.6%) of the workers were immediately treated at the emergency care unit of the nearest hospital. In two cases (16.6%), the wounds were treated immediately with surgical debridement, decompression, and careful cleansing of the lesion site. Hand X-rays were done before surgical treatment in two cases (cases 8 and 12). In the other six cases (50%), surgical treatment was performed many hours later (cases 3, 4, 5, 6, 9, 10).

Four (33.3%) other workers (cases 1, 2, 7, 11) did not receive prompt emergency hospital care, probably because they did not realize the import of the lesion. Overall, the interval between trauma and the implementation of an effective therapy was 42.5 hr (SD 56.0), corresponding to 1.77 days (SD 2.33).

The size of the entry wound was between 1 and 7 mm. Clinical presentation was initially inconspicuous, but after about 6 hr swelling, pain, and edema involved the whole hand. All patients initially received anti-inflammatory drugs (non-steroidal anti-inflammatory drugs or corticosteroids),
anticoagulants, wide-spectrum antibiotics, and tetanus toxoid. Surgical management included in all cases debridement and cleansing with lukewarm or cold saline. The incisions were left open up to 30 days to allow daily cleaning of tissues. Complications that required specific treatment were phlegmon and edema with volume increase of the affected finger (case 6) and tissue asphyxia due to resin solidification (case 5).

Long-term complications were: recurrent severe edema for several years (case 1), granulomatous inflammation due to foreign bodies with incarceration of the median nerve (case 9), bacterial superinfection of the wound, and subsequent dry gangrene with loss of cutaneous substance from the dorsum of the hand (case 3).

The two (16.6%) patients who did not develop complications (cases 8 and 12) had received immediate and appropriate surgical treatment: they healed completely, regained full function of the hand, and returned to their job.

In 10 (83.4%) cases, disabling functional deficits remained: amputation of the finger was necessary in six (50%) cases; in the other four (33.3%), finger range of motion and sensitivity remained totally or partially impaired.

**DISCUSSION**

High-pressure injection equipment exploits the energy potential of the air issuing from a pump. Once the external constraint that maintains it under pressure is removed, the air and the substances, which are dissolved in it expand rapidly back to their original volume.

High-pressure jets puncture the skin, injecting foreign substances into tissues (fascial planes, tendon sheaths) [Ebelin, 1994]. Their expansion through the tissues depends on jet density and speed and on the resistance of body structures [Schoo et al., 1980; Mrvos et al., 1987].

The small size of the entry wound and the minimal, non-specific early symptoms often cause the seriousness of these lesions to be underestimated and treatment to be delayed [Sirio et al., 1989; Pinto et al., 1993]. In a few hours, symptoms become more and more marked, with pyrotic pain and significant swelling; the skin acquires a mottled appearance [Mrvos et al., 1987; Ebelin, 1994]. From the physiopathological point of view, tissue distension and vessel compression result in ischemic necrosis and eventually gangrene.

Water and air generally cause no serious damage [Peters, 1991; Harvey et al., 1996]: in these cases medical treatment with wide spectrum antibiotics and tetanus prophylaxis are usually sufficient [Ramos et al., 1970].

By contrast, when a toxic substance has been injected [Pai et al., 1991; Ebelin, 1994] chemical irritation of tissues [Pai et al., 1991], cell damage, further vasospasm, thrombosis and, frequently, bacterial superinfection occur [Peters, 1991]. The various substances contained in paint and solvents have an irritating, sensitizing, burning action on tissues. In these cases, and when the injected substance brings with it contaminated material, thrombus, granuloma, local sepsis, and even gangrene arise.

Correct management of these lesions is primarily surgical, with immediate removal of the foreign material, debridement, cleansing of necrotic areas, placing of a drain. Medical treatment includes tetanus and antimicrobial prophylaxis and antibiotic administration.

Delayed surgical treatment may allow the establishment of severe tissue damage whose natural outcome is fibrosis and neurovascular injury [Lewis, 1985] or gangrene, which

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### TABLE I. Characteristics of Wound, Management, and Outcome of 12 Subjects Who Received Jet Injuries to the Hand

<table>
<thead>
<tr>
<th>Year</th>
<th>Case</th>
<th>Age</th>
<th>Job</th>
<th>Wound location</th>
<th>Foreign material injected</th>
<th>Time to first medical intervention</th>
<th>Wound management</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>1</td>
<td>32</td>
<td>Spray painting</td>
<td>P3 II left</td>
<td>Paint solvent</td>
<td>2 hr</td>
<td>DDD</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1976</td>
<td>2</td>
<td>45</td>
<td>Spray painting</td>
<td>P3 II left</td>
<td>Paint solvent</td>
<td>2 hr</td>
<td>DDD, cross-finger flap</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1979</td>
<td>3</td>
<td>42</td>
<td>Spray painting</td>
<td>P2 II left</td>
<td>Epoxy paint</td>
<td>6 days</td>
<td>DDD</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1980</td>
<td>4</td>
<td>29</td>
<td>Spray painting</td>
<td>P2 II left</td>
<td>Paint solvent</td>
<td>2 days</td>
<td>DDD, cross-finger flap</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1981</td>
<td>5</td>
<td>33</td>
<td>Spray painting</td>
<td>P2 – 3 II left</td>
<td>Epoxy stucco</td>
<td>2 days</td>
<td>DDD, cross-finger flap</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1984</td>
<td>6</td>
<td>51</td>
<td>Greasing</td>
<td>P3 II left</td>
<td>Hydraulic oil</td>
<td>7 days</td>
<td>DDD</td>
<td>Permanent loss of hand function</td>
</tr>
<tr>
<td>1986</td>
<td>7</td>
<td>47</td>
<td>Greasing</td>
<td>P1 V left</td>
<td>Industrial grease</td>
<td>1 day</td>
<td>DDD</td>
<td>Permanent loss of hand function</td>
</tr>
<tr>
<td>1989</td>
<td>8</td>
<td>42</td>
<td>Spray painting</td>
<td>Left palm</td>
<td>Paint solvent</td>
<td>Immediate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>DDD</td>
<td>Recovery</td>
</tr>
<tr>
<td>1990</td>
<td>9</td>
<td>38</td>
<td>Greasing</td>
<td>P1 II left</td>
<td>Hydraulic oil</td>
<td>36 hr</td>
<td>DDD</td>
<td>Permanent loss of hand function</td>
</tr>
<tr>
<td>1993</td>
<td>10</td>
<td>35</td>
<td>Spray painting</td>
<td>P1 I left</td>
<td>Epoxy paint</td>
<td>12 hr</td>
<td>DDD, cross-finger flap</td>
<td>Digit amputation</td>
</tr>
<tr>
<td>1994</td>
<td>11</td>
<td>36</td>
<td>Spray painting</td>
<td>Right palm</td>
<td>Epoxy paint</td>
<td>1 day</td>
<td>DDD, cross-finger flap</td>
<td>Permanent loss of hand function</td>
</tr>
<tr>
<td>2000</td>
<td>12</td>
<td>46</td>
<td>Spray painting</td>
<td>Left palm</td>
<td>Epoxy paint</td>
<td>Immediate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>DDD</td>
<td>Recovery</td>
</tr>
</tbody>
</table>

<sup>a</sup>Immediate, within 30 min.

P1, first phalanx; P2, second phalanx; P3, third phalanx; finger, I, II, III, IV, V. DDD, decompression, debridement, drainage.
ultimately requires amputation [Pinto et al., 1993; Stoffelen et al., 1994].

An X-ray should precede the surgical treatment both to detect fractures and to guide the decompression by showing the extent of the spread of the contaminant, which may contain radio-opaque substances. Angiographic investigations are also useful to evidence the presence of unperfused areas. A physical rehabilitation program subsequently allows to reduce the degree of functional impairment [Lewis, 1985; Moutet et al., 1991; Jebson et al., 1993].

Although all of the 12 workers received surgical treatment, only two (16.6%), who were treated immediately and correctly, achieved complete functional recovery; four workers did not regain full functional ability despite not requiring amputation; amputation of the finger was necessary in the remaining six cases. In the present sample, the substance injected did not affect outcome, as the two workers who healed completely had received an injection of the same substance as the six who had permanent disability (Table I).

In line with previous reports, our data confirm that immediate treatment can lead to complete functional recovery, and that the implementation of a correct surgical protocol vastly improves the rate of success; indeed, the palm lesions of the two workers who achieved full recovery did not spread to the arm [Mrvos et al., 1987; Sirio et al., 1989; Ebelin, 1994; Stoffelen et al., 1994].

In most cases, the lesions were produced by mishandling of paint sprayers [Mrvos et al., 1987]. As in the cases reported by Peters [1991], the majority of accidents were due to carelessness by the workers, and were more frequent at the end of the work shift; only in three (25%) cases was the accident due to rupture of the equipment.

None of the workers was wearing appropriate protective gloves at the time of the accident. Gloves resistant to high-pressure jets have become available over the last few years and should consistently be worn.

Prompt medical intervention and correct management of the distinctive lesions due to high-pressure jets by emergency care operators are thus crucial factors when these essential safety precautions have not served or have been omitted.

REFERENCES


