

# HIGH-PRESSURE INJECTION INJURIES OF THE HAND IN A CHINESE POPULATION

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**We performed a retrospective review of 28 digits in 28 patients who suffered high-pressure injection injuries of the hand during the last 10 years. They were all men, with a mean age of 36 years. All were work injury and the injuries were classified into mild, moderate and severe and were either treated conservatively or surgically. There were seven patients with mild injuries and six of these were successfully treated by conservative methods. Sixteen patients had moderate injuries and all were successfully treated with repeated debridement and delayed direct closure. The index fingers of two severely injured patients were salvaged with digital artery flaps and the remainder of the involved fingers were amputated. The authors advocate proper identification of mild injuries to allow conservative treatment, the application of digital artery flaps for resurfacing large finger defects and have formulated a treatment protocol according to the severity of the injury.**

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## INTRODUCTION

High-pressure injection injury of the hand is a rare injury but improper management can result in disastrous outcomes and, even, amputation. Amputation rates as high as 48% have been reported (Schoo et al., 1980). The reason for such high amputation rates probably relates to the type of injected material, time to treatment, amount of soft tissue involvement and proximal spread of the injected substances (Gelberman et al., 1975; Lewis et al., 1998; Pai et al., 1991). Management should be based on the severity of the injury. Although mild injuries may give rise to a poor outcome, conservative treatment can be justified in certain instances (Kendrick and Colville, 1982; Peters, 1991). While immediate, aggressive, surgical decompression and removal of foreign material is required in most circumstances, this often results in significant loss of tissue and, later, requires challenging reconstruction.

The purpose of the present study was to review the treatment of our patients with high-pressure injection injuries of the hand and ascertain whether it is possible to formulate a treatment protocol which improves on those previously described.

## PATIENTS AND METHODS

We conducted a retrospective review of all patients admitted with high-pressure injection injuries of the hand from July 1994 to July 2004. The demographic data, types of injected materials, mechanism and site of injection, extent of soft tissue involvement, time to treatment, extent of surgery and final outcome were recorded. The patients were classified into mild, moderate and severe injuries (Table 1). Based on this

study, we formulated a treatment protocol according to the severity of the injury, which is also shown in Table 1.

All patients were managed according to the severity of the injury, based on the injected material, time to treatment, extent of soft tissue involvement and clinical neurovascular status.

Mild injuries were treated by conservative methods with broad-spectrum antibiotics, close observation of the vascular condition of the fingers and keeping patients prepared for surgery, in case this was necessary. The extent of soft tissue involvement was determined clinically, with the aid of radiographs.

Moderate and severe injury patients were managed with broad-spectrum antibiotics and immediate surgical treatment, including decompression of the affected finger through a Bruner type of incision, meticulous removal of all foreign material and debridement of all devitalized tissue. The extent of soft tissue involvement was determined with the aid of radiographs and, then, intraoperatively. All wounds were irrigated with large amounts of saline. No chemical solvent was used to assist in removing foreign material. All wounds were either loosely sutured or left open with packing at the end of the primary surgery.

Repeated debridement was performed until the wound condition was good. Delayed closure was then performed. Soft tissue reconstruction with digital artery flaps was performed if a wide wound defect was present (Fig 1). Ischaemic digits were amputated at as distal a level as possible.

The digital artery flap used was a heterodigital arterialized flap which was raised from the side of a finger. An Allen test was performed pre-operatively on the donor digit to make sure both digital arteries were patent. The surgery was performed under general anaesthesia and tourniquet, after elevation of the limb

**Table 1—Treatment protocol for high pressure injection injuries of the hand**

<i>Severity</i>	<i>Nature</i>	<i>Treatment</i>
Mild	<ol style="list-style-type: none"> <li>1. Injected material is usually oil</li> <li>2. Relative low-pressure injection</li> <li>3. No treatment delay</li> <li>4. Small area of involvement without proximal extension (confirmed with radiograph)</li> <li>5. Preserved sensation and circulation</li> </ol>	<ol style="list-style-type: none"> <li>1. Conservative during the initial treatment period</li> <li>2. Close observation with antibiotics coverage</li> <li>3. +/- steroid</li> <li>4. Prepared for surgery</li> </ol>
Moderate	<ol style="list-style-type: none"> <li>1. Moderate soft tissue involvement</li> <li>2. No treatment delay</li> <li>3. Neurovascular bundles not compromised</li> </ol>	<ol style="list-style-type: none"> <li>1. Prompt decompression, wide debridement, open packing</li> <li>2. +/- repeated debridement</li> <li>3. Delayed closure</li> </ol>
Severe	<ol style="list-style-type: none"> <li>1. Injured by paint and solvents</li> <li>2. From high-pressure spray guns</li> <li>3. Delay in treatment</li> <li>4. Extensive soft tissue involvement with proximal extension</li> <li>5. Loss of sensation and poor circulation</li> </ol>	<ol style="list-style-type: none"> <li>1. Prompt decompression and meticulous removal of foreign materials and dead tissue</li> <li>2. +/- repeated debridement</li> <li>3. Late reconstruction or staged amputation</li> <li>4. Early amputation if indicated</li> </ol>



Fig 1 Wide wound defect of the left index finger after debridement.

to provide a bloodless field. After making a template of the defect, the flap of appropriate dimensions was drawn, centred over the midlateral line of the donor digit but without involving resection of the distal pulp

(Fig 2). The digital artery, the dominant dorsal vein and venous comitantes were dissected from the digital nerve, which is more superficial and can be left undisturbed. The flap was raised after ligating and dividing the artery and vein at its distal margin (Fig 3). It was transposed to resurface the defect of the recipient digit. The tourniquet was released to check flap perfusion and the donor site was resurfaced with a full thickness skin graft, with a tie-over dressing (Fig 4). A window was made over the loose, bulky dressing for flap monitoring. Finger mobilization exercises were started at 7 days, as soon as the graft had taken, to prevent finger stiffness.

All surgery was performed by experienced orthopaedic surgeons and all patients received postoperative physiotherapy to mobilize the injured hands. They were followed up regularly in specialist out patient surgical clinics to assess their functional outcome.

A finger flexion lag with a pulp-to-distal palmar crease distance of more than 1.5 cm was considered unsatisfactory.

## RESULTS

A total of 28 male patients with 28 injured digits, all injured at work, were reviewed. The mean age of the patients was 36 (range 22–48) years. The most commonly injured age group was from 35 to 40 years-old. This age group constituted 60% of the series. Twenty-five patients had injured the left hand and 3 had injured the right hand. Twenty-five non-dominant and three dominant hands were involved. Eighteen index fingers and ten middle fingers were injured. No palmar injection injury was seen or involved in our series and there were no cases of injection of radiolucent materials. The details of the 28 patients were summarized in Table 2.



Fig 2 Design of a digital artery island flap on the radial side of the middle finger.

Seven patients had mild injuries. The sites of injection were all finger tips and radiographs showed only a small area of soft tissue involvement. Six of these were successfully treated by conservative methods and one required surgical decompression one day after initiating conservative management, because of increasing pain and swelling of the affected digit during the period of observation.

Sixteen patients suffered moderate injuries and the sites of injection were all at the base of the distal phalanx. Radiographs of these patients showed that the foreign material involved only the distal phalanx with proximal extension to the distal part of middle phalanx. All patients were successfully treated by immediate decompression, subsequent debridement and delayed closure.

Five patients were deemed to have severe injuries because radiographs showed extensive soft tissue involvement and large amount of spread of foreign material, with proximal extension to the middle phalanx (Fig 5). The site of injection involved the middle phalanx in all cases. All patients were treated by immediate surgical decompression and aggressive debridement. Two index fingers of two patients were salvaged with one digital artery flap per finger after two debridements



Fig 3 The flap has been raised after ligating and dividing the digital artery and dorsal dominant vein distally while leaving the digital nerve in situ.

of each finger. The sensibility in the injured fingers was good and there were no significant donor finger mobility at a mean follow-up 12 months. A further three patients who had had considerable delay before treatment required amputation of the affected fingers at the proximal phalanx in two patients and at the middle phalanx in one patient.

## DISCUSSION

The majority of high-pressure injection injuries will produce significant morbidity to the hand. However, there is actually a spectrum of injuries which range from mild to severe finger damage. The importance of prompt treatment, adequate decompression and aggressive debridement, with broad spectrum antibiotics coverage, are well documented in the literature (Neal and Burke, 1991; Pai et al., 1991; Pinto et al., 1993).

Relative low-pressure injection injuries largely occur because the length of pipe from engine to finger is longer and the pressure in the pipe drops with distance from the machine. The patients may also have sufficient time to withdraw the injured hand with longer distance between

the engine and the injured hand, so less amount of material is injected into the finger. With high-pressure injuries, the distance from the injection machine to the injured finger is shorter and direct injection of larger amounts of materials occurs. With respect to the types of material injected, our local experience is similar to

that in the literature, with the most commonly injected materials being automotive grease, diesel oil and paint (Gelberman et al., 1975; Pai et al., 1991).



Fig 4 The flap has been transposed to resurface the wound defect and the donor site reconstructed with a full thickness skin graft, with a tie-over dressing.



Fig 5 A lateral radiograph showing extensive soft tissue involvement with proximal extension to the middle phalanx.

**Table 2—Summary of 28 cases of high-pressure injection injuries of the hand**

	<i>No. of patients</i>	<i>Distribution of injection sites</i>	<i>Injected materials</i>	<i>Mechanism of injury</i>	<i>Time to treatment mean (range)</i>	<i>No. of amputations</i>	<i>Follow-up mean (range)</i>	<i>No. of fingers with flexion lag &gt; 1.5 cm</i>
Mild	7	N-D I/F tip 5 N-D M/F tip 2	Grease 5 Oil 2	Engine injector 5 Hydraulic pump 2	6 hours (4-12)	0	12 months (3-80)	0
Moderate	16	N-D I/F D/P 7 N-D M/F D/P 6 D I/F D/P 3	Grease 8 Oil 6 Paint 2	Engine injector 6 Hydraulic pump 8 Spray gun 2	6 hours (4-12)	0	13 months (4-85)	1
Severe	5	N-D I/F with extension 3 N-D M/F with extension 2	Paint 5	Spray gun 5	18 hours (16-24)	3	12 months (4-85)	1

N-D, non-dominant; D, dominant; I/F, index finger; M/F, middle finger; D/P, distal phalanx.

Our series clearly illustrates that the majority of mild injuries can be treated conservatively without complications. Identification of these mild injuries is, therefore, of paramount importance. They can be recognized clinically in the early stages after injection. The injected material is usually grease or oil injected at a relative low pressure, with no delay to treatment. The area of soft tissue involvement, as determined by radiographs, is small, without proximal extension, and the neurovascular status is clinically good. That radiographs aid in determination of the extent of soft tissues involvement is well documented (O'Reilly and Blatt, 1975) but they may be misleading after injection of radiolucent materials. Therefore, the radiological findings must be correlated with the clinical findings. While mild injuries can be treated conservatively, initially, close clinical observation of the finger condition and preparation for possible surgery is necessary.

Aggressive debridement is the key to success in treating high-pressure injection injuries of the hand. However, we need to avoid over-dissection of the normal tissues in those injuries considered "moderate", as this adds to the problems of reconstruction later and may, even, lead to a greater likelihood of amputation. Judicious use of steroid has also been advocated to control the inflammation. The use of immediate high-doses of systemic corticosteroids followed by high-dose oral steroids in tapered doses is proposed to decrease the chemical inflammation and deleterious tissue responses to the injected material, (Phelps et al., 1977; Schoo et al., 1980). We did not use steroid in our cases as we still worry about its side effects and feel that more data is needed before we will be happy to use it routinely.

Despite early surgical intervention, the amputation rate for the severe injuries is obviously significant. This may present a dilemma: whether to elect for early amputation or repeated surgery in an attempt to salvage the digit. Early amputation should be considered for those digits which are cool, with poor perfusion and loss of sensation, as suggested by Lewis et al. (1998). It is obvious that decisions in this respect will always be multifactorial and will include such factors as the individual patient's general health and circumstances and surgical factors, such as the technical availability of flap surgery.

The use of a heterodigital artery flap for resurfacing large finger defects is widely advocated in the literature (Teoh et al., 2003; Rose, 1983). Although not commonly used after these injuries, we salvaged 2 fingers by use of such flaps and we believe that heterodigital flaps are the

best surgical option in these circumstances. We would recommend their consideration in selected cases.

It is important in all cases of high-pressure injection injury that we inform the patient adequately of the risk of amputation, perhaps, especially, when attempting conservative management or finger retention and reconstruction. Amputation is, largely, a complication of the injury, not of the surgery. If the patient is not informed properly before treatment and the finger becomes ischaemic later, this may become a medico-legal issue.

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