Chapter 35

HAND CRUSH INJURY AND COMPARTMENT SYNDROME

KEY FIGURES:

Volar forearm fasciotomy incisions
Hand/dorsal forearm fasciotomy incisions
Finger fasciotomy incisions

The previous chapters about the hand have discussed easily identifiable, individual injuries to the upper extremity. A crush injury is more complex and may affect all of the tissues of the hand and forearm. It is, therefore, more difficult to treat. The risk of long-term disability after a crush injury is quite high.

Initially, the affected hand and forearm may appear to have suffered only minor damage because external wounds are few. Significant damage to the skin and underlying tissues may not become appreciable for hours or even days after the injury. Initial care plays an important role in final functional outcome.

Most of the necessary interventions require surgical expertise. However, the initial examiner must be aware of all of the potential problems that may develop so that proper specialty help can be obtained. This chapter outlines such problems and discusses specific treatment for compartment syndrome (the most severe complication of crush injury) if specialty help is not available. It may save not only hand function but also the patient's life.

Crush Injury: Definition and Examples

A crush injury occurs when a compressive type of force is applied to the tissues. At the site of injury the tissues experience several forces simultaneously, including shearing, contusion, and stretching in addition to pressure. This scenario is much different from what the tissues experience when injured, for example, with a knife.

Examples of crush injuries include the following:

- Getting the fingers, hand, or forearm caught in a wringer or roller machine.
- A motor vehicle accident that occurs as the patient is resting an arm along the window sill on the outside of the car. The car flips over onto that side, crushing the extremity.
- Getting the hand or forearm caught between two heavy objects that are compressed together.

Effects on the Tissues

Skin and Subcutaneous Tissue

The skin may be seriously injured with multiple lacerations and contusions. Foreign material may be embedded in the wounds. Alternatively, the skin may look largely intact. However, large flaps of skin may have been created by the injury. If the skin is detached from the underlying fascia and muscle (**degloving injury**), the circulation to the skin is greatly compromised. The result can be significant skin loss.

In addition, blood and serum may collect in the tissue plains between skin and muscle. Build-up of pressure may cause further tissue damage and possibly a **compartment syndrome** (see below).

Muscle

Direct pressure injury and shearing forces lead to overstretching and tearing of the muscle. The results are bleeding and swelling within the muscle itself. A compartment syndrome with potentially devastating consequences may develop (see below). In addition, disruption of muscle-tendon connections may result in loss of function.

Tendons

Although a crush injury probably will not tear a tendon completely, the stretching forces may create small, partial tears. During the healing process, scar tissue forms to heal such tears and may cause the tendons to adhere to surrounding tissues. Adhesions may interfere significantly with the tendon's ability to glide smoothly, resulting in loss of joint motion and hand function.

Nerves

Usually, nerves are not torn by a crush injury. However, the nerve's ability to conduct electrical impulses may be temporarily or possibly permanently disrupted. It may take weeks to even months to determine whether the loss of nerve activity is permanent.

With damage to sensory nerves, the patient may experience tingling and numbness (paresthesias) or even painful hypersensitivity to touch. With damage to motor nerves, weakness or complete loss of function may result.

Blood Vessels

Blood vessels can be injured by direct compression (depending on how long the extremity was crushed) or shearing forces, which may injure the inner layer (the intima). Either mechanism can cause the vessel to clot.

If the injured vessel is an artery, the surrounding tissues lose their blood supply and ischemia results. If the injured vessels are veins, diminution of venous outflow from the damaged area leads to a build-up of pressure in the tissues. This pressure may contribute to the formation of compartment syndrome (see below).

Injury to a major artery or to the veins of the extremity can result in devastating tissue loss if appropriate intervention is not forthcoming.

Bone and Joints

Joint capsules and surrounding ligaments may rupture, resulting in joint dislocation or joint instability. Fractures may occur, and often the bone is broken into several pieces (comminuted fracture).

In children, the growth plates of the bones may be disrupted. Disruption of growth plates interferes with subsequent bone growth, and the bone may not grow to its proper length.

Initial Approach to Patients with a Crushed Hand or Forearm

The key is to get a good history and do a thorough exam. You should have a high index of suspicion so that you do not miss a potentially devastating underlying injury.

History

It is important to know the nature of the injury as well as background information about the patient to guide your physical exam and treatment options. Information that you should obtain includes:

- Extent of injury (e.g., fingers, hands, forearms)
- Mechanism of injury
- Force of crush (some pieces of equipment have known compression forces)

- Duration of crush forces (seconds, minutes?)
- History of previous injury or chronic hand problems (e.g., symptoms compatible with carpal tunnel syndrome)
- Smoking history (encourage patients *not to smoke* because smoking may worsen the injury to the tissues)
- Tetanus toxoid status (be sure tetanus immunizations are up to date)

Physical Exam

The injured extremity must be thoroughly examined. Particular attention should be paid to the following factors. An asterisk indicates that positive findings may indicate a compartment syndrome.

- Appearance of skin (look for blisters, open wounds, elevated areas, foreign material, other abnormalities)
- Circulation to the hand (palpable pulses in the radial and ulnar arteries, capillary refill in the fingers)
- Palpation of forearm and hand (significant swelling, tissue tightness)*
- Neurologic exam (e.g., complaints of tingling or numbness, ability to differentiate between sharp and dull objects, ability to move fingers)*
- Pain out of proportion to injury (e.g., additional pain when you passively move fingers or wrist)*
- Deformity indicating possible bone or joint injury
- Radiographic studies to document a fracture

* Finding may indicate the presence of a compartment syndrome.

What to Do Next

1. If you find evidence of **arterial compromise**, exploration and vascular reconstruction are needed. A specialist is required.
2. **Fractures or dislocations** should be reduced and treated appropriately. See chapter 30 for specific information.
3. If the patient has no evidence of a compartment syndrome (see below) but reports numbness and tingling of the hand consistent with **compression of the median nerve**, a carpal tunnel release should be done. This procedure decreases the pressure on the median nerve and may prevent permanent neural damage. See chapter 38 for details about surgical release of the median nerve.
4. **Lacerations** to the skin should be cleansed thoroughly and examined carefully. If the tissues are soft and the skin is still attached to the underlying muscle, the wounds may be loosely closed. If you

are concerned about swelling in the tissues, leave the wounds open. You do not want to do anything that may increase pressure in the tissues. Once the swelling resolves, you may want to close the wounds or leave them to heal secondarily.

5. If you note **evidence of a degloving injury**, a plastic surgeon (if available) should evaluate the patient. It is quite likely that much of the degloved skin will die, even if it looks viable at the initial examination. If no specialist is available, wash out the wound to ensure that no blood has collected under the skin. Then reposition the skin on top of the muscle. Do not try to suture the skin together, because sutures place added tension on the skin flaps and may further compromise the circulation. The skin will demarcate gradually over the next several days. Skin that turns purple and dies should be excised.
6. **If the patient has a swollen and somewhat painful extremity but the forearm and hand tissues still feel soft**, the patient should be watched closely. Splint the hand in neutral position, and gently elevate the hand. Give pain medication (avoid aspirin and nonsteroidal anti-inflammatory agents), and reexamine the patient several times over the next 48 hours for evidence of a compartment syndrome. After a few days of splinting, as the swelling and pain resolve, the patient should start moving the hand and fingers to prevent stiffness.
7. If the patient has signs and symptoms of a **compartment syndrome**, urgent surgical intervention is required.

Compartment Syndrome

A compartment syndrome develops when increased pressure builds up within a fixed, well-defined space (such as the tissues of the forearm). The increase in pressure prevents venous and lymphatic outflow, which leads to a further increase in tissue pressure. Without appropriate intervention to relieve the pressure, a vicious cycle develops. High tissue pressures also prevent oxygen and nutrients from getting to the tissues. Muscle and nerve are the tissues most prone to injury.

If a compartment syndrome remains untreated, even for a few hours, the result is tissue death. For the patient, tissue death translates into tissue loss and permanent disability.

Muscle death can be a serious problem from more than just the functional standpoint. A byproduct of the dead muscle, myoglobin, can injure the kidneys and lead to permanent kidney damage. Compartment syndrome endangers not only the normal functioning of the hand but also the patient's life.

Signs and Symptoms

It is important to be aware of the potential for development of compartment syndrome and to educate the patient about the early warning signs. The key is early diagnosis so that you can intervene before permanent damage has occurred. An untreated compartment syndrome can lead to severe morbidity and extremity loss and even endanger the patient's life.

- **Severe pain** in the affected extremity, out of proportion to the injury
- Significant **swelling and tightness** in the forearm or hand tissues
- **Pain with passive stretch of a muscle group** (e.g., passive extension of the fingers or wrist stretches the flexor muscles and causes pain in the volar forearm, whereas passive flexion of the fingers or wrist stretches the extensor muscles and causes pain in the dorsal forearm)
- **Tingling or numbness in the hand**, along the median, ulnar, and radial nerve distributions

Note: Pulses at the elbow and wrist may be completely *normal* even with a significant build-up of pressure in the forearm and hand.

Compartment pressure can be measured, but results are highly unreliable without proper equipment and an experienced clinician. In general, if the patient has the above signs and symptoms, treatment should be instituted.

Treatment of compartment syndrome is a *true surgical emergency*. You must get help early. If you have no access to a provider with surgical expertise, the following information will be useful.

Treatment

Fasciotomy

The key to treating a compartment syndrome is to open the involved tissue compartments to relieve the pressure before permanent tissue damage has occurred. This procedure is done in the operating room under general anesthesia.

Skin incisions are made to access the underlying muscle fascia. The fascia must be opened (hence the term *fasciotomy*) to relieve the pressure in the muscles; opening the skin alone is not sufficient.

The need for this procedure is *emergent*. It should not be delayed for days until a specialist is available.

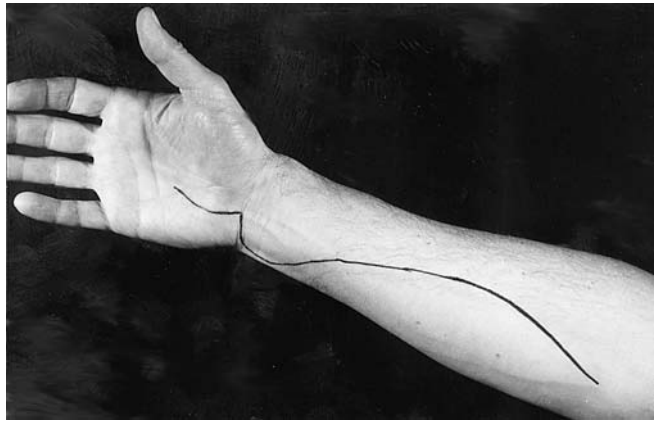
Forearm

The forearm has three compartments: volar (flexor), dorsal (extensor), and mobile wad (upper forearm muscles on the radial side). The

compartments of the forearm are somewhat interconnected. Opening (i.e., releasing) the volar compartment *may* relieve the pressure in the other two compartments. However, if the forearm still feels tight after release of the volar compartment, an additional incision should be made to release the dorsal compartment. When making the incisions, take care to avoid injury to the superficial veins.

The **volar compartment** is opened by making a curvilinear incision that starts in the palm (to release the carpal tunnel), then crosses the wrist transversely to the ulnar side of the forearm. The incision then is extended up the center of the forearm in a large arc.

The **dorsal compartment** and **mobile wad** are released by a straight, longitudinal incision on the dorsal surface of the forearm (see figure on next page).



Markings for an incision to decompress the volar forearm. The incision begins in the hand for full decompression of the carpal tunnel.

Hand

On the **volar surface** of the hand, the carpal tunnel should be opened to relieve the pressure, which can injure the median nerve.

On the **dorsal surface**, the interosseous muscles are released by placing the first longitudinal incision over the index metacarpal and another over the ring finger metacarpal. Slide to either side of the underlying bone to release the fascia around the surrounding muscles.

The **thenar muscles** are released through an incision along the radial side of the thumb metacarpal.

The **hypothenar muscles** are released through an incision along the ulnar side of the little finger metacarpal.

Markings for the incisions needed to decompress the dorsum of the hand and the dorsum of the forearm.

Fingers

If the fingers are very swollen and tight, they must be opened. A mid-axial, lateral incision is used to release each finger. The incisions are positioned along the ulnar side of the index, middle, and ring fingers and are made along the radial side of the thumb and little finger. Be careful to avoid injury to the underlying neurovascular bundle.

When the fascia around the muscle is opened, the muscle "bulges out" dramatically. Initially, the muscle may look purple and nonviable. Wait several minutes; often the muscle becomes redder and healthier looking. Only muscle that remains dusky and purple and obviously looks dead should be excised.

Proper incision for decompression of a finger. The course of the digital nerve is illustrated by the dashed line.

Postfasciotomy Care

1. The incisions should be left open. Saline dressings or antibiotic gauze may be placed over the open wounds. Be sure that the dressings are applied loosely. Daily dressing changes can be started 24–48 hours after the operation. The patient may require anesthesia for the initial dressing change.
2. A splint should be used to keep the hand in neutral position.
3. The hand should be gently elevated (higher than the elbow) to promote venous return and decrease swelling.
4. Further surgery is needed for wound closure. In general, wait at least 3–4 days for the swelling to decrease. A split-thickness skin graft is almost always required for wound closure. If you attempt to close any of the incisions primarily, make certain that there is *no tension on the skin*.
5. Adequate stabilization is required for all fractures. Usually, temporary stabilization can be attained with a splint. If an orthopedic surgeon is available, more definitive bone stabilization can be performed at the time of fasciotomy or wound closure.

Prevention of the Vicious Cycle the Leads to a Compartment Syndrome

Elevate the hand and forearm. The patient must keep the injured hand and forearm gently elevated and not let them dangle in a dependent position The dependent position promotes swelling of injured tissues. The hand should be higher than the elbow.

Use a splint instead of a cast for immobilization of broken bones until the swelling has decreased. A tight cast can contribute to an increase in tissue pressure. If there is a fair amount of swelling in the forearm or hand or if you do not have much experience making a cast, consider putting the extremity in a splint for the first few days. Although a splint does not immobilize the fracture as well as a cast, it is worth taking this precaution initially to prevent the development of a compartment syndrome.

Be sure that the splint is held loosely in place. It is possible to secure the splint too tightly with an Ace wrap—be careful.

If you have placed the patient in a cast: If the patient complains that the cast seems too tight or reports numbness in the fingers, bivalve the cast immediately. Make cuts in the cast along the medial and lateral sides, and separate the underlying padding. If this maneuver does not

relieve the symptoms, the cast should be removed and the extremity examined closely for signs of a compartment syndrome.

If an open wound is present: Do not close the skin if it seems at all tight. It is better to have an open wound that heals with an ugly scar than to risk the development of a compartment syndrome by closing the skin tightly.

Keep a high index of suspicion. A compartment syndrome can occur even with an open wound and even when the patient has normal pulses.

Bibliography

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