Chapter 30

Compartment Syndrome and Volkmann Ischemic Contracture

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Introduction:

This chapter is included for those general surgeons with an interest in upper extremity surgery and with the time and desire to help these poor, afflicted patients who have had injuries that were improperly treated. All general surgeons must recognize the conditions that lead to upper extremity compartment syndrome with the resultant chronic deformity known as Volkmann Ischemic Contracture. When a patient presents with symptoms of compartment syndrome urgent treatment is necessary to save the limb. In most district hospitals, the etiology will be either a supracondylar fracture with impingement on the blood supply or a tight cast. These tight casts will often be ones applied by traditional bone setters. Immediate treatment in these cases should be removal of the cast. Often the cast applied by the traditional bone setter will be for a minimally displaced fracture. Once the swelling has subsided, the fracture or dislocation may be reduced if necessary. In most cases, presentation will be delayed and a fasciotomy may be necessary even after the fracture reduction and cast removal.

Fig 1
Supracondylar fracture with impingement on the neurovascular bundle
Compartment syndrome exists when the interstitial pressure within one of the forearm or hand compartments is elevated (this rarely occurs in the upper arm). The increased pressure leads to venous outflow obstruction within the compartment, which is followed by decrease in arterial perfusion, decrease in oxygenation, and finally ischemia and gangrene. There are many possible etiologies for compartment syndrome in Africa including lack of blood flow from proximal injuries, elevation of internal pressure in the osteofascial compartments, and external pressure with constriction of blood flow. Fractures and dislocations at or above the elbow may lead to interruption of blood flow followed by ischemia. Fractures, crush injuries, electrical burns, and snake bites lead to fluid or blood accumulation within osteofascial compartments with an increase in internal pressure. This is followed by ischemia and then gangrene. Full thickness circumferential thermal burns and tight casts may cause external pressure with ischemia and later gangrene.

Compartment syndrome must be suspected in these conditions and treatment carried out immediately to prevent Volkmann’s ischemic contracture. Fractures and dislocations must be reduced and tight casts removed as an emergency procedure. Fasciotomies are often needed for snake bites and electrical burns and escharotomies for circumferential burns when there are symptoms of compartment syndrome. The symptoms include paresthesias, pallor, loss of pulses, paralysis and, most important, pain when the distal fingers are extended. Another method for determining when a fasciotomy or escharotomy in a burn patient should be done is by measuring oxygen saturation in the fingers or thumb. If this falls below 90% then surgery is indicated.

Measuring compartment pressures is unnecessary as patients will present late. If you think the compartments need to be released, then go ahead and release them based on your exam.

In all cases, except for acute full thickness burns, the incisions should be through the deep muscle fascia. In burns, the incision can be just through skin, an escharotomy.

In the acute situation, the wounds are dressed with a wet or non-adherent dressing or silver sulfadiazine and the extremity splinted and elevated.

The basic incisions are shown below:
Figure 2 shows two volar incisions. What is most important is that the incision is on the ulnar side of the wrist so that the palmar cutaneous branch of the median nerve is not injured (it will lie between the palmaris longus and flexor carpi radialis). The forearm incision is carried into the palm to release the carpal tunnel. The palm incision should be in line with the ring finger.

Figure 3 shows the dorsal incisions for the interosseous compartments. All 4 of these compartments can be opened with these two incisions that are between metacarpals 2 & 3 and 4 & 5.

It is important to reduce fractures and dislocations on admission. If there is too much swelling, then the extremity can be elevated until the edema subsides. In delayed cases, fasciotomies may need to be performed as soon as the patient is seen.

The aim of this chapter is not to cover the material that is well covered in major textbooks but to cover the late reconstruction in Volkmann’s ischemic contracture. There are different stages of ischemia—see below.
Volkmann’s ischemic contracture, one of the consequences of compartment syndrome in the upper extremity, is seen all too often in Africa, not only the result of the commonly associated supracondylar fracture of the humerus, Fig 1, but also from the work of traditional bone setters, Fig 4 and 5. Traditional bone setters are seen throughout Africa, especially in countries such as Nigeria and Ethiopia and in other countries where orthopaedic surgeons are not readily available. In most cases, the traditional bone setters stabilize the fracture very well (Fig 5) and many patients attest to their skill in treating fractures. They do not have formal training, and most often they do not have x-rays to identify the fracture. There are many complications from traditional bone setting from compartment syndrome to necrotizing fasciitis, gas gangrene and late ischemic contracture. The author has seen a number of cases where the extremity was swollen after trauma suggesting a fracture and the traditional bone setter applied his “cast” with his presumptive diagnosis of a fracture. Later, when complications developed, x-rays showed no fracture. The method is similar in each country whereby wooden/plywood strips or sticks are placed over the fracture site and these are wrapped tightly with cloth or leather strips to stabilize the extremity. This chapter will deal with the treatment of established Volkmann’s Contracture. Necrotizing fasciitis and gas gangrene are covered in the chapter on hand infections.

All these conditions can be prevented by early splinting, elevation of a complex fracture and/or a crush injury and then careful checking and documentation of peripheral pulses. Major textbooks discuss measuring compartment pressures but this will be difficult to do in many locations, and delay in treatment may lead to loss of function. When there has been early reduction of a fracture or dislocation with splinting and elevation, casting can be done several days later when the swelling has diminished. When preventive measures have not been followed and there are symptoms of compartment syndrome, immediate removal of casts and fasciotomies should be done.

**Established Ischemic Contracture**

Obviously, there are many variables in compartment syndrome and the resulting ischemic contracture. Most cases in Africa will present in the chronic stage. There are two main classification systems. **Holden** has described two levels of injury. In Level I, the injury is proximal to the contracture as in an
arterial injury in supracondylar fractures, Fig 1. Usually, the volar compartment of the forearm is compromised first. In level II, the damage to the muscles and nerves is directly under the area of trauma as in the “casting method” by the traditional bone setters. Since the constricting pressure is circumferential, the damage is not only to flexor but also extensor muscles. When a “cast” is applied to injuries near the wrist, the proximal forearm may be completely normal. Many factors determine the underlying injury such as magnitude of the fracture, swelling, amount of pressure, how long pressure was applied, age, etc.

**Holden Classification**

Level I—Injury is proximal to the ischemia and later contracture, as in a brachial artery injury

Level II—Ischemia is directly under the injury (pressure)

**Tsuge classification** is based on the three levels of severity of Volkmann’s Contracture and is outlined below:

- **Mild**—resulting contracture of 2-3 fingers only
- **Moderate**—all fingers are flexed with thumb flexed in palm, wrist in flexion and partial loss of sensation in the hand
- **Severe**—all muscles that flex and extend wrist and fingers are involved.

In Holder Level I injuries, the volar forearm compartments are first affected. When early treatment is not carried out, the other compartments—mobile wad and extensor compartments—may become involved. Most Holden II injuries will be in the moderate to severe category in the Tsuge classification.

In the Holden Classification, surgery in Type II (as seen with traditional bone setters) is based on:

1. Severity of contracture
2. Amount of muscle damage
3. Condition of potential soft tissue coverage
4. Function of nerves and remaining muscles (are all compartments involved or is the extensor and mobile wad compartments spared)
5. Available muscles for reconstruction
Figures 6 and 7 represent a mild Holden Level II secondary to direct and circumferential compression.

Figure 8
Represents a more severe Holden II

Most cases of Volkmann’s Contracture that this author has seen are late cases of Holden Type II with the severe type in the Tsuge classification. These children have ischemic flexor and extensor muscles and significant sensory loss. The forearms are atrophic, the wrists are flexed, and the fingers are usually held in a tight intrinsic minus position—MPJ hyperextended and IPJs flexed. See Figures 9 and 10 below.
Figures 9 and 10 represent severe ischemia in the Tsuge classification secondary to circumferential pressure from a native bone setter’s cast.

What can be done in this situation? For most general surgeons who have had limited hand and upper extremity experience—**NOTHING**!

**Why then include this problem in this text?** The reason is that these patients and families are discouraged with little hope, and these children will go throughout life without two good hands in a world where they need two good hands to survive. Most of the patients will be children since closed fractures of the upper extremity are more common in young children. Additionally, they are of a developmental stage that their misery is non-specific and complaints are often easily ignored by their caregivers. Most often they cannot articulate the magnitude of their discomfort and they are left “casted” with what their caregivers consider “normal” pain. Motor function cannot be restored without very sophisticated reconstructive procedures, which are beyond the scope of this chapter; however, some sensory restoration can be achieved with the fairly straightforward technique of neurolysis, providing the patient with a “helping hand.” A **neurolysis** of the median and ulnar nerves should be done. The nerves can be identified in the forearm and any tight scar can be removed. This will not restore perfect sensation but, hopefully, adequate protective sensation.

**Treatment of Holden Type I Ischemic Contracture.**

In cases that present early, tendon Z-plasties, flexor-pronator muscle slide, and tendon transfers as FDS to FDP can be used. Necrotic muscle should be excised. Usually the muscles deep in the volar compartment are involved first—FPL and FDP. Neurolysis of median and ulnar nerves should be done. The reader is referred to major texts and anatomy atlases for complete descriptions of the surgical techniques. When only the volar compartment is involved, especially the FPL and FDP, then an ECRL to distal FDP (or FDS if necessary) transfer is relatively straightforward and gives a satisfactory reconstruction of finger flexion. EIP can be transferred to the distal FPL. Usually, the distal tendons are preserved and can be used to motor the fingers. In long standing contractures, tenolysis of these distal tendons will likely be necessary.

**Treatment of Holden Type II Ischemic Contracture:** (Local constricting force as seen in tight casts and with traditional bone setters)

**Mild/Moderate forms**—unusual (only seen if “cast” removed early)
Findings will be a flexed wrist and hyperextended MPJ of fingers with flexed IPJs—an Intrinsic Minus position, as the intrinsic tendons are paralyzed and/or atrophic. There will be limited necrosis and scar formation at the site of injury. Release should be done through incisions for a typical fasciotomy or directly over the site of greatest injury. Incisions should be placed where tendon and nerves will not be left uncovered after release. Release and excision of these ischemic, atrophic, scarred muscles and nerves should be done. These muscles are pale and do not contract. They may bleed but this is not a sign of viability. If the cast is on the distal forearm, the proximal muscles may be normal as in the case above, and tenolysis and Z-plasties of the distal tendons may be sufficient—as long as they are intact and can be released. If the proximal muscles appear viable with good color and contractility, then the FDS tendons can be excised and Z-plasties done on the FDP and FPL tendons (in contrast to the ischemic contracture seen in Holden I, the superficial, not deep, muscles are most likely damaged). Proximal muscle slides are not adequate as might be the case with Holden I type injuries. Complete release of the nerves in the area of compression should be done. If a skin graft is not sufficient closure, then a pedicle flap will be necessary, such as a groin or superficial epigastric flap.

**Severe form—most commonly seen:** The goal of surgery is to give the patient a helping hand.

Findings will be fixed contractures and atrophy, including atrophy distal to the site of original compression. The fingers will have a severe Intrinsic Minus posture.

The involved muscles will likely be necrotic and should be excised. Z-plasties will not be sufficient. If only the volar compartments are necrotic then the ECRL may be transferred to motor the FDP and the EIP can be transferred to the FPL at the level of the wrist. All proximal necrotic muscles in the volar compartment are excised and a tenolysis of the distal FDP and FPL tendons may be necessary at the time of the transfers. Unfortunately, in these severe Holden II injuries, both the volar and extensor compartments are often involved and there are no tendons available for transfer. Neurolysis of the median and ulnar nerves should be done in an attempt to restore protective sensation. A severe, fixed flexion contracture of the wrist can be treated with flexor tendon release/excision, proximal row carpectomy and if necessary a wrist fusion in neutral or slight extension when growth is nearly complete. MPJ flexion contractures will require MPJ capsulotomies (See Burn Reconstruction Chapter). PIPJ flexion contractures may be passively corrected
in many cases but sometimes they will also need volar capsulotomies. The MPJs and PIPJs need to be pinned for several (3-5) weeks with pins from the metacarpal heads to the fingertips—position of protection or “safe” position: MPJ flexion and IPJ extension. Even if the fingers do not move, placing the hand in position of protection with some sensation gives the patient a helping hand. These procedures may also be performed for the thumb. The adduction contracture of the thumb may be released with a Z-plasty or with a dorsal flap reconstruction of the web space. The AddP tendon will need to be released at its insertion into the base of the proximal phalanx. The thumb MC should be pinned to the index MC to hold it in a palmar abducted position for 3-4 weeks. (This is the position the thumb is in when it picks up a large textbook.)

**Hand Therapy**

It is hoped that these patients will have some residual functioning muscle and that therapy will help. These are difficult cases, and each case will have to be individualized based on what muscles are functioning and to what degree and the therapist's capabilities at your hospital.

There are other sophisticated procedures for intrinsic contractures and restoration of finger flexion with free microvascular flaps. Gracilis and other microvascular transfers may be used in Holden Type I and Tsuge mild to moderate cases where the extensor tendons are intact. As stated above, these Holden Type I are ischemic contractures that are due to proximal lesions and not direct pressure where both flexors and extensors are destroyed from circumferential injury.

**Summary**

This is a very severe condition that is best prevented. **In the district hospital, when injuries prone to this complication are first seen and where close observation may not be possible, a fasciotomy or escharotomy should be carried out immediately as a preventive measure.** The initial exam should check for pain with extension of the fingers. If there is any suggestion of a tight compartment, release should be carried out as soon as possible. Fasciotomy wounds heal well. Aggressive emergency surgery is indicated in hopes that a few of the muscles may be protected from ischemia and necrosis.

Most of the time these cases will present to a referral hospital late, but reconstruction and rehabilitation may still be possible. In mild to moderate Holden Type I injuries, neurolysis and tendon transfers may give the patient a functional hand. In most cases, surgery will only provide a hand with protective
sensation and adequate position, “a helping hand,” but this is a huge advantage over a totally non-functional and poorly positioned hand, especially in the context of the developing world.