Compartment Syndrome of the Upper Extremity
Clinical Manifestation & Treatment

Intro

• Compartment syndrome
  — First described in 1881 by Richard von Volkmann
  — Pressure elevation in a closed fascial compartment resulting in tissue perfusion compromise
    • Increased volume within the confined fascial space
    • Restricts the compartment from expanding
  — Most common causes are fracture and soft tissue injury
  — Surgical emergency

Intro

• Compartment syndrome
  — Compartment syndrome is clinical diagnosis
  • Difficult to diagnose in obtunded and children
  • May be necessary to measure compartment pressure
  — Upper extremity
    • The forearm are the most commonly affected
    • Especially in the volar compartments

Causes of Compartment Syndrome of the Upper Extremity

• Fracture
• Crush injury
• Injection injury
• Ring avulsion
• Suction injury
• Penetrating trauma
• Constrictive dressings
• Casts
• Burns
• Infection
• Bleeding disorders
• Spider bite or Snake bite
• Arterial injury
• Reperfusion
• In utero compression
• Extravasation of infusions
• Injection of illicit drugs
• Regional anesthesia
• Prolonged compression

Clinical manifestation

• Symptoms
  — Pain out of proportion to the nature of injury
    • Early and common finding
    • Persistent, increasing pain
    • Despite immobilization and limb elevation
  — Paresthesias
    • Onset within approximately 30 min. to 2 hr.
    • Ischemic nerve dysfunction

• Devastating loss of function
  — Volkmann ischemic contracture
  — Neurologic deficit
  — Paralysis
  — Infection
  — Amputation
  — Death
• Rhabdomyolysis may occur with muscle ischemia
  — Myoglobinuria and possibly renal failure
• Early recognition and expeditious surgical intervention
Clinical manifestation

• 5 P’s herald compartment syndrome
  – Pain
  – Pallor
  – Paralysis
  – Paresthesia
  – Pulseless

• The signs and symptoms
  – A stepwise fashion
  – Rapid progression over a few hours
  – The timing of the specific findings varies
  – Most of these symptoms present after a substantial amount of time has elapsed

Examination findings:

• Tense, swollen compartment on inspection
• Pain out of proportion with passive stretch of muscles

Most of these symptoms present after a substantial amount of time has elapsed

Examination findings:

• Diminished sensation
  – Confusing peripheral nerve injury from trauma or ACS
    – If injury to median n. and/or ulnar n.,
      » Pain and tenderness may be minimal or absent even in the ongoing progression
  – Loss of fine touch and two-point discrimination are more typical in ACS
    – Nonmyelinated type C sensory fibers are most sensitive to hypoxia

– Muscle weakness
  – Onset within approximately 2-4 hours
  – Difficult to assess and may be attributable to pain, or nerve injury
  – Typical sequence
    – Diminished subjective fine touch followed by hypesthesia
    – Then progressive motor weakness and subsequent anesthesia

– Paralysis
  – Late finding, suggests permanent muscle damage
  – Pallor from vascular insufficiency
    – Uncommon, distal pulses are rarely compromised
      – Occurring only after arterial injury
    – Irreversible tissue damage can occur in the presence of palpable pulses
      – Arterial pulses and normal capillary refill can persist despite the presence of a prolonged, severe ACS


• Data supporting the accuracy of clinical symptoms and signs are limited
  – Poor sensitivity and specificity
  – May be unreliable
• Definitive diagnosis can only be made by measuring compartment pressures

Lab and image Studies
• **Laboratory values are NOT used for diagnosis**
  – Rhabdomyolysis
    • Serum creatine kinase (CK) rises as muscle injury develops
    • Myoglobinuria and possible acute renal failure
    • Develop within 4 hours of the onset of ACS
• **CT and MRI are NOT used for diagnosis**
  – Only of value for delineating the areas of edema and muscle death resulting from ACS

Measurement of Compartment Pressure
• Measuring compartment pressures
  – May be unnecessary if the diagnosis is clinically obvious
  – Whenever a clinician suspects ACS based upon the risk factors and clinical findings
  – Difficult to determine whether the patient is developing signs of ACS
    • Young children, obtunded or critically ill patients
    • Under anesthesia
  – Entails no major complications

• Measurement techniques
  – **Simple needle manometer system**
    • Injecting a small quantity of saline into compartment and measuring the resistance from tissue pressure
  – **Slit catheter technique**
    • Inserting a catheter into compartment and monitoring the pressure via a transducer
  – **Arterial pressure monitoring device**
  – **Handheld manometer (Stryker STIC device)**
    • Portable, simple, and accurate
Proper placement of the catheter is essential for accurate monitoring.

- Significant differences in pressure measurements obtained at varying distances from a fracture.
  - Pressures are higher within 5 cm of the fracture.


Catheter placement for monitoring of the deep flexor compartment of the forearm

- Accessed between the tendons of the flexor carpi radialis (FCR) and palmaris longus (PL)

- Approach from the midline toward the ulna


New technologies are less invasive

- Laser Doppler flowmetry
- Tc99m-methoxy-isobutyl isonitril scintigraphy
- Near-infrared spectroscopy

- Less practical and not cost-effective


• Pulse oximeter
  – Insensitive instrument for diagnosis
  – SHOULD NOT be relied upon

• The normal pressure of tissue compartment
  – Between 0 - 8 mmHg
• Elevated compartment pressure and clinical findings
  > 20 mmHg
  • Capillary blood flow becomes compromised
  20 - 30 mmHg
  • Pain develops
  > 30 mmHg
  • Ischemia

• No consensus about the compartment pressure threshold used to determine the need for fasciotomy
  – Traditional recommendations for decompression include absolute pressure above 30 mmHg or 45 mmHg


• The pressure necessary for injury varies depending upon clinical circumstance
• The use of absolute measurements may lead to unnecessary fasciotomy, or neglect needed fasciotomy
• Threshold based upon the difference between the diastolic pressure (or mean arterial pressure) and compartment pressure
  – Delta pressure

• Fall below a specific value, perfusion pressure becomes compromised
  – Difference between Diastolic Blood Pressure and the compartment measuring ≤ 20 mmHg
  – Difference between Mean Arterial Pressure and the compartment measuring ≤ 30 mmHg

• Serial or continuous measurements are important when patient risk or clinical suspicion is high
• When compartment pressures are trending downward, it is often safe not to intervene emergently
Management

• With early diagnosis and appropriate treatment, the complications of ACS can be prevented and normal function of the extremity maintained

Immediate management of suspected ACS

– If the diagnosis is not confirmed but remains concern, a period of observation is indicated
– Relieving all external pressure on the compartment
  • Any dressing, splint, cast, or other restrictive covering
  • The limb should NOT be elevated or placed in a dependent position

  – Analgesics and supplementary oxygen
  – Intravenous isotonic saline

Fasciotomy

– Definitive treatment for ACS
  • Wide exposure and direct release of the deep fascia
  • Careful search for separate subcompartments
  • Additional release is indicated for additional discrete compartments or restrictive epimysium
– Occasionally not indicated
  • Avoided when the muscle is already dead
    – No benefit and increase the risk of infection

  • Analgesics and supplementary oxygen
  • Intravenous isotonic saline

Upper arm

– Rare
– Lateral incision
  • Access to the anterior and posterior compartments
  • Extend distally into the forearm; proximally to decompress the Deltoid m.


Volar forearm

– Ulnar approach
  • Least amount of iatrogenic injury to muscle artery and nerve
  • A longitudinal skin incision
    – Beginning just radial to the FCU at the wrist → proximally to the medial epicondyle
    – Deep dissection: between FCU and FDS
  • 2 oblique transition across to decompress the lacertus fibrosus (anterior cubital fossa) and carpal tunnel (median n.)


Two midline incisions directly over anterior and posterior compartments

• Less disruption to the perforating septal vessels

- **Volar-curvilinear incision**
  - C → D
    - Ulnar border of distal forearm → cross over to radial side → curves back to approach FCU and ulnar nerve of elbow
  - D → E
    - Ulnar side of elbow flexion crease to cover brachial a. and median n. when the wound is opened
  - Deep dissection: between FCR and BR

- **Dorsal forearm and mobile wad**
  - Release of volar compartment often results in dorsal compartment and mobile wad decompression
  - **One single dorsal incision**
    - From 2 cm distal to the lateral epicondyle toward Lister’s tubercle
    - Deep dissection: between EDC and ECRB

- **Hand**
  - **Volar and dorsal interosseous compartment**
    - 2 longitudinal dorsal incisions
      - Between 2nd-3rd and 4th-5th metacarpals
      - Decompress all osteofascial envelopes

- **Thenar and hypothenar compartment**
  - Longitudinal incisions at junctions of the glabrous and nonglabrous skin
    - Thenar: Radial side of the 1st metacarpal bone
    - Hypothenar: Ulnar side of the 5th metacarpal bone

- **Adductor pollicis compartment**
  - Incision centered dorsally over the 1st web space
Carpal tunnel
- Incision begins from Kaplan’s cardinal line, extending proximally the point just distal to the volar wrist crease
- Palmaris fascia is divided longitudinally to expose transverse carpal ligament
- Transverse carpal ligament incision

Digital compartment
- Midaxial incision, and through Cleland’s ligament
  - Ulnar incision: Index, middle, ring finger
  - Radial incision: Thumb, little finger
  - To minimize potentially adverse effects to the sensibility

Aftercare
- Wound care
  - Wet dressing
  - Integra (Bovine collagen matrix)
    - It can be grafted later
  - Immediate STSG
- Return to OR for debridement after 48 or 72 hrs, and repeat every 48 hrs.
- Continue for wound closure or reconstruction is individualized to the patient’s condition

Wound closure
- Prioritize coverage of neurovascular structure, exposed joint and tendons
- Undermining the skin flap for tension-free closure
- STSG
- VAC (Vacuum-assisted wound closure)
  - Shorter hospital stay
  - Reduce need of STSG
  - Lower rate of nosocomial infection

Outcomes
- If intervention is provided on a prompt basis, patient will recover with minimal residual dysfunction
  - Although no clear different outcome was shown between short and long intervals from diagnosis to fasciotomy

Volkmann’s Contracture
- Irreversible tissue ischemia results in muscle necrosis, which leads to contracture
  - Typical posture
    - Elbow flexion
    - Forearm pronation
    - Wrist flexion
    - Thumb adduction
    - MCP joint extension, IP joint flexion
  - Median n. is more compromised by ischemia because lies in the deeper zone
Management

• Eventual normal functioning of the affected limb should not be expected.
• The main goal in the management is to restore function.
• General principles of reconstruction
  1. Exposure of the forearm musculature
  2. Debridement of any fibrotic and nonfunctioning muscle
  3. Neurolysis, especially median and ulnar nerves
  4. Tenolysis of scarred tendons

Mild contracture

   – The flexor/pronator slide
     • Improve the position of the hand as well as function of the forearm flexors.
     • Residual function of the forearm flexors in the setting of mild shortening.

– The procedure
  • Detachment of the flexor pronator aponeurosis from the proximal forearm and a distally directed slide
  • Suture pexy of the musculature.
  • Moving the origin distally, the flexion contracture is relieved

• Moderate contracture
  – Tendon lengthening
    • Isolated tendon lengthening is not recommended
      – The problem is recurrence because of scar contracture
      – Loss of grip strength
    

– Tendon transfer
  • Most commonly performed with an extensor tendon
  • Flexor tendons can be used in the case of dorsal muscle necrosis


• Left FPL and 2nd FDS/FDP tendons lengthening
• Camitz transfer
  – PL → APB insertion site
- Severe contracture
  - Free muscle transfer
  - Most frequently using a gracilis muscle, and neurotizing with the obturator nerve.


- The advantage
  - The tissue that has been entirely unaffected by the ischemic insults.
- The disadvantage
  - Require microsurgical expertise
  - Lengthy interval of time for reinnervation of the transferred muscle.

- 2005.08
  Acute compartment syndrome and Emergency fasciotomy
- 2007.04
  Free functional gracilis myocutaneous flap
- 2008.03
  Removal of skin paddle
Thanks for your attention!!