Compartment Syndromes
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Today
- What is it
- Pathophysiology
- Diagnosis
- Treatment

What is Compartment Syndrome?
Increase in hydrostatic pressure in closed osteofascial space resulting in decreased perfusion of muscle and nerves within compartment
- Increased pressure in closed fascial space
  - Exceeds capillary perfusion pressure
• **RAISED PRESSURE WITHIN A CLOSED SPACE** with a potential to cause **irreversible damage** to the contents of the closed space

Richard Von Volkmann, 1881

• “For many years I have noted on occasion, following the use of *bandages too tightly applied*, the occurrence of *paralysis and contraction of the limb, NOT … due to the paralysis of the nerve by pressure*, but as a quick and massive disintegration of the contractile substance and the effect of the ensuing reaction and degeneration.”

Today

• What is it
• Pathophysiology
• Diagnosis
• Treatment
Pathophysiology

• Local Blood Flow is reduced as a consequence:
  \[ \text{LBF} = \frac{P_a - P_v}{R} \] (A-V Gradient)

Pathophysiology

• A continuous increase in pressure within a compartment occurs until the low intramuscular arteriolar pressure is exceeded and blood cannot enter the capillaries.

Pathophysiology

• Autoregulatory mechanisms may compensate:
  – Decrease in peripheral vascular resistance
  – Increased extraction of oxygen

• As system becomes overwhelmed:
  – Critical closing pressure is reached
  – Oxygen perfusion of muscles and nerves decreases

• Cell death initiates a “vicious cycle”
  – increase capillary permeability
  – increased muscle swelling
Pathophysiology

- Increased compartment pressure
  - Increased venous pressure
  - Decreased blood flow
  - Decreases perfusion

- Increased muscle swelling
  - Increased permeability
  - Increased compartment pressure

- Increased pressure
  - Increased venous pressure
  - Decreased blood flow
  - Decreases perfusion
Muscle Ischemia

- 4 hours - reversible damage
- 8 hours - irreversible changes
- 4-8 hours - variable

Muscle Ischemia

- Myoglobinuria after 4 hours
  - Renal failure - Check CK levels
  - Maintain a high urinary output
  - Alkalinize the urine
Nerve Ischemia

• 1 hour - normal conduction
• 1- 4 hours - neuropraxic damage reversible
• 8 hours - axonotmesis and irreversible change

Hargens et al. JBJS 1979

Pathophysiology:

• **CAUSES:**

  • *Increased Volume - internal:* hemmorhage, fractures, swelling from traumatized tissue, increased fluid secondary to burns, post-ischemic swelling
  
  • *Decreased volume - external:* tight casts, dressings

  • *Most common cause of hemmorhage into a compartment:* fractures of the tibia, elbow, forearm or femur

Etiology

• Fractures
• Arterial Injury
  - Post-ischemic swelling
  - Reperfusion injury
• Soft Tissue Injury (Crush)
• Patient Obtunded-(limb compression)
• Burns
Pathophysiology:

*Most common cause* of compartment syndrome is *muscle injury* that leads to edema

Arterial Injuries

- *Secondary to revascularization:*
  - Ischemia causes damage to cellular basement membrane that results in edema
  - With reestablishment of flow, fluid leaks into the compartment increasing the pressure

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"The hidden component of any fracture is the soft tissue injury, its severity and variability."

– AO Manual

**Signs & Symptoms**

- Tense compartment on palpation
- Elevated compartment pressure

**Difficult Diagnosis**

- Classic signs of the 5 P’s - **ARE NOT RELIABLE:**
  - pain
  - pallor
  - paralysis
  - pulselessness
  - paresthesias
- These are signs of an ESTABLISHED compartment syndrome where ischemic injury has already taken place
- These signs may be present in the absence of compartment syndrome.
Diagnosis

• Palpable pulses are usually present in acute compartment syndromes unless an arterial injury occurs

• Sensory changes—paresthesias and paralysis do not occur until ischemia has been present for about 1 hour or more

Diagnosis

• The most important symptom of an impending compartment syndrome is PAIN DISPROPORTIONATE TO THAT EXPECTED FOR THE INJURY and PAIN WITH PASSIVE STRETCH

• Clinical diagnosis
  – High index of suspicion

Signs & Symptoms

• Pain
  – May be worse with elevation
  – Patient will not initiate motion on own

• Be careful with coexisting nerve injury
Signs & Symptoms

- Parasthesia
  - Secondary to nerve ischemia
- Must be differentiated from nerve injury
  - Paralysis (Weakness)
    - Ischemic muscles lose function

Tissue Pressure

- Normal tissue pressure
  - 0-4 mm Hg
  - 8-10 with exertion
- Absolute pressure theory
  - 30 mm Hg - Mubarak
  - 45 mm Hg - Matsen
- Pressure gradient theory
  - < 20 mm Hg of diastolic pressure – Whitesides
  - < 30 mm Hg of diastolic pressure McQueen, et al

Tissue-Pressure: Principles

- Originally, fasciotomies for tissue-pressures greater-than 30mmHg

  - *Whitesides et al in 1975* was the first to suggest that the significance of tissue pressures was in their *relation to diastolic blood pressure*.

  - McQueen et al: *absolute compartment pressure is an UNRELIABLE indication for the need for fasciotomies*. BUT, pressures within 30mmHg of DP indicate compartment syndrome.
Tissue-Pressure: Principles

• Heckman et al demonstrated that pressure within a given compartment is not uniform.
• They found tissue pressures to be highest at the site or within 5cm of the injury.
• 3 of their 5 patients requiring fasciotomies had sub-critical pressure values 5cm from the site of highest pressure.

Who is at high risk? - Beware of polytrauma patient

• Increased risk for compartment syndrome
  – Inability to accurately obtain history and physical exam
    • Head trauma
    • Drug/ETOH intake
  – May have decreased diastolic pressure
    • Compartment syndrome can occur at lower absolute pressure

High energy fractures

• Severe comminution
• Joint extension
• Segmental injuries
• Widely displaced
• Bilateral
• Floating knee
• Open fractures
Impaired Sensorium

- Alcohol
- Drug
- Decreased GCS
- Unconscious
- Chemically unconscious
- Neurologic deficit
- Cognitively challenged

Diagnosis

- The presence of an *open fracture does NOT rule out the presence of a compartment syndrome*
  - 6-9% of open tibial fractures are associated with compartment syndromes
  - McQueen et al found *no significant differences in compartment pressures between open and closed tibial fractures*
  - *No significant difference in pressures between tibial fractures treated with IM Nails and those treated with Ex-Fix*

Criteria-Compartment Pressure

- Accurately examine
  - Difference < 30mm Hg
- Impaired
  - Absolute > than 30mm Hg
Needle Infusion Technique-Historical

- Needle inserted into muscle, tube with air/saline interval kept at this height, manometer indicates pressure
- Air injected by syringe via 3-way stopcock
- When the pressure of the injected air exceeds the compartment pressure, the saline interval moves in the tube
- At this point, the second person reads the pressure from the manometer

Pressure Measurement

- Infusion
  - manometer
  - saline
  - 3-way stopcock
  (Whitesides, CORR 1975)
- Catheter
  - wick
  - slit catheter
- Arterial line
  - 16 - 18 ga. Needle (5-19 mm Hg higher)
  - transducer
  - monitor
- Stryker device
  - Side port needle

Pressure Measurement

- Needle
  - 18 gauge
  - Side ported
- Catheter
  - wick
  - slit
- Performed within 5 cm of the injury if possible-Whitesides, Heckman
Most Common Locations

• Leg: *deep posterior and the anterior compartments*

• Forearm: *volar compartment,* especially in the deep flexor area

Pressure

• Deeper muscles are initially involved
• Distance from fracture affects pressure

Heckmen et al. JBJS 1994

Compartments

• Anterior
• Lateral
• Posterior
  – Deep
  – Superficial
Compartments
Where to Measure

• Anterior
• Lateral
• Posterior
  – Deep
  – Superficial

Today

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Treatment

• Remove restricting bandages
• Serial exams
• When diagnosis made
  – Immediate FASCiotomy
    • All compartment fasciotomy
Treatment

THE ONLY EFFECTIVE WAY TO DECOMPRESS AN ACUTE COMPARTMENT SYNDROME IS BY SURGICAL FASCIOTOMY!!! (unless missed compartment syndrome)

Treatment

• Fasciotomy
  – One incision
    • With or without Fibulectomy
  – Two incisions

• All 4 compartments must be released
  – Not selective

One Incision

• Direct lateral incision
Perifibular Fasciotomy

- One incision
- Head of fibula to proximal tip of lateral malleolus
- Incise fascia between soleus and FHL distally and extended proximally to origin of soleus from fibula
- Deep posterior compartment released off of the interosseous membrane, approached from the interval between the lateral and superficial posterior compartments

- Lateral compartment
  Avoid superficial peroneal nerve

- Anterior compartment
• Superficial posterior compartment

• Deep posterior compartment

Alternative

Through intermuscular septum to reach superficial posterior compartment
Two incisions

- Lateral
- Medial

Double Incision

- 2 vertical incisions separated by a skin bridge of at least 8 cm
- Anterolateral Incision: from knee to ankle, centered over interval between anterior and lateral compartments
Double Incision
- Posteromedial Incision: centered 1-2cm behind posteromedial border of tibia
- Soleus must be detached from tibia in order to adequately decompress proximal portion of deep posterior compartment

Thigh
- Rare
- Crush injury with femur fracture
- Over distraction
  - relative under distraction

Thigh
- Quadriceps
  - Lateral
- Hamstrings
  - Posterior
- Adductor
  - Medial
Treatment

• Based upon involvement
• Usually Quadriceps and Hamstrings
• Usually, a single lateral incision will suffice

Compartments of the Forearm

• Forearm can be divided into 3 compartments: Dorsal, Volar and “Mobile Wad”
• Mobile Wad: Brachioradialis, ECRL, ECRB
• Dorsal: EPB, EPL, ECU, EDC
• Volar: FPL, FCR, FCU, FDS, FDP, PQ

Henry Approach

• Incision begins proximal to antecubital fossa and extends across carpal tunnel
• Begins lateral to biceps tendon, crosses elbow crease and extends radially, then it is extended distally along medial aspect of brachioradialis and extends across the palm along the thenar crease
• Alternatively, a straight incision from lateral biceps to radial styloid can be used.
Henry Approach

- Fascia over superficial muscles is incised
- Care of NV structures

Henry Approach

- Brachioradialis and superficial radial n. are retracted radially and FCR and radial artery are retracted ulnar to expose the deep volar muscles
- Fascia of each of the deep muscles is then incised

Dorsal Approach

- Usually not necessary for forearm compartment syndrome
- Straight incision from the lateral epicondyle to the midline of the wrist
- Interval between the ECRB and EDC is used to access deep fascia
Post Fasciotomy…

• Must get bone stability
  – IMN/palte
  – exfix
• ~48hrs after procedure patient should be brought back to OR for further debridement
• Delayed skin closure or skin-grafting 3-7 days after the fasciotomies

Aftercare

• Xeroform
• VAC dressings
• Elevation of limb
• Serial tighten jacob’s ladder
• Delayed wound closure
  – Split thickness skin graft

Remember…

• Fasciotomies are not benign
• Complications are real ≥25%
  – Chronic swelling
  – Chronic pain
  – Muscle weakness
  – Iatrogenic NV injury
  – Cosmetic concerns
*** BUT if they are needed do not come up with excuses to not do them !!!
Chronic (Exertional) Compartment Syndrome

- Transient rise in compartmental pressure following activity
- Symptoms
  - Pain
  - Weakness
  - Neurologic deficits

Chronic Compartment Syndrome

- Stress Test
  - Serial Compartment Pressure
    - Resting >15mm Hg
    - 5 min post-ex. >25mm Hg
  - Volumetrics
  - Nerve conduction Velocities

Chronic Compartment Syndrome

- Treatment
  - Modification of activity
  - Splinting
  - Elective Fasciotomy
Conclusion

- Very important to make diagnosis
- Missed compartment is devastating
- Physical exam
- Re-examine patient!
- Remember Pain with passive stretch
  - If in doubt…do the fasciotomy

THANK YOU