# Compartment Syndromes

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## Today

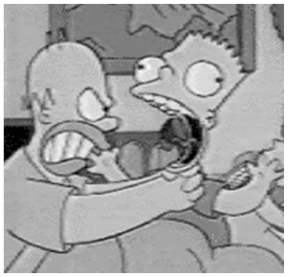
- What is it
- Pathophysiology
- Diagnosis
- Treatment

## 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."

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## Pathophysiology

- Local Blood Flow is reduced as a consequence:

  $LBF=P_a-P_v / R$ (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

Repetitive Cycle

Increased muscle swelling

↓

Increased permeability

↓

Increased compartment pressure

## Muscle Ischemia

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

Hargens JBJS 1981

## 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

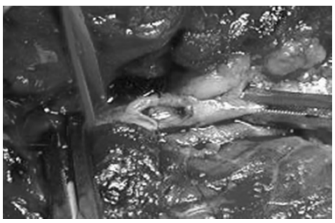
- Fractures
- Arterial Injury
  - Post-ischemic swelling
  - Reperfusion injury
- Soft Tissue Injury (Crush)
- Patient Obtunded-(limb compression)
- Burns

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

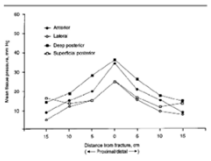
- Normal tissue pressure
  - 0-4 mm Hg
  - 8-10 with exertion
- Absolute pressure theory
  - 30 mm Hg - Mubarak
  - 45 mm Hg - Matsen
- Pressure gradient theory
  - < 20 mm Hg of diastolic pressure – Whitesides
  - < 30 mm Hg of diastolic pressure McQueen, et al

## 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***

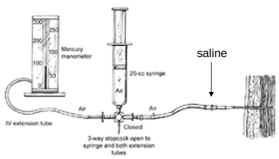
## Criteria-Compartment Pressure

- 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 pressure, the saline interval moves in the tube
- AT this point, ***the second person reads the pressure from the manometer***

***NEED 2 PEOPLE !***

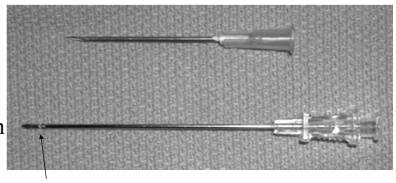



## Pressure Measurement

- 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

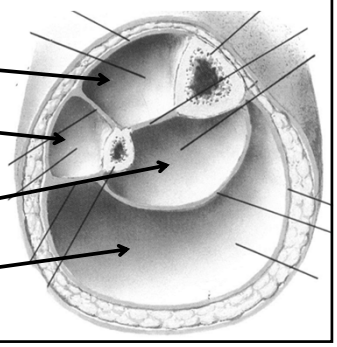
## Pressure

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

Heckmen et al. JBJS 1994

## Compartments

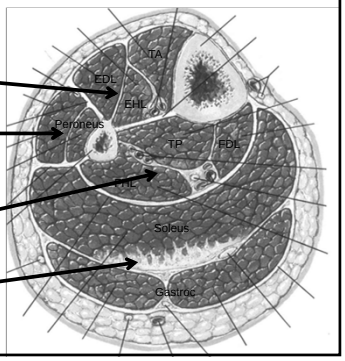
- Anterior
- Lateral
- Posterior
  - –Deep
  - –Superficial



## Compartments
## Where to Measure

KEEP CALF OFF THE BED

- Anterior
- Lateral
- Posterior
  - –Deep
  - –Superficial




## Today

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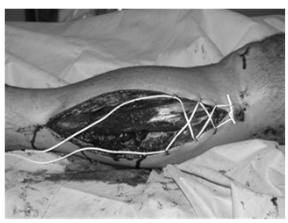
## Treatment

- Remove restricting bandages
- Serial exams
- When diagnosis made
  - Immediate FASCIOTOMY
    - All compartment fasciotomy

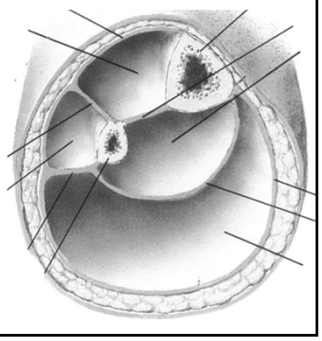


## Treatment

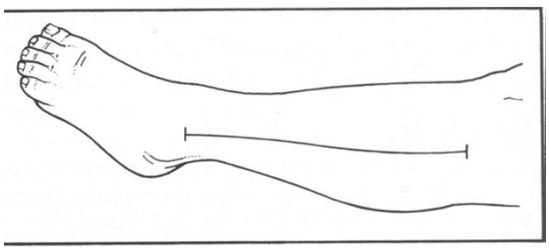
***THE ONLY EFFECTIVE WAY TO DECOMPRESS AN ACUTE COMPARTMENT SYNDROME IS BY SURGICAL FASCIOTOMY!!! (unless missed compartment syndrome)***

## Treatment

- Fasciotomy
  - –One incision
    - With or without Fibulectomy
  - –Two incisions
- All 4 compartments must be released
  - –Not selective



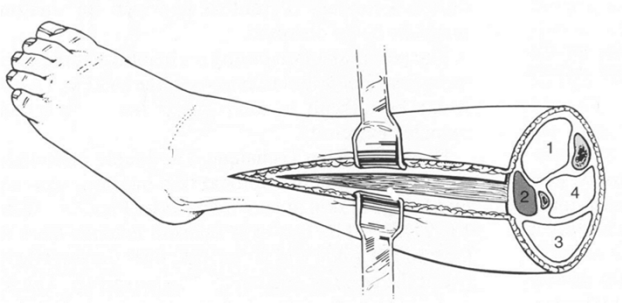
## One Incision



- Direct lateral incision

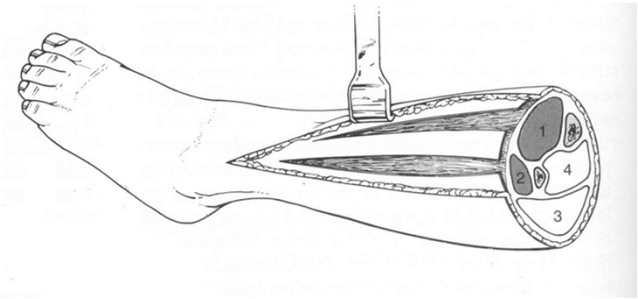
# Perifibular Fasciotomy

- 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 superfical posterior compartments

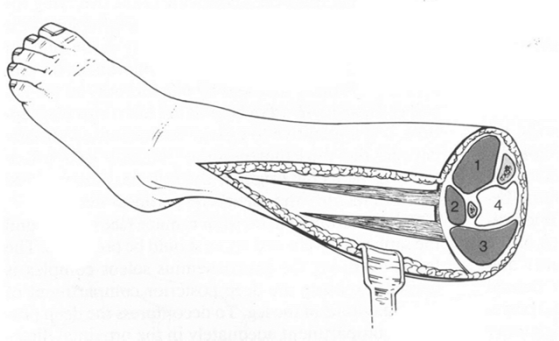



- Lateral compartment

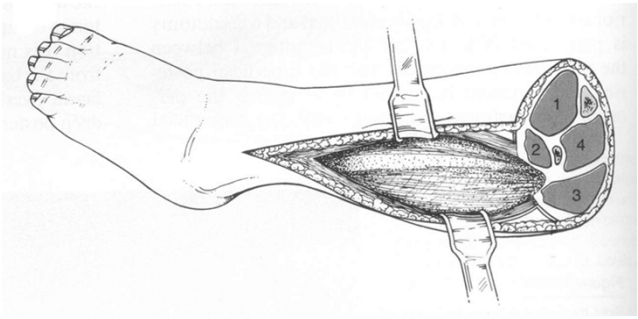
Avoid superficial peroneal nerve




- Anterior compartment



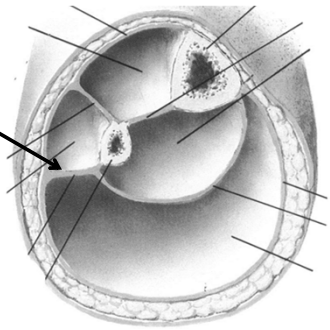

• Superficial posterior compartment




• Deep posterior compartment

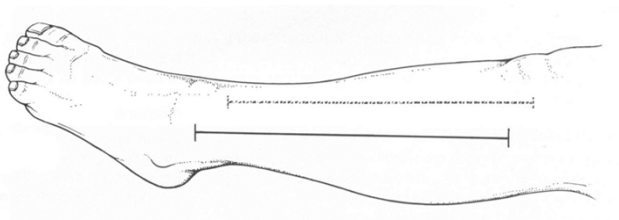
Alternative

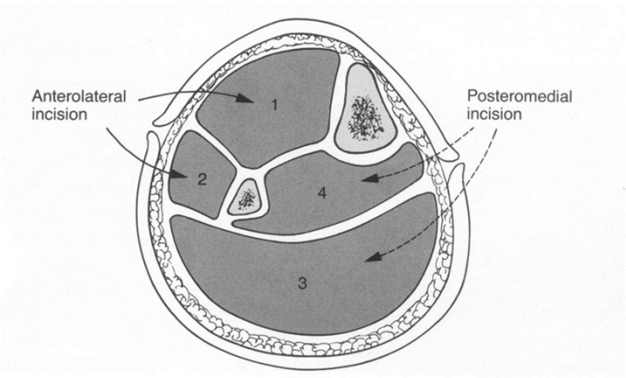
Through intermuscular septum to reach superficial posterior compartment



## Two incisions

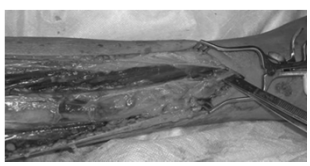
- Lateral
- Medial





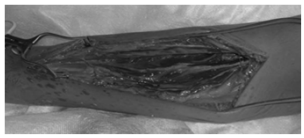

## Double Incision

- 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



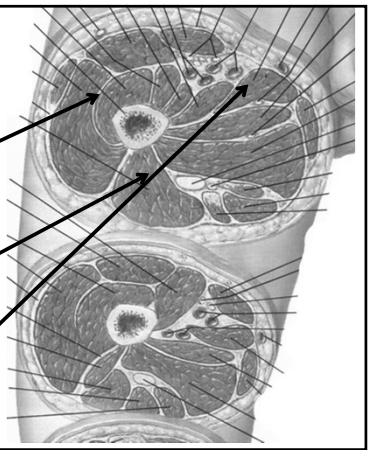
- Soleus must be detached from tibia in order to adequately decompress proximal portion of deep posterior compartment

## 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

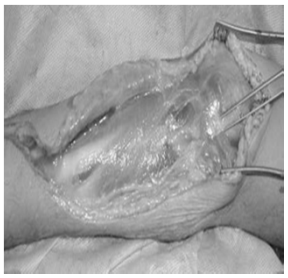
- Forearm can be divided into 3 compartments: Dorsal, Volar and "Mobile Wad"
- Mobile Wad: Brachioradialis, ECRL, ECRB
- Dorsal: EPB, EPL, ECU, EDC
- Volar: FPL, FCR, FCU, FDS, FDP, PQ

## 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.

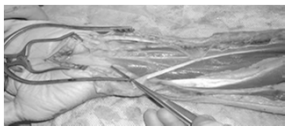
## Henry Approach

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

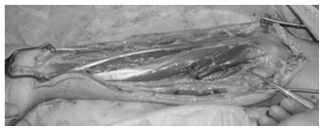


## Henry Approach

- Brachioradialis and superficial radial n. are retracted radially and FCR and radial artery are retracted ulnar to expose the deep volar muscles

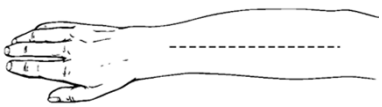


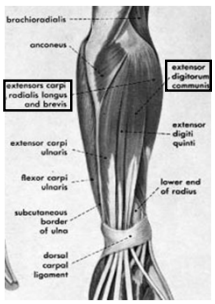
- Fascia of each of the deep muscles is then incised



## 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



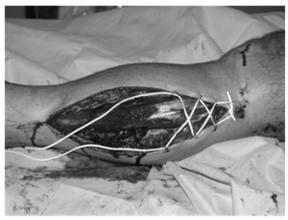


## Post Fasciotomy…

- 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…

If can only close one side-close lateral

- 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
      - » Rydholm et al CORR 1983
  - –Volumetrics
  - –Nerve conduction Velocities
    - » Pedowitz et al. JHS 1988

# 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