PLEASE CLICK ON THE FOLLOWING LINK TO WATCH THE LECTURE ONLINE:-

https://www.youtube.com/watch?v=z4PbFaA0q_I&list=PLuBRb5B7fa_d_ITkxtB-KQYUusx0C1s_x&index=5

open fractures

"The bone is a plant, with its roots in the soft tissue, and when its vascular connections are damaged, it often requires, not techniques of a cabinet maker, but the patient care and understanding of a gardener."

Girdlestone



Abdullah Alkhawaldah MD, FACS

RMS Jordan. Foot And Ankle surgery

Learning objectives

- Specify the goals and principles of open fracture management
- Describe the initial management of open fractures
- Outline the classification of open fractures and the implications for treatment
- Outline the definitive management of soft tissues and the fracture
- Select appropriate techniques to provide stability in open fractures
- Discuss the issue of early soft-tissue coverage

goals

- Prevent infection
- Preservation of viable soft tissues
- Promote fracture-healing
- Restore function

The “big 5” in open fracture care

- Treat as an emergency
- Debridement and redebridement
- Stabilize fracture and soft tissue
- Early closure
- Antibiotics

Initial Evaluation

An open fracture is defined as one with an associated break in the skin that is capable of communicating with the fracture and/or its hematoma

ATLS protocols

Cultures in the Emergency Department

Treat as an emergency

- General:
  - ATLS 1° survey
  - ATLS 2° survey
  - Tetanus
  - Status of chest, head, cardiovascular system

Treat as an emergency

- Local
  - Do not expose unnecessarily (3–4x increase in infection rate)
  - Saline dressing, alignment, and splintage
- Distal
  - Neurovascular status

Classifications

- Gustillo and Anderson

Gustillo and Anderson

Grade	Wound	Contamination	Soft-tissue damage	Bone injury
I	< 1 cm	Clean	Minimal	Simple, minimal comminution
II	> 1 cm	Moderate	Moderate, some muscle	Moderate comminution
IIIA.	> 10 cm	High	Severe with crushing	Soft-tissue cover possible
IIIB.	> 10 cm	High	Severe loss of cover	Requires reconstructive surgery
IIIC.	> 10 cm	High	**Vascular injury requires repair**	Requires reconstructive surgery

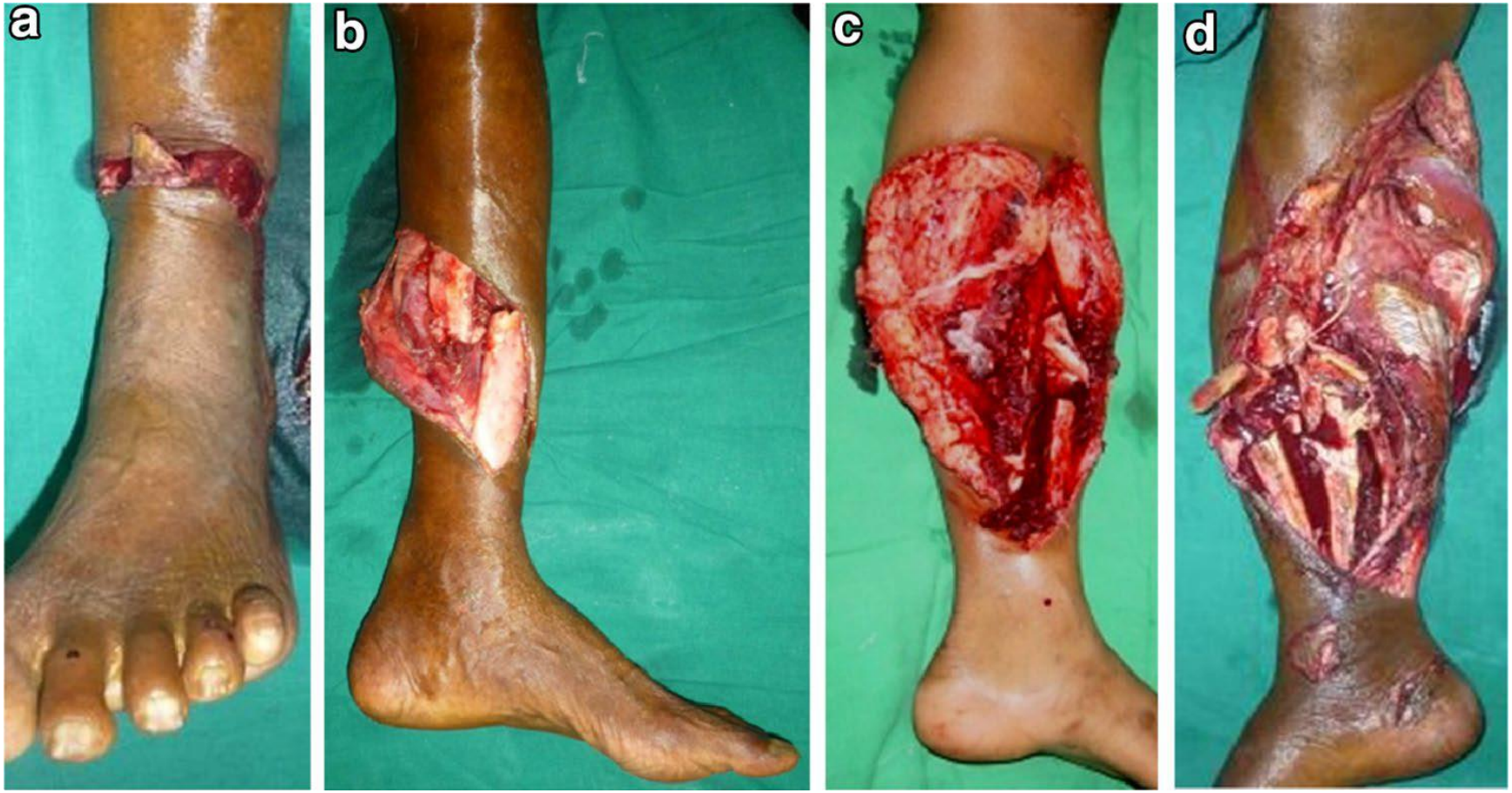
FIGURE 53.2 Gustilo-Anderson classification of open fracture wounds. **A,** Type I open fracture of patella and type II open fracture of tibial shaft. **B,** Type IIIA open fracture with extensive laceration of skin and muscles that involves almost entire leg. **C,** Type IIIA open tibial fracture with extensive periosteal stripping but without massive contamination. **D,** Type IIIB open fracture of tibia stabilized with external fixation. **E,** Type IIIC fracture of proximal third of humerus.

Classification (Gustilo & Anderson)

Type	Infection rate%
I	**0-2**
II	**2-5**
IIIA	**5-10**
IIIB	**10-50**
IIIC	**25-50**

Disadvantages of Gustilo–Anderson classification

1. Definition has undergone many modifications and does not have uniformity in application
2. Includes wide spectrum of Injuries in Type IIIB Injuries
3. Mainly depends on size of the skin wound
4. Does not evaluate the severity of injury to Skin, Bone, Musculotendinous units separately
5. Does not address the question of Salvage
6. Poor interobserver reliability


a
b
c
d

mangled extremity

- limb with an injury to at least three out of four systems (soft tissue, bone, nerves, and vessels). Mangled extremities have historically been associated with very high amputation rates

Mangled Extremity Severity Score

A score of greater than 7 has been reported to predict amputation

Component	Points
A. Skeletal and soft tissue injury	
Low energy (stab; simple fracture; "civilian gunshot wound")	1
Medium energy (open or multiplex fractures, dislocation)	2
High energy (close-range shotgun or "military" gunshot wound, crush injury)	3
Very high energy (same as above plus gross contamination, soft tissue avulsion)	4
B. Limb ischemia (score is doubled for ischemia >6 hours)	
Pulse reduced or absent but perfusion normal	1
Pulseless; paresthesias, diminished capillary refill	2
Cool, paralyzed, insensate, numb	3
C. Shock	
Systolic blood pressure always >90 mm Hg	0
Hypotensive transiently	1
Persistent hypotension	2
D. Age (yr)	
<30	0
30–50	1
>50	2

These scores also have been designed to address limbs that have combined orthopedic and vascular injuries

Mangled Extremity Severity Score			
TYPE	**CHARACTERISTICS**	**INJURIES**	**POINTS**
SKELETAL/SOFT-TISSUE GROUP			
1	Low energy	Stab wounds, simple closed fractures, small-caliber gunshot wounds	1
2	Medium energy	Open or multiple-level fractures, dislocations, moderate crush injuries	2
3	High energy	Shotgun blast (close range), high-velocity wounds	3
4	Massive crush	Logging, railroad, oil-rig accidents	4
SHOCK GROUP			
1	Normotensive hemodynamics	Blood pressure stable in field and in operating room	0
2	Transiently hypotensive	Blood pressure unstable in field but responsive to intravenous fluids	1
3	Prolonged hypotensive	Systolic blood pressure <90 mm Hg in field and responsive to intravenous fluid only in operating room	2
ISCHEMIA GROUP			
1	None	Pulsatile limb without signs of ischemia	0*
2	Mild	Diminished pulses without signs of ischemia	1*
3	Moderate	No pulse by Doppler, sluggish capillary refill, paresthesia, diminished motor activity	2*
4	Advanced	Pulseless, cool, paralyzed, and numb without capillary refill	3*
AGE GROUP			
1	<30 years		0
2	30-50 years		1
3	>50 years		2

Table 2. Parameters of Ganga Hospital severity score[12]

Parameter		Score
Skin losses	No loss	1
	Some loss/degloved *(+2 to above if over bone)*	2
	Extensive loss/exposed bone	5
Soft tissue injury	No injury	1
	Repairable	2
	Irreparable	3
	Loss of <2 compartments	4
	Loss of ⩾2 compartments	5
Bony injury	Fracture, no bone loss	1 - 2
	Joint involvement	3
	Bone losses: < 4cm	4
	> 4cm	5
Additional risk factors	Age >65 Contamination Chronic illness Systemic injury Other trauma	+2 for each

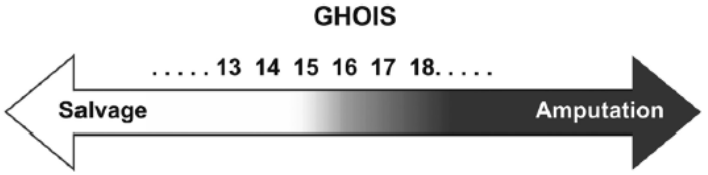


Table 3 Ganga Hospital Open Injury Score (GHOIS)

Covering structures: skin and fascia	
Wound with no skin loss and not over the fracture site	1
Wound with no skin loss and over the fracture site	2
Wound with skin loss and not over the fracture site	3
Wound with skin loss and over the fracture site	4
Wound with circumferential skin loss	5
Functional tissues: musculotendinous and nerve units	
Partial injury to musculotendinous unit	1
Complete but repairable injury to musculotendinous units	2
Irreparable injury to musculotendinous units, partial loss of a c partment, or complete injury to posterior tibial nerve	3
Loss of one compartment of musculotendinous units	4
Loss of two or more compartments or subtotal amputation	5

Skeletal structures: bone and joints

- Transverse or oblique fracture or butterfly fragment <50 % circumference
- Large butterfly fragment >50 % circumference
- Comminution or segmental fractures without bone loss
- Bone loss <4 cm
- Bone loss >4 cm

Comorbid conditions: add 2 points for each condition present

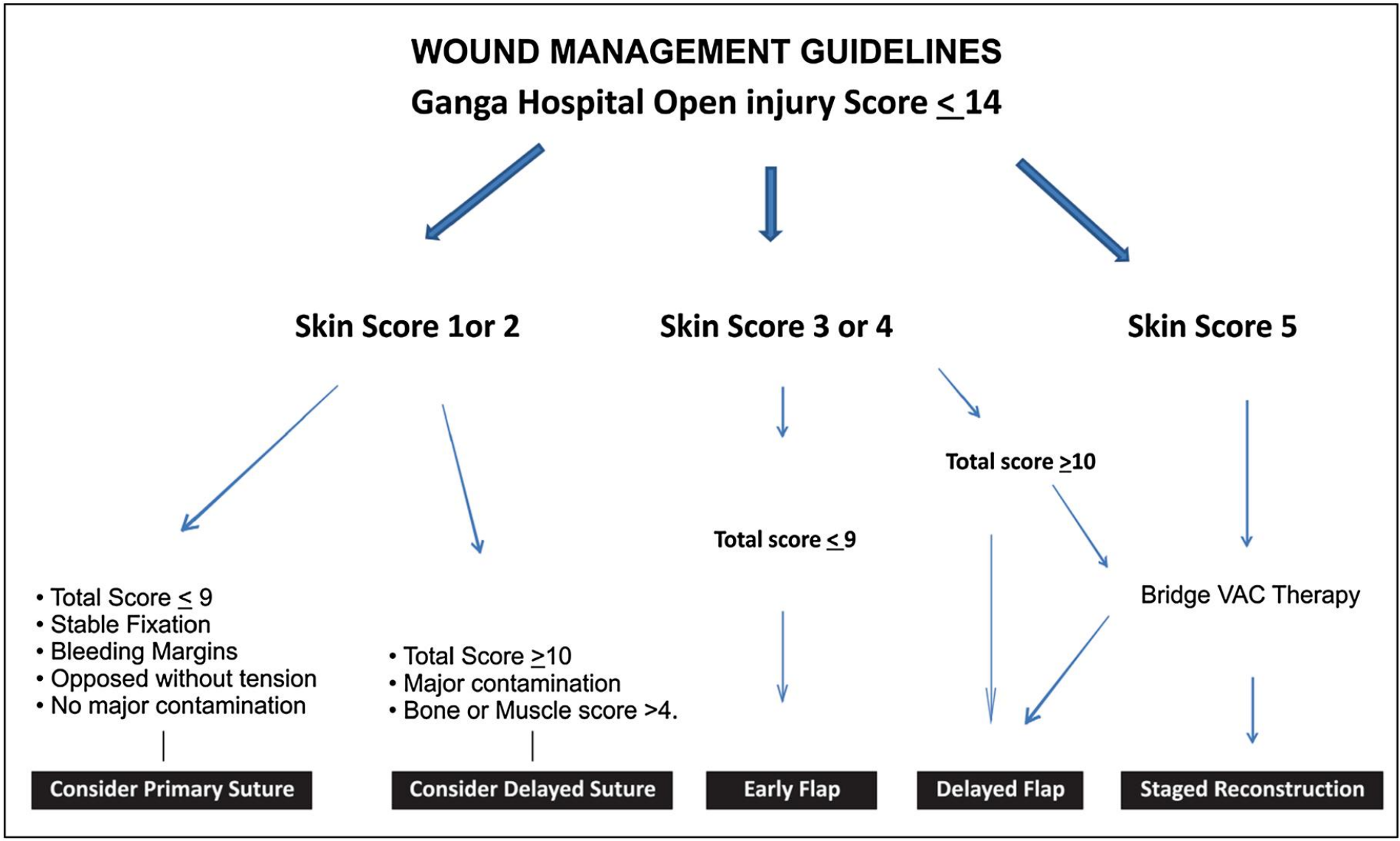
- Injury leading to debridement interval >12 h
- Sewage or organic contamination or farmyard injuries
- Age >65 years
- Drug-dependent diabetes mellitus or cardio respirator diseases leading to increased anesthetic risk
- Polytrauma involving chest or abdomen with injury severity score >25 or fat embolism
- Hypotension with systolic blood pressure <90 mmHg at presentation
- Another major injury to the same limb or compartment syndrome

14 or less salvage and injuries with score of 17 or more have little success with salvage

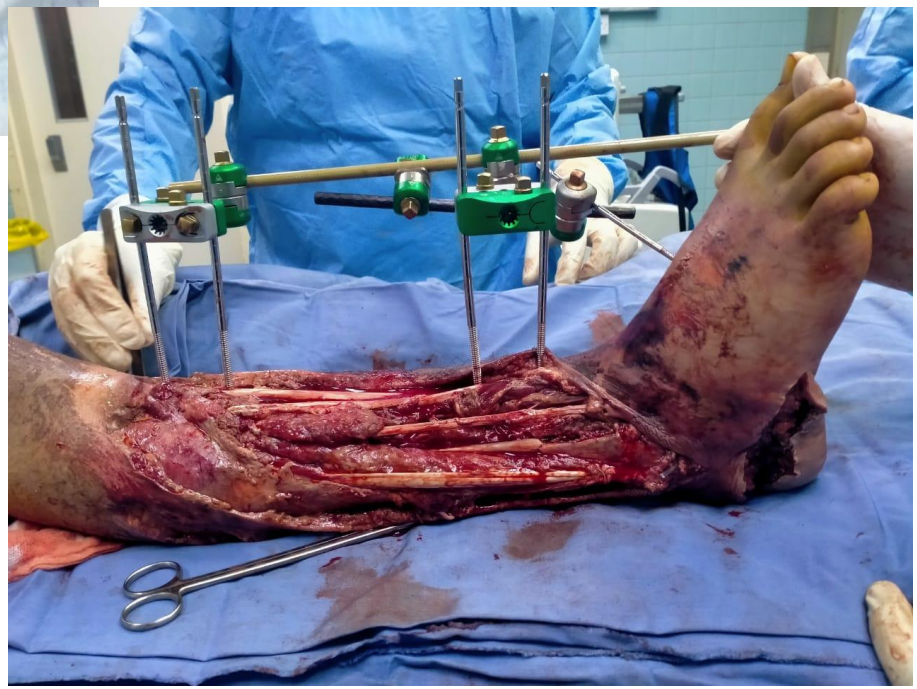
- Specifically designed for type IllB injuries.
- Assesses severity of injury to skin, muscle, and bone separately.
- Total score predicts amputation.
- Individual score provides guidelines for reconstruction.
- Scoring includes comorbidities that influence outcome.
- Better intra- and interobserver agreement compared with Gustilo classification.

Table 5 Primary closure of open wounds

Indications (all must be present)
Type 1,11 III A and B injuries of limbs without vascular deficit
Wounds without primary skin loss or secondary skin loss after debridement
Ganga Hospital skin score of 1 or 2 and a total score of 10 or less
Injury to debridement interval <12 h
Presence of bleeding wound margins which can be apposed without tension
Stable fixation achieved either by internal or external fixation
Contraindications(any of the below)
Type IMC injuries
Ganga Hospital skin score of 3 or more and a total score of >10
Wounds in patients with severe polytrauma involving and an injury severity score >25
Sewage or organic contamination/farmyard injuries
Peripheral vascular diseases/thromboangiitis obliterans
Drug-dependent diabetes mellitus/connective tissue disorders/ peripheral vasculitis


WOUND MANAGEMENT GUIDELINES
Ganga Hospital Open injury Score ≤ 14
Skin Score 1or 2
Skin Score 3 or 4
Skin Score 5
Total score ≥10
Total score ≤ 9
• Total Score ≤ 9
• Stable Fixation
• Bleeding Margins
• Opposed without tension
• No major contamination
• Total Score ≥10
• Major contamination
• Bone or Muscle score >4.
Bridge VAC Therapy
Consider Primary Suture
Consider Delayed Suture
Early Flap
Delayed Flap
Staged Reconstruction

- GHOIS was found to have 100% sensitivity and 95% of specificity in predicting salvage
- GHOIS score of 17 and above was more accurate for predicting amputation with a sensitivity of 75% and specificity of 93.7%



Irrigation

- Warm sterile saline or tap water
- Beware pressure systems
- Remove all foreign material
- “The solution to pollution is dilution”

Wound Irrigation

- This is the key component in preventing infection as it decreases bacterial load and removes FB
- High pulsatile lavage is the most effective???
- 3L for type I
- 6L for typeII
- 9L for type III

- Current evidence indicates that **normal saline** should be routinely used as there is no advantage in adding any soap, antiseptic, or antibiotic to the fluid.
- The use of **Betadine** has also no advantage but has the disadvantage of staining the tissues and obscuring contamination and small dirt particles. It is also possibly toxic to tendon sheaths, cartilage, and periosteum.
- **High-pressure lavage**, which was once popular, is now not used as it has not shown any advantage. It may also have the disadvantage of damaging tissues such as periosteum and tendon sheaths and it may also push dirt and debris deeper into the tissues.

- low-pressure lavage with normal saline is preferred

Debridement

- Clinical assessment of tissue necrosis
- Highly subjective
- Two discreet phases:
  - Wound irrigation
  - Removal of all necrotic or devitalized tissue including bone

Debridement

- No delay!
- Timelines are controversial
- Pitfalls:
  - Insufficient exposure
  - Too cautious
  - Poor planning

Current literature suggests no obvious advantage in performing debridement within 6 hours compared to debridement performed between 6 and 24 hours after injury

Operative treatment

- tourniquet used **only** if major bleeding
- Experienced surgeon!
    - inexperience → under-debridement

Most agree that surgery should be done urgently taking into account the

Stability of the patient
The preparation of the operating room
Availability of appropriate assistance
Availability of adequately trained theatre staff

Soft tissue debridement

- **Muscle viability 4 C's**
  - contractility
  - capacity to bleed
  - color
  - consistency

Bone debridement

- Remove avascular, contaminated fragments
- Protect soft tissue attachments
- Retain key bone fragments ?
  - articular surface

- Re-evaluate “crucial tissues” at 2nd debridement

Redebridement

•Need for Second-Look Debridement

- High-energy blast injuries
- Severe contamination, farmyard, and sewage contamination
- Delayed presentation >12 hours
- Evidence of infection during debridement
- Initial debridement considered unsatisfactory

Infection

- **Local Factors**
- Organic, farmyard, or sewage contamination Poor debridement with retention of foreign debris and nonviable tissues
- Inadequate skeletal stabilization
- Presence of dead space
- Debridement later than 24 hours

Systemic Factors

- Presence of shock and ARDS
- Comorbid factors like age above 65 years, metabolic disorders like diabetes mellitus, history of smoking
- Compartment syndrome and hypovascular tissues
- Prolonged hospital stay and exposure to resistant organisms
- Poor nutrition

Antibiotics

- Prophylactic antibiotic therapy proven
- 13.9–2.7% decrease in sepsis rate

~80%

- Open fractures are contaminated by definition

“early treatment”

What antibiotic?

Open Fracture Type	*Recommended Systemic Antibiotic Prophylaxis*
Gustilo and Anderson type I	First-generation cephalosporin (cefazolin) Alternative: clindamycin with β-lactam allergy
Gustilo and Anderson type II	First-generation cephalosporin (cefazolin) Alternative: clindamycin with β-lactam allergy
Gustilo and Anderson type III	First-generation cephalosporin (or clindamycin with β-lactam allergy) plus aminoglycoside (gentamicin) Alternatives: Third-generation cephalosporin (ceftriaxone or piperacillin/tazobactam)
Fecal or potential clostridial contamination	Consider addition of penicillin to above regimen (cefazolin/gentamicin)

OPEN FRACTURES	FIRST-GENERATION CEPHALOSPORINS (GRAM-POSITIVE COVERAGE) CEFAZOLIN	IF ANAPHYLACTIC PENICILLIN ALLERGY (INSTEAD OF FIRST-GENERATION CEPHALOSPORIN) CLINDAMYCIN
Wound <1 cm; minimal contamination or soft tissue damage	<50 kg: 1 gm Q 8 hr 50–100 kg: 2 gm Q 8 hr >100 kg: 3 gm Q 8 hr	<80 kg: 600 mg Q 8 hr >80 kg: 900 mg Q 8 hr
Wound 1–10 cm; moderate soft tissue damage; comminution of fracture	<50 kg: 1 gm Q 8 hr 50–100 kg: 2 gm Q 8 hr >100 kg: 3 gm Q 8 hr	<80 kg: 600 mg Q 8 hr >80 kg: 900 mg Q 8 hr
Severe soft-tissue damage and substantial contamination with associated vascular injury	<50 kg: 1 gm Q 8 hr 50–100 kg: 2 gm Q 8 hr >100 kg: 3 gm Q 8 hr	<80 kg: 600 mg Q 8 hr >80 kg: 900 mg Q 8 hr

- Avoid Ciprofloxacin & other fluroquinilones as they inhibit osteoblastic activity
- Avoid high concentration of aminoglycosides as they inhibit osteoblastic function

recommendation

- Use a first or a second generation Cephalosporin every 8 hrs until 24 hrs after the wound is closed
- Add Gentamicin to type III #
- Add a penicillin if there is a risk of anaerobic infections

How long ?

- Initiate within 3 hrs following injury
- Infection rate is doubled if antibiotic administration is delayed > 3hrs
- There is evidence that a single day of antibiotics is as good as a five day regimen in preventing infection

There is no evidence of benefit for the continued administration of antibiotics beyond 24 hours after definitive coverage or débridement and coverage with a sterile dressing

East Practice Management Guidelines Work Group: Update to Practice Management Guidelines for Prophylactic Antibiotic Use in Open Fractures

William S. Hoff, MD, FACS, John A. Bonadies, MD, FACS, Riad Cachecho, MD, FACS, FCCP,

With regard to duration of antibiotic coverage, the original guidelines recommend that antibiotics be discontinued 24 hours after successful wound closure for type I and type II fractures. For type III fractures, antibiotics should be continued for 72 hours subsequent to the injury or not >24 hours subsequent to successful soft tissue coverage of the wound.

Factors influencing outcomes

- Presence of compromising factors
  - Age
  - Smoking
  - DM
  - Malignancy
  - Pulmonary insufficiency
  - immunodeficiency

Stabilize soft tissue and fracture

- External fixation:
  - Plan pins
  - Consider temporary versus to completion
  - Understand mechanics
- Internal fixation:
  - Depending on grade, contamination, and delay

plate fixation is ideal for fractures of the upper limb. The choice between a locking nail and a plate for the lower limb bones is made depending on the fracture morphology, the instrumentation that is available, and the surgeon's preference

Make the Plastic reconstructive surgeon your friend

Role of fixation

- Protection of soft tissue from additional damage
- Improves wound care & healing
- Promotion of mobilization & rehabilitation
- In multiple injury reduces ARDS& MOF as the SIRS is calmed

The tibia

- Optimal treatment is less clear
- Evidence to support that EX fix is successful in the treatment of sever open#
- Associated with fewer complications
- Take into account future reconstructive procedures

What about Tibia? nailing

- Reamed vs. unreamed
- Evidence is inconclusive
- Meta-analysis fails to

demonstrate any significant differences with regard to infection, non-union or re-operations

Plate fixation

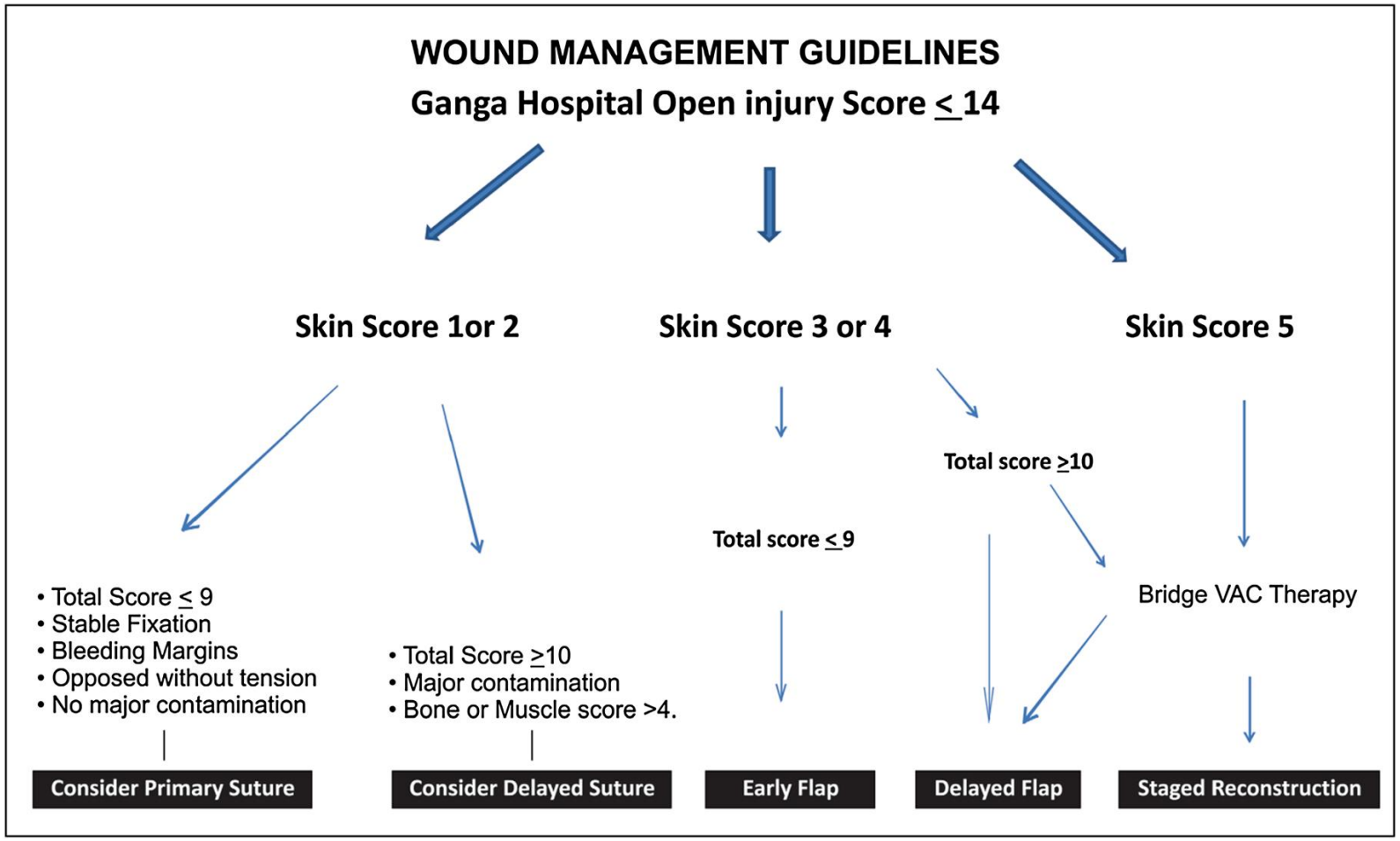
- Intra-articular & metaphyseal fractures
- Upper extremity (forearm & humerus)
- Femur in ARDS

- Plate techniques
  - Standard
  - MIPO
  - LISS
  - Locked
  - Peri-articular

Wound Coverage and Closure

- A number of studies have shown excellent outcomes with closure performed within 3 days after injury
- DeLong et al have shown that closure within 24hrs to be safe
- Hertel et al have found that immediate coverage of type IIIA&IIIB was associated with lower rate of infection….fix and flap

Assessment of skin loss requires experience and must be done after the skeletal length is restored.
A: In the emergency room and during debridement, all lacerated wounds appear to have skin loss as they gape due to bone shortening and angulation. B: Once fracture reduction is achieved, the wound margins usually come together and primary closure is possible in nearly a third of injuries.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Consider Primary Suture
Consider Delayed Suture
Early Flap
Delayed Flap
Staged Reconstruction

Vacuum-assisted closure

- A successful method for accelerating wound healing by reducing chronic oedema, increase local blood flow& enhance granulation tissue formation

Negative pressure wound therapy (NPWT)

- Therapy not dressing
- Manages exudate
- Prevents colonization
- Promotes granulation

Vacuum components

Tubing

OpSite or Tegaderm

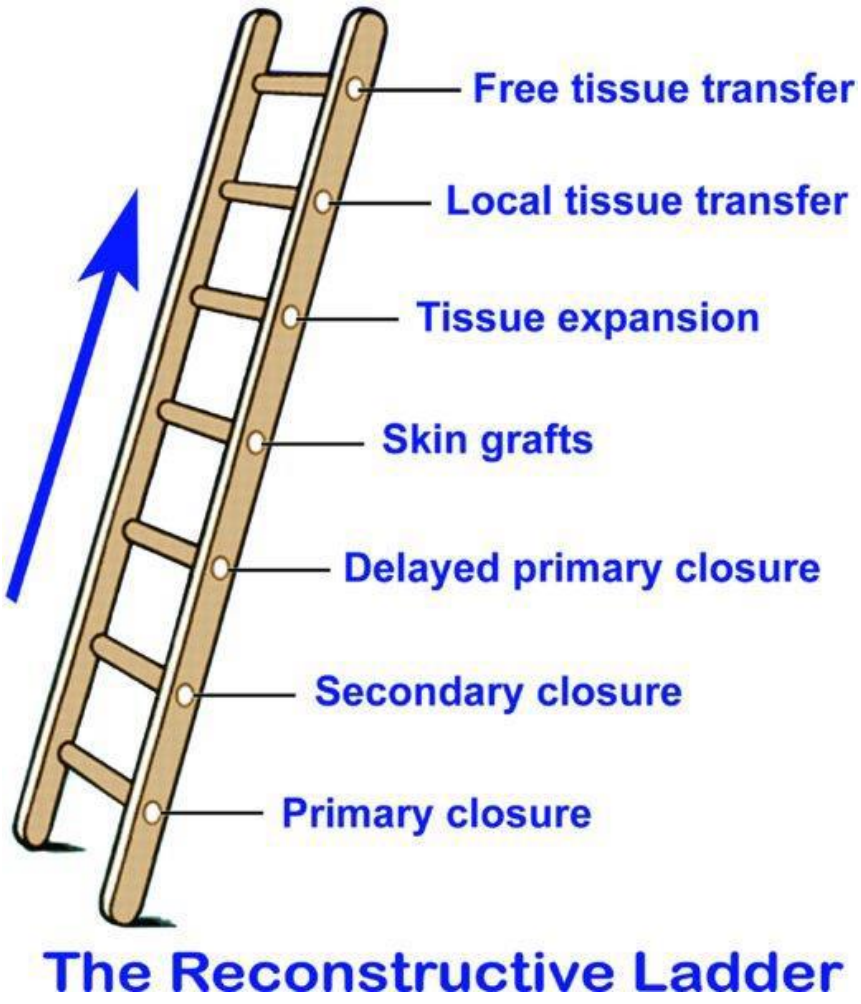
Granuflex seals

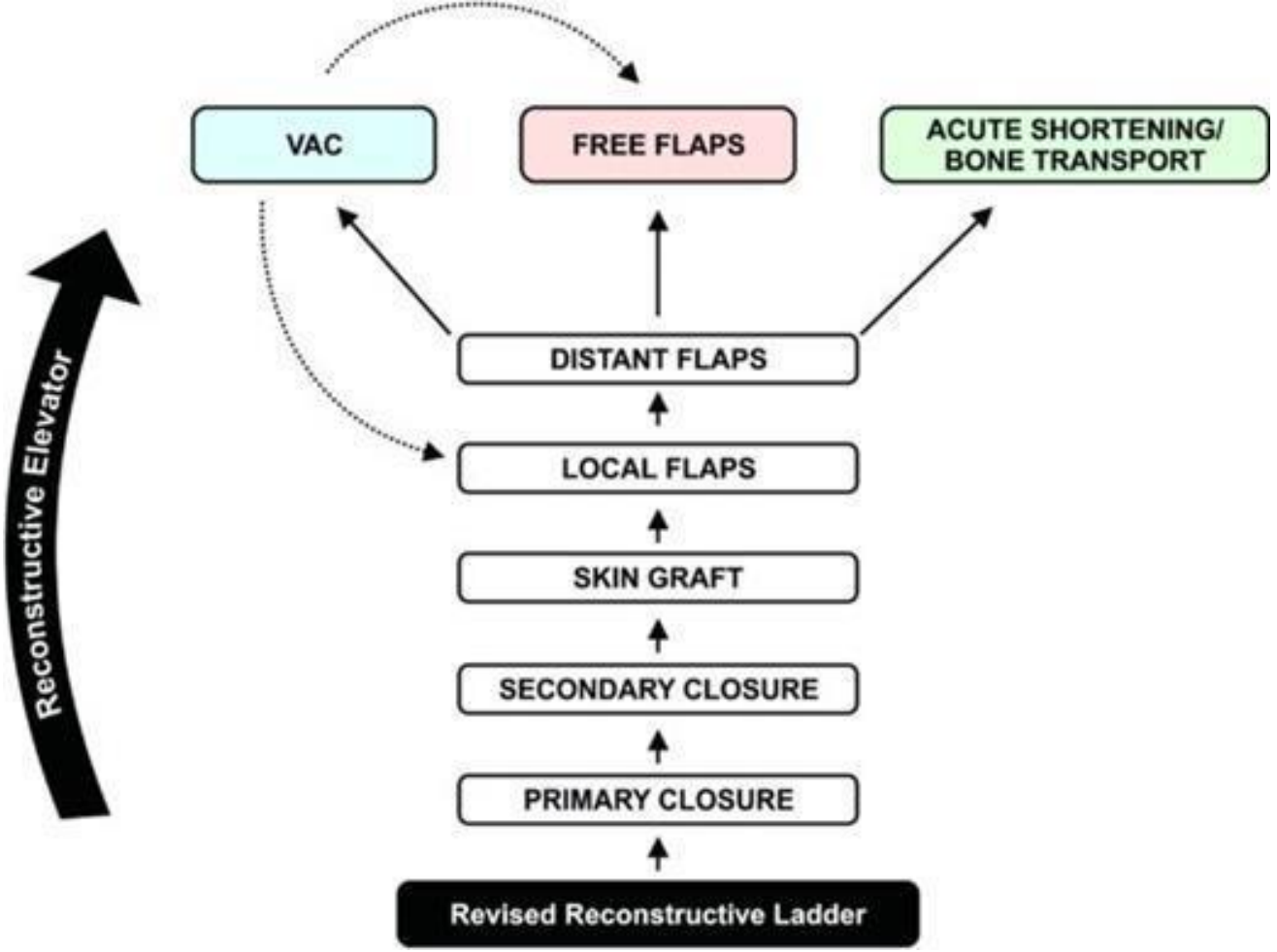
Vacuum

Open-cell foam

Soft tissue coverage options

- traditional advice was to choose the simplest option as the first choice for soft tissue cover





The revised reconstructive ladder includes the newer methods of reconstruction such as NPWT and acute shortening/bone transport.

The "reconstructive elevator" concept is more popular now where the most appropriate and effective method of cover is chosen as the primary choice, however complex it may be.

, “Wide, early, experienced debridement to clearly healthy tissue and early rotational or free muscle flap cover may be better in experienced hands than sequential debridement and delayed closure

Godina

Take-home messages

- Treat as an emergency
- Adequate debridement
- Appropriate antibiotics and dressing
- Stabilize fracture and soft tissues

ACUTE COMPARTMENT SYNDROME

Abdullah Alkhawaldah MD, FACS
RMS Jordan. Foot And Ankle surgery

Objectives

- Define compartment syndrome
- Review Pathophysiology of Acute Compartment Syndrome
- Review Current Diagnosis and Treatment
- Risk Factors
- Clinical Findings
- Discuss surgical treatment.

Compartment Syndrome

(ACS) acute compartment syndrome is defined as:

the elevation of intracompartmental pressure (ICP) to a level and for a duration that without decompression will cause tissue ischemia and necrosis. .

Compartment Syndrome
Etiology

↓ Compartment Size

- tight dressing; Bandage/Cast
- localised external pressure; lying on limb
- Closure of fascial defects

↑ Compartment Content

- Bleeding; Fx, vas inj, bleeding disorders
- Capillary Permeability;
  - » Ischemia / Trauma / Burns / Exercise / Snake Bite / Drug Injection / IVF

Compartment Syndrome
Etiology

- Fractures-closed and open
- Blunt trauma
- Temp vascular occlusion
- Cast/dressing
- Closure of fascial defects
- Burns/electrical
- Exertional states
- GSW
- IV/A-lines
- Hemophiliac/coag
- Intraosseous IV(infant)
- Snake bite
- Arterial injury

Fractures

- The most common cause
- incidence of accompanying compartment syndrome of 9.1%
- The incidence is directly proportional to the degree of injury to soft tissue and bone
- occurred most often in association with a comminuted, grade-III open injury to a pedestrian

Blick et al JBJS 1986

Blunt Trauma

- 2nd most common cause
- About 23% of CS
- 25% due to direct blow

McQueen et al; JBJS Br 2000

Compartment Syndrome
Pathophysiology

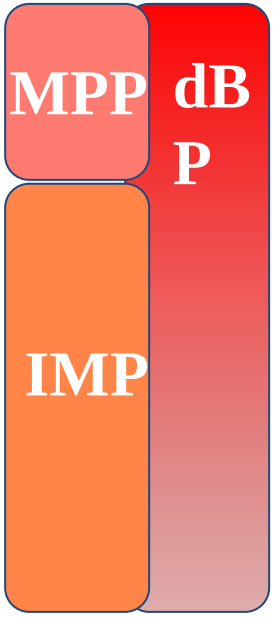
- Normal tissue pressure
  - 0-4 mm Hg
  - 8-10 with exertion
- Absolute pressure theory
  - 30 mm Hg - Mubarak
  - 45 mm Hg - Matsen
- Pressure gradient theory
  - < 20 mm Hg of diastolic pressure – Whitesides
  - McQueen, et al

What's the normal Muscle Perfusion Pressure (MPP)?

MPP is the diastolic Blood Pressure (dBP)

minus

the IntraMuscular Pressure (IMP)

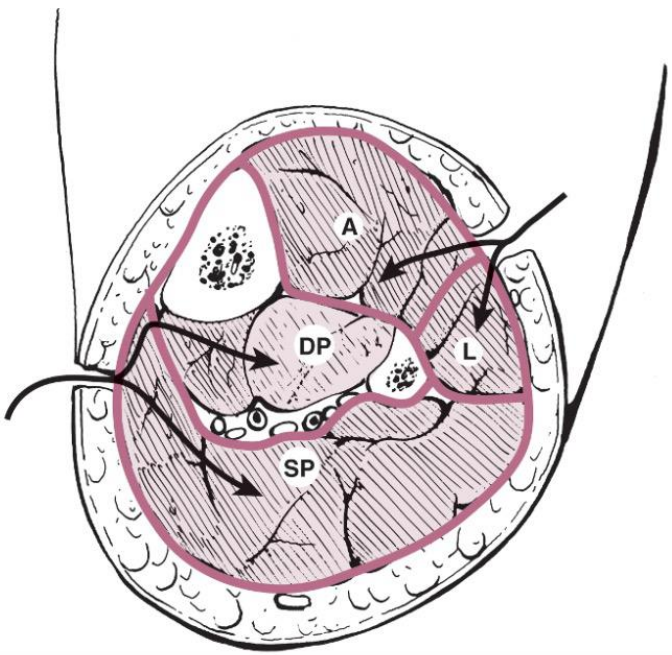


If MPP is below 30 mm mercury (Hg), muscle hypoxia will occur

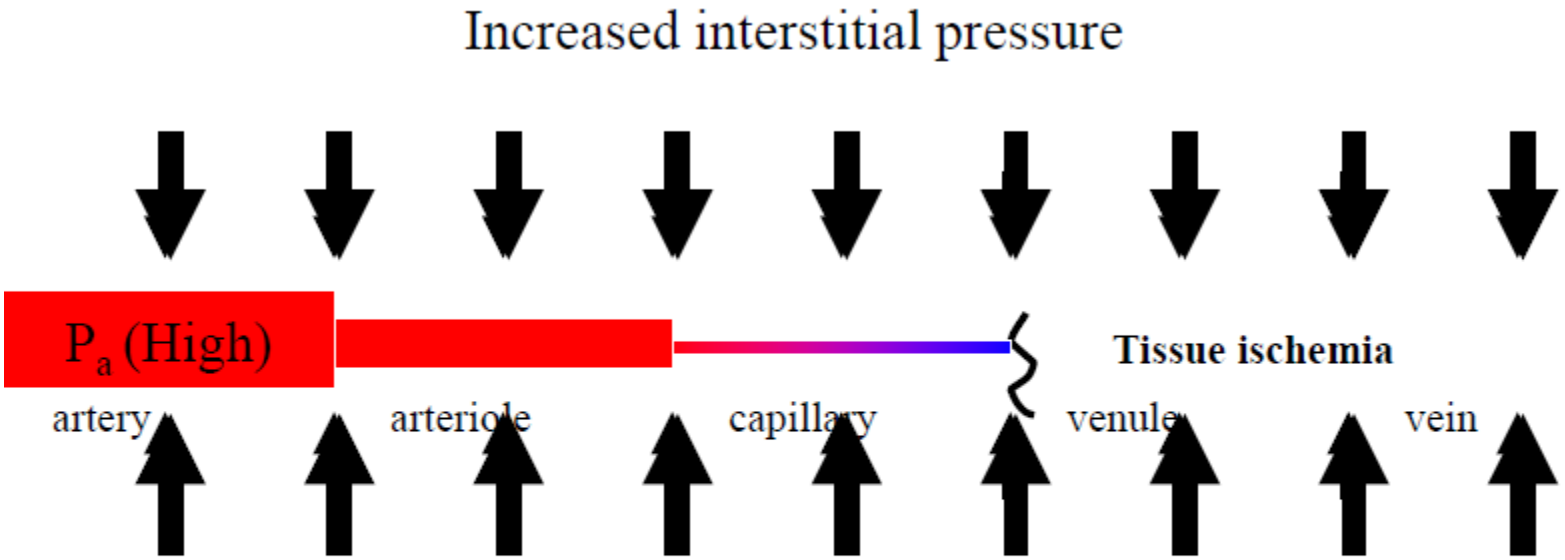
Pathophysiology of Compartment Syndrome

Normal resting IMP 0-8 mm Hg in adults, 13-16 mmHg in children.

- •Elevated in CS.
- •Does not measure degree of tissue injury.



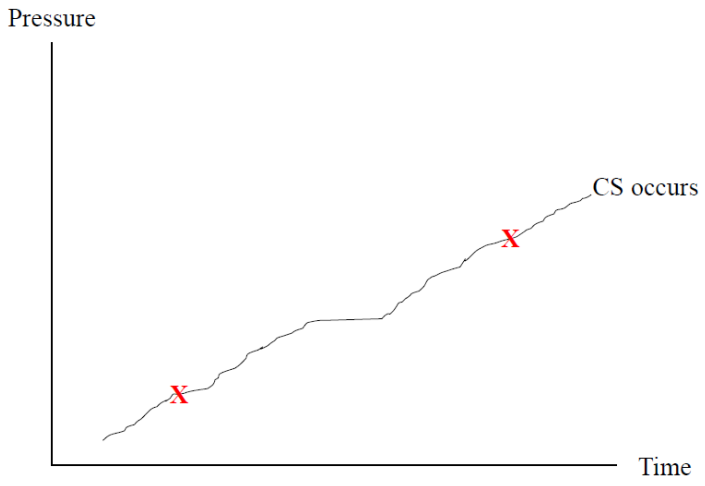
Vascular Consequences of Elevated Intracompartment Pressure:

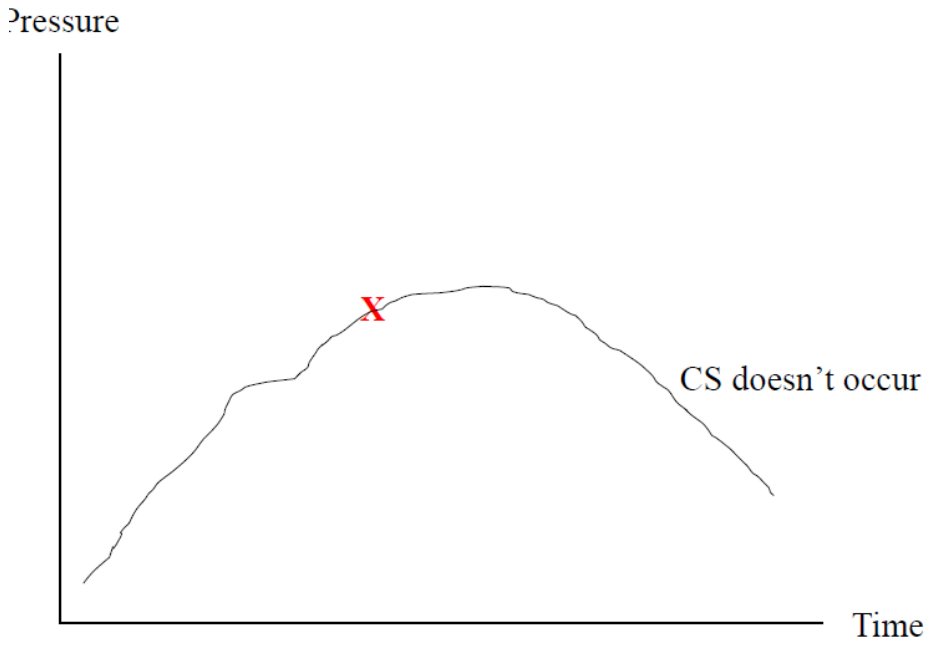


- **Lysis of cell walls**
- **Release of osmotically active cellular contents into interstitial fluid**
- **Increased interstitial pressure**
- **More cellular injury…**

Compartment Syndrome is also a pressure-time phenomenon

- Tissue doesn’t become irreversibly damaged until it has been ischemic for 6 -8 hours.
- In patients with extremity injury, you don’t know when the clock started.





significant muscle necrosis can occur in patients with normal blood flow if intracompartmental pressure is increased to more than 30 mm Hg for longer than 8 hours

Perfusion Pressure (ΔP)

- Currently, the “differential pressure” is considered the most reliable indicator of when fasciotomy is not necessary:
  MAP- IMP < 45 mm Hg
- DBP - IMP < 30 mm Hg

Compartment Syndrome
Tissue Survival

- Muscle
  - 3-4 hours - reversible changes
  - 6 hours - variable damage
  - 8 hours - irreversible changes
- Nerve
  - 2 hours - looses nerve conduction
  - 4 hours - neuropraxia
  - 8 hours - irreversible changes

Compartment Syndrome
Diagnosis

- Pain out of proportion
- Palpably tense compartment
- Pain with passive stretch
- Paresthesia/hypoesthesia
- Paralysis
- Pulselessness/pallor

Clinical Evaluation

"Pain and the aggravation of pain by passive stretching of the muscles in the compartment in question are the most sensitive (and generally the only) clinical finding before the onset of ischemic dysfunction in the nerves and muscles."

Whitesides AAOS 1996

Clinical Evaluation

- Pain – most important. Especially pain out of proportion to the injury (child becoming more and more restless /needing more analgesia)
- Most reliable signs are pain on passive stretching and pain on palpation of the involved compartment
- Other features like pallor, pulselessness, paralysis, paraesthesia etc. appear very late and we should not wait for these things.

Willis &Rorabeck OCNA 1990

Clinical Evaluation

- Beware of epidural analgesia
    - Strecker JBJS 1986
    - Morrow J. Trauma 1994
- Beware long acting nerve blocks
    - Hyder JBJS Br 1995
- Beware controlled intravenous opiate analgesia

Compartment Syndrome
Differential Diagnosis

- Arterial occlusion
- Peripheral nerve injury
- Muscle rupture

Compartment Syndrome
Pressure Measurements

- Suspected compartment syndrome
- Equivocal or unreliable exam
- Clinical adjunct
- Contraindication
  - Clinically evident compartment syndrome

Compartment Syndrome
Pressure Measurements

- Infusion
  - manometer
  - saline
  - 3-way stopcock

  (Whitesides, CORR 1975)
- Catheter
  - wick
  - slit wick
- Arterial line
  - 16 - 18 ga. Needle

  (5-19 mm Hg higher)
  - transducer
  - monitor
- Stryker device
  - Side port needle

Compartment Syndrome
Pressure Measurements

- Arterial line
  - Zero at the level of the affected limb

Compartment Syndrome
Pressure Measurements

- Measurements must be made in all compartments
- Anterior and deep posterior are usually highest
- Measurement made within 5 cm of fx
- Marginal readings must be followed with repeat physical exam and repeat compartment pressure measurement

Heckman, Whitesides JBJS 1994

Threshold for fasciotomy

- McQueen, Court-Brown JBJS Br 1996
- 116 pts with tibial diaphyseal fx had continuous monitoring of anterior compartment pressure for 24 hours
  - 53 pts had ICP over 30 mmHg
  - 30 pts had ICP over 40 mmHg
  - 4 pts had ICP over 50 mmHg
- Only 3 had delta pr(DBP-ICP) of < 30, they had fasciotomy
- None of the patients had any sequelae of the compartment syndrome
- Decompression should be performed if the differential pressure level drops to under 30 mmHg

Medical Management

- Ensure patient is normotensive ,as hypotension reduces prefusion pressure and facilitates further tissue injury.
- Remove cicumferential bandages and cast
- Maintain the limb at level of the heart as elevation reduces the arterial inflow and the arterio-venous pressure gradient on which perfusion depends.
- Perfusion pressure = A pr(30-35mmHg) – V pr(10-15mmHg)
- Supplemental oxygen administration.

Medical Management

- Compartmental pressure falls by 30% when cast is split on one side
- Falls by 65% when the cast is spread after splitting.
- Splitting the padding reduces it by a further 10% and complete removal of cast by another 15%
- Total of 85-90% reduction by just taking off the plaster!

Garfin, Mubarak JBJS 1981

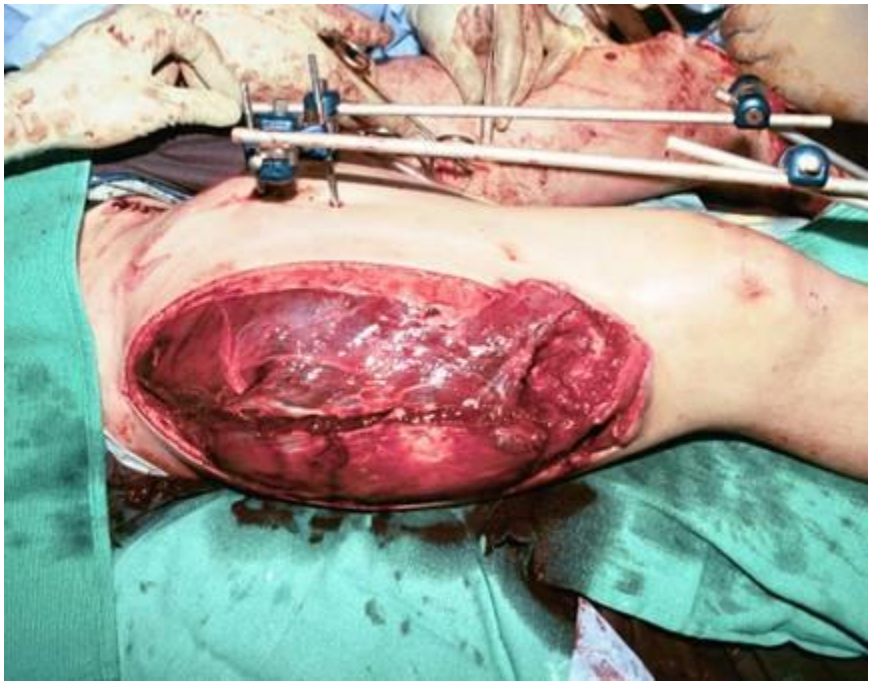
Surgical Treatment

- Fasciotomy,
  Fasciotomy,
  Fasciotomy,

– *All compartments !!!*

Compartment Syndrome
Surgical Treatment

- Fasciotomy - prophylactic release of pressure before permanent damage occurs. Will not reverse injury from trauma.



- Fracture care – stabilization
  - Ex-fix
  - IM Nail

Compartment Syndrome
Indications for Fasciotomy

- Unequivocal clinical findings
- Pressure within 15-20 mm hg of DBP
- Rising tissue pressure
- Significant tissue injury or high risk pt
- > 6 hours of total limb ischemia
- Injury at high risk of compartment syndrome
- CONTRAINDICATION -
  Missed compartment syndrome (>24-48 hrs)

by evidence-based research in humans, fasciotomy after 12 hours has been associated with adverse outcomes

Fasciotomy Principles

- Make early diagnosis
- Long extensile incisions
- Release all fascial compartments
- Preserve neurovascular structures
- Debride necrotic tissues
- Coverage within 7-10 days

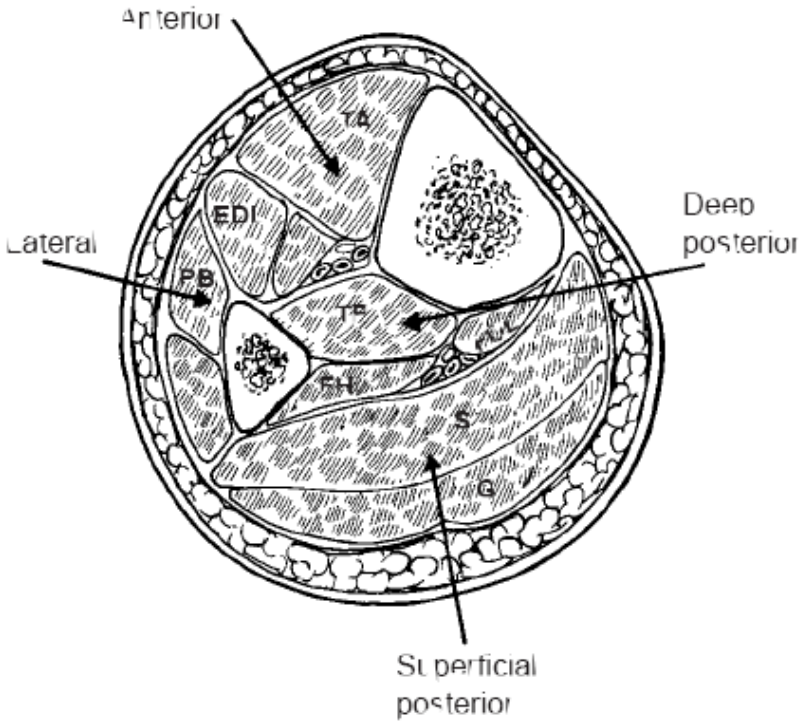
Use a Generous Incision

- Lengthening the skin incisions to an average of 16 cm decreases intracompartmental pressures significantly.
- The skin envelope is a contributing factor in acute compartment syndromes of the leg and The use of generous skin incisions is supported

Cohen, Mubarak JBJS Br 1991

Compartment Syndrome
Lower Leg

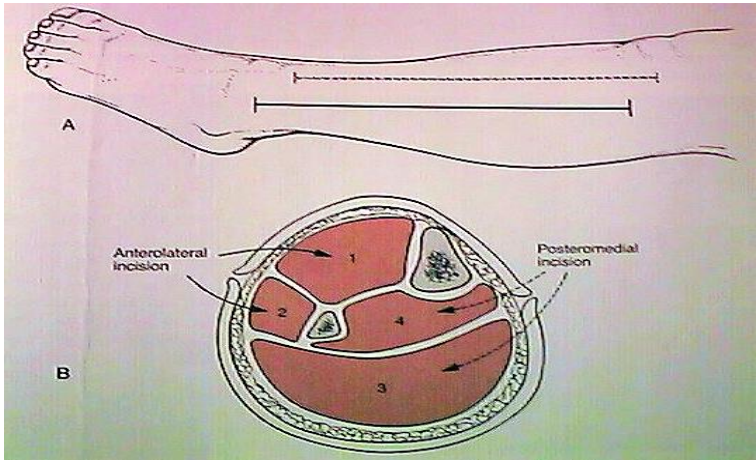
- 4 compartments
  - Lateral: Peroneus longus and brevis
  - Anterior: EHL, EDC, Tibialis anterior, Peroneus tertius
  - Supeficial posterior-Gastrocnemius, Soleus
  - Deep posterior-Tibialis posterior, FHL, FDL

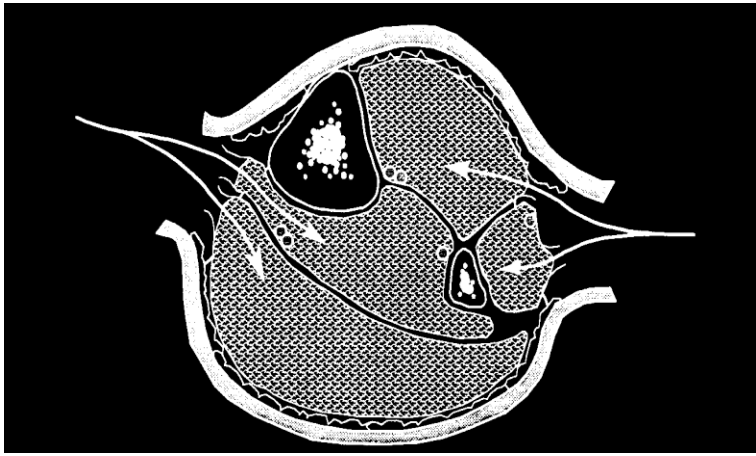


Double Incision

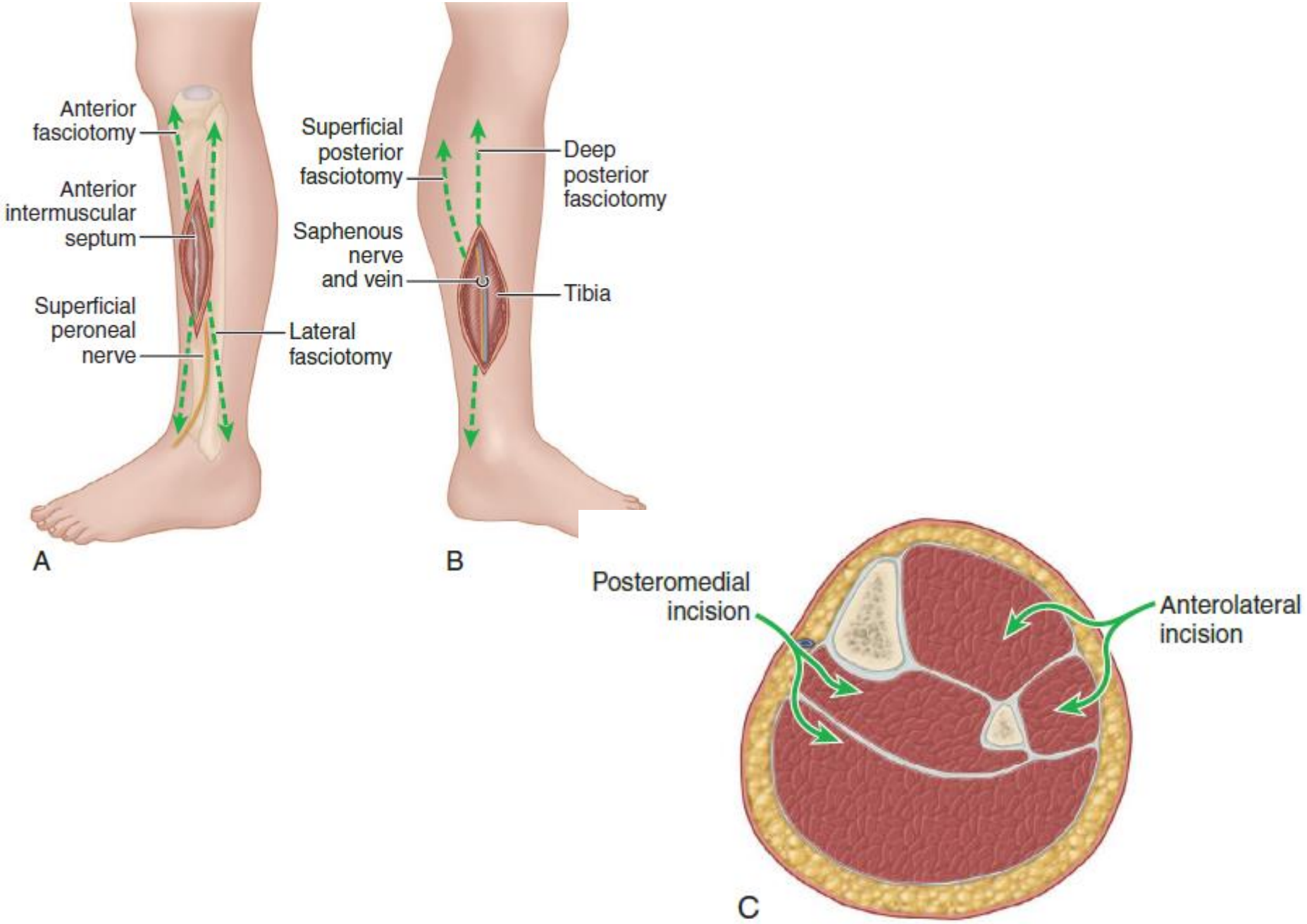
- In most instances it affords better exposure of the four compartments
- 2 vertical incisions separated by minimum 8 cm
- One incision over anterior and lateral compartments
    - Superficial peroneal nerve
- One incision located 1-2 cm behind postero -medial aspect of tibia
    - Saphenous nerve and vein

double-incision technique generally is safer and more effective





Mubarak et al JBJS 1977

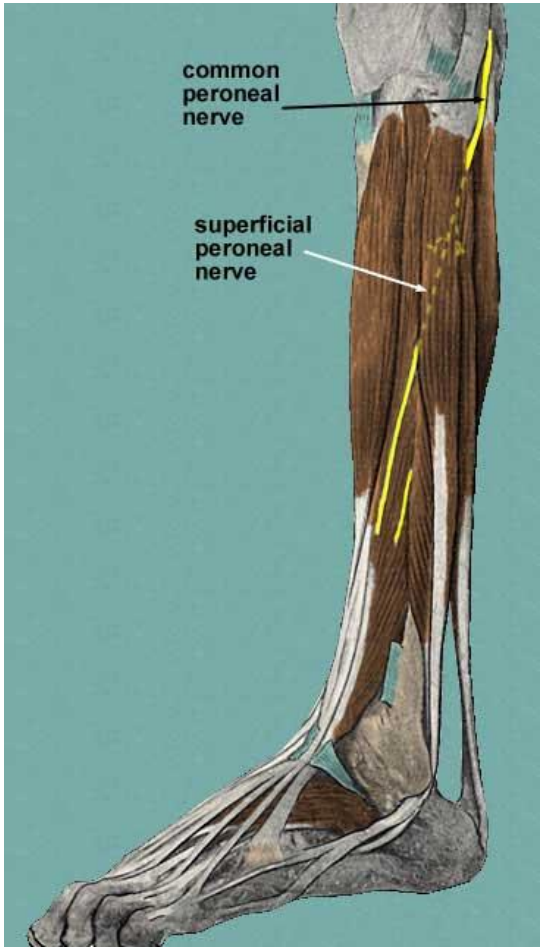

Anterior fasciotomy
Anterior intermuscular septum
Superficial peroneal nerve
Lateral fasciotomy
A
Superficial posterior fasciotomy
Deep posterior fasciotomy
Saphenous nerve and vein
Tibia
B
Posteromedial incision
Anterolateral incision
C

Two–incision fasciotomy of leg

Make a 20- to 25-cm incision in the anterior compartment, centered halfway between the fibular shaft and the crest of the tibia

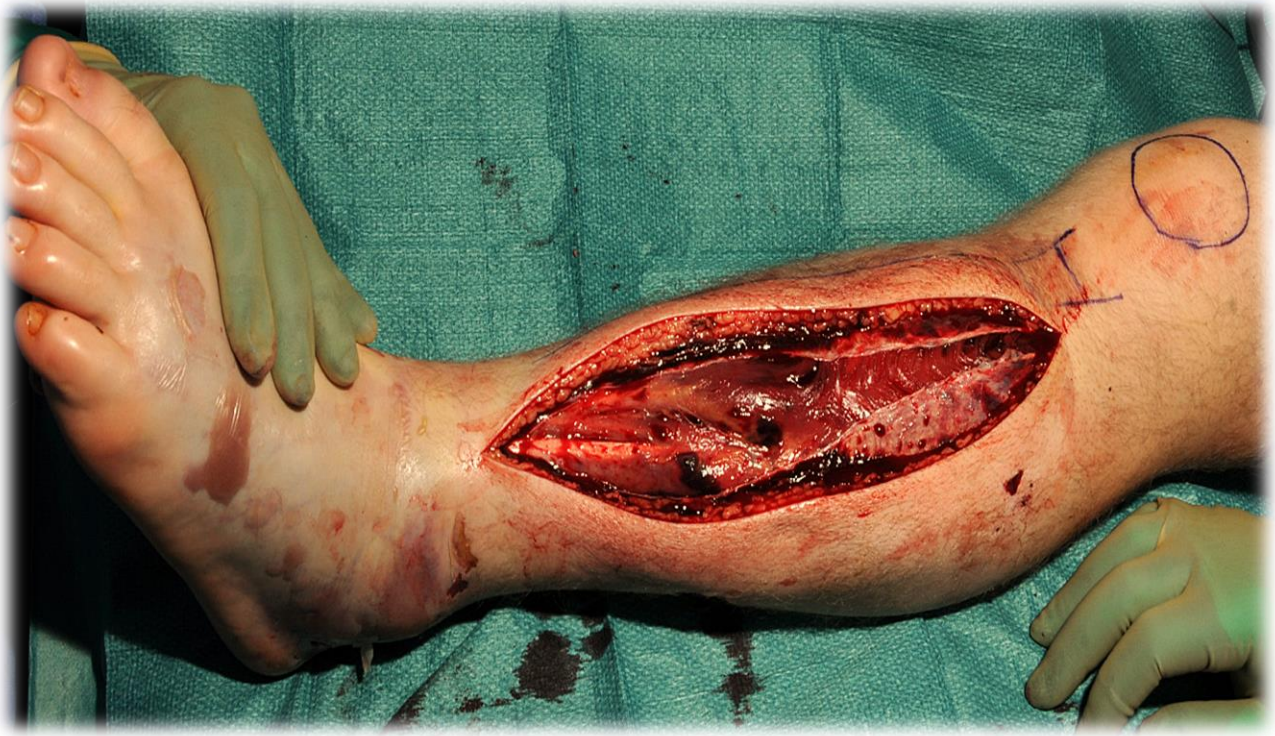
Look for Superficial Peroneal Nerve

- superficial peroneal nerve exits from lateral compartment about 10 cm above lateral malleolus and courses into the anterior compartment
- Risk of injury



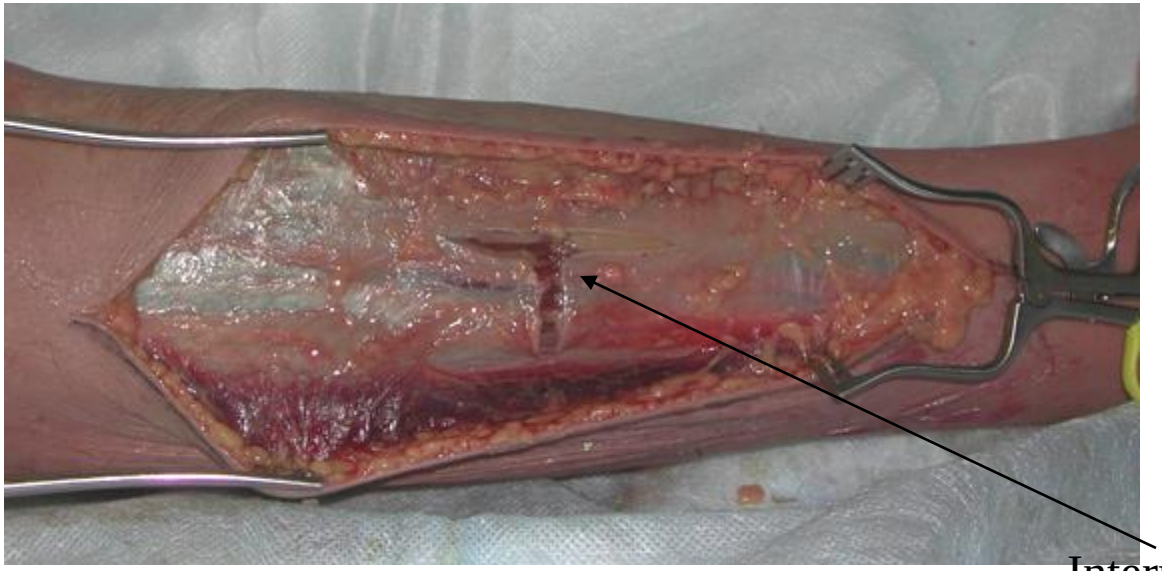
Two–incision fasciotomy of leg

1. Anterolateral incision
    - To release anterior and lateral compartments

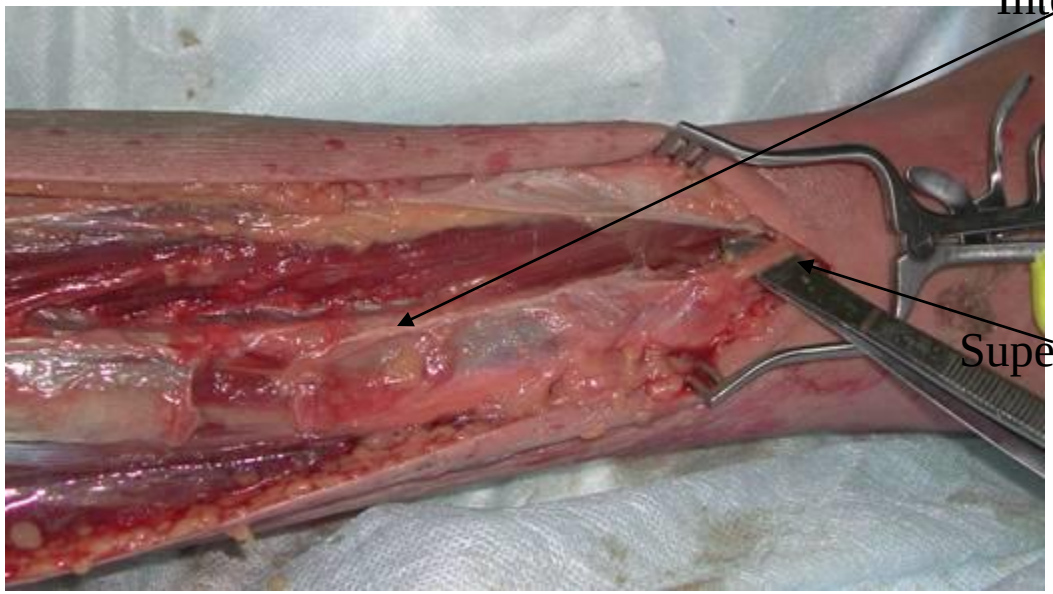


Fasciotomy: Lateral Leg

the superficial peroneal nerve just posterior to the septum.



Intermuscular septum



Superficial peroneal nerve

Two–incision fasciotomy of leg

1. Anterolateral incision
2. Posteromedial incision

Make a second longitudinal incision 2 cm posterior to the posterior margin of the tibia

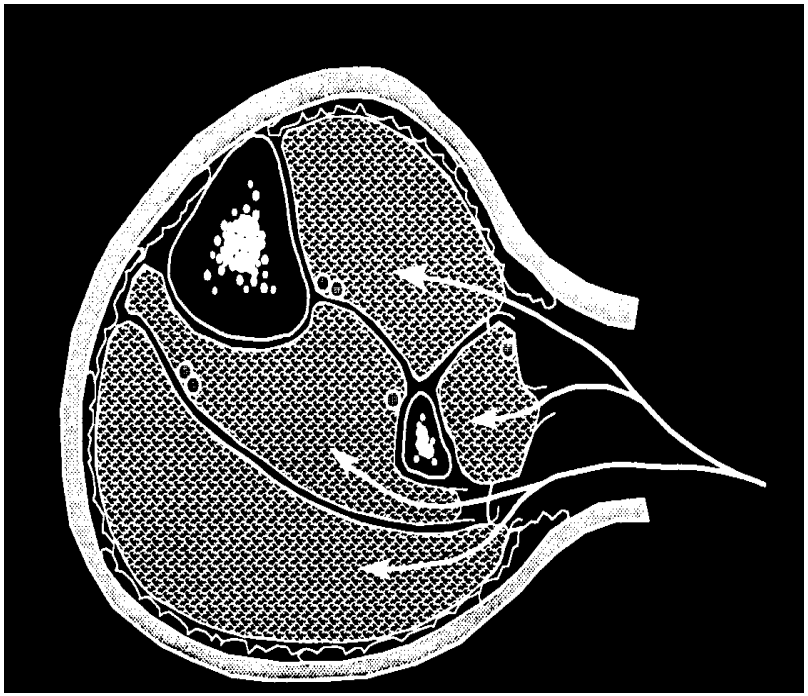
Fasciotomy: Medial Leg

Temporary fixation of the fracture

1. Anterolateral incision
2. Posteromedial incision
3. External fixator

Single Incision

- Perifibular Fasciotomy
  - Matsen et al (1980)
  - Single incision just posterior to fibula
  - Common peroneal nerve

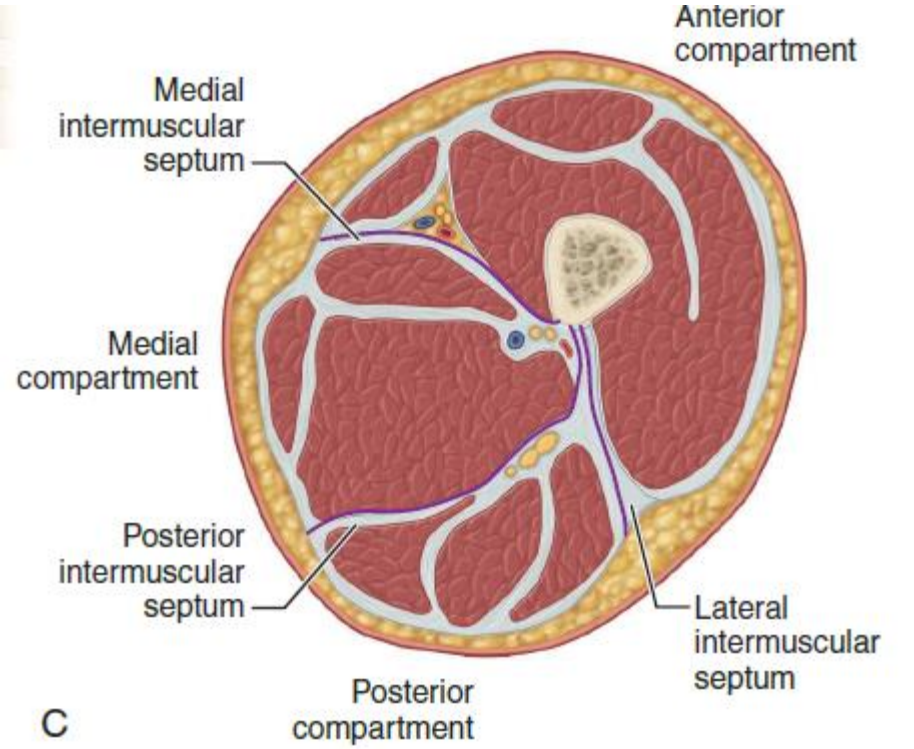


Release of all four compartments appears to be a safer approach for most patients

ACUTE COMPARTMENT SYNDROME OF THIGH

high level of morbidity

blunt trauma (with or without fracture) and vascular injury

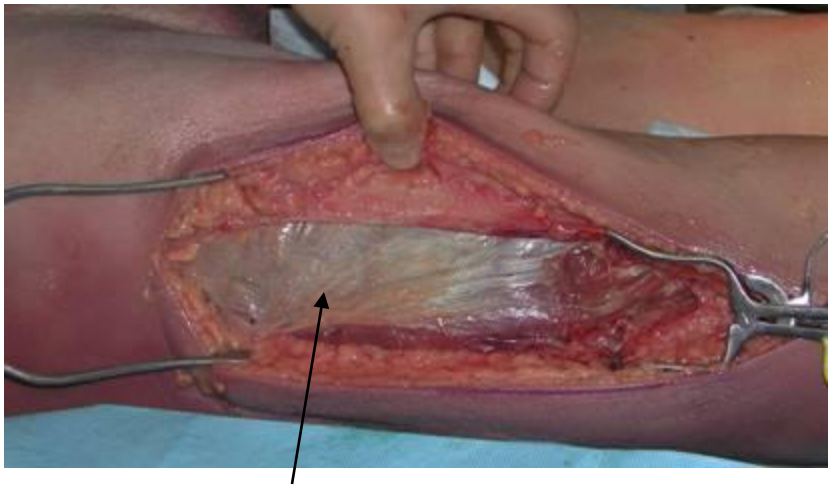


Compartment-Specific Diagnostic Criteria of Acute Compartment Syndrome of the Thigh

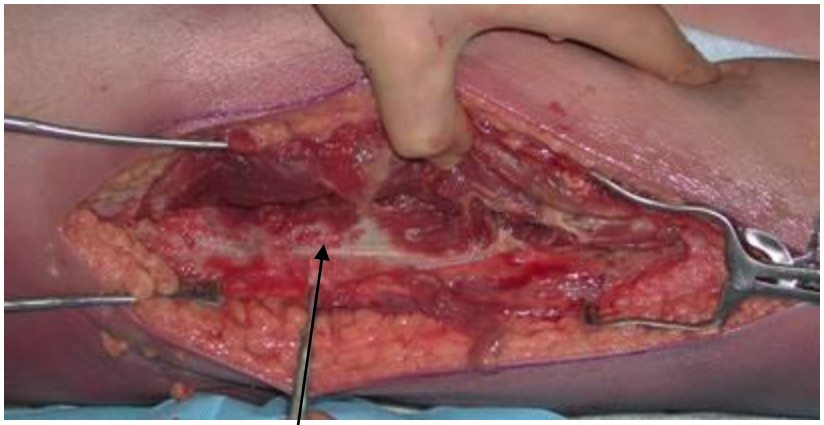
	ANTERIOR COMPARTMENT	POSTERIOR COMPARTMENT	MEDIAL COMPARTMENT
Pain with passive stretch	Passive knee flexion with hip in extension	Passive knee extension with hip in flexion	Passive hip abduction with knee in extension
Motor deficit	Knee extension	Knee flexion, plantar flexion (sciatic tibial branch), dorsi-flexion, great toe extension (peroneal branch)	Hip adduction
Sensory deficit	Passive hip abduction with knee in extension	Hip adduction	Proximal-medial thigh (obturato nerve cutaneous branch)

Compartment Syndrome
Thigh

- Lateral to release anterior and posterior compartments
- May require medial incision for adductor compartment



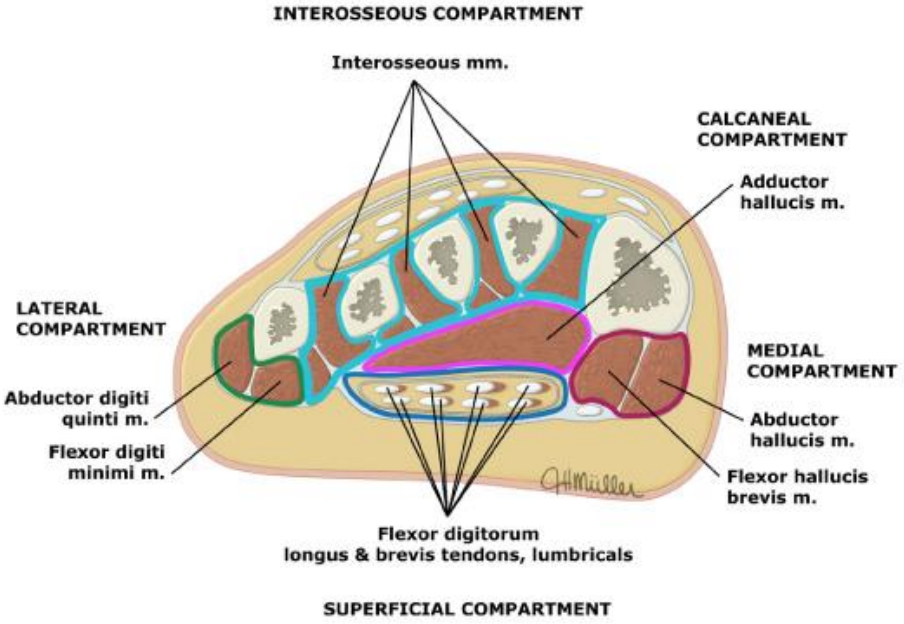
Vastus lateralis

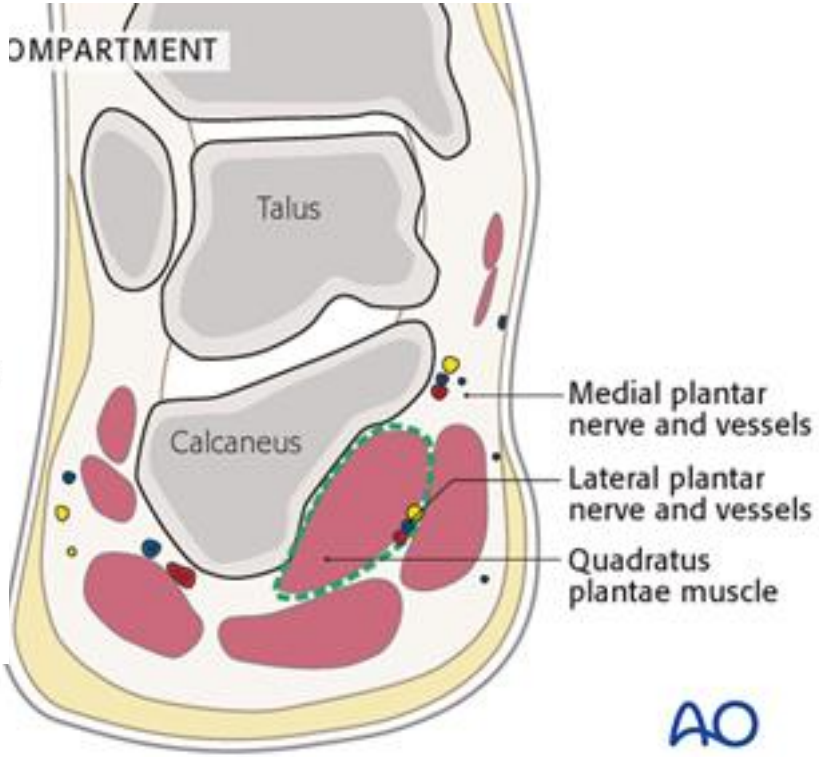


Lateral septum

Compartment Syndrome
Foot

- 9 compartments
  - Medial, Superficial, Lateral, Calcaneal
  - Interossei(4), Adductor
- Careful exam with any swelling
- Clinical suspicion with certain mechanisms of injury
  - Lisfranc fracture dislocation
  - Calcaneus fracture

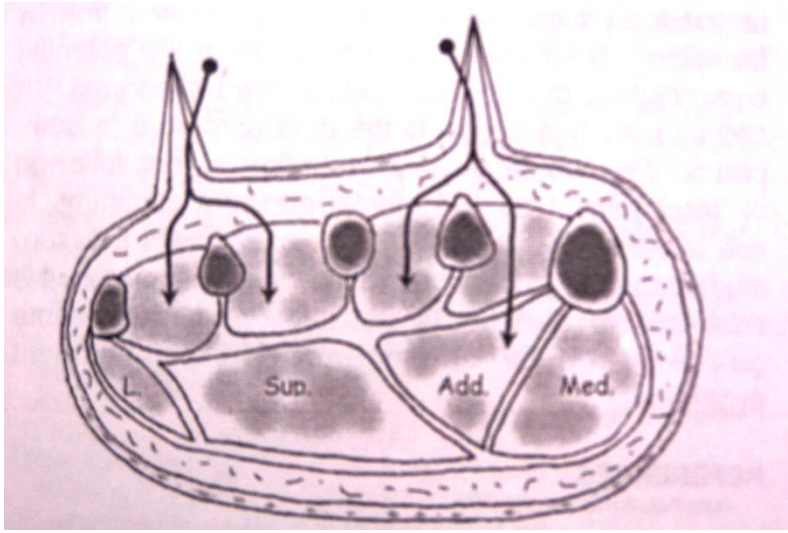

INTEROSSEOUS COMPARTMENT
Interosseous mm.
CALCANEAL COMPARTMENT
Adductor hallucis m.
LATERAL COMPARTMENT
MEDIAL COMPARTMENT
Abductor digiti quinti m.
Flexor digiti minimi m.
Abductor hallucis m.
Flexor hallucis brevis m.
Flexor digitorum longus & brevis tendons, lumbricals
SUPERFICIAL COMPARTMENT

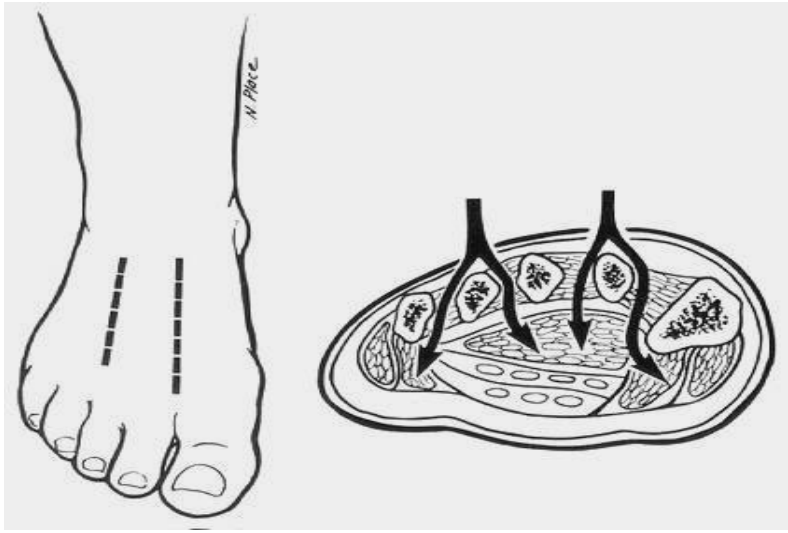

OMPARTMENT
Talus
Calcaneus
Medial plantar nerve and vessels
Lateral plantar nerve and vessels
Quadratus plantae muscle

Compartment Syndrome

Foot

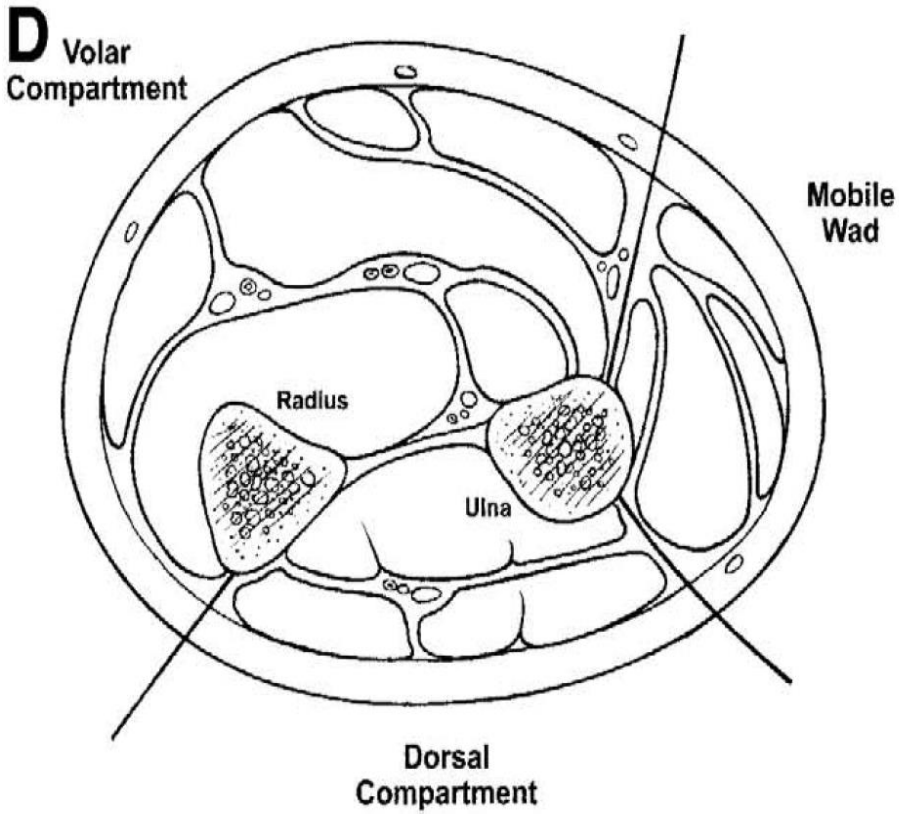
- Dorsal incision-to release the interosseous and adductor
- Medial incision-to release the medial, superficial lateral and calcaneal compartments





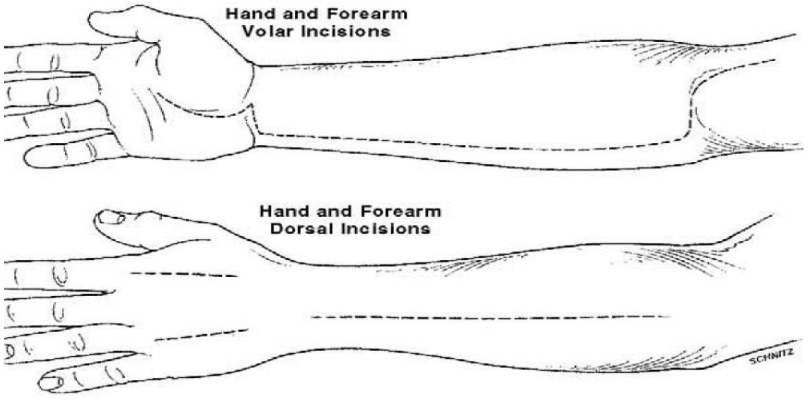
Compartment Syndrome
Forearm

- Anatomy-3 compartments
  - Mobile wad-BR,ECRL,ECRB
  - Volar-Superficial and deep flexors
  - Dorsal-Extensors
  - Pronator quadratus described as a separate compartment



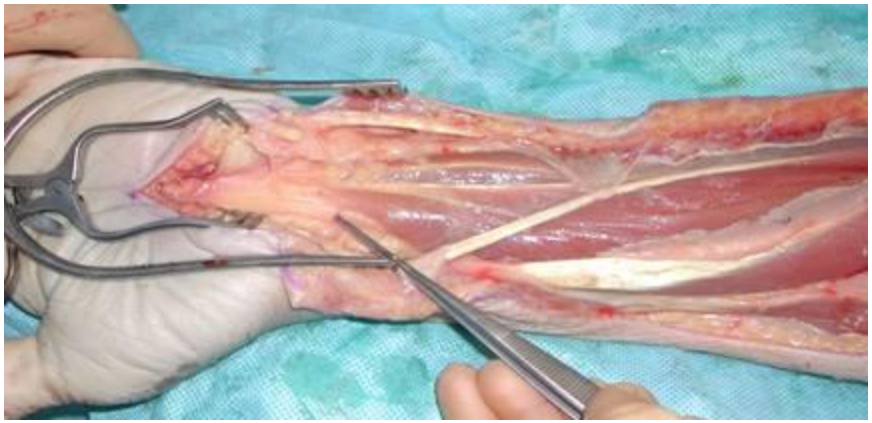
Forearm Fasciotomy

- Volar-Henry approach
  - Include a carpal tunnel release
- Release lacertus fibrosus and fascia
- Protect median nerve, brachial artery and tendons after release



Forearm Fasciotomy

- Protect median nerve, brachial artery and tendons after release
- Consider dorsal release



Wound Management

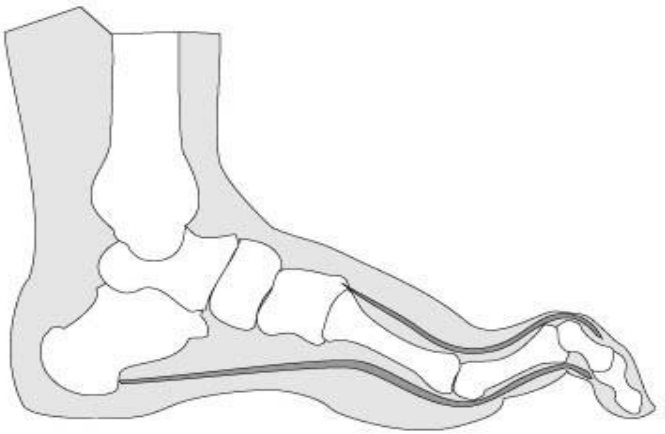
- After the fasciotomy, a bulky compression dressing and a splint are applied.
- “VAC” (Vacuum Assisted Closure) can be used
- Foot should be placed in neutral to prevent equinus contracture.
- Incision for the fasciotomy usually can be closed after three to five days

Wound Management

- Wound is not closed at initial surgery
- Second look debridement with consideration for coverage after 48-72 hrs
  - Limb should not be at risk for further swelling
  - Pt should be adequately stabilized
  - *Usually requires skin graft*
  - DPC possible if residual swelling is minimal
  - Flap coverage needed if nerves, vessels, or bone exposed
- Goal is to obtain definitive coverage within 7-10 days

Complications related to CS

- Late Sequelae
  - Volckmann’s contracture
  - Weak dorsiflexors
  - Claw toes
  - Sensory loss
  - Chronic pain
  - Amputation



Volkmann's ischemic contracture is the end stage of neglected ACS with irreversible muscle necrosis leading to ischemic contractures

Complications of Fasciotomy

Muscle Weakness

Chronic venous insufficiency

Tethered scars

Impaired sensation

Ulceration

Costs

Consequences of Compartment Syndrome

Ischemic myonecrosis Ischemic contracture

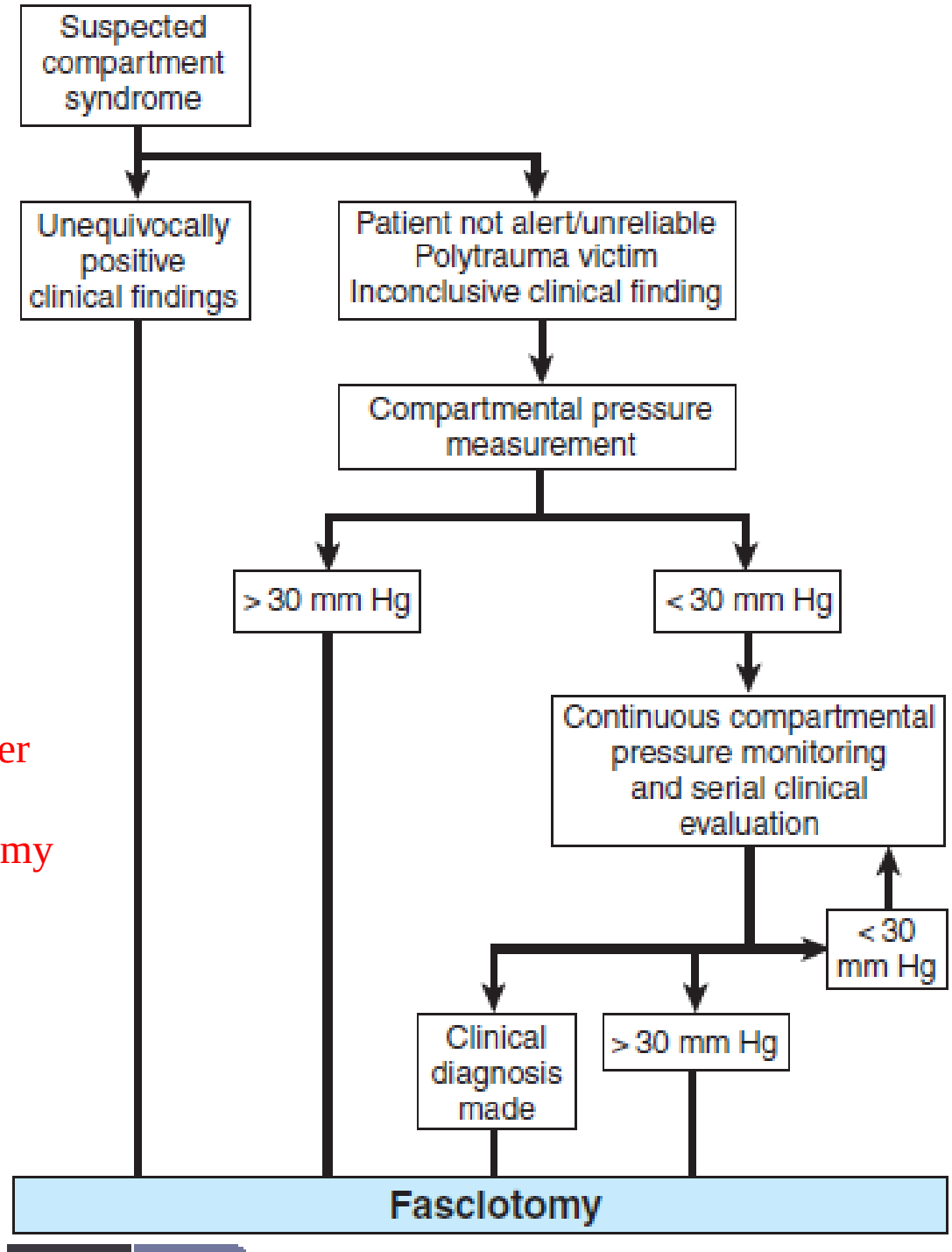
Ischemic neuropathy

Crush Syndrome Rhabdomyolysis

Renal Failure

Delay in dx/rx is the cause of a poor outcome

if compartmental pressures are greater than 30 mm Hg in the presence of clinical findings, immediate fasciotomy is indicated.



Take home message

- Keep a high index of suspicion
- Treat as soon as you suspect CS
- If clinically evident, do not measure
- Fasciotomy
  - Reliable, safe, and effective
  - The only treatment for compartment syndrome,

    when performed in time