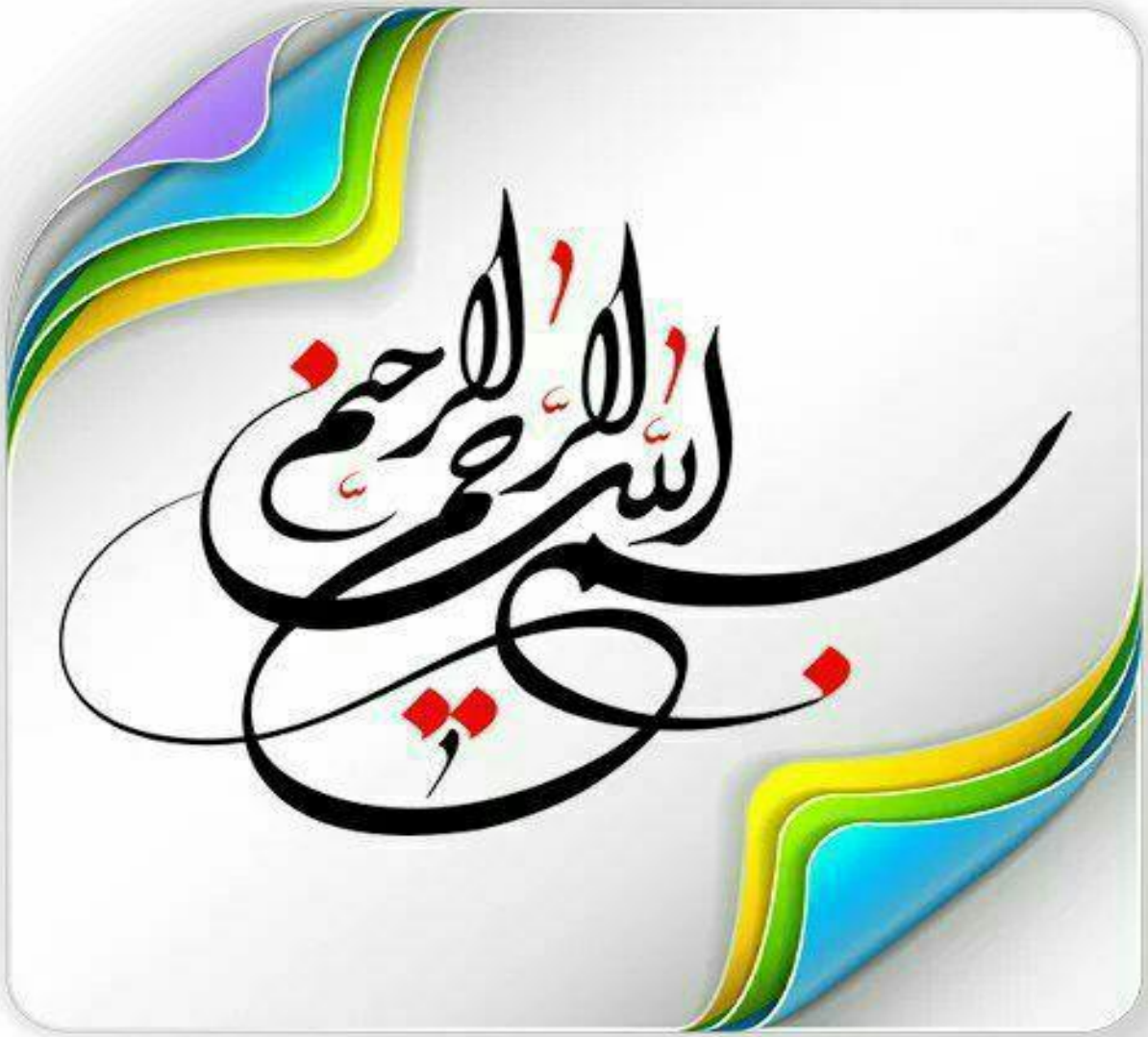

بسم الله الرحمن الرحيم

Damage Control Orthopedics (DCO)

- The concept of damage control orthopedics (DCO) provided a solution to the management of these borderline patients together with patients in an unstable or extremis condition.

- The damage control concept consists of three separate components:
- (a) Resuscitative surgery for rapid hemorrhage control
- (b) Restoration of normal physiologic parameters
- (c) Definitive surgical management

- Within the DCO, the first stage involves early temporary stabilization of unstable fractures and the control of hemorrhage.
- The second stage consists of resuscitation of the patients in the ICU and optimization of their condition.

- Finally, the third stage involves delayed definitive fracture management when the patient's condition allows.
- The favorite tool of the trauma surgeon to achieve temporary stabilization of the fractured pelvis or a long bone is the external fixator.

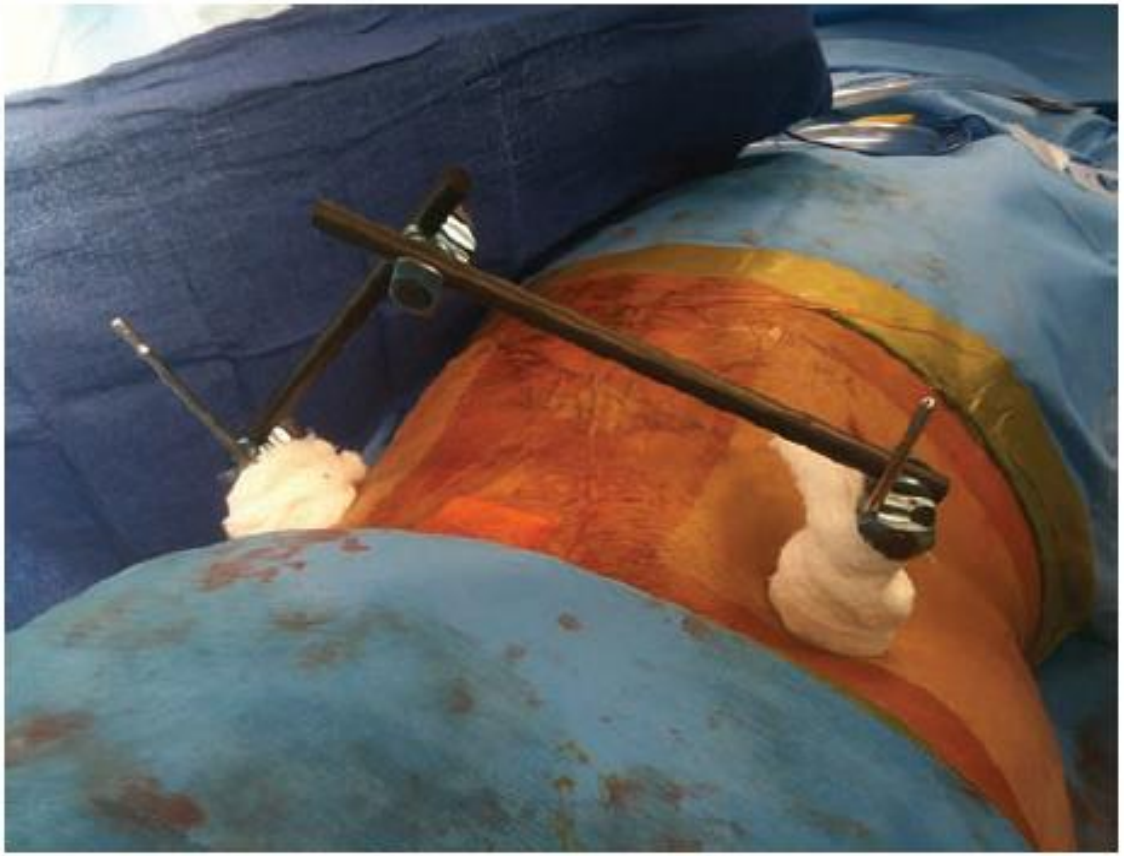


FIGURE 46-38 Patient with pelvic ring fracture where the anterior injury was stabilized with a two-pin anterior supra-acetabular fixator.

D

- External fixation is a quick and minimally invasive method of providing stabilization .

- The delayed definitive procedure to stabilize long bone fractures, in particular the femur, is usually intramedullary nailing which is carried out when the condition of the patient allows.

E

- In a retrospective analysis it was found that a secondary procedure lasting more than 3 hours was associated with the development of MODS.
- Also the patients who developed complications had their surgery performed between days 2 and 4, whereas patients who did not go on to develop MODS were operated on between days 6 and 8.

- According to these reports conversion of the external fixator to a nail should be done within the first 2 weeks as this minimizes the risk of developing deep sepsis.

TABLE 9-7 Indications for Early Total Care

Stable hemodynamics

No need for vasoactive/inotropic stimulation

No hypoxemia, no hypercapnia

Lactate <2 mmol/L

Normal coagulation

Normothermia

Urinary output >1 mL/kg/h

TABLE 9-8 Indications for "Damage Control" Surgery

1. Physiologic criteria
   - Blunt trauma: hypothermia, coagulopathy, shock/blood loss, soft tissue injury = Four vicious cycles
   - Penetrating trauma: hypothermia, coagulopathy, acidosis = "Lethal Triad"
2. Complex pattern of severe injuries—expecting major blood loss and a prolonged reconstructive procedure in a physiologically unstable patient

Standard of Care for the Treatment of Skeletal Injuries

- The recommended sequence of treatment is:
  - tibia,
  - femur,
  - pelvis,
  - spine,
  - and
  - upper extremity.

Management of Unilateral Fracture Patterns

- In these cases it is recommended that careful immobilization of diaphyseal fractures is the first phase of fracture management.

- If there are periarticular fractures of the large joints and urgent open reduction and fixation is impossible, transarticular external fixation (TEF) should be performed.

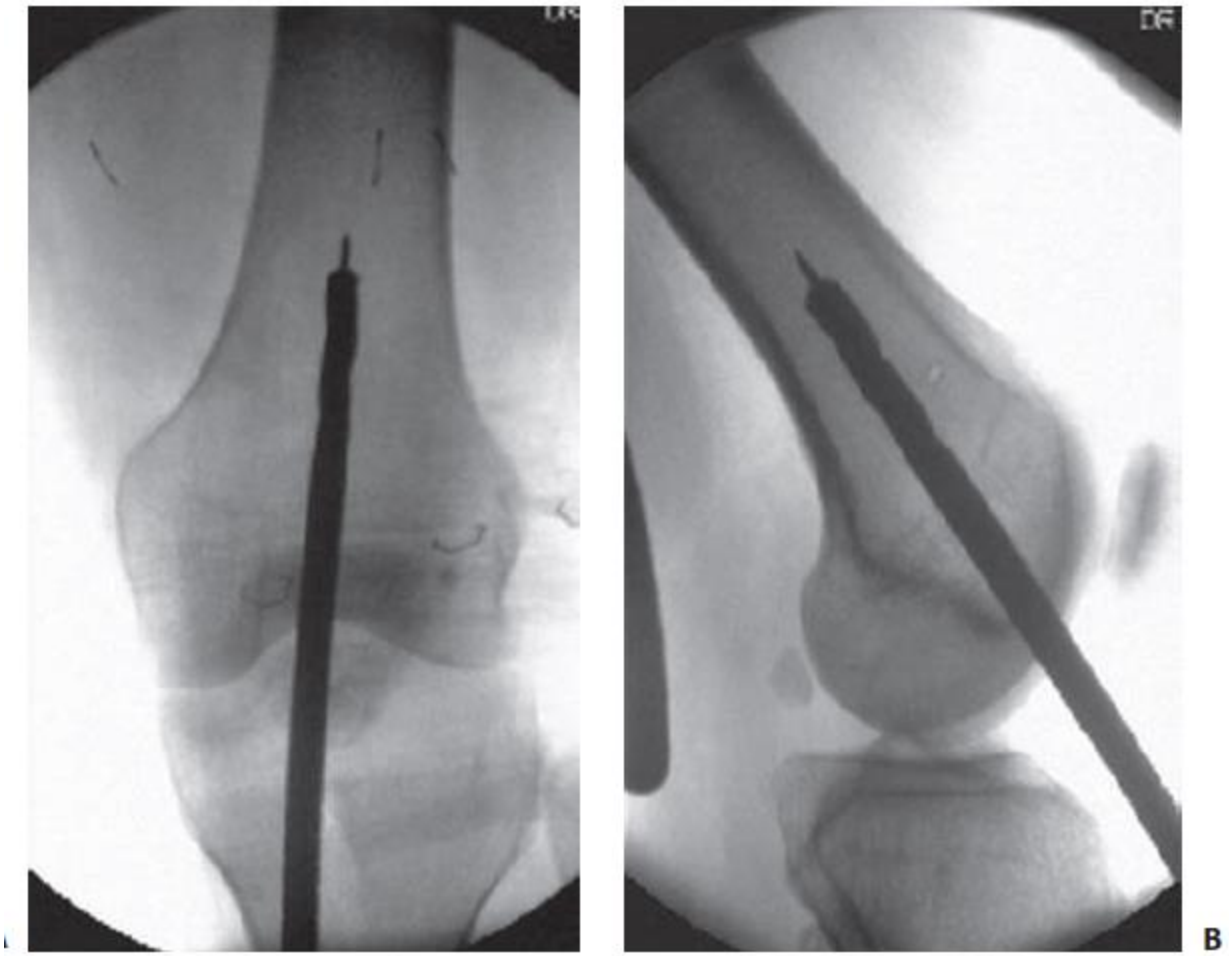
- In any case with a concomitant vascular injury or any evidence of a developing compartment syndrome, fasciotomies should be undertaken.

B

- In multifocal injuries of the lower extremity such as ipsilateral distal femoral and proximal tibial fractures, known as a floating knee:

- If the floating knee occurs in a stable patient, a retrograde femoral nail can be inserted through a small incision at the knee joint which is flexed at 30 degrees.

- An antegrade tibial nail can then be inserted through the same incision.


B

- The same fracture pattern in an unstable patient is best treated using a transarticular external fixator to span both fractures.

- In metaphyseal and periarticular fractures, the priorities of treatment are often dictated by the state of the soft tissues.

- A high priority is given to femoral head and talar fractures.

- Other periarticular fractures have a lower priority **unless** complicated by factors such as vascular dysfunction, compartment syndrome, or an open wound.

- Apparently minor fractures to the hand, fingers, tarsus, and toes should not be overlooked.

Management of Bilateral Fracture Patterns

- In bilateral fractures, simultaneous treatment is ideal.
- This is particularly true in bilateral tibial fractures where both legs are surgically cleaned and draped at the same time.

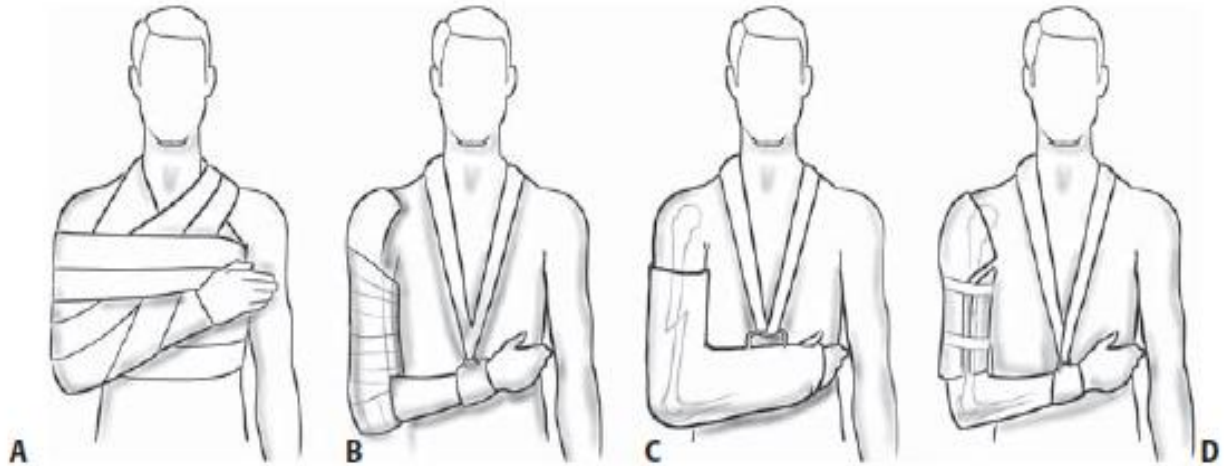
- However, the operative procedure is performed sequentially because of the problems inherent in the use of fluoroscopy.

- If the vital signs of the patient deteriorate during the operation the second leg may be temporarily stabilized using an external fixator.

Upper Extremity Injuries

- The management of upper extremity fractures in multiply injured patients is usually undertaken secondary to the treatment of injuries of the head, trunk, or lower extremity.

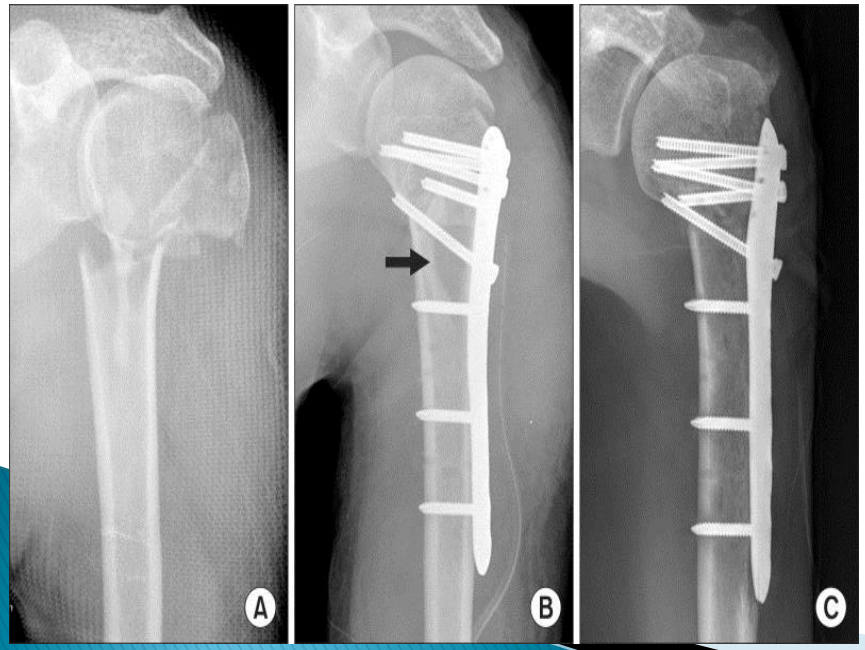
- If there is a **closed fracture** of the upper extremity without any associated injury, such as vascular or nerve damage or compartment syndrome, proximal fractures of the shoulder girdle, proximal humerus, and humeral shaft can be stabilized by a shoulder body bandage

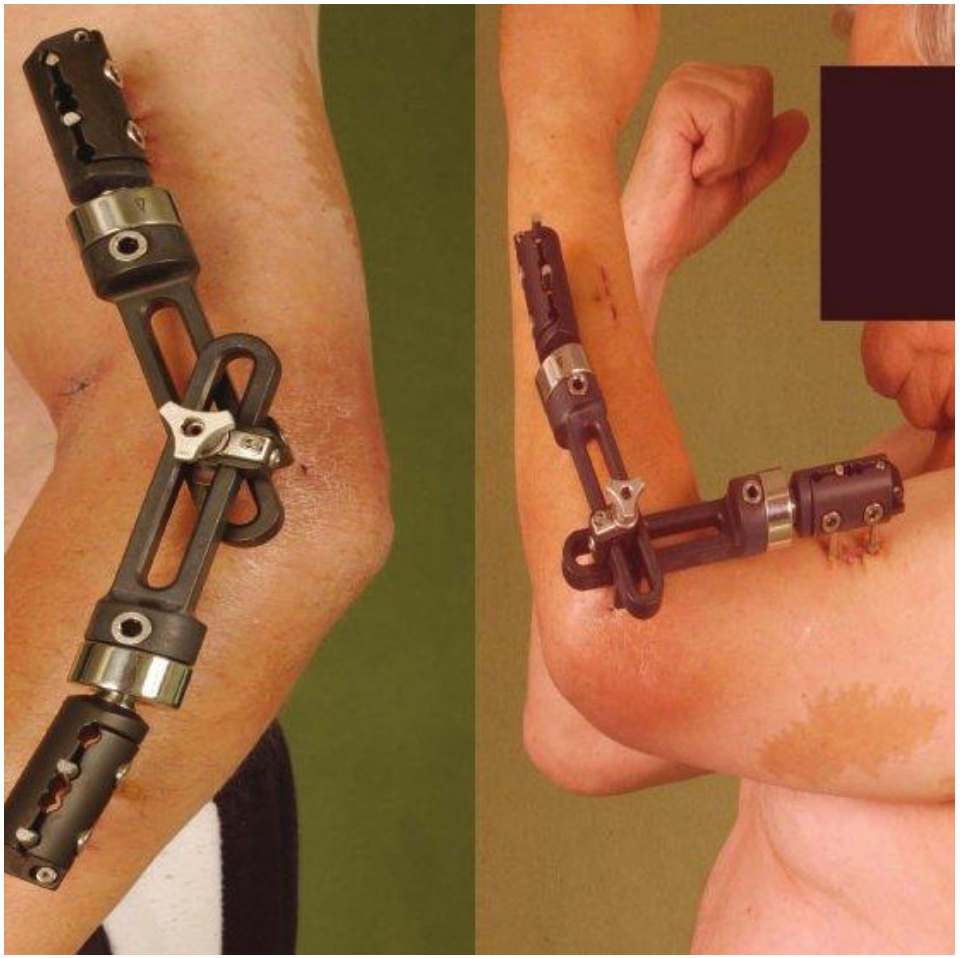

A
B
C
D

- Definitive osteosynthesis performe during the secondary management phase.

- External fixation is an alternative for the temporary stabilization of humeral diaphyseal fractures and TEF may be used to stabilize fractures about the elbow if definitive stabilization has to be delayed.

C





Unstable Pelvic Injuries

- In AO classification, type A injuries include stable fractures such as
  - fractures of the pelvic rim,
  - avulsion fractures and
  - undisplaced anterior pelvic ring fractures.

- The posterior rim is not injured at all.

- Type B injuries comprise fractures with only partially intact posterior structures and rotational dislocations may be possible.

- However these injuries are associated with a high risk of intra-abdominal damage.

- If the injury results in an open book type of fracture with both alae being externally rotated urogenital lesions and hemorrhagic complications are much more common.


R

- In C type injuries, the pelvis shows translational instability of the dorsal pelvic ring, because the stabilizing structures are all divided (Fig. 9-8).
- L5 transverse process fractures, called the “sentinel sign” for a VS injury, typically represent an avulsion fracture by the iliolumbar ligaments.

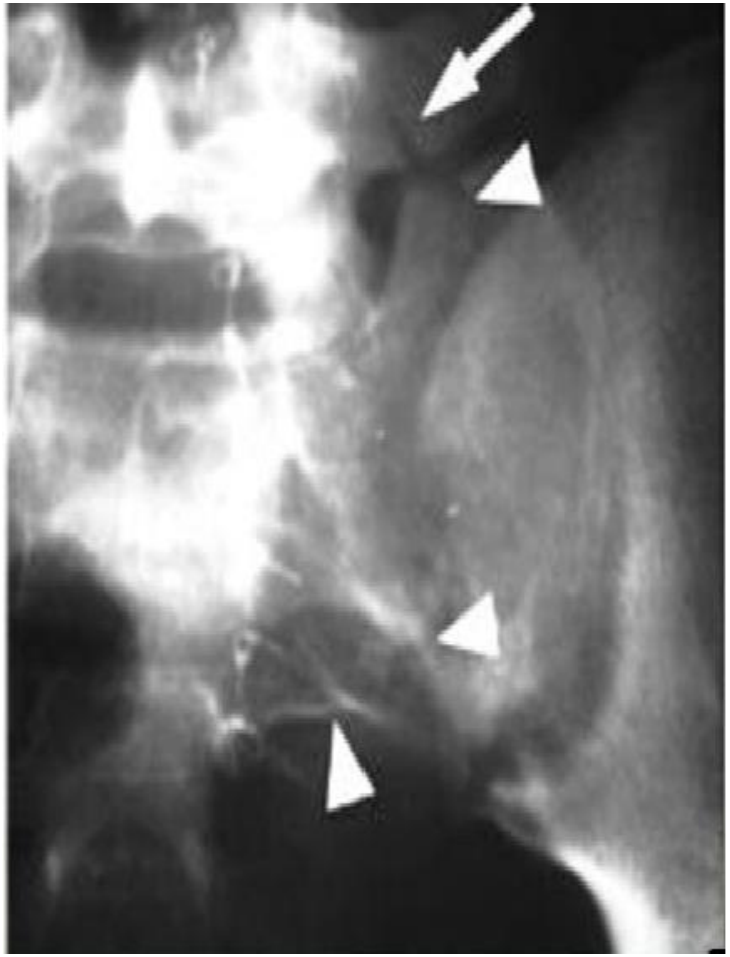
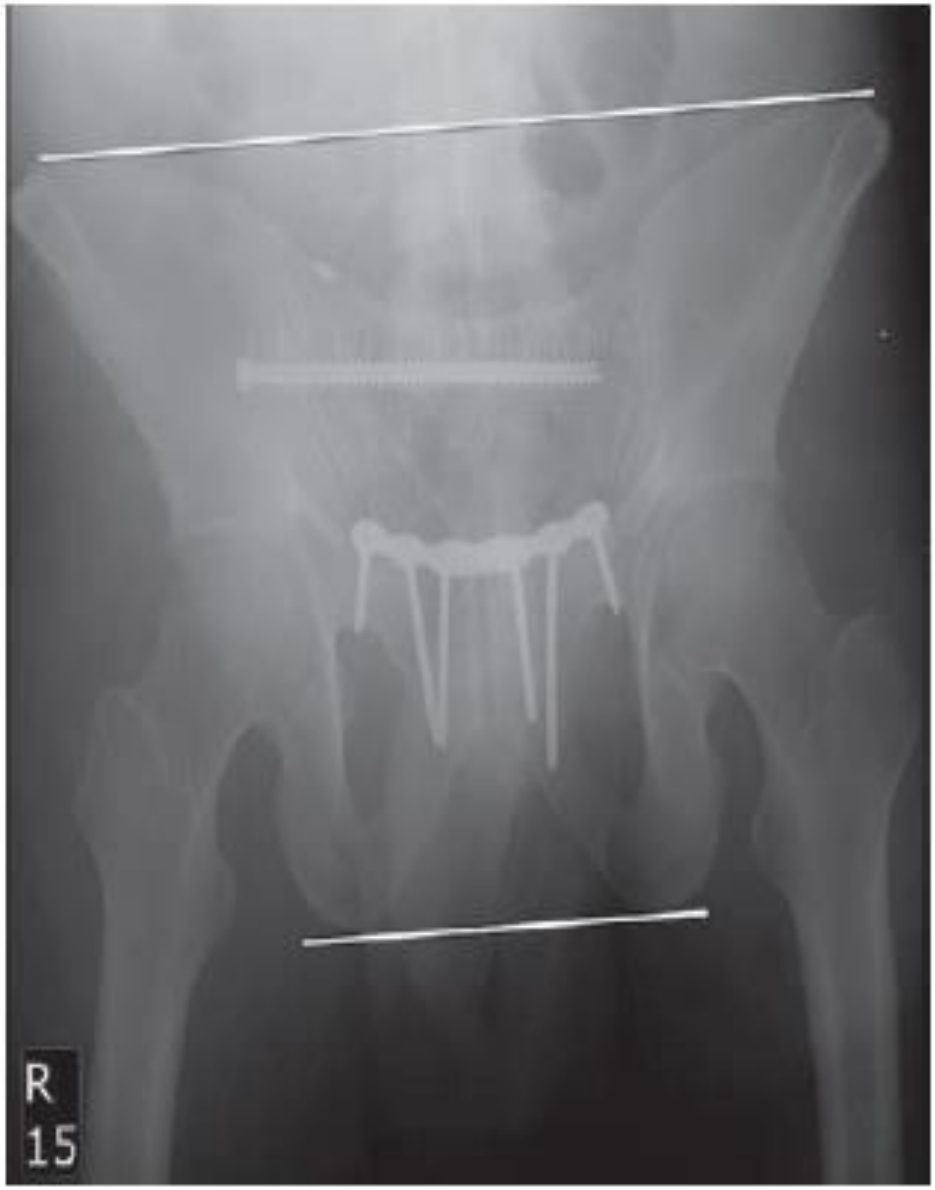


FIGURE 9-8 Type C pelvic fracture. Three-dimensional computed tomography scan.

- In type A injuries operative treatment is generally not required .
- type B injuries adequate stabilization is obtained by osteosynthesis of the anterior pelvic ring only.
- Type C injuries require anterior and posterior osteosynthesis to gain adequate stability.



c

- Generally , we recommend that fractures of the pelvic ring be stabilized as soon as possible to avoid ongoing blood loss.

Complex Pelvic Injuries

- Pelvic injuries associated with any other injury to local pelvic organs.

- These injuries comprise about 10% of pelvic injuries and they are associated with a significantly higher mortality of between 30% and 60% in comparison with simple pelvic injuries.

- The therapeutic goal is based on a combined strategy of :

- intensive shock treatment,
- early stabilization of the pelvic ring,
- and potential operative hemorrhage control and packing

- During the first laparotomy **intraperitoneal** ruptures of the bladder are repaired.

- In injuries of the urethra, it is recommended that the urethra be splinted with a transurethral catheter in the acute phase and that a definitive reconstructive procedure be undertaken during the secondary period to reduce the incidence of late strictures.

FIGURE 46-4 Incorrect placement of a suprapubic catheter that is too low and in the field of a Pfannenstiel incision.

- In **open pelvic fractures** with injuries to the rectum or anus a temporary colostomy of the transverse colon in first 6–8 hr.
- At the end of the procedure, an extensive antegrade wash-out of the distal colon is assumed to reduce the microbial load.

Hip Dislocation

- The first study available is usually the anteroposterior (AP) pelvis radiograph.
- This is usually taken as part of the initial trauma workup and helps the direct treatment.
- The diagnosis of hip dislocation should be apparent on this single radiographic view (Fig. 48-5).

FIGURE 48-5 The trauma AP pelvis radiograph demonstrates a patient with a posterior dislocation of the right hip. Note the superior location of the femoral head and the internally rotated proximal femur.

Assessment of Fracture Severity

- **Closed Fractures.**

- Fractures in polytrauma patients managed either with the ETC or the DCO approach must be stabilized before being admitted to the ICU.

- **Open Fractures.**
- It involves :

- careful assessment of the damage to the soft tissues,
- radical debridement,
- extensive irrigation,
- and stable fracture fixation.

- Open fractures resulting from **low-energy** trauma are usually associated with less soft tissue damage and may almost be treated like closed injuries.

- Open fractures resulting from **high-energy** trauma often have extensive soft tissue damage combined with significant bone destruction.
- This injury requires a sequential program of management.

- The treatment plan consists of an

- adequate debridement,
- initial temporary stabilization
- followed by definitive secondary stabilization and
- wound closure.

- **Open Intra-articular** Fractures.
- A two-step strategy :
- Initially, the injury is debrided and the joint surface is reconstructed using a minimal invasive osteosynthesis technique.
- The joint is then immobilized by bridging, or transarticular, external fixation.
- The definitive osteosynthesis is carried out secondarily following soft tissue healing.

FIGURE 10-16 Large skin flaps, especially over the joints, may be viable and can be retained with great benefit. Here, an open injury of the lower end of the femur has a large flap **(A, B)** which satisfied the requirements for primary closure which was done after suitable internal fixation **(C, D)**. Primary healing of both the skin **(E)** and bone were achieved.

TABLE 10-6 Gustilo and Anderson's Classification[84,85]

Type	Wound	Level of Contamination	Soft Tissue Injury	Bone Injury
I	<1 cm long	Clean	Minimal	Simple, minimal comminution
II	>1 cm long	Moderate	Moderate; some muscle damage	Moderate comminution
III A	Usually >10 cm	High	Severe with crushing	Usually communited; soft tissue coverage of bone possible
III B	Usually >10 cm	High	Very severe loss of cover	Bone cover poor; usually requires soft tissue reconstructive surgery
III C	Usually >10 cm	High	Very severe loss of cover and vascular injury requiring repair	Bone cover poor; usually requires soft tissue reconstructive surgery

Salvage or Amputation?

TABLE 10-9 Mangled Extremity Severity Score (MESS)[104]

Type	Definition	Points
A	**Skeletal/soft tissue injury**	
	• Low energy (stab;simple fracture; "civilian" GSW)	1
	• Medium energy (open or multiple fractures; dislocation)	2
	• High energy (close-range shotgun or "military" GSW; crush injury)	3
	• Very high energy (above and gross contamination; soft tissue avulsion)	4
B	**Limb ischemia** (*Score doubled for ischemia >6 hours)	
	• Pulse reduced or absent but perfusion normal	1*
	• Pulseless; paraesthesia; diminished capillary refill	2*
	• Cool; paralysed; insensate; numb.	3*
C	**Shock**	
	• Systolic BP always >90 mm Hg	0
	• Hypotensive transiently	1
	• Persistent hypotension	2
D	**Age (years)**	
	• <30	0
	• 30–50	1
	• >50	2

- A score of >7 has been reported to predict amputation accurately in both retrospective and prospective studies.

Treatment Options
Debridement and Lavage

- Debridement should be done as soon as possible after injury and the traditional teaching was that it preferably be completed within 6 hours.
- A soft brush may be used.
- It is preferable to apply a tourniquet.

Lavage

- Typically more than 9 L of fluid is required in Type IIIb injuries.

- 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

- At present, lowpressure lavage with normal saline is preferred.
- Debridement must be done in a systematic fashion with proper attention to the thorough removal of devitalized tissues.
-

- In situations where there is a good soft tissue envelope as in upper limb and femoral fractures or in situations where soft tissue cover could be achieved within 48 to 72 hours primary **internal fixation** can be considered.

- As a general rule, plate fixation is preferable for all open upper limb injuries and periarticular injuries with or without articular surface involvement.

- Lower limb diaphyseal fractures are usually treated by IM nailing either as a primary or secondary procedure.

Acute Compartment Syndrome

- *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.

Epidemiology

- The underlying condition causing acute compartment syndrome was most commonly a fracture (69% of cases) (Table 29-1).

- The most common fracture associated with acute compartment syndrome in adults is tibial diaphyseal fracture.

TABLE 29-1 **Conditions Associated with Injury Causing Acute Compartment Syndrome Presenting to an Orthopaedic Trauma Unit**

Underlying Condition	% of Cases
Tibial diaphyseal fracture	36
Soft tissue injury	23.2
Distal radius fracture	9.8
Crush syndrome	7.9
Diaphyseal fracture forearm	7.9
Femoral diaphyseal fracture	3.0
Tibial plateau fracture	3.0
Hand fracture(s)	2.5
Tibial pilon fractures	2.5
Foot fracture(s)	1.8
Ankle fracture	0.6
Elbow fracture dislocation	0.6
Pelvic fracture	0.6
Humeral diaphyseal fracture	0.6

TABLE 29-2 Causes of Acute Compartment Syndrome

Conditions Increasing the Volume of Compartment Contents

Fracture
Soft tissue injury
Crush syndrome (including use of the lithotomy position)[84]
Revascularization
Exercise[94]
Bleeding diathesis/anticoagulants[66,125]
Fluid infusion (including arthroscopy)[10,133]
Arterial puncture[134]
Ruptured ganglia/cysts[31]
Osteotomy[45]
Snake bite[153]
Nephrotic syndrome[147]
Leukemic infiltration[152]
Viral myositis[78]
Acute hematogenous osteomyelitis[145]

Conditions Reducing Compartment Volume

Burns
Repair of muscle hernia[4]

Medical Comorbidity

Diabetes[21]
Hypothyroidism[67]

TABLE 29-3 Risk Factors for Development or Late Diagnosis of Acute Compartment Syndrome

Demographic	Altered Pain Perception
Youth	Altered conscious level
Tibial fracture	Regional anesthesia
High-energy forearm fracture	Patient-controlled analgesia
High-energy femoral diaphyseal fracture	Children
Bleeding diathesis/anticoagulants	Associated nerve injury
Polytrauma with high base deficit, lactate levels, and transfusion requirement	

- The second most common cause of acute compartment syndrome is soft tissue injury, which when added to tibial diaphyseal fracture makes up almost two-thirds of the cases.

- From adolescence younger patients are at more risk of compartment Syndrom.

- Males were almost six times more likely to develop acute compartment syndrome if aged between 20 and 29 years compared with those aged over 40 years.
-

- Youth, regardless of gender, is therefore a significant risk factor for the development of acute compartment syndrome after tibial fracture

- High-energy injury is generally believed to increase the risks of developing an acute compartment syndrome

Diagnosis of Acute Compartment Syndrome

- **Clinical Diagnosis**

- Pain is considered to be the first symptom of acute compartment syndrome.
- Pain may, however, be an unreliable indication of the presence of acute compartment syndrome because it can be variable in its intensity.

- Pain may be absent in acute compartment syndrome associated with nerve injury or minimal in the deep posterior compartment syndrome.

- Children may not be able to express the severity of their pain, so:
  - restlessness,
  - agitation, and
  - anxiety
  - with increasing analgesic requirements should raise the suspicion of the presence of an acute compartment .

- Clinical diagnosis of acute compartment syndrome in the foot is so unreliable that other methods should be used.

- Pain with passive stretch of the muscles involved is recognized as a symptom of acute compartment syndrome.

- Thus pain is increased, for example, in an anterior compartment syndrome when the toes or foot are plantarflexed.
- This symptom is **no** more reliable than rest pain

- **Paresthesia** and **hypoesthesia** may occur in the territory of the nerves traversing the affected compartment and are usually the first signs of nerve ischemia, although sensory abnormality may be the result of concomitant nerve injury.

- **Paralysis** of muscle groups affected by the acute compartment syndrome is recognized as being a late sign.
- If a motor deficit develops, full recovery is unusual.
- full recovery in only 13% of patients with paralysis as a sign of their acute compartment syndrome.

- **Palpable swelling** in the compartment affected may be a further sign of compartment syndrome, although the degree of swelling is difficult to assess accurately, making this sign very subjective.

- Casts or dressings often obscure compartments at risk and prevent assessment of swelling.

- **Peripheral pulses** and capillary return are always intact in acute compartment syndrome unless :
  - there is major arterial injury or disease or
  - in the very late stages of acute compartment syndrome when amputation is inevitable.
- If acute compartment syndrome is suspected and pulses are absent, then arteriography is indicated.

Compartment Pressure Monitoring

- difference between the diastolic pressure and the tissue pressure (ΔP).
- It is important to measure the peak pressure within the limb, which usually occurs within 5 cm of the level of the fracture.
- Recommended catheter placement for each of the anatomic areas is summarized in Table 29–4.

TABLE 29-4 Recommended Catheter Placements for Compartmental Pressure Monitoring

Anatomic Area	Catheter Placement
Thigh	Anterior compartment
Leg	Anterior compartment Deep posterior if clinically suspected
Foot	Interosseous compartments Consider calcaneal compartment in hindfoot injuries
Forearm	Flexor compartment
Hand	Interosseous compartment

Threshold for Decompression in Acute Compartment Syndrome

- One level believed to be critical was **30 mm Hg** of ICP because this is a value close to capillary blood pressure.
- Some authors felt that **40 mm Hg** of tissue pressure should be the threshold for decompression, although some recognized a significant variation between individuals in their tolerance of raised ICP.
- In a series of patients with tibial fractures, a tissue pressure of **50 mm Hg** was recommended as a pressure threshold for decompression in normotensive patients.

- The authors concluded that a ΔP of 30 mm Hg is a safe threshold for decompression in acute compartment syndrome.

- The threshold may differ for children who have a low diastolic pressure and are therefore more likely to have a ΔP less than 30 mm Hg.
- Mars and Hadley recommend the use of the mean arterial pressure rather than the diastolic pressure to obviate this problem.

Timing

- If the ICP is rising, the ΔP is dropping and less than 30 mm Hg, and this trend has been consistent for a period of 2 hours, then fasciotomy should be performed.

- Fasciotomy should not be performed based on a single pressure reading except in extreme cases.

Treatment

- The most effective treatment for acute compartment syndrome is fasciotomy, which if delayed can cause devastating complications.

Fasciotomy

- Skin incisions must be made along the **full length** of the affected compartment.
- There is no place for limited or subcutaneous fasciotomy in acute compartment syndrome.
- It is essential to visualize all contained muscles in their entirety (Fig. 29-11) to assess their viability and any muscle necrosis must be thoroughly debrided to avoid infection.

Author's Preferred Method of Management

- Early diagnosis of acute compartment syndrome is essential, and it is important to be aware of the patients at risk of developing acute compartment syndrome.
- Good clinical examination techniques in the alert patient will help to identify the compartments at risk.
- Compartment monitoring should be used in all "at risk" patients as defined in Table 29-3.

- In practice this means that all tibial fractures should be monitored, but if resources to do so are limited, then younger patients should be selected for monitoring.

- The anterior compartment should be monitored, but in rare cases where symptoms are present that cannot be explained by the tissue pressures in the anterior compartment, the posterior compartment should also be monitored.

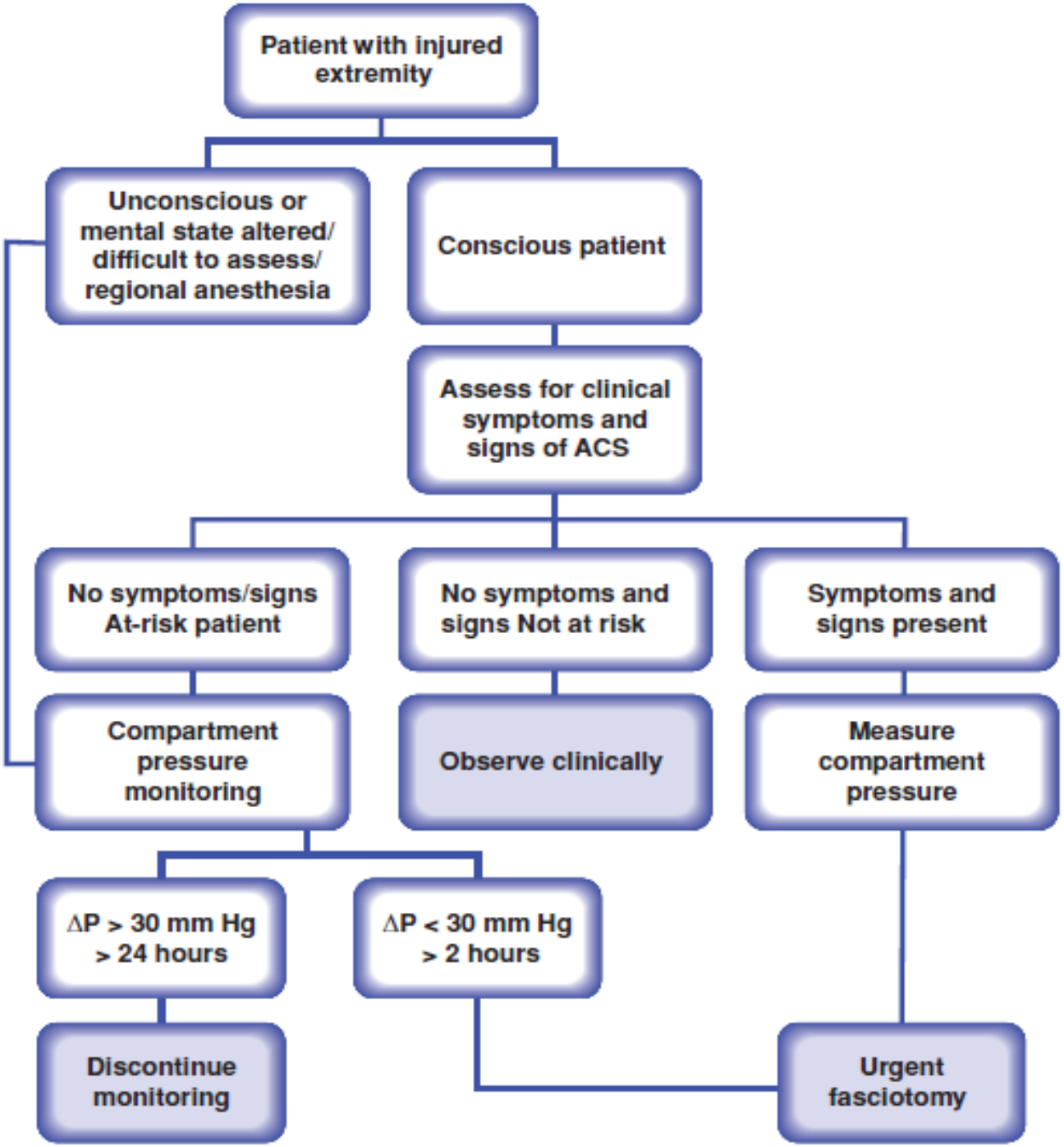
- Fasciotomy is performed on the basis of a persistent differential pressure of less than 30 mm Hg (Fig. 29–15).

- If the ΔP is less than 30 mm Hg but the tissue pressure is dropping, as can happen for instance for a short time after tibial nailing, then the pressure may be observed for a short period in anticipation of the ΔP rising.

- On the other hand, if the ΔP remains less than 30 mm Hg or is reducing, then immediate fasciotomy is indicated.

- I prefer four-compartment fasciotomy in the leg because it is simpler and gives an excellent view of all compartments.
- If any muscle necrosis is present this should be thoroughly debrided.
- At this stage if a fracture is present, it should be stabilized if this has not been done previously

- A “re-look” procedure should be performed at 48 hours after fasciotomy with further debridement if necessary.
- If the wound is healthy closure should be undertaken at this stage with either direct closure or split skin grafting.
- I do not use gradual closure techniques because of the risk of wound edge necrosis and prolonged times to coverage..


Patient with injured extremity
Unconscious or mental state altered/ difficult to assess/ regional anesthesia
Conscious patient
Assess for clinical symptoms and signs of ACS
No symptoms/signs At-risk patient
No symptoms and signs Not at risk
Symptoms and signs present
Compartment pressure monitoring
Observe clinically
Measure compartment pressure
ΔP > 30 mm Hg > 24 hours
ΔP < 30 mm Hg > 2 hours
Discontinue monitoring
Urgent fasciotomy