DNB
Master Solutions in Orthopedics
Volume - 2



Conceptual Orthopedics

The Learning Never Ends

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Paper 1

DNB Orthopedics (Dec 2022)

Question 1

Fat Embolism Syndrome:

a. Describe the pathophysiology

b. Clinical features and diagnosis

c. Management of fat embolism in a case of closed fracture shaft femur

Answer 1a.

Introduction

- Fat embolism syndrome follows long bone fractures.
- Its classic presentation consists of an asymptomatic interval followed by pulmonary and neurologic manifestations combined withpetechial hemorrhages.
- The syndrome follows a biphasic clinical course.
- The initial symptoms are probably caused by mechanical occlusion of multiple blood vessels with fatglobules that are too large to pass through the capillaries.
- Unlike other embolic events, the vascular occlusion in fat embolism is often temporary or incomplete since fat globules donot completely obstruct capillary blood flow because of their fluidity and deformability.

The late presentation is thought to be a result of hydrolysis of the fat to more irritating free fatty acids which then migrate to other organs via the systemic circulation

Etiopathophysiology

- It is most common after skeletal injury, and is most likely to occur in patients with multiple long bone and pelvic fractures.
- Patients with fractures involving the middle and proximal parts of the femoral shaft are more likely to experience fat embolism.
- Age also seems to be a factor in the development of FES: young men with fractures
- are at increased risk.
- Fat embolism and FES are also more likely to occur after closed, rather than open, fractures.
- Two events promote entrance of marrow contents into the circulation following a fracture: movement of unstable bone fragments and reaming of the medullary cavity during placement of an internal fixation device.
- Both of these cause distortion of and increased pressure within the medullary cavity, permitting entry of marrow fat into torn venous channels that remain open even in shock because they are attached to the surrounding bone.
- Multiple fractures release a greater amount of fat into the marrow vessels than do single fractures, increasing the likelihood of FES.

There are two theories which have gained acceptance:

The mechanical theory

- FES results from physical obstruction of the pulmonary and systemic vasculature with embolized fat.
- Increased intramedullary pressure after injury forces marrow into injured venous sinusoids, from which the fat travels to the lung and occludes pulmonary capillaries.
- Fat emboli can cause cor pulmonale if adequate compensatory pulmonary vasodilation does not occur.

The biochemical theory

- Circulating free fatty acids are directly toxic to pneumocytes and capillary endothelium

  in the lung, causing interstitial hemorrhage, edema and chemical pneumonitis.
- It is also possible that coexisting shock, hypovolemia and sepsis, all of which reduce liver flow, facilitate the development of FES by exacerbating the toxic effects of free fatty acids.

Answer 1b.

Clinical Presentation

- An asymptomatic latent period of about 12-48 hours precedes the clinical manifestations.
- The fulminant form presents as acute cor pulmonale, respiratory failure, and/or
- embolic phenomena leading to death within a few hours of injury.
- Clinical fat embolism syndrome presents with tachycardia, tachypnoea, elevated temperature, hypoxemia, hypocapnia, thrombocytopenia, and occasionally mild neurological symptoms.
- A petechial rash that appears on the upper anterior portion of the body, including the chest, neck, upper arm, axilla, shoulder, oral mucous membranes and conjunctivae is considered to be a pathognomonic sign of FES, however, it appears late and often disappears within hours.
- CNS signs, including a change in level of consciousness, are not uncommon.
- They are usually nonspecific and have the features of diffuse encephalopathy: acute confusion, stupor, coma, rigidity, or convulsions.
- Cerebral edema contributes to the neurologic deterioration.
- Hypoxemia is present in nearly all patients with FES, often to a Pa02 of well below 60 mmHg.
- Acute cor pulmonale is manifested by respiratory distress, hypoxemia, hypotension and elevated central venous pressure.

Laboratory Studies

- Arterial blood gas:
  - An increase in pulmonary shunt fraction alveolar-to-arterial oxygen tension difference, within 24-48 hours of a sentinel event associated with fat embolism syndrome, is strongly suggestive of the syndrome.
- Hematocrit, platelet count, fibrinogen:
  - Thrombocytopenia, anemia, and hypofibrinogenemia are indicative of fat embolism syndrome; however, they are nonspecific.
- Urine studies:
  - Fat globules in the urine are common.

Imaging Studies

- Chest radiography: Serial radiographs reveal increasing diffuse bilateral pulmonary infiltrates within 24-48 hours of onset of clinical findings Showing snow storm appearance
- Noncontract head CT: Normal or may reveal diffuse white-matter petechial hemorrhages consistent with microvascular injury.
- Nuclear medicine ventilation/perfusion imaging of the lungs: Performed for suspicion of pulmonary embolus, the findings from this scan may be normal or may demonstrate subsegmental perfusion defects.
- Helical chest CT for pulmonary embolism: may be normal initially or Nodular or ground glass opacities in the setting of trauma suggest fat embolism.
- MRI: Multiple, nonconfluent, hyperintense lesions were seen on proton-density– and T2-weighted images.
- Transcranial Doppler sonography: Cerebral microembolic signals can be detected as long as 4 days after injury.

Gurd's Criteria for Diagnosis of FES

Discussion:

Dx of FES requires at least one sign from major criteria and at least four signs from the minor criteria category;

Gurd's Major Criteria:

1. Axillary or subconjuctival petechia occurs transiently (4-6 hours) in 50-60 % of the cases;
2. Hypoxemia (PaO sub 2, <60 mmHg; FiO sub 2, <= 0.4)

1. Central nervous system (CNS) depression disproportionate to hypoxemia,
2. Pulmonary edema

Gurd's Minor Criteria:

1. Tachycardia (more than 110 beats per minute)
2. Pyrexia (temperature higher than 38.5 degrees)
3. Emboli present in retina on funduscopic examination
4. Fat present in urine
5. Sudden unexplainable drop in haematocrit or
6. Thrombocytopenia
7. Increasing sedimentation rate
8. Fat globules present in sputum

Answer 1c.

Treatment

The most effective prophylactic measure is to reduce long bone fractures as soon as possible after the injury.

- Maintenance of intravascular volume is important because shock can exacerbate the lung injury caused by FES.
- Albumin has been recommended for volume resuscitation in addition to balanced electrolyte solution, because it not only restores blood volume but also binds fatty acids, and may decrease the extent of lung injury.
- Mechanical ventilation and PEEP may be required to maintain arterial oxygenation.
- High dose corticosteroids have been effective in preventing development of FES in several trials, but controversy on this issue still persists.

Surgical Care

Early stabilization of long bone fractures is recommended to minimize bone marrow embolization into the venous system. Rigid fixation within 24 hours has been shown to reduce the incidence of ARDS fivefold.

- Surgical technique, particularly of reaming or nailing the marrow, may help reduce the volume of fat embolization.
- Prophylactic placement of inferior vena cava filters may help reduce the volume of fat reaching the heart.

Prognosis:

- The duration of FES is difficult to predict because FES is often subclinical oroversshadowed by other illnesses or injuries.
  - Increased alveolar-to-arterial oxygen gradient and neurologic deficits, including coma, may last days or weeks.
  - Hematologic aberrations due to FES frequently are indistinguishable from other causes common in these patients.
- As in adult respiratory distress syndrome (ARDS), pulmonary sequelae usually resolve almost completely within 1 year.
  - Residual subclinical diffusion capacity deficits may exist.
  - Residual neurologic deficits may range from nonexistent to subtle personality changes to memory and cognitive dysfunction to long-term focal deficits.
- Fat embolism syndrome alone has not yet been reported to cause global anoxic injury, but it may contribute with other cerebral insults.

Question 2.

Peripheral nerve injury:

a. Describe the anatomy of peripheral nerve

b. Classification of diagnosis of peripheral nerve injuries

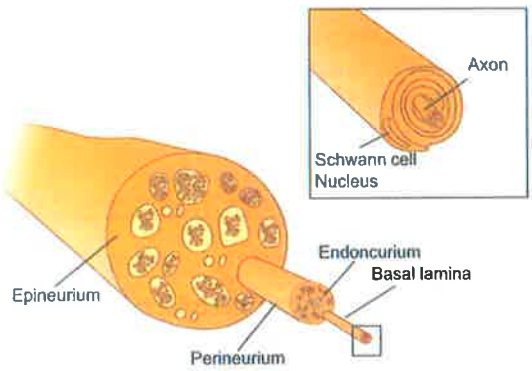
c. Algorithm the management of radial nerve palsy

Answer 2a.

Structure of the Peripheral Nerve

- Motor component
  - Nerve supply to the face and limbs originates from cell bodies located within the cranial nerve motor nuclei and anterior horn of spinal cord gray matter
  - Cell body gives rise to an axonal process, and groups of axons from each spinal level exit the cord as the ventral motor root
  - Each individual axon of a peripheral motor nerve terminates at the muscle endplate regionà supplies large group of muscle fibers.

  - Motor axon and the muscle fibers it supplies → motor unit, an important structural unit in EMG studies and in understanding recovery from nerve injury.
- Sensory component
  - Reside in dorsal root ganglia outside the spinal cord, carrying afferent impulses
  - Two processes extends from the cell body
    - One proximallyàsecond order neurons to brain
    - One distally à forming the axons of the peripheral sensory nerves
- Sensory and motor axons are associated with supporting glial cells, the Schwann cells
  - Unmyelinated axonsà wrapped in groups by Schwann cell cytoplasm.
  - Myelinated axonsà Schwann cell membrane tightly around the axon à myelin.



- Each peripheral nerve is made up of a bundle of fasciclesàmultiple fascicles covered by epineurium the outermost part of the nerve
- Each fascicle is surrounded by a connective tissue layeràperineurium
- In the fascicle àmyelinated and unmyelinated axons, connective tissue, small capillaries, and extracellular fluid compose àendoneurium.

Answer 2b.

Classification of peripheral nerve injuries

Seddon	Sunderland	Pathology
Neurapraxia	1	Focal demyelination; block of nerve conduction without axonal degeneration
Axonotmesis	2	Axonal degeneration with intact endoneurium
Axonotmesis	3	Axonal degeneration; endoneurial disruption with intact perinerurium
Axonotmesis	4	Axonal degeneration; endoneurial and perineurial disruption with intact epineurium
Neurotmesis	5	Complete axonal degeneration; disruption of all connective tissue elements

- Seddon (1943) clasisifciation → 3 types
  - Neurapraxiaàconduction block, intact axon
  - Axonotmesisà Loss of axonal continuity without associated disruption of the fascicular connective tissue
  - Neurotmesis à disruption of the entire nerve, including connective tissue supports
- Sunderland(1951)→ 5 grades
  - Grade 1 → neurapraxia
  - Grade 2 → axon disruption
  - Grade 3 → axon+ endoneurium disruption
  - Grade 4 → axon+ endoneurium + perineurium disruption
  - Grade 5 → axon+ endoneurium + perineurium + epineurium disruption

Diagnostic Investigations Electrophysiologic techniques

- Includes nerve response amplitude and conduction velocity along the course of each nerve
  - Nerve conduction velocity (NCV) → to assess the speed of transmission of an electrical impulse across the nerve
  - Nerve response amplitude
    - Sensory nerve → SNAP(sensory nerve action potential)
    - Motor nerve → CMAP(compound motor action potential)

Timing of electrodiagnostic studies Following Acute Nerve Injury

- Done to differentiate the loss of function that occurs from axonal loss (axonotmesis or Wallerian degeneration) from those which results from demyelination (neurapraxia)

- Immediately after injury
- 10-21days
  - Best time to do NCS is around 14days
- 2–6 weeks
  - Best time to do EMG
  - Spontaneous electrical activity in muscle fibers develops
  - And continues until the muscle is reinnervated or degenerates completely.
  - Demyelinating disease → muscle still has supply from intact axon →No spontaneous electrical activity is seen EMG.
- 3–6 months
  - Upon voluntary contraction, the amplitude, duration, rate of firing, and recruitment pattern of MUPs to be noted
  - In intact neuro muscular unit à orderly and graded recruitment of motor units, with futher contraction
  - In nerve injury → The number of motor units available to generate contractile force is reducedà There is no change in the configuration of MUPs
- 6–12 months
  - These are follow ups study to document the extent of regeneration and the progress.

Answer 2c.

Treatment / Management

Conservative treatment

options depend on the severity of the injury and the patient's symptoms.

They include:

- Analgesic medications, including oral or topical NSAIDs
- Corticosteroid injections and steroids can help decrease any inflammation contributing to the Process.
- Maintaining full ROM.
- Preventing contractures particularly of 1st web space.
  - Dynamic cock-up splint (external splint) is used for this purpose



The majority (up to 92%) resolve with observation alone for 3 to 4 months in the setting of injuries or fractures to the humerus.

Wait for return of nerve function as according to Steindler's formula for nerve regeneration

- (1mm = 1Day)
- 30 days for motor recovery to manifest (N-M junction) and nerve ends to sprout
- e.g., nerve injury is 90-120 mm above lateral condyle. brachioradialis arises 20 mm above lateral condyle it will take 70-100 days + 30 days = 4-5 months.

The return of function /recovery following radial nerve palsy follows a predictable clinical pattern. Brachioradialis followed by ECRL are the first to return; whereas EPL and EIP are last to return.

Indication of early exploration

- Radial nerve injury secondary to manipulation of fracture (absolute indication)
- Open fractures
- Fractures in which satisfactory alignment is not possible by closed methods
- Fractures with associated vascular injury
- Patients with multiple trauma.

What is a tendon transfer?

The tendon of a functioning muscle is detached from its insertion and reattached to another tendon or bone to replace the function of a paralyzed muscle or injured tendon. The transferred tendon remains attached to its parent muscle with an intact neurovascular pedicle.

Timing of tendon transfer

- Neuro-muscular junctions in the muscle degenerate if not reinnervated in about a year's time, so it is prudent to do tendon transfer after year as the likelihood of regaining function is meager

- Reinnervation can be expected after 1-3 months, functional reinnervation up to 1 years, no reinnervation >3 yrs.

Tendon Transfers for Radial Nerve Injury

ORIGINAL JONES transfer (1921)

1. PT -->ECRL and ECRB;
2. FCU -->EDC III-IV;
3. FCR -->EPL; EDC II, EIP

FCU Transfer (Standard Transfer) (MODIFIED JONES)

1. PT -->ECRB
2. FCU -->EDC
3. PL -->rerouted EPL (EPL is taken out of dorsal retinaculum (in the region of snuff box and junction is made between PL and EPL). This gives a combination of abduction and extension force on thumb)

II. FCR transfer (of Starr; Brand; Tsuge)

1. PT -->ECRB
2. FCR -->EDC II-V
3. PL -->rerouted APL

III. Boyes Transfer (Superficialis transfer)

1. PT -->ECRB
2. FCR -->APL and EPB
3. FDS III -->EDC II-V via interosseous membrane 4. FDS IV EIP; EPL via interosseous membrane problems with standard transfer (FCU transfer)/ MODIFIED JONES

Excessive radial deviation which is due to:

1. Removal of the only preserved ulnar deviator (FCU)
2. PT ECRB transfer. ECRB is a radial deviator
3. In PIN palsy ECRL may be spared that leads to excessive radial deviation.

Prevention

Alter the insertion of tendon by centralizing the ECRL (attach to IV metacarpal) or alternately one may attach the proximal resected end of ECU to (PT ECRB) transfer which is not preferred as it limits total excursion.

Option in patients with absent PL

- Boyes transfer.
- Substitute FDS III and IV for PL (Tsuge and Goldner)
- brachioradialis (possible only in PIN palsy)
- FCU transfer to both thumb and finger extension

Internal splint (PT -->ECRB transfer /Burkhalter PROCEDURE) Eliminates need of splintage.

1. To act as a substitute during regrowth of the nerve, avoiding use of external splints
2. To act as a helper as reinnervation proceed

To intervene when the results of the nerve repair are considered poor or the nerve is irreparable.

Question 3.

a. Describe evaluation of femoral anteversion

b. What are the clinical and radiological methods to measure the femoral anteversion

c. Discuss the role of femoral anteversion in orthopedics

Answer 3a.

Femoral neck anteversion (FNA), also called femoral torsion or femoral version, is defined by the angle of the femoral neck in relation to the femoral shaft in the coronal plane. It is calculated as the angle made by the femoral neck line with that of the posterior condylar axis of the distal femur.

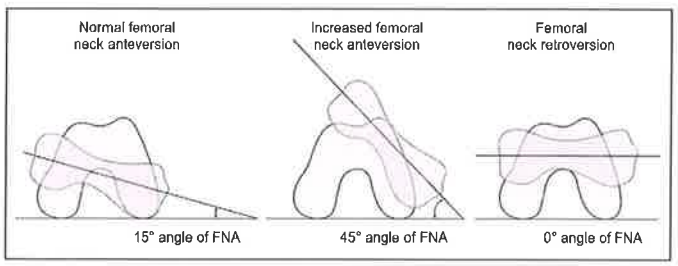
- At birth the anteversion is high and as the child starts weight bearing the angle gradually becomes that of the adult size. Childhood= 40°, decreases as growth occurs, Adults = 15°
- If it does not reduce with age then a compensatory in toeing happens in an attempt place the femoral head well within the acetabulum.

Prognosis/ Natural history:

- Most children with excessive anteversion gradually improve on 'in toeing' gait.
- In some, external tibial torsion decreasing in toeing gait
- Children (3-12 months age)
  - Average- 39-40° anteversion
- Anteversion reduces 1-2° per year till 10 years
  - At 10 years average anteversion (24°)
- By age of 16 years, it becomes 15-16°
- Matovinovic-Anteversion in normal children

decreased by 1degree per year where as it
- Decreased 1.6° per year in affected children.

- People with reduced muscle tone (spastic palsy) often have excessive anteversion due
  - To tight adductors obese children have reduced anteversion.



Answer 3b.

Measurement:

1. "C" arm: Examine the femoral neck under "C" arm and rotate the hip until the neck is Seen as the longest (true AP view of neck was obtained). Now the angle subtended by limb to the table is the femoral anteversion.
2. Clinical: Craig's Test Patient in prone position

↓

Rotate hip internally

↓

Until the max prominence of Greater Tuberosity is noted by palpation

↓

The angle of tibia to the table represents anteversion.

3. CT Scan:

Single axial slices using CT can be used to define the neck axis However, the height and angle of slices used for the 3D reconstruction affect the final result, as the femoral neck has an asymmetrical shape . Alternatively, two axial slices can be taken to define the femoral neck axis, one at the femoral head and the other at different heights of the distal femoral neck

4. Ultrasound:
   - It uses anterior tangent of femoral head and GT as reference line.
   - The transducer is tilted till the tangent is horizontal on monitor
   - This represents the anteversion angle
5. MRI :-

MRI scans can be directly aligned to anatomical features such as the femoral neck, thereby allowing the depiction of the whole region. This is particularly useful at high femoral neck inclination angles, where positioning bias is greatest . The distal femoral axis can be evaluated with one single axial slice with reference to one of the axes described earlier

Answer 3c.

Greater FNA is also associated with a number of orthopaedic pathologies IN TOEING GAIT

Altered movement associated with differences in FNA also appears to have consequences for musculoskeletal health. The shorter hip extension moment arm and longer moment arm for hip flexion shown with increased FNA are consistent with the gait pattern in individuals with cerebral palsy, and the shorter abductor and adductor lever arms are likely to produce pelvic instability during gait (Laplaza and Root, 1994; Scheys et al., 2008). The increased internal rotation moment arm length, combined with a decreased external rotation moment arm length, is likely to be part of the cause of in-toeing gait in children with cerebral palsy

- Evaluation for intoeing
  - Femoral anteversion
    - Hip motion (tested in the prone position)
      - Increased internal rotation of >70° (normal is 20-60°)
      - Decreased external rotation of < 20° (normal 30-60°)
    - Anteversion estimated on degree of hip IR when greater trochanter is most prominent laterally
    - Trochanteric prominence angle test
  - Patella internally rotated on gait evaluation
  - Tibial torsion
    - Look at thigh-foot angle in prone position
    - Normal value in infants- mean 5° internal (range, −30° to +20°)
    - Normal value at age 8 years- mean 10° external (range, −5° to +30°)
  - Metatarsus adductus

- Adducted forefoot deformity, lateral border should be straight
- A medial soft-tissue crease indicates a more rigid deformity
- Evaluate for hindfoot and subtalar motion

2) increased risk of anterior cruciate ligament injury

Related to altered knee kinematics during landing , lower hip abductor and vastus medialis activity, impaired tracking of the patella and femoral trochlear dysplasia

Greater hip load and the altered relationship with the acetabulum--resulting from increased FNA may play a role in the genesis of osteoarthritis This suggestion is reinforced by a prevalence of unilateral osteoarthritis in limbs with higher FNA

3) Chondromalacia: patellae internal rotation can lead to change in "Q Angle"
4) Torsional malalignment syndrome:
   - Increased femoral anteversion
   - Tibial external torsion
   - Genu valgum
5. Patello femoral arthritis.

Treatment:

1. Careful education of parents
2. Observation

Indications for surgery

Staheli's five indications for surgical correction

A. Child older than 8 years
B. D eformity causing cosmetic/ functional deficit
C. Measured anteversion > 50°
D. Medial hip rotation > 85°, lateral hip rotation less than 10°
E. Family aware of risk of procedure.

Stevens/ Coworkers indications include

1. Tripping
2. Anterior knee pain
3. Patellar maltracking potentially causing labral tear Osteotomies:

Femoral osteotomies are done to correct anteversion levels of osteotomies

A. Intertrochanteric
B. Subtrochanteric
C. Supracondylar level

Osteotomies are fixed with blade plate/ DHS crossed pin fixation.

Question 4.

a. Describe the pathophysiology of Polytrauma Patient

b. Discuss the principle of damage control orthopedics Vs early total care

Answer 4a.

Poly trauma Definition

- At least 2 severe injuries of head, chest or abdomen, one of them in association with an extremity injury

Or

- A patient with two or more injuries, one of them being potentially life threatening Or
- 2 or more regions with ISS score > 15
- Polytrauma - largest killer in the world – younger age
- Trimodal peak of death
  - Immediate death
  - Early death
  - Late death

Pathophysiology

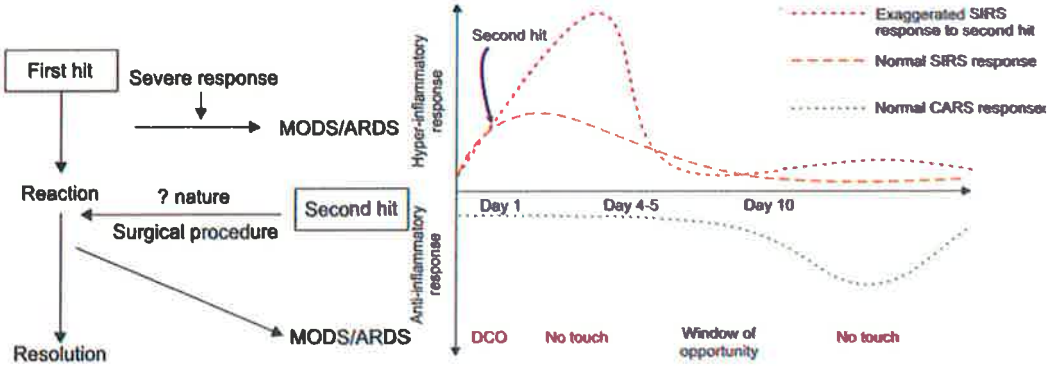
The Abbreviated Injury Severity (AIS) - 1971

- Has undergone multiple revisions; most recent: AIS-90
- Nine body regions
  - Head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, and external
- Increasing severity index score
  - 1 - minor; 2 - moderate; 3 - serious; 4 - severe; 5 - critical; 6 - unsurvivable
- Provides the basis for newer systems like ISS, NISS
- Used alone, cannot predict outcome

Injury Severity Score (ISS) - 1974

- Squaring the worst AIS score in each respective region
  - 6 regions: head/neck, face, chest, abdomen, extremities including pelvis, external
  - Sum of the three highest scores

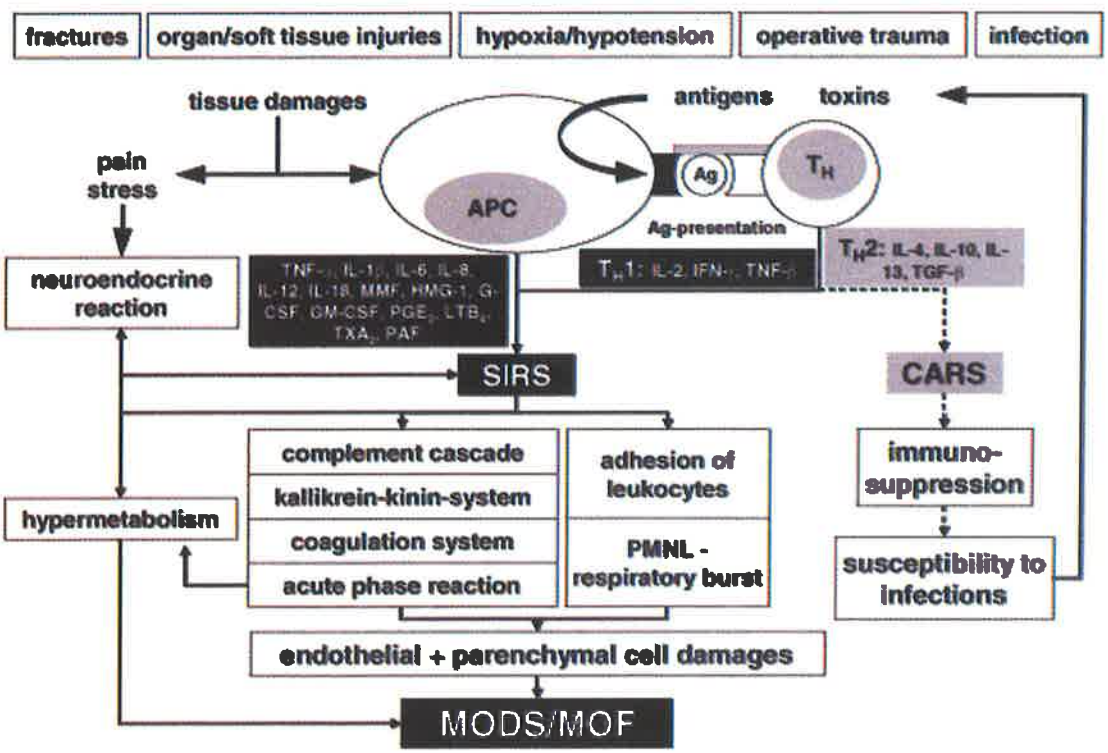
- Higher ISS scores → increased risk of mortality and longer hospital stays
- Most common method of measuring polytrauma severity
- Drawback: If the same region has multiple injuries, the score is diluted



- The injury → first hit to the systemic status

- Surgery to stabilize the fractures → second hit
- When the second hit exceeds a threshold level → SIRS → MOF → Death
- Therefore, polytrauma patients should be adequately resuscitated before second hit

The pathophysiology of the polytraumatized patient is a complex phenomenon aiming at the restoration of homeostasis and preservation of life. The initial response to major trauma is dominated by the effort to control the shock. During the subsequent phase of the immune system activation (Systemic Inflammatory Response Syndrome – SIRS – and Counter Anti- inflammatory Response Syndrome – CARS) the organism is trying to restore the physiologic equilibrium. Depending on the characteristics of the initial trauma (first hit) and the impact of actions and interventions that follow (second hit), patients may either recover or develop complications



Answer 4b.

Damage Control Orthopaedics (DCO)

- Definition/History
  - Definitive treatment delayed until physiology has improved
  - Popularized in 2000
  - Replaced the 1980s philosophy of Early Total Care (ETC), the concept of fixing long bone fractures as soon as possible because patients were "too sick not to operate"
    - ETC led to exacerbation of the "second-hit" in a subset of patients with hemodynamic instability, head, and/or chest injuries
- Involves staging definitive management to avoid adding trauma to patient during vulnerable period
  - The decision to operate and surgical timing on multiple injured trauma patients remains controversial
  - Intra-operative hypotension increases mortality rate in patients with head injury
- Parameters that help decide who should be treated with DCO ISS >40 (without thoracic trauma)
  - ISS >20 with thoracic trauma
  - GCS of 8 or below
  - Multiple injuries with severe pelvic/ abdominal trauma and hemorrhagic shock
  - Bilateral femoral fractures
  - Pulmonary contusion noted on radiographs
  - Hypothermia <35 degrees c
  - Head injury with AIS of 3 or greater
  - IL-6 values above 500pg/dL
- Optimal time of surgery
  - Patients are at increased risk of ARDS and multisystem failure during the acute inflammatory window (period from 2 to 5 days characterized by a surge in inflammatory markers)
  - Therefore only potentially life-threatening injuries should be treated in this period including
    - Unstable pelvic fracture
    - Compartment syndrome
    - Fractures with vascular injuries
    - Unreduced dislocations
    - Traumatic amputations
    - Unstable spine fractures
    - Cauda equina syndrome
    - Open fractures
- Stabilization followed by staged definitive management
  - To minimize trauma, initial stabilization should be performed and followed by staged definitive management
    - Includes initial pelvic volume reduction via sheet, pelvic packing, skeletal traction, binder, or external fixation
      - If hemodynamically stable
        - Proceed with further imaging including CT chest, abdomen, pelvis
      - If not hemodynamically stable
        - Consider exploratory laparotomy and/or pelvic angiography and embolization
  - Definitive treatment delayed for
    - 7-10 days for pelvic fractures
    - Within 3 weeks for femur fractures (conversion from exfix to IMN)
    - 7-10 days for tibia fractures (conversion from external fixation to IMN)

- EARLY APPROPRIATE CARE
  - Definition/history
    - Identifies major trauma patients and definitively treats the most time- critical orthopaedic injuries while minimizing the secondary inflammatory response, guided by laboratory parameters of adequate resuscitation
    - Popularized in 2013
  - Parameters
    - Lactate of < 4.0 mmol/L
    - pH ≥ 7.25
    - Base excess ≥ -5.5 mmol/L
  - Optimal time of surgery
    - Goal is to definitively treat spine, pelvis, femur, and acetabulum fractures within 36 hours of injury

- Outcomes
  - Decreased delay to surgery
  - Decreased complication rates
  - Increased hospital revenues
  - Main reason for delay to treatment with implementation of this protocol was surgeon decision.

Question 5.

Calcium Metabolism

Answer 5.

Location

- Bone (99%), it provides mechanical stability and serves as a reservoir sometimes needed to maintain extracellular fluid (ECF) calcium concentration. (0.5–1% of skeletal calcium is freely exchangeable (e.g., in chemical equilibrium) with that in the ECF).
  - Blood and extracellular fluid (0.1%)
  - Intracellular (1%)
- Function
  - Calcium has a wide range of function including
    - Muscle cell contraction
    - Nerve conduction
    - Clotting mechanisms
- Regulation

  Sites involved:-
  - Absorption from the digestive tract
  - Resorption from bone
  - Reabsorption in the kidneys

The concentration of ionized calcium in the ECF must be maintained within a narrow range because of the critical role it plays in a wide array of cellular functions, especially those involved in neuromuscular activity, secretion, and signal transduction

- Hormones invovlved :-

  PTH

  Vit D
- Control of the ionized calcium concentration in the ECF ordinarily is accomplished by adjusting the rates of calcium movement across intestinal and renal epithelia. These adjustments are mediated mainly via changes in blood levels of the hormones PTH and 1,25(OH)2D. Blood ionized calcium directly suppresses PTH secretion by activating parathyroid calcium-sensing receptors (CaSRs). Also, ionized calcium indirectly affects PTH secretion via effects on 1,25(OH)2D production. This active vitamin D metabolite inhibits PTH production by an incompletely understood mechanism of negative feedback.
- In blood, total calcium concentration is normally 2.2–2.6 mM (8.5–10.5 mg/dL), of which ~50% is ionized. The remainder is bound ionically to negatively charged proteins (predominantly albumin and immunoglobulins) or loosely complexed with phosphate, citrate, sulfate, or other anions.

Dietary Intake and Absorption

- Dietary requirements
  - 2000 mg/day for lactating women
  - 1500 mg/day for pregnant women, postmenopausal woman, and patients with a healing bone fracture
  - 1300 mg/day for adolescents and young adults
  - 750 mg/day for adults
  - 600 mg/day for children
- Intestinal absorption of ingested calcium involves both active (transcellular) and passive (paracellular) mechanisms
- Optimal rates of calcium absorption require gastric acid
- Some calcium, ~2.5–5.0 mmol/d (100–200 mg/d), is excreted as an obligate component of intestinal secretions and is not regulated by calciotropic hormones
- The feedback-controlled hormonal regulation of intestinal absorptive efficiency results in a relatively constant daily net calcium absorption of ~5–7.5 mmol/d (200–400 mg/d), despite large changes in daily dietary calcium intake.
- Dysfunction
  - Hypercalcemia
  - Hypocalcemia
- Dysfunction
  - Hypercalcemia
  - Hypocalcemia

Clinical Manifestations Of Rickets

- The clinical pictures caused by rickets vary considerably depending on the age of the child, the severity of the disease, and to some extent the underlying cause of the deficient state.
- In infants and young children, The child is listless, apathetic, and irritable, with fairly profound hypotonia and muscle weakness. Occasionally so severe that a child one or two years old is unable to walk, stand, or even sit without support lower body weight, shorter Ligamentous laxity Excessive sweating

Examination

- (Craniotabes), widening of the sutures, and persistence of the anterior and posterior fontanels.
- Prominence of the frontal bones (frontal bossing) is a common sign.

Caput quadratum or ' 'hot-cross-bun skull".

- Eruption of teeth may be considerably delayed.

Teeth are generally poorly mineralized

rachitic rosary :- The cartilaginous portions of costochondral junctions become enlarged and cupped, producing a row of firm, smooth, nodular masses on either side of the sternum

Harrison's groove, a frequent finding in severely affected children

Protuberant abdomen (rachitic pot belly). A thoracic kyphosis is common (rachitic catback)

- Bowing of the tibiae, femora, radii and ulnae is common. Rachitic saber shins and coxa vara
- Sausage-like enlargements of the ends of the phalanges and metacarpals, with regular constrictions corresponding to the joints (string-of-pearls deformity)
- Pathological fractures of the long bones
- Roentgenographic Features of Rickets
- Recommended views
  - AP and lateral of affected bone
- Findings
  - Physeal widening
  - Metaphyseal cupping
  - Decreased bone density
  - Looser's zones
    - Pseudofracture on the compression side of bone
  - Rachitic rosary
    - Prominence of rib heads at the osteochondral junction
  - Lower extremity bowing
    - Often genu varum
  - Codfish vertebrae
  - Cat back
    - Dorsal kyphosis
- Histology
  - Disordered and elongated zone of proliferation
  - Poorly defined zone of provisional calcification
  - Widened osteoid seams
  - "Swiss cheese" trabeculae
  - Abnormally arranged collagen fibers
    - Run perpendicular to haversian canals

Treatment

The most widely used treatment for vitamin D deficiency consists of vitamin D2 (ergocalciferol) or vitamin D3 (cholecalciferol). The dosing scheme recommended for treatment of vitamin D deficient rickets is 1000 IU daily for newborns <1 month, 1000–5000 IU daily for infants 1–12 months old, and 5000–10,000 IU daily for children 1 year and older. Treatment is continued until there is radiographic evidence of healing; subsequently, the dose of vitamin D is reduced to 400 IU daily. Calcium intake should be maintained at approximately 1000 mg/day (30–75 mg/ kg of elemental calcium per day in three divided doses) to avoid "hungry bone" syndrome (worsening hypocalcemia after the start of vitamin D therapy). This leads to resolution of the biochemical and radiological abnormalities within 3 months

Question 6.

a. Define Stress, Strain and Young's Modulus of Elasticity in relation to Orthopaedic implants.2+2+2

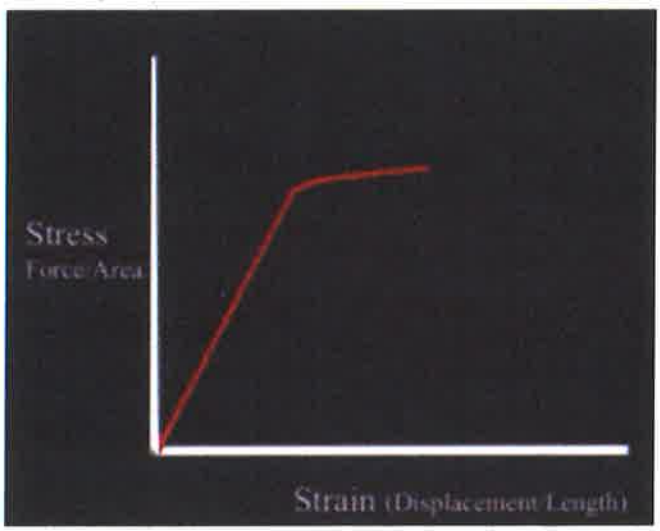
b. Discuss the recent advances in materials in Orthopaedic surgery. 4

Answer 6a.

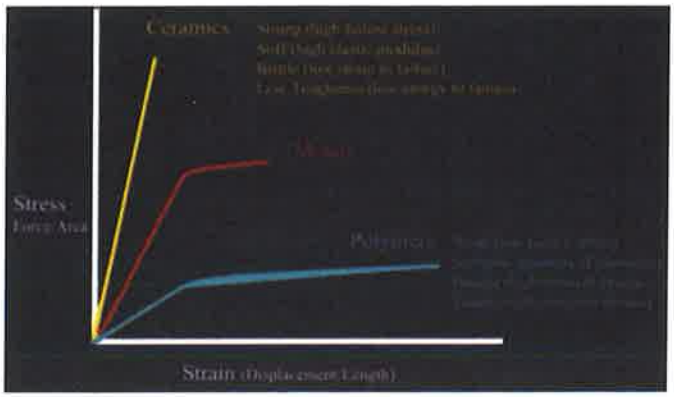
The ability of a thing to tolerate outside forces is referred

to as stress and strain. The internal structure of a material, like a metal plate, will alter when a force is applied to it in order to resist it. The applied force will be directly offset by these modifications. Stress is the internal force that resists the external force. Strain is the term used to describe the material's deformation brought on by outside forces.

Stress is measured in megapascals (MPa), which can be computed by dividing force by area. In real terms, this means that a material, like a metal plate, will elongate when a load, like a tensile force, is applied to it. The precise definition of strain is the relative measurement of a body's deformation brought on by loading. This explains, to put it simply, how an object responds to being loaded. A stress-strain curve is a graphic that shows how stress and strain can be calculated and graphed together to provide helpful information on the characteristics of materials. The following figure illustrates that strain is positioned on the x-axis and stress is on the y-axis.

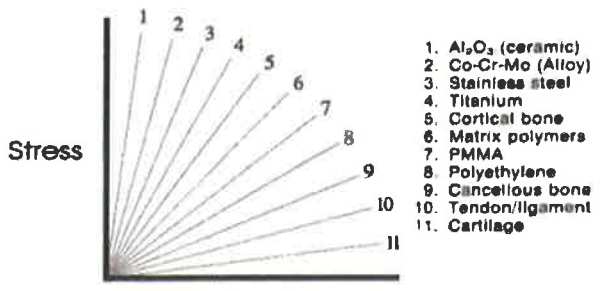


On a load/extension curve, this elongation first exhibits a linear connection to the applied load and can be represented as a straight line. This relationship must maintain its direct proportionality across the linear sections of the stress-strain curve, according to Hooke's law. This is significant because it makes it possible to determine the precise amount that a plate will bend under a given tension. From a practical standpoint, this enables designers to produce devices that can sustain loads adequately and facilitates material comparisons. But when the material reaches a certain strain, it starts to distort and loses its ability to take on its original form when the tension is lifted. As you can see below, this is known as the yield point.



Young's Modulus:

For a particular material, this value indicates the connection between stress and strain during the linear portion of the stress-strain curve. In essence, it characterizes a material's elasticity. It can be computed by dividing the stress by the strain, or, to put it another way, it can be seen as the slope of the line drawn through the curve's elastic sections on a stress-strain graph. Stainless steel and other stiff materials with high moduli are characterized by low moduli, which are found in soft materials like ultra-high molecular weight polyethylene, which is used to make joint replacement implants. A helpful comparison of materials used in orthopedics today is Young's modulus:



Relative Values of Youngs Modulus

Common values for Young's Modulus

Stainless Steel- 200

Titanium- 100

Cortical Bone- 7 to 21

Bone Cement- 2.5 to 3.5

Cancellous Bone- 0.7 to 4.9

UHMW-PE- 1.4 to 4.2

Answer 6b.

- These days, polymers, metal, and bioceramics are the materials that orthopedics uses most frequently. Recent findings indicate that biomedical nanotechnology is receiving particular attention.
- There has been more talk about the possible applications of ceramal nanoparticles, or nano-ceria, in orthopedics.
- After studying cerium oxide nanoparticles' impact and mechanism in mouse osteoblast precursors, it was shown that these particles enhanced matrix mineralization and elevated the expression of osteogenic genes.
- Because silver nanoparticles with antimicrobial activity are smaller than those that have toxic effects on bone-forming cells in vitro, there is a proposal to utilize them to combat infections in orthopedic implants.
- The antimicrobial properties of gold nanoparticles have been emphasized. These findings show how applying nanomedicine to improve the efficiency of materials can have a favorable effect.
- The appropriate mechanical properties and biocompatibility of magnesium alloys have led to increased study attention in recent times.
- Currently, magnesium-based metal alloys, which have good osseointegration properties, constitute the next generation of biodegradable metal materials.
- A study has been conducted to examine the intraoperative clinical sites of human bone fixed with magnesium screws and a note has been made of the homogenous deterioration and a good contact between the implant and the bone.
- To tackle load-bearing zone fractures, future research is focusing on the development of alloys with a low degradation rate and an improved mechanical strength.
- The creation of novel materials as well as techniques for surface modification are the main topics of current study.
- A new generation of orthopedic implants with superior implant integration and bone healing would result from the development of new methods and tactics for composite coatings that more closely resemble the structure of human bone.
- The field of orthopedics is quickly benefiting from the recent advancement and use of 3D printing technology, however the topic of orthopedic implants has not received enough attention. Due to their potential applications as gels for direct ink writing, solutions for stereolithography equipment, and filaments for fused deposition modeling, polymers are among the most frequently utilized materials in 3D-printed bone substitutes.
- In their evaluation of the viability, Feltz et al. used biocompatible materials to replicate surgical implant models using desktop 3D printers, reporting lower manufacturing costs; nonetheless, they were unable to attain mechanical qualities comparable to those of conventional stainless-steel implants. 3D printed materials can be used in orthopedics to make life-size anatomical models, implants, and prostheses.
- The materials used in orthopedics will keep changing to lower the cost of implants, preserve patient safety, improve surgical methods, and lower the risk of infection.

Question 7.

Discuss the biomechanics and clinical uses of floor rection orthosis (FRO)

Answer 7.

Introduction:

- Floor reaction orthosis is revolutionary orthosis: Custom fabricated, moulded plastic device that supports the ankle and foot area of the body and extends from below the knee down to and including the foot.
- It was described by Saltiel for the use of weak quadriceps or planter flexion in 1969
- It holds the ankle in equinus to prevent the heel from touching the ground. As the body weight brings the heel downwards, the supra patellar band will press the knee back preventing knee from buckling during stance phase. It allows the knee to flex during swing phase when the foot is off the ground allowing the patient to remove her or his hand from knee.

The ankle joint is kept in 5 to 7 degrees of plantar flexion in order to shift the line of floor reaction

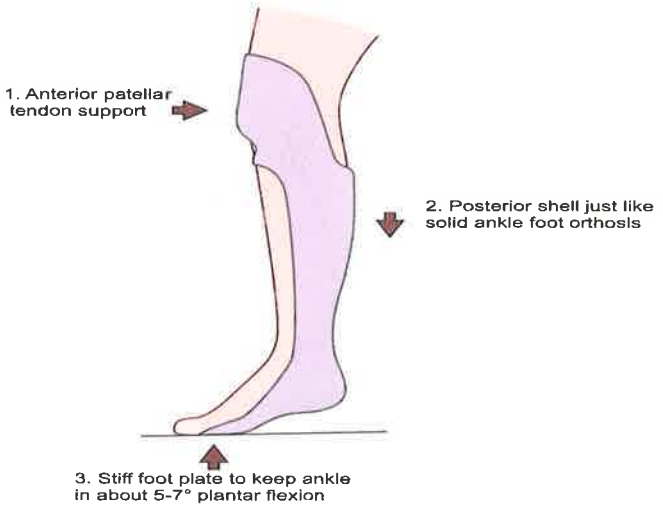
- There are two ways to fabricate the FRO:

1. FRO as a single solid unit (Figure A)
2. AFO with an additional anterior shell (Figure B)



Component of FRO

- FRO has a posterior shell like solid ankle foot orthosis.
- Toe plate is stiff and long with slight plantar flexion.
- Anterior shell comfortably capture the resultant extension moment and stabilize the knee



Principles of FRO

- Mechanical & Biomechanical:
- Newton's third law: for every action, there is an equal and opposite reaction.
- Body weight over the orthosis and over the ground.

GRF:

- The GRF has a point of application on the sole of the foot, magnitude, a line of direction, GRF force offered support surface, equaling and opposing force due to body mass passing through the foot to the ground surface; GRF is resolved into vertical (Counteraction body weight) and horizontal (leading to forward movement) components.
- GRF is provide stability during stance phase.

Force System:

- FRO design 3 point force system. The 3 point force system permits angular change or control over a joint.
  - The first force system is similar to control plantar flexion (Leaf Spring AFO)
  - Second force system is same as in case of solid AFO to control inversion and eversion.
  - Third force system controls dorsiflexion.
- Another set of Force system is working in this FRO:
  - A posteriorly directed force on the upper tibia or preferably on the patellar tendon.
  - A compression force in the plastic at the ankle joint form mid stance to toe-off
  - An upwardly directed force on the sole of the foot during and after mid stance.

Principles of FRO

- When feet absorb the reaction forces and keep the knee and ankle straight. Here the foot and orthosis absorb the forces and keep knee straight.
- FRO holds the ankle in slight equinus to prevent the heel from touching the ground
- When body brings the heel down, there is a turning point at which orthosis joint press the proximal leg back, making extension of knee
- Prevents knee from buckling during stance phase allows to flex in swing phase and permits ground clearance.

Indication of FRO

1) Lower limb weakness eg. Post polio paralysis
2) Neurological conditions
   a) For assist knee extension at mid stance and compensate for weak/ absent gastro soleus (places extension forces close to knee)
   b) Generally all the previous conditions with quadriceps having a fair muscle power.
3) In management of a crouch gait, which is characterized by excessive ankle dorsiflexion, increased knee flexion, and increased hip flexion in mid stance.

Clinical Uses:

1. Spina bifida

2. Cerebral palsy
3. Brain injury
4. Spinal cord injury

Contraindication:

- Fixed contracture of knee and ankle
- Can not be prescribed bilaterally
- Hip flexion contracture >30 degree

Advantages:

1. Lightweight
2. Easily trainable to patients
3. Cosmetically better
4. Prevents knee from buckling
5. Stabilizes knee foot and ankle

Disadvantages:

- Has to be custom made.

Question 8.

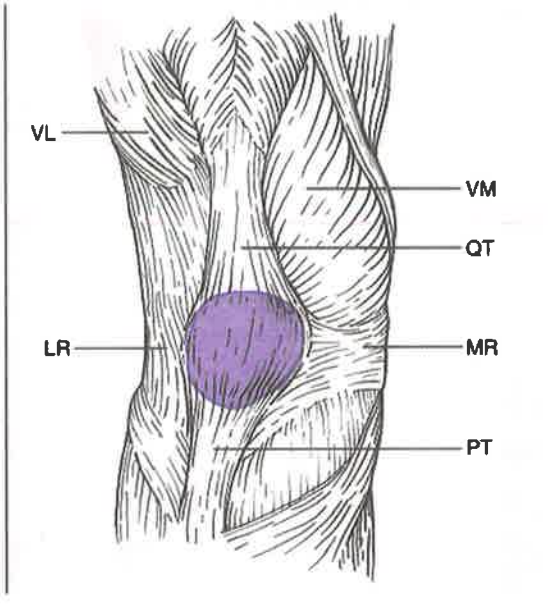
a. Describe the extensor mechanism of knee joint. 3

b. Describe biomechanics of patello femoral joint. 3

c. Describe the factors predisposing to patellar instability. 4

Answer 8a

- The patella is firmly invested in a strong facial structure formed by the coalition of the quadriceps tendon, fascia lata, and iliotibial band.
- These structures join to form the cascade and the strong expansions known as the medial and lateral retinaculi.
- The patella tendon originates at the apex of the patella and inserts onto the tibial tubercle.
- The quadriceps tendon with its associated soft tissues, the patella, and the patella tendon are collectively known as the extensor mechanism.
- The quadriceps muscle is composed of four major separate muscles:
  1. The rectus femoris
  2. Vastus medialis
  3. Vastus lateralis
  4. Vastus intermedius.
- The quadriceps tendon was classically described as a trilaminar structure with distinct insertions of each muscle onto the patella from superficial to deep.
- The rectus femoris is a long fusiform muscle whose fibers insert at a 7- to 10-degree angle medially in the frontal plane relative to the shaft of the femur.
- The vastus medialis consists of the vastus medialis longus that inserts on the patella at an angle of approximately 15 to 18 degrees, and the vastus medialis obliquus that inserts more distally on the patella at an angle of 50 to 55 degrees.
- Innervation of the vastus medialis obliquus is by a separate branch of the femoral nerve.
- The vastus lateralis inserts on the lateral margin of the patella at an angle of approximately 30 degrees.
- The more lateral fibers travel past the patella, contributing to the lateral retinaculum, and ultimately fuse with the iliotibial tract.
- The vastus intermedius lies deep to the other major elements of the quadriceps complex.
- The majority of its fibers insert onto the superior aspect of the patella.



Soft tissue anatomy of the patella. VL, vastus lateralis; LR, lateral retinaculum; VM, vastus medialis; QT, quadriceps tendon; MR, medial retinaculum; PT, patellar tendon

- The patellar retinaculum derives from the deep investing fascia lata in combination with the aponeurotic fibers from the vastus medialis and vastus lateralis.
- The retinaculum inserts directly into the proximal