• Chance for optimal healing

• Septic complications

~ 3 % ?
~ 15 % ?
• Septic complications  ~ 3%  
• Posttraumatic arthrosis  ~ ?%  
• Problems of fracture healing  ~ 10%
• Septic complications ~ 3 %
• Posttraumatic arthrosis ~ ? %
• Problems of fracture healing ~ 10 %
• Compartment syndrome ~ ? %
• Sudeck dystrophy ~ ? %
Compartment syndrome

Volkmann’s ischemic contracture
Physiologic circulation

Pressure (hgmm)

100

50

Flow: \( F = \frac{(P_1 - P_2)}{R} \)

- \( F \): flow
- \( P \): blood pressure
- \( R \): vascular resistance

Place of metabolism

Velocity (cm/s)

Cross section (cm²)

arteries

arterioles

capillaries

venules

veins
Compartments:

Intracranial
Intraabdominal
Crural
Forearm
Thigh
Hand

hypoxemia tolerance?

Fig. 3.15 Fascial compartments in (a) the forearm and (b) the calf.
Increased compartment content

A. **Bleeding**
   1. Major vascular injury
   2. Hemorrhagic diathesis
   3. Coagulopathy

B. **Increased capillary permeability**
   1. Postischemic swelling
   2. Exercise
   3. Trauma (other than major vascular)
   4. Burns
   5. (Intra-vasal) drugs, venoms, animal poisons
   6. Nephrotic syndrome

C. **Increased capillary pressure**
   1. Exercise
   2. Venous obstruction
   3. Tight bandage, plaster, brace
   4. Localized external pressure
      (deep coma, buried leg/ extremities)
Decreased compartment size

- 1. (Too) tight closure of fascial defects
- 2. (too) large implant
SIGNS AND SYMPTOMS

• **Pain**
  
Pain is perhaps the earliest and most important and consistent sign.

• **Paresthesia**
  
Paresthesias in the cutaneous distribution of the peripheral nerve coursing through the affected compartment

• **Paralysis**
  
Irreversible muscle fiber changes occur as early as 6 hours after the onset of tissue ischemia

• **Pulselessness??**
  
The loss of palpable pulses has been shown to occur late, or sometimes not at all, in the course of compartment syndromes!
Pathophysiology of compartment syndrome

Direct tissue damage

Trauma
- bleeding
- tissue pressure ↑
- Muscle perfusion ↓
- Cellular hypoxia
- interstitial pressure ↑
- osmotic pressure ↑
- capillary permeability ↑
- capillary pressure ↑ ~ interstitial pressure ↑

Shock
- A-V grad ↓
- Blood viscosity ↑
- Permeability ↑

Histamin, serotonin, cytokines, leukotrienes
"free radicals"
Normal intracompartamental pressure = 0 - 8 Hgmm monitoring
Conservative therapy?

- Cooling the extremity
- Elevation of the extremity to the level of the heart
- Cut and loosen all circular bandages,
- Check $CPK$ enzyme every 6 hrs
- Check renal function carbamide & creatinin levels daily
- Check that urine output > 60 ml/hour
- Painkillers
- Antioxidants:
  - vitamin „C”
  - vitamin „E”
Indication for surgery on the extremities:

• Severe pain
• Tight tissues (blistering)
• Numbness in digits (1st interdig. space)
• Intracompartmental pressure ≥ 30 hgmm
• Further elevation of CPK
• Suspicion of comp. syndr.!!!
treatment

• DC (=decompressive craniectomy) ?
  • open cranium

• Ventricular brain?

• DL (=decompressive laparotomy)
  – open abdomen

• Open /decompressing/ fasciotomy of extremities

Closure only after normalization of circulation
Acute Subdural Hematoma (ASDH)
Fasciotomy of the hand

+carpal tunnel releas!
Open dermatofasciotomy
Open dermatofasciotomy
We were too late…

- Muscles show functional changes after 1 to 3 hours of ischemia
- Irreversible functional loss after 6 hours of ischemia
COMPARTMENT SYNDROME
IRREVERSIBLE STAGE
ischemic contracture (Volkmann)
Open dermatofasciotomy of the leg

All 4 compartments should be opened, max 2 incisions
Fasciotomy of the foot
TREATMENT

• Wound closure after 5-10 days

Open fasciotomy
SUDECK DYSTROPHY

- pain, discoloration, swelling,
- weakness, stiffness,
- hyperhydrosis,
- focal osteoporosis
If you don’t know something give it a name

- Causalgia
- RSDS
- Algodystrophy
- Postraumatic painful osteolysis
- Postraumatic chronic pain
- Transient osteoporosis
- e.t.c > 25 name
• Genetical disposition (HLA DQ1) ?
• $\frac{♀}{♂} = 3/2$
• Average age is \(\sim 50\) years
• Depression is a predisposing factor
• High sympathetic activity

• *Not life-threatening* „only” crippled
Reperfusion injury? Abnormal coupling of neurons?

Chronic irritation of a peripheral sensory nerve led to an abnormal state of activity in the internuncial neuron center, which in turn led to a continuum of increased stimulation of efferent motor and sympathetic neurons.
Stages of Sudeck dystrophy

- I. pseudoinflammation (1-12 weeks)
- II. dystrophy (3-9 months)
- III. atrophy (6-18 months or forever)
I. **First stage:** (1-12 weeks) Pseudoinflammation
constant burning and aching pain in the extremity, acute hyperaemia, increased sweating (hyperhydrosis), redness, swelling, tenderness, distal to the injury

![Image of hand with symptoms]

The pain is increased by external stimuli or motion and is out of proportion to the severity of the original injury and related physical findings. The stimuli that trigger the pain response can vary from peculiar noises, vibration, and excitement to emotional upset, deep breathing, laughing, or the use of certain words!!!
Treatment in the first stage

- Elimination of the responsible noxious stimulus.
- Immobilization, cooling
- Pain killers/ NSAID/
- Sympatholytic drugs, vasodilators/nifedipin/, calcitonin, corticosteroids, ganglion stellate blockade.
- Physiotherapy: subaqual exercises, TENS
- Emotional support for patients
II. Stage (Dystrophy 4-9 months)

- significant edema; cold, glossy, later pale dry skin;
- limited range of joint motion.
- X-ray films often reveal a diffuse osteopenia
III. Stage (atrophy)

- this stage occurs 6-18 months or many years after the onset of symptoms and is marked by

- progressive atrophy of the skin and muscle,
- joint motion is severely limited
  - serious fibrosis, and contractures that may be irreversible.
- Marked, diffuse osteopenia is seen on the x-ray films.
- The pain may involve the whole limb.
III. Stage atrophy

Patchy atrophy of bones
Differential diagnosis:

- thrombosis (!)
- inflammation (erysipelas, osteomyelitis aseptic: gout, rheumatism)
- tumors
- inactivity
Problems of bone union

• Delayed union
• Non union
• Pseudoarthrosis

Position &/or vascularity of fragments
Possible „union” problems

• All in One?
  – Non (delayed)-
  – Mal- union
  – Cross-

  – Malposition
    • Angular dislocation > 10°
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DISTURBED BONE HEALING:

Pseudoarthrosis

Formation of a false joint where a fibro-cartilaginous cavity is lined with a pseudosynovial membrane
Malunion

Fracture healing is achieved in the wrong position
CAUSES OF DISTURBED BONE HEALING

- Poor vascularity (biology)
- Instability
- Infection
- Others

**Traumatic & iatrogenic**
- Inadequate stabilization
- Bone resorption at fracture site

**Osteitis & osteomyelitis**

**Noncompliance:**
- Inappropriate weight bearing, smoking, improper diet, etc
- Neuropathy, paraplegia, hemiparesis
- Diabetes, chronic alcoholism, etc
CAUSES OF DISTURBED BONE HEALING: poor vascularitiy

traumatic

iatrogenic

minimal invasive
CAUSES OF DISTURBED BONE HEALING:

- Instability
  - too flexible

- Inadequate stabilization

Inadequate stabilization
CAUSES OF DISTURBED BONE HEALING:

• Poor vascularity
• Infection
• Others?
CLASSIFICATION OF NONUNION

• Site
  - *Diaphyseal*
  - rarely: metaphyseal - intraarticular

• Bone ends
  - Hypertrophic
  - Atrophic

• Aseptic/infected
DIAGNOSIS OF NONUNION:

History

Clinical signs:
- Pain, swelling, redness
- Motion at fracture site

Follow-up x-rays

Implant loosening or breakage

No signs of progress in healing
VARIOUS TYPES OF NONUNION

- elephant foot
- horse foot
- atrophic
- necrotic
- defect
Characteristics of hypertrophic non-union

- Biology: good
- Stability: lacking

• treatment consists of:
  - Providing stability
  - Correcting deformity, if present
  - No bone graft required
Characteristics of atrophic non union:

- Biology: poor
- Stability: poor

Treatment consists of:
  - Providing stability
  - Bone grafting
Characteristics of avital non-union

- Biology: poor
- Stability: lacking
- Soft tissue coverage?
- Infection?

- treatment consists of:
  - debridment
  - providing stability
  - improving soft tissue coverage
  - bone grafting
PRINCIPLES OF TREATMENT

Stabilization

- Enhancement of biology
- ± eradication of infection
Stabilization by plating

Advantage:
In a single procedure
  interfragmentary compression,
  Correction of malposition
  Bone transplantation

Disadvantage:
  - Invasive
  - Longer time
  necessary for full load bearing

Plating done on tension side (biomechanics...)

Wave plate increases local stability placement of bone grafts
DISTURBED BONE HEALING

Nonunion

Union is delayed and a fracture has ceased to show any evidence of healing
DISTURBED BONE HEALING

Delayed union

Failure to consolidate within the normally expected time

9 months after injury

15 months after injury
Stabilization—external fixation:

Advantage:
- Preferable under poor soft-tissue conditions
- Little damage to the fracture site
- Correction of complex multiplanar deformities
- Callus distraction

Disadvantage:
- Pin-track infection
- Time consuming
- Patient discomfort
- Little advantage in aseptic nonunion
POSTTRAUMATIC ARTHROSIOSIS

• Intraarticular fractures, cartilage damage
• Loss of blood supply
  • femur neck fractures → femoral head necrosis ~ 50 %
  • talus neck fractures → talus necrosis ~ 90 %
  • scaphoid fractures → wrist arthrosis ~10 %
• Ligament injuries lead to instability
• Malunited fractures – asymmetrical weight bearing
• Infections: osteomyelitis, arthritis
SYMPTOMS of Arthrosis

• Pain

• Swelling

• Loss of function
  » XRay
Arthrosis after sports...

I. Changes on the weight bearing surfaces:
   - cartilage cracked
   - chondroitin - sulfate concentration ↓
   - number of hyalin cells ↓
   - joint surface is uneven
   - the joint space ↓

54 y champion
Clinical degree of arthrosis:

- Fatigue, dull pain
- Initial pain
- Loading pain
- Permanent pain
- Limitation of motion
- Deformity
- Crepitation

Indication for surgery
Surgical possibilities:

Make it pain-free
Make it stable
Keep it mobile
AD: Stable & painfree

IPA: or denervation: Mobile & painfree

TEP: Mobile & Stable & painfree
Take home:

1. Compartment syndrome can be limb/life threatening
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2. Symptoms of c.s.: irreducible pain, swelling, paresthesia
   Even with palpable pulse!
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   Biomechanical - geometrical
   Scaphoid: 10 %, femoral neck 50 %, talus neck 90%
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5. Postraumatic arthrosis should be prevented
   can be treated by arthrodesis interposition AP
   denervation prosthesis