Avascular Necrosis

**Osteonecrosis**: cellular necrosis of bone and marrow elements.

**AVN**: osteonecrosis of epiphysis or subchondral bone.

**Bone infarct**: osteonecrosis of metaphyseal or diaphyseal bone.

Disruption of vascular flow due to:

1. Thrombosis
2. External compression
3. Vessel wall disease
4. Trauma
AVN

Physeal scar is not AVN but complete physeal scars are associated with AVN in 44% of femoral head.
Etiology

- Traumatic vs nontraumatic.
- Corticosteroids (peak dose rather than cumulative dose, >20 mg/day)
- Sickle cell disease (prevalence of AVN = 4 – 20 %)
- Alcoholism (> 400 ml / week)
- Gaucher disease (marrow infiltration / edema)
- Nitrogen narcosis
- Radiation (direct effect)
- Chemotherapy (direct effect)
- Collagen disease
- Pancreatitis
- pregnancy, malignancy, IBD (thromboplastin release)
- Caisson disease / Dysbarism
- Idiopathic
Lipid disorders as etiology

- **Fat embolism d/t:**
  1. Fatty liver.
  2. Destabilization and coalescence of plasma lipoproteins.
  3. Disruption of fatty marrow or fatty tissues in nonosseous regions.

- **AVN d/t fat embolism.**

- **Phases:**
  1. Interosseous vascular occlusion.
  2. Increase lipase, increase FFA, PGs.
  3. Focal intravascular coagulation, platelet aggression, thrombosis.
  4. Osteonecrosis.
Osteonecrosis eventually develops in only a relatively small percentage of patients with any of the conditions.

“A genetic mutations leading to hypercoagulability, which results in microthrombosis and osteonecrosis when challenged by environmental (epigenetic) events”
Why Hip?

- Partly due to vascular anatomy: susceptible to damage with hip fracture / dislocation.
AVN, Hip

3rd - 5th decade of life.
300,000 to 600,000 in US.
Account for 5 to 12 % of THA in US.
The prevalence of AVN after:
Hip dislocation = 10% to 25%
Displaced femoral neck fracture = 15 to 50 %
Clinical:
- Deep groin pain
- Pain on internal rotation
- Decreased range of motion
- Antalgic gait
- **Clicking in the hip (necrotic fragment collapse)**
- Pain on int rot & limited ROM = femoral head collapse
**X-ray**: Cysts, Sclerosis, Crescent sign (subchondral collapse of the necrotic segment)
Diagnosis

- Tc 99 bone scan: 25 – 45 % FN.
- MRI: Gold standard (99 % Sn and Sp)

Single-density line on T1: normal/ischemic bone interface
Double-density line on T2: hypervascular granulation tissue
- Transient Osteoporosis
- Bone Marrow Edema
<table>
<thead>
<tr>
<th>Stage</th>
<th>Clinic</th>
<th>X-ray</th>
<th>MRI</th>
<th>Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>Normal</td>
<td>Normal to uniform edema (decrease T1, increase T2) Inc Subchondral with Gado</td>
<td>Cell necrosis</td>
</tr>
<tr>
<td>1</td>
<td>+ / -</td>
<td>Normal or Patchy OP</td>
<td>Same as above</td>
<td>Sinus congestion, hypoplastic marrow, empty lacunae</td>
</tr>
<tr>
<td>2</td>
<td>Pain Stiff</td>
<td>Mixed osteopenia Cystic, sclerosis,</td>
<td>Crescent shape</td>
<td>Central necrosis, marginal fibrous, new bone</td>
</tr>
<tr>
<td>3</td>
<td>Pain Stiff</td>
<td>Crescent sign Cortical collapse, joint preserved</td>
<td>Crescent sign, sequestra, Cortical collapse Joint preserved</td>
<td>Granulation tissue around necrosis</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>DJD, flattening Narrow joint space</td>
<td>DJD, narrow joint space</td>
<td>Exaggerated stage 3</td>
</tr>
</tbody>
</table>

**Staging: AVN, Hip**

**Ficat and Arlet**
Staging: AVN, Hip
Steinberg modification of Ficat / U Penn

0: normal imaging.

1: normal X-ray, abnormal bone scan / MRI.
   A: mild: < 15% head affected
   B: moderate: 15-30 %
   C: Severe: > 30%

2: lytic and / or sclerotic changes.
   A: mild: < 15% head affected
   B: moderate: 15-30%
   C: Severe: > 30%

3. Crescent sign (subchondral collapse).
   A: mild: < 15% articular surface, B: 15-30, C: > 30%
4. Flattening.
   A: Mild: <15% head / < 2mm depression,
   B: Moderate: 15-30% / 2-4 mm
   C: Severe: >30% > 4 mm

5. Joint space narrowing / acetabular changes.
   A: Mild, B: Moderate, C: Severe

6. Advanced DJD.
Treatment Options
AVN, Hip

- Non-weight bearing
- Core decompression
- Core decompression + vascularized fibular graft
- Core decompression + non-vascularized fibular graft
- Core decompression + autologous bone marrow cells
- Osteotomy
- Resurfacing arthroplasty
- Bipolar arthroplasty
- Total hip arthroplasty
## Treatment approaches

**AVN, Hip**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Symptoms</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2</td>
<td>None</td>
<td>Observation, (core decomp / bone grafting)</td>
</tr>
<tr>
<td>1, 2</td>
<td>Present</td>
<td>Core decomp (bone grafting)</td>
</tr>
<tr>
<td>1C, 2C, 3, 4A</td>
<td>Present</td>
<td>Bone grafting, resurfacing or THA</td>
</tr>
<tr>
<td>3B, 4C</td>
<td>Present</td>
<td>Resurfacing or THA</td>
</tr>
<tr>
<td>5, 6</td>
<td>present</td>
<td>THA</td>
</tr>
</tbody>
</table>
Treatment:
1. Core decompression

- Initially as diagnostic tool (histologic specimen) then therapeutic (Ficat and Arlet).
- Goal: to decompress the femoral head and reduce intraosseous pressure.
- Controversial, difficult to compare the results.
- Can be combined with:
  1. nonvascularized grafts (allograft bone or demineralized bone matrix)
  2. vascularized bone grafts (fibula or iliac crest)
  3. electrical stimulation, or electromagnetic fields.
Core decompression vs Conservative treatment

Mont: (review) 42 studies, 1206 hips with core decompression and 819 conservative:

1. Of the hips treated prior to collapse, 71% had a good result after core decompression and 35% had a good result after nonoperative management.

2. Satisfactory clinical result in 64% of the hips with core decompression and in only 23% of those with nonoperative management.

The results of core decompression were substantially poor when there had been collapse of the femoral head preoperatively.
Core decompression

- Single core tract vs multiple core holes.

- Two plane fluoroscopy, fracture table, guide wire into osteonecrotic area, starting hole just proximal to lesser trochanter level to avoid stress fracture, biopsy specimen.

- WB with crutches for six weeks.

- Core decompression with nonvascularized or vascularized grafts to enhance bone formation and to prevent fracture.

- Grafting with demineralized bone matrix enhances the healing potential but it does not change the anatomy of the femoral neck if THA needed.

- Using growth factors to enhance osteogenic or angiogenic potential (fibroblast growth factor or vascular endothelial growth factor).
Core decompression seems to be more effective than symptomatic treatment. In order to optimize the results of core decompression, the osteonecrosis must be diagnosed and treated early.

The prognosis is better when the hip is treated before collapse, when the lesion is smaller, and when there is a sclerotic rim.

Patients who continue to take steroids seem to have a worse prognosis.
2. Free vascularized fibular grafts

To prevent femoral head collapse and enhance vascularization of the bone.

5 principles:
1. Decompression of the femoral head
2. Removal of the necrotic bone
3. Replacement with fresh autogenous cancellous bone
4. Support of the subchondral bone with a strong viable bone strut
5. Revascularization and osteogenesis of the femoral head
Free vascularized fibular grafts

Technique

- Lateral decubitus position.
- Two teams: one performs on hip, other harvests the ipsilateral fibula.
- Gluteus medius / TFL.
  - make a core (16 to 19 mm), distal to vastus ridge into the necrotic area.
- Removal of necrotic bone and replace with autogenous cancellous bone from GT.
- Assess the packing of the cavity with water-soluble contrast medium and fluoroscopy.
- Insertion of the fibula with its peroneal vessels into the core to within 3 to 5 mm of the subchondral area and is stabilized with a 0.62-mm Kirschner wire.
- Anastomosis of ascending branches of LFCA / V to peroneal vessels.

NWB x 6 w, PWB x 3 – 6 m.
Free vascularized fibular grafts
Free vascularized fibular grafts  

Results

**Urbaniak**: 103 patients treated with a free vascularized fibular graft, F/U 7 y:

31 of 103 hips had required conversion to a THA. Patients with preoperative collapse of the femoral head had a worse prognosis.

**Urbaniak**: (review) 1523 hips treated with a free vascularized fibular graft, F/U 6 m to 22 y:

91% success rate in hips with no preoperative subchondral or articular collapse.
85% if collapse had been present.
73% if there had also been joint-space narrowing.
Core decompression vs free vascularized fibular grafts in two studies

- **Kane**: prospective, 39 hips treated with core decompression or a free vascularized fibular graft, F/U 2–5 y:
  - core decompression success rate = 42%.
  - free vascularized fibular graft success rate = 80%.

- **Scully**: retrospective, Pt with Ficat 3 treated with free vascularized fibular graft or core decompression, 50 months survival rate was:
  - 81% in free vascularized fibular graft.
  - 21% core decompression.
3. Core decompression and implantation of autologous bone marrow cells

Theory:
Since osteonecrosis may be a disease of mesenchymal cells, the possibility has been raised that bone marrow containing osteogenic precursors implanted into a necrotic lesion of the femoral head may be of benefit in the treatment of this condition.

(Valérie Gangji, MD Department of Rheumatology and Physical Medicine, Erasme University Hospita, Belgium)
Bone Marrow Implantation

Two-year prospective, controlled, double-blind study on the effect of implantation of bone marrow cells into the zone of osteonecrosis of the femoral head through the trephine used for the core decompression.

- 13 Pt, 18 hips, stage 1 - 2,
- Core decompression (control) vs core + bone marrow implantation.
- 24 months F/U.
... Bone Marrow Implantation

Technique:


2. Core decompression: lateral incision distal to GT, 3- mm trephine under fluoro to necrotic lesion.

3. Bone marrow injection: 50 ml through the trephine over a few minutes.

Postop care: 3 days H, NWB x 3 weeks.
Bone Marrow Implantation

Outcomes: Safety, clinical symptoms, disease progression.

Results:
1. Significant reduction in pain in bone marrow group (p=0.02).
2. 5 of 8 deteriorated to stage 3 in control group.
3. 1 of 10 deteriorated to stage 3 in bone marrow group.
Conclusions: Bone marrow implantation is a safe & effective treatment for early stages of AVN.

INDICATIONS:
Stage-I or II osteonecrosis.

CONTRAINDICATIONS:
Skin lesions affecting the lower limb
Active infection
Coagulopathy
Anemia (Hb < 100), leukopenia (<4000/mm³).
Trephine: outer diameter = 5 mm, inner = 3 mm.
Trephinning