# Knee Reconstruction

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# 1 Principles of Total Knee Arthroplasty

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**Take-Home Message**

- The primary goal in total knee arthroplasty (TKA) procedures is to provide patients with pain relief and improve function through implantation of a stable prosthesis.
- Variations in implant designs include posterior stabilized (PS), cruciate retaining (CR), bicruciate substituting (BCS), and ACL/PCL retaining.
- Basic principles of TKA: balance of the soft tissues, equalization of flexion and extension gaps, and restoration of the mechanical axis, joint line, and patellofemoral alignment and mechanics.

**Indications and Contraindications**

- Primary indication: end-stage degenerative osteoarthritis (primary, posttraumatic, secondary to avascular necrosis, osteochondritis, or sepsis).
- Additional indications include inflammatory arthropathies, osteonecrosis, tumor, and fracture.
- Contraindications: preexisting sepsis or infections (including osteomyelitis) either at knee or distant site and severe vascular disease.

**Radiography**

- Plain radiographs of the knee should include weight-bearing anteroposterior (AP), lateral (at 30° of flexion), PA flexed (or alternatively a tunnel view), and merchant views of the involved knee, as well as a long-leg hip-to-ankle standing AP radiograph of both limbs to assess asymmetry and mechanical and anatomic limb axes.
- AP and lateral plain radiographs of the hips may be indicated in the context of symptoms of groin pain, stiffness, or limited range of motion or may be indicated for severe knee pain with normal knee radiographs.
- Magnetic resonance imaging (MRI) may be indicated to evaluate meniscal and ligament integrity.

**Templating**

- The purpose of preoperative templating is to assist the surgeon in selecting an appropriate implant design and size of the femoral and tibial component, as well as assess the patient's deformity and mechanical versus anatomic axis.
- Tibiofemoral angles: Assess the degree of malalignment and/or deformity using a standing AP radiograph:
  - Anatomic tibiofemoral angle: angle formed from the shaft axis of the femur to the tibia

  - Mechanical: angle formed from the femoral mechanical axis to the tibial shaft axis
- The goal is to template for placing the tibial component at 90° to the anatomic-mechanical axis to model the normal joint line during the gait cycle.

## Implant Designs

- *Total knee replacement*: The two most common implant designs are the posterior stabilized (PS) and cruciate retaining (CR). Meta-analyses have shown no difference in implant type with regard to postoperative extension angle, patient satisfaction, complications (such as anterior knee pain), short- and long-term knee society outcomes (pain and function), as well as similar prosthesis survivorship. The most significance difference between the two implant designs is the *greater flexion angle and increased range of motion in the PS design as compared to the CR design.*
  - *Posterior-stabilized implant*

| Advantages | Disadvantages |
|---|---|
| Less technically demanding | Patella clunk syndrome (esp early designs) |
| Increased range of motion | Tibial post fracture |
| Predictable knee kinetics | Impingement |
| Restricted axial rotation and condylar translation | |

  - *Cruciate-retaining implant*: indicated for patients with a functional posterior cruciate ligament, younger age, and more active lifestyle

| Advantages | Disadvantages |
|---|---|
| Bone preservation | Sagittal laxity/tightness |
| | Potential paradoxical rollback |
| Increased proprioception | Less flexion |
| | Tibial bearing damage (shear) |

## Implant Fixation

- *Cemented:* A static fixation without osseointegration potential that provides immediate mechanical stability in the acute postoperative period. Cemented implants are indicated for patients with poor bone quality.
- *Non-cemented:* Biologic interface between the native bone and the implant. A non-cemented implant may be indicated in patients with adequate bone quality. Two non-cemented implant options include hydroxyapatite coating or high-porosity trabecular metal, which function by encouraging bony ingrowth at the implant-bone interface. Traditionally, non-cemented components had a high failure rate, especially on the tibial side.
- *Hybrid fixation:* The femoral (or tibial) component is cementless, while the tibial (or femoral) and patellar components are cemented.

**Surgical Approaches**

- *Medial parapatellar approach*:
  - Overview: most common approach
  - Advantages:
    - Good exposure to all three compartments.
    - Facilitates difficult primary TKA and is recommended for revision TKA.
    - Rectus snip can be easily used in cases of a difficult exposure.
  - Disadvantages: potential disruption to extensor mechanism
- *Midvastus approach*:
  - Overview:
    - Vastus medialis fibers split parallel.
    - Patellar eversion.
  - Advantages:
    - Preservation of the patellar vasculature
    - Preservation of the vastus medialis insertion on quadriceps tendon
    - Potentially allows for accelerated rehabilitation
    - Reduced need for lateral retinacular release
  - Disadvantages:
    - Disruption of the vastus medialis.
    - Articular surface exposure can be inferior in obese patients compared to separating the vastus medialis and quadriceps.
  - Contraindications:
    - Less than 80° of preoperative knee motion
    - Hypertrophic arthritis
    - Previous high tibial osteotomy
    - Obesity
- *Subvastus ("southern") approach*:
  - Overview:
    - Incision is made inferior to the vastus medialis.
    - Elevation of the vastus medialis from the medial intermuscular septum.
    - Patellar eversion.
  - Advantages:
    - Preservation of the patellar vasculature
    - Preservation of the extensor mechanism

    - Reduced need for lateral retinacular release
    - Earlier clinical recovery

  - Disadvantages:

    - Exposure is less predictable.
    - Increased difficulty everting patella.

  - Contraindications:

    - Obesity
    - Muscular thighs
    - Patients with marked deformity in knee
    - Revision TKA
    - Previous knee arthrotomy

- *Lateral parapatellar approach*:

  - Overview:

    - Primary indication is severe valgus deformity (common deformity in rheumatoid arthritis).
    - Lateral arthrotomy starts lateral to the quadriceps tendon and extends 1–2 cm lateral to the patella and through the medial edge of Gerdy's tubercle, ending in the anterior compartment fascia.
    - Iliotibial band release/lengthening.
    - Medial patellar eversion.

  - Advantages:

    - Direct exposure to the pathological features of the valgus deformity
    - Improved patellar tracking via preservation of the *vastus medialis*
    - *No need for lateral release*
    - Minimal risk of patellar avascular necrosis because of preservation of medial blood supply

  - Disadvantages:

    - Difficult to address medial pathology.
    - The *common peroneal nerve* is at risk for damage during this approach.
    - The *lateral meniscus* may be incised accidentally if arthrotomy is performed too close to the joint line.
    - Increased difficulty medially everting the patella.

  - Contraindications:

    - Fixed varus deformity

## Complications

- *Arterial injury*: The prevalence of arterial injury following TKA is 0.03–0.17 % and most commonly involves the popliteal artery. The major risk factor is preexisting peripheral arterial disease, and the risk is compounded by the use of a tourniquet during the procedure.*Arthrofibrosis:* Stiffness after TKA, also termed arthrofibrosis, prevalence ranges in the literature from 1 to 25 %. Proposed risk factors include poor preoperative range of motion, previous operations, diabetes, depression, and poor patient education; perioperative, surgeon technique and operative time; and postoperative, infection and poor pain control and patient compliance with physiotherapy.
- *Aseptic loosening*: Aseptic loosening is one of the most common reasons for revision TKA and is best diagnosed by radiographic presence of radiolucent lines around the components, periprosthetic fractures, and *changes in component positions in successive radiographs.*
- *Mortality*: Incidence of mortality has been reported as 0.2 % at 20 days and 1.6 % at 1 year postoperative. Independent predictors of mortality include increased patient age, diabetes, and simultaneous bilateral TKA.
- *Peroneal nerve injury*: The prevalence of common peroneal nerve palsy is 0.3–9.5 %, although these numbers are thought to be underestimates of the true prevalence given the wide spectrum of nerve injury presentations. Controversy surrounds proposed risk factors, but some are thought to be younger age, higher body mass index, preoperative valgus deformity, preoperative flexion contracture, and duration of perioperative tourniquet use.

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## 2 Prosthesis Mechanical Alignment, Q Angle

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**Take-Home Message**

- Restoration of neutral mechanical alignment requires perpendicular cuts to the mechanical axes of the femur and the tibia.
- Femoral component should be lateralized and placed parallel to the neutral rotational axis of the femur (i.e., epicondylar axis) or externally rotated 3° relative to the posterior condylar axis (if using a posterior referencing system); preoperative valgus deformity may require more external rotation of the femoral component if using a posterior referencing system.
- Q angle should be minimized by avoiding internal rotation of the tibial and femoral components, by lateralizing the femoral component, and by placing the patellar component superior and medial.

## Alignment Goals

- *Restore near-neutral mechanical coronal alignment* to the lower extremity.
  - Accepted range of coronal alignment is ±*3° from neutral (0°)*.
- Mechanical axis should pass through the *central 1/3* of the knee.
- Minimize Q angle.

## Preoperative Radiographic Evaluation

- *Standing* AP, flexed PA (the Rosenberg view), hip-to-knee standing alignment, and merchant and lateral radiographs of bilateral knees.
- Identify medial or lateral joint space gapping (can be a sign of collateral ligament insufficiency), subluxation of femur on the tibia (on AP and/or lateral), and bone defects.
- Anticipate the need for ligament releases to balance the knee and/or ↑ prosthetic constraint for MCL/LCL incompetence.
- *Standing full-length radiographs* (AP and lateral) assist in *determining femoral valgus cut angle* if femoral or tibial deformity is present or in very tall (>190 cm) or short (<152 cm) patients.
- Excessive *preoperative deformity and femoral bowing* ↑ risk of postoperative *malalignment*.
- *Merchant* view evaluates *patellofemoral articulation* and articular congruence (patellar tilt).
- Preoperative patellar tilt predicts risk of postoperative tilt.

## Long-Leg Alignment

- *Mechanical axis* of limb passes from *center of femoral head to center of ankle* (i.e., center of plafond).
- Normally passes through central 1/3 to slightly medial of knee joint; if passes medial 1/3 = varus alignment; if passes lateral 1/3 = valgus alignment.
- Quantified by *mechanical axis deviation (MAD)*, measured as perpendicular distance from center of knee to mechanical axis of the limb:
  - Normal MAD: *8 ± 7 mm medial to center of knee*
  - Varus MAD: >15 mm medial to center of knee
  - Valgus MAD: >10 mm lateral to center of knee
- *Anatomic tibiofemoral angle* formed by line bisecting femoral diaphysis and a second line bisecting tibial diaphysis; normal angle: *5–7° valgus*.
- *Mechanical tibiofemoral angle* formed by mechanical axes of femur and tibia (see below); normal angle: *1 ± 2° varus*.
- Postoperative neutral mechanical axis permits even load distribution across medial and lateral condyles of prosthesis.

### Femoral Alignment

- *Anatomic axis of femur (AAF)* defined by a line bisecting femoral diaphysis.
  - Determines entry point of femoral intramedullary cutting guide, which parallels anatomic axis.
  - Normal distal femur is in *5–7° of anatomic valgus*.
- *Mechanical axis of femur (MAF)* defined by line from center of femoral head to intersection of anatomic axis and intercondylar notch.
- *Valgus cut angle (VCA)* defined as difference between AAF and MAF; normal angle: ~*6°*.
- Template VCA on standing full-length AP radiograph.
- VCA perpendicular to mechanical axis of femur and limb.
- Since proximal femoral offset does not vary significantly from patient to patient, *VCA tends to vary with patient height*; *tall* patients require *VCA <5°*; *short* patients require *VCA >7°*.
- Consider VCA of 3° in valgus knees to "overcorrect" alignment; however, this is surgeon preference rather than an accepted rule.

### Tibial Alignment

- *Anatomic axis of tibia (AAT)* defined by line that bisects tibial diaphysis.
- Determines entry point for tibial intramedullary cutting guide.
- *Normal tibia in 2–3° of anatomic varus*.
- *Mechanical axis of tibia (MAT)* defined by line from center of tibia plateau to center of ankle; *usually coincident with AAT, unless tibial deformity*.
- Proximal tibia cut should be perpendicular to mechanical axis of tibia.

### Limb Alignment and Implant Survival

- *>3° of tibial component varus* risks early implant failure, usually through medial plateau bone collapse.
- *>8° of femoral component valgus* contributes to early implant failure.
- Historically superior implant survivorship and patient satisfaction for neutral to slightly valgus limb alignment (between 2.5° and 7.4° of *anatomic valgus*).
- Recent literature questions whether modern implant survivorship is improved for TKA aligned ±*3° from neutral (0°)*.
- Excessive *preoperative* malalignment (>8° of varus or >11° of valgus) has ↑ risk of failure; can be incompletely mitigated by postoperative neutral alignment.
- *Soft tissue balance* is also key factor in load distribution across prosthesis and for implant survival.

## Q Angle

*Anatomy*

- *Q angle* is defined as angle between line from anterior-superior iliac spine (ASIS) to center of patella (axis of quadriceps) and second line from center of patella to tibial tuberosity (axis of patellar tendon).
- Normal angle: *11* ± *7°*.
- Varies with patient height; *greater in short patients; less in tall patients*.
- *Larger Q angles ↑ lateral subluxation forces on the patella*; risk for pain, mechanical symptoms, accelerated wear, and dislocation.

*Intraoperative Management*

*Femoral Component*

- Can use a combination of anteroposterior (Whiteside's line), transepicondylar, or posterior condylar axes to assess axial femoral rotation.
- *Anteroposterior axis (Whiteside's line)* defined as a perpendicular line from center of trochlear groove to intercondylar notch and the neutral rotational axis (i.e., transepicondylar axis).
- *Transepicondylar axis (TEA)* defined as line connecting medial sulcus (insertion of MCL) and lateral epicondyle; some believe TEA may most consistently produce a balanced flexion gap but is difficult to determine intraoperatively.
- *Posterior condylar axis* defined as line tangent to posterior condyles; in normal knee, 3° internally rotated relative to transepicondylar axis; if lateral femoral condyle hypoplastic, referencing posterior condylar axis internally rotates femoral component.
- Internal rotation of femoral component ↑ Q angle.
- Medialization of femoral component ↑ Q angle.

*Tibial Component*

- Place tibial component in neutral rotation, centered over *medial 1/3 of tibial tubercle*.
- Internal rotation of tibial component ↑ Q angle, by causing relative external rotation of the tibial tubercle.
- Medialization of tibia component ↑ Q angle.

*Patellar Component*

- Implant superiorly on patella and/or medialize.
- Medialization ↓ Q angle, but smaller patellar component needed.
- Perform lateral release, if intraoperative lateral subluxation of patella observed during trialing:
  - Required less often with medialization of component.
  - Release the tourniquet prior to performing a lateral release, as tourniquets may cause false subluxation of the patella.

*Postoperative Assessment*

- *CT scan* is best for assessing malrotation of femoral and tibial components.
  - AP axis of *femoral component* should be perpendicular to *TEA*, and posterior condylar axis of prosthesis should be parallel to TEA:
    - Mild internal rotation (IR) ≤3°.
    - Moderate IR 4–6°.
    - Severe IR ≥6°.
    - ≥4° of IR may benefit from early revision.
  - *Tibial component* rotation defined as angle between a line bisecting the tibial tubercle and a line drawn perpendicular to the posterior aspect of the tibial insert:
    - *Up to 18° of IR* can be normal, based on this measurement technique.
    - ≥27° of IR is usually abnormal and symptomatic.

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# 3 Ligament Balancing: Coronal and Sagittal

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**Take-Home Message**

- Ligament balancing is critical for successful TKA outcomes.
- Sagittal imbalances in *either* the flexion or extension gap can be corrected with altering the *femur* and/or soft tissues, whereas imbalances in *both* the flexion and extension gap can be corrected by altering the *tibia* and/or polyethylene thickness.
- Coronal plane balancing can be achieved by *gradually*, stepwise releasing the contracted *medial* (for *varus* deformity) or *lateral* (for *valgus* deformity) soft tissues.
- An intraoperative flexion contracture can be managed by releasing the posterior capsule and posterior osteophytes and/or resecting more distal femur.
- In general, soft tissues are contracted on the concave side of the deformity and loose/attenuated on the convex side.

## Definitions

- "Balanced knee":
  - Full ROM (however the passive *flexion* achievable *postoperative* is dependent on *preoperative motion*)
  - Symmetric medial/lateral balance at full extension, midflexion, and 90° flexion
  - Near-neutral varus/valgus mechanical alignment in extension and flexion
  - Balanced flexion/extension gap without medial/lateral tightness or laxity
  - Well-tracking patella
  - Correct rotation balance between components
- Coronal plane balancing → correcting varus/valgus deformity
- Sagittal plane balancing → correcting (equalizing) flexion/extension gap
- *Gap balancing technique* → Bony resection on the tibia and femur is determined by the intraoperative tension of the ligaments.
- *Measured resection technique* → Bony resection on the tibia and femur is made first, and the ligaments are balanced depending on the bony resection.

## Etiology of a Poorly Balanced Knee

- Coronal plane imbalance: Medial or lateral ligamentous complexes become tight and/or stretched depending on deformity.
- Sagittal plane imbalance: Often caused by a progressive flexion contracture deformity from a tight posterior capsule, tight hamstrings, or large posterior osteophytes; improper intraoperative tibial and femoral bone resection can lead to intraoperative sagittal plane imbalance.

## Radiography

- Standard AP, lateral, merchant views + the Rosenberg view (45° flexion PA view)
- Bilateral long-leg standing axis films to assess overall limb alignment

## Treatment Operative

- Coronal Balancing
  - Varus deformity:
    - Lateral structures on convex side of deformity → attenuated.
    - Medial structures on concave side of deformity → contracted.
    - Goal → Release medial structures, and tighten lateral structures.
    - A near-neutral alignment after the bony resections should be achieved prior to performing soft tissue releases.
    - Algorithm for a gradual medial release:
      - Remove *osteophytes*, meniscus + *capsule* attachments on the medial side of the tibia.
      - Release *deep MCL*:

        - Do *not* release superficial MCL → will result in valgus instability requiring a constrained prosthesis or repair with augmentation.
      - Can release posteromedial corner (*semimembranosus and posteromedial capsule*).
      - Can consider partial superficial MCL release, but should be used with extreme caution:
        - Posterior oblique portion → Release if tight in extension.
        - Anterior portion → Release if tight in flexion.
  - Valgus deformity:
    - Lateral structures on concave side of deformity → contracted
    - Medial structures on convex side of deformity → attenuated
    - Goal → Release lateral structures, and tighten medial structures.
    - A near-neutral alignment after the bony resections should be achieved prior to performing soft tissue releases.
    - Lateral release:
      - Remove *osteophytes*, lateral *capsule*.
      - Release *iliotibial band (ITB)* if tight in *extension*.
      - Release *popliteus*/posterolateral corner if tight in *flexion*.
      - Release *lateral collateral ligament (LCL)* if tight in *flexion and extension* → may require a constrained prosthesis.
    - If the *MCL* is i*ncompetent*, a *constrained* total knee arthroplasty will be required.
    - When releasing the posterolateral corner, be cautious of the *peroneal nerve*.
    - The *inside-out technique* can be used using lamina spreaders and/or tensors to determine which structures are tight on the lateral side of the knee and thus which need releasing.
- *Sagittal Balancing*
  - Traditional teaching in TKA has focused on obtaining equal flexion/extension gap → tibial insert stable through entire arc of motion.
  - Pearls:
    - Symmetric gap (*flexion and extension*) → Adjust *tibia (or polyethylene)*.
    - *Asymmetric* gap → Adjust *femur*.
    - Adjusting femoral component size alters anteroposterior (AP) diameter:
      - Will help with *flexion* gap
      - Does *not* affect prosthesis height → thus does *not* affect extension gap
  - Flexion contracture:
    - Posterior structures on concave side of deformity → contracted.
    - Goal → Carefully release posterior structures.

- Posterior release → can more safely be performed in flexion to allow popliteal artery to fall further out of field:
  - Remove *posterior osteophytes*.
  - Pierce/release *posterior capsule* (e.g., off the posterior femoral condyles).
  - Consider *medial/lateral gastrocnemius* release or *hamstring releases* in rare situations.

– *Strategies for achieving equal flexion and extension gaps:*

- Tight in flexion, tight in extension → Cut more tibia.
- Loose in flexion, loose in extension → Use thicker PE or thicker tibial insert.
- Tight in flexion, balanced in extension → Downsize femoral component.
  - Can also:
    - Release or resess the PCL (for cruciate-retaining designs).
    - Increase the posterior slope in tibia.
    - Resect more posterior femoral condyle (i.e., anteriorize the femoral component).
    - Release posterior capsule (use with caution as this may affect extension gap as well).
- Tight in flexion, loose in extension → Downsize femoral component and use thicker tibial insert.
- Balanced in flexion, tight in extension → Resect more distal femur or release posterior capsule (again, releasing the posterior capsule may also loosen the flexion space).
- Balanced in flexion, loose in extension → Augment distal femur, or distalize the joint line (will require a revision component if augments are used); may also downsize the femoral component (or anteriorize the femoral component) and increase the thickness of the polyethylene.
  - Remember → Altering femoral component size does *not* affect extension gap.
- Loose in flexion, tight in extension → Resect more distal femur, and upsize femoral component.
  - In revisions, can use thinner distal femoral augmentation.
- Loose in flexion, balanced in extension → Upsize femoral component, or increase the size of posterior augments (in revisions).
  - Can also posteriorize femoral component (may require an augment), provided that doing so will not notch the anterior femoral cortex.

## Complications

- Correction of severe combined deformity of *valgus + flexion contracture* can lead to *peroneal nerve palsy* from over-lengthening a previously contracted nerve:
  - At baseline in these patients, nerve on concave side → tight
  - With correction of alignment, nerve put on even more stretch
  - Treat in the recovery with immediate knee flexion and removal of dressing:
    - Allow up to 3 months for return of function.
    - Although recovery of function can occur, *complete nerve recovery* occurs in less than *30 %* of patients.
- Posterior release can lead to *popliteal artery injury*.
- A *flexion contracture* present postoperatively, which was corrected intraoperatively, is often due to tight *hamstring* tendons.
- Not balancing flexion gap (if left too loose) in a posterior-stabilized (PS) knee can lead to cam-post dislocation, resulting in a *posterior knee dislocation*.

## Arthroplasty Salvage Options for Knees That Have Instability Not Correctable by Soft Tissue Balancing

- *Coronal plane* instability (varus/valgus) – can be treated with a *constrained* prosthesis with a thicker post.
- *Anteroposterior instability with an incompetent extensor mechanism* – requires a *hinge*-type prosthesis with *extensor mechanism reconstruction*.
  - Knee arthrodesis can also be considered.
- *Global* knee instability requires a *hinge*-type prosthesis.

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## 4 Implant Designs in TKA

Bryan D. Haughom and Michael B. Cross

**Take-Home Message**

- TKA implant designs range from relatively *unconstrained* (*cruciate retaining and posterior stabilized*) to more *constrained designs* (*non-hinged and hinged*). Every effort is made to minimize the amount of constraint needed in both primary and revision settings.
- Regardless of design (i.e., degree of constraint), a successful arthroplasty requires stable fixation, near-neutral mechanical alignment, and adequate soft tissue balancing.
- Each design has its unique complications, e.g., *cruciate retaining* (*PCL rupture or late PCL insufficiency*) and *posterior stabilized* (*cam jump (dislocation), post impingement, patellar clunk, and post fracture*).
- With increasing constraint, there is an increasing risk of aseptic loosening due to the increased strain at the interface.

**Background**

- A number of design options are available in TKA including unconstrained (posterior cruciate ligament [PCL] retaining, i.e., cruciate retaining (CR) and p*osterior stabilized (PS)*) and more *constrained* (with both *hinged and non-hinged* varieties) designs.

- Debate continues with regard to the ideal primary arthroplasty implant, with the PCL remaining at the heart of the controversy. Surgeons are divided into those who routinely sacrifice the PCL, those who retain it, and those who decide based upon the pathology.
- Most surgeons attempt to utilize the least amount of constraint as necessary to provide a stable, well-balanced knee.
- Long-term studies show excellent outcomes (>90 % survival at 10 years) with the use of both cruciate-retaining and posterior-stabilized knees in the setting of primary TKA.
- Constrained TKA plays a more prominent role in the revision setting.
- Despite the continued debate, most surgeons would agree that the most important factors in long-term outcomes are implant stability, restoration of a near-neutral mechanical axis, and soft tissue balancing.

**Concepts in Knee Arthroplasty Design**

- *Posterior cruciate ligament*:
  - *Primarily* f*unctions in the sagittal* plane, preventing relative *posterior subluxation of the tibia*
  - *Secondary* stabilizer to *resist varus angulation and external tibial rotation at 90°*
  - Facilitates *femoral rollback* in knee flexion
- *Femoral rollback*:
  - Characterized by relative posterior translation of the tibiofemoral contact point with knee flexion:
    - Occurs primarily on the *lateral* side of the knee
  - Facilitated by the *PCL* in *CR* implants
  - Effectively created by tibial *post-cam* contact in *PS* implants
- *Constraint*:
  - Defined as design elements that provide stability to the knee that offset instability secondary to soft tissue deficiency.
  - Constrained options exist for the *coronal* (i.e., *high tibial post and/or wider post* designs) and *sagittal* (i.e., *hinged* components) instability.
  - Typically reserved for complex primary and revision TKA.
  - Instability is the cause of ~10–25 % of failed TKA, highlighting the importance of appropriately balancing and when necessary utilizing adequate constraint.

**Design Options**

- In *in*creasing degree of constraint, design options include:
  - Cruciate-retaining (CR) TKA
  - Posterior-stabilized (PS) TKA

- Constrained (non-hinged) TKA
- Constrained (hinged) TKA

**Cruciate-Retaining (CR) TKA**

- Central to the CR design is the preservation of the PCL. Additional design modifications include a *PCL cut out on the tibial tray* and a *flatter tibial tray* to facilitate femoral rollback.
- Advantages:
  - Retention of a native "central stabilizer" (PCL).
  - Stress is transferred to native tissue, as opposed to the tibial post (in the PS design), potentially avoiding post wear.
  - *Conservation of bone*:
    - Radiographically, one should look for a *lack of a box* on *lateral* radiograph.
  - More consistent joint line (to facilitate PCL tensioning).
  - Preservation of proprioceptive fibers.
  - Some evidence suggests improved function with certain motions (i.e., stair climbing, kneeling, squatting).
- Disadvantages:
  - Some evidence suggests potential for *paradoxical motion* (anterior translation) though this is controversial.
  - Attention should be paid to avoiding over-tightening flexion gap (with PCL retention) which can lead to increased wear:
    - Tibial resection requires greater slope than PS designs.
  - Late instability can develop with rupture of the PCL:
    - Presents with difficulty with stairs, instability, hyperextension, and/or recurrent effusions
  - Relative contraindications:
    - Large deformity correction (flexion contracture or varus/valgus >15°).
    - Inflammatory arthritis.
    - Prior patellectomy (potential increased anteroposterior instability).
    - All of these are debated however in the literature.

**Posterior-Stabilized (PS) TKA**

- Central to the design of a PS knee is the sacrifice of the PCL. A tibial post articulates with a femoral cam during flexion to facilitate femoral rollback. Additionally, the tibial post serves to prevent posterior tibial subluxation (and resultant "cam jump" or dislocation). Tibial polyethylene is characteristically more congruent in PS designs.

- Advantages:
  - Proponent of PS knees argues balancing is performed with greater ease in comparison to CR knees.
  - Theoretically less “sliding” wear with cam-post flexion kinematics as opposed to CR designs.
  - Some contend deformity correction (large flexion contracture, varus/valgus >15°) easier with PS design.
  - No concern of ligamentous laxity in the setting of inflammatory arthritis or prior PCL injury.
  - Can be used in prior patellectomy patients.
  - Historically was believed that *higher flexion* can be achieved with PS designs:
    - Now most recognize that the biggest determinate of *postoperative flexion angle* is the amount of *preoperative motion*.
- Disadvantages:
  - *Greater bone resection*:
    - The flexion gap increases with PCL sacrifice, resulting in greater femoral resection to adequately balance.
    - Can lead to an elevated joint line and risk of patella baja
  - Risk for elevated joint line (as above)
  - Risk of *dislocation*:
    - Femoral cam jump typically occurs in high flexion (with or without a varus/valgus force). It is characterized by the tibial post translating out of the confines of the femoral cam and posterior subluxation of the tibia. Often caused by a loose flexion gap:

      (a) Treatment is initially *closed reduction*.
      (b) *Revision* required for *recurrent instability*.
  - *Tibial post fracture/wear:*
    - PS designs rely upon cam-post articulation; however, inherent stresses are placed. Polyethylene post is at risk of wear (particularly in hyperextension). Can result in increased osteolysis from post wear.
  - *Patellar clunk*: *pain and audible clunk* associated with the entrapment of hypertrophied nodule (scar) at the proximal pole of the patella in the box. Distinct complication of *earlier PS designs*. Typically occurred at *30–45° flexion.*

**Cruciate Retaining Versus Posterior Stabilized**

- Despite the fervent dogma surrounding the use of PS and CR knees, studies have shown excellent long-term outcomes with regard to implant survival and patient function in both designs.

**Constrained (Non-hinged) TKA**

- The primary design features of a constrained non-hinged TKA is a high central post, wider post, and a deep femoral cam box; this acts to provide varus/valgus constraint.
- All constrained (non-hinged) designs are by definition posterior-stabilized designs as well.
- Important implant in complex primary and revision TKA.
- Indications:
  - Severe coronal deformity (particularly valgus deformity)
  - Collateral ligament insufficiency/deficiency
  - Recurrent instability (either midflexion, extension, or flexion in the coronal plane) in the setting of a standard PS or CR implant
  - Persistent flexion/extension imbalance
- Disadvantages:
  - Larger intercondylar notch bone cut needed to facilitate larger tibial post. Results in more bone loss and potential difficulty with revision surgery
  - Increased constraint:
    - *Increased stress* placed at implant-bone/implant-cement *interface*, resulting in *higher risk of aseptic loosening*
    - More stress placed on longer post-cam articulation, with *increased risk of post fracture and polyethylene wear*
  - The use of *stemmed* components to decrease stress at the interface

**Constrained (Hinged) TKA**

- Hinged TKA components are the most constrained components available on the market. They are characterized by a *linked* articulation at the *tibiofemoral joint*, which controls *sagittal and coronal motion*. Many designs possess a *rotating platform* which allows for *axial rotation*.
- Indications:
  - Severe collateral ligament deficiency
  - Hyperextension instability (i.e., recurvatum)
  - Massive bone loss: periarticular tumor resection, infection, high-energy periarticular trauma, and neuropathic joint
  - Global instability with dislocation
  - Deficient extensor mechanism (including when performing an extensor mechanism allograft)
- Advantages:
  - Affords global stability *(coronal and sagittal)* in the face of soft tissue deficiency
  - Can be used in situations of massive bone loss

- Disadvantages:
  - Risk of *aseptic loosening* is greater with increasing degree of constraint. Higher forces transmitted to bone-cement/bone-implant interface.
  - *Large degree of bone resection* is necessary to implantation. Subsequent revision surgery is more difficult.

  Requires the use of stems.

## 5 Patellofemoral Joint

Rachel M. Frank

**Take-Home Message**
- Isolated PF arthritis is often caused by PF instability.
- PF arthritis most commonly occurs in conjunction with TF arthritis, rather than in isolation.
- Treatment options vary, but ultimately many patients require TKA.

**Definitions**

- Main function of patella → *improve mechanical advantage* of extensor mechanism by increasing lever arm of quadriceps
- Q angle → angle from ASIS to center of patella to tibial tuberosity
  - *Males → 11–17°*
  - *Females → 14–20°*
- Maximum patellofemoral contact → 90° of knee flexion

**Etiology**

- PF arthritis occurs most commonly with tibiofemoral arthritis rather than in isolation.
- *Risk factors for patella instability* leading to PF arthritis:
  - Patella alta.
  - Trochlear dysplasia.
  - Excessive lateral patellar tilt.
  - Increased Q angle causes lateral shift of patella → increases contact force at PF joint and can lead to patella instability.
  - *Miserable malalignment syndrome* → combination of femoral anteversion, genu valgum, and external tibial torsion:
    - Leads to increased Q angle

- History of inflammatory arthritis (i.e., rheumatoid arthritis).
- History of trauma (i.e., patella fracture).

**Pathophysiology**

- Changes in articular cartilage → increased water content, increased IL-1 content, increased matrix metalloproteinase (plasmin, stromelysin) levels, increased chondrocyte activity and proliferation, decreased proteoglycan quantity, and decreased collagen quantity and stiffness.
- Changes in subchondral bone → increased thickness, osteophyte development, osteochondral junction breakdown, cyst formation, and microfracture formation.
- Patella cartilage is thick but thought to be less stiff and more compressible than other joints.

**Radiography**

- Standard AP, lateral, and merchant views:
  - Blumensaat's line (lateral view) → corresponds to roof of intercondylar notch.
    - With knee flexed to 30, line should touch inferior pole of patella.
  - Insall-Salvati ratio (lateral view) → ratio of patellar length (superior to inferior poles) to patella tendon length (inferior pole of patella to tibial tubercle):
    - Normal: between *0.8 and 1.2* (<0.8 suggests patella alta; >0.8 suggests patella baja).
  - Sulcus angle (merchant view) → formed by medial/lateral condyles and deepest point of sulcus, measurement of trochlear depth; *>138° indicates PF dysplasia.*
- Bilateral long-leg standing axis films to assess alignment and Q angle.
- MRI can be helpful in documenting status of patellar/trochlear cartilage to determine appropriateness for cartilage restoration procedures in early disease states.

**Treatment**

- Nonoperative:
  - Weight loss
  - NSAIDs
  - Injections → corticosteroid ± hyaluronic acid
  - Patella bracing/strapping
  - Physical therapy → quadriceps strengthening (focus on vastus medialis oblique (VMO))
  - Activity modification → avoid provocative knee flexion (deep squatting, stairs)
- Operative:
  - Arthroscopic debridement → controversial
  - Patellofemoral arthroplasty (PFA):

    - Relative indications → *isolated PF compartment disease*, normal alignment, and PF tracking; often performed in younger patients
    - Contraindications: inflammatory arthritis, poor patient understanding of the procedure and risks of future degeneration of the tibiofemoral joint, and severe patellar malalignment or maltracking
    - Improvements in trochlear design from inlay to onlay style have decreased incidence of postoperative patellar instability:
      – Onlay trochlear implant is placed perpendicular to AP axis of femur, so component rotation is not affected by native trochlear inclination.

– TKA:
    - With patella resurfacing:
      – Maintain a post-cut patellar thickness of greater than 12 mm to decrease risk of postoperative fracture.
      – Avoid overstuffing the patella to decrease risk of anterior knee pain.
    - Strict attention to rotational alignment of tibial/femoral components.
    - Aggressive lateral release if necessary (however, often times not required once alignment is corrected).
    - Avoid performing maneuvers that increase the Q angle including:
      – Internal rotation of the tibial component
      – Internal rotation of the femoral component
      – Lateral placement of the patellar component
      – Inferior placement of the patellar component
      – Medial placement of the femoral component

– Patellectomy:
    - Rarely performed due to 25–50 % reduction in knee extension strength and increased tibiofemoral contact forces

– Tibial tubercle osteotomy ± lateral release (for early OA):
    - Anteriorization (Maquet osteotomy)
    - Anteromedialization (AMZ, Fulkerson osteotomy):
      – *Anteriorization* → elevates distal extensor mechanism and shifts *patellar contact forces proximally*
      – *Medialization* → *decreases lateral force vector*
      – *Contraindicated* in patients with significant medial facet OA (as well as medial femoral condyle OA)

– Cartilage restoration (for focal grade IV osteochondral defects in young patients):
    - Microfracturing
    - Autologous chondrocyte implantation (ACI):
      – Improved outcomes when performed concurrently with AMZ compared to when performed in isolation

    - Osteochondral allograft/autograft:
        - Regardless of lesion size, better than microfracture and ACI if there is subchondral bone marrow edema present on MRI
  - Patellectomy:
    - Salvage, last resort only

**Treatment Algorithm**

- Young patient with isolated patellar or trochlear defect → realignment + cartilage restoration
- Young patient with mild PF disease → nonoperative management
- Young patient with severe, isolated PF disease → consider PFA versus TKA
- Patient with severe PF disease + mild-moderate TF disease → TKA

**Complications**

- PFA → implant failure and poor outcomes with early implant design.
  - Progressions of *tibiofemoral arthritis* and *patellar malalignment/instability* are *common causes of PFA failure*.
  - Patella fracture.
  - Adverse reactions to metal debris in joint (rare with nonmetal-backed patellas).

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## 6 Wear in TKR: Thickness, Geometry, Kinematics, Polyethylene Sterilization, and Machining

Peter K. Sculco

**Take-Home Message**

- Polyethylene wear dependent on contact stress – combination of load, contact area, and PE thickness.
- PE minimum thickness is 8 mm.
- Conformity of PE to femoral component geometry: highly conforming → higher contact area → lower stress → less wear.
- PCL retaining TKR: PE flat to allow more sliding versus PCL substituting use post-cam mechanism to ensure femoral rollback versus mobile-bearing PE highly conforming but higher backside wear.
- Sterilization of PE with gamma irradiation: irradiation → free radicals → cross-linking of PE chains.
- Sterilization in air is bad → oxidation of PE → decreased toughness and rapid clinical failure.
- Direct compression molding of PE has smoother finish and lower wear rate than a machined PE component.

### Types of PE Wear in TKR and PE Thickness

Four modes of wear in TKR:
Mode 1: articulation between intended bearing surfaces.
Mode 2: primary bearing surface against nonintended second surface (in TKR, if femoral component penetrates through a PE tibial bearing and rubs against tibial baseplate).
Mode 3: third body wear: contaminant particles directly abrade one or both of the primary surfaces (cement debris).
Mode 4: two secondary (nonprimary) surfaces rubbing together (backside wear between inferior surface of PE and tibial baseplate).

Wear damage (changes in appearance of PE)

Seven patterns of surface damage: embedded debris, scratching, pitting, burnishing, surface deformation, abrasion, and delamination. Delamination is seen in PE that has undergone oxidation.

Types of wear: steady-state linear (number of cycles) and time dependent (fatigue and delamination after accumulation of many cycles)

*PE thickness*: 8 mm is minimum PE thickness.

Contact stress increases with thinner PE design and results in greater wear. Catastrophic failure of PE if thickness less than 4 mm. No change in stress pattern once PE is 8 mm in thickness.

**PE Articular Geometry**

Conformity between tibial and femoral articulating surfaces has both sagittal and coronal geometries. As radius of femoral and tibial surfaces coincides, the articular conformity increases.

Most TKR design is a single radius for each condyle of femoral component and a single, slightly larger radius for each tibial plateau. Coronal (frontal) conformity limits internal/external rotation usually highly conforming (not much rotation in normal knee).

*High conformity* (deep dished PE): large contact areas → lower contact stresses → more constraint → less wear.

Downside: may not allow for physiologic movement (rotation).

*Low conformity* (flat PE) allows more physiologic motion.

Downside: smaller contact areas → higher contact stresses → greater sliding → higher wear rates.

Mobile bearing has high conformity → larger contact area → reduced wear compared to fix bearing but potential increase in 3rd body wear from metallic tray and inferior PE surface.

**PE Kinematics**

Motion pattern in a TKR: rolling, sliding, and rotation.

Design goal: Replicate femoral rollback → increase flexion.

Posterior cruciate-retaining (CR) TKR:

PCL tension → posterior femoral translation.
PE insert has flat surface that allows sliding.
Flat PE shape has large contact area, which lowers stress.

Posterior-stabilized (PS) cruciate-substituting TKR:

PE has a post-cam mechanism and more posterior femoral rollback with flexion than CR.
Downside: wear or fracture of post (rare).

Mobile bearing (MB): The design goal is to allow more normal joint kinematics with high conformity, larger contact areas, lower contact stresses, and presumably less wear.

**PE Sterilization**

PE sterilized with gamma irradiation between 3 and 3.5 Mrads.

Initially in the 1970s, gamma irradiated in air → oxygen led to oxidation of PE → breaks PE bonds → reduced toughness → fatigue cracking and delamination of PE → clinical failure.

Currently, gamma irradiation and packaging performed in argon, nitrogen, or a vacuum environment.

Gamma irradiation also produces free radicals which cross-links PE chains → improve wear resistance but decrease ductility (highly cross-linked has higher risk for post fracture).

**PE Machining**

Two types of PE fabrication

- Compression molding:

  Molding PE powder directly into PE shape
  Surface finish smooth, no machining marks
  0.05 mm wear/year in vitro

- Machined

  Made from stock PE material. Cylindrical ram-extruded bars or large sheets of PE
  Implant machined into final shape
  May generate subsurface cracking that predisposes to delamination
  0.11 mm/year wear in vitro

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## 7 Revision Total Knee Arthroplasty

Matthew P. Abdel

**Take-Home Message**

- The most common indications for revision total knee arthroplasty (TKA) include infection, patellofemoral issues, aseptic loosening, osteolytic wear, arthrofibrosis, and instability (flexion, varus, or valgus).
- Infection must be ruled out before proceeding with revision TKA:
- ESR, CRP, and aspiration (*WBC count above 1,700 cells/μL and/or neutrophil count >65 % is suspicious for infection*).
- Management of the extensor mechanism during revision TKA is essential, with virtually *no drawbacks to a quadriceps snip*.

### Indications for Revision

- Septic – should be evaluated using serum ESR and CRP, as well as a synovial fluid aspiration:
  - *Aspiration results of WBC >1,700 cells/μL, neutrophil count >65 % is suspicious for infection.*
  - *Sinus tract* communicating with the joint is an infection despite aspiration results.

- Aseptic:
  - Patellofemoral issues/extensor mechanism complications (poor patellar tracking, overstuffing of the patellofemoral joint, patellar fracture, incompetent extensor mechanism)
  - Abnormal joint line problems (e.g., instability)
  - Component loosening
  - Osteolytic wear:
    - Gamma irradiated polyethylene in air has most rapid wear rates.
    - Wear may be accelerated by third body wear.
  - Instability (most commonly midflexion instability, coronal plane instability, and flexion instability)
  - Periprosthetic fracture
  - Arthrofibrosis
  - Patellar clunk:
    - In *posterior-stabilized (PS)* total knee arthroplasties (TKAs), especially with *older designs*
    - Typically occurs at 30–45° flexion
    - Pain and audible clunk associated with the entrapment of hypertrophied nodule (scar) at the proximal pole of the patella in the box

**Assessment**

- History
  - Risk factors for infection: *previous infection*, draining wound, recent dental work, recent systemic infection (e.g., urosepsis), or prior revision procedure.
  - Query most recent antibiotic use.
  - Neurogenic pain such as radiculopathy (numbness, tingling into the foot).
  - Symptoms:
    - *Pain with weight bearing → mechanical etiology*
    - *Night pain and/or pain at rest → infection or tumor*
- Physical examination:
  - Appearance of wound (often difficult to differentiate aseptic versus septic etiology, unless persistent draining sinus present).
  - Effusion – good predictor of mechanical problem if the aspiration is normal:
    - Hemarthrosis can be a sign of midflexion instability.
  - Range of motion (ROM) – a stiff knee in a patient with previously good motion is suspicious for infection.
  - Ligamentous stability in both coronal and sagittal planes.
- Laboratory analysis:
  - ESR

- CRP – most specific systemic test
- CBC with differential
- Aspiration:
  - Obtain if infectious laboratories (ESR, CRP) are abnormal.
  - Send aspiration for cell count with differential and cultures (aerobic, anaerobic, fungal, AFB, gram stain).
  - WBC count above 1,700 cells/μL and/or neutrophil count >65 % is suspicious for infection.
  - Gram stain is a poor test, though often used.
  - Systemic WBC count does not correlate with periprosthetic joint infection.
  - Other possible tests to rule out infection include urinary dipstick test for strong presence of leukocyte esterase.

**Imaging**

- Radiographs:
  - *AP pelvis* (evaluate if hip joint may be source of pain)
  - *Full-le*ngth standing hip-to-ankle radiograph to evaluate alignment
  - Standing AP radiograph of both knees
  - Lateral radiograph of affected knee
  - Patellar views of both knees (i.e., merchant view)
  - *Prior radiographs*:
    - Pre-index surgical intervention radiographs
    - Immediate radiograph after primary procedure
    - Helps to confirm loosening, wear, and osteolysis
- Computerized tomography (CT)
  - Useful to determine extent of bone loss and osteolysis (usually underestimated by radiographs)
  - Allows for accurate assessment of component position (particularly *femoral and tibial component rotation*)

**Goals of Revision TKA**

- Remove components with minimal bone loss.
- Restore bony deficiencies and metaphysis with either allograft or tantalum metal or cement (if small contained defects).
- Restore joint line.
- Balance knee ligaments.
- Obtain stable and rigid fixation of revision implants.

**Prosthesis Selection**

- Unconstrained posterior cruciate ligament (PCL)-retaining TKA:
  - Rarely utilized during revision TKA
  - May be used when converting a unicompartmental knee arthroplasty or a high tibial osteotomy to a total knee arthroplasty
- Unconstrained PS TKA:
  - Utilize if *lateral collateral ligament (LCL) and medial collateral ligament (MCL) are functional* and there is no varus or valgus instability, respectively.
- Constrained PS TKA without a hinge:
  - *Wider and higher* central post assists with varus and valgus instability *if LCL and MCL are deficient*, respectively.
  - May assist with flexion instability given taller post.
- Constrained hinged TKA with rotating platform (RP):
  - Most constrained option
  - Constrained in the sagittal and coronal planes
  - Allows polyethylene to rotate, reducing forces at the bone-prosthesis interface
  - Indications:
    - MCL or LCL deficiency with global instability
    - Flexion gap instability, often in the setting of prosthetic knee dislocation
    - Posttraumatic TKA with compromised ligaments
    - Multiply revised TKA with compromised ligaments
    - Hyperextension instability (or recurvatum) seen in neurogenic patients
    - Oncologic reconstruction
    - In conjunction with extensor mechanism allograft
    - Deficient extensor mechanism
- Stemmed implants are always required for revision knee arthroplasty given the improved results over nonstemmed components:
  - Hybrid technique – cement around the metaphysis and the junction of the stem and keel of the component, but also use a press fit stem.
  - Fully cemented – difficult to remove if acutely infected.

**Anderson Orthopedic Research Institute (AORI) Classification of Bone Defects**

- Type 1: Minor femoral or tibial defects with intact metaphyseal bone, not compromising the stability of a revision component

- Type 2: Damaged metaphyseal bone that is typically cancellous in nature and requires reconstruction (cement fill, prosthetic augment, or bone graft) to provide stability of the revision component:
  - A: Defects in one femoral condyle or one tibial plateau
  - B: Defects in both femoral condyles or both tibial plateaus
- Type 3: Segmental deficiencies compromising a major portion of either femoral condyles or tibial plateaus, occasionally associated with collateral or patellar ligament detachment

**Surgical Treatment**

- Surgical exposure:
  - Large incision: Clean the medial and lateral gutters, and safely mobilize the extensor mechanism.
  - Advanced techniques in the setting of a tight extensor mechanism with difficult exposure:
    - Quadricep snip: *no difference in outcome.*
    - V-Y turndown: high incidence of extensor lag.
    - Tibial tubercle osteotomy (TTO): can be used in the setting of a fully cemented stemmed TKA to gain access to the metaphysis for cement removal; complications include nonunion, hardware prominence.
- Removal of implants:
  - The goal is minimal bone loss.
  - Lateral release may help expose lateral aspect of tibial baseplate.
  - Establish joint line:
    - 1.5–2 cm above head of fibula.
    - 3 cm distal to the medial epicondyle.
    - 1 cm from the superior pole of the patella to the proximal most portion of femoral component flange in extension.
    - Utilize contralateral knee x-rays to assess patellar height on the femur, distance from the inferior pole of the patella to joint line, or the distance from the adductor tubercle to the joint line.
- Balance flexion/extension gaps
- Balance medial and lateral gaps/ligamentous stability.
- Address patellofemoral tracking:
  - Keep current patella unless infection case or etiology of maltracking.
  - Patellar thickness should be *>12 mm* to avoid fracture.
- Salvage options:
  - Arthrodesis
  - Amputation

## Complications

- Wound complications
- Infection
- Stiffness
- Extensor mechanism disruption
- Pain
- Neurovascular injury

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## 8 Unicompartmental Osteoarthritis: Options for Management

Rachel M. Frank

**Take-Home Message**

- Osteoarthritis (OA) affecting either the medial or lateral compartment only (or patellofemoral compartment only), with medial compartment OA > lateral compartment OA.
- Etiology can vary, with predisposing factors including malalignment (varus leading to medial compartment OA, valgus leading to lateral compartment OA), prior meniscectomy, and prior articular cartilage injury; risk factors such as prior arthroscopy and prior ACL tear are controversial.
- Nonoperative options include weight loss, injections, and bracing; surgical options include cartilage/meniscal restoration, realignment, UKA, and TKA.

**Definitions**

- OA affecting either the medial or lateral compartment only; medial > lateral
- Can be primary (intrinsic) or secondary (trauma, infection, congenital)

**Etiology**

- Malalignment → varus leading to medial compartment OA, valgus leading to lateral compartment OA
- Prior articular cartilage injury
- Prior partial, subtotal, or total meniscectomy
- Prior ACL injury or prior knee arthroscopy (controversial)

**Pathophysiology**

- Changes in articular cartilage → increased water content, increased IL-1 content, increased matrix metalloproteinase (plasmin, stromelysin) levels, increased chondrocyte activity and proliferation, decreased proteoglycan quantity, and decreased collagen quantity and stiffness
- Changes in subchondral bone → increased thickness, osteophyte development, osteochondral junction breakdown, cyst formation, and microfracture formation
- Changes confined to medial or lateral compartment

**Radiography**

- Standard AP, lateral, merchant views + the Rosenberg view (45° flexion PA view).
- Bilateral long-leg standing axis films to assess alignment.
- Unilateral findings OA → joint space narrowing, osteophytes, subchondral sclerosis, and subchondral cysts.
- MRI can be helpful in documenting status of ACL, but not necessary.

**Treatment**

- Nonoperative:
  - Weight loss
  - Injections → corticosteroid ± hyaluronic acid
  - Unloader bracing → attempts to unload affected compartment, effectiveness controversial; compliance is an issue.
- Operative:
  - Articular cartilage ± meniscus restorative procedures:
    - Strict indications → isolated full-thickness chondral defects and/or meniscal deficiency:
      - Not for diffuse unicompartmental or bi-/tricompartmental OA
    - Must consider concomitant pathologies including malalignment and ligamentous instability → staged versus concurrent procedures
    - Salvage procedure(s)
  - Osteotomy:
    - The goal is to realign mechanical axis to unload affected compartment:
      - High tibial osteotomy typical for varus malalignment
      - Distal femoral osteotomy typical for valgus malalignment
    - Open or closed wedge
    - Strict recovery/compliance required with NWB regimen
    - Good-excellent 10+ year outcomes:
      - No difference in osteotomy patients post-TKA versus primary TKA patients
  - Unicompartmental knee arthroplasty (UKA):
    - Typically reserved for older (>60 years), nonobese (weight <82 kg), and lower-demand patients; however, indications are evolving.
    - Strictly contraindicated in inflammatory arthritis, fixed varus deformity >10°, fixed valgus deformity >5°; flexion contracture >10°, grade IV patellofemoral articular cartilage disease:
      - ACL deficiency absolute contraindication to mobile-bearing UKA and fixed-bearing lateral UKA:
        - Controversial in fixed-bearing medial UKA
    - Compared to TKA → faster recovery, less EBL, less soft tissue morbidity, and less expensive.
    - Preserves "normal" knee kinematics given retention of ACL and PCL.
  - Total knee arthroplasty (TKA):

  - Preferred in cases with severe unicompartmental OA + mild-moderate arthritic changes in opposite compartment and/or patellofemoral compartment
  - Advantageous in larger patients and ACL-deficient patients
  - Potential longer survivorship in TKA versus UKA

**Treatment Algorithm**

- Attempt nonoperative management first as described above
- Surgical intervention for patients that remain symptomatic
  - Main indications → pain relief + improve function
- Obese patients → weight loss first
- Young, athletic patients with high-demand, high-activity levels → osteotomy
  - Cartilage/meniscus restoration if appropriate
- Active patients with low-moderate activity levels → UKA
- Active patients with diffuse arthritic changes in either opposite compartment or patellofemoral compartment → TKA

**Complications**

- Main complication from UKA → tibial stress fracture (after pain-free interval)

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## 9 Spontaneous Osteonecrosis of the Knee (SONK)

Rachel M. Frank and Michael B. Cross

**Take-Home Message**

- SONK presents with a *sudden* onset of *severe* knee pain and by definition is an osteonecrosis lesion without clear etiology that can lead to osteoarthritis and subsequent knee surgery.
- Most common in *middle-aged and elderly females*, most often in the *medial femoral condyle*.
- *MRI* is the most helpful to make the diagnosis.
- Mainstay of treatment is *nonoperative* with *protected weight bearing*, though surgical intervention is sometimes warranted.

**Definitions**

Spontaneous osteonecrosis of the knee (SONK) – sudden onset subchondral insufficiency fracture often without a known etiology that is most commonly found in the medial femoral condyle

**Etiology**

- Unclear in most cases
- Important to differentiate from other diagnoses, including *osteochondritis dissecans* (more common in *lateral femoral condy*le in *younger* patients), *transient osteoporosis* (more common in *young to middle-aged men*), and occult fractures
- Can occur *following arthroscopy* of the knee

**Pathophysiology**

- Not well understood
- Likely component of *localized vascular insufficiency* causing necrosis of the subchondral bone, which ultimately leads to disruption of the nutrition and structural support of the overlying articular cartilage

**Radiography**

- AP, lateral, and merchant views of the knee with weight-bearing *flexion views*.
- Radiographs initially are likely to be normal or with minimal changes early in the disease process.

- *MRI* is the most helpful in diagnosis and in determining the extent of the disease.
  - The absence of focal epiphyseal contour depression and absence of lines of low signal intensity deep in condyle are good prognostic factors for benign disease course.
  - MRI can rule out other soft tissue injuries including meniscal and/or ligamentous pathology.
  - MRI can also be used to follow nonoperative treatment course to determine resolution of disease process.

**Classification**
None described

**Treatment**

- Nonoperative:
  - NSAIDs
  - Pain relievers, including narcotics for a short-term basis
  - Activity modification
  - *Protected weight bearing for up to 6–8 weeks*
  - Physical therapy to strengthen core and quadriceps
  - Possible role for vitamin D and bisphosphonate therapy
- Operative:
  - *Avoid arthroscopy*
  - Osteotomy to correct malalignment
  - Unicompartmental or total knee arthroplasty if nonoperative treatment fails

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## 10 Common Complications After TKA

Brandon J. Erickson and Michael Hellman

**Take-Home Message**

- Extensor tendon injury:
  - Patellar tendon rupture: 0.22–2.5 %.
  - Quad tendon rupture: 0.1 %.
  - Concomitant patella fracture can occur as well.
  - When surgically correcting these, you must address malrotation.
  - If patient needs reoperation for this, outcomes are poor (23 % required reoperation after extensor mechanism repair).
- Patellofemoral joint issues:
  - Soft tissue impingement (patellar clunk syndrome) – synovial/scar tissue or Hoffa's fat pad impinges between patellar and femoral components; treat conservatively but if this fails, perform arthroscopic debridement.
  - Instability/dislocation – most common reason for repeat surgery after TKA.
  - Component wear – often in obese patients secondary to increased forces across joint.
  - Fracture – often spontaneous and asymptomatic; older implant designs with single peg had increased risk of fracture and loosening.
  - Implant loosening – 0.06 to 4.8 %; often asymptomatic; lateral release increases risk as does obesity.
- Periprosthetic fracture:
  - The most common area is the supracondylar region of femur above a well-fixed TKA:

    Often treated with ORIF if implant is stable
  - Tibia fractures are less common:

    Often associated with implant loosening
  - 0.3–2.5 % of patients who get TKA will sustain a periprosthetic fracture:

    Patella: 0.33–5.2 %
  - Where the fracture occurs/implant stability will dictate treatment:

    Above a well-fixed implant – treat with fixed-angled, locked, percutaneous plate

    If implant is loose – revision TKA to long-stem prosthesis

    With significant bone loss – revision TKA to distal femoral replacement tumor prosthesis

**Definitions**

- PFJ: patellofemoral joint
- MPFL: medial patellofemoral ligament

**Etiology**

- Extensor tendon injury:
  - Risk factors: obese patients, revision cases, difficult exposure, preoperative flexion contracture/angular deformity, quadriceps release (quadsnip), diabetes, and kidney malfunction
- Patellofemoral joint issues:
  - Soft tissue impingement (patellar clunk syndrome) – synovial/scar tissue or Hoffa's fat pad impinges between patellar and femoral components; can cause mechanical symptoms of locking/catching/popping and pain.
  - Instability/dislocation – from patient factors, errors in surgical technique, or implant design flaws.
  - Component wear – obesity increases stress across PFJ, leading to faster wear of polyethylene, as does increased deep knee bending.
  - Fracture – often spontaneous and asymptomatic; older implant designs with single peg had increased risk of fracture and loosening secondary to stress riser created by large peg.
  - Implant loosening – 0.06–4.8 %; often asymptomatic; obesity increases risk by 6.3 times, lateral release increases risk by 3.8 times, an elevated joint line increases the risk 2.2 times, and flexion beyond 100° increases the risk by 2.1 times the normal.
- Periprosthetic fracture:
  - Trauma, often low energy, in elderly patients secondary to osteoporosis, disuse osteopenia, and stress shielding around implant (transition from implant to native bone is a stress riser).
  - Patella fracture can be secondary to excessive or inadequate bone resection at the time of the TKA; improper alignment increases risk for patella fracture:
    - Medial parapatellar approach compromises patella vascularity (if combined with lateral release, vascularity is significantly damaged).

**Pathophysiology**

- Extensor tendon injury:
  - Often follows trauma
  - Can also be an eccentric load on tendon
- Patellofemoral joint issues:
  - Instability/dislocation:

    - Patient risk factors: severe patellofemoral degeneration, significant preoperative valgus malalignment, and patellar subluxation
    - Technique errors: patella alta, leaving limb in significant valgus, uneven patellar resection or lateral placement of button, increased internal rotation of tibial/femoral components, and medial translation of femoral component
    - Design flaws: shallow/narrow trochlear groove

- Periprosthetic fracture:
  - Patient risk factors:
    - Rheumatoid arthritis, osteolysis, osteoporotic bone, and steroid use
  - Technique-specific risk factors:
    - Notching the anterior femoral cortex
- Beware of bipartite patella (accessory ossification center) – not a fracture:
  - Superolateral aspect of patella, often bilateral

**Radiography**

- AP/lat/merchant views of knee – evaluate patellar height (lateral) for quad/patellar tendon rupture and resting position of patella (merchant).
- CT scan to determine component stability and malpositioning, especially in patellofemoral instability.
- MRI rarely necessary.

**Classification**

- Lewis and Rorabeck (periprosthetic femur fracture around TKA):
  - Type I – non-displaced, component stable
  - Type II – displaced, component stable
  - Type III – displaced or non-displaced, component loose or failing
- Felix and associates (periprosthetic tibia fracture):
  - Type I – fracture at tibial plateau.
  - Type II – adjacent to prosthetic stem.
  - Type III – distal to prosthetic stem.
  - Type IV – involving the tibial tubercle.
  - Each type is further classified as A, B, and C:
    - A – fracture around well-fixed implant
    - B – fracture around radiographically loose implant
    - C – Intraoperative fracture

- Goldberg (periprosthetic patella fracture):
  - I – fractures not involving implant/cement composite or quad mechanism
  - II – fractures disrupting the quad mechanism or implant fixation
  - IIIA – fracture of inferior pole w/ patella tendon rupture
  - IIIB – fracture of inferior pole, non-displaced, intact patella tendon
  - IV – lateral fracture-dislocation (shear fracture)

**Treatment**

- Extensor tendon injury:
  - Quad injury can be treated conservatively if patient maintains the ability to extend knee to 20° and is low demand:
    - Immobilize in extension.
    - If this fails or patient is unable to straighten leg, operative intervention with suture repair will be needed:
      - Use the Scuderi (quad flap) turndown technique.
  - Patellar tendon injury:
    - Poor outcomes (up to 75 % failure rate with suture repair).
    - Often require graft augmentation (Achilles allograft, semitendinosus autograft) to aid suture repair.
    - Soft tissue coverage can be an issue – medial gastrocnemius flap can help tale tension off the skin.
  - Periprosthetic fracture:
    - Non-displaced:
      - Can consider cast immobilization with NWB and close radiographic follow-up
    - Displaced femoral fracture with well-fixed prosthesis:
      - Consider retrograde IM nail if prosthesis is cruciate-retaining TKA:
        - Posterior-stabilized design does not allow access to canal.
      - Often treated with fixed-angled, locked, percutaneous plate.
    - Displaced tibial fracture with loose prosthesis:
      - Revision arthroplasty with longer stem.
      - If implant is stable, consider ORIF.
    - External fixators are not frequently used because of risk of pin-site infections.
  - Patellofemoral joint:

- Patella fracture:
  - Conservative – if component is not loose and patient can extend to 20°, this is a viable option.
  - Operative intervention (ORIF or component revision) if patient has significant loss of extension or component is loose.
  - In non-resurfaced patella: ORIF – cannulated screws alone or tension band construct via cerclage wires, suture, cannulated screws/wires or sutures:
    - Biomechanically, cannulated screws with tension band construct fail at the highest loads.
  - Patellectomy (only if not repairable):
    - You will lose the benefit of the patella which is to increase the moment arm of the extensor mechanism by moving the attachment point for the quadriceps away from the center of rotation of the knee (basically the pt will be weaker in extension by approximately 50 % without their patella).
  - Loosening:
    - Only treat if patient has pain and mechanical symptoms or implant has become dislodged.
  - Instability/dislocation:
    - Conservative – IT band stretching and vastus medialis strengthening, patellar stabilization brace
    - Operative – if conservative measures fail:
      - Lateral release – although risks increasing overall instability.
      - Vastus medialis advancement of medial soft tissue imbrication.
      - Tibial tubercle osteotomy – either medialization or anteromedialization.
      - Last resort is component revision.
  - Patella clunk syndrome:
      - Start conservative with strengthening of quads, massage, and ultrasound.
      - If this fails, perform arthroscopic debridement.

**Complications**

- Periprosthetic fractures:
  - Malalignment (usually valgus deformity with hyperextension)
- Repeated subluxation or possible frank dislocation:
  - Often associated with MPFL rupture

- PF joint:
  - Refracture
  - Malunion or nonunion
  - Component loosening
  - Continued instability

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## 11 Deep Venous Thrombosis, Venous Thromboembolism (Prevention and Treatment)

Rachel M. Frank and Michael B. Cross

**Take-Home Message**

- *Prevention* of symptomatic venous thromboembolism is essential, but one must outweigh risk of bleeding versus risk of pulmonary embolism for each individual patient.
- The AAOS recommends the use of *pharmacologic and/or mechanical devices* for VTE prophylaxis in patients undergoing elective TKA/THA; however, there are *no consensus pharmacologic* agent recommendations.
- Proximal DVTs require treatment; however, the necessity of treatment for DVTs distal to the trifurcation is unclear.
- Early diagnosis and treatment is the key to survival in patients with PE.

### Definitions

- *Virchow's triad → endothelial injury, hypercoagulable state, venous stasis*
- VTE → venous thromboembolic event, which encompasses the disease spectrum of both DVT and PE

### Etiology/Risk Factors

- Risk factors for VTE (Table 1):

**Table 1** Risk factors for DVT/PE

| | | |
|---|---|---|
| Genetic | | Protein S deficiency |
| | | Factor V Leiden mutation (Arg506Gln mutation) |
| | | Prothrombin gene mutation (G20210A mutation) |
| | | Protein C deficiency |
| | | Antithrombin III deficiency |
| | | Heparin cofactor II deficiency |
| | | Plasminogen deficiency |
| | | Factor XII deficiency |
| | | Dysfibrinogenemia |
| | | Increased factor VIII activity |
| | | Increased factor XI activity |
| | | Primary hyperhomocysteinemia |

| | | |
|---|---|---|
| Acquired | Traumatic | Acute trauma |
| | | Surgery within the last 3 months |
| | | Especially major abdominal, pelvic, and orthopedic surgery |
| | Lifestyle | Obesity |
| | | Cigarette smoking |
| | | Increasing age |
| | | Travel (e.g., air) lasting longer than 4 h within the last 2 months |
| | | Prolonged immobilization |
| | Medical | Prior history of VTE |
| | | Malignancy |
| | | Hypertension |
| | | Stroke with paresis/paralysis of the extremity |
| | | Secondary hyperhomocysteinemia |
| | | Antiphospholipid syndromes (e.g., SLE) |
| | | Congestive heart failure |
| | | Myocardial infarction |
| | | Myeloproliferative disorders (e.g., polycythemia vera, essential thrombocythemia) |
| | | Nephrotic syndrome |
| | | Inflammatory bowel disease |
| | | Sickle cell anemia |
| | | Marked leukocytosis in acute leukemia |
| | | Chronic kidney disease |
| | | Hematopoietic stem cell transplantation |
| | | Pregnancy and puerperium |
| | Medication related | Oral contraceptive |
| | | Hormonal replacement |
| | | Heparin-induced thrombocytopenia |

- Factors specifically associated with increased risk of DVT:
  - Polytrauma
  - Hip fracture or pelvic fracture requiring prolonged immobilization or bed rest
  - Elective TKA/THA:
    - *Elective TKA 2–3× greater rate than elective THA*
- Factors specifically associated with increased risk of PE:
  - Hip fracture or pelvic trauma
  - Elective TKA/THA:
    - Occurs more frequently with *cement pressurization* of femoral canal
    - In general, during THA, DVTs occur most frequently during *femoral preparation*:
      - *Intraoperative heparin* can be used to prevent DVT during femoral preparation.
      - *Neuraxial anesthesia* also reduces risk of VTE.

**Pathophysiology**

- During surgical dissection, blood vessel intimal injury can be sustained:
  - In an attempt to form a clot to prevent excessive bleeding:
    - Vessel contraction
    - Collagen release
    - Tissue thromboplastin (tissue factor) release → extrinsic coagulation pathway
      - Activates factor VII → activates factor X → converts prothrombin to thrombin
        - Converts fibrinogen to *fibrin* → induces clot formation
- Venous stasis → clot formation

**Diagnostic Modalities**

- Physical examination
  - DVT → calf pain, low-grade fevers, and erythema and swelling in the lower extremity; *Homans' sign* not specific
  - PE → pleuritic chest pain, dyspnea, tachypnea, tachycardia, and fever
- Imaging
  - DVT → venous duplex ultrasound more sensitive and specific for DVTs *proximal to trifurcation* compared to distal, helical CT with contrast (when PE is being evaluated)
  - PE → CXR (often negative), V/Q scan (rare), *helical chest CT with contrast (most commonly used)*, pulmonary angiography (gold standard but rarely used)
- EKG → tachycardia, nonspecific ST-T wave changes; "classic" finding of S1-Q3-T3 is nonspecific.
- ABG on room air → typically reveals hypoxemia, hypocapnia, and respiratory alkalosis

**Prophylaxis**

- Mechanical prophylaxis
  - Compressive stocking
  - Pneumatic compression devices → recommended by AAOS across all risk groups:
    - Increase venous return
    - Increase endothelial-derived fibrinolysis
    - Decrease venous compliance
    - Decrease venous stasis
- Chemical prophylaxis
  - Multiple possible agents:

  - Warfarin → limits *vitamin K metabolism* by inhibition of vit K 2,3 epoxide reductase, limiting production of *clotting factors II, VII, IX, and X*
    - Also *limits* production of *protein C and protein S*
      - *Temporary prothrombotic effect*
    - Reversed by *vitamin K, fresh frozen plasma (FFP)*
    - *Half-life of single dose → 2–5 days*
  - Aspirin → acts on *platelets* and inhibits production of prostaglandins and thromboxanes via irreversible inactivation of cyclooxygenase (*COX) enzyme;* remains active for *7–10 days*
  - Low molecular weight heparin (enoxaparin, dalteparin) → enhances *inhibition of Xa*:
    - Reversed by *protamine*
    - Not associated with heparin-induced thrombocytopenia (HIT)
    - Half-life approximately 4.5 h, duration in plasma approximately 12 h
  - Unfractionated heparin → enhances *ATIII inhibition of IIa and Xa*:
    - Reversed by *protamine.*
    - Risk of heparin-induced thrombocytopenia (HIT) → typically thrombocytopenia 5–12 days into therapy.
    - Half-life is 1–2 h but is dose dependent.
  - *Fondaparinux (Arixtra)* → factor *Xa inhibitor*:
    - Increased bleeding complications given that there is *no reversal agent*.
    - *Half-life is 15–20 h and may last for 2–3 days*.
- *Inferior vena cava filter*
  - Preoperatively placed in patients with known DVT or who are at high risk for DVT
  - Preoperatively placed in patients who *cannot tolerate chemical prophylaxis due to high risk of bleeding*

**Treatment Considerations**

- Prevention of symptomatic venous thromboembolism is essential but must *outweigh risk of bleeding* versus *risk of pulmonary embolism.*
- Risk factors for major bleeding:
  - History of bleeding disorder
  - History of recent GI bleed
  - History of recent hemorrhagic stroke
- Risk factors for pulmonary embolism:
  - History of hypercoagulable state
  - Previous PE

### Treatment Options for DVT and PE

- *Proximal DVT:* intravenous *heparin* (until warfarin therapeutic) + *warfarin*; another option is *therapeutic Lovenox* if warfarin cannot be tolerated:
  - Distal DVT treatment (below knee) → controversial if warrants treatment.
  - Duration of treatment is variable, typically *3–6 months*.
- *PE: IV heparin + warfarin*:
  - Duration of treatment is variable, typically 3–6 months.
  - Occasionally thrombolytics are warranted in emergent situations.
  - Surgical removal (embolectomy) of the clot if PE life threatening.

### AAOS 2011 Clinical Practice Guidelines

- Recommend *against* routine postoperative Doppler.
- Recommend *for* work-up of potential previous VTE events.
- Recommend *for* work-up of known bleeding disorders or active liver disease.
- Recommend *for* cessation of antiplatelet agents before TKA/THA (usually 7 days).
- Recommend *for* use of pharmacologic and/or mechanical devices for VTE prophylaxis:
  - Unable to recommend specific agents
  - Unable to recommend duration of prophylaxis
- Patients with previous VTE should receive mechanical and pharmacologic prophylaxis.
- Patients with known bleeding disorder should receive mechanical prophylaxis.
- Recommend *for* early mobilization following TKA/THA.
- Recommend neuraxial anesthesia to help limit blood loss.
- Unable to recommend for or against IVC filters.

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## 12 Perioperative Management of the Rheumatoid Arthritis Patient

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**Take-Home Message**

- Rheumatoid arthritis (RA) patients should be evaluated for cardiovascular/pulmonary disease, cervical spine involvement, and cricoarytenoid arthritis, in addition to the usual perioperative evaluation.
- RA patients with prolonged use of glucocorticoids may have suppression of the HPA-axis and require stress dose steroids in the perioperative period.
- Methotrexate and hydroxychloroquine can be continued in the perioperative period.
- Discontinue agents that can cause leukopenia such as cyclophosphamide, azathioprine, and sulfasalazine at least 1 day prior to surgery.
- Discontinue biologic disease-modifying antirheumatic drugs (DMARD) for 1–2 treatment cycles; resume postoperatively once wound healing is complete.

**Background**

- Patients with RA should receive the same preoperative cardiovascular, pulmonary, and other risk assessment as other patients.
- Additional considerations:
  - Coordinate care with rheumatologist.
  - Assess:
    - Level of immune suppression
    - Hypercoagulable states
    - Status of rheumatologic disease
    - Steriod use

**Perioperative Evaluation and Management**

- Cardiovascular disease:
  - RA is associated with a 60 % increase risk of cardiovascular death as compared to the general population.
- Pulmonary disease:
  - Variety of pulmonary diseases:
    - Fibrosis, bronchiolitis, and pleuritis
- Cervical spine disease:
  - C1/C2 instability, atlantoaxial impaction, and subaxial disease:
    - Risk factors associated with instability include glucocorticoid use, seropositivity, nodular disease, and erosive peripheral joint disease.
  - *Obtain C-spine flexion/extension views to detect subluxation.*
- Cricoarytenoid joint disease:
  - Prevalence: up to 75 % of patients affected.
  - May lead to *difficulty with intubation*.
  - Physical symptoms include hoarseness, sore throat, dysphagia, odynophagia, pain with speech, and radiation of pain to ears.
  - Consider in patients with postoperative respiratory difficulty.
  - Assess with direct laryngoscopy.
- Anemia:
  - Common in patients with RA.
  - Postoperative blood transfusions often required in large joint arthroplasty.
  - Consider preoperative autologous blood donation.

- Neutropenia:
  - Common in patients with Felty's syndrome
  - Usually no intervention is required
  - Extremely low counts can be treated with G-CSF
- Laboratory testing:
  - Urinalysis, bone morphogenetic protein, complete blood count, and coagulation panel.
  - Vitamin D deficiency associated with suboptimal outcomes in patients undergoing total joint arthroplasty.
  - Exclude asymptomatic urinary tract infection.

**General Preoperative Management**

- Preoperative physical therapy:
  - Associated with better physical function at 12 weeks
- Weight reduction:
  - Reduce stress on joints
  - Possible increased incidence of infection in obese patients following total joint arthroplasty
- Thrombosis risk:
  - Incidence of 1 %.
  - Patients with RA have a reduced relative risk for venous thromboembolism as compared to patients with OA.

**Perioperative Antirheumatic Medication Management**

- Glucocorticoids:
  - Prolonged use can *suppress HPA-axis*.
  - Usefulness of ACTH stimulation testing unclear.
  - Supplementation of glucocorticoids may be necessary in perioperative period:
    - Patients on low dose (*<7.5 mg/day prednisone*) or any dose for less than 3 weeks:
      - Give usual daily dose (no need for stress dose steroids).
    - Patients on intermediate doses (*7.5–20 mg/day*):
      - Data suggest overuse of stress dose steroids.
      - Individualize steroid use based on chronicity of treatment, stress of surgery, and infection risk.

  - Patients on chronic moderate- to high-dose therapy *(>20 mg/day prednisone or >3 weeks*):
    - Assume secondary adrenal suppression.
    - Treat with stress dose steroids.

- Methotrexate:
  - Concern that immune modulating effect may increase risk of infection.
  - Most prospective and retrospective studies suggest *MTX can be continued without impairing wound healing or increasing risk of infection*.
  - Little evidence to suggest stopping MTX perioperatively improved wound healing or decreased incidence of infection.

- Leflunomide:
  - May impair wound healing; studies are contradictory.
  - *Consider holding in patients where large wounds are anticipated*.
  - Long half-life (approximately 2 weeks).
  - Resume 3 days post-op.

- Cyclophosphamide, azathioprine, sulfasalazine:
  - All may cause neutropenia.
  - Discontinue on day of surgery.

- Hydroxychloroquine:
  - Continue in perioperative period.
  - One study showed increased risk of post-op infection in association.
  - *Long half-life and persists in tissues, therefore impractical to discontinue*.

- Biologic agents:
  - Interfere with TNF-alpha, IL-1, IL-6, T cell costimulation, or deplete B lymphocytes.
  - Little evidence regarding the optimal use in perioperative period.
  - Generally, discontinue and restart once wound healing has completed:
    - TNF-alpha inhibitors:
      - *Infection is a known complication of therapy*.
      - Hold in the perioperative period, at least 1–2 treatment cycles.
      - Restart after wound healing has progressed to suture or staple removal.
      - Half-lives of drugs vary.
    - B cell-depleting agents (rituximab):
      - Prolonged B cell depletion with treatment
      - Associated with increased risk of pulmonary infection

  - No published data regarding surgical complications
  - Elective surgery: await return of B cells (CD 19+)
  - *Not a contraindication to non-elective surgery*
  - Recommend discussion with rheumatologist

- IL-1 receptor antagonist (anakinra):
  - Insufficient data to guide use
  - Infection rate similar to those patients receiving placebo

- T cell costimulation (abatacept):
  - No trials assessing perioperative safety.
  - Recommend discussion with rheumatologist:
    - NSAIDs
      - *Stop three half-lives prior to surgery.*
      - Aspirin should be discontinued 1 week prior to surgery.

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