Patella Fractures
and
Extensor Mechanism Injuries

Paul S. Whiting MD
Director of Orthopaedic Trauma Research
Assistant Professor – University of Wisconsin
Overview & Objectives

• Epidemiology & Mechanism of Injury
• Anatomy & Biomechanics
• Diagnosis & Classification
• Non-Operative Treatment
• Operative Treatment
  • Patella Fractures: Simple & Complex
  • Quad/Patella Tendon Injuries
• Complications
• Summary/Key Points
Illustrative Cases Throughout This Lecture
Epidemiology & Mechanism of Injury

• Patella Fractures:
  • ~1% of all fractures

• Mechanism of Injury:
  • Direct impact (fall, dashboard)
  • Indirect (forceful quadriceps contraction)
    • Frequent cause of patella tendon/quad tendon ruptures
  • Combined (impact + quad contraction)
Anatomy – Blood Supply

• Geniculate arteries (branches of popliteal artery)
  • Lateral Superior (LS)
  • Medial Superior (MS)
  • Lateral Inferior (LI)
  • Medial Inferior (MI)
  • Supreme (S)
    (branch of SFA)
  • Anterior Tibial Recurrent (ATR)
    (branch of anterior tib)

• Robust blood supply:
  • Even in setting of fracture, most fragments retain blood supply
Anatomy – Articular Facets

• Medial Facet:
  • Separated from lateral facet by vertical ridge
  • Usually concave, but can be convex

• Odd Facet:
  • Medial border of the patellar articular surface
  • Only contacts femur in flexion >45 degrees

• Lateral Facet:
  • Largest facet (typically)
  • Concave

Image Source: Misir et al. Fracture Patterns and Comminution Zones in OTA/AO 34C Type Patellar Fractures. J Orthop Trauma 2020 May;34(5). E159-e164. Fig. 1.
Anatomy – Bipartite Patella

• Normal anatomic variant
• Secondary ossification center fails to fuse to primary ossification center
• Often *mistaken* for an acute fracture
• Most commonly superolateral
• Smooth, well-corticated edges
• Bilateral in ~50% of patients

Image Source: Rockwood and Green’s Fractures in Adults, 9th Edition, Fig. 59-2.
Anatomy – Articular Cartilage

• Undersurface of Patella:
  • Covered with thick articular cartilage
  • Up to 1cm thick

• Distal pole:
  • Devoid of cartilage
  • As a result, most distal pole fractures are extra-articular injuries
Biomechanics

- Extensor mechanism critical for:
  - Maintaining upright posture
  - Generating torque for knee extension
- Patella serves to *displace* the quad tendon away from knee’s center of rotation:
  - Increases quad tendon’s moment arm
  - ↑ Mechanical advantage up to 50%
- Significant tensile forces generated
  - Up to 6,000 N (~8x body weight)
Biomechanics

• Patella Experiences 3-Point Bending forces in knee flexion
  • Where articular cartilage is thickest

• Patello-Femoral Contact Forces:
  • Greater than any other joint
  • Up to 7x body weight
  • Highest during squatting, ascending and descending stairs
Diagnosis – Physical Exam

• All Extensor Mechanism Injuries:
  • Hemarthrosis/Effusion
  • Inability to perform straight leg raise
    * If retinaculum intact, pt may be able to SLR

• Patella fractures:
  • Palpable defect between fracture fragments

• Quad Tendon/Patella Tendon Injury:
  • Palpable defect:
    • Proximal to patella (quad tendon injury)
    • Distal to patella (patella tendon injury)
Diagnosis – Patella Fractures

• X-rays (AP/Lateral)
  • Typically sufficient to confirm diagnosis
  • Lateral view:
    • degree of displacement
  • AP view:
    • fracture obliquity & degree of comminution
• Sunrise view:
  • Additional fracture characteristics
Diagnosis – Patella Fractures

• Advanced imaging:
  • CT Scan
    • In comminuted fractures, helpful for pre-op planning
    • Improved understanding of fracture pattern:
      • # of fragments
      • Fracture orientation
      • Articular impaction/step-off
  • MRI
    • Rarely needed for isolated patella fractures
    • Useful if concomitant knee ligament injury suspected
Diagnosis – Quad/Patellar Tendon Injuries

- **X-ray: Lateral view**
  - In 90 flexion, superior pole normally rests *posterior* to the anterior femoral line
  - With patella tendon injury, patella rests *anterior* to the anterior femoral line

Image Source: Rockwood and Green's Fractures in Adults, 9th Edition, Fig. 59-3.
Diagnosis – Quad/Patellar Tendon Injuries

• X-ray: Lateral view
  • Insall-Salvati Ratio:

\[
\frac{\text{Length of patella tendon (b)}}{\text{Length of patella (a)}}
\]

• >1.2 = patella tendon tear (patella alta)
• < 0.8 = quad tendon tear (patella baja)

• Example:

\[
\text{Patella tendon length} = 67\text{mm} \quad \text{Patella length} = 45\text{mm}
\]

\[
\text{Ratio} = 1.49 \quad \text{(patella alta)}
\]

Image Source: Rockwood and Green’s Fractures in Adults, 9th Edition, Fig. 59-3.
Diagnosis – Quad/Patellar Tendon Injuries

• X-ray: AP view

  • Normal Patella position:
    • Inferior pole within 2cm of the plane formed by distal femoral condyles

  • Patella alta:
    • Concern for patella tendon injury

  • Patella baja
    • Concern for quadriceps tendon injury

*Image Source: Rockwood and Green’s Fractures in Adults, 9th Edition, Fig. 59-3.*
Diagnosis – Quad/Patellar Tendon Injuries

• MRI:
  • Confirms physical exam and X-ray findings in quad/patella tendon injury
  • *Disruption* of quadriceps (or patellar tendon)
  • *Laxity or redundancy* of the opposite side of the extensor mechanism
Classification

• Descriptive Classification
  • Displaced vs. Undisplaced
  • If *displaced*, need to describe...
    • Primary Fracture Line (Transverse vs. Vertical)
    • Location (midportion vs. superior or inferior pole)
    • Degree of comminution

• AO/OTA Classification rarely used

Image Source: Rockwood and Green’s Fractures in Adults, 9th Edition, Fig. 59-4.
Non-Operative Treatment

- Patients medically unfit for surgery
- Non-displaced fractures
- “Minimally displaced” fractures with intact extensor mechanism
  - No clear consensus on “acceptable” amount of displacement
  - Depends in part on patient’s 
    activity level
- Pre-existing arthritis:
  - Favors non-operative treatment
Non-Operative Treatment

• 63 yo M – Fall from standing – Closed Fx – Intact Extensor Mechanism

Injury Films showing 3mm articular gap
- WBAT, hinged knee brace
- Locked in full extension

6-week F/U X-rays
- Allowed Active Flexion,
  Passive Extension 0-60°
- Progress 10° per week

12-week F/U X-rays
- Allowed Unrestricted
  ROM/strengthening
Non-Operative Treatment – Example # 2

- 80 yo M – Fall from standing – Intact Ext. Mechanism – Bad arthritis

Injury Films – some articular incongruity
- WBAT, hinged knee brace
- Locked in full extension

2-week F/U
- No interval displacement

6-week F/U X-rays
- Allowed Active Flexion, Passive Extension 0-60°
- Progress 10° per week

12-week F/U X-rays
- Allowed Unrestricted ROM/strengthening
Operative Treatment – Many Options!

• Most described techniques are for simple fractures:
  • Transverse
  • Non-comminuted
  • Good bone quality

• Simple Fracture patterns best illustrate key concepts:
  • Resisting tensile forces
  • Interfragmentary compression

Image Source: Rockwood and Green’s Fractures in Adults, 9th Edition, Fig. 59-6.
Operative Treatment – Transverse Fractures

• Tension Band Wire (TBW) – Concept:
  • Converting *tensile* forces (extensor mechanism) into *compressive* forces (at the fracture site)

Used with permission. Image Source: http://surgeryreference.aofoundation.org
Operative Treatment – Transverse Fractures

• Tension Band Wire (TBW) – Concept:
  • Controversial Theory
  • Several Biomechanical Studies refuting this theory
Operative Treatment – Transverse Fractures

• Tension Band Wire (TBW) – Concept:
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Conclusions: Tension band wiring fulfills from a biomechanical perspective the requirements for sufficient stability of transverse patella fracture fixation. It should, however, rather be considered as a static fixation principle than a dynamic one. Tension band wiring with cannulated screws was found advantageous over Kirschner wires in terms of interfragmentary movements at the posterior fracture site.
Operative Treatment – Transverse Fractures

• Tension Band Wire (TBW): **Alternative approach:**
  • Achieve compression *intra*-operatively with cannulated screws
  • Utilize SS wire or non-absorbable suture to *augment* fixation
    • Wire/Suture acts in “Neutralization” Mode
  • Wire or suture can be cut by prominent screw tips
  • Prominent screws *also* compromise biomechanical stability of screw/TBW constructs (cadaveric study)
    - Increased fracture gapping during cyclic loading

Avery et al. *CORR* 2019

Make sure screw tips are buried

Courtesy of OTA archives
Case Example: 42yo F, fall while running uphill

• Healthy, active, high-intensity athlete
Transverse Patella Fracture

• **Pre-operative Plan**
  
  • Reduction Technique(s)
    • examples will be illustrated
  
  • Implant Choice
    • Traditional TBW?
    • Cannulated screws?
  
  • “Tension Band” Material
    • 18-gauge wire vs. suture?
  
  • Soft Tissue Augmentation
    • When is it needed?
Reduction Techniques

- Large pointed reduction clamps ("Weber clamps")
  - Generating compression
  - Best to use two clamps
- One K-wire in each fragment
  - Use these as "joysticks"
  - Helps fine-tune reduction rotationally and in the sagittal plane
Reduction Techniques – Rotational Views

**Key Point:** Multiple lateral views (int/ext rotation) are **critical** to assess accurate articular reduction.
Implant Placement

- Place K-wires as posterior as possible
  - Closer to articular surface
  - Biomechanically superior

- If using traditional TWB:
  - Provides a more balanced tension band construct

- If using cannulated screws:
  - Improved compression of articular surface
Implant Choice:

Traditional TBW vs. Cannulated Screws?

Either is fine for *simple* fractures

Image Source: Smith ST et al. Early Complications in the Operative Treatment of Patellar Fractures, *J Orthop Trauma.* 1997 Apr;11(3):183-7. Fig. 1D.
Implant Choice:

• Traditional Tension Band Wire
  • Advantages:
    • Low-cost
    • Simple, time-tested
  • Disadvantages:
    • Does not generate compression at Fx site
    • Hardware prominence VERY common
    • Implant removal in **up to 38% of cases**

Gosal et al. Injury, 2001
Implant Choice:

- Cannulated Screws
  - Advantages:
    - Generates compression at Fx site
    - Higher load to failure than:
      - TWB construct with K-wires
      - Screw fixation alone

Image Source: Carpenter JE, et al. Biomechanical evaluation of current patella fracture fixation techniques. *J Orthop Trauma* 1997;11(July(5)):351–60. Fig. 1.
OTA Video Library Link:
Implant Choice:

• Cannulated Screws
  • Disadvantages:
    • Higher cost
    • Challenge: passing wire/suture through screw
  • No standard screw size recommendation:
    • 4.5 mm
    • 4.0 mm
    • 3.5 mm
    • Pros/Cons of each size
  • Key advantage of 4.5 mm screws:
    • Ability to use commonly available suture passer
      • Easier than Keith Needles
Implant Choice:

- Cannulated Screws
  - Disadvantages:
    - Dependent on bone quality
    - Hardware prominence may be similar if SS wire is used for the tension band
      - Wire knots still present

Image Source: Smith et al. JOI 1997. Fig 1D.

Image Source: Carpenter et al. JOI 1997. Fig. 1.
Implant Choice:

• If using cannulated screws...
• What to use for the tension band?
  • Suture vs. SS wire?

Busel et al. *Injury*, 2020
Implant Choice:

- If using suture for the tension-band
  - Heavy, non-absorbable
- Figure-of-Eight passed through cannulated screws
- Supplemental Cerclage
  - Running, Locking

- Case series of 50 patients
  - 96% rate of union
  - 8% rate of hardware removal

Buesl et al. *Injury*, 2020
Post-Op Rehabilitation

- No clear consensus
  - Often locked in extension ‘til wound heals
- When ROM is allowed...
  - Begin w/ *active* flexion/*passive* extension
  - Progressive range (hinged brace useful)
    - Start with a defined ROM limit
    - May use intra-operative fluoroscopic stress view to determine safe ROM range for rehab
  - Can progress each week

Lateral Fluoro View:
*Anti-gravity* flexion
Post-Op Rehabilitation

• Post-Op Rehab example...
  • Begin active flexion/passive extension
  • Start 0-60 degrees at 6 wks post-op
  • Progress 10 degrees/wk from 6-12 wks
  • Active extension/strengthening at 12 wks

Lateral Fluoro View:
Anti-gravity flexion
Complex Patella Fractures – Operative Treatment

• Big Picture:

  • If possible...
    try to convert *comminuted* fractures into *simple* fractures

  • If not possible...
    consider *alternative* fixation strategies

OTA Video Library Link
Video

OTA Video Library Link:

• https://otaonline.org/video-library/45037/annual-meeting-and-conferences/multimedia/16845974/comminuted-patella-fractures
Complex Case Example

- 57 yo F, fall from standing
- Baseline ambulatory status: normal (independent)
Comminuted Inferior Pole Fractures

• Treatment options:
  • Non-operative?
  • Partial patellectomy?
  • ORIF?
    • Reduction Technique(s)?
    • Implant Options?
    • “Tension Band” Material?
    • Soft Tissue Augmentation?
Comminuted Inferior Pole Fractures

Reconstructing the inferior pole: preserves articular congruity

Next Step: How to secure reconstructed inferior pole to intact superior pole?
Comminuted Inferior Pole Fractures

• Bony healing:
  • More reliable than soft tissue healing
  • Use this to your advantage if possible

• Limited real estate
  • Maximize bony stability, but...
  • Augment w/ soft tissue repair techniques
Comminuted Inferior Pole Fractures

- Incorporate patella tendon into repair
  - Running, locking stitch
  - Sutures passed through bony tunnels
  - Tied over bony bridge (superior patella)
Follow-Up:

- ROM: 0-130°
- No pain
- Back to baseline function
Complex Case:

- 35 yo M, fall while running down a hill
- Otherwise healthy
Mesh Plates

- Comminuted Fracture Patterns
- Containment of Small Fracture Fragments
- Customizable
- “Fragment-Specific” Fixation

Video

OTA Video Library Link:
Quadriceps & Patella Tendon Repair

• Similar Operative Technique for both
  • Approach:
    • Midline anterior incision
    • Elevate full thickness flaps
  • Identify medial & lateral extent of retinacular tears
    • Repair during closure
  • Debride tendon stump
  • Prepare bony surface
    • Burr or curettes
    • Stimulates tendon-to-bone healing

Quadriceps & Patella Tendon Repair

- Drill bone tunnels
  - 3 (or more) parallel tunnels
- Suture:
  - Heavy (#2 or #5)
  - Non-absorbable
- Running locking technique
  - Enter tendon from end
  - Up & back medially
    - Up & back laterally
    - 4 strands total

Used with permission. Image Source: Ilan et al. JAAOS 2003, Fig. 3.
Quadriceps & Patella Tendon Tears

- Pass sutures through bone tunnels
  - Keith needle
  - Suture passer
- Tie sutures down over bony bridge b/w holes
  - 3 holes = 2 knots
  - Augment if needed
    - Cerclage through tibial tubercle
    - Circumferential purse-string suture

Used with permission. Image Source: Ilan et al. JAAOS 2003. Fig. 3.

Image Source: Rockwood and Green's Fractures in Adults, 9th Edition, Fig. 59-9.
Special Considerations: Patella Tendon Injuries

• Tiny inferior pole fractures:
  • Usually non-articular
  • Often too small to fix

• Preferred Treatment:
  • Fragment excision with patella tendon advancement (essentially converting this to a patella tendon repair)
Video

Video Link:
Special Considerations: Patella Tendon Injuries

- Inferior pole fragment excision w/ patella tendon advancement:
  - Make sure to attach tendon *closer* to anterior cortex
  - Better reproduces normal anatomy
  - Posterior attachment causes patellar rotation/maltracking
Quadriceps & Patella Tendon Tears

• Summary:
  • Prepare tendon & bone
  • Parallel drill tunnels
  • Heavy non-absorbable suture
  • Running-locking suture
  • Sutures through drill tunnels
  • Tie over bony bridge
  • Retinacular repair
  • Augment if needed using cerclage/purse-string
  • Alternative: suture anchors
Complications - Common

- Hardware prominence/pain
  - VERY common (up to 60%)
  - Often require reoperation for hardware removal
- Implant-dependent:
  - Highest rates with traditional Tension Band Wire construct (using 18G stainless steel wire)
  - Lower rate (8%) with cannulated screws + suture tension band

Buse et al. Injury, 2020
Complications – Less Common

• Extensor mechanism weakness
  • Common, but often very minor
    • 2-4cm loss of terminal extension
  • Extreme: total patellectomy:
    • 49% loss of quadriceps strength

• Knee stiffness
  • Typically can be prevented by early ROM
  • If unable to reach 90° of flexion by ~8wks, consider intervention:
    • Closed manipulation under anesthesia
    • +/- arthroscopic lysis of adhesions
    • Quadriceps-plasty in extreme cases.
Complications - Uncommon

• Infection/wound complications
  • <5% in most series
  • Up to 11% in open fractures

• Non-union
  • < 1% in most series
  • Up to 7% in open fractures

• Post-traumatic patello-femoral arthritis
  • Higher with partial patellectomy than with ORIF
Complications - Uncommon

• In rare cases, total patellectomy may be required:
  • Highly comminuted fractures
  • Severe infection or tumor
  • Failed internal fixation
  • Post-traumatic arthritis

• VMO advancement technique
  • Improved strength & functional outcomes vs. std patellectomy
Complications - Uncommon

• Re-fracture
• Re-rupture
• Loss of reduction/failure of fixation
  • Reported range of 0-20% in literature
  • Risk Factors:
    • Severe comminution
    • Osteopenia/Osteoporosis
    • Inadequate fixation
    • Overly aggressive physical therapy
    • Patient non-compliance
  • Illustrative case next...
88 yo F – s/p patella ORIF 6 wks ago
Injury Films (from outside hospital)

On today’s X-rays, the inferior pole fracture is healing well
88 yo F, 6 wks s/p failed patella ORIF

- Treatment Plan?
  - Fracture Reduction
    - (Nonunion preparation)
  - Implant Options?
    - How to generate compression?
- Soft Tissue Augmentation?
  - How? What materials?
- Bone Grafting?
  - If so, what type?
Fluoro Images

**Key Point:** With clamps compressing *posteriorly*, plates can compress *anteriorly*
**Key Point:** Revision fixation with poor bone quality: augment as much as possible!
Post-Op Images

Rehab Protocol:
- Post-op WB status?
- Brace? What kind?
- ROM? If so, what range?
Follow-up: 2 & 6 wks

• 2 wks:
  • Sutures out
  • X-rays (to ensure no unexpected early failure of fixation)

• 6 wks:
  • Fracture healing
  • Started active flexion/ passive extension
Follow-Up:

• ROM:
  • 3 mo: 0-94°
  • 6 mo: 0-110°
  • Back to baseline function
Failed Fixation: Take Home Points

• Construct *stability* is the priority
  • Revision, poor bone quality

• Generating compression:
  • Anterior plates (alternative: mesh plate)
  • Screws

• Soft Tissue Augmentation
  • Figure-of-eight: suture + tension-band wire
  • Purse-string suture

• Rehab Protocol:
  • Conservative in setting of revision
Overview & Objectives

✓ Epidemiology & Mechanism of Injury
✓ Anatomy & Biomechanics
✓ Diagnosis & Classification
✓ Non-Operative Treatment
✓ Operative Treatment
  ✓ Patella Fractures: Simple & Complex
  ✓ Quad/Patella Tendon Injuries
✓ Complications
✓ Summary/Key Points
Summary – Patella/Extensor Mechanism Injuries

• *Most* require operative treatment
• Significant *tensile* forces – must be overcome by fixation construct
• Simple transverse fractures – surgeon preference
  • traditional TWB or cannulated screws can provide reliable outcomes
• Complex fractures – maximize bony stability, augment w/ soft tissue
• Quadriceps & Patella Tendon Injuries – drill tunnels/suture repair
• Revision fixation – Generate compression, combine fixation methods
  • Augment w/ soft tissues & use conservative rehab protocol
• Complications – Symptomatic hardware most common (up to 60%)
  • Implant-dependent
References


- Bui, Christopher N. MD; Learned, James R. MD; Scolaro, John A. MD, MA, Treatment of Patellar Fractures and Injuries to the Extensor Mechanism of the Knee, JBJS Reviews: October 2018 - Volume 6 - Issue 10 - p e1.


