Post-operative rehabilitation following multi-ligament knee reconstruction

Twin Cities Orthopedics Virtual Grand Rounds

Jill Monson, PT, OCS

Twin Cities Orthopedics (TCO)
Training HAUS
Eagan, MN | Edina, MN
Thank you

• Karie Nash

• TCO team members contributing to virtual grand rounds

• Dr. LaPrade and our multi-specialty complex knee team

• Our patients
Overview

• Epidemiology of multi-ligament knee injury (MLKI)

• Scientific foundations for post-operative precautions
  • Biology, biomechanics, confounders

• Early post-operative rehabilitations priorities
  • Recovery → Transition phase emphasis
  • Understanding how to make progressions
Language/Abbreviations

**Cruciates:**
- ACL: anterior cruciate ligament
- PCL: Posterior cruciate ligament

**Medial/Posteromedial Knee:**
- MCL: medial collateral ligament
  - dMCL: deep MCL
  - sMCL: superficial MCL
- PMC: posteromedial corner
- POL: posterior oblique ligament

**Lateral/Posterolateral Knee:**
- ALL: anterolateral ligament
- BF: Biceps femoris
- ITB: iliotibial band
- FCL: fibular collateral ligament
- PLC: Posterolateral corner
- PFL: Popliteofibular ligament
- PT: Popliteus tendon

**Other:**
- CPN: common peroneal nerve
- MLKI: multi-ligament knee injury
- PF: Patellofemoral
MLKI EPIDEMIOLOGY
Multi-Ligament Knee Injury (MLKI)

- **MLKI** = Tear of ≥2 of the 4 major knee ligaments (ACL, PCL, MCL/PMC, FCL/PLC)
  - Incidence: <0.02% of all orthopaedic injuries

- **Knee Dislocation** = rupture of both cruciates with or without additional grade III medial or lateral side injury
  - Incidence: 0.001% to 0.013% per year
  - Likely higher d/t spontaneous reduction
Status Post:
1) Revision PCLr,
2) Revision FCLr/PTFJr with hamstring autograft
3) Revision MM root repair
4) Biceps femoris repair
5) Peroneal Nerve Neurolysis
Demographic Shift = Expectation Shift?

- Males>Females
- Younger (Mean age $37 \pm 15$ years)
  - Rate of knee dislocation inversely related to patient age
- More sporting injuries - MLKI rates with skiing (29.4%) and ball sports (6.9%)
  - MVA only 19.2% in same study
    - Moatshe et al. OJSM 2017; Schlumberger et al. KSSTA 2020
- Return to Sport:
  - Reporting inconsistent
  - Overall RTS 53%, competitive athletes 22%
    - Everhart et al. Arthroscopy 2018

4) Biceps femoris repair
5) Peroneal Nerve Neurolysis
Mechanism of Injury

• High energy trauma (MVA, fall from height) or low energy trauma (sports)
  • 50.3-51% high energy trauma
  • 47-49.3% low energy trauma
    • Engebretsen et al. KSSTA 2009; Moatshe et al. Arthroscopy 2017

• Often knee hyperextension + varus or valgus force

• Typically a contact injury

• Concomitant “trauma” injuries
### Table 1: Explaining Schenck's knee dislocation classification

<table>
<thead>
<tr>
<th>KD</th>
<th>Injury to single cruciate + collaterals</th>
<th>Injury to ACL and PCL with intact collaterals</th>
<th>Injury to ACL, PCL, MCL</th>
<th>Injury to ACL, PCL, FCL</th>
<th>Injury to ACL, PCL, MCL, FCL</th>
<th>Dislocation + fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>KD I</td>
<td></td>
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<tr>
<td>KD II</td>
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<td>KD III M</td>
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<td>KD III L</td>
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<td>KD IV</td>
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<tr>
<td>KD V</td>
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</tr>
</tbody>
</table>

Additional caps of “C” and “N” are utilized for associated injuries. “C” indicates an arterial injury. “N” indicates a neural injury, such as the tibial or, more commonly, the peroneal nerve. ACL, anterior cruciate ligament; FCL, fibular collateral ligament; KD, Knee Dislocation Classification I–V; MCL, media collateral ligament.
Neurovascular (NV) Injury

- Higher risk when both cruciates are involved

- With knee dislocation (compared to MLKI alone):
  - Common Peroneal Nerve (CPN) Injury: 38% (14% MLKI)
  - Popliteal artery injury: 18% (4% MLKI)
    - Kahan et al. JBJS 2021
- PLC injury = 42 times higher odds of CPN injury, 9.2 times higher odds of popliteal a. injury
  - Moatshe G. et al. Arthroscopy 2017
Concomitant Joint Injury

• In presence of MLKI:
  
  • Meniscal injury: 37.3-55%
  
  • Cartilage injury: 28.3-48%

  • Moatshe G. et al. Arthroscopy 2017
  • Krych A. et al. KSSTA 2015
SCIENTIFIC FOUNDATION FOR POST-OP PRECAUTIONS
Foundations for Post-Op Precautions

**Biology**
- Tissue-specific healing timeframes & considerations

**Biomechanics**
- Joint biomechanics
- Structure-specific considerations
- Movement/exercise-specific considerations

**Confounders**
- Intrinsic & extrinsic factors
- Modifiable & non-modifiable
Foundations for Post-Op Precautions

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Early Recovery

Multiple, large soft tissue incisions

Concomitant extra-articular work (soft tissue repair):
- Biceps femoris tenon, IT band, lateral capsule, lateral gastrocnemius tendon

Concomitant intra-articular work:
- Meniscus repair
- Fracture fixation

Bone tunnels at multiple ligament reconstruction sites

- Autograft and allograft tissue
- Various fixation methods

Neurovascular Issues:
- Nerve injury (Common peroneal nerve)
- Vascular injury/bypass (Popliteal artery)
Biology: Overview of Healing

Hemostasis & Inflammation (immediately through day 3)
- Hematoma
- Inflammatory mediators released
- Macrophages clear wound site
- Growth factors & cytokines released
- VEGF (vascular endothelial growth factor) stimulates angiogenesis

Proliferation (3 days to 14 days)
- Scaffold of specific tissue type is built (type III collagen, bone callus, etc.)
- Ground substance
- Scarring
- Ongoing angiogenesis

Remodeling/Maturation (14+ days)
- Mature tissue type fills in scaffold (Type 1 collagen, Bone, etc.)
- Collagen fibers align, diameter increases, cross-links form
- Tissue adapts, strengthens (influenced by mechanical stress)

Piraino A. Frontiers in Orthopaedic Science: The Science of Neuromuscular Healing. 2017 Orthopaedic Section, APTA, Inc.)
Biology: Structure Specific Considerations

**Ligament Graft**
- Graft material (auto, allo) *harvest site morbidity*
- Bone tunnels w/hardware fixation
- Extra-articular suture fixation
- Ligament healing, maturation process (up to 24 mos)

**Tendon/Soft Tissue Repair**
- Location of injury & repair
- Tissue quality, chronicity of injury
- Fixation technique, security of fixation
- Post-injury tissue strength ~ 80% of pre-injury strength

**Nerve Injury**
- Injury severity, location (<7cm favorable)
- Patient age (<25 y/o favorable)
- Initial recovery: 3-6 mos Late stage: up to 2 yrs
- Secondary surgery

**Bone/Fracture Healing**
- Hardware fixation required?
- Soft tissue impact of external fixator (quad)
- Alignment restored?
- Bone density loss

*References*
Peskun CJ. CORR 2012; Niall DM. JBJS(Br) 2005; Woo J. Biomechanics 2006; Piraino 2017; Nagelli Sports Med 2017
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ANATOMY & BIOMECHANICS
Tibial IR Restraint:
- ACL
- POL (in extension)

Tibial ER Restraint:
- MCL (throughout ROM)
- Meniscus
- PCL (>90° flexion)
- FCL/PLC (shallower)

Tibial IR Restraint:
- ALL
- PCL (pmb >90° flexion)
Varus Restraint:
- FCL (PLC)
- Cruciates

Valgus Restraint:
- MCL
- POL
- ACL
Load to Failure

Load to Failure (N)

- ACL
- MCL
- PCL
- FCL
- PLC

Load to Failure (N) values:
- ACL: около 2000 N
- MCL: около 500 N
- PCL: около 4500 N
- FCL: около 1000 N
- PLC: около 1500 N
Posterior Cruciate Ligament (PCL) Anatomy

- 2 distinct PCL bundles:
  - Anterolateral bundle (strongest)
  - Posteromedial bundle
- Codominant contributions to knee stability (between the bundles)
  - Resists *Posterior tibial translation* → Tibial rotation (ER & IR)
- Meniscofemoral ligaments
  - Anterior (Ligament of Humphrey)
  - Posterior (Ligament of Wrisberg)

PCL Biomechanics

- **AL bundle:**
  - Lengthens with knee flexion
  - AL bundle resists PTT through most of flexion (90°)

- **PM bundle:**
  - Lengthens with knee extension
  - Resists PTT near full extension & resists hyperextension
  - PM bundle can resist PTT again in deep, end range flexion

- Both provide rotational stability throughout the range
  - More pronounced near 90°

Medial Knee Anatomy

- **sMCL**: (superficial MCL)
  - Long, primary stabilizer
  - Proximal & distal tibial attachments
  - Highest load to failure & stiffness

- **dMCL**: (deep MCL aka “mid-third medial capsular ligament”)
  - Short, secondary stabilizer
  - Meniscotibial and meniscofemoral attachments
  - Lowest load to failure & stiffness

- **POL**: (Posterior oblique ligament)
  - Consists of 3 fascial expansion off distal semimembranosus tendon
  - Merges with posteromedial capsule

LaPrade MD, Kennedy MI, Wijdicks CA, LaPrade RF. SMAR 2015
Medial Knee Biomechanics

- **sMCL**: Resists valgus (proximal) and tibial rotation (distal) throughout ROM
- **dMCL**: Secondary restraint to valgus & rotation
- **POL**: Tensions at posteromedial knee in extension. Resists IR→valgus→ER

- **Anterior** bundles elongate with **flexion**
- **Posterior** bundles elongate with **extension**

LaPrade MD, Kennedy MI, Wijdicks CA, LaPrade RF. SMAR 2015
Hosseini A, Qi W, Tsai TY, Liu Y, Rubash H, Li G. KSSTA
Lateral Knee Anatomy

Posterolateral Corner (PLC):

- 3 primary structures:
  - Fibulocollateral ligament (FCL or LCL)
  - Popliteus Tendon (PT)
  - Popliteofibular ligament (PFL, aka “arcuate ligament”)

- Popliteus Tendon is the strongest structure
  - PT (700N) → PFL (298 N) → FCL (295N)

Lateral Knee Biomechanics

- **PLC:**
  - Resists hyperextension, varus, tibial ER
    - More pronounced near *extension*
  - Resists PTT near full *extension*

- **FCL:**
  - Resists varus *throughout range*
  - Resists tibial ER near full *extension*

LaPrade RF et al AJSM 2005 Sep;33(9):1386-91.
ROM Precautions:
Knee flexion ROM limit
90° x 2 weeks post-op
(Prone PROM for PCLs)

*Some structures will have a hyperextension (HE) precaution
(PCL, PLC, FCL, POL)

0-0-90° to honor ligament/graft length/tension with HE or deeper flexion angles

2 weeks = early collagen proliferation has occurred
Biomechanics: OKC Quadriceps

- Quadriceps anterior pull at tibia
- Anterior tibial translation
- More pronounced in last 30°

Into terminal extension (50°→0°)

- Negligible tibial translation either direction

Isometric Point @ mid-range (~60°)

- Posterior line of pull through patellar tendon
- Slight posterior tibial translation

From Deeper Flexion (>60°)

References:
Biomechanics: OKC Quadriceps

**Precaution:**
Modified arc of motion with quadriceps strengthening (varies per structures involved)

*Positional restrictions evolve gradually as healing progresses*

Biomechanics: OKC Hamstrings

- From terminal extension (0° → 30°)
  - Minimal mechanical advantage to induce posterior tibial translation

- Into Progressive Flexion (>30°)
  - Increasing mechanical advantage to create progressively more dramatic posterior tibial translation

Biomechanics: OKC Hamstrings

**Precaution:**
NO resisted hamstring curling into knee flexion x 4 months

>30 degrees = more joint shear, PTT
4 months = more mature graft

Hamstring Pull

From terminal extension (0° → 30°)
Increasing mechanical advantage to create progressively more dramatic posterior tibial translation

Biomechanics: Weight Bearing (CKC) Exercise

ATT = anterior tibial translation
PTT = posterior tibial translation

Early Flexion <45/50°

Maximized
• Quad mechanical advantage
• ATT

Minimized
• HS mechanical advantage
• PTT

Deeper Flexion >60°

Maximized
• HS mechanical advantage
• PTT

Minimized
• Quad mechanical advantage
• ATT

Escamilla JOSPT 2012; Shelbourne JOR 2011; Escamilla Clin Biomech 2009; Toutoouni Clin Biomech 2000

*/General estimates*
Biomechanics: Weight Bearing (CKC) Exercise

ATT = anterior tibial translation
PTT = posterior tibial translation

Precaution:
No squatting >70° x 4 months post-op

>70 degrees = more joint shear, PTT
4 months = more mature graft

Minimized
• HS mechanical advantage
• PTT

Maximized
• Quad mechanical advantage
• ATT

Escamilla JOSPT 2012; Shelbourne JOR 2011; Escamilla Clin Biomech 2009; Tootoungi Clin Biomech 2000

= direction+magnitude of muscle pull
= Tibial slope
*General estimates
Biomechanics: Gait

- Best quality, most abundant literature related to ACL
  - Studies re: PCL, other structures lacking, outcomes/observations more variable
- Loading response:
  - Sagittal Plane: Quad activation + excursion into shallow flexion + tibial slope = ATT \(\rightarrow\) ACL strain
    - ACL injury \(\rightarrow\) Increased demand placed on MCL to control ATT
  - Transverse Plane: MLKI disrupts static structures that normally control rotational movement

Biomechanics: Gait

• Mid-stance:
  • Adduction moment through knee
  • Knee stabilized by lateral, posterolateral structures
    • PLC, biceps femoris, ITB
  • Varus thrust gait as a result of injury to these structure
    • ↑ tensile stress at lateral knee structures
    • ↑ compressive forces through medial compartment
Biomechanics: Gait

Mid-stance:
- Adduction moment through knee
- Knee stabilized by lateral, posterolateral structures
- PLC, biceps femoris, ITB
- Varus thrust gait as a result of injury to these structures
- \[\uparrow\] tensile stress at lateral knee structures
- \[\uparrow\] compressive forces through medial compartment

Precaution:
Post-operative weight bearing restrictions (NWB, PWB, ??)

**Currently under investigation within our practice**

**Very little high-quality literature on non-ACL ligament loading with gait**
Foundations for Post-Op Precautions

Biology
- Tissue-specific healing timeframes & considerations

Biomechanics
- Joint biomechanics
- Structure-specific considerations
- Movement/exercise-specific considerations

Confounders
- Intrinsic & extrinsic factors
- Modifiable & non-modifiable
## Confounders: Healing

<table>
<thead>
<tr>
<th>Non-Modifiable</th>
<th>Modifiable</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Baseline joint health</td>
<td>• Nutrition</td>
</tr>
<tr>
<td>• Prior (chronic) injury, alignment, OA</td>
<td>• TCO bone health team??</td>
</tr>
<tr>
<td>• Implants/foreign materials</td>
<td>• Psychological stress</td>
</tr>
<tr>
<td>• Infection</td>
<td>• TCO sports psych team??</td>
</tr>
<tr>
<td>• Age</td>
<td>• Smoking</td>
</tr>
<tr>
<td>• Older = slower, impaired healing</td>
<td>• Delays tissue healing</td>
</tr>
<tr>
<td>• Sex hormones</td>
<td>• Increases complications</td>
</tr>
<tr>
<td>• Systemic disease</td>
<td><strong>Patient education</strong></td>
</tr>
<tr>
<td>• Medication</td>
<td><strong>Collaborative, team approach</strong></td>
</tr>
</tbody>
</table>

**Patient education**

**Collaborative, team approach**
## Confounders: Orthopaedic & Beyond

### Neurovascular Injury
- Vessel: Emergency vascular bypass, compartment release
  - Wound healing (emergency surgery same day/week as knee surgery)
- Nerve: Foot drop $\rightarrow$ orthotics need (AFO) $\rightarrow$ altered gait pattern
  - Additional delayed surgery (after knee recovers)

### Additional Trauma
- Fracture, joint dislocation above/below knee
- Internal injuries, brain injury/concussion, DVT, infection
- Psychological response to traumatic injury (with or w/o brain injury)

### Social, Economic Factors
- Health insurance
- Financial resources (time off work)
- Transportation to/from clinic for high # of visits, long duration of care
- Advocacy, In-home support (especially in early recovery)
EARLY POST-OPERATIVE REHABILITATION: Key Priorities
POST OP RECOVERY PHASES

Day 1 → Recover → Transition → Rebuild → Restore

1 week → 6 weeks
POST OP RECOVERY PHASES

- Recover
- Transition
- Rebuild
- Restore

6 weeks to Transition
10 weeks
POST OP RECOVERY PHASES

1. Recover
2. Transition
3. Rebuild (10 weeks)
4. Restore (6 months)
POST OP RECOVERY PHASES

- Recover
- Transition
- Rebuild
- Restore

6 months ➔ 12+ months
POST OP RECOVERY PHASES

- **Recover**
  - Day 1
  - 6 weeks

- **Transition**
  - 6 weeks
  - 10 weeks

- **Restore**
Early Post-Surgical Rehab Pyramid

- Effectively re-introduce loading ➔ Functional Strengthening
- Effectively re-activate target muscles safely ➔ Isolated Strengthening
- Nourish Joint ➔ Restore ROM
- Manage Complications, Protect Joint, Manage Symptoms

Day 1 ➔ Recover (6 weeks)
6 weeks ➔ Transition (10 weeks)
Early Post-Surgical Rehab Pyramid

Effectively re-introduce loading → Functional Strengthening

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Early Post-Surgical Rehab Pyramid

Manage Complications, Protect Joint, Manage Symptoms
Education: Day 1 Post-Op Clinic

**Patient Education Folder:**
- PT referral
- Protocol
- TRAC testing scheduling document (4, 7, 10 mo.)
- Post-op priorities education document
- Contact information
- Medical education document (wound care, medication, etc.)
- Intra-operative photos
Observing for Post-Operative Complications

- DVT
- Nerve Injury
- Vascular Injury/Compartment Syndrome
- Infection
- Fracture
Complications: DVT

DVT
- Painful, progressive lower leg swelling (ankle, foot, toes swollen)
- Painful to palpation of the calf
  - Can be general tenderness or tenderness to the deep veins
    - Usually along saphenous vein (central calf)
- Pain with passive ankle DF
- DVT risk factors best defined using Wells’ Criteria for DVT
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>Active cancer</td>
<td>No 0</td>
</tr>
<tr>
<td>Treatment or palliation within 6 months</td>
<td>Yes +1</td>
</tr>
<tr>
<td>Bedridden recently &gt;3 days or major surgery within 12 weeks</td>
<td>No 0</td>
</tr>
<tr>
<td>Calf swelling &gt;3 cm compared to the other leg</td>
<td>No 0</td>
</tr>
<tr>
<td>Measured 10 cm below tibial tuberosity</td>
<td>Yes +1</td>
</tr>
<tr>
<td>Collateral (nonvaricose) superficial veins present</td>
<td>No 0</td>
</tr>
<tr>
<td>Entire leg swollen</td>
<td>Yes +1</td>
</tr>
<tr>
<td>Localized tenderness along the deep venous system</td>
<td>No 0</td>
</tr>
<tr>
<td>Pitting edema, confined to symptomatic leg</td>
<td>No 0</td>
</tr>
<tr>
<td>Paralysis, paresis, or recent plaster immobilization of the lower extremity</td>
<td>No 0</td>
</tr>
<tr>
<td>Previously documented DVT</td>
<td>No 0</td>
</tr>
<tr>
<td>Alternative diagnosis to DVT as likely or more likely</td>
<td>No 0</td>
</tr>
</tbody>
</table>

- A score of 1-2 is considered moderate risk with a pretest probability of 17%.
- A score of 3 or higher suggests DVT is likely. Pretest probability 17-53%.
Complications: Nerve Injury

**Nerve injury**
- Sensory-motor deficits expected for the first 1-2 days post-op if patient received a nerve block during surgery
- Progressive deterioration (rather than gradual recovery) of:
  - Specifically pathway of superficial and deep peroneal nerves
  - Superficial peroneal nerve
    - Motor (myotomes)
      o lateral compartment of leg
      o peroneus longus
      o peroneus brevis
  - Sensory (dermatomes)
    o majority of skin on the dorsum of foot, excluding webspace between hallux and second digit
    o anterolateral distal 1/3 of leg
  - No associated reflex
  - Deep peroneal nerve
    - Motor (myotomes)
      o tibialis anterior
      o extensor digitorum longus/brevis
      o peroneus tertius
      o extensor hallucis longus/brevis
    - Sensory (dermatomes)
      o articular branch to the ankle joint
      o 1st dorsal webspace
  - No associated reflex
## Complications: Vascular Injury

<table>
<thead>
<tr>
<th>Vascular injury → Compartment syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Disproportionately high pain that does not respond to analgesics</td>
</tr>
<tr>
<td>- Severe pain with stretch of the involved compartment</td>
</tr>
<tr>
<td>- Parasthesia or numbness</td>
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<tr>
<td>- Loss/reduction of lower extremity pulse (dorsalis pedis/posterior tibial pulses)</td>
</tr>
<tr>
<td>- Reduced capillary refill at toes/foot</td>
</tr>
<tr>
<td>- Dusky appearance of toes/foot</td>
</tr>
<tr>
<td>- Foot is cold</td>
</tr>
<tr>
<td>- Progressive lower leg swelling (into foot, toes as well)</td>
</tr>
<tr>
<td>- Firmness/tightness at lower leg compartments</td>
</tr>
<tr>
<td>- Compartment syndrome risk factors include: lower leg trauma, vascular compromise, excessively tight/compressive dressing</td>
</tr>
<tr>
<td>- 5 Ps (pain, palor, pulselessness, paresthesia, paralysis)</td>
</tr>
</tbody>
</table>
Complications: Infection, Fracture

**Infection**
- Foul smelling, purulent/pus-like discharge
  - Blood and serosanguinous fluid are normal for the first few days after surgery.
- Progressive redness, warmth (expanding/intensifying rather than retracting/diminishing)
- Tenderness around affected area
- Fever >101.5 degrees

**Fracture**
- Pain increased from baseline with weight bearing or muscle activation
- Focal pain and swelling over the involved region of bone
- Associated trauma/MOI after surgery
Management for Dr. LaPrade’s Patients

STEPS TO TAKE WHEN RED FLAGS OBSERVED

1. Contact the medical team for consult:
   a. PT team member to contact MD team:
      i. teamlaprade@tcorn.com attention Chris Armstrong, PA
   b. Patients may call 952-456-7412 if needed

2. Pursue urgent medical visit referral and/or imaging consult as recommended
   a. TCO urgent care
      i. Locations: https://tcorn.com/ortho-urgent-care/?qclid=EAIaIQobChMlo--Wstl78QIVUGpvBBf2qdHEAYASAAEgLDLtF_BwE
   b. Duplex ultrasound for DVT screening
      i. CDI (US available in Eagan on select days)
         1. Eagan office should be able to coordinate a visit at another location if US not available on-site
      ii. Vascular & Interventional Experts (VIE)
         1. Located on-site at TCO locations
            a. Minnesota Drive, Edina (available Mon-Fri)
            b. Plymouth (available Fri)
            c. Woodbury (available Tues)

3. Send to ED
   a. Edina: Fairview/M Health Southdale
   b. Eagan: Fairview/M Health Ridge (Burnsville)
   c. Link to all Fairview/M Health ED Locations:
      https://www.fairview.org/specialties/emergency-services-and-critical-care#locations1
**Joint Protection: WB Restriction**

**RESEARCH PROTOCOLS IN PROGRESS**

<table>
<thead>
<tr>
<th>Ligament(s) Involved</th>
<th>Control Precaution</th>
<th>Experimental Precaution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Ligament</td>
<td>NWB</td>
<td>PWB (40% of BW)</td>
</tr>
<tr>
<td>PCL</td>
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<tr>
<td>FCL</td>
<td>PWB (40% of BW)</td>
<td>WBAT</td>
</tr>
</tbody>
</table>

*6-week weight bearing restriction period for all*

*Exclusion: unstable meniscus repair, revision surgery, fracture*
Joint Protection: Bracing

• MLKR patients remain in a brace **longer**:  
  • ADLs: until 6 month stress x-rays show stable knee  
  • Higher level activities: throughout the 1st year

• PCLR:  
  • Immobilizer until swelling reduces enough to transition into dynamic PCL brace (usually 2-3 weeks)

• Non-PCLR:  
  • Immobilizer until WB (6 weeks) - transition to hinged brace

• AFO indicated for common peroneal n. injury
Symptom Management: Swelling

Day 3 PO
Day 5 PO
Day 8 PO
Swelling Management: All of the time

**Vasopneumatic Cryotherapy:**
- 30 min on/off in first week
- Multiple times daily in first 2-3 weeks

**Compression Stockings:**
- NWB: 6 weeks at surgical limb, 2 weeks at non-surgical
- WBAT: 2 weeks at surgical limb only

**Tubigrip Stockings**
Swelling Management: Some of the time

Foam Croutons “Burritos”:
Construct packet(s) of small foam croutons to apply under tubigrip over an area of stagnant fluid accumulation (enclose within cover-roll tape or small size tubigrip (ends taped/stitched shut) to make a little “burrito” of croutons)

*creates channels in the fluid to help drain it
Early Post-Surgical Rehab Pyramid

- Effectively re-introduce loading → Functional Strengthening
- Effectively re-activate target muscles safely → Isolated Strengthening
- Nourish Joint → Restore ROM
- Manage Complications, Protect Joint, Manage Symptoms
Nourish the Joint ➔ ROM
Nourish the Joint ➔ ROM

GIRL, PLEASE.
Nourish the Joint ➔ ROM

TRUST ME

I'M AN EXPERT
Single-Stage Multiple-Ligament Knee Reconstructions for Sports-Related Injuries

Outcomes in 194 Patients

Robert F. LaPrade,† MD, PhD, Jorge Chahla,‡ MD, PhD, Nicholas N. DePhillipo,†§ MS, ATC, OTC, Tyler Cram,‡ ATC, Mitchell I. Kennedy,‖ BS, Mark Cinque,‖ MD, Grant J. Dorman,‖ MSc, Luke T. O’Brien,‖ PT, MPhty (Sports), Lars Engebretsen,§*** Prof., MD, PhD, and Gilbert Moatshe,§** MD, PhD

Investigation performed at The Steadman Clinic, Vail, Colorado, USA

• Immediate ROM permitted (0-90 deg limit x 2 wks, then progress as tolerated)

• Mean post-operative Knee ROM (2 yr f/u): 0-0-134 deg

• Post-operative multi-direction knee laxity within acceptable range (stress radiography)
Immediate ROM permitted (0–90 deg limit x 2 wks, then progress as tolerated)

Mean post-operative Knee ROM (2 yr f/u): 0–0–134 deg

Post-operative multi-direction knee laxity within acceptable range (stress radiography)
# ROM: Precautions & Unique Considerations

**No Hyperextension (HE)**
- Avoid graft tension on structures that natively limit knee HE
- PCL & PLC: Avoid HE x 8 weeks
- FCL & POL: Avoid HE x 2 weeks then gradual return to symmetry

**Prone &/or PROM Knee Flexion ROM**
- PCL: PRONE x 2 weeks (avoid positional sag into PTT), PASSIVE x 6 weeks (avoid hamstring pulling into PTT)
- FCL, PLC: PASSIVE → AAROM gradually over 6 weeks (fibular head disruption, secondary contributors to PTT stability)

**Patellofemoral Compartment Adhesion Management**
- Inflammation x 48-72 hrs → proliferation (collagen spray) x 2 wks
- Extensor mechanism = pulley system (patella/tendons = rope)
- Scar under the tendons, between the tissue layers = supergluing the rope to the pulley = ineffective pulley!
Graft Considerations

- FCL/PLC: Hypertrophic Changes
- MCL: Ossification
- PCL: Double Bundle Allograft
Autograft Harvest:

- Additional soft tissue trauma about the joint
- Tendon healing required from stripping
- Additional regions of collagen proliferation
  - Increased likelihood of scarring

EXCESS SCAR = STIFF JOINT

*MANAGE THESE REGIONS TO MINIMIZE EXCESS SCAR*
(Manage inflammation, supported ROM, manual interventions, gentle & effective early muscle activation)
ROM Support Strategies

• Patellar/Peripatellar Mobilizations
  • Patella
  • Quad & Patellar Tendons
  • Suprapatellar pouch
  • Infrapatellar fat pad

• Strong, repetitive quad activation
  • Couple with patellar mobilizations
    • Proximal with contraction
    • Distal with relaxation
ROM: Flexion Precautions

• Prone PROM 0-90°x 2 weeks (PCL)
  • Avoid posterior tibial sag/translation (PTT) d/t positioning
  • PROM to minimize HS pulling induced posterior shear

• PASSIVE ROM (PROM) x 6 weeks
  • PCL, PLC, biceps femoris repair
  • Minimize dynamic PTT via hamstring pulling

• No hyperextension (PCL, PLC) x 8 weeks
ROM: Hyperextension Precaution
ROM: Hyperextension Precaution
Early Post-Surgical Rehab Pyramid

Effectively re-activate target muscles safely → Isolated Strengthening
Muscle Re-action: Nerve Injury

FCL/PLC Procedures
Common Peroneal Nerve (CPN)

- **Transient CPN Neuropraxia**
  - Not unusual when nerve block used
  - Should resolve within 2-3 days
  - **If NOT – contact medical team**

- **Complete CPN Injury/Palsy**
  - Critical to retain ankle DF ROM
  - Improves future outcomes with tibialis posterior tendon transfer
Muscle Re-activation: Nerve Injury

• Low Frequency Electrical Stimulation (≤20 Hz)

Brief post-surgical electrical stimulation accelerates axon regeneration and muscle reinnervation without affecting the functional measures in carpal tunnel syndrome patients

Tessa Gordon, Nasim Amiriiani, David. C. Edwards, K. Ming Chan

Muscle Re-activation: Nerve Injury

<table>
<thead>
<tr>
<th>Neuromuscular Electrical Stimulation (Quad)</th>
<th>Low Frequency Electrical Stimulation (Nerve Injury)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stimulation Frequency: 50-100 Hz</td>
<td>• Stimulation Frequency: ≤20 Hz</td>
</tr>
<tr>
<td>• Dosing: 10-15 minutes (intermittent), 3-7x/wk, until strength recovers</td>
<td>• Dosing: 1 hour daily (constant) x 2 weeks</td>
</tr>
<tr>
<td>• Target: Directly to muscle</td>
<td>• Target: Along pathway of nerve (proximal to injury location)</td>
</tr>
</tbody>
</table>
Quad Re-activation: Electrical Stimulation (NMES)

• Over-ride quadriceps activation deficit
  • Hart JATA 2010

• Recover Strength
  • Kim JOSPT 2010
  • Gatewood Knee Surgery, Sports Traumatology, Arthroscopy 2017
Quad: Blood Flow Restriction Therapy (BFR)

- Tennent Clin J Sports Med 2017
  - BFR group had increase in:
    - thigh girth
    - extension and flexion strength

- Excellent tool for patients who are NWB x 6 weeks
  - Safe to initiate within the first 2 weeks after surgery
    - Hughes BJS 2017, Patterson Front. Physiol. 2019, Minniti AJSM 2019

- Introduction of BFR:
  - Bleeding resolved
  - Initiate at lower intensity then build to therapeutic dosing (80%) as tolerated
  - Modify time under occlusion per tolerance
# Quad: Blood Flow Restriction Therapy (BFR)

**TABLE 1** | Model of exercise prescription with BFR-RE.

<table>
<thead>
<tr>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Load</td>
</tr>
<tr>
<td>Restriction time</td>
</tr>
<tr>
<td>Type</td>
</tr>
<tr>
<td>Sets</td>
</tr>
<tr>
<td>Cuff</td>
</tr>
<tr>
<td>Repetitions Pressure</td>
</tr>
<tr>
<td>Rest between sets</td>
</tr>
<tr>
<td>Restriction form</td>
</tr>
<tr>
<td>Execution speed</td>
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*Patterson Front. Physiol. 2019*
Quad: Blood Flow Restriction Therapy (BFR)

TABLE 1 | Model of exercise prescription with BFR-RE.

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<td>Frequency</td>
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<tr>
<td>2–3 times a week (&gt;3 weeks) or 1–2 times per day</td>
</tr>
<tr>
<td>(1–3 weeks)</td>
</tr>
</tbody>
</table>

Editorial Commentary: Blood Flow Restriction Therapy Continues to Prove Effective

Robert F LaPrade 1, Jill K Monson 2, Jon Schoenecker 2

Repetitions Pressure | (75 reps) – 30 × 15 × 15 × 15, or sets to failure |
40–80% AOP
Rest between sets    | 30–60 s                                          |
Restriction form     | Continuous or intermittent                        |
Execution speed      | 1–2 s (concentric and eccentric)                  |
Execution            | Until concentric failure or when planned rep scheme is completed |
POST OP RECOVERY PHASES

- Recover
- Transition
- Rebuild
- Restore

6 weeks
16 weeks
Early Post-Surgical Rehab Pyramid

Effectively re-introduce loading → Functional Strengthening
GOALS for Transition

- Transition off crutches
- Load: Muscle | Tendon
- Continue to avoid:
  - OKC hamstring
  - Squat >70 degrees
- Work Capacity
Clean Up Time

- Pain/Effusion
- Range of Motion
- Quad Function
- Gait
Gait s/p MLKR

Gait adaptations following multiple-ligament knee reconstruction occur with altered knee kinematics during level walking

Corey J. Scholes¹ · Joe T. Lynch¹ · Milad Ebrahimi¹ · Brett A. Fritsch¹ · David A. Parker¹

- **Initial Contact**: significantly greater knee flexion observed at surgical limb
- **Loading response**: significantly reduced knee flexion (excursion) at surgical limb

“More constrained pattern of knee motion”
Isolated **Open Chain** Strengthening: **Extension**

- **From 0°**
- **Iso at 0°**
- **Iso at 60°**
- **Isotonic through arc 0-60°**

*OKC extension arc to avoid PTT*
Isolated **Open Chain** Strengthening: **Flexion**

- Shallow ISOs
- Hip hinge
- Bridge
- AROM slides

8-16 weeks
Weight shift

Progressive quad demand

NWB activation

WB isometrics

Progressive depth

Heavy, slow eccentrics

Velocity-based eccentrics

Considerations:
- Pain, effusion, ROM, OKC vs. CKC, precautions, ensuring effective dose-response

Early Load Progressions
Restore Full Motion

Extension

Don’t forget to address neural tension to restore full end range extension!

Flexion

Mobilization strategies to reduce posterior pinching with end range flexion progressions
Clean Up Time

- Pain/Effusion
- Range of Motion
- Quad Function
- Gait
Dr. LaPrade TRAC Testing Protocol: MLKR Patients

Clinical Testing (Physical Therapist) → Biomechanics Lab Testing (Biomechanist) → Surgical F/U (Surgeon)

LOCAL PATIENTS:
• Do NOT need same-day testing corresponding with MD appointment
• Complete testing 1-3 weeks prior to MD visit (to allow for outcomes to be shared prior to date of MD visit)

OUT-OF-TOWN PATIENTS:
• Require same-day testing to correspond with MD appointment

4 MONTHS 7 MONTHS 10 MONTHS
Dr. LaPrade TRAC Testing Protocol:

MLKR Patients

Clinical Testing (Physical Therapist)

Biomechanics Lab Testing (Biomechanist)

Surgical F/U (Surgeon)

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OUT-OF-TOWN PATIENTS:

• Require same-day testing to correspond with MD appointment

4 MONTHS 7 MONTHS 10 MONTHS

• Testing timelines are listed at the TOP OF EVAL NOTE and IN THE PROTOCOL

• Have patient call to schedule WELL IN ADVANCE

• WHEN IN DOUBT...EMAIL JILL!

jillmonson@tcomn.com
4 Month Clinical Testing Protocol: Baseline

**Effusion**
- calf, knee, thigh

**Girth:**
- Limb Length: ankle, knee

**ROM:**
- hip abduction

**Strength (HHD):**
- hip abduction

**FUNCTIONAL TESTS**

- **One Leg Rise Test**
  - (Culvinor, 2016; Ericsson, 2013)

- **Y Balance Anterior Reach**
  - (Smith, 2014; Stiffler, 2017)
4 month Training HAUS Lab Protocol: 45 min

1. Strength
   - Maximal Isometric Quadriceps Test @ 90° of flexion
   - LSI and Relative strength to BW
4 month Training HAUS Lab Protocol: 45 min

2. Coordination
   ▪ Double Leg Squat
     ▪ Force Distribution between Limbs
   ▪ Single leg squat
     ▪ Sagittal/Frontal Strategy
Clean Up Time

- Pain/Effusion
- Range of Motion
- Quad Function
- Gait
POST OP RECOVERY PHASES

Recover

Transition

Rebuild

Restore

- Recover: 6 months
- Transition: 10 weeks
- Rebuild: 6 months
- Restore: 12+ months
Anterior Loading Progressions

Emphasize:
- 85% on Front Limb
- Parallel Shin/Spine
- Neutral Hip

“Distalize” Load & Add Time Under Tension
Anterior Loading Progressions

Emphasize:
- 85% on Front Limb
- Parallel Shin/Spine
- Neutral Hip

ISOLATED QUAD exercise on the menu for a VERY LONG TIME

IDENTIFY and CORRECT QUAD AVOIDANCE in CKC

“Distalize” Load & Add Time Under Tension
Overload Progressions

Considerations for Loading:
• Pain, effusion, ROM, OKC vs. CKC, precautions, ensuring effective dose-response

“Kick Stand Squat”
• 85% of weight on Front Limb
• Parallel Shin/Spine
• Knee Over Toe
• Neutral Hip in Transverse/Frontal Plane
• Pressure through Big Toe, Ball of the Foot & Heel
• Goal is to prevent Hip Dominant squat strategy we often see in MLKR

- NWB activation
- WB isometrics
- Progressive depth
- Volume & Heavy, slow eccentric
- Velocity-based eccentric
Posterior Loading Progressions

Early:
avoid open chain

Middle:
progressive open chain

Late:
heavy, eccentric

Caution with Nordics/Kneeling

**Wait until normal stress x-rays with MD at 6-month follow-up appointment**
Goals: Beyond Limb Symmetry Index (LSI)

Compare to pre-surgical limb status
EPIC (Estimated Pre-Injury Capacity) *(Wellsandt, 2017)*

Compare to body size / dimensions
• “Allometric Scaling”: weight, height, limb length

Compare to healthy normals
• Appropriate matching: Age, Sex, Sport, Level of sport/experience

Are Muscle Strength and Function of the Uninjured Lower Limb Weakened After ACL Injury?: Two-Year Follow-up After Reconstruction
Kyu Sung Chung, MD et al. AJSM 2015
In Conclusion

| Understand Precautions                              | • Knee joint biomechanics                 |
|                                                    |   • Biology                             |
|                                                    |   • Confounders                          |
| Master the early phases of rehab                   | • Promote recovery while protecting      |
|                                                    |   multiple structures                    |
|                                                    |   • Ask for help when needed             |
| Clean up your messes!                               | • **Perfect** the early recovery goals   |
|                                                    |   before progressing to the “fun stuff”  |
| Set goals & track outcomes                         | • Measure your patient’s progress        |
|                                                    |   • Adjust and progress your plan of care|
|                                                    |   to promote continual positive changes  |
Thank you!