2018 Affiliations & Disclosures

**Employment**
- Oregon Health & Science University

**Volunteerism**
- Mount Hood Meadows Emergency Mountain Services
- Portland State University Athletics

**Independent consultant/publication committees**
- Joint Restoration Foundation (Colorado)
- Moximed, Inc (California)
- Histogenics (Massachusetts)
- Zimmer (Texas)
- Medinet (Japan)

**Research support (PI)**
- Community Tissue Services (Ohio)
- Merk-Serono (Switzerland)
- Histogenics (Massachusetts)
- JRF Ortho (Colorado)
- Moximed (California)
- Zimmer-Biomet (Indianapolis)
Introduction to Revision ACL

- **Incidence:** 30 primary ACL reconstruction per 100,000
  - “Success” rates: ~75 – 95 %
  - Thus 5-25% ACL surgery “fail”

- ~100k revACLs in US/year
  - Increasingly common
  - Significant # of pts undergoing ACL reconstruction are at risk of unsatisfactory outcome
Patient “Dissatisfaction” Factors

Comorbidities

Instability

Complications
Categories of Failure

- No singular definition of “failure”
- **Recurrent instability**
  - Graft failure
    - Re-rupture
    - Under/imbalanced constraints
- **Postoperative complications**
  - Infection, loss of motion, fracture, hardware related (pain/hydrolysis)
- **Comorbidities related to concomitant abnormalities**
  - Malalignment (Coronal, Sagittal)
  - Extensor dysfunction (e.g., arthro-fibrosis, patella compression/baja)
  - Donor site pain (BTB > HT)
  - Cartilage damage
    - Osteoarthritis spectrum
    - Meniscus tears
Non-graft related causes of ACL failure

• **Loss of motion**
  – Non-anatomic graft placement
  – Impingement
  – Infection, Capsulitis
  – Cyclops lesion
  – Concomitant ligament surgery
  – Immobilization

• **Extensor mechanism dysfunction**
  – Anterior knee pain
  – Donor site pain
  – Quadriceps muscle weakness
  – Patellar tendonitis
  – Patellar fracture
  – Patellar tendon rupture

• **Degenerative Arthritis**
  – Initial traumatic event (bone bruise)
  – Meniscectomy
  – Damage secondary to recurrent giving way

• **Hardware Related**
  – Impingement/mass effect
  – Aseptic hydrolysis v. Infection
    • Crawford et al. OJSM 2015
Differentiating Occult Propionibacterium acnes Infection From Aseptic “Biologic” Interference Screw Hydrolysis After ACL Reconstruction. OJSM 2015

Introducing a Novel Culture Protocol for Detecting Low-Virulence Organisms

Kathryn Metcalf,* BA, Jia-Wei Kevin Ko,* MD, Samantha Quilici,* PA, Penelope Barnes,* MBBS, PhD, and Dennis C. Crawford,*† MD, PhD

Investigation performed at the Department of Orthopaedics and Rehabilitation, Oregon Health and Science University, Portland, Oregon, USA

• Present 2 cases of insidious proximal tibial pain > 2 years post ACL recon with “BioAbsorbable Tibial Fixation”
  • Infection v. “Bio-Absorbable” screw hydrolysis & fragmentation

• Describe a specific culture procedure developed to identify occult device related infection from aseptic “biologic” interference
  • Institutional Standard of Care OHSU (Barnes et al.)
Differentiating Occult Propionibacterium acnes Infection From Aseptic “Biologic” Interference Screw Hydrolysis After ACL Reconstruction. OJSM 2015

Culture Procedure

- 6 samples from “region of greatest suspicion”
  - 5 → microbiology
  - 1 → surg. pathology
- Each specimen taken with separate clean instrument
- Samples incubated on blood agar and chocolate media plates aerobically & anaerobically for 5 days (Kaiser Lab, Portland)
- Samples incubated in thioglycolate broth anaerobically for 10 days.
- Allows for growth of fastidious organisms (e.g. Propionibacterium )
Etiology of ACL Graft Failure

- Surgical technique “Non-Anatomic”
- Incomplete graft incorporation or failed healing
- Activity Related or Traumatic
- Arthrofibrosis +/- rehab compliance & efficacy
Etiology of ACL Graft Failure

- **Early Failure (<3 months)**
  - Incomplete incorporation or healing
    - Biologic vs. Mechanical
      - Irradiated Grafts, Failed fixation, infection
    - Arthro-fibrosis
      - Rehab/restriction compliance
      - Mechanical blocks
        - Poor tunnels
- **Mid-term Failure (3-6 months)**
  - Surgical Technique
    - Failure to restore stability
  - Secondary pathology manifests
    - Unable to return to activity
- **Late failure (> 6 months)**
  - Return to Sports & re-injury
    - Consider activity modifications
  - Progressive degeneration
    - Missed or occult cartilage injury?
Sub-Types Technical Failure ACL Surgery
Technical Issues: US MARS study group

Published in final edited form as:

Femoral Tunnel Malposition in ACL Revision Reconstruction

Joseph A. Morgan, M.D. ¹, Diane Dahm, M.D. ¹, Bruce Levy, M.D. ¹, Michael J. Stuart, M.D. ¹, and MARS Study Group*”

¹Department of Orthopaedic Surgery, Mayo Clinic, Rochester, Minnesota

MARS
Multicenter Anterior cruciate ligament (ACL) Revision Study

460 revisions performed by 87 surgeons
• 276 (60%) “technical cause of failure”
• 219 (48%) femoral tunnel malposition
• 117 (25%) femoral tunnel primary cause of failure
  • 42 (36%) too vertical
  • 35 (30%) too anterior
  • 31 (27%) too vertical & anterior
“Tunnels” Considerations

- Tunnel Malposition
  - Femoral tunnel
  - Tibial tunnel

- Tunnel preparation
  - Avoid over drilling
  - NO turnicate
  - Use AM portal if Transtibial constrains

- Tunnel “widening”
  - Radiographs
    - Not necessarily quantitatively accurate > CT
Preoperative Bone Tunnel Assessment

Bone Tunnel Placement

- **Anatomic**
  - Expanded
    - ACL graft with a large bone block or bone graft tunnel
  - Non-Expanded
  - Overlap
    - Bone graft tunnel
  - No Overlap
    - New anatomic bone tunnel

- **Nonanatomic**
Preoperative Evaluation

• Determining patient dissatisfaction origin
  – Recurrent instability
  – Postoperative complications (Arthrofibrosis, pain, mechanical)
  – Pre-existing comorbidities (Alignment, BMI, cartilage/meniscus injury)

• Indications for revision ACL
  – “Reconstruct a ruptured or incompetent ACL graft after ACL reconstruction with goal of stabilizing the knee...maximizing function and activity level. Be cautious of ability to effect complete pain relief”

• History
  – Cause of injury, history of re-injury, symptoms (pain v. instability), original graft type, operative technique, graft fixation, rehab timeline & compliance, return to activity (level & timing)

• Physical examination
  – Alignment, gait (varus thrust, hyperextension), p/a ROM, Extensor mechanism, ligament exam, incisions, quad atrophy?
Preoperative Evaluation

Radiographic examination:
Preoperative imaging should be assessed for:

- Presence of interfering hardware
- Tunnel position
- Tunnel expansion
- **X-rays**
  - True lateral (tib. Tunnel)
  - AP view (fem. Tunnel)
  - Merchant’s view (both knee)
  - Standing AP and PA @ 45 flexion views AP view both knees (joint space narrowing)
  - Standing long films of lower extremities (align.)
Preoperative Evaluation

Imaging:

– CT scan
  • Tunnel trajectory/size
  • Bony avulsion/cortex integrity

– MRI Scan
  • ACL graft
  • Articular cartilage
  • Collateral ligaments

– Bone Scan (+/-)
  • Osteoarthritis
  • Infection
Preoperative Planning: Expectations

Essential for patients to understand the realistic outcomes after revision ACL

- Restores stability (possibly 100%)
- Unpredictable “return to activity”
  - Lose ~1 level Tegner activity scale
- May not relieve pain from...
  - Extensor mechanism dysfunction (TTO)
  - Compartment overload
    - Patella femoral dysfunction (TTO)
    - Varus/Valgus overload/thrust (HTO/DFO)
  - Articular cartilage injury
    - repair v. transplants
Preoperative Planning

“Success” of revision ACL influences:

- Patient expectations
- Etiology of primary failure
  - Graft, surgical technique, trauma
- Pre-operative laxity of the knee
  - secondary restraints
- Status of cartilage
  - Lateral Meniscus!, Hyaline, OA
- Patient demographic: Risks
  - Gender, age, general health & activity, employment status, Weight gain, education
Preoperative Planning

Important **preoperative factors:**

- Range of motion
- Placement of previous incisions
- Type of graft previously used
  - Which autografts maybe available?
- Type & location
  - Fixation hardware
  - Bone tunnels
- Presence of associated
  - Ligamentous injury
  - Cartilage injury
  - Bone integrity/density
Preoperative Planning

Staged procedure may be required when there is:

- Loss of motion
  - Release/Debride > MUA prior
  - PT; restore A&P ROM
    - 1-6 months
- Massive bone tunnel enlargement
  - Bone grafting & healing
    - ~ 6 months, consider CT
- Overlapping bone tunnels fixation
  - Associated Medial MAT
## Graft selection: Autograft

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Faster and more complete biological incorporation</td>
<td>• Autograft tissue may not be available</td>
</tr>
<tr>
<td>• No added costs</td>
<td>• Donor site morbidity</td>
</tr>
<tr>
<td>• No risks of disease transmission</td>
<td>• Greater surgical exposure required</td>
</tr>
<tr>
<td>• Better objective stability results and lower failure rate compared to allografts</td>
<td>• Limited soft tissue and bone block size</td>
</tr>
</tbody>
</table>
## Graft selection: Allograft

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wide variety of tissue</td>
<td>• Cost</td>
</tr>
<tr>
<td>• No limitation of soft tissue or bone block size</td>
<td>• Slower graft incorporation</td>
</tr>
<tr>
<td>• No donor site morbidity</td>
<td>• Risk of disease transmission</td>
</tr>
<tr>
<td>• Decreased operative time (no autograft harvest required)</td>
<td>• Inferior objective results and higher failure rate compared to autografts</td>
</tr>
</tbody>
</table>
Technical considerations in ACL revision surgery

• Skin incision; placement may allow simultaneous:
  – Graft harvest
  – Drilling of the Tib. Tunnel
  – Tibial graft fixation
    • But do not constrain approach

• Hardware removal:
  – Don’t underestimate; -”no one looks good taking out” …. 

• Leave secure hardware if it does not interfere

• Bone tunnel placement most technically challenging
  – Best: recapitulate ACL origin & insertion footprint

• Graft fixation (all fixation options for bone & soft tissue)
  – Need to be facile with numerous options & techniques
Role of extra-articular reconstruction

OTT & ALL

- Over the top & Ant Lat Ligament
- Extra-articular recon has longer lever arm.
  - Better controls tibial rotation
- Extra-articular recon may reduce forces on ACL graft
  - Over constrains knee (AJSM 2016)
- Useful in complex revision ACL
  - Multiple failed revisions
  - Lack of Intra-articular options
  - Gross instability (Marfans, Multi-Lig)
Technical considerations in ACL revision surgery

Associated surgical procedures

- **Osteotomy** (malalignment)
  - Slope & Coronal Plane
- **Posterolateral reconstruction**
  - Double & Triple varus…
- **MCL/POL reconstruction**
  - Over constraint with early repair
- **Meniscal repair/transplant**
  - MAT assist with AP translation
- **Articular cartilage surgery**
  - Osteochondral v. cell based
Rehabilitation

• Avoid pressure to RTS
• Rehab program dictated by:
  – Graft type (Allo v. Auto)
  – Bone quality
  – Type of fixation
  – Assoc. surgery

• Soft tissue grafts w/ suspensory fixation may require more & longer postop protection

• Min. 9 months Ret. To Competitive Sports
Summary

• Etiology of ACL “failure” is multifactorial
• Failure etiology dictates ACL Revision recon strategy
• Technical failure is primary culprit
• Surgical planning is crucial for ACL Revision
• Consider failure potential when planning primary ACL recon
  – It’s not simply: Auto v. Allograft
Hardware Issues

• Avoid hardware
  – Preferable if;
    • Allows anatomic recon
  – Not possible
    • Consider necessity of staged procedure?

• Remove
  – Single stage?
  – Extraction equipment
    • Be prepared
  – Bone graft option
    • ALLO, Auto, Proprietary
Hardware Interference & ACL Revision

- CT scan
- Low strength MRI less responsive to metal artifacts
- Historic methods
  - Open surgery is OK
  - Remember cortical fixation is strongest
    - Endobuttons
    - Interference screws
  - “over the top”
    - Post and washer
Open “Over the top” Technique

• Secondary anatomic real estate challenges
  – Morbid Obesity
  – Peri-articular hardware

• Open lateral incision
  – Peroneal n- posterior
  – Poplitear a - medial
  – “over the top” wrasp
  – Fix with
    – Staples v. Bi-cortical post
Complex Revision Scenario

- 26 y f med student
- ACL BptB recon, MMx 9 y ago
- Instability & standing pain limiting ADL’s
- Anterior tibial tunnel, tibial tunnel widening, abscent MMx
Staged ACL Recon (Ach ALLO) after MAT
Achilles Allograft with Bone

8-14 mm bone block depending on tunnel aperture and Femoral or Tibial defect

Kim SJ et al.. JBJS. 2010;92:145-57 Described use for PCL.
Allograft Achilles with Calcaneal Bone Single stage Revision, Tib Tunnel
Recurrent ACL Instability

- 18 y male
  - Soccer athlete
    - Non-contact ACL injury
  - 2 prior ACL reconstruction
    - Autograft ACL (14 y)
    - Allograft revision ACL (16 y)
    - Intact medial meniscus
- Complaint of instability
  - 1+ Lachman
  - MRI intact graft
  - Lateral Xray
    - 15 degree slope
Neutralize Tibial Slope
Anterior Femoral Tunnel? Post Autograft Bone Patella Tendon
Anterior femoral tunnel > PF OA
Questions

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“Simple” Primary ACL Recon Approach

Trans-tibial Reconstruction of the ACL using Tibialis Anterior Allograft

Michael Rose, MD and Dennis Crawford, MD, PhD

The authors have nothing to disclose