Anterior Cruciate Ligament Reconstruction: Current Concepts Review

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What is an ACL?

• stabilizing knee ligament
• Prevents abnormal anterior displacement and rotation of tibia on femur
• Two bands: small anteromedial band (tight in flexion) and large, bulky posterolateral portion (tight in flexion)
• Ultimate tensile load and stiffness is 2160±157N and 242±28N
• Normal ACL not isometric
Normal ACL function
ACL tears

- risk of injury = 1 in 3000 Americans
- Football and basketball in younger patients
- skiing in older patients
- Substantial anterior tibial shear forces stress acl from quads contraction (esp 0 – 30 degrees contraction) (Sakane, ‘97)
ACL tears continued

- Typically torn in non-contact deceleration results in valgus twisting injury
- Athlete lands on leg and pivots in opposite direction
Significance of ACL tears

- Persistent joint instability and pain
- Structures at risk: Meniscus

Chondral damage

- cytokines, keratan sulphate ↑
- Acute traumatic hemarthrosis – 60 – 70% incidence of ACL injury
- Associated meniscal injury – about 40 – 50%
- Associated bone bruise – 80%
Significance of meniscal tear

- 40 – 50% are repairable

- Meniscal destruction leads to degenerative changes
Significance of bone bruise

- Posterolateral tibia ± anterolateral lateral femoral condyle
- 65% at 6 years shown to be significant
- Cartilage thinning and persistent subchondral marrow changes despite ACL reconstruction
Plain films in acute ACL injuries

- Usually no finding
- Occasionally may find small avulsion fracture, lateral tibial condyle = *Segond fracture*
MRI in ACL tears

Normal Anterior Cruciate Ligament

Torn Anterior Cruciate Ligament
Pivot shift

• Positive Pivot
The Lachman test

Negative

Positive
Physical exam: Lachman vs. Anterior Drawer

• Lachman when done at 15 – 30 degrees of knee flexion – 85% specific for complete tear

• Anterior Drawer: 50% specific with a complete tear
Factors affecting progression of osteoarthritis

- Meniscal lesions
- Osteochondral lesions
- Concomitant ligamentous pathology
Natural history of ACL- deficient knee

- Untreated; anterior laxity, rotatory instability + meniscal tears
- Increase in X-ray changes of Deg. joint disease
- 1/3 with isolated ACL injuries show min. instability
- 2/3 will show gross instability
- Over 50% young patients will re-injure same knee after 1 year
- Over 1/3 of middle-aged patients will re-injure same knee after 1 year
Natural history continued

- Not fully understood
- Acute hemarthrosis of knee, may have:
  - occult lesions
  - osteochondral fractures
  - subcortical fractures
  - transcortical fractures
Treatment options – OA and ACL deficiency

- Disease progressive, no cure – temporizing
- Analgesics, anti-inflammatories, PT, bracing, modification of activities
- Bracing: prevents instability at low loads, relieves arthritic pain, esp. medial compartment (Lindenfeld, 1997), (Matsuno, 1997)
- ACL reconstruction
Non-operative treatment

- No good evidence that brace wear decreases rate of re-injury
- Older patients with isolated ACL injury who moderate their activity find non-operative treatment satisfactory in majority of cases (literature – 80%)
Indications for surgery – factors to consider

• Degree of ACL injury
• Presence of associated ligamentous, chondral and meniscal conditions
• Age/activity level/occupation
• Sports participation
• Patient compliance with post-op rehab
Timing of surgery

- Read the soft tissues
- Captured knee
- Creation of stiff knee – worst
- Pitfalls of ACL surgery

- FIRST attempt = best attempt; revision surgery outcomes 50 – 70% good - excellent
Types of ACL grafts

**AUTOGRAFT**
- bone-patellar tendon-bone
- Quadrupled semitendinosus/gracilis tendon
- Bone quadriceps tendon

**ALLOGRAFT**
- Achilles tendon
- Bone-patellar tendon-bone
- Hamstring tendons
Patellar Bone-Tendon-Bone Graft
BTB graft continued
Hamstring tendon graft

Harvested Hamstring Tendons

Braided Tendons Form A Replacement ACL
### Ultimate tensile load of intact Human ACL and a few common replacement ACL grafts

<table>
<thead>
<tr>
<th>Graft type</th>
<th>Ultimate tensile load</th>
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<tbody>
<tr>
<td>Intact ACL</td>
<td>2160±154</td>
</tr>
<tr>
<td>Bone-patellar tendon-bone</td>
<td>2376 ±151</td>
</tr>
<tr>
<td>Single-strand semitendinosus</td>
<td>1216±50</td>
</tr>
<tr>
<td>Quadruple hamstring</td>
<td>4108±200</td>
</tr>
<tr>
<td>Quadriceps tendon (10mm)</td>
<td>2352±495</td>
</tr>
</tbody>
</table>
Meta-analysis of Patellar vs. Hamstring tendons in ACL reconstruction

- Controlled trials with minimum 2 year follow-up
- Evaluated; return to pre-injury level of activity, KT testing, Lachman scores, pivot shift scores, ROM, complications, failures
- 4 studies fulfilled inclusion criteria
- B-T-B showed a >20% chance return to pre-injury activity level versus hamstring, (p value = 0.01)

Yunes, M. et al “Patellar Versus Hamstring Tendons in ACL reconstruction; A Meta-analysis” Arthroscopy Vol. 17, No. 3 (March) 2001; pp248-257
Meta-analysis continued

- Relative risks and 95% confidence intervals shown
- BPTB patients are stat. Significantly more likely to return to return to pre-injury level of activity
**Meta-analysis continued**

**Table 3. PAT Versus ST&G: Relative Risks for Each Outcome**

<table>
<thead>
<tr>
<th>Positive Outcome</th>
<th>O’Neill et al.13</th>
<th>Aghetti et al.12</th>
<th>Marder et al.14</th>
<th>Corry et al.20</th>
<th>Pooled Risk Ratio, P Value</th>
<th>Absolute % of PAT Patients With Outcome</th>
<th>Absolute % of ST&amp;G Patients With Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return to preinjury activity level</td>
<td>1.05 (0.92-1.20)</td>
<td>1.33 (0.86-2.07)</td>
<td>1.03 (0.73-1.46)</td>
<td>1.37 (1.05-1.78)</td>
<td>1.18 (1.04-1.34); 0.04</td>
<td>75</td>
<td>64</td>
</tr>
<tr>
<td>Adverse Outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>KT Max Manual &gt; 3 mm</td>
<td>0.61 (0.24-1.51)</td>
<td>0.70 (0.44-1.11)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.63 (0.44-1.02); 0.06</td>
<td>27</td>
</tr>
<tr>
<td>KT 20 lbs &gt; 3 mm</td>
<td>0.78 (0.48-1.26)</td>
<td>0.68 (0.24-1.93)</td>
<td>0.63 (0.11-3.55)</td>
<td>0.35 (0.15-0.82)</td>
<td>0.13 (0.01-1.07)</td>
<td>0.57 (0.37-0.87); 0.019</td>
<td>17</td>
</tr>
<tr>
<td>Lachman &gt; 1</td>
<td>1.41 (0.40-4.93)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.81 (0.38-1.73); 0.59</td>
<td>7</td>
</tr>
<tr>
<td>Pivot Shift &gt; 0</td>
<td>—</td>
<td>0.78 (0.33-1.82)</td>
<td>0.69 (0.31-1.51)</td>
<td>0.48 (0.21-1.13)</td>
<td>0.48 (0.15-1.51); 0.21</td>
<td>0.63 (0.39-1.01); 0.05</td>
<td>16</td>
</tr>
<tr>
<td>Pivot Shift &gt; 1</td>
<td>—</td>
<td>0.33 (0.01-7.87)</td>
<td>0.47 (0.13-1.75)</td>
<td>1.04 (0.02-51.62)</td>
<td>0.48 (0.15-1.51); 0.21</td>
<td>0.63 (0.39-1.01); 0.05</td>
<td>16</td>
</tr>
<tr>
<td>ROM loss extension ≥ 1°</td>
<td>2.38 (0.12-48.53)</td>
<td>15.00 (2.11-106.49)</td>
<td>1.38 (0.75-2.54)</td>
<td>0.52 (0.10-2.75)</td>
<td>—</td>
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<tr>
<td>ROM loss flexion = 1°</td>
<td>1.88 (0.42-8.46)</td>
<td>1.00 (0.36-2.75)</td>
<td>1.18 (0.82-1.70)</td>
<td>1.04 (0.07-36.30)</td>
<td>1.20 (0.84-1.72); 0.31</td>
<td>14</td>
<td>12</td>
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<tr>
<td>Complications</td>
<td>1.18 (0.39-3.52)</td>
<td>3.00 (0.13-76.83)</td>
<td>1.10 (0.41-2.96)</td>
<td>0.81 (0.31-2.06)</td>
<td>1.04 (0.59-1.83); 0.89</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Failures</td>
<td>0.47 (0.07-3.22)</td>
<td>0.33 (0.01-7.87)</td>
<td>0.95 (0.06-14.55)</td>
<td>0.78 (0.18-3.37)</td>
<td>0.63 (0.23-1.73); 0.37</td>
<td>3</td>
<td>4</td>
</tr>
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</table>

*As explained in the results section, we were unable to pool these results because of significant heterogeneity.
Rehabilitation in ACL injury

- Goals ROM
- Graft weakest at 6 – 12 weeks
- Ligamentization at 24 weeks
- Maturation 1 – 3 years
- Closed chain quad exercises: 4 – 8 months
- Open chain for hamstring
Rehab continued

- Rehab depends on: graft selection
- Meniscal repair
- Chondral debridement
  - Micro-fracturing
  - Brace hamstring for 6 weeks
Femoral notchplasty/roofplasty

- Create clearance for graft when knee is in extension
- Prospective, randomized study 100 pts found no beneficial short-term effect of performing a notchplasty (M. Cohen, 1998)
- Minimizing it – reduced post-op bleeding, pain, swelling and notch regrowth

McMaster University
Drilling femoral and tibial tunnels

- Tunnel placement CRITICAL
- Tibial tunnel 7mm ant PCL
- Femoral tunnel 1-2mm ant to femoral cortex
- Post placed tibial tunnels, good outcomes (Harner et al, 1994)
- Ideal graft position still unknown
Tibial drill guide

www.medicalphoto.com
Tibial guide wire
Femoral drill hole
Endoscopic view of femoral drill guide
Longitudinal graft tunnel motion

- Bungee effect – endobutton 1 – 3 mm
- AP motion windshield wiper effect
- May be reduced graft fixation near joint line
Graft Preconditioning and Tensioning

- Inadequate tension – continued instability, excessive tension – restrict knee motion
- Prospective, randomized study, min F/U = 2 years, grafts tensioned to 80N < laxity than the 20N, no diff. clinically
- Precise amount of tension has yet to be determined
Graft Pretensioning

- May not be of benefit
- 75% viscoelasticity returns to normal one minute after fixation for:
  - 5-10lbs tension at 15° flexion BPTB
  - 4.5 kg – 6.75 at 20° to 30° flexion hamstring
Positioning of the graft
Insertion of Interference screws

- With B-T-B, no difference if use metallic, titanium or biodegradable screws used (Benedetto et al, 1998)
• Other methods: DIRECT-staples, washers, cross-pins INDIRECT – buttons, suture posts
• Ultimate tensile loads of these devices range from 200 to 1600N
Insertion of femoral screw
Completed ACL Reconstruction

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Graft fixation

• B-T-B, rigid fixation within osseous tunnels – healing analogous to # healing

• Soft tissue tendon grafts diff fixation – rabbit study with semi-T found increased structural properties with time, at 1 year ultimate tensile load 25% normal ACL (Blickenstaff et al, 1997)

• No definitive studies comparing biomechanical properties between bone-bone and bone-tendon healing in the ACL-reconstructed knee
Comparison of Donor Site morbidity (BTB + Hamstring)

- **BONE-Patellar TENDON-BONE Autograft**
  - Patellar pain reported 4% to 40%
  - Patellar baja may develop
  - Incidence patellar pain lower with immediate and aggressive rehab
  - Pain usually resolves after 3-6 months

- **HAMSTRING TENDON Autograft**
  - 3 years post ham. muscle strength about 95% pre-op
  - Evidence of post-harvest firm scar formation
  - Soreness harvest area noted up to 3 months, not major patient complaint

*McMaster University*
Future directions

- Basic fibroblast growth factor
- Transforming growth factor-beta
- Platelet derived growth factor
  - Enhancing ligament insertion sites
  - Gene therapy
  - Meniscal transplantation