Update on ACL Graft Selection

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ACL Graft Selection

ACL reconstruction is the:

- 6th most common procedure performed in Orthopedic Surgery
- 100,000 ACL reconstruction per year
- 85% of surgeons doing ACL surgery do < 10/yr
- Failure rate estimated at 10-15%
ACL Graft Selection

The ideal graft should

- Reproduce native anatomy and normal biomechanics
- Rapidly incorporate with strong initial fixation
- Low donor site morbidity
- Limit risk of disease transmission
- Allow for sufficient graft length and diameter
- Be cost effective
ACL Graft Selection

- Important variables to consider in ACL surgery
  - Graft selection
  - Graft fixation
  - Tunnel placement
  - Functional rehabilitation
ACL Graft Selection

- Bone Patella Bone Autograft was considered the “Gold Standard” for graft choice - this is rapidly changing
- With the evolution of ACL surgical technique and improvements in technology, there is more variability in graft choice
- With no “Gold Standard” it is important when choosing a graft, to understand the advantages and disadvantages of each.
ACL Graft Selection

- Autograft
  - Bone - Patellar - tendon bone
  - Semitendinosis and Gracilis
  - Quadriceps tendon
ACL Graft Selection

- Allograft
  - Bone patellar-tendon bone
  - Semitendinosis Gracilis
  - Achilles tendon
  - Quadriceps tendon
Criteria for ACL graft selection

- Biomechanics of normal ACL and ACL Graft
  - All current auto/allograft choices have higher ultimate strength than native ACL

- Biological Healing
  - BPTB autograft incorporate into bone tunnels as early as 6 weeks
  - Hamstring autograft – 12 weeks
  - Allograft as much as 6 months
Criteria for ACL graft selection

- Ease of harvest
  - Operative time: BPTB auto is the most difficult
  - Hamstring is faster to harvest
  - There is a learning curve to all types of graft harvesting with added potential for complications

- Return to play
  - Surgeon dependent
  - Lack of objective evidence in decision criteria for return to play
Criteria for ACL graft selection

- Donor site morbidity
  - BPTB auto > QT auto > Hamstring auto

- Donor site complications
  - Fracture of patella
  - Nerve injury with hamstring harvest
  - Anterior knee pain
Outline

- **Graft Choices**
  - **Autograft**
    - Patella Tendon
    - Hamstring
    - Quadriceps Tendon
  - **Allograft**
    - Patella Tendon
    - Achilles Tendon
    - Soft Tissue Allograft
      - Tibialis
      - Hamstring
    - Sterilization
## Biomechanical Properties

<table>
<thead>
<tr>
<th>Graft</th>
<th>Ultimate Strength (N)</th>
<th>Stiffness (N/mm)</th>
<th>Cross Sectional Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact ACL</td>
<td>2160</td>
<td>242</td>
<td>44</td>
</tr>
<tr>
<td>BPTB (10 mm)</td>
<td>2977</td>
<td>620</td>
<td>50</td>
</tr>
<tr>
<td>QDHS</td>
<td>4590</td>
<td>861</td>
<td>53</td>
</tr>
<tr>
<td>Quad Tendon (10 mm)</td>
<td>2352</td>
<td>463</td>
<td>62</td>
</tr>
<tr>
<td>Anterior Tibial Tendon (single)</td>
<td>3412</td>
<td>344</td>
<td>38</td>
</tr>
<tr>
<td>Posterior Tibial Tendon (single)</td>
<td>3391</td>
<td>302</td>
<td>48</td>
</tr>
</tbody>
</table>

All grafts have higher strength & stiffness than native ACL
Grafts - Autograft

- Bone-patella tendon-bone
  
  **Pros**
  - Most likely quickest healing
  - Excellent fixation
  - Good track record (results 90-95%)
  - Strength of graft
  
  **Cons**
  - Linked to PF pain & DJD
  - Risk of patella fracture
  - Patella Tendon rupture
  - Larger incision
  - More painful surgery
**Grafts - Autograft**

- **Hamstrings (Semitendinosis / Gracilis)**
  - **Pros**
    - Strongest tensile strengths (>4000 N)
    - Smaller incision
    - Pediatric patient
    - ? Hamstring regrowth
  - **Cons**
    - ? Fixation strength
    - Residual muscle weakness
    - Soft tissue to bone healing
    - Harvest – possible short graft
    - Graft size - diameter
Grafts - Autograft

- **Quadriceps Tendon**
  - **Pros**
    - Similar tensile strength to BPTB
    - Fixation similar to BPTB
    - Less anterior knee pain
Grafts - Autograft

- Quadriceps Tendon
  - Cons
    - Longer Incision
    - Less experience
    - Quad tendon weakness
Autograft Results

- BPTB vs. Hamstring
  - No study to date demonstrated a superiority of any graft source in stability and functional outcomes
  - Morbidity of hamstring graft harvest is less than the morbidity of bone-patella tendon-bone graft harvest
    - Laxdal et al. (Arthroscopy ’06)
    - Yasuda et al. (AJSM ’95)
  - Anterior knee pain, knee extension loss, kneeling pain & arthritis statistically greater with the use of BPTB grafts compared to HS grafts
    - Sajovic et al. (AJSM ’06)
    - Kartus et al. (Arthroscopy ’01)
  - Recent prospective 5 yr FU study of 2 equally matched groups: statistically higher incidence of OA of the knee in patients BPTB graft (50%) compared to HS graft (17%)
    - Sajovic et al. (AJSM ’06)
Autograft Results

- BPTB vs. Hamstring = Meta-analysis
  - Yunes et al (Arthroscopy ’01) = 411 patients
    - BPTB group had significant less laxity by KT-1000 than the hamstring group
    - BPTB = 18% higher rate of “return to preinjury level of activity”
  - Freedman et al (AJSM ’03) = 1976 patients
    - Increased PF pain, less laxity, lower rates of graft failure, improved stability, and higher patient satisfaction in the BPTB group
  - Prodromos et al (Arthroscopy ’05) = 56 studies
    - HS group = higher stability depending on fixation type
  - Goldblatt et al (Arthroscopy ’05) = 1039 patients
    - Anterior knee pain, increased kneeling pain, flexion deficit with BPTB autograft and extension deficit compared with HS autograft
    - BPTB more likely to result in normal Lachman exam, pivot shift exam, KT-1000 side-to-side difference <3mm, and fewer results with significant flexion loss
Autograft Results

- BPTB vs. Quad Tendon
  - Staubli et al (AJSM ’99)
    - BPTB > tensile strength
  - Lee et al. (Arthroscopy ’04)
    - Comparable results of BPTB vs. Quad
Autograft Results

- Comparison of all 3
  - Joseph et al. (Orthopaedics ’06)
    - Early comparison of 3 autografts
    - Free quad tendon group achieved earlier full knee extension
    - Less pain with quad tendon
    - Similar clinical results
Grafts - Allograft

- Public concern for disease transmission
- Biomedical Tissue Services (BTS) 2008
- “Dentist Pleads Guilty to Stealing and Selling Body Parts”
- Acquiring body parts from funeral homes without proper screening and consent
Grafts - Allograft

- Disease transmission and infection

- American Association of Tissue Banks
  ✓ AATB
AATB Screening guidelines

- Consent
- History of donor
  - Prior infections
  - Risk factors (homosexuality, sex for money, illegal drug use, hemophilia)
- Physical Exam
  - Needle wounds
  - Infection
AATB Screening guidelines

Screening Tests on Blood and Tissue

- Donors must test negative for antibodies to (HIV)
- Nucleic acid test (NAT) for HIV-1
- Hepatitis B surface antigen
- Antibody to hepatitis B core antigen
- Antibodies to the hepatitis C virus (HCV)
- Nucleic acid test (NAT) for HCV
- Antibodies to T-lymphotrophic virus, and syphilis
AATB Screening guidelines

✓ Nucleic acid testing for HIV and HCV
✓ A new provision of the AATB as of March 9, 2005
✓ Nucleic acid testing markedly shortens the window of time for the detection of the viruses.
AATB guidelines

- Tissue excisions must commence within 24 hours of asystole if the body was cooled
- Within 15 hours of death if the body was not cooled
- An aseptic technique is used to retrieve all tissues
- Tissues are cultured after harvest and prior to processing
- All musculoskeletal tissues are processed in a bacteriologically controlled and climate-controlled environment
Secondary Sterilization

- Eliminate all possibility of infection while maintaining all biologic and mechanical properties of the tissue
- No technique currently exists that fulfills these requirements
- Gamma irradiation is a popular method
- 2.5 megarads w/o significantly altering biomechanical properties of graft
- Eliminating bacterial surface contamination
Grafts - Allograft

- The estimated risk for HIV transmission with a connective tissue allograft is estimated to be 1:8,000,000.
- CDC reported 26 cases of allografts associated with bacterial infections in an estimated 1 million musculoskeletal allograft.
- The majority of infected grafts were from tissues processed by the same tissue bank. This tissue bank was closed.
- All were processed aseptically.
- None were terminally sterilized.
Allograft storage options

- Fresh Frozen allografts
  - between temperatures of -80 to -196 degrees F
  - allows for storage of up to 3 to 5 years,
  - the process kills the cells.

- Cryopreservation
  - tissue undergoes controlled-rate freezing
  - cellular water is extracted by glycerol and dimethylsulfoxide.
  - shelf life of 10 years and up to 80% of cells can remain viable.
Allograft storage options

- Freeze drying or lyophilization
  - Residual moisture level of <5%.
  - Stored at room temperature for up to 3 to 5 years.
  - Requires rehydration
Grafts - Allograft

- Bone-patella tendon-bone
  - Pros
    - Bone – bone healing
    - Graft size
    - Fixation
    - Incision size
    - Shorter OR time
    - Less post-op pain
  - Cons
    - Risk of infection
    - Slower healing
    - Cost
    - Availability
Grafts - Allograft

- Achilles tendon
  - Pros
    - Bone – bone healing on femur
    - Size of graft
    - Ease of retroscrew fixation
    - Smaller incision
    - Shorter OR time
    - Less post-op pain
  - Cons
    - Risk of infection
    - Slower healing
    - Cost
    - Availability
Grafts - Allograft

- **Soft tissue (hamstring / tibialis)**
  - **Pros**
    - Graft strength
    - Variability in size
    - Smaller incisions
    - Less post-op pain
    - Shorter OR time
Grafts - Allograft

- Soft tissue (hamstring / tibialis)
  - Cons
    - Risk of infection
    - Slower healing
    - Cost
    - Availability
Allograft Results

- Levitt et al (CORR '94)
  - BPTB / Achilles allograft
    - 85% success, no difference in grafts

- Caborn et al (Arthroscopy '02)
  - Tibialis tendon
    - No early failures and comparable results to auto

- Singal et al (Arthroscopy '07)
  - Tibialis tendon
    - 23% ACL failures requiring revision

- Indelli et al (CORR '04)
  - Achilles tendon
    - 92% returned to pre-injury activity level
Auto vs. Allo

- No level I randomized studies
- BPTB
  - Rihn et al (KSSTA ’06)
    - No clinical difference between 2 groups
  - Barrett et al (AJSM ’05)
    - Older patients > 40
    - Allo = quicker return to activity but increase laxity
  - Shelton et al (Arthroscopy ’97)
    - Similar results @ 2 & 5 years
    - Allo = less incision pain / extension loss
  - Harner et al (CORR ’96)
    - No differences in outcome
Auto vs. Allo

- **BPTB auto vs. Achilles allo**
  - Poehling et al (Arthroscopy ’05)
    - Similar long-term results
    - Less early pain and function limitation in allo group

- **BPTB – Meta-analysis**
  - Krych et al (Arthroscopy ’08) = 534 patients
    - NO DIFFERENCES when irradiated grafts were removed from analysis

- **Meta-analysis**
  - Prodromos et al (KSSTA ’07)
    - Allograft = 3x higher instability rates
<table>
<thead>
<tr>
<th>Graft</th>
<th>Biologic Incorporation</th>
<th>Initial Fixation</th>
<th>Morbidity</th>
<th>Ease of Harvest</th>
<th>Versatility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patella Tendon Auto</strong></td>
<td>+ Bone Healing (6 weeks)</td>
<td>+ Interference screw</td>
<td>- Large incision</td>
<td>Debatable</td>
<td>Single tunnel only</td>
</tr>
<tr>
<td><strong>Hamstring Auto</strong></td>
<td>Tendon-bone healing (8-12 weeks)</td>
<td>Variable</td>
<td>+ Smaller incision, less post-op pain</td>
<td>Debatable</td>
<td>Single &amp; double tunnel</td>
</tr>
<tr>
<td><strong>Allograft Soft Tissue</strong></td>
<td>- Slower</td>
<td>Variable</td>
<td>+ None Less post-operative pain</td>
<td>+ The best! No incision</td>
<td>Single &amp; double tunnel</td>
</tr>
<tr>
<td><strong>Quad Tendon Auto</strong></td>
<td>+/- Bone &amp; tendon healing</td>
<td>Variable</td>
<td>Possibly less than patellar tendon</td>
<td>Debatable</td>
<td>Single &amp; possibly double tunnel</td>
</tr>
</tbody>
</table>
Return to Play

- Issue of return to play related to graft?
- Prospective, randomized study of hamstring or patellar tendon autograft
  - Pre-injury return > BPTB
  - O’Neill et al
- Meta-analysis
  - Return to pre-injury:
    - BPTB = 75%, HS = 64%
  - Yunes et al (Arthroscopy ’01)
- Return to play factors:
  - School / graduation / timing of season
  - Family / work demands
Based on these Results

- **My graft choice:**
  - Achilles Allograft
  - Hamstrings Autograft: Pediatric patients, any patient opposed to allograft
  - Soft tissue allograft: revisions, multiligament reconstructions

- **Fixation**
  - Bio absorbable interference screws
THANK YOU