Prevalence

- 1 out of every 3000 people will suffer an ACL injury per year.

- Approximately 100,000 ACL reconstructions are performed annually.

Prevalence

- Disrupted more than any other ligament in the body

**ACL Function**

- **Primary restraint to anterior displacement of tibia relative to the femur**
- **Secondary stabilizer of rotation, mainly with internal and external tibial rotation**
- **Cruciates cross with tibial internal rotation**
Ligament Restraints

- ACL provides 85% of restraint to anterior displacement of tibia between 30-90 degrees of knee flexion
- Secondary Restraints – remaining 15%
  - ITB 25%
  - Mid 1/3 medial capsule 22%
  - Mid 1/3 lateral capsule 20%
  - MCL 16%: LCL 12%


- Minimum 5 year FU
- 1820 patients
- 78% - 1415 patients
- 75 (5.3%) had injury to other knee
- 61 (4.3%) had injury to reconstructed knee


- Women suffered more injuries than men to contralateral knee (7.8% to 3.7%)
- Injuries to reconstructed knee not significantly different (4.3% vs 4.1%)
- No difference in those returning to sports sooner than 6 months compared to those after 6 months
- Risk
  - 17% < 18
  - 7% 18-25
  - 4% > 25

Anatomy

- Intercondylar notch
- A-shaped notch – higher risk for ACL injury
- With ER ACL gets caught against notch and is cut by LFC


Others though cast doubt that notch size contributes to ACL injury


Intercondylar Notch

- 615 male professional basketball players
- NBA combine workouts between 1992-1999
- NBA league-wide injury database used to identify injured players
- Notch width index did not predict rate of ACL injury

Anatomy

- **Q-angle**
  - Those who sustained ACL injury displayed significantly larger Q-angle than those that did not sustain injury


Anatomy

- **Notchplasty**
  - Before 1988 done only to increase visualization of intercondylar area
  - Noticed upon subsequent arthroscopy that the lateral aspect of graft became frayed
  - Now routinely take 11 mm for standard 10 mm graft


Anatomy

- **Absolute Size of ACL**
  - Volume calculated via MRI scans
  - 27 noninjured knees of those injured with noncontact ACL injury
  - 27 age matched controls

Anatomy

- Contralateral volume for injured subjects was significantly smaller than non-injured subjects
- Injured group volume = 1921 mm$^3$
- Uninjured group volume = 2151 mm$^3$


ACL – Where Does It Fail

- 80% Mid Substance
- 18% Femur
- 2% Tibia
- Younger patients often have an avulsion of the tibial spine which is the insertion of the ACL

ACL

- 35mm long
- Stretches 10-12 mm (1/3 increase) before it ruptures
ACL

- > 50% disruption
- > 50% risk of progression to complete failure


Mechanism of Injury

- Combined valgus and external rotation applied to the knee while the foot is firmly planted.

Mechanism of Injury

- Non contact external rotation
Mechanism of Injury

- Excessive internal rotatory force or combination of internal rotation and hyperextension

Mechanism of Injury

- Hyperextension
- Perception of knee "giving out"

Mechanism of Injury

- Most injuries are noncontact injuries in which sudden limb deceleration accompanied by contraction of the quadriceps muscle group
- Football player planting and cutting
- Basketball player catching a pass and planting to cut toward basket
Mechanism of Injury

- 6 experts visually examined 39 videos of ACL injury situations
- 72% did not involve contact
- >50% of women injured pushed just before injury
  - Perturbation may have influenced injury


Mechanism of Injury

- Knee flexion angles at injury were higher in males than females
- Females 5.3 times higher risk of sustaining valgus collapse
- Preventive programs should include distractive elements


Injury From External Contact

- O'Donoghue “unhappy triad”
- Combination of valgus, flexion, and external rotation applied to knee while foot is planted
- Injury to ACL, MCL and Medial Meniscus (Lateral meniscus?)

Lateral Meniscus!


Physical Examination

- Patient usually feels and hears a “pop” (80-90%)
- Acute hemarthrosis develops within 12 hours

Factors Determining Treatment Choices

- Access to rehab facility
  - 4 week lag time
  - Surgery on acutely injured knee will lead to decreased ROM and impaired function
  - One month prior to surgery begin PRE-HAB
    - Increase strength
    - Increase ROM
    - Decrease swelling
Surgical Procedures

- Ideal Operation:
  - Fixation:
    - Screws rather than sutures
    - Bone-IPT-bone better fixation
  - Excellent strength
  - Allows immediate motion
  - Permits early activity
  - Prevent recurrence

Primary Repair

- Original tissue is repaired back to itself
- Poor long term results for intra-substance tears repaired as an isolated procedure
- Rupture affects blood supply
  - Medial intragenicular artery injured
  - Tissue becomes necrotic
  - Decreases integrity of graft
- Appropriate only when true avulsion occurs

Indications for Primary Repair

- True avulsion
  - Usually occurs in teens
  - Ligaments stronger than bones
  - Epiphyseal growth plate open
  - Fixation of bony fragment with screw
- Sedentary individuals
- Older individuals – less active
- Partial ACL rupture with minimal instability
Primary Repair with Marrow Stimulation

- 99 patients
- 26 treated with primary repair of proximal ACL tears
- Marrow stimulation via microfracture at femoral footprint

Primary Repair with Marrow Stimulation

- 25 month follow up (17-38 mo)
- Subjective scales lower (improved) following procedure
- Ligament laxity different
  - 3.5 mm pre - 1.3 mm post


Reconstructive Procedures

- Replace original graft
- Infrapatellar Tendon (IPT)
- Extra-articular structure becomes an intra-articular structure
  - Rejection phase
  - May create a synovitis response
  - This can lead to decreased blood supply

Different Procedures

- Autograft: own tissue
- Allograft: from “tissue bank”
- Synthetics: man made tissue
Ligament Substitutions

- Increased tensile strength
- Increased fatigue strength
- Decreased immunogenicity
- Easy to install
- Allows early rehab and return to activity
- Allows biological ingrowth

Isometricity/Physiometry

- Constant tension on ligament throughout ROM
- The ideal placement for intra-articular grafts
- Improper placement is most common cause of surgical failure

Autograft

- Patellar tendon
  - Bone-IPT-bone procedure
  - Gold standard
  - Central 1/3 of IPT (10mm) on average
- Semitendinosis/gracilis
  - Double, triple or quadruple looped for reinforcement
- Iliotibial band/Quadriceps tendon
  - Not used very often
Patellar Tendon Autograft

Advantages
- Readily available
- Excellent strength
- Best well documented long term results
- Allows most aggressive rehab of all biological tissue secondary to strength and bone-bone healing

Disadvantages
- Weakens extensor mechanism (?)
- Associated risks
  - Patellar chondrosis
  - Tendinitis
  - ROM deficits
  - Patellar fracture
  - Tendon rupture
- Requires diligent rehabilitation
  - IPCS may result
  - Excessive proliferation of scar tissue secondary to vascular supply

Anatomic/pathologic limitations
- Small/narrow tendon
- Chronic tendinitis
- Reduced performance in some jumping sports
Surgical Technique

- Bone-central 1/3 tendon-bone
- Free graft, nothing attached
- Procedures
  - Open reconstruction
  - Arthroscopically assisted procedure: Hole drilled out through femur, screw fixation from outside
  - Endoscopic technique: Do not drill all the way out of femur, screw fixation from inside

Semi-T, Gracilis Tendon

Semi-T/Gracilis Autograft

- Advantages
  - Readily available
  - Double/triple loop gives excellent strength (120-140%)
  - Doesn’t compromise the extensor mechanism
  - Biological graft (immunogenicity)
  - No weakness of hamstrings

No Loss of Hamstring Strength


No Loss of Hamstring Strength


Semi-T/Gracilis Autograft

- Two possible explanations for maintaining hamstring strength:
  - Tendons remain functional
  - Compensatory hypertrophy of undisturbed knee flexors.
- MRI cross sectional areas of biceps femoris, semimembranosus and sartorius muscles were not significantly different

Semi-T/Gracilis Autograft

- Distal most insertion of semi-T & Gracilis tendons after harvest were always more proximal than the non-op side
- Majority of cases demonstrated some but never complete re-growth or scar formation of these tendon remnants


Semitendinosis/Gracilis Graft

- Disadvantages
  - Limited long-term follow-up studies
  - Slower rehabilitation
  - Soft tissue to bone healing
  - Still requires diligent rehabilitation
  - Chronic tendonitis of Semimembranosus
  - Small tendon

Lizard Tail Phenomenon
Lizard Tail

- Study to evaluate the ability of the native semi-T to regenerate after harvest for ACL replacement
- Rabbit model: All 10 specimens demonstrated regeneration at 16 and 28 weeks with normal appearing histological and morphological characteristics
- Biomechanical strength 23% normal at 16 weeks and 62% normal at 28 weeks


Lizard Tail

- Patellar tendon harvest site has been shown to refill with scar tissue
- Biomechanically inferior to native patellar tendon and not suitable for revision ACL reconstruction


Lizard tail in humans

- 40 patients; pre-post ultrasonography
- Post US @ 2 wks, 1,2,3,6,12,18,24 mo.
- 2 weeks: site occupied by an area of increased thickness and decreased echo, suggesting edema of soft tissue
- 1 month: irregular hypoechoic structure appeared in near anatomic position

Lizard tail in humans

- 2 mo: Thickness, width, and cross-sectional area were significantly greater than pre-operatively.
- 1 yr: Distinct edges and reduction in thickness and width.
- 18 & 24 mo: Echogenicity of structure very similar to that of normal tendon, but approx. 4 cm proximal to pes anserine.


ACL ALLOGRAFT

Allograft

- Indications
  - Older individual with substantial DJD or low desire for high impact activities
  - When short convalescence is important
  - Accept increased likelihood of graft failure
Allograft

**Advantages**
- Biological graft – cadaveric tissue retrieved from tissue bank which is capable of remodeling and repair
- Decreased surgical morbidity with endoscopic placement, no compromise of normal anatomy
- May require less intense of rehabilitation
- No other options

**Disadvantages**
- Transmission of communicable disease
- Prolonged remodeling/revascularization time
- Expense and availability – graft alone >$2000
- Tissue radiation – decreased tensile strength (?)
- YUCK effect - GJD
  - External biological tissue
  - Greater chance of infection
  - May create chronic synovitis

Allograft vs Auto in Younger

**Systematic review with meta-analysis**
**Comparative studies of allograft vs autograft in those <25 years of age and high activity level**
**7 studies – 788 auto; 288 allo**
**Mean age 21.7 years; follow up time =24-51 months**

Allograft vs Auto in Younger

- Pooled failure variance
  - Autografts = 9.6/788
  - Allografts = 25% (57/228)


Thermal Treatment to Partial ACL Tears

- Thermal energy has been useful in treatment of shoulder instability for some time
- Recently thermal energy has been used to treat laxity of the ACL following surgery or in partially torn ACL’s

BE CAREFUL!
Thermal Treatment for ACL’s

- A paucity of in vivo, in vitro, and clinical data are available with regard to this potential treatment regime.

Lopez and Markel

- Monopolar RFE to the normal ACL of one knee in each of 18 dogs with sham treatment of the contralateral ACL.
- Results showed rupture of all treated ligaments approximately 55 days after surgery.
- Rupture detected by sudden onset of NW status and + drawer sign.


Sekiya JK, Golladay GJ, Wojtys E

- Case Study
- 16 yo female injured L knee playing basketball
- ACLR with semi T/Gracilis
- 5 months after surgery patient re-injured knee.
- Arthroscopy revealed irreparable medial meniscus tear with ACL in continuity but lax

Autodigestion

- ACL treated with heat probe 65 degrees C as recommended by manufacturer
- Graft shrinkage was seen. Following procedure Lachmans revealed no increased laxity compared to uninvolved side
- 13 week after 2nd surgery sustained non contact knee injury


Autodigestion

- PE revealed 3+ Lachman’s with no end point
- 2 weeks later arthroscopy revealed to remnant of previous hamstring graft identifiable in the notch
- Revision with BPTB
- 9 months following surgery no subjective instability and Lachman’s (-)


Autodigestion

- 23 year old male athlete
- Hyperextension injury playing semi professional football
- Tx four weeks after injury with RFE
- Operative report detailed ligament treated on anterior aspect with "good visual shrinkage"
- Post treatment “looked like a normal ligament with no laxity”

Autodigestion

- Braced 3 weeks in full extension
- Returned to full activities in 15 weeks
- (-) Lachmans, pivot shift and no c/o pain or instability
- 6 months later reported to clinic after sustaining non-contact twisting injury while playing soccer. Felt “pop” in same knee
Autodigestion

- Minimal swelling and med joint line pain
- 2+ Lachman’s, 2+ pivot shift and 8mm side to side difference laxity with KT-1000
- MRI revealed non-visualization of ACL
- Absence of ACL noted during surgery

Reasons for Autodigestion

- Biomechanical alteration of the collagen may have led to failure of the graft.
- An immune-mediated response resulted in autodigestion of the graft.


Thermal Shrinkage – 2 Year FU

- 64 patients
- 2 centers
- Lax ACL from native or previous reconstructions
- > 2 year follow-up


Thermal Shrinkage – 2 Year FU

- Failure as determined by 5mm increase in laxity with KT-1000
- **Overall** 50.8%
- Previous reconstructions 78.9%
- Native ACLs 38.1%

Surgical Delay

- Relationship between ACL reconstruction delay and incidence of secondary injury
- 1434 patients
- Time to surgery after initial injury


Surgical Delay

- Time delay
  - 0-3 months
  - 4-12 months
  - > 12 months
- Association noted between time to surgery and injury
- Trochlea, lat fem condyle, med tib plateau, medial meniscus


Early Revision Predictors

- 32 adolescents – ACL surgery
- Mean age 15.2 years
- 21(91%) followed at 10-20 years after
- Clinical, radiographic and QOL data

Early Revision Predictors

- Reconstructed knee significantly more OA compared with non-involved knee
- Tegner and Lysholm scores not different pre and post
- Strength and stability improved
- Subjective scales varied


Graft Failure

Categorization of Graft Failure

- Error in Surgical Technique
- Failure of Incorporation
- Trauma

Error in Surgical Technique

- Initially incompletely recognized or addressed complex ligament injuries
- Inadequate notch plasties
- Improper tunnel placement
- Improper graft tensioning
- Insufficient fixation

Failure of Incorporation

- Failure of graft to mature and remodel

Trauma

- Insufficient or excessive rehabilitation
- Recurrent injury (knee abuser)
Strain on ACL

- Running Downhill 125%
- Isometric quad contraction, 22° knee flex, 20-lb 62-121%
- Isometric quad contraction, 0° knee flex, 20-lb 87-107%
- Jog on floor 89%
- Leg lift, 22° knee flexion 12-79%
- Jog 5 mph on treadmill 62-64%
- Isometric quad contraction, 45° knee flexion, 20-lb 80%
- Walk without assist device 36%
- Half-squat, one leg 21%
- Quad set 18%
- Walk with crutches, 50-lb weight bearing 7%
- Stationary cycle 7%
- Isometric hamstring contraction 7%


Ligamentization

- Necrosis
- Revascularization
- Cellular proliferation
- Collegen formation
Necrosis
- First 3 weeks following surgery
- Graft needs blood supply
- Native cells diminish
- Graft nourished by synovial fluid and bone blood supply

Revascularization
- Within first 6-8 weeks
- Inflammatory response under control
- Bone plugs generally incorporate into tunnels within 12 weeks

Cell proliferation
- Tissue begins to become vascularized
- Fibroplasia
- Fibroblastic activity collagen and elastin
- Tensile strength of ligament slowly increases
Collagen formation (Maturation)

- Long-term process
- Collagen remodeled in lines of stress according to tensile forces placed on tissue
- Tissue gradually assumes normal appearance
- May require over 1 year

Graft Maturity

- Comparison of quad tendon with bone to hamstring autograft
- 26 patients
  - 12 quad
  - 14 hamstring
- 1.5 T MRI .5 years postoperatively


- Signal to noise ratio
  - Quad tendon = 1.74
  - Hamstring = 2.44


- Rehab may require modifications
Graft Maturity

- Comparison of allografts versus autografts
- 52 patients
- 30 allografts
- 22 autografts
- 3.0 T MRI 2 years postoperatively


Graft Maturity

- Outcomes
  - Subjective
    - IKDC
    - Tegner scores
  - Physical examination
    - Lachman's test
    - Anterior drawer


Graft Maturity

- All normal function by 2 years
- No subjective score difference
- No difference in laxity measures
- Signal/noise quotient allograft significantly higher than autograft
- Indicating inferior graft maturity

Structured Rehab with Surgery
Vs. Structured Rehab and option for surgery

- 121 young active adults – acute ACL tear
  - Rehab + ACL repair
  - Rehab and option for repair


Structured Rehab with Surgery
Vs. Structured Rehab and option for surgery

- 2 year follow-up
- Change in outcome scales
  - 4 subscales of KOOS
  - Short Form 36 Survey
  - Tegner Activity Scale


Structured Rehab with Surgery
Vs. Structured Rehab and option for surgery

- Both groups saw improvements
- No significant change between two groups in either primary or secondary outcomes
- Early structured rehabilitation with surgery did not attain better outcomes than structured rehabilitation

Editorial: Arthroscopy

- Apples vs. Apples + Oranges
- 39% of delayed group went ahead to have surgery
- 100% of surgery group had surgery, but so did 39% of conservative
- Tegner scores were significantly different
- Tegner better at measuring higher demand activities than KOOS


Editorial: Arthroscopy

- Surgical group returned to cutting activities
- Non surgical group limited to jogging
- Surgery group 39 of 60 (65%) sustained meniscal damage at time of injury, but only 29 (48%) ended up with resections
- Delayed surgery group 30 of 59 (51%) sustained meniscal tears at time of injury, but in end 41 of 59 (70%) required resection


General ACL Rehabilitation
Discussion Today
Single-Bundle ACL Reconstruction

Discussion Tomorrow
Double-Bundle ACL Reconstruction

Single-Bundle Technique
- Used since 1970's
- Geometry of ACL very complex
- Single-bundle technique does not duplicate normal anatomy?

Single-Bundle Technique

- High level of OA following ACL reconstructions.
- Single-bundle unable to control valgus and internal rotation force (Pivot Shift)


Knee OA following ACL reconstruction prevalence rates in studies may be too high
- Methodological quality of studies low


Highest rated studies report OA range of 0-13% for those with isolated ACL injury
- OA ranges of 21-48% with combined injuries

Single-Bundle Technique

- 2007 review
- 124 papers on double bundle
- 120 since 2000


Meta-Analysis

- Double-bundle restores KT-1000 outcomes 0.52 mm closer than single-bundle (Sig)
- Odds of normal pivot shift is higher in Double-bundle than those in single-bundle but – (Not Sig).


http://www.docjago.com/uch/multiple_instab-Derrien/image004.jpg
Randomized controlled trial
- Formal PT
  ♦ (17 sessions)
- Home based
  ♦ (4 sessions)
- 88/129 patients returned at 2 or 4 years


Outcomes
- ACL QOL score
- Knee ROM
- Knee laxity
- IKDC scores
- Home based group had higher mean ACL QOL scores 38 weeks after surgery
- Both groups improved from pre-post


Systematic review
- Level 1 & 2
- 54 appropriate studies

CPM Following ACL
- 6 studies all had some limitations
- Potentially caused type II error
- No advantage for CPM use
- Except for possible decrease in pain


Early Weight Bearing
- 1 RCT discussed later
- Early weight bearing probably justified

Post Operative Bracing
- 11 studies
- No study demonstrated worse outcomes when bracing was not used
- No increase in postop injuries, increased pain, decreased motion, or increased knee laxity in controls

Home-Based Rehab

- 4 RCTs
- All have some potential bias!
- Despite this it is reasonable to conclude that a minimally supervised physical therapy–based program can result in successful ACL rehabilitation


Systematic review

- Level 1 & 2
- 54 appropriate studies


OKC vs CKC

- 5 RCTs
- All have some potential bias!
- All short term outcomes (6 weeks)
- 3 demonstrate lack of power
- Need for additional study

Neuromuscular Electrical Stim

- 14 RCTs
- For NM ESTM to be successful it must be applied at **high intensity**
- **May help** achieve quad strength
- But is **not a requirement**


CPM

- No long term benefit
- No increased ROM
- Insurance not always approve so cost issue


Early Weight Bearing

- No new studies

Postoperative Bracing

- 6 new studies since 2005
- None demonstrated advantage from bracing

OCK vs CKC

- OKC activity after 6 weeks may increase strength without harming graft
- Not sufficient evidence for OKC prior to 6 weeks

NMES

- No new studies
- Some home units may not be strong enough to elicit contraction
Accelerated Rehabilitation

- 2 new studies since 2005
- Most return at 6 months
- Unknown if shorter time frames harmful


Neuromuscular Training

- 9 new studies since 2005
- Most have shown efficacy
- Recommended some form of training be included


Home Based Therapy

- 2 new studies since 2005
- Biases and limitations
- Have not been shown to be deleterious

74 patients – RCT
- Neuromuscular program
- Strengthening program
- Follow-up
  - 6 months
  - 1 year
  - 2 years
- Outcomes
  - Cincinnati knee score
  - VAS pain; short form 36
  - Functional tests; strength


No significant differences between programs at 1 and 2 years for Cincinnati knee scale
- At 2 years
  - NE group significantly improved function and reduced pain
  - SE group significantly improved hamstring strength
- Both SE and NE type of exercises should be used following ACL reconstruction


Postoperative
- 1-2 decades ago knee placed in 20-30 degrees of flexion for 6-8 weeks with restricted weight bearing
- Recent advances in surgical technique and understanding of tissue healing have allowed early p/o ROM and immediate weight bearing
## Past vs. Present

<table>
<thead>
<tr>
<th>PAST</th>
<th>PRESENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged Immobilization</td>
<td>Immediate Motion</td>
</tr>
<tr>
<td>Non-Weight Bearing</td>
<td>Early Weight Bearing</td>
</tr>
<tr>
<td>Slow Progression of Activity</td>
<td>Accelerated Return to Activity</td>
</tr>
</tbody>
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### Immobilization

- Generally knee placed in controlled motion brace locked in extension or between 20-0 degrees of flexion
- Correct isometric placement allows full ROM without disrupting the autograft
- If procedure combined with collateral ligament repair or meniscus repair, ROM may be restricted

### Immobilization

- Knee is kept immobilized during ambulation and at night, but removed for supervised exercises
Cryotherapy

- Patients utilizing continuous cryotherapy
  - Required less medication
  - Converted from injectable to oral meds sooner
  - Greater percentage of compliant patients


Cryotherapy

- Patients utilizing continuous cryotherapy
  - Were out of bed and ambulating sooner
  - Performed ROM exercises with more ease.


Knee Effusion

- 53 year old male following bilateral patellar tendon rupture repair after fall.
- Used cryocuff device for 2 weeks straight.
- Returned at 4 weeks with eschars of both knees
- Then debridement, dressing change and wound coverage

Lee CK, et al. Severe frostbite of knees after cryotherapy. Orthopedics. 2007;30:

http://www.healio.com/orthopedics/journals/ORTHO/7BF4A82C-BAD6-4708-8242-D8581857CCA7D/Severe-Frostbite-of-the-Knees-After-Cryotherapy?full=1
Knee Effusion

- 4 weeks after free tissue skin graft transplant

Lee CK, et al. Sever frostbite of knees after cryotherapy. Orthopedics. 2007;30:
http://www.healio.com/orthopedics/journals/ORTHO/%7B8F4A824C-BAD6-
7D08-A422-D9811857CCA57D%7D/Severe-Frostbite-of-the-Knees-After-
Cryotherapy?full=1

Knee Effusion

- 188 patients; single surgeon
- Effusion, ROM, instability, MVIC and activation level.
- Effusion grade did not correlate with quadriceps central activation ratio
- People may adapt to effusion?
- Experimentally induced effusion may be different than natural effusion


Rate of Exercise Progression

- Depend on surgical procedure and graft selection
- Can progress most rapidly with bone-tendon-bone repairs or allograft repairs with bone plugs due to better fixation
- Open procedures, or procedures using semi-T, Gracilis, quad tendon or iliotibial band may require slower progression due to soft tissue fixation
Rate of Exercise Progression

- Even though early movement will create a stronger better oriented scar and ligament healing, too much stress or too rapid progression can stretch or damage repairs.

Graft Strength

- Animal studies indicate that graft strength may reach weakest point at 6-8 weeks postoperatively.


Graft Strength

- Graft may only reach failure loads of 11 and 50% of native ACL at 1-year post operative.

Graft Strength

- Most studies done on animal models
- Makes determining optimal load and optimal timing of load in humans difficult to determine.


Primary Goal of ACL Reconstruction

- Restoration of knee stability
- Safe and expedient return to normal activities and athletics
- Early recognition of complications

Maximum Protection Phase

0-6 weeks: Goals

- Protect graft fixation
- Minimize effects of immobilization
- Control swelling and inflammation
- Achieve full extension ASAP
- Educate patient on rehab
Brace

- Dependent on fixation.
- Generally:
  - 0-1 week: locked in full extension for ambulation and sleeping
  - May be longer with soft tissue healing, e.g., hamstring, quad tendon
  - 1-4 weeks: Unlocked for ambulation, sleeping

Weight Bearing

- Generally:
  - 0-4 weeks: weight bearing as tolerated
  - Emphasis on achieving full knee extension at heel strike with FWB on involved side
  - Decrease ambulation with flexed knee
  - Wean off crutches when good quad control and able to perform SLR with no lag
Bone Mineral Density - ACL

- BMD and BMC
- 15 Subjects
- Ages 17-51 Years
- Time from surgery 6 to 32 months
- BMD < in involved lower extremity


Bone Mineral Density - ACL

- 6.6% < at trochanteric region
- 4.0% < for entire hip
- 3.4% < for intertrochanteric region


Weight Bearing

- 24 patients per group
  - Controls
  - 6-12 weeks
  - 6-7 months
  - 12-15 months

Weight Bearing

- Smith squat rack
- Pedar sensors
- 3 sets of 9 squats randomized
- 3 angles (30, 60, 90°)
- 3 weights (40# bar only, 35% BW, 50% BW)


Weight Bearing

- Do you feel like equal weight placed through both feet?
- Significant differences (p<0.05) between with group interaction with weight and angle


Weight Bearing

- 6-12 weeks
  - Unconsciously “Unload LE”
- 6-7 months
  - Unconsciously “Unload LE”
- 12-14 months
  - Do not “Unload”

Weight Bearing

- Most patients thought they had demonstrated equal WB
- ? Accelerated rehabilitation program
- Full sports at 6 months after surgery
- Benefit of early single-leg exercise


Weight Bearing

- RCT with 49 patients
- Immediate weight bearing vs delayed weight bearing x 2 weeks
- BPTB ACL reconstruction
- Follow up 2 weeks and final


Weight Bearing

- ROM – NS at 2 weeks or final (6-14 mo)
- VMO EMG activity significant increase at 2 weeks in weight bearing group
- Final follow up both groups EMG same

Weight Bearing

- Statistically significant decrease in anterior knee pain
- Pain in 7/20 restricted WB
- Pain in 2/25 immediate WB
- ROM and KT scores not sig different between groups


Maximum Protection Phase

0-6 weeks

- Control of postoperative pain, and edema: use cryotherapy, e-stim, elevation and compression
- Caution if using Cryocuff and Tube-grip together – may compromise vascular flow


Maximum Protection Phase

0-6 weeks

- Begin setting exercises and muscle stimulation to prevent atrophy
- Due to closed packed position, little stress placed on graft in full knee extension
Quadriceps Atrophy

- Atrophy and weakness of quadriceps can begin immediately following ACL repair and is the major group that undergoes atrophic changes.


Quad Atrophy

- Like to see forceful quadriceps contraction within the 4th post-operative day
- If unable to initiate we will begin neuromuscular electrical stimulation to facilitate a contraction

Electrical Stimulation of Thigh


Electrical Stimulation of Thigh


---

Range of Motion

- Regain full extension ASAP!

- What is normal motion?
- Both men and women have hyper-extension
  - Men = 5° while Women = 6°

- 502 patients
- 14.1 years PO
- Regression analysis
- Most important factor in subjective scores
  - Knee motion


- 98% of patients with normal motion, normal articular cartilage and intact menisci had normal radiographs
- Even a 3-5° loss of extension motion compared to opposite knee affected outcomes

Study to determine factors related to motion loss after ACL reconstr.

- 217 consecutive patients
- ROM recorded at:
  - Day of surgery
  - 6 weeks
  - 3 months


Maximum Protection Phase

- Regain full extension ASAP
- Passive knee extension with heel block, prone knee hangs
Maximum Protection Phase

- Immediate motion to decrease risk of complications related to loss of motion
- Complication rates range from 9-74%


Cyclops lesion 15-year old
Hamstring ACL 16 weeks PO

Maximum Protection Phase

- Knee “Thunks”
- Knee is bent slightly and gently allowed to “thunk” down into extension
- May be hard for patient to understand or tolerate so may want to do on uninvolved side first

Maximum Protection Phase
- Flexion will generally return in time.

Maximum Protection Phase
- If hamstring repair may hold active heel slides for up to 3 weeks.
- Some allograft procedures require lifting of pes – hold active hamstring contraction x 3 weeks

Maximum Protection Phase
- Generous patellar mobilizations to decrease risk of IPCS, arthrofibrosis, knee flexion contracture
- Wall slides and heel slides to increase knee flexion
Maximum Protection Phase

- Precaution:
- By 4-6 weeks bone plugs should be adequately healed
- Suppose 8-12 weeks before soft tissue healed into tunnels with hamstrings
- At 4-6 weeks the graft itself is at its weakest point in the rehab process


Maximum Protection Phase

- Stretching
- If hamstring may hold stretching of gastroc and hamstrings for up to 3-4 weeks

Maximum Protection Phase

- 4-6 weeks graft weak and actually necrotic
- Avoid resisted OCK activities in the range of 30-0 degrees of flexion
Maximum Protection Phase

- Total Leg Strength (TLS)
  - SLR x 4
  - Multi-hip

Moderate Protection Phase
6-12 weeks

- Normalize gait
- Maintain full extension
- Protect fixation
- Full flexion ROM
- Improve strength, endurance, and proprioception of lower extremity

Moderate Protection Phase
6-12 weeks

- This phase is characterized by exercises utilized to increase strength and ROM
- Muscles require increased intensity to allow adaptation for sport-specific demands
- By 9-12 weeks graft is becoming more vascularized
- Progressive exercises to work on strengthening not only quads and hams, but TLS should be emphasized
- 120° of knee flexion and extension should easily be obtained during this time frame
Moderate Protection Phase
6-12 weeks

- **Precaution:**
- Avoid CKC exercises between 60-90º of knee flexion (PF) and OKC between 30-0º of knee flexion as anterior tibial translation may stretch graft!

Minimal Protection Phase
12-24 weeks

- OKC isotonic exercise from 90 - 45º safe
- Advanced CKC exercises
  - Single leg squats
  - Leg press 0 - 45º
  - Step-up progression
  - Balance and proprioception

Minimal Protection Phase
12-24 weeks

- Bilateral squats level ground
- Progress with weighted balls or dumbbells
Minimal Protection Phase

12-24 weeks

- Advanced CKC exercises
  - Squats on labile surface
  - Watch for proper form!
  - Balance and proprioception
Minimal Protection Phase
12-24 weeks
- Single-leg exercises important
- Athletes in competition spend tremendous amounts of time in a single-leg position
- Single-leg landing training

Good Landings!

Minimal Protection Phase
12-24 weeks
- Single-leg landing training
- Good Landings!

Poor Landings!
- Be careful of excessive rotation in the transverse plane upon landing.
Minimal Protection Phase
12-24 weeks

- Lunges
- Lunge onto labile surface
- Lunge with perturbation
- Sports specific tasks

Minimal Protection Phase
12-24 weeks

- Emphasis placed on light functional activities such as jogging, stepping, footwork and agility drills
- These activities can be initiated if strength assessment reveals 75-80% of uninvolved side and arthrometer reveals stable graft

Minimal Protection Phase
12-24 weeks

- Plyometrics and velocity spectrum isokinetics can be begun
- By 6 months most return to full pre-injury activity level
Return to Sport Phase 6-9 Months

- Goals

- Progress:
  - Strength
  - Power
  - Proprioception

Return to Sport Phase 6-9 Months

- Continue strengthening and flexibility as previous
- Walk/jog progression
- Forward/backward running
- Cutting/crossover
- Sports specific drills

Return to Sport Phase 6-9 Months

- Double leg squat on BOSU
- Labile surface
Return to Sport Phase 6-9 Months
- Plyometrics
- Double leg jumps
- Labile surface

Return to Sport Phase 6-9 Months
- Plyometrics
- Single leg jumps
- Labile surface
Deficits in Quad Strength

- **Literature review**
- **Side to side strength differences**
  - 6 months = 23% (3-40%)
  - 12 months = 14% (3-28%)
- **Self reported function deficits**
  - 6 months = 14%
  - 12 months = 13%
- **Hop tests**
  - 6 months = 11%
  - 12 months = 13%


Survival of Graft

- All patients – one surgeon 1993-1994
- Telephone or email
- Minimum 15 years after surgery


- 775 patients met criteria
- BPTB = 314; Ham = 359
- 673 (89%) responded
- 23% had suffered graft rupture or contralateral ACL tear
- Graft survival not different between groups
  - Ham = 88%; BPTB 91%

**Survival of Graft**

- Contralateral rupture 2x as frequent as graft rupture in BPTB group
- Positive family history of ACL injury doubled odds of having injury to graft or contralateral ACL
- Men less favorable survival rate of graft than women.


**Smoking and ACL Reconstruction**

- ACL reconstruction in patients who use tobacco associated with increased rates of
  - Infection
  - VTE
  - Subsequent ACL reconstruction


**Smoking and ACL Reconstruction**

- 66 smokers – FU 5.67 years
- 238 non-smokers – FU 6.61 years
- Similar in age, gender, graft type, fixation and associated meniscal and chondral pathology

Smoking and ACL Reconstruction

- Assessment
  - IKDC scores
  - Crucimeter readings


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Smoking and ACL Reconstruction

- SS Poor outcomes in smokers
  - IKDC scores
  - Frequency of pain
  - Intensity of pain
  - Laxity


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Smoking and ACL Reconstruction

- Less likely to return to their original level of pre-injury sport
- Well-known negative effects of smoking on tissue healing affects ACL reconstruction patients also!

Smoking and ACL Reconstruction

- 14 studies
- 8 smoking and ligaments
- 6 smoking and articular cartilage
- Negative association of smoking


Smoking and ACL Reconstruction

- Negative effects from various perspectives
  - Molecularly
  - Biomechanically
  - Clinically