ACL Reconstruction in Skeletally Immature Patients: Treatment Options

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Quick Overview

• Increased involvement in organized sports

• Dodwell, et al reported a 20 fold increased from 1996-2009 in the rate of ACL reconstruction per 100,000 population aged 2-20 in New York state (1)

• A 2012 study showed ACL injuries represent nearly 25% of all high school knee injuries (12)
Intrinsic Risk Factors

- Female sex
  - Females 2-9 times higher rate of non-contact ACL injury
- Decreased femoral notch width
- Decreased ACL volume
- Increased posterior slope
- Increased Q angle
- Increased anteversion
- Greater generalized ligamentous laxity
- Quadriceps dominant musculature
- Weak core and hip strength
Extrinsic Risk Factors

- Pivoting and cutting sports
- Footwear
- Weather conditions
- Playing surfaces
The History and Physical

- Events surrounding the injury
- Mechanism of injury
- Knee effusion
  - 65% correlation rate (2)
- Other injuries
- Lachman test
- Anterior drawer test
- Pivot-shift
- Other routine exam maneuvers to check for other injuries
- Assess for possible limb-length discrepancy (don’t want to get blamed for it)
Radiography

- AP, lateral, merchant are all necessary to rule out a possible fracture or osteochondral fragment
- Hip to ankle for comparison of limb-lengths during follow up
- Bone age radiograph
- MRI
Historical Treatment

• Maintain comfort
• Functional knee brace
• Directed knee rehabilitation to regain normal range of motion in knee
• Should have normal ROM and knee strength by 6-8 weeks and can return to activity
  – Non-contact sports and restricted in those that require rapid directional changes
• Transphyseal surgery after skeletal maturity reached
Should We Operate?...

• Risks for surgery
  – Complication rates for infection, neurovascular damage, etc all very low
  – Growth plate arrest
    • Historical concern
    • Has led to varying techniques
Should we Operate?...

- If we stabilize the knee earlier, what effect does that have on other aspects of the child’s life?

  - Boykin et al (6)
    - Used the Child Health Questionnaire and the International Knee Documentation Committee Score
    - Self-esteem, mental health, emotional role, and social limitations categories all significantly correlated with knee function

  - Non-operative treatment associated with up to 50% sports drop out rate (8)

  - Quality of Life is affected
Should we Operate?...

- Ramski, DE et al (5)
  - Meta-analysis of non-operative and operative treatment
  - “Trends” favoring early surgery
  - Patients after non-operative and delayed treatment had more knee instability and inability to return to previous activity levels
  - Quality analysis revealed the majority of the studies were inconsistent with reporting outcomes
Should we Operate?...

- Millet et al (3)
  - 26 patients
    - 10 medial meniscus injuries (longer wait time statistically significant)
    - 15 lateral meniscus tears
    - 3 medial collateral ligament tears
    - 1 femur fracture
Should we Operate?...

- Dumont, Guillaume D et al (5)
  - 370 pediatric patients
  - >150 days to treatment statistically significant for increase in medial meniscus tears (37.8% vs 53.5%)
  - Lateral meniscus tear rates similar in two groups
  - Presence of chondral injury significantly associated with presence of meniscal tear in the same knee compartment
  - Increased age and weight independently associated with higher rate of MMT.
Should we Operate?...

• Concomitant Procedures are on the Rise
  – Nationwide database query between 2007-2011 (12)
    • Meniscetomy (27.6% increase in 10-14 year olds)
    • Meniscus Repair (54.8% increase in 10-14 year olds)
    • Shaving Chondroplasty (81.3% increase in 10-14 year olds)
So What About the Physes?...

• More and more studies showing that those with open physes were not at increased risk for early revision or early reoperation compared to those with closed physes
  – Scintalin RP, et al (9)
  – Guzzanti, et al (10)
  – Meller, et al (11)

• Multiple studies correlate no surgery and delayed surgery with worse outcomes

• Current surgical techniques minimize physeal involvement or avoid them altogether (not including some surgeries that show a tethering effect can occur)
So What We Know...

• Multiple studies correlate no surgery and delayed surgery with worse outcomes.

• Current surgical techniques minimize physeal involvement or avoid them altogether (not including some surgeries that show a tethering effect can occur).
OPERATE
Unless...

• No concomitant injuries

• Limited goals for participation in athletic activities

• No symptoms of instability
Surgical Options

• Extraphyseal

• Partial Transphyseal

• Transphyseal (wont discuss except for indications)

• All-Epiphyseal
Graft Options

- Hamstring tendon autograft
- Allograft
- Patella tendon or bone-tendon-bone autograft
- Quadriceps tendon autograft
- Tensor Lata Autograft
- Allograft
Extraphyseal

• When neither the femoral or tibial physis is directly violated
Modified MacIntosh

- Combined extra-articular and intra-articular physeal-sparing
- Uses the iliotibial band
- Proximally harvest the central 1/3 and leave it attached at its insertion site (Gerdy’s tubercle)
- Bring free end through the knee joint in an over the top position, under the intermeniscal ligament, then sutured onto the periosteum anteriorly
Modified MacIntosh

- Kocher, et al (13) in 2005 reported:
  - 4.5% failure rate
  - No incidences of growth disturbance
  - IKDC score of 96.7

- Chudik, et al (14) in 2007 showed how as you grow, the graft migrates
  - (in a canine model)
Modified MacIntosh

• Long term follow up from Johnson in 2003(15)
  – Excellent Lysholom scores on 52 of 84 knees at 9.8 years
  – Poor outcome in 13/48
  – 58% had reduced level of activity
Partial Transphyseal

- When either one of the femoral and tibial physis are transversed

- In skeletally immature patients you try to drill more vertically to minimize area of physis that is transversed
Insall Technique

• Release distal IT band from Gerdy’s tubercle and mobilize proximally

• Tubularize tendon

• Reroute “over the top” of the lateral femoral condyle and through intercondylar notch

• Can drill vertical tunnel through tibial physis OR entirely within physis
Insall Technique

• Benefits
  – For tibial insufficiency
  – IT band deforming force in certain instances (arthrogryposis) and rerouting it can be beneficial
  – Active transfer, not just static constraint
  – Can avoid physis completely if choose to

• Drawbacks
  – Not anatomic when child gets older
Insall Technique

• Scott WN, et al (16)
  – 111 ACL insufficient knees
  – Followed 2-7 years
  – 90 knees had negative Lachman (81%)
  – 93 knees had anterior drawer of +1 or less (84%)
  – 104 knees had negative pivot shift (94%)
  – Subjective rating
    • 82 knees excellent (74%)
    • 23 knees good (21%)
    • 6 knees poor (5%)
Insall Technique

• Windsor R, et al (17)
  – 5-10 year follow-up
  – All patients (62 knees) had buckling pre-operatively
  – 35 excellent, 21 good, 4 fair, and 4 poor results
    • Pain major reason for fair or poor results
    • No fair or poor result had intact menisci
  – Buckling absent in 93% of post op
All Epiphyseal

- Avoids both the femoral and tibial physis
- Proponents claim the more anatomic graft placement improves rotational stability
Anderson Technique

• Drills outside-in transepiphysyal bone tunnels
• Secures hamstring autograft with suspensory cortical fixation on femoral side
• Secures autograft to tibia with a suture over a screw
Anderson Technique

• Anderson, AF (25)
  – 4 year follow up (mean 4.1 years)
  – 12 patients, average age of 13.3 years
  – Mean IKDC score of 96 ± 4.4 points
  – KT difference of 1.5 ± 1.1 mm
  – No incidence of LLD
Ganley-Lawrence Technique

- Utilizes a quadrupled hamstring autograft
- Utilizes intraoperative computed CT (O arm) to confirm tunnel placement
- Secures in all tunnels with interference screws
Ganley-Lawrence Technique

- Lawrence et al (26)
  - Only three patients
  - None had growth disturbance
  - All returned to pre-injury level
Cordasco-Green Technique

• “all-epiphyseal and all-inside”
• Modification of Lawrence Technique
• Employs the cortical button on the femur and the tibia
• Involves inside-out drilling of proximal tibial and distal femoral epiphyseal sockets, leaving cortically based bone bridges
• Avoids the use of screws
Comparison of Techniques

• Kaeding CC, et al (27)
  – 10 studies of ACL reconstruction in skeletally immature patients
  – Tanner II and Tanner III
    • Both all-epiphyseal and transphyseal all showed favorable outcomes
  – Tanner 1
    • “Insufficient evidence from physeal-sparing techniques to conclude it was a well tolerated technique”
Hamstring

• Advantages
  – Less donor site morbidity
  – Less patellar pain
  – Material properties similar to ACL

• Disadvantages
  – Some laxity results over time
  – Must have tunnel <12mm or growth arrest
Complete Transphyseal

- Guzzanit et al found lower rates of physeal bridge formation with soft tissue in tunnels (10)

- Kumar, et al (18) used hamstring autograft and had growth arrest in only 1/72 patients
Bone-Patellar Tendon-Bone

- **Advantages**
  - Greater strength
  - Better fixation in femur and tibia

- **Disadvantages**
  - More likely to interrupt physeal growth
Others

- Quadriceps
- Fascia Lata
  - In extra-physeal surgeries
- Allograft
  - Preserves tendons for future surgery
  - Use in those with generalized ligamentous laxity or collagen disease
  - Does have higher failure rate in children but may not apply in those with disorders
So Which Graft?

- Kennedy A, et al (7)
  - Biomechanical study subjected cadaveric knees to AP, varus and internal rotation forces
  - Each knee subjected to the forces with intact ACL, after disruption, and after reconstruction
    - All-epiphyseal, transtibial over-the-top, and IT band physeal sparing techniques
  - IT band reconstruction best restored AP stability and rotational control
    - Overconstrained the knee to rotational control at some forces
  - All physeal-sparing reconstruction techniques restored some stability
Graft Failure

- Kaeding, et al (20) in 2011 reported on graft failure rates
  - 8.2% in patients 10-19 yoa
  - 4% in patients 20-29
  - 1.8% in patients 30-39 yoa
- Allograft and autograft failures* activity related?
Graft Failure

- Gebhard et al (21)
  - 68 patients with short term follow up (32 months)
  - Mean age 12.5 years
  - Transphyseal
  - Compared hamstring autograft, bone-patella-bone autograft, quadriceps graft, and fascia alta graft
  - No significant difference in outcomes and no growth disturbance
So Which Surgery and Which Graft?...

- Patient Specific
- Must take Skeletal Age into account
- Surgeon Specific
My Algorithm

- Confirm on exam and MRI
- Brace and start rehab
- Skeletal age
- Are they unstable?
- Associated intra-articular disease?
- Assess current activity level and anticipated future activity level
- Number of years left for growth
My Algorithm

• If I proceed with surgery...
  – < 2 years growth remaining
    • Transphyseal with hamstring autograft
  – 2-5 more years of growth remaining
    • All epiphyseal with hamstring autograft
  – > 5 years growth and no other intra-articular pathology
    • Serious discussion with family concerning future surgery
    • If I proceed, all epiphyseal with hamstring autograft
Prevention

• Increasing evidence that suggests neuromuscular control and relative knee position during jumping and landing are the most important biomechanical factors

• Swartz, et al (23)
  – Increased knee valgus and decreased hip flexion in prepubescent subjects versus adult controls

• Noyes, et al (24)
  – Improvements in knee separation and neutral landing after neuromuscular training
  – Most noteworthy in females
Prevention

• Females
  – Tend to be one leg dominant
  – Valgus with landing
  – One knee relatively straight
  – Most weight on one leg
  – Trunk tilted so center of mass is shifted outside of feet
THANK YOU
References


