History and Rationale for Accelerated Rehabilitation Program for ACL Reconstruction

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ACL Reconstruction

- ACL surgery should allow patients to regain 2 normal knees
- Achieving stability has been a higher priority than achieving full ROM
- Has led to less than ideal results

Accelerated Rehabilitation

- "Evidence indicates that...the accelerated rehabilitation program has been more effective than our initial program in reducing limitation of motion (particularly knee extension) and loss of strength while maintaining stability and preventing anterior knee pain."

Shelbourne, AJSM 1990. Accelerated Rehab

Accelerated Rehabilitation

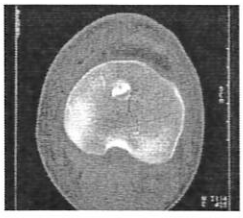
- Program was developed to prevent ROM problems after ACL reconstruction
- Still obtain good knee stability
- Used BPTB graft exclusively
- Allows for quick bone-to-bone healing that accommodates our rehab

Patellar Tendon: Advantages

- Readily available (2 per patient)
- Strong graft
- Viable early
- Bone-to-bone healing
- High success rate
- Allows for unrestricted rehabilitation and early return to sports

Patellar Tendon Graft

- Button fixation allows for tight bone fit in tunnels
- Quick bone-to-bone healing
- MRI at 2 weeks post-op



Accelerated Rehabilitation

- Through the years the concept of "accelerated rehabilitation" has been wrongly portrayed
- People have concluded

Accelerated rehab = Quick return to sport

Accelerated Rehabilitation

- Quick return to sports occurred because patients achieved full ROM early post-op
- Did not have increase in graft tears with quicker return to sports
- We learned that early return full ROM = Good short- and long-term results

Accelerated Rehabilitation

- Our surgery and rehab have been developed to allow patients to have predictably good results
- What we do now is based on data with understanding that all patients want 2 normal knees post-op
- We have achieved this with current treatment approach

Accelerated Rehabilitation

- Rehabilitation program evolved
- History of evolution will give good understanding of rationale for treatment

History

- ACL surgery in the 1970's
  - Goal was to give chronic ACL deficient knee stability
  - Patients with acute injuries were almost always given a trial of rehabilitation and bracing
  - Most procedures were extra-articular
  - Patients were casted in 30^{0} flexion for 6 weeks for protection
  - Knee stiffness was desired because extra-articular procedures would loosen over time
  - Knee extension greater than 0^{0} was discouraged

History

- Intraarticular grafts were added to augment the extra-articular procedures beginning in the late 1970's
- Rehab was not altered to account for intraarticular surgery
- Goal was still to make the knee stable by leaving it "slightly" stiff
- But the added intraarticular procedures caused many more stiff knees and patients with disabling arthrofibrosis

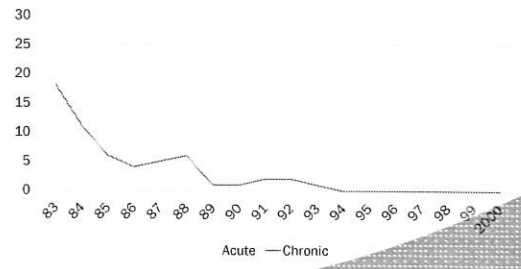
History

- Began practice in 1982
- Research of the treatment outcomes has been the focus of my practice
- Goal
  - To identify
    - major complications
    - patients who did extremely well after surgery
  - Study factors related to the good and bad outcomes to determine ways to improve treatment

History

- Surgeons started doing ACL reconstruction for acute injuries as well
  - Mostly for athletes in "high risk sports"
  - Thinking was to do surgery as quickly as possible after the injury
  - Common for a patient to have surgery the same day or within a few days of injury
  - Post-op treatment
    - 6 weeks of casting with knee in 30° of flexion
    - Wanted bone plugs to heal before ROM exercises were introduced
    - Rate of arthrofibrosis was higher with acute surgery

% of Patients with Scar Resection



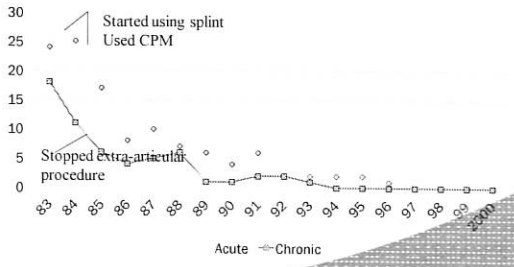
History

- Something had to be done to decrease rate of arthrofibrosis
- Knees were stable but
  - Rehab process was difficult
  - Patients were miserable
  - Patients couldn't return to normal activities very well, let alone sports

History

- Began to make changes
  - Stopped using a cast and used a splint
  - Started using CPM machine
  - Stopped doing extraarticular procedure

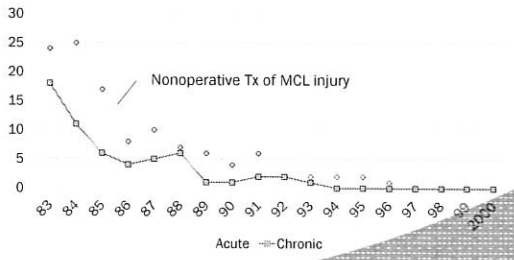
% of Patients with Scar Resection



History

- Data showed us that with combined MCL repair with acute ACL reconstruction had
  - High rate of arthrofibrosis (30%)
  - 80% had long-term ROM deficits
- Began nonoperative management of MCL injury

% of Patients with Scar Resection



History

- These few changes reduced the rate of scar resection to around 8-10%
- In 1986, performed a study to determine compliance of rehabilitation
  - Rehab still included
    - Use of splint
    - Non-weightbearing for first 3-4 weeks
    - Restricted activities
  - Medical student called patients to ask them
    - Do you wear your splint all the time?
    - Are you putting any weight on your leg?
  - Because it was an independent person asking the questions, patients felt more comfortable about answering honestly

History

- Found out
  - Most patients weren't wearing their splint all the time
    - All would take it off in bed
    - Wouldn't bother to put it back on to get up and move around the house
  - Patients were putting weight on their leg
  - Some didn't bother with crutches at all
- Compared data between compliant and non-compliant patients

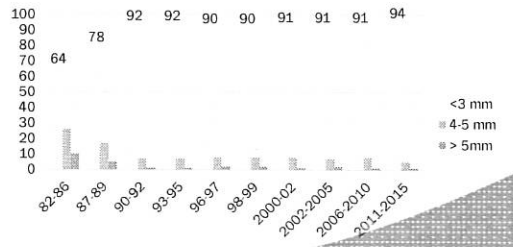
History

- Non-compliant patients were doing better
  - Better ROM
  - Better strength
  - But no difference in stability
- This study was huge eye-opener!
- Realized restrictions were not necessary
- Began to make rehab changes

History

- "Accelerated Rehab" changes
  - Full extension exercises began day of surgery
  - Hospital stay was 2-3 days versus 5-6 days
  - Weight bearing allowed as tolerated with splint
  - Splint could be discontinued around 1-2 weeks as leg control improved
  - ROM exercises for flexion also emphasized
  - Strengthening exercises started at 2-3 weeks post-op
    - Leg press
    - Squats
    - Bike
  - Biggest concern – Would stability be maintained?

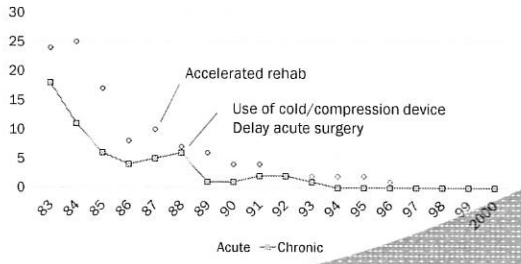
Objective Stability Consistently Obtained
KT-1000 Man/Max Difference



History

- Most patients benefitted from the changes
- Process of rehab smoother
  - Less pain
  - ROM gains were less of a struggle
- Rate of scar resections decreased

% of Patients with Scar Resection



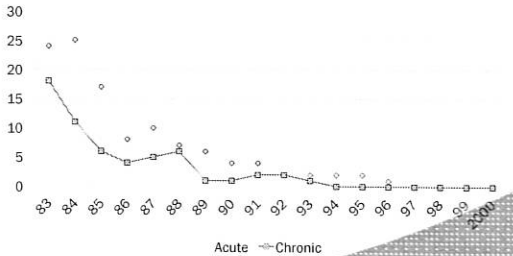
History

- Continued to make small changes in rehab related to when exercises were introduced
- Pre-op changes:
  - Delay surgery to obtain
    - Full ROM
    - Gain leg control
    - Eliminate swelling

History

- Post-op changes
  - Main emphasis – eliminate problems we had with swelling
  - Backed off of how often we got patients out of bed to walk
  - Eventually changed to
    - Keeping patients down with leg elevated above the heart for 5-7 days after surgery
    - Allowed up for bathroom privileges only – WB as tolerated
    - Cold/compression device at all times except for performing ROM exercises
    - Emphasized knee extension exercises 4-6x/day
    - Flexion exercises – gentle 2x/day
  - Gradually eliminated the need for scar resection surgery

% of Patients with Scar Resection



History

- Full knee extension – includes normal hyperextension

- The aggressiveness in which we pushed for full extension equal to the normal knee was the final change affecting results

History

- The use of the contralateral PTG for primary ACL reconstruction began 1994
- Came about because we observed the ease of rehab for patients who had revision ACL reconstruction with contralateral PTG
- Overwhelming success in my practice

Contralateral Graft

- Report comparing 434 Contra versus 228 Ipsi PTG (Shelbourne/Urch AJSM 2000)
  - No difference in knee extension between groups
  - Knee flexion better in Contra group at 1,2, 4 and 8 weeks post-op
  - Quadriceps strength better in Contra group at 1, 2 and 4 months post-op
  - No difference in KT1000 stability between groups

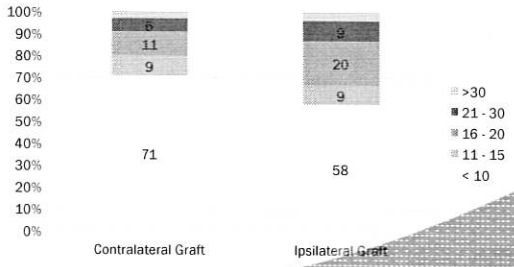
Contralateral Graft

- Another report of Contralateral graft regarding the donor site (Shelbourne et al. 2014)
- Study of 279 patients with contralateral graft compared to a control group of ipsilateral grafts
- Evaluated strength and subjective scores

Contralateral Graft

- Strength compared to pre-op normal knee:
  - Contralateral
    - ACL Knee – Mean 116%
    - Donor Knee – Mean 114%
  - Ipsilateral - Mean 105%

% Difference Between Knees for Quad Strength at 2 Years Post-op



Contralateral Graft

- Still use Contra PTG
- Rehab program is different for each knee
- Only successful if rehabilitation is done correctly

Rehabilitation Philosophy

ACL		Donor Site
▪ Prevent/control hemarthrosis	Conflicting Goals	▪ Regain strength – only rehab concern
▪ Return full symmetrical ROM		▪ High rep, low resistance strengthening
▪ Provide appropriate stress to stimulate the graft to mature		

Current Rehab Program

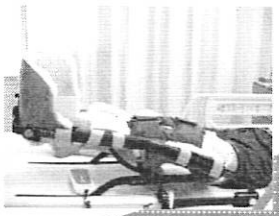
- Starts in surgery
- Full ROM checked at the end of surgery
- Assures that the new ligament fits perfectly in the notch

Current Rehab Program

- If you have limitation of motion at time of surgery
  - Graft is not placed correctly or too tight
  - ROM can't be obtained post-op without graft failure
- No matter what graft or technique you use, you must have full ROM at end of surgery to assure good long-term result

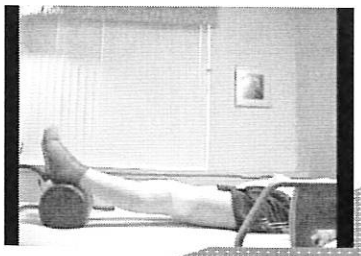
Immediate Post-op

- ACL knee placed in CPM machine for elevation
- Cold/compression device is worn all the time except when doing specific exercises



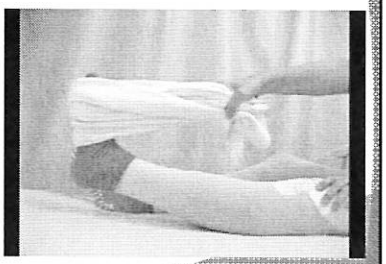
Immediate Post-op

- Heel prop exercises with leg raise



Day after surgery

- Towel stretch
- Patient has good active terminal extension

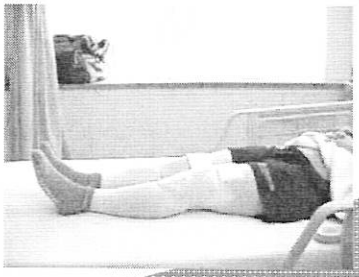


Day after surgery

- Patient has normal hyperextension
- These exercises are done to make sure the graft fits perfectly in the notch

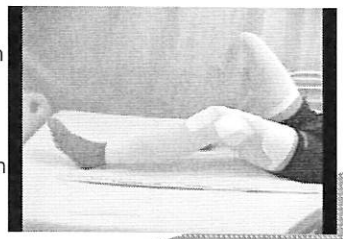
Day after surgery

- Towel stretch
- Patient has good active terminal extension



Day after surgery

- Flexion evaluated with yardstick
- Easy method for patients to monitor flexion



Contralateral PTG

- Rehabilitation of the graft-donor knee
  - Begin high-repetition/low resistance exercises
  - Shuttle machine

First 5 days at home

- Bed rest except for bathroom privileges
- Heel prop extension exercises 10 min 3x/day
- Flexion exercises 3x/day
- Shuttle exercises for graft knee (if Contra graft)
- Cold/compression device worn continually except during exercises

1 week post-op

- Walking

1 week post-op

- About 110° of flexion in ACL-reconstructed knee

1 week post-op (Contra PTG)

- Step box
  - Use a level that the patient can do 25 to 100 reps 3 times/day
  - Good technique is important

1 week post-op (Contra PTG)

- Controlled leg-press exercise

Instructions for week 2

- Maintain full hyperextension
- Increase flexion
- Emphasize a normal gait pattern
- Use cold/compression device after exercise
- Step-down and leg press exercises for graft knee
- Can return to daily activities
- Monitor swelling and adjust activities to keep swelling to a minimum

Gradual Progression

- Strengthening exercises for ACL reconstructed knee added as full flexion is achieved
- Functional activities
- Individual agility drills
- Sport-specific agility drills
- Jogging just to jog is NOT allowed
  - Repetitive activity causes swelling that limits ROM
  - Better to do stationary bike for conditioning

Gradual Progression

- If isokinetic strength is around 80% (of normal knee pre-op), then begin more intense functional work
- Every other day to allow period of rest
- Specific functional activity to increase strength
  - Example – controlled jumping drills in basketball (rebounding, jump shot)
  - May need to do every other day, depending in soreness in tendon

History

- This process of "accelerated rehabilitation" did allow patients to return to sports quicker after surgery
- But this happened because full ROM returned quicker followed by quicker return of strength
- Accelerated Rehabilitation = Obtain full ROM as quickly as possible after surgery
- Rest of rehab falls into place as long as full ROM is maintained throughout the process

ROM and Results

- Through all the rehab improvements, we continued to monitor results
- Study showed KT1000 stability did not change after full ROM was achieved or after participation in functional sports agility program (Shelbourne/Davis AJSM 1999)
- Many patients have high degrees of hyperextension
  - >25% of males and >40% of females have greater than 7 degrees of hyperextension (DeCarlo, J Sports Rehab, 1997)

ROM and Results

- However, could this degree of hyperextension be detrimental to the ACL graft?
- MRI and lab studies have shown posterior bowing and increased stresses on the ACL graft with hyperextension
- Recent study to evaluate stability and graft tear rates between groups of patients based on knee extension

Hyperextension Study: Methods

- 2329 ACL reconstructions done by the senior author from 1998-2009
- Patients excluded if they had revision ACL surgery, bilateral ACL involvement, or preoperative arthritic changes
- Minimum 2 year follow-up

Hyperextension Study: Methods

- Two groups analyzed based on ROM before and after surgery
  - Group A- 6^0 to 15^0 hyperextension (mean 8^0)
  - Group B- 3^0 hyperextension to 4^0short of neutral (mean 0^0)
  - Data collected prospectively as part of ongoing long-term ACL research database
- Patients excluded if they had $4\text{-}5^0$ hyperextension

Hyperextension Study: Results

- Stability- Mean side-to-side difference with KT-1000 maximal manual measurement
  - Group A- 2.0 mm (range -1-5)
  - Group B- 2.1 mm (range -1-6)
  - *p= 0.701*

Hyperextension Study: Results

- Graft tear/failure rate within 5 years post op
  - Group A- 22/278 (6.9%)
  - Group B- 30/275 (9.8%)
  - *p= 0.246*
- Group A subgroup analysis
  - 6-9 degrees hyperextension- 6.8%
  - >10 degrees hyperextension- 7.4%
  - *p= 0.804*

Hyperextension Study: Results

	Group A Mean ± SD	Group B Mean ± SD	P-value
Activity rating pre-op	8.3 ± 1.1	8.4 ± 1.0	.3527
Activity rating post-op	8.4 ± 1.1	8.4 ± 1.1	.8117
CKRS total score	95.3 ± 7.1	93.9 ± 9.3	.1553
CKRS stability score	19.6 ± 1.4	19.3 ± 2.1	.107
IKDC total score	89.3 ± 11.4	88.2 ± 13.8	.933
IKDC "giveway" score	4.6 ± 0.7	4.7 ± 0.8	.174

Hyperextension Study: Discussion

- No alteration in ACL surgical technique or postoperative rehabilitation protocol based on knee hyperextension
- Postoperative immobilization was not used.
- Rehab focused on immediate passive hyperextension

Hyperextension: Passive and Active ROM

Conclusion

- Patients with higher degrees of knee hyperextension can be treated with ACL reconstruction with a patella tendon autograft
  - No increase in graft tear/failure
  - No difference in activity level, function, or stability

Long-Term Research

- Long-term prospective study to continually evaluate patients after ACL reconstruction
- Subjective surveys sent yearly
- Patients invited to return for physical examination and x-rays at 2, 5, and every 5 years thereafter
- Have been analyzing results of patients with a minimum of 20 years of follow-up

Demographics

- Surgery dates: 1982 through 1994
- Ipsilateral graft
- Excluded revision surgery, arthritic at time of surgery, deceased, graft tears
- 1500 surgeries meet criteria
- Minimum 20 year f/u
  - Both subjective and physical exam for 423 pts (28%)
  - Subjective only for additional 448 pts (30%)
  - For total of 871 patients (58%)

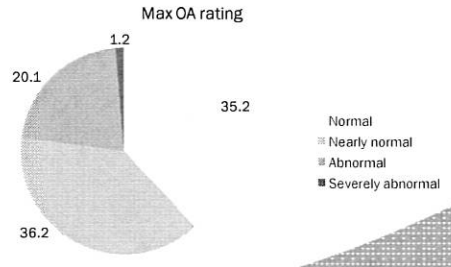
Demographics

- Mean surgery age: 23.2 years
- Mean age at follow-up: 47.9 ± 7.7 years (range, 34-76)
- Objective f/u time: Mean 22.5 ± 2.1 years (range, 20-32 years)
- Subjective f/u time: 24.0 ± 3.4 yrs. (range, 20-33.1 years)

Methods

- Looked at results of groups based on:
  - Demographics
  - Meniscus
  - Articular cartilage status
  - ROM – extension and flexion normal versus less than normal
  - Presence of OA on radiographs

Results: Maximum OA Rating



% of Patients with Normal Radiographs: Meniscus and ROM Groups

Meniscus Group (n)	All patients %	Normal ROM %	< Normal ROM %	*P*-value
Both Intact (191)	46	51	43	.014*
Med-Rem (112)	24	31	17	.003*
Lat-Rem (50)	36	54	26	.194
Both-Rem (52)	15	14	16	.373

*Normal ROM group had less OA

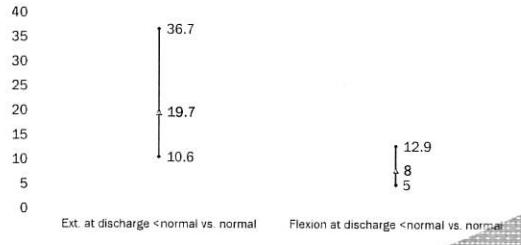
Results: IKDC Objective

- % with normal ratings
  - Extension (with 2^0 of opp knee) – 78%
  - Flexion (within 5^0 of opp knee) – 71% normal
  - Effusion – 84%
  - Single-leg hop – 77%

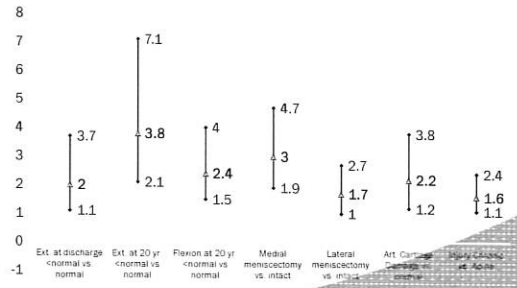
Results

- ROM: Mean 3/0/137° vs 4/0/141° in NI knee
  - 75% had some degree of hyperextension
  - 85% had extension to at least 0°
- Isokinetic quadriceps strength: Mean 90 ± 13%
- KT1000 man/max difference: Mean 1.4 ± 1.7 (range -3 – 6)

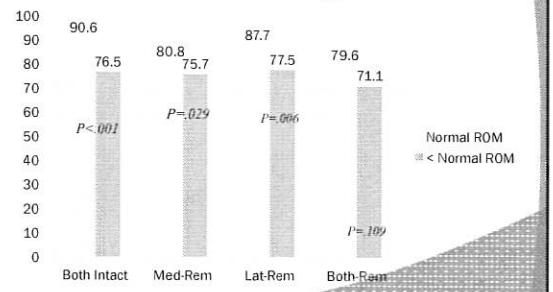
ROM loss at discharge and Odds of ROM loss at 20 year f/u



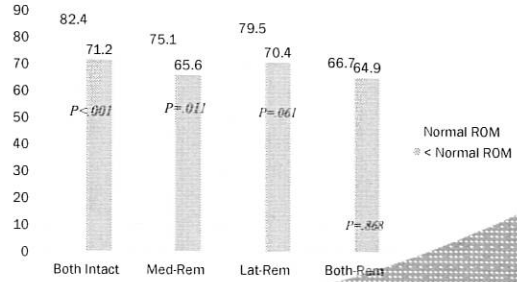
Odds (95% CI) of Developing OA: Significant Factors



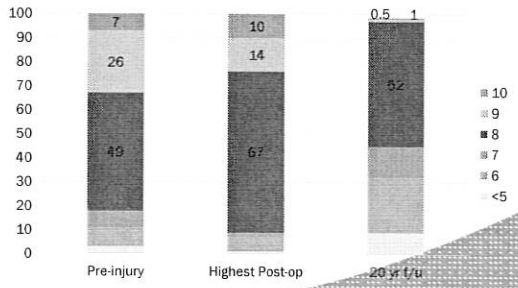
CKRS Subjective Scores: ROM Ratings



IKDC Subjective Scores: ROM Ratings



Activity Rating



Conclusions: 20 year f/u data

- Failing to achieve normal flexion and/or extension by time of discharge increases probability of continued loss of motion 8 to 20 times respectively at 20 years f/u
- ROM loss increased the odds of developing OA in the long-term
- Development of OA significantly affected also by meniscectomy, articular cartilage and chronicity of injury

Accelerated Rehabilitation

- Goal – give patient the best chance of a normal knee in the long term
- Any loss of extension or flexion significantly affects the results
- "Accelerated" mean achieve full ROM as quickly as possible after surgery and maintain full ROM throughout the process
- Full ROM, to included hyperextension, should be the goal regardless of graft choice