Two-Stage Revision ACL Reconstruction: Indications, Techniques, and Outcomes

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Disclosures

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Abstract

The number of primary anterior cruciate ligament (ACL) reconstructions is rapidly increasing. Despite a published success rate of 80-90% following ACL reconstruction (ACLR), with the increase in the number of primary ACL reconstructions, there is a growing subset of patients with persistent or recurrent functional instability who often require revision ACLR. Prior to proceeding with revision ACLR, it is important to identify any additional knee pathology, consider the technical challenges of revision, and manage the patient's expectations. The decision to perform a two-stage versus a single-stage revision ACL reconstruction rests on technical considerations and coexistent knee pathology. Evaluation of prior tunnel positions, tunnel widening, arthrofibrosis, and active infection, as well as concomitant meniscal, chondral or ligamentous injury are important aspects of treating ACL failures that will determine the need for a two-staged approach. This evidence-based review will cover the indications for two-stage revision ACL reconstruction, surgical techniques, evidence for bone grafting of prior ACL tunnels, and outcomes of two-stage revision stratified by initial cause of ACL reconstruction failure.

Background

- ACLR is the gold standard treatment for young, active patients who sustain an ACL rupture
- The number of primary ACLRs in the United States is increasing: 87,000 in 1994 to 130,000 in 2006[1]
- About 2 to 11% of patients have ACLR graft failure, particularly younger patients and those who had an allograft ACLR[2-4]
- ACLR graft failure may result from technical errors, a traumatic event, biological failure of graft incorporation, concomitant pathology, or a combination of factors
- As a result, the need for revision ACLR is increasing, with an estimated 13,000 revision ACLRs in the United States annually[5]
- Outcomes of revision ACLR are inferior to those of primary ACLR, with lower outcome scores and higher graft failure[6]
- Two-stage revision ACLR is utilized in a small, challenging subset of patients, most commonly involving bone grafting for widened tunnels
- Two-stage ACLR comprises approximately 7 to 9% of revision ACLRs[5,7]

Acute traumatic failure of ACLR graft seen on MRI sagittal, coronal, and ACL in-plane oblique planes

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Evaluation of the Failed Primary ACL Reconstruction

Causes of ACLR Failure

1. ACLR graft rupture
2. Loss of motion/arthrofibrosis
3. Infection
4. Missed concomitant pathology
    1. Ligamentous injury
    2. Chondral lesions or arthritis
    3. Meniscal tear or deficiency
5. Malalignment
6. Patellofemoral dysfunction

Full thickness chondral defect of medial femoral condyle

ACLR failure with varus alignment and posterolateral corner (PLC) injury, treated with high tibial osteotomy and staged PLC reconstruction (not shown)

Causes of ACLR Graft Failure

1. Traumatic (32%)
    1. More commonly occurs after 1 year postoperatively
    2. Tunnels properly positioned
    3. Often similar to initial ACL injury
2. Technical (24%)
    1. Early, atraumatic graft failure within first 6-12 months
    2. Tunnel malposition: anterior or vertical femoral tunnel, posterior tibial tunnel
    3. Graft fixation
    4. Failure to address malalignment or concomitant ligament injury
3. Biologic graft failure (7%)
    1. Failure of graft incorporation
    2. May be greater concern for allograft
4. Excessive rehab or premature return to activities
    1. Rare in isolation, may contribute
5. Combination of above (37%)

Note: % causes of failure based on demographics of initial MARS Cohort[7]

Patient Evaluation

- History of the original injury
    - Could suggest concomitant injury
    - Was full range of motion present prior to primary ACLR?
- Primary ACLR operative report and images
    - Graft type, fixation, exam under anesthesia, concomitant procedures, operative findings
- Postoperative course
    - Unusual rehab, stiffness, early return to activity, post-operative KT-1000
- History of symptoms following ACLR
    - Pain, stiffness, instability, infection
    - Traumatic versus atraumatic
    - Onset after primary ACLR
    - Did patient ever have a well-functioning knee after ACLR?
- Patient age, activity level, smoking, BMI, and co-morbidities
- Patient expectations must be elicited

Physical Exam

Gait, overall limb alignment, and knee alignment are assessed first. A complete, systematic evaluation of the knee is performed and *compared to the contralateral knee*:

- Presence or absence of effusion
- Prior surgical incisions
- Tenderness to palpation
    - Joint line tenderness suggests meniscal tear
- Strength testing
    - Weakness may indicate incomplete rehabilitation from primary ACLR
- Patellofemoral tracking, crepitation, chondromalacia
    - Can contribute to anterior knee pain after ACLR or suggest concomitant patellofemoral pathology
- Range of motion
    - Subtle loss of terminal extension causes bent knee gait, quadriceps fatigue/weakness, anterior knee pain, and may predispose to arthritis[8,9]
    - Prone heel height measurements in comparison to contralateral side allow subtle loss of extension to be identified (1cm = 1°)
- Ligamentous stability
    - Anterior and posterior laxity as well as medial and lateral
    - Missed posteromedial or posterolateral instability could abnormally stress the ACLR graft and predispose to failure
    - Lachman most sensitive, pivot shift under anesthesia most specific[10]
    - KT-1000 provides objective measurement of anterior translation

Image of the Pivot Shift test

Imaging

Radiographs

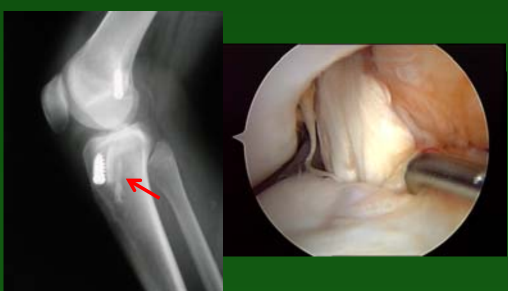
- Radiographs are obtained in all patients with failed ACLR to assess
  - Tunnel position
  - Prior hardware position
  - Tunnel widening
  - Tibial slope
  - Fracture or dislocation
  - Degenerative joint disease

- We obtain a four-view series at initial evaluation
  - Weightbearing AP in extension
  - 45 degree flexed PA (Rosenberg)
  - Lateral
  - Skyline/Merchant view
  - Mechanical axis radiographs are added when malalignment is suspected

Example of four-view series with proper tunnel position:

Example of vertical and anterior femoral tunnel placement:

Example of posterior tibial tunnel placement (arrow):



Tunnel Widening

- Knee radiographs are reviewed for any evidence of tunnel widening or bone defects

- If any widening is suspected, advanced imaging is warranted
  - MRI permits assessment of tunnel widening,[11,12] may show the characteristic bone edema pattern following traumatic rerupture (posterior aspect of lateral tibial plateau and anterolateral femoral condyle), and provides information about ACLR graft status, articular cartilage, menisci, and other ligaments
  - CT provides the best bony detail of tunnel widening and bone defects, outperforming radiographs and MRI[13-15]

- Our preferred approach is MRI in all cases of suspected ACLR failure with selective use of supplementary CT in cases where MRI does not provide sufficient assessment of tunnel position and widening

Example of tibial tunnel widening on radiographs and MRI:

Example of femoral tunnel widening on radiographs and MRI:

Treatment Decision Making for the Failed ACLR

- Revision ACLR is indicated for ACLR patients with a symptomatic, unstable knee that interferes with desired patient activity level
    - Not indicated for failed ACLR graft that does not interfere with function or cause symptoms
- Contraindications to revision ACLR
    - Medical comorbidities precluding surgery
    - Active infection
    - Relative: malalignment, stiffness, degenerative changes
- Single-stage procedure can be performed for most revision ACLR cases (>90%)[5,7]
    - Properly positioned tunnels with good bone stock following hardware removal
    - Poorly positioned tunnels such that primary tunnels and hardware do not interfere with proposed position of new tunnels
    - Can perform concomitant tunnel grafting or additional fixation (e.g. stacked interference screws) for mild tunnel widening (under ~10-15mm)[16-18]

Indications for Two-Stage Revision ACLR

- Tunnel widening
    - *Most common indication for two-stage revision ACLR*
    - Authors recommend two-stage if widening >10-15mm[16-18]
    - Stage 1: tunnel bone grafting, removal of ACL stump and excess tissues
    - Stage 2: revision ACLR (may obtain CT or MRI prior to surgery to verify tunnel fill)
- Loss of range of motion
    - Consider two-stage if >5 degrees loss of extension, >20 loss of degrees flexion
        - Want to avoid a bent knee gait
    - Stage 1: arthroscopic lysis of adhesions and manipulation
    - Can perform removal of failed ACLR hardware and tunnel bone grafting during stage 1 if indicated
    - Aggressive postoperative rehab to attain full motion d
    - Stage 2: revision ACLR once normal motion obtained
- Active infection
    - Stage 1: irrigation & debridement, removal of hardware
    - Antibiotics to eradicate infection
    - Stage 2: revision ACLR
- Concomitant surgery that would hinder revision ACLR or rehabilitation
    - Depends on specifics of patient, pathology, rehabilitation, and surgeon preference
    - May include:
        - Significant varus or valgus malalignment requiring femoral or tibial osteotomy
        - Multiligamentous laxity requiring reconstruction
        - Symptomatic meniscal deficiency treated with meniscal allograft transplantation
        - Chondral lesions treated with cartilage restoration procedures
    - Stage 1: address concomitant pathology
    - Stage 2: revision ACLR

ACL Tunnel Bone Grafting Surgical Technique

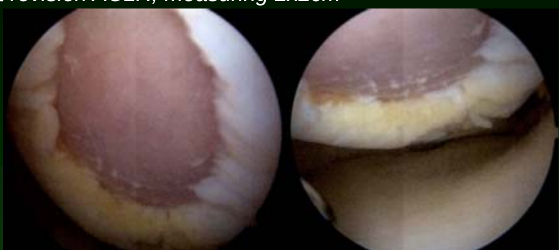
Anesthesia and Positioning

- Regional and/or general anesthesia may be used
- Patient is positioned supine on operating table
- Examination under anesthesia is performed
  - Range of motion
  - Pivot shift test
  - Lachman
  - Anterior and posterior drawer
  - Dial test at 30 and 90 degrees knee flexion
  - Varus and valgus testing at 0 and 30 degrees
- Foot of operating table is flexed
  - Must be able to hyperflex operative knee
- Tourniquet applied and operative leg placed in leg holder
- Contralateral leg in gynecologic leg holder

Arthroscopy and Preparation

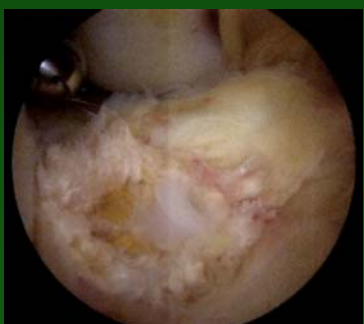
- Diagnostic arthroscopy is performed to identify and document all concomitant pathology
  - Concomitant pathology should be addressed as indicated in a single-stage or two-stage fashion

Example: Medial femoral condyle chondral defect identified at revision ACLR, measuring 2x2cm



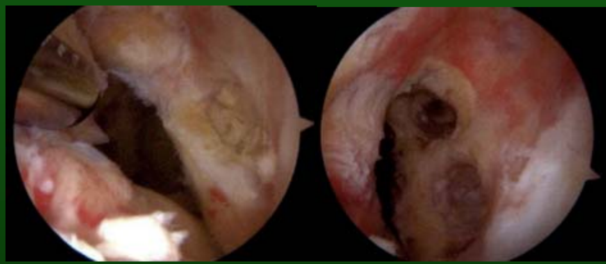
- Notchplasty is performed if needed to avoid graft impingement
- Inspect tibial and femoral footprints of torn ACLR graft
  - Remove residual ACLR graft from the lateral wall of the femoral notch and tibia
- Hardware is removed as needed, if unable to be bypassed at revision surgery
  - Remove soft tissue/bone over screw
  - 3.5mm screwdriver often successful
  - Specialized equipment for previous implants
  - Nitinol wire facilitates screwdriver seating
  - Broken screw removal kit

Example of prominent screw at the tibial tunnel



Tunnel Bone Grafting

- After hardware removal, the widened tunnels are debrided of soft tissue and sclerotic bone with shaver, burr, radiofrequency device, and curette



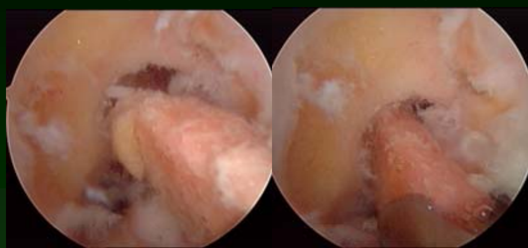
- Native bone stock should be preserved as much as possible
- Autograft or allograft may be used for bone grafting tunnels

Bone Graft Options in Revision ACLR

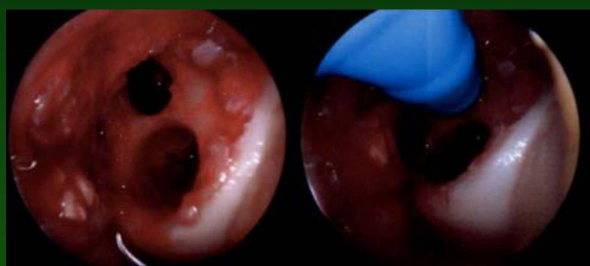
Type	Benefits	Negatives
Illiac Crest Autograft	Structural graft[a], Significant Volume available	Donor Site Morbidity
Anterior Tibial Plateau Autograft	Avaliable through same incision[b], local	Technically difficult to avoid desired tibial tunnel tragectory, limited quantity
Gerdy's tubercle Autograft	Available locally	limited quantity
Crushed Cancelous Allograft	No donor site morbidity, Large quantity	Osteoconductive only, Cost

a: Dowels can be harvested to impact for large defects
b: if transpatellar portal is utilized

- Graft may be in the form of a dowel[19]
  - 1mm larger than tunnel diameter
  - Impact into tunnel with bone tamp for press-fit



- Alternatively, crushed, cancellous graft may be used with impaction grafting



- Graft may be inserted arthroscopically via an enlarged anteromedial portal
  - Packing graft in a 3mL syringe with tip cut off and advancing graft with the plunger allows delivery of cancellous graft to the tunnel without extravasation in the joint
- A small medial parapatellar arthrotomy can be used if grafting cannot be adequately performed arthroscopically
- Tibial tunnel grafting is performed from the inferior aspect of the tibial tunnel with care taken not to introduce graft into the joint
- Inspect the knee to ensure no loose pieces of graft

Second-Stage Timing and Technical Aspects

Tunnel Grafting Postop Course

- Aspirin 81 mg or 325mg and ankle pumps are used for DVT prophylaxis postoperatively
- Patients are initially kept non-weightbearing for two weeks after Grafting and range of motion exercises are begun immediately
- At two weeks, patients are advanced to touchdown weightbearing, with continued range of motion, straight leg raises, and heel slides
- Weightbearing is progressed as tolerated at about 6-8 weeks
- Serial radiographs are obtained to follow the bone grafting incorporation and a CT scan at approximatley 3-4 months postoperatively to ensure the tunnel bone grafting was successful

Example: preoperative (top row) and two-week postoperative (bottom row) AP and lateral radiographs demonstrating appropriate bone graft in the tunnels

Graft Choice

- Depends on multiple factors including primary ACLR graft, surgeon preference, and patient preference
  - Autograft: hamstring, quadriceps, BTB
  - May havest autograft ipsilaterally or contralaterally
  - Allograft: Achilles, BTB, hamstring, quadriceps, tibialis anterior
- Bone patellar tendon bone (BTB) autograft and allograft are most commonly used in the revision ACLR setting, followed by hamstring autograft[7,20-21]
  - MARS data suggests autografts have improved outcomes and decreased risk of re-rupture at 2 years compared to allografts[21]

- Authors' preferred grafts for revision ACLR
  - Use BTB autograft if available
  - Second option is nonirradiated fresh-frozen BTB allograft[22]
  - Always have BTB allograft available in the room, as a backup or supplement to autograft
  - BTB allograft allows bone for supplementary bone grafting or extra-large bone blocks

Second-Stage ACLR

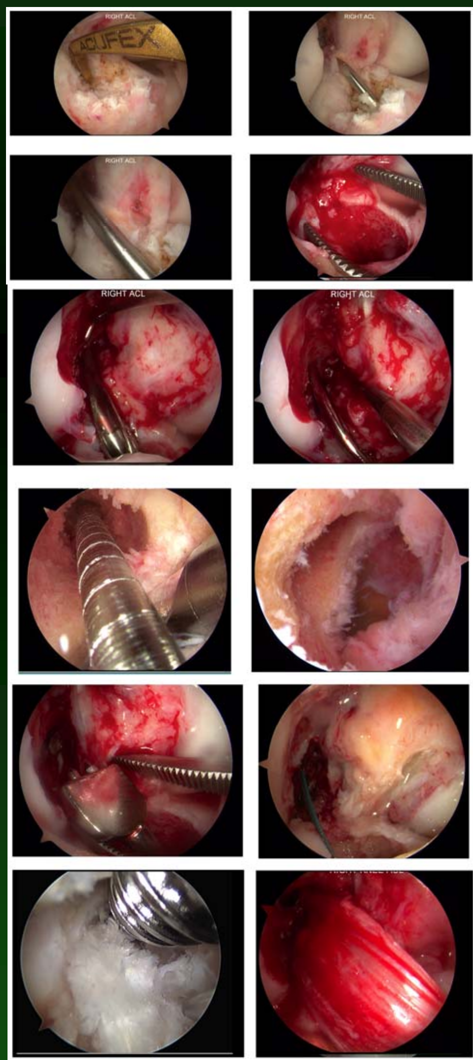
- Once tunnels are confirmed to be filled with bone and patient has normal motion, second-stage ACLR can be performed

- Anesthesia, patient positioning, examination under anesthesia, and diagnostic arthroscopy are performed in the same manner as the first-stage

- Bone grafted tunnels are inspected and probed to ensure graft stability

- Additional debridement or notchplasty is performed if needed to prevent graft impingement
  - We prefer to use ¼ inch osteotomy and a spherical burr, followed by a shaver and rasp to smooth the area

- We employ a transtibial technique for primary and revision ACLR drilling,[23] although an anteromedial technique can be used as well



- If bone graft incorporation is questionable, BTB graft preparation can be delayed until after bone tunnels are drilled, to allow variation in bone plug size if needed

- Graft is fixed on tibial and femoral sides with metal interference screws if using BTB graft

- Supplemental suspensory fixation should be considered due to potentially weak bone grom bone-grafted tunnels
  - Especially on the tibial side

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Outcomes and Conclusions

Outcomes

- Outcomes of revision ACLR are inferior to those of primary ACLR, with lower outcome scores and higher graft failure[6,24,25]
- Return to sport is lower after revision ACLR compared to primary
  - 62-74% for revision ACLR[20]
- Few studies have specifically addressed outcomes of two-stage revision ACLR

Outcomes Following 2-Stage Revision ACLR

Study	Laxity SSD[b]			IKDC Scores*			Pivot Shift[c]				
	1.36mm ± 1.11mm (mean±SD)*			61.2 ± 19.6 (mean±SD)*				Pre-Op	Post-Op		
Thomas et al. N=49[a], Avg Follow-up: 6.2yrs (3-11)		Pre-Op	Post-op	Subjective Scores			0	0	43		
	0 to 3mm	0	46	<50	12		1+	4	5		
	3-4mm	9	1	51-60	6		2+	34	1		
	≥5mm	40	2	61-70	10		3+	11	0		
				71-80	14						
				>80	7						
				Objective scores							
				A	12						
				B	28						
				C	8						
				D	1						
	Laxity SSD[d]				IKDC Scores		Pivot Shift			Mean Lysholm	
		Pre-Op	Post-Op		Pre-Op	Post-Op		Pre-Op	Post-Op	Pre-Op	Post-op
Francesco et al. N=30, Avg Follow-up: 6.9 yrs (5-11)		7.4mm (3-10)	3.1mm (1.3-3.8)	Objective scores			0	0	25	65.4 (48-82, SD: 7.9)	90.2 (72-100, SD: 7.9)
				A or B	0	27	1+	5	5		
				C	18	3	2+	13	0		
				D	12		3+	12	0		
	P<0.001			P<0.0001			P<0.0001			P<0.001	

a: HT= 4 strand hamstring, BPTB= bone-patellar tendon-bone, iBPTB= ipsilateral bone-patellar tendon bone, iHT= ipsilateral 4-strand hamstring
b: Side-to-side deifference (SSD), measurements per Westminster cruciometer
c: Pivot Shift: 1+ (glide), 2+ (clunk), 3+ (subluxation)
d: measurements per KT-1000 arthrometer
*: At Final Follow-up

Conclusions

Despite successful clinical outcomes for primary ACLR, revision ACLR presents a unique set of challenges including bone loss, arthrofibrosis, and graft choice limitations. A two-stage revision ACLR is a viable treatment option that should be considered for patients presenting with a failed ACLR in the setting of bone loss due to tunnel widening, infection, arthrofibrosis, or concomitant pathology that would impede single-stage ACLR surgery or rehabilitation.

Rehabilitation

- Rehabilitation protocol following two-stage ACLR is identical to primary ACLR
- Stage 1 (weeks 1-6)
  - Protect ACLR and regain full range of motion
  - Stationary bicycle
- Stage 2 (weeks 6-12)
  - Continue range of motion and begin knee and core strengthening
  - Begin stair climber at 6 weeks
  - Running may begin at 8-10 weeks
- Stage 3 (weeks 12-18)
  - Advance strengthening, agility training, plyometrics
- Return to sports at approximatley 6-8 months based on "functional sports assessment"
- Concomitant procedures (MAT, HTO, cartilage procedures) will alter the rehabilitation process and return to sport

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