



Figure-of-4 Cruciate Remnant Objective Assessment Test Reducibility of Anterior Cruciate Ligament Stump for Feasibility of Arthroscopic Primary Anterior Cruciate Ligament Repair

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Abstract: Suture of the anterior cruciate ligament (ACL) has reemerged as a treatment option for proximal ACL tears. Preoperative imaging can provide insight into the feasibility of performing arthroscopic primary ACL repair, but the final decision is taken only after confirming with arthroscopy that the ACL remnant is reducible. We describe a test called the Figure-of-4 Cruciate Remnant Objective Assessment test that objectively interprets the reducibility of the ACL remnant for arthroscopic primary ACL repair.

In the past, before arthroscopy was used clinically, open anterior cruciate ligament (ACL) repair techniques had good clinical results with short-term follow-up.^{1,2} But the techniques fell out of favor in the 1980s, after it was reported that the results deteriorated in the medium and long term.³ With better understanding of ACL biology and effective application of arthroscopic techniques (improved technology, instruments, and implants), primary ACL repair has re-emerged as a treatment option for proximal ACL tears.⁴ With arthroscopy, anatomical repair of proximal ACL tears can be performed with minimal intervention, preserving most of the ACL remnant with its neurovascular supply.⁵⁻⁷ Preoperative imaging can provide insight into the feasibility of performing

arthroscopic primary ACL repair, but the final decision is taken only after confirming with arthroscopy that the ACL remnant is reducible.⁸ Thus, we need an arthroscopic technique to determine the reducibility of the ACL remnant. Here, we describe the Figure-of-4 Cruciate Remnant Objective Assessment (4 CROSS) test, which is used to objectively determine the reducibility of the ACL remnant for arthroscopic primary ACL repair.

Surgical Technique

Magnetic Resonance Imaging Assessment

Preoperative magnetic resonance imaging (MRI) in ACL-injured patients is used to evaluate the length and quality of the ACL remnant. This allows the surgeon to consider the feasibility of arthroscopic primary ACL repair after arthroscopic confirmation.

Patient Setup

The patient is placed in a supine position on the operating table. The standard arthroscopy position is set up with a lateral post just proximal to the knee, at the level of the padded tourniquet, to prevent the hip from externally rotating; a foot roll is used to maintain 90° of knee flexion (Fig 1). This allows the knee to be moved freely through its full range of motion.

Skin Landmarks, Incision, and Exploration

Standard anterolateral and anteromedial portals are created, and a full diagnostic arthroscopy is performed.

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The authors report the following potential conflicts of interest or sources of funding: B.S.-C. reports personal fees from Arthrex. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

Received January 4, 2019; accepted February 16, 2019.

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2212-6287/1912

<https://doi.org/10.1016/j.eats.2019.02.008>

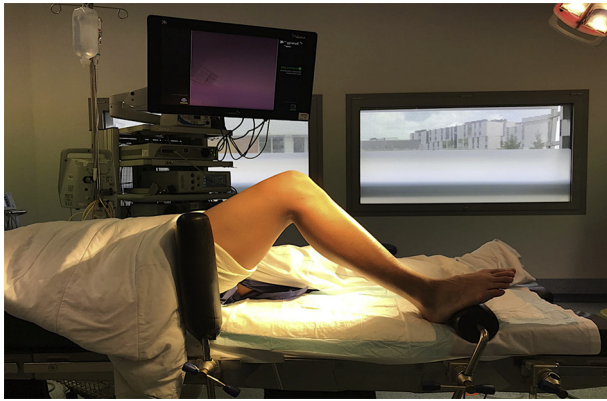


Fig 1. Patient setup. The patient is placed in a supine position with a lateral post just proximal to the right knee, at the level of the padded tourniquet; a foot roll is used to maintain 90° of knee flexion.

Any associated meniscus tears (medial and lateral) and cartilage lesions are treated.

The knee is flexed to 90° to evaluate the ACL remnant. The location of the ACL tear (proximal, midsubstance, distal) and tissue quality of the ACL remnant (fraying, bulbous transformation) are determined. Patients with proximal ACL tears and good-quality remnant tissue are considered for the 4 CROSS test.

Technique: 4 CROSS Test

The main aim of the 4 CROSS test is to assess the reducibility of the ACL remnant and help to select appropriate patients for arthroscopic primary ACL repair. This is done in 2 positions: first with the knee in 90° of flexion and second with the knee in the figure-of-4 position.

Step 1: Testing in 90° of Knee Flexion

In 90° of knee flexion, the proximal end of the ACL remnant is captured with arthroscopic forceps, and the ligament is reduced to its footprint in the intercondylar notch.

Step 2: Testing in Figure-of-4 Position

With the ACL remnant reduced to its footprint using arthroscopic forceps, the assistant gradually shifts the position of the lower limb from 90° of knee flexion to the figure-of-4 position. During this change, the operating surgeon looks for any gapping to appear between the ACL's femoral footprint and the proximal end of the ACL remnant (Fig 2).

If there is gapping in 90° of knee flexion or the figure-of-4 position, the ACL remnant is considered non-reducible and not amenable to arthroscopic primary ACL repair. If no gapping is observed in the 2 positions, the

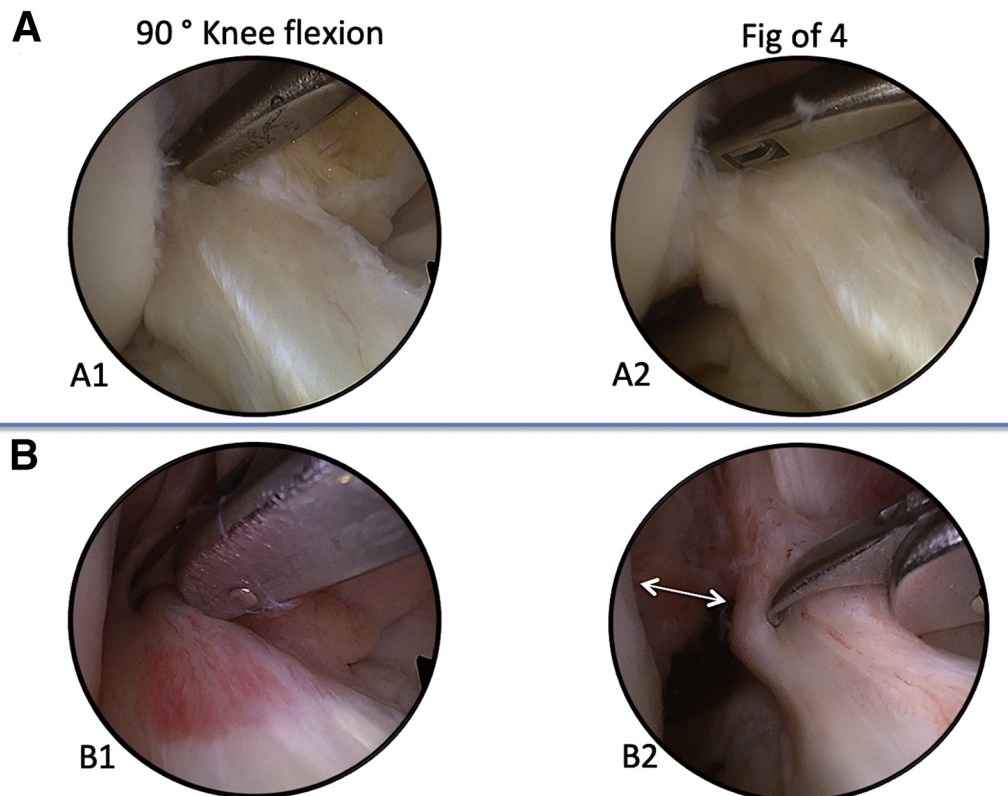


Fig 2. Figure-of-4 Cruciate Remnant Objective Assessment test. (A) Right knee: reducible anterior cruciate ligament remnant I at 90° of knee flexion (A1) and in the figure-of-4 position (A2). (B) Right knee: the anterior cruciate ligament remnant is reducible at 90° of knee flexion (B1), whereas in the figure-of-4 position, an irreducible gap (white arrow) persists (B2).

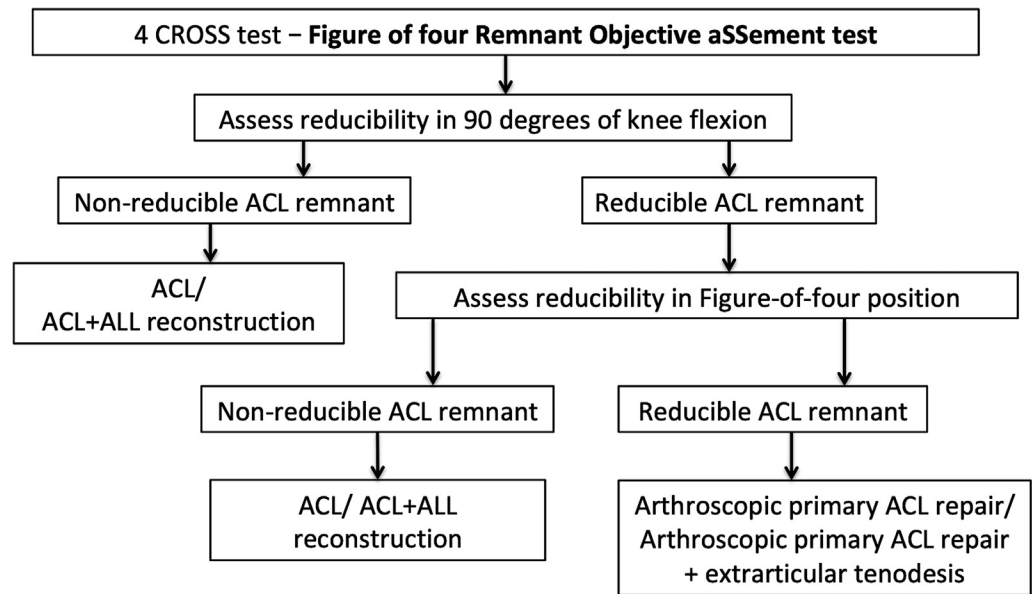


Fig 3. Figure-of-4 Cruciate Remnant Objective Assessment test surgical treatment decision tree.

remnant is reducible, and the patient is eligible for arthroscopic primary ACL repair. The surgical treatment decision tree based on the 4 CROSS test is given in Fig 3.

The pearls and pitfalls of the 4 CROSS test are given for each surgical step in Table 1. The advantages of the test and its limitations are presented in Table 2.

Discussion

This Technical Note and the accompanying video (Video 1, available at www.arthroscopyjournal.org) describe a simple and quick test, the 4 CROSS test, that is used to objectively assess the reducibility of the ACL remnant to determine whether arthroscopic primary ACL repair is feasible. It is an objective test to help select the appropriate patients for arthroscopic primary ACL repair.

The goal of arthroscopic primary ACL repair in patients with proximal ACL tears is to effectively append the ACL remnant to its femoral footprint without placing undue tension on it. Failure to append the ACL remnant will hamper its healing to bone and may result in clinical failures during follow-up. Arthroscopic primary ACL repair is a viable surgical option performed in carefully selected patients with proximal ACL tears and a reducible ACL stump with good remnant tissue quality (without fraying or bulbous transformation).

MRI has recently been used to identify the ACL tear pattern and quality of the stump tissue.⁸ However, it is still recommended to confirm the MRI findings with arthroscopy before performing primary ACL repair. One major advantage of arthroscopic evaluation over MRI is the ability to test the reducibility of the ACL

Table 1. Surgical Steps, Pearls, and Pitfalls for the Figure-of-4 Cruciate Remnant Objective Assessment Test

Surgical step	Pearls	Pitfalls
Remnant debridement	Debridement of ACL remnant through the AM portal	Aggressive debridement of the remnant will result in it shortening; insufficient debridement will impede its mobilization
Notch debridement	View the femoral footprint with minimal debridement and preparation with multiple drill holes	Incorrect debridement may lead to inappropriate femoral tunnel placement
Evaluation of ACL remnant in 90° of flexion	Is ACL remnant reducible in 90° of knee flexion?	AM bundle is taut and PL bundle is loose
Evaluation of ACL remnant in figure-of-4 position	Is ACL remnant reducible in figure-of-4 position?	PL bundle is taut
Management of associated lesions	Assessment of posterior root and posterior horn of the menisci	Perform before ACL fixation

ACL, anterior cruciate ligament; AM, anteromedial; PL, posterolateral.

Table 2. Advantages and Limitations of the Figure-of-4 Cruciate Remnant Objective Assessment Test

Advantages	Limitations
Easy to perform	Does not evaluate tissue quality
Corresponds to the anterior cruciate ligament being under tension with the knee flexed, which allows for good arthroscopic evaluation	
Does not require a specific device	
Low cost	

remnant to its femoral footprint in real time and assess whether a tension-free repair can be performed for the proximal ACL tear.

Conclusions

It is essential to test the reducibility of the ACL remnant in 2 different positions (i.e., 90° of knee flexion and figure-of-4 position), as this allows the reducibility of both the anteromedial and posterolateral (PL) bundles of the ACL to be evaluated. The anteromedial bundle of the ACL is isometric, and its femoral attachment is the ACL’s point of rotation. In 90° of knee flexion, the PL bundle is loose. The PL bundle tightens with internal rotation and varus of the tibia. Therefore, to test the reducibility of the PL bundle, it is essential to test the ACL remnant in this internal rotation and varus position, which can be achieved by putting the lower limb in the figure-of-4 position. Testing the ACL’s

reducibility in these 2 positions is important for appropriate patient selection. We believe this can be assessed objectively using the 4 CROSS test.

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