

Level V Evidence

Partial Rupture of the Anterior Cruciate Ligament

Wolf Petersen, M.D., and Thore Zantop, M.D.

Abstract: The anterior cruciate ligament (ACL) consists of two major fiber bundles, namely the anteromedial (AM) and posterolateral (PL) bundles. Although disagreement exists among arthroscopic surgeons about the occurrence of isolated ruptures of the AM or PL bundle, there are reports of partial ruptures of the ACL in the literature. A potential reason for controversy could be that with conventional magnetic resonance imaging, isolated PL ruptures are difficult to diagnose because of the oblique course of this bundle. Another reason could be that isolated ruptures of the AM or PL bundle are difficult to diagnose during arthroscopy. During arthroscopy, an isolated PL bundle rupture can easily be missed when viewing from the standard anterolateral portal. The AM bundle overlies the PL bundle, and the PL bundle can only be seen by retraction of the AM bundle with a probe. When the knee is extended, the PL bundle is tight and the AM bundle is moderately lax. As the knee is flexed, the femoral attachment of the ACL becomes horizontally oriented, causing the AM bundle to tighten and the PL bundle to relax. Whereas the AM bundle is the primary restraint against anterior tibial translation in flexion, the PL bundle tends to stabilize the knee near full extension, particularly against rotatory loads. The different bundle contributions to knee stability in the flexed or extended positions can aid in the diagnosis of partial ACL ruptures. Isolated rupture of the AM bundle has more effect on the anterior drawer sign than on the Lachman test, whereas the converse is true for isolated rupture of the PL bundle. Rotational instability as a result of PL bundle rupture can be tested with the pivot-shift test. Pivot shift can be negative in cases with isolated AM bundle rupture. If only one bundle of the ACL is torn, isolated AM or PL bundle reconstruction should be considered. Although potentially difficult, a careful diagnostic evaluation is necessary before ACL surgery. **Key Words:** Anterior cruciate ligament—Partial rupture—Diagnosis—Reconstruction—Anatomy.

Early descriptions of two functional bundles of the anterior cruciate ligament (ACL) date back to an anatomic study performed by Weber.¹ Since then, it has been well recognized that the ACL consists of two bundles, the anteromedial (AM) and posterolateral (PL) bundles, so-named for the orientation of their tibial insertions.^{2,3}

The PL bundle is tight in extension, whereas the AM bundle is tight in flexion, which correlates with increased contributions to knee stability and the likelihood of partial ruptures in these positions.³

However, there is still controversy about the occurrence of partial ACL ruptures among arthroscopic surgeons. This article was written to elucidate this issue considering both biomechanical data and clinical experience.

From the Department of Trauma, Hand, and Reconstructive Surgery, Wilhelms University Muenster, Muenster, Germany.

The authors report no conflict of interest.

Address correspondence and reprint requests to Wolf Petersen, M.D., Department of Trauma, Hand, and Reconstructive Surgery, Wilhelms University Muenster, Waldeyerstrasse 1, D-48149 Muenster, Germany. E-mail: Wolf.Petersen@ukmuenster.de

© 2006 by the Arthroscopy Association of North America

0749-8063/06/2211-6215\$32.00/0

doi:10.1016/j.arthro.2006.08.017

BIOMECHANICS

Although there is a significant amount of load sharing between the two bundles, the PM bundle resists anterior subluxation near full extension whereas the AM bundle resists anterior drawer between 60° and 90° of flexion.³

In addition, the ACL also plays a role with regard to stabilization against rotatory loads.⁴ Anterior tibial drawer is normally accompanied by a coupled tibial rotation.

In the ACL-deficient knee, the axis of rotation shifts medially, and tibial internal rotation causes a coupled anterior tibial translation magnifying the subluxation of the tibial plateau.³

CLASSIFICATION OF PARTIAL ACL TEARS

The reciprocal tension pattern of the AM and PL bundles suggests that partial ruptures can affect individual bundles depending on knee flexion angle at the time of injury.³ An anterior directed force when the knee is close to full extension has the potential to damage the PL bundle, whereas a similar force applied when the knee is in greater flexion has the potential to damage the AM bundle.

Some surgeons may doubt that a partial rupture can occur. Yet, there are reports of isolated ruptures of the AM or PL bundle of the ACL in the literature.^{5,6} Eriksson⁵ stated that in his experience, patients with isolated AM bundle ruptures often do quite well and do not need surgery whereas those with isolated PL bundle ruptures report subjective instability. Ochi et al.⁷ reported a series of 169 patients with ACL rupture. In 17 cases (10%) a partial ACL tear was found. An isolated AM tear was found in 13 of 17 cases, and an isolated PL bundle was seen in only 4 cases.

ARTHROSCOPIC DIAGNOSIS

A potential cause of controversy is that isolated ruptures of the AM bundle and especially the PL bundle are difficult to diagnose during arthroscopy. An isolated AM rupture can be identified during arthroscopic probing. However, during arthroscopy, an isolated PL bundle rupture can easily be missed when viewing from the standard anterolateral portal. In such cases the AM bundle overlies the PL bundle, and the PL bundle can only be seen by retraction of the AM bundle with a probe. When the knee is placed in the figure-of-4 position, however, the PL bundle is more easily identified. Bleeding and discontinuity are signs of rupture. A lax PL bundle is not a sign of rupture (because the PL bundle is normally lax in 90° of knee flexion).

A lax PL bundle in 90° of flexion could lead to an incorrect assumption that the rest of the ACL is elongated and therefore insufficient. The biomechanical

behavior of the normal PL bundle teaches us that this assumption is wrong. If the PL tightens when the knee is extended, this bundle should be considered intact. This creates a dilemma; in full extension (when the PL is tight), the ligament is difficult to visualize.

CLINICAL DIAGNOSIS

With conventional magnetic resonance imaging (MRI), isolated PL ruptures are difficult to diagnose because of the oblique course of this bundle, and we find no studies in the literature reporting the sensitivity and specificity of MRI to detect isolated AM or PL bundle tears. If the physician is familiar with the specific anatomy of the ACL, MRI can be helpful in the diagnosis of partial ruptures. However, a standard examination for visualization of the PL bundle still has to be performed, and further research is needed.

Careful clinical examination, with or without anesthesia, can be helpful to diagnose a partial ACL rupture. In a biomechanical study Furman et al.⁶ found that transection of the AM bundle caused a positive anterior drawer sign and a negative Lachman sign whereas the converse was true for the PL bundle. Thus, if only one of these signs is positive when compared with the normal contralateral knee, a partial rupture of a predictable bundle of the ACL has probably occurred.⁶ However, one has to keep in mind that there are individual variations in response to both the anterior drawer and Lachman tests.

In 1976, when the study of Furman et al.⁶ was performed, most persons believed that the ACL stabilized mainly against anteriorly directed loads. However, recent biomechanical studies have shown that the ACL bundle and especially the PL bundle also contribute to the control of rotational stability of the knee joint.⁴ In the clinical situation rotational stability can be tested with the pivot-shift test. Therefore it seems likely that a positive pivot shift can be considered to be an indicator of a rupture of the PL bundle. This theory is supported by our clinical experience treating patients who present with recurrent instability after standard, single-bundle ACL reconstruction (AM bundle reconstruction) with a graft positioned in an undesirably vertical position (11- to 1-o'clock position). In such patients the pivot shift is positive, the Lachman test may or may not show increased translation (despite a firm end-point), and the anterior drawer is negative. We have observed similar findings in patients with isolated rupture of the PL bundle.

Yet, a clinical study validating the pivot-shift test, Lachman test, and anterior drawer sign for detection

of isolated PL and AM bundle ruptures has not been performed. More research in this field is needed.

CLINICAL RELEVANCE

What is the clinical relevance of partial rupture of the ACL? Recent biomechanical and clinical studies have shown that reconstruction techniques that address both bundles of the ACL provide better rotational stability than techniques that address only a single (AM) bundle.^{8,9} Therefore it seems logical that in patients with a partial rupture of the ACL, the intact bundle may be preserved and only the torn bundle need be reconstructed.

Adachi et al.¹⁰ described 40 cases of isolated AM bundle rupture and compared the results with a control group of 40 patients who underwent single-bundle reconstruction of the complete ACL. The indication for an AM bundle reconstruction was an ACL injury in which an ACL remnant was observed bridging the femur and tibia, with a diameter from one third of the ACL. The side-to-side differences in anterior displacement measured by use of the KT-2000 arthrometer (MEDmetric, San Diego, CA) at 30 lb were significantly reduced from a mean of 5.3 ± 2.6 mm preoperatively to 0.7 ± 1.8 mm in the AM bundle group; the mean value of 6.0 ± 2.4 mm was reduced to 1.8 ± 2.1 mm in the single-bundle group.

Isolated PL bundle ruptures are less frequently diagnosed than isolated AM bundle ruptures. Later, the same group of investigators reported on 17 patients with an isolated rupture of either the AM bundle or the PL bundle.⁷ In 13 cases AM bundle reconstruction was performed; in only 4 patients isolated PL bundle reconstruction was performed. Outcomes were not reported.

These observations and results are in accordance with our own clinical experience, and we recommend isolated AM or PL bundle reconstruction for patients with a single-bundle rupture. In addition, in patients with recurrent rotational instability after single-bundle reconstruction and a vertically oriented graft (11 to 1 o'clock or "high-noon" position), isolated reconstruction of the PL bundle should be considered. Unfortunately, in many of these patients the tibial tunnel is drilled in the posterior aspect of the ACL insertion to prevent notch impingement. Were a new PL tunnel to be placed posterior to this tunnel, it would be

located posterior to the anatomic ACL insertion site. (This is not physiologic and risks injury to posterior structures including the menisci.) In such cases we recommend revision with a single tibial tunnel and two femoral tunnels (restoring the anatomic femoral footprint of the AM and PL bundles) rather than attempting isolated PL bundle reconstruction. We recommend isolated PL bundle reconstruction only for cases of a vertical graft associated with a negative anterior drawer sign and when the original tibial bone tunnel is adequately anterior (parallel to the anterior horn of the lateral meniscus).

CONCLUSIONS

If only one bundle of the ACL is torn, isolated AM or PL bundle reconstruction should be considered. We quote Jack C. Hughston¹¹: "repair what is torn."

REFERENCES

1. Weber W. *Mechanik der menschlichen Gehwerkzeuge*. Göttingen: Dieterichsche Buchhandlung, 1836.
2. Zantop T, Petersen W, Fu F. Anatomy of the anterior cruciate ligament. *Oper Tech Orthop* 2005;15:20-28.
3. Amis AA, Dawkins GP. Functional anatomy of the anterior cruciate ligament. Fiber bundle actions related to ligament replacements and injuries. *J Bone Joint Surg Br* 1991;73:260-267.
4. Gabriel MT, Wong EK, Woo SL, Yagi M, Debski RE. Distribution of in situ forces in the anterior cruciate ligament in response to rotatory loads. *J Orthop Res* 2004;22:85-89.
5. Eriksson E. Do we need to perform double-bundle anterior cruciate ligament reconstructions? *Oper Tech Orthop* 2005; 15:4.
6. Furman W, Marshall JL, Girgis FG. The anterior cruciate ligament: A functional analysis based on postmortem studies. *J Bone Joint Surg Am* 1976;58:179-185.
7. Ochi M, Adachi N, Deie M, Kanaya A. Anterior cruciate ligament augmentation procedure with a 1-incision technique: Anteromedial bundle or posterolateral bundle reconstruction. *Arthroscopy* 2006;22:463.e1-463.e5.
8. Yagi M, Wong EK, Kanamori A, Debski RE, Fu FH, Woo SL. Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. *Am J Sports Med* 2002;30:660-666.
9. Yasuda K, Kondo E, Ichiyama H, Tanabe Y, Tohyama H. Clinical evaluation of anatomic double-bundle anterior cruciate ligament reconstruction procedure using hamstring tendon grafts: Comparisons among 3 different procedures. *Arthroscopy* 2006;22:240-251.
10. Adachi N, Ochi M, Uchio Y, Sumen Y. Anterior cruciate ligament augmentation under arthroscopy. A minimum 2-year follow-up in 40 patients. *Arch Orthop Trauma Surg* 2000;120: 128-133.
11. Baker CL Jr. Memorial: Jack Hughston. *Oper Tech Orthop* 2005;15:2-3.