Original Article

Accuracy of radiographic determination of the posterior femoral wall integrity in anterior cruciate ligament reconstruction[☆]

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ABSTRACT

Objective: To evaluate the accuracy of radiographs in determining integrity of the posterior femoral cortex following ACL reconstruction.

Methods: Fifty adult volunteers undergoing primary arthroscopic transtibial ACL reconstructions were prospectively enrolled into this study. Plain radiographs and fine-cut CT of the operative knee were obtained post-operatively. Three blinded orthopaedic surgeons were asked to measure the distance from the femoral tunnel to the posterior cortex on lateral radiographs. Inter/intra-observer reliabilities were assessed with the interclass correlation coefficient. The true measurement of the posterior wall was determined on CT. For each, a measurement was made at the aperture, 5 mm, and 10 mm along the tunnel. Plain radiographic measurements were compared to the CT measurement of back wall using a paired *t*-test.

Results: All measurements made on the lateral radiograph were significantly different from those from the respective CT scans for each surgeon ($p < 0.0001$) at all points. When radiographic measurements were compared to CT at the level of the intra-articular aperture, 29 subjects showed violation of the posterior cortex, with only one being identified on plain films. At 5 mm, 7 subjects demonstrated posterior cortical violation, and none were identified on lateral radiographs. The posterior cortex remained intact in all cases at 10 mm.

Conclusion: Lateral radiographs of the knee are insufficient for evaluation of the posterior cortical integrity following primary ACL reconstruction. Direct visualization of the femoral tunnel remains the gold standard for evaluation of the posterior wall and may be supplemented by CT scan if there remains concern over graft fixation.

1. Introduction

Anterior cruciate ligament reconstruction is one of the most commonly performed orthopaedic procedures.^{1,2} Success in restoring stability to the knee requires precise anatomic tunnel placement, and femoral tunnel malposition has been shown to be the most common cause of premature graft failure.^{2–4} The femoral tunnel must be placed far posterior but not so much as to compromise the posterior cortex and thereby graft fixation.^{5–7} Adequate visualization of tunnel proper femoral tunnel position and integrity is essential but may be technically challenging, more so with the traditional transtibial technique.^{7,8}

Posterior cortical breach of the lateral femoral condyle may be

recognized acutely or in the revision setting followed failed fixation.^{6,7} Management depends on the acuity, location, and extent of the breach. While substantial blowout may be evident either under direct visualization or radiographic evaluation, early recognition of subtle breach is important to ensure maintained adequate graft fixation.

Direct visualization of a posterior wall breach is the gold standard for diagnosis; however arthroscopic visualization may be obscured by soft tissue, debris, poor pressure or flow, suboptimal portal placement, aberrant patient anatomy, or the breach may be subtle. Radiographs may further be utilized to evaluate femoral tunnel position and posterior wall integrity. However the accuracy of plain film radiographic indices in predicting malposition or breach of the posterior wall of the

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Fig. 1. Posterior wall measurements made at intra-articular aperture (0 mm) as well as 5 mm and 10 mm along the femoral tunnel on (A) lateral plain radiographs at post-operative follow-up as well as (B) computed tomography scan with 1.5 mm cuts through and parallel to the roof of the intercondylar notch.

Fig. 2. Accuracy of measurements made via plain film lateral radiographs as compared to CT-based indices for each surgeon.

lateral femoral condyle remains unexplored. The purpose of this study was to evaluate the accuracy of radiographs in the determination of the integrity of the posterior wall. We hypothesize that plain film radiographs are inaccurate means for determining if a breach in the posterior femoral cortex has occurred during ACL reconstruction.

2. Methods

Fifty consecutive adult volunteers indicated to undergo primary ACL reconstruction were prospectively enrolled into this study. We included all patients undergoing arthroscopic transtibial ACL reconstruction between 18 and 50 years old. Patients with a prior ACL reconstruction undergoing revision surgery as well as those whose procedures were not performed completely arthroscopically were excluded.

All reconstructions were performed using either patellar tendon or

quadrupled hamstring autograft. Femoral tunnels were established through standard transtibial over-the-top guide. Following reaming, operating surgeons were asked to make an intraoperative assessment of the posterior wall of the femoral tunnel. Operative technique and method of fixation was otherwise not standardized, as this did not impact the outcomes of interest.

Prior to discharge, a limited CT scan of the operative knee was obtained consisting of several 1.5 mm cuts through and parallel to the roof of the intercondylar notch. Finally, at the first postoperative visit, typically between seven and ten days, a true lateral of the knee was obtained, again with a 10 cm magnification marker.

Blinded to the identities of the patients and operating surgeons, three attending orthopaedic surgeons were asked to measure the distance from the femoral tunnel to the posterior femoral cortex (representing the “back wall”) on the post-operative lateral radiographs on three separate scheduled occasions separated in time. These values were analyzed for interobserver reliability and intraobserver reproducibility and each assigned a *kappa coefficient*. The “true” measurement of the posterior wall on CT scan in each case was determined by consensus from two seasoned institutional radiologists. For each CT scan and lateral radiograph, a measurement was made at the intra-articular level of the tunnel (0 mm) and then at 5 mm increments along the length of the tunnel up to 10 mm (Fig. 1). As such there were 3 measurements on each radiograph that could be compared to same level measurements on the CT scan which served as a “gold standard” measurement.

Intra- and inter-observer reliabilities were each assessed with the interclass correlation coefficient (ICC). The ICC ranges from 0 to 1 with 1 indicating perfect reliability. The literature would support any correlation > 0.5 as large, 0.5–0.3 as moderate, 0.3–0.1 as small. The correlation coefficient was used to assess correlation of plain radiographic and CT measurements. A Weak correlation < 0.4, a Strong

Fig. 3. Comparison of the measurements made by each of the three surgeons based on plain film lateral radiographs to those based on the fine-cut CT scan (A) at the intra-articular aperture (0 mm). Violation of the posterior femoral cortex was evident in 29 subjects, only one of which was correctly identified on plain film radiographs. (B) At 5 mm, 7 subjects were found to have cortical breach, none of which were identified on lateral radiographs. (C) At 10 mm, no subjects were found to have cortical breach. In all cases there was a statistically significant difference between lateral radiographic and CT-based measurements.

correlation is > 0.7 and a moderate correlation falls between. The plain radiographic measurements were compared to the computed tomography measurement of the true postoperative back wall using a *paired t-test*.

3. Results

There was a significant difference between the measurements made on lateral plain film and fine-cut CT scan for each surgeon ($p < .0001$) at all points along the tunnel (0, 5, and 10 mm), demonstrating poor accuracy (Fig. 2).

When plain radiographic measurements for each surgeon were compared to those made on CT scan at the level of the intra-articular aperture (0 mm), 29 subjects showed violation of the posterior femoral cortex at this level and only once was this identified by one of the surgeons (Fig. 3A). Additionally, two patients were incorrectly diagnosed with posterior cortical breaches on plain films but were confirmed to have intact cortices on CT scan. At 5 mm, 7 subjects showed posterior cortical violation, and none of these were identified on lateral radiograph (Fig. 3B). The posterior cortex remained intact in all cases at 10 mm (Fig. 3C). The posterior wall was directly visualized in all cases by the operating surgeon and in no instance was found to have a substantial cortical breach. The average posterior wall at the aperture measured 1.4 ± 0.5 mm (1–2 mm).

There was at least moderate intraobserver reliability overall (Fig. 4A). Two surgeons demonstrated good reliability while the third was moderate. The interobserver reliability additionally ranked as

moderate (Fig. 4B).

4. Discussion

Tunnel malposition is the most common and modifiable cause of premature ACL graft failure, cited as the chief contributing factor in as many as 80% of cases.⁴ Posterior cortical breach of the lateral femoral condyle is a recognized complication of an inadequately placed femoral tunnel and often compromises graft fixation.^{6,7} This may occur at the aperture or within the femoral tunnel, in which the cortical rim remains intact and in the absence of direct visualization of the tunnel may give a false appearance of posterior wall integrity.^{6,7} While the gold standard for diagnosis is direct arthroscopic visualization, this may be hindered by debris or soft tissue within the tunnel, low pressure or flow, faulty instrumentation, suboptimal portal placement, aberrant patient anatomy, or the breach may be small, subtle, or occur following graft passage. Therefore the surgeon may rely on alternative means by which to assess tunnel integrity such as plain radiography.

In this investigation, we found that plain film radiographic analysis was insufficient to diagnose posterior cortical breach at any level and that a large number would be missed if not evaluated by more advanced imaging. Despite at least moderate intra- and inter-observer reliability, plain film measurements were significantly different from CT-based measurements at all points along the tunnel. A significant number of posterior wall breaches were missed on plain film, more so the more distal the breach. Intraoperative visualization was additionally inadequate for detection.

Fig. 4. (A) Intra- and (B) inter-observer reliability in determining posterior wall cortical thickness at each level (0, 5, and 10 mm) along the femoral tunnel on plain film lateral radiographs.

Posterior wall breach may be recognized acutely or diagnosis can be delayed and only appreciated in the revision setting.⁶ If recognized acutely, depending on location of recognition of the breach, different salvage options are available.⁶ Within 5 mm of the intra-articular aperture, anterior redirection of the guidewire is often adequate. With extension past 5 mm, suspensory, hybrid, or over-the-top fixation may be necessary.^{9,10} Therefore radiographic determination of location would potentially direct management in the absence of direct visualization; however plain films were found to be inadequate. If recognized post-operatively, so long as the knee is stable, observation may be acceptable. However with loss of fixation and adequate bone stock, the above revision techniques may be implemented. With loss of fixation secondary to osteolysis and tunnel widening, staged revision is often necessary.

While CT serves as a reliable means to discern cortical integrity, the clinical implications and ultimate management of the posterior cortical breaches diagnosed on CT were not evaluated in this study. As a result, we may have over diagnosed otherwise minor and potentially clinically benign breaches. However the purpose of this investigation was strictly to determine whether plain post-operative lateral radiographs could accurately predict or rule out posterior femoral cortical breach, and we confirmed our hypothesis that plain films are indeed inaccurate. Therefore the operating surgeon must remain vigilant and ensure that if adequate intraoperative visualization is not possible or if there is any concern over tunnel position or graft fixation then a post-operative CT scan should be obtained. Additional investigation should be directed

into determining whether alternative radiographic views aside from a true lateral of the knee may improve the accuracy of diagnosis of posterior cortical breach.

5. Conclusion

Lateral radiographs of the knee are insufficient for evaluation of the posterior cortical integrity following primary ACL reconstruction. We found a weak correlation between the radiographic and CT-based measurements of posterior wall thickness at all points along the tunnel. Direct visualization of the femoral tunnel remains the gold standard for evaluation of the posterior wall and may be supplemented by CT scan if there remains concern over graft fixation.

Disclaimers

The authors are employees of the U.S. Federal Government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of William Beaumont Army Medical Center, the Department of Defense, or United States government.

This investigation was furthermore not presented at any previous meetings and is not currently submitted or accepted elsewhere.

Conflict of Interest

All authors have no relevant conflicts of interest to disclose. There was no pharmaceutical or industry support for this investigation. We do not have any financial or personal relationships to disclose.

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