Quantitative Measurement Of A Standardized Pivot-shift: Comparison Between The Awake And The Examination Under Anesthesia In Patients With Acute ACL Injury

Bruno Ohashi, M.D.1, Nicola Lopomo, PhD2, Stefano Zaffagnini, M.D.2, Yuichi Hoshino, M.D.3, Ryosuke Kuroda, M.D.3, Kristian Samuelsson, M.D.4, James J. Irrgang, PhD1, Volker Musahl, M.D.1. The PIVOT Study Group1.

1University of Pittsburgh, Pittsburgh, PA, USA, 2Istituto Ortopedico Rizzoli, Bologna, Italy, 3Kobe University, Kobe, Japan, 4 Sahlgrenska University Hospital, Göteborg, Sweden.


Introduction: A positive pivot shift test following reconstruction of the anterior cruciate ligament (ACL) correlates with poor functional outcome and development of early osteoarthritis[1,2]. There is a move towards standardization of clinical laxity tests, both with respect to performance and grading of the test[3,4]. Standardization of the pivot-shift test was recently proposed and is able to significantly reduce the variation between expert surgeons using their preferred pivot-shift test technique[5]. Tools for quantification of the pivot-shift test have been developed and can provide valuable data for the diagnosis of ACL deficient knees and functional evaluation of ACL reconstructed knees[6,7]. The purpose of this study was to compare the pivot shift examination in patients while awake vs. under anesthesia (EUA). Two non-invasive systems, one based on image analysis, the other using inertial sensors were utilized to quantitatively assess the pivot-shift test in patients with acute unilateral anterior cruciate ligament (ACL) injury. We hypothesized that patients would have similar tibial translation and acceleration during the pivot shift test under anesthesia and while awake.

Methods: This study was a multicenter study involving four different centers (Bologna, Italy; Gothenburg, Sweden; Kobe, Japan; Pittsburgh, USA) and was approved by the Institutional Review Board of each center. A total of 25 patients were enrolled in this study and underwent anatomic single bundle ACL reconstruction with hamstring tendon autografts. To be included in the study patients had to be between 16 and 50 years of age, time from injury < 12 months, scheduled for ACL reconstruction, with an injury that involved at least one of the two bundles of the ACL. Exclusion criteria included: 1) prior ligament surgery of the involved knee; 2) greater or equal than a grade III concomitant collateral ligament injury; 3) concomitant posterior cruciate ligament (PCL) injury; 4) inflammatory or other forms of arthritis; 5) any other injury or condition involving the lower extremity that affects the subjects’ ability to walk or participate in Level I and II activities, or 6) prior or concurrent injury or surgery to the contra-lateral knee. Quantitative kinematic tests were performed (1) pre-operatively prior to anesthesia and (2) pre-operatively during EUA in the operating room. Skin markers were attached to bony landmarks around the knee, (1) Gerdy’s tubercle, (2) the fibular head, and (3) the lateral epicondyle. A standardized pivot-shift test was performed consisting of three steps (example for the left knee examination): (1) left hand holds the heel while internally rotating the leg; (2) with thumb up, the right hand applies a valgus moment just distal to the joint line; (3) while flexing the knee with the left hand, rotational stress is released and the reduction is felt with the right hand. An iPad® was used to record a video of the standardized pivot shift test, simultaneously tracking the markers throughout the maneuver (Fig.1). An image analysis of the video (Fig.2a) was performed and the magnitude of the tibial translation of the lateral compartment and reduction time was automatically calculated by the iPad application. An inertial sensor, fixed to the skin with a velcro strap on the anterior lateral tibia, simultaneously recorded the range and slope of tibial acceleration during the standardized pivot shift test (Fig.2b). A paired t-test was used to determine differences in translation and acceleration during the pivot-shift test while the patient was awake and under anesthesia. Additionally, intra-class correlation coefficients (ICC) were calculated to determine agreement between the awake examination and EUA. Statistical significance was set to 95% (P<0.05).

Results: The average age of the patients was 26.4 years, 13 patients were male and 12 females. The pivot shift in the awake condition was found to be grade 0 in one patient, grade I in 13, grade II in 9 and grade III in 2 patients. All patients had complete rupture of the ACL, 12 patients had isolated injury of the ACL, 13 had concomitant lesions in the knee involving the medial meniscus (7), lateral meniscus (3), both menisci (2), or associated chondral lesion (2). Tibial translation was significantly greater during EUA (3.07 ± 1.41) when compared with the awake examination (2.06 ± .93; p<0.05). The acceleration was also significantly greater during EUA (6.92 ± 3.88 m/s²) when compared to the awake exam (3.57 ± 1.77 m/s²; p<0.05). Additionally, the ICCs, which were used to determine agreement between the awake examination and EUA were not significantly different from 0 for both translation (ICC=0.05, p=0.594) and acceleration (ICC= -0.009, p=0.863).

Discussion: This study found that in patients with acute ACL injury, significant differences were found in quantitative parameters during the pivot shift test performed while awake and under anesthesia. There was little agreement between the awake and
EUA measurements. Thus, muscular guarding in patients with acute ACL injury may influence tibial acceleration during the pivot shift test almost two fold. This study underlines the importance of adding EUA for pre-operative examination and planning.

**Significance:** Based on the findings of this study, analysis of the pivot shift test in the awake patient needs to be used with caution. Future plans are to utilize quantitative pivot shift analysis to assess function of the ACL graft. The goal of quantitative pivot shift studies is to individualize ACL reconstruction surgery through the establishment of a kinematics-based diagnosis and ultimately improve clinical outcome for patients with ACL injury.

**Acknowledgments:** The authors would like to acknowledge funding from the ISAKOS/OREF research grant.
