The Potential of Accelerometers in the Evaluation of Stability of Total Knee Arthroplasty

INTRODUCTION:
Instability is one of the main causes for early revision after Total Knee Arthroplasty (TKA) surgery (Bade 2010), often as a consequence of misalignment or inadequate ligament balancing (Sharkey 2002; Mc Auley 2004; Morgan 2005; Parratte 2008). Subtle instability may result in pain and reduced function. However, instability is not easy to assess quantitatively in a clinical setting. The aim of this study was to investigate the use of an accelerometer attached to the proximal tibia, as an evaluation of knee stability of TKA patients while performing daily activities. It was postulated that there would be different acceleration between TKAs and normal controls which could indicate abnormal TKA kinematics involving instability. Our hypothesis was that the TKAs will show characteristics of instability in a significant proportion of patients with pain or difficulty with activities requiring absolute stability.

METHODS:
A tri-axial accelerometer (GLI Interactive LLC, Seattle, WA), strapped to the anterior proximal tibia, was used to measure the accelerations along 3 axes to a maximum of 2g with a sample rate of 100 Hz. To test that acceleration readings reflected the tibia itself, a dummy leg was flexed and extended through 30 degrees, and the accelerations were measured with the accelerometer strapped to the leg (anatomic fixation) and rigidly fixed to the plastic tibia. Twenty acceleration values were obtained for each type of fixation and a t-test used to compare with a significance level of 0.05.

All experiments on the patients were IRB approved and carried out under HIPAA regulations. Patients were seen in the clinics of three surgeons (JZ, FJ, JS). We tested 38 TKA knees in 27 patients, 11 male and 16 female, in the age range of 50-80 years, with a minimum follow up of 6 months. Twelve patients were unilateral where the TKA and the normal opposite side were tested. The TKAs were of the posterior cruciate retaining (23) and posterior stabilized types (15). In addition, we tested 35 knees in 18 shoulder patients, 7 male and 11 female, who had no known knee pathology, in the age range of 50-80 years, to act as age-matched controls.

The patients were tested either in stockings, with no footwear, or flat footwear, and the accelerometer was attached directly to the leg with no intervening clothing. The patients were tested for the following five activities:

1) Starting with the test leg, walk 3 steps then come to a sudden stop.
2) Sit down for 3-4 seconds then stand back up.
3) Step up on a 7 inch high box with the test leg, followed by the non-test leg.
4) Step down from the 7 inch high box with the test leg, followed by the non-test leg.
5) Take one step forward with the non-tested leg and make a tight 90 degrees turn towards the non-tested knee direction.

The tests were repeated on the opposite leg in the same sequence. While performing the activities, the patients responded to a questionnaire on instability and pain for each activity. A typical output from the accelerometer for activity 1 is shown in Figure 2. At the time of the sudden stop, there was a peak negative acceleration followed immediately by a peak positive acceleration in the anterior-posterior direction. The measurement used was the Total Magnitude. This same pattern of positive and negative peaks was found for all activities.

For the statistical analysis, the mean total magnitude of the acceleration was compared between the TKA group and the control group in the anterior-posterior direction for all activities using Student’s t-test. The same test was also done to compare TKA subjects’ TKA knees with their contralateral non-operated knees. Statistical significance was set at p-value <0.05.

RESULTS:
The values for ‘rigid’ and ‘anatomic’ fixation were 2.64 ± 0.10 and 2.30 ± 0.45 respectively, not significant at p < 0.05. The comparison between the TKA and control knees is shown in Table 1. There was a significant difference between the TKA and control groups while stepping down (p = 0.003) and while turning in the non-tested knee direction (p = 0.018). Significance was almost reached for the sudden stop activity at p = 0.1. In all cases, the TKAs had the higher mean acceleration values.

SIGNIFICANCE:
With the advantages of low cost and ease of use, the method is a simple way to objectively assess instability in different activities, which could have application in evaluating TKA, or other reconstructive procedures of the knee.

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