Clinical evaluation of an inertial measurement unit in monitoring pelvic position during total hip arthroplasty

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Introduction: Acetabular cup position is an important factor in the success of total hip arthroplasty (THA). Malpositioning of the acetabular component has been linked to increased risk of dislocation, liner fracture, and wear. In order to position the acetabular cup correctly, the surgeon must be able to develop an accurate perception of pelvic orientation prior to cup impaction. Two recent studies conducted at a community hospital and a tertiary hospital reported that orthopedic surgeons demonstrated optimal placement success rates of 25 - 50%, with lower overall rates of optimal abduction angles compared to anteversion. Varying pelvic anatomy, excess soft tissue and limited visual cues in the surgical field make it difficult to develop an accurate picture of pelvic orientation with high consistency. Optical navigation and intraoperative radiography have been developed to address this issue. However, the associated increases in cost, length of surgery, and patient radiation exposure are deterrents. Considering the implications of cup malpositioning and the low observed rates of accurate cup orientation at high and low-volume institutions, a priority should be placed on developing efficient methods and technology to assist surgeons in component positioning. The purpose of this study was to evaluate and compare the efficacy of a non-invasive inertial measurement unit (IMU) against surgeon perception in monitoring pelvic position during THA.

Methods: Ten patients scheduled to undergo primary or revision THA were consented to participate in an IRB-approved study during preoperative clinical visits at a tertiary hospital. Prior to surgery, a 4 x 3 x 0.75 inch IMU was applied on the patient's skin in the region of the sacrum while in the standing position, and secured with clinical tape and sterile dressings. The pelvis was then leveled using a hip goniometer and the IMU was zeroed to record neutral standing pelvic orientation. IMU data was streamed and captured wirelessly throughout the procedure. Surgeons were blinded to all data throughout the study period. Prior to cup impaction, the surgeon was asked to indicate the intended cup abduction angle and the degree to which the cup impactor was manipulated to compensate for perceived pelvic tilt. The degree of pelvic tilt as determined by the IMU (angle β) was then recorded (Figure 1). AP-pelvis radiographs were measured in Martell Hip Analysis Suite post-operatively to calculate the cup abduction angle, which was then compared to the surgeon's intended abduction angle to determine surgeon accuracy. To predict the final cup abduction angle, the degree of pelvic tilt recorded by the IMU (angle β) was subtracted from the abduction angle of the cup impactor (angle α) that was positioned using the OR table as a reference (Figure 1). This value was then compared to the measured post-operative cup abduction angle in order to assess the accuracy of the IMU in measuring pelvic tilt. Surgeon accuracy and IMU accuracy were compared to determine if the IMU was more or less effective than surgeon perception at determining pelvic tilt.

Results: Of the ten patients, seven were male and three were female. In five cases, surgeons indicated that they adjusted the impactor inferiorly (range 5 - 15°) to compensate for perceived inferior pelvic tilt. The mean intended abduction angle indicated by the surgeons intraoperatively was 43.7° (range 40° - 45°), while the mean measured post-operative abduction angle was 40.1° (range 25.9° - 49.4°). In five of the cases, the surgeon's post-operative abduction angle fell within 2° of his intended abduction angle. One cup
was over-abducted (4.4°), and four cups were under-abducted by an average of 10.8° (range 3.9° - 19.1°). Following analysis of the post-operative films, it was observed that the surgeons placed the acetabular cup on average 5.4±6.0° from their intended abduction angle (range 0.3° - 19.1°). Following the analysis of the IMU offset data, it was observed that the IMU deviated on average 3.1±2.6° (range 0.7° - 7.2°) from its expected orientation value. The IMU deviated more than 2° from the expected pelvic tilt in five cases.

**Discussion:** Our results revealed that in ten THAs, the IMU was able to measure the orientation of the pelvis to a higher degree of accuracy than surgeons at a tertiary hospital using standard surgical techniques (3.1±2.6°, 5.4±6.0°, respectively). Furthermore, in cases where surgeon intended cup abduction and indicated IMU degree of tilt were greater than 2° away from post-operative measured values, the IMU accuracy deviated considerably less than surgeon accuracy (4.5±3.8° vs. 9.5±6.1°, respectively). The maximum IMU deviation (7.2°) was also notably smaller than the maximum surgeon deviation from intended cup position (19.1°). These results suggest that an IMU device can be useful as an accurate and cost-effective guide for surgeons during cup impaction. A system in which the pelvis could be monitored and adjusted intraoperatively based on accurate IMU data would allow the surgeon to place the pelvis in optimal position prior to cup impaction, and increase overall cup placement accuracy. While these results are encouraging, this study was limited by a small cohort of THAs. More data is needed to confirm these results.

**Significance:** This is the only known study to assess the utility of a widely available, major market inertial measurement unit in providing accurate feedback on pelvic position during total hip arthroplasty.