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Quantifying Pelvic Motion During Total Hip Arthroplasty Using a New Surgical Navigation Device

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A B S T R A C T

Background: Accurate cup positioning is one of the most challenging aspects of total hip arthroplasty (THA). Undetected movement of the patient during THA surgery can lead to inaccuracies in cup anteversion and inclination, increasing the potential for dislocation and revision surgery. Investigations into the magnitude of patient motion during THA are not well represented in the literature.
Methods: We analyzed intraoperative pelvic motion using a novel navigation device used to assist surgeons with cup position, leg length, and offset during THA. This device uses an integrated accelerometer to measure motion in 2 orthogonal degrees of freedom. We reviewed the data from 99 cases completed between February and September 2016.
Results: The mean amount of pitch recorded per patient was 2.7° (standard deviation, 2.2; range, 0.1°-9.9°), whereas mean roll per patient was 7.3° (standard deviation, 5.5; range, 0.3°-31.3°). Twenty-one percent (21 of 99) of patients demonstrated pitch of >4°. Sixty-nine percent (68 of 99) of patients demonstrated >4° of roll, and 25% (25 of 99) of patients demonstrated roll of ≥10°.
Conclusion: Our findings indicate that while the majority of intraoperative motion is <4°, many patients experience significant roll, with a large proportion rolling >10°. This degree of movement has implications for acetabular cup position, as failure to compensate for this motion can result in placement of the cup outside the planned safe zone, thus, increasing the potential for dislocation. Further study is warranted to determine the effect of this motion on cup position, leg length, and offset.

Accurate acetabular cup placement is one of the most challenging aspects of total hip arthroplasty (THA). Improper placement of the acetabular component can increase the likelihood of dislocation and revision surgery [1–4]. To minimize these risks, surgeons position the acetabular cup component within a supposed functional "safe zone" of 40° ± 10° of inclination and 15° ± 10° of anteversion [5], first proposed by Lewinnek et al [6]. This range is thought to be associated with a lower likelihood of instability and dislocation; however, there is growing debate regarding its true association with lower dislocation rates [7,8]. Although others have suggested alternate ranges (eg, 40° ± 10° abduction/30° ± 10° anteversion [9] or 30° abduction/20° anteversion [10]), the Lewinnek zone continues to be the benchmark. Placement of the acetabular component within this safe zone, however, is particularly challenging, given the potential movement of the pelvis that occurs intraoperatively during THA [11–15]. Changes in pelvic tilt, rotation, and obliquity directly affect anteversion and inclination [16–19]. One study reported that for every 1° increase in pelvic obliquity, anteversion changed

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by −0.4°, and for every degree increased pelvic tilt, anteversion was altered by 0.8° [18]. Another study reported a linear relationship between pelvic tilt and anteversion, with every 1° increase in posterior pelvic tilt associated with a 0.74° change in anteversion [17]. Inclination changed in a nonlinear fashion, with each 1° increase in tilt initially altering inclination by 0.29°. The magnitude of change grew more dramatic as pelvic tilt increased, with 15° of posterior tilt associated with a change of 0.47° of inclination [17].

Surgeons attempt to orient the patient on the operating table in a neutral position before surgery. When positioned laterally, a neutral patient position implies that the patient's sagittal plane is coplanar with the operating table (which is coplanar with the floor), whereas the patient's longitudinal axis is in line with the long dimension of the operating table (Fig. 1). Patient positioners are utilized during the procedure to maintain the patient in this position. Surgeons generally assume that the pelvis remains in this neutral position throughout the procedure, despite the movement and manipulation of the leg and hip joint that occurs during THA. In traditional hip arthroplasty, there is no method of determining if the pelvis remains in the same position throughout the procedure, including the time of implantation of the acetabular component [11]. Significant movement can occur between the initial patient positioning and acetabular component trialing and implantation. Such movement can result in errors in placement of the acetabular components, errors which, if not accounted for or corrected for, can increase the likelihood of components being placed outside the safe zone, leading to increased wear, edge loading, impingement, and dislocation [17,18].

The purpose of this study was to record the magnitude and direction of patient movement during THA surgery. Simple and reliable methods for monitoring and/or compensating for changes in patient position during surgery have not been developed to date, with previous studies using specialized equipment to monitor movement [11,12,14,20]. These devices, however, while providing some useful data, are cumbersome and could interfere with the normal surgical workflow. We used a novel navigation device that uses infrared optical technology and integrated inertial sensors to make intraoperative measurements during THA procedures. Although predominantly used to assist surgeons with component placement by monitoring cup position, leg length, and offset parameters, the device is also able to measure the 2-dimensional motion (or "tilt") of the pelvis (relative to gravity) and record the magnitude and direction of movements during surgery. Our hypothesis was that significant pelvic motion would be recorded during THA between patient positioning and final implant placement.

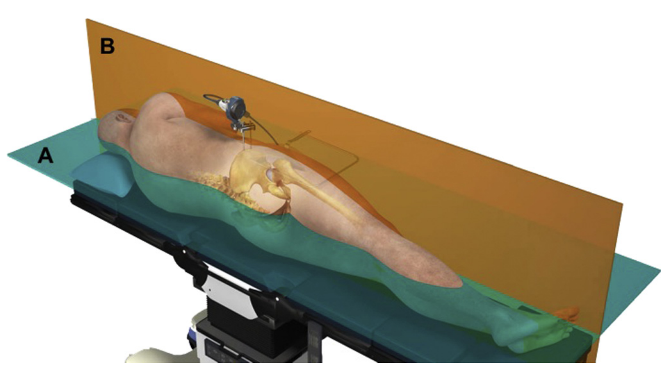

Fig. 1. Neutral positioning of the patient in the lateral position. The patient's sagittal plane, A, is coplanar with the operating table. The patient's frontal plane, B, is oriented along the long axis of the table.

Methods

Study Design

This study was a retrospective review of navigation system data from THA procedures performed at one of 7 sites using the navigation tool. A total of 11 orthopedic surgeons contributed case data for this study. All procedures were performed via the posterior approach with surgeons utilizing their choice of patient positioner and retractor.

Data Eligibility

Data were eligible for inclusion in this study if the patient underwent a THA procedure between February and September 2016 at one of the participating facilities (4 in New York City, 2 in Chicago, and 1 in upstate New York). Only navigation system data were reviewed; no patient identifiers or demographic data were included in the analysis. Procedures where the navigation tool was used were eligible for inclusion in the study. Data were excluded from procedures where the navigation tool was removed before measurements being taken with either trial components or final implants in place or cases where there was instability in the navigation system's pelvic platform such that accurate measurements were not obtainable from the navigation tool.

Intellijoint HIP Navigation Tool

The Intellijoint HIP (Intellijoint Surgical, Inc, Waterloo, ON, Canada) navigation tool is a miniature surgical tool that uses infrared optical technology and integrated microelectronics, including inertial sensors, to measure cup implant angle, leg length, offset, and center of rotation to assist surgeons with component placement during THA. The device has been described in detail previously [21]. In brief, with the patient in the lateral decubitus position, a pelvic platform is fixed to the ipsilateral iliac crest via 2 surgical pins. A camera is magnetically secured to the pelvic platform while a tracker is magnetically attached to a femoral platform fixed to the greater trochanter or to a cup impactor, to measure changes in leg length and offset, as well as native acetabular orientation and cup position (Fig. 2). The camera captures motion and position data from the tracker to calculate center of rotation, length leg, and offset for both the native hip and the artificial joint. The attachment of the camera to the pelvic platform creates a fixed system, such that the camera and the pelvis are rigidly coupled (ie, any movement of the pelvis will also move the camera).

Pelvic Motion Calculations

The navigation system camera, in addition to its optical components, contains integrated inertial sensors (in particular, a 3-axis accelerometer). The inertial sensing system is configured to measure motion and orientation in 2 orthogonal degrees of freedom (ie, similar to a 2-axis bubble level).

Movement is recorded by the navigation system at specific steps during the surgical procedure. Immediately after patient positioning (before hip exposure), the camera is installed on the patient's iliac crest and an initial measurement is recorded to register the horizontal plane, which coincides with the patient's sagittal plane. In addition, the patient's frontal plane is registered and the frontal and sagittal planes are combined to form the patient registration (ie, the spatial relationship between the camera and the patient's anatomy). Later in the procedure (after surgical exposure, hip dislocation, and femoral head resection but