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The Learning Curve Associated With Robotic-Assisted Total Hip Arthroplasty

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ABSTRACT

There are no reports examining the learning curve during the adoption of robotic assisted THA. The purpose of this study was to examine the learning curve of robotic assisted THA as measured by component position, operative time, and complications. The first 105 robotic-assisted THAs performed by a single surgeon were divided into three groups based on the order of surgery. Component position, operative time, intra-operative technical problems, and intra-operative complications were recorded. There was a decreased risk of acetabular component malpositioning with experience ($P < 0.05$). Operative time appeared to decrease with increasing surgical experience ($P < 0.05$). A learning curve was observed, as a decreased incidence of acetabular component outliers and decreased operative time were noted with increased experience.

Multiple factors have the potential to influence the short- and long-term outcomes of total hip arthroplasty (THA) including patient characteristics, surgical technique, and implant features. Optimal component positioning is one surgeon-controlled factor, which plays a large role in preventing complications including hip dislocations, accelerated bearing wear, poor biomechanics, leg length discrepancy, and revision surgery [1–3]. Currently, hip instability and mechanical loosening account for over 40% of revision hip arthroplasties; and both conditions may be directly related to component positioning [4].

The ideal orientation of the acetabular component continues to be debated. Lewinnek et al defined a safe zone for acetabular components as $15^\circ \pm 10^\circ$ of anteversion and $40^\circ \pm 10^\circ$ of inclination. This safe zone was based on hip stability; however, higher rates of bearing surface wear have been seen when the acetabular component inclination is greater than 45° [5]. This has led some authors to modify the safe zone for acetabular inclination to 30–45° [2]. Other authors have put forth a combined anteversion safe zone, which takes femoral anteversion into account for determination of the safe zone [6]. Two large studies have recently been published documenting a significant percentage of malpositioned acetabular components at high volume institutions [2,7]. Depending on the safe zone used, only 38–47% were in the ideal position.

Appropriate femoral component selection and positioning are essential for satisfactory reconstruction. Improper femoral component placement may lead to leg length inequality, altered offset, and instability. Limb length inequality can be a source of patient dissatisfaction, and is the second most common cause of litigation in reconstructive surgery [8].

Multiple techniques have been put forward over the last two decades to optimize component positioning including: computer navigation, mechanical navigation, intra-operative fluoroscopy, and robotic assistance [9–12]. Many of these guidance techniques have shown the ability to decrease component malposition; however, these techniques often present intra-operative challenges [11,13,14]. Technical complexity, increased operating room time, and expense have been offered as reasons not to adopt navigation [15].

Robotic assisted THA is a new technology, which has the potential to improve acetabular component position compared to a conventional technique [10]. Robotic assisted THA utilizes a computed tomography (CT) based navigation system; and a robotic arm, which assists in acetabular reaming and component placement. Like all surgical procedures, robotic assisted THA likely has a learning curve; and to our knowledge, no study exists examining the learning curve of robotic assisted THA. The purpose of this study was to examine the learning curve of robotic assisted THA as measured by component position, operative time, and intra-operative complications.

Materials and Methods

Subjects

Using a prospectively constructed database, we performed a review of the first 105 robotic assisted THAs performed by the senior

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author (BGD). From June 2011 to August 2013 patients undergoing robotic assisted THA via a posterior approach were included. Patients were excluded if they had missing or rotated postoperative anteroposterior radiographs. The patients were divided into three groups of 35 for comparison purposes. Group A consisted of the first 35 patients undergoing robotic assisted THA by the senior surgeon. Group B consisted of patients 36–70, and Group C consisted of patients 71–105. Component positioning, operative time, intra-operative technical problems, and complications were compared between the groups. Age, gender, and body mass index (BMI) were recorded on all patients. Institutional review board approval was obtained prior to initiation of this study.

Surgical Technique

All patients underwent preoperative CT scans of the affected hip and knee. A standard preoperative template was utilized to determine component sizing and positioning; this served as a comparison for a three dimensional computer based model built from the CT scan. The senior surgeon templated component placement using the three dimensional CT scan data prior to each case. A standardized mini-posterior operative approach was utilized for all robotic assisted THAs. All patients were placed in the lateral decubitus position. An incision 10–12 cm was utilized to perform a mini-posterior approach to the hip. The hip was dislocated and a screw was placed in the greater trochanter for femoral registration. The robotic assisted THAs were performed using the MAKO robotic hip system (MAKOplasty total hip application; MAKO Surgical Corporation, Fort Lauderdale, FL, USA), which is a robotic-assisted computer navigation system that uses RIO (Robotic Arm Interactive Orthopedic System) for reaming the acetabulum and acetabular component placement. Following femoral registration the neck osteotomy is navigated and created. The femur was then prepared for an uncemented implant. The acetabulum was then exposed and registered using three pins and an array in the iliac crest. Pelvic tilt and rotation are accounted for by the navigation system and the robotic arm was used to prepare the acetabulum and impact the acetabular component. For this study, all acetabular components were planned at 40° of inclination and 20° of anteversion. The hip was trialed for stability. During the study period no acetabular components required a change in position due to stability. Intraoperative feedback of leg length, offset, and femoral version was provided by the navigation system.

Implants

All robotic assisted THAs used the Restoris Trinity acetabular component (Corin Group PLC, Cirencester, UK). The femoral components utilized either the Restoris Metafix (Corin Group PLC, Cirencester, UK) or Smith & Nephew Anthology (Smith & Nephew, London, UK) stem depending on preoperative templating.

Radiographic Measurements

At the two-week postoperative visit all patients received a supine AP pelvic radiograph, which was used to measure acetabular inclination and anteversion. Pelvic radiographs with the symphysis rotated greater than 10 mm from the coccyx were discarded, and a radiograph from the three-month follow-up visit was used for measurement. The measurements were obtained using Trauma-Cad software (build number 2.2.535.0, 2012, Voyant Health, Petach-Tikva, Israel). This software allows measurement of cup inclination and version on the AP pelvis. The accuracy of this software for inclination and version measurements has been validated [16]. Leg length discrepancy (LLD) was measured by drawing a bi-ischiatic line using the inferior aspect of the obturator foramen and measuring a perpendicular line to the lesser trochanters. The difference between the distance, in millimeters (mm), to the lesser trochanters was the LLD. The femoral head size was used to calibrate all postoperative radiographs. If the obturator foramen were asymmetrical a line between the radiographic tear-drops was used. If the lesser trochanters were poorly visible the patient was not included in LLD measurements. All radiographs were interpreted by an independent observer who was blinded to groups. Previous radiographic measurements have been evaluated using this technique for intra-observer and inter-observer reliability and shown to have satisfactory correlation ($r > 0.82$ and $P < 0.001$) [10].

Operative Time

Operative time was recorded in minutes (min) from incision until the time closure began. The average operative time was calculated for each group. If operative time for a patient was not recorded the patient was not included in the average.

Intra-Operative Technical Problems and Complications

Technical problems, such as, failure of the robotic or navigation systems were recorded intra-operatively and tabulated. Intraoperative delays secondary to the robotic system were also recorded. Intra-operative complications were recorded. Post operative complications were not included.

Statistical Analysis

The average acetabular inclination, anteversion, and LLD were calculated along with the standard deviation (SD) and range for each group. Calculation of the number of hips that were in the safe zones of Lewinnek et al (inclination, 30°–50°; anteversion 5°–25°) and Callanan et al (inclination 30°–45°; anteversion, 5°–25°) was done for all groups [2,17]. The average operative time along with the SD was calculated with available data. An analysis of variance (ANOVA) was used to compare means and standard deviations for acetabular inclination, acetabular anteversion, LLD, operative time, complications, age, and BMI. A chi-squared analysis was used to compare the frequencies of outliers and gender between groups.

Results

Patient demographics are displayed in Table 1 for age, BMI, and gender. The average age for patients undergoing THA for groups A, B, and C was 60.2, 60.4, and 56.2 respectively with no difference between groups. BMI for groups A, B, and C was 29.2, 28.3, and C 30.8 respectively with no difference between groups. Gender was different between groups with 20 males in group A, 9 in group B, and 16 in group C ($P < 0.05$).

There was no difference for mean acetabular inclination, acetabular anteversion, or leg length discrepancy as experience increased ($P > 0.05$). Table 2 displays acetabular inclination averages, ranges, and standard deviations for the three groups. Table 3 displays acetabular anteversion averages, ranges, and standard deviations for the three groups. Average acetabular inclination was 40.7° ± 3.4, 39.9° ± 2.5, and 39.3° ± 3.0 for groups A, B, and C respectively. Average acetabular anteversion was 16.5° ± 3.8, 17.4° ± 3.4, and 16.7° ± 3.9 for groups A, B, and C respectively.

Outliers

The cumulative number of outliers was two for the Lewinnek safe zone and six for the Callanan safe zone. Fig. 1 displays acetabular component positioning in relation to previously documented safe zones for the three groups. Outliers are depicted. The risk of having an acetabular component outside of Lewinnek's safe zone was not