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Original Article

Component Position and Metal Ion Levels in Computer-Navigated Hip Resurfacing Arthroplasty

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ABSTRACT

Background: Metal ion levels are used as a surrogate marker for wear in hip resurfacing arthroplasties. Improper component position, particularly on the acetabular side, plays an important role in problems with the bearing surfaces, such as edge loading, impingement on the acetabular component rim, lack of fluid-film lubrication, and acetabular component deformation. There are little data regarding femoral component position and its possible implications on wear and failure rates. The purpose of this investigation was to determine both femoral and acetabular component positions in our cohort of mechanically stable hip resurfacing arthroplasties and to determine if these were related to metal ion levels.
Methods: One hundred fourteen patients who had undergone a computer-assisted metal-on-metal hip resurfacing were prospectively followed. Cobalt and chromium levels, Harris Hip, and UCLA activity scores in addition to measures of the acetabular and femoral component position and angles of the femur and acetabulum were recorded.
Results: Significant changes included increases in the position of the acetabular component compared to the native acetabulum; increase in femoral vertical offset; and decreases in global offset, gluteus medius activation angle, and abductor arm angle ($P < .05$). Multiple regression analysis found no significant predictors of cobalt and chromium metal ion levels.
Conclusion: Femoral and acetabular components placed in acceptable position failed to predict increased metal ion levels, and increased levels did not adversely impact patient function or satisfaction. Further research is necessary to clarify factors contributing to prosthesis wear.

Hip resurfacing arthroplasty (HRA) provides an alternative to total hip arthroplasty and can be considered as a bone-preserving option for the treatment of hip arthrosis, particularly in the younger patient [1]. HRA has gained popularity over the past 20 years as a viable option to preserve function and activity levels [2,3]. The risk of femoral neck fracture has been well documented, as have increased revision rates for smaller components and in dysplastic hips [4,5]. Of greater concern, however, are the high rates of early failures and revisions associated with metal-on-metal bearing surfaces [6].

Serum or plasma metal ion levels are used as a surrogate marker of implant wear rates and may be elevated in the presence of problems with the bearing surfaces, such as edge loading, impingement on the acetabular component rim, lack of fluid-film lubrication, and acetabular component deformation [7-9]. Component position, particularly on the acetabular side, plays an important role in many of these factors. Historically, the optimal acetabular position, defined in the coronal and sagittal planes, has been inclination of 40° ± 10° and anteversion of 15° ± 10° [10]. These values were initially determined with reference to the complication of dislocation, which is less common in HRA due to large femoral head size [11]. Inclination above 55° has been associated with higher ion levels and failure rates in HRA, as have

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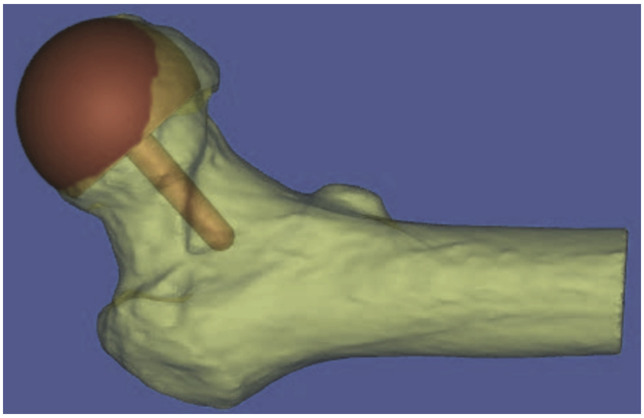

Fig. 1. Planned femoral component position—anteroposterior view.

increased acetabular anteversion and decreased femoral head size [12-16]. There is, however, little data regarding femoral component position and its possible implications on wear and failure rates. The purpose of our investigation was to determine both femoral and acetabular component position in our cohort of mechanically stable hip resurfacing arthroplasties and to determine if these were related to metal ion levels.

Materials and Methods

Hip resurfacing implants have been used at our institution since 2005. One hundred thirty-eight consecutive patients presenting for elective HRA by 2 surgeons at our institution were recruited between 2005 and 2014. These patients have been prospectively followed for an average of 4.5 years and have received a total of 162 implants, consisting of either the articular surface replacement (DePuy, Warsaw, IN) or the Birmingham Hip Resurfacing (Smith & Nephew, Memphis, TN). All procedures were performed using computer-assisted surgery technology to guide the femoral component orientation [17]. To avoid confounding wear issues, infections, fractures, patients with bilateral implants, and mechanically unstable hips were removed from the cohort, which was limited to patients with well-fixed components who had at least 1-year follow-up beyond the wear-embedding period. In addition, patients were required to have normal renal function (evidenced by creatinine <120 mg/mL for males and <110 mg/mL for females) to ensure adequate metal ion clearance. This resulted in 96 men and 18 women with a total of 114 implants available for analysis. There have been no revisions in this group. Approval for this study was obtained from our institution's research ethics board, and all patients provided informed consent.

Based on preoperative computed tomographic (CT) scans, optoelectronic digital navigation (Optotrak Certus Motion Tracking System, Northern Digital Inc, Waterloo, Canada) was used to register the native femur and to track and visualize femoral component placement. In addition, using a rapid prototyping machine (Dimension SST, Stratasys, Inc), a 3-dimensional custom jig was created to fit the femoral head and neck. This jig facilitated placement of the central pin, and subsequently the stem of the femoral component, in 5 degrees of valgus with respect to the native femoral neck [17].

Beginning at the 1-year postoperative visit, plasma samples were drawn and sent to the Trace Elements Laboratory at the University of Western Ontario for high-resolution inductively coupled mass spectrometer for determination of cobalt and chromium levels. Repeat levels were subsequently performed at 1- or 2-year intervals for asymptomatic patients, and more frequently if there were clinical or radiographic concerns. A threshold of 7 ppb was chosen as the upper limit of acceptable ion levels based on the British Medicines and Healthcare Products Regulatory Agency [18]. This recommendation is based on values obtained from whole blood samples, rather than from plasma. Comparing standard reference values for normal cobalt and chromium in both plasma and whole blood, it was noted that physiologic cobalt levels are slightly higher in plasma than in whole blood, whereas physiologic chromium levels are, conversely, slightly higher in whole blood than in plasma [19]. In addition, Langton et al [20] previously demonstrated good correlation between serum and whole blood cobalt and chromium levels. Consequently, in the absence of safe threshold recommendations for plasma values, 7 ppb was still felt to be appropriate.

Fig. 2. Planned femoral component position—lateral view.

Use of optoelectronic navigation allowed the 3D orientation of the femoral components to be determined accurately by postoperative analysis of recorded navigational data (Figs. 1 and 2). These values were compared to values for the neck-shaft angles. In addition, horizontal offset (defined as the horizontal distance between the center of the femoral canal and the center of the femoral head) and vertical offset (defined as the vertical distance between the junction of the lesser trochanter with the femoral neck and the center of the femoral head) were measured.

Because navigational techniques were not used to implant acetabular components, acetabular position (inclination and version) was determined from preoperative CT scans and postoperative plain films. Inclination was determined from the first outpatient anteroposterior pelvis X-ray, and version was measured on a supine lateral hip X-ray according to the method described by Woo and Morrey [21].

In addition to component position, several other values were determined from preoperative and postoperative plain