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Predicting Femoral Head Diameter and Lesser Trochanter to Center of Femoral Head Distance: A Novel Method of Templating Hip Hemiarthroplasty

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ABSTRACT

Lesser-trochanter-to-center-of-femoral-head-distance (LTCHD) is commonly used in hip reconstruction. Demographic and radiographic variables were analyzed to predict the LTCHD and femoral head size (FHS). Two hundred twenty six patients after hip arthroplasty and 136 patients after hip hemiarthroplasty (HA) were retrospectively reviewed. Five variables significantly affected the LTCHD and four affected the FHS. For LTCHD, it was relative neck length (RNL), gender, height, race, age and weight. For FHS it was gender, height, age and race. The average predicted LTCHD was within 2.86 mm, and the FHS was 1.63 ± 1.10 mm of the intra-operative measurements. By using our regression formulas the LTCHD and FHS can be calculated preoperatively to help improve precision in leg length and offset reconstruction.

Pre-operative templating is important to the success of partial and total hip arthroplasty [1–3]. One of the ways to translate this plan to the actual hip reconstruction and assist in achieving leg length equality is to use the lesser trochanter to center of femoral head (or center of rotation) distance (LTCHD) [4–6]. Intraoperatively this distance can be measured during femoral implant trialing [6]. The LTCHD can then be compared to preoperatively measured contralateral side LTCHD, measured on a quality antero-posterior (AP) pelvis x-ray with a magnification marker ball placed at the level of the hip joint [7]. Good quality x-rays are often difficult to obtain in the setting of trauma, as is the case with planning a hemiarthroplasty (HA) for displaced femoral neck fracture; therefore, having an alternative method of calculating LTCHD and femoral head size (FHS) would allow surgeons performing hemiarthroplasty to be better prepared at the time of surgery. We hypothesize that demographic data in a multivariate regression model can be used to create a formula to predict the LTCHD and the FHS.

Materials and Methods

Institutional review board approval was obtained for this retrospective chart review of patients who had a total hip arthroplasty or metal-on-metal hip resurfacing from 2007 to 2011. We used this total hip arthroplasty (THA) cohort to derive the LTCHD formula. We also identified a second cohort of patients who had hip hemiarthroplasty or femoral head resurfacing hemiarthroplasty from 2009 to 2011. This cohort was used to derive the FHS formula. Tables 1A and 1B have detailed demographic information for both cohorts.

258 patient's charts were reviewed for the THA cohort and 167 consecutive patients were identified for the hemiarthroplasty cohort. Patients were excluded if the records were incomplete, if they had bilateral hip surgery, a significant deformity of the contralateral hip joint, or if the lesser trochanter could not be visualized on the available imaging study, leaving us with 226 patients available for review in the total hip cohort and 136 patients in the hemiarthroplasty (HA) cohort. A single observer measured the LTCHD for all patients in the THA cohort using electronic templating software (DP). We used OrthoView software (Version 5.3.2 WK Meridian Technique Limited, Southampton, Hampshire UK) to correct magnification using contralateral implant as the magnification marker. We used the same software to precisely determine the location of the center of femoral head and measure the LTCHD (Figs. 1–4). Intra-observer correlation was calculated for the primary observer (DP) by re-measuring the LTCHD in a set of first 50 consecutive patients three months from the original measurement. Inter-observer correlation was calculated by having an independent

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Table 1A
Demographic Data for the THA Cohort.

	Number of Patients	Average Age	Average Height	Average Weight	White	Non-White
Male	128 (56.6%)	59.9	69.9	197.0	111 (49.1%)	17 (7.5%)
Female	98 (43.4%)	65.0	64.0	150.5	85 (37.6%)	13 (5.8%)
Total	226 (100%)	62.1 (29–106)	67.3 (56–79)	177.3 (82–320)	196 (86.7%)	30 (13.3%)

Percent values are in relation to the total number of patients in the THA cohort (n = 226 patients).

observer (BG) by re-measuring the LTCHD in a set of first 50 consecutive patients. Using a stepwise multivariable regression analysis, five demographic variables (age, gender, height, weight and ethnicity) and one radiographic variable (relative neck length) were analyzed to determine which variables would correctly predict the LTCHD and FHS when used in a regression equation.

Femoral head size was determined in the THA cohort, by measuring the bony FHS using the OrthoView software. This was done by best-matching a circle to the native femoral head. The diameter was calibrated to known magnification marker (opposite side implant) and displayed by the OrthoView software (Fig. 1). In the HA cohort, FHS was obtained from the operative logbook with the actual implant stickers.

Relative neck length (RNL) was recorded as −1, 0 or 1 for short, normal and long respectively. This was measured as LTCHD that was less than femoral head size by 10% (−1, or short LTCHD), within ± 10% of the FHS (0, or normal LTCHD) or greater than FHS by 10% or more (1, or long LTCHD). Demographic information was gathered from anesthesia records at the time of surgery. Implant size was verified against OR logs with actual implant stickers for both cohorts. If LTCHD was measured intra-operatively this was recorded as well. Intraoperative LTCHD was measured as described by Matsuda et al [5]. Briefly, prior to the femoral neck cut, distance was measured from the top of the lesser trochanter to the center of the native head. This was reproduced with trials and confirmed once the final stem was impacted. A shorter (or longer) neck length was chosen to most closely reproduce the intraoperatively measured LTCHD.

Multivariate regression was used on the THA cohort to derive the LTCHD formula. This equation was validated using a group of 100 THA patients who had their LTCHD measured intraoperatively by a single observer (senior author, WM). Demographic distribution in the test sample was similar to the main THA cohort (Table 2A).

The FHS equation was derived by using the first 100 patients in the HA cohort and validated using the remainder of the cohort not used in the creation of the formula (36 patients). Demographic distribution in the test sample of 36 patients was similar to the main HA cohort (Table 2B). SPSS version 16.0 (SPSS for Windows, rel. 16.0.0, 2007; SPSS Inc.) statistical software was used for all statistical calculations.

Results

Multivariate regression analyses showed that five variables significantly affected the LTCHD and four affected the FHS. For LTCHD formula these included relative neck length ($P < 0.001$), gender ($P < 0.001$), height ($P < 0.001$), race ($P = 0.001$), age ($P = 0.001$) and weight ($P = 0.006$). For FHS equation these included gender ($P < 0.001$), height ($P < 0.001$), race ($P = 0.001$) and age ($P = 0.007$).

The following regression models were obtained with an R^2 value of 0.47 for LTCHD and 0.68 for FHS equations.

$$\text{LTCHD (mm)} = 9 * (\text{N}) + 2.35 * (\text{G}) + 0.6 * (\text{H}) + 0.05 * (\text{A}) + 0.005 * (\text{W}) - 1(\text{R})$$

Where: N-relative neck length = (−1 for short neck, 0 for normal length, 1 for long neck); G-gender (0 for woman, 1 for man); H-height in inches; A-age in years at the time of surgery; W-weight in pounds; R-race (0 for white and 1 for all others).

For the THA cohort the average OrthoView measured LTCHD was 46.65 (35–65); average predicted LTCHD was 45.82 (32–60) and the average intra-operatively measured LTCHD was 49.44 (38–64). The intraclass correlation coefficient (ICC) between predicted and dictated LTCHD was 0.65.

For the HA cohort average implanted prosthetic femoral head size was 46.5 mm (41–55). The average predicted FHS was 46.2 mm (42–54). The ICC between predicted and implanted FHS was 0.9.

$$\text{FHS (mm)} = 10.5 + 3 * (\text{G}) + 0.53 * (\text{H}) + 0.015 * (\text{A}) - 1 * (\text{R})$$

Where: G-gender (0 for woman and 1 for man); H-Height in inches; A-age in years; R-race (0 for white and 1 for all others).

Intra-observer and inter-observer reliability was determined using ICC as described by Winer [8]. An ICC of 0–0.24 reflects absent to poor, 0.25–0.49 low, 0.50–0.69 fair, 0.7–0.89 good, and 0.90–1.0 excellent correlation. We re-measured a set of 50 records and our inter-observer correlation was 0.98 and intra-observer correlation of 0.97. Inter-observer and intra-observer correlation was excellent, showing good reproducibility of our measurement method.

The average predicted LTCHD was within 2.86 (0.01–11.33) mm of the intra-operatively measured value and had a fair ICC (0.65). Over 89% of values fell within one centimeter of the intra-operatively measured LTCHD. For the FHS formula, the average predicted value was within 1.63 ± 1.10 mm of the implanted value and had an excellent ICC of 0.9.

Discussion

Pre-operative planning is a critical part of success for total hip arthroplasty and hip hemiarthroplasty [5]. As THA is gaining popularity with predicted 174% increase in the number of cases by 2030 amounting to 572,000 cases per year the number of patients with leg length inequality is expected to increase [1,9]. This increase, despite various ways of equalizing limb length, demands further study into this clinical problem.

Table 1B
Demographic Data for the HA Cohort Used to Create the FHS Formula.

	Number of Patients	Average Age	Average Height	Average Weight	White	Non-White
Male	38 (38%)	68.4	69.1	164.4	20 (20%)	18 (18%)
Female	62 (62%)	77.3	63.5	139.8	33 (33%)	29 (29%)
Total	100 (100%)	73.9 (41–101)	65.6 (57–76)	149.1 (84–163)	53 (53%)	47 (47%)

Percent values are in relation to the total number of patients in the HA cohort (n = 100 patients).