INTRODUCTION

Malposition of the acetabular component is a risk factor for post-operative dislocation after total hip arthroplasty (THA)[1]. Current radiographic techniques for assessing cup anteversion have been developed, but they have limitations[2]. The purpose of this study is to investigate the effect of and reduce the error caused by various pelvic postures on cup anteversion measurement. We hypothesize measurement of cup anteversion has a strong linear relationship with pelvic tilt or rotation. Applying techniques that measure pelvic posture (tilt or rotation) correction parameters (CP) for cup anteversion can be calculated and the accuracy of cup anteversion assessment can be improved[3, 4].

METHODS

Six subjects were recruited to receive pelvic CT scans with IRB approval. With CT data and cup CAD models as input, Analyze™, a medical imaging software, was applied to create a 3D pelvic model. The pelvic model was then realigned according to Lewinnek’s study, which suggested orienting the anterior pelvic plane (APP) parallel to coronal plane. Cup placements were simulated in 15 positions relative to APP in every subject, including cup inclination of 30°, 40° and 50° coupled with anteversion of -5°, 5°, 15°, 25° and 35°, respectively (Figure 1).

Analyze™ was also utilized to simulate X-ray projection by controlling parameters - including location of central X-ray beam, source-object distance and pelvic posture - to create a digitally reconstructed radiograph (DRR). For each data set, two sets of DRRs (20 synthetic radiographs) were created simulating different pelvic postures with respect to the defined reference planes: 1) simulated pelvic tilt ranging from -21° to 9°, 2) simulated pelvic rotation ranging from -12° to 12°. There were 300 radiographs generated for one single subject (Figure 2-A).

Cup anteversion was measured on DRRs with Einzel-Bild-Röntgen-Analyse (EBRA)™, a software package for radiographic measurement (Figure 2-B)[1]. Errors between radiographic measurements and pre-determined cup anteversion were evaluated for pre-determined pelvic postures. For each combination of subject and simulated cup orientation, a linear regression analysis was performed and CP was generated, with error caused by radiographic measurement as the dependent variable and either pelvic tilt angle or pelvic rotation angle as the independent variable.

A double-blind test was performed. Participant 1 simulated six sets of cup placement in pre-determined positions with Analyze™, then realigned the pelvis with pre-determined positions (6 sets with pelvic rotation and 6 sets with pelvic tilt) and created biplanar synthetic radiographs. Participant 2 performed the radiographic measurements of cup anteversion on DRRs created by the Participant 1, using conventional and biplanar cup anteversion measurements. The absolute value of errors were calculated by comparing predetermined cup anteversion with cup anteversion measured on DRR and corrected cup anteversion and results were compared among groups.

STATISTICS

Linear regression analysis was performed to calculate CPs of pelvic posture. Pair T-test was performed to compare accuracy between conventional and biplanar cup anteversion assessments. Values of p < 0.05 were regarded as significant.

RESULTS

CPs of pelvic tilt and pelvic rotation were -0.81±0.15 (-0.50—1.11) and 0.66±0.19 (0.41—1.17), respectively, and R² of CPs were 0.98±0.02 (0.89—0.99) and 0.97±0.03 (0.81—0.99), respectively (P<0.001). Using median value of CPs as default CP for correction, corrected cup anteversion showed significantly higher accuracy for subjects with pelvic tilt(P=0.0136). Corrected cup anteversion did not show significant differences for subject for pelvic rotation (P=0.0847) (Figure 3).

DISCUSSION

Planar cup anteversion measurements are inaccurate without including information about pelvic posture. With the development of pelvic posture assessment techniques, it is time to integrate pelvic posture into the estimation of cup anteversion.

This study showed CP of a given cup had very strong linear correlation. Although different initial cup positions had different CPs, most of CPs varied within a relatively narrow range. The specific sensitivity of pelvic tilt to accurate cup anteversion measurements is especially noteworthy. Using the median value of CPs could significantly improve the accuracy of radiographic cup anteversion measurement among subjects with pelvic tilt. Although there was no significant improvement when correcting for pelvic rotation, better accuracy could be observed.

The present study has important clinical significance as improved cup anteversion measurements were demonstrated by integrating information about pelvic posture, which are useful in the differentiation of dislocation and reorienting cup during revision surgery.

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REFERENCES