Patient-specific variability and accuracy of hip abduction/anteversion angular measurements.

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Introduction: Total hip replacement (THR) is one of the most successful procedures in orthopedic surgery. The positioning of the cup seems crucial for the outcome of the procedure. Hip stability and durability greatly depends on the correct component placement and has been related to malpositioning of the acetabular cup and its angular orientation with respect to the abduction and anteversion angles. Relationship between cup alignment and polyethylene wear has also been recorded (1, 2).

Measuring abduction and anteversion angles is thus of key importance in planning and assessing THR. This raises three issues: 1) how to define the angles; 2) what are their average values and ranges, and 3) what are clinically safe deviations from them. Only a few works describe the native acetabular orientation. Several studies have suggested safe zones for the anteversion and abduction angles to reduce the risk of postoperative complications with great variability in these suggestions (3). The measurements made on X-ray images introduce additional inaccuracy, and are related to the pelvic tilt from the X-ray beam (4). These findings raise questions about reliability of some previous works. Anda et al (5) showed that CT studies do not alleviate this problem.

The aim of this study is to propose a new method, for computing patient-specific abduction/anteversion angles and demonstrate its variability in normal population, and the method's repeatability, accuracy and robustness.

Methods: The following protocol was performed on 34 CT studies that were retrospectively collected. The inclusion criteria included patients between the age 20-
50 years without fractures or osteoarthritis. We measured for each patient the anterior pelvic plane (APP) the left and right acetabular rim planes (PARIM-L, PARIM-R) (Figs 1a, 1b). The APP is directly computed from three landmark points: the foremost pubis landmark point (PUBIS) and the left and right anterior-superior iliac spine (ASIS-L, ASIS-R). The left and right acetabular rim planes are each defined by a set of eight or more points (ARIM-L, ARIM-R) identified on the acetabular rim boundary. All landmarks were selected on the CT datasets using AmiraDev©. Subsequent computations were performed with a custom Matlab© programs.

The planes are computed by least-squares fitting the average plane that minimizes the sum of the squared distance of the points to the plane. The left and right abduction angles (ABD-R, ABD-L) are the angle between the projections on the xz plane of the PARIM plane's normal vector and the symmetry line of the three pelvic landmarks. The left and right anteversion angles (ANT-L, ANT-R) are computed as the angle between the ARIM normal vector and its projection on the APP planes.

The accuracy of the abduction and anteversion angles is computed as follows. For the APP, each of the three landmarks (ASIS-L, ASIS-R, PUBIS) are repeatedly identified at different times. Their average position is their center of mass, from which the average APP is computed. For PARIM-L and PARIM-R, several sets of at least eight points on the acetabular rim are repeatedly identified at different times. The average PARIM-L, PARIM-R are computed from a least-squares fit of all the resulting planes. The average ABD-R, ABD-L, ANT-L, ANT-R angles are then computed from the average planes. The angles variability are computed by taking the set of APPs resulting from all the combinations of three points and the set of all PARIM-L and PARIM-R resulting from the set of rim points.

The inter- and intra-observer assessment is obtained by having the same surgeon and then two surgeons repeatedly identify manually the anatomical landmarks and rim points and comparing the results of each. Statistics on the results (average, range, histogram, SD) can then be computed.

Three series of calculations were performed: 1- Evaluation of the abduction and anteversion on 25 individuals. Six values were acquired for each individual: left and
right anteversion and abduction and the difference between left and right for each angle. 2- Evaluation of the inter-observer variability on the measurement on one individual. Each of the three APP landmarks was acquired 20 times, and each ARIM point set was acquired 8 times. The angles between all possible combinations were then calculated, yielding a total of $8 \times 20 \times 20 \times 20 = 64,000$ values from which we obtained angle value distributions, maximum angles differences, and maximum measured error. 3- Evaluation of the intra-observer accuracy by comparing angle measurements of a specific patient as defined by two surgeons.

**Results:** First series: the mean right and left anteversion angles values of 25 individuals are $17.2 \pm 5.7^\circ$ and $17.6 \pm 5.5^\circ$ respectively, with a range of $20.3^\circ$–$24.5^\circ$. The mean right and left abduction angles are $53.7 \pm 6.5^\circ$ and $54.2 \pm 6.9^\circ$ respectively, with a range of $23.4^\circ$–$24.2^\circ$ (Figs 1c, 1d). The mean difference between left and right angle values of each patient is $0.3^\circ$ and $0.5^\circ$ respectively. Second series: the anteversion and abduction angles calculated for all the possible combinations for a specific individual are $21.8 \pm 0.5^\circ$ and $56.8 \pm 1.1^\circ$ respectively. Third series: the difference between anteversion and abduction angles of one individual as measured separately by two surgeons are $2.4^\circ$ and $0.7^\circ$ respectively.

**Discussion**

1. The abduction and anteversion variation range between patients is significant ($>20^\circ$) – thus the importance of patient-specific planning vs. planning based on averages.

2. The differences between the left and right abduction and anteversion angles of the same patient with normal anatomy are small. Therefore, the values of one side can often be used as a guide for the other side in procedures such as fracture reduction and THR.

3. Intra- and inter-observer manual landmark selection on CT datasets is reliable: its variability has a small influence on the abduction and anteversion angle values ($\max=2^\circ$ and $2.5^\circ$ respectively). Thus, the value is reliable and justifies the use of intraoperative navigation to achieve it.

4. The proposed method to compute patient-specific abduction and anteversion angles from a CT study from the anterior pelvic plane and the left and right acetabular rim planes is reliable and accurate.
References


![Image](image1.png)

(a) landmark points on pelvis
(b) computed planes from landmarks
(c) anteversion angle histogram
(d) abduction angle histogram

**Figure 1:** (a) **Landmark point definitions on CT.** ASIS-L, ASIS-R: anterior superior iliac spin (left and right); PUBIS: pubis landmark point; ARIM-L, ARIM-R: set of acetabular rim points (left and right). (b) **Computed planes from landmarks.** APP: anterior posterior plane, computed from ASIS-L, ASIS-R, and PUBIS. PARIM-L and PARIM-R: acetabular rim plane (left and right), computed from ARIM-R and ARIM-L respectively. The left and right abduction (ABD-L and ABD-R) and anteversion (ANT-L and ANT-R) angles are computed from APP and PARIM-L and PARIM-R, respectively. (c) and (d) **Abduction and anteversion angles histogram.** Histograms are for all patients and measurements.