Measuring Acetabular Component Position on Lateral Radiographs

Ischio-Lateral Method

Nicholas Pulos, B.A., John V. Tiberi III, M.D., and Thomas P. Schmalzried, M.D.

Abstract

The standard method for the evaluation of arthritis and postoperative assessment of arthroplasty treatment is observation and measurement from plain films, using the film edge for orientation. A more recent employment of an anatomical landmark, the ischial tuberosity, has come into use as orientation for evaluation and is called the ischio-lateral method. In this study, the use of this method was evaluated as a first report to the literature on acetabular component measurement using a skeletal reference with lateral radiographs. Postoperative radiographs of 52 hips, with at least three true lateral radiographs taken at different time periods, were analyzed. Component position was measured with the historical method (using the film edge for orientation) and with the new method using the ischio-lateral method. The mean standard deviation (SD) for the historical approach was 3.7° and for the ischio-lateral method, 2.2° ($p < 0.001$). With the historical method, 19 (36.5%) hips had a SD greater than ± 4°, compared to six hips (11.5%) with the ischio-lateral method. By using a skeletal reference, the ischio-lateral method provides a more consistent measurement of acetabular component position. The high intra-class correlation coefficients for both intra- and inter-observer reliability indicate that the angle measured with this simple method, which employs no further technology, increased time, or cost, is consistent and reproducible for multiple observers.

Plain radiographs remain the primary skeletal imaging modality for arthritis and postoperative assessment of total joint arthroplasty. For the acetabular component, the abduction angle, or lateral opening angle, is commonly measured on an anterior-posterior (AP) projection of the angle between the inter-teardrop line (a skeletal reference on the image) and the line tangential to the opening of the acetabular component.[1]

With the recognition of femoral-acetabular impingement (FAI),[2] there has been increased interest in the lateral projection radiograph.[3,4] A true lateral projection has been used in hip arthroplasty to assess the anterior (or posterior) opening angle of the acetabulum, which is a surrogate for anteversion.[5-8] This projection can be used to assess component position in the axial plane and the potential for anterior or posterior FAI, which can influence range of motion and stability.[9-11] Both the lateral opening angle and version of the acetabular component have been related to multiple clinical outcome measures.[12,13]

Several lateral projection radiographs of the hip have been described.[14-18] The Johnson lateral is obtained with the patient supine and both hips extended. A 25° dorsal oblique X-ray beam is aimed at the groin and also angled approximately 25° cephalad, so that the X-ray beam is roughly perpendicular to the long axis of the femoral neck (to better visualize the femoral neck).[15]

The Danelius-Miller[16] modification of the Lorenz view[14] describes a lateral projection where the patient is supine and the contralateral hip is flexed. The X-ray beam is parallel to the table and effectively shoots through the groin without dorsal angulation (Fig. 1). Such a view has been referred to as a cross-table or a shoot-through lateral view that displays the hip and pelvis at 90° from the AP radiograph (Fig. 2).

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Figure 1 Positioning for radiographs as outlined by Danelius-Miller.[16] The patient's right hip is to be imaged with the contralateral hip flexed.[18]

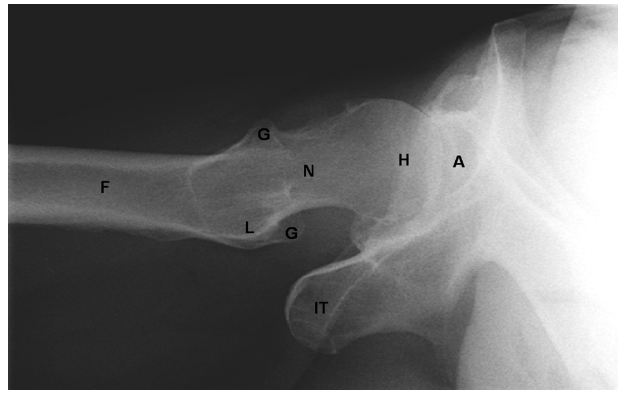

Figure 2 Danelius-Miller[16] lateral radiograph of a female patient with osteoarthritis. F, femur; L, lesser trochanter; G, greater trochanter; N, neck of the femur; H, head of the femur; A, acetabulum; IT, ischial tuberosity.

The hip to be imaged is internally rotated 15° to 20° for visualization of the femoral neck and the trochanters. The Danelius-Miller[16] lateral view is sometimes referred to as a "Johnson's shoot-through" for apparent reasons.

True lateral radiographs, such as the Danelius-Miller,[16] are useful tools in the evaluation of acetabular component position. However, since such lateral radiographs are taken with a beam angle at 25° cephalad, they project a socket opening that is slightly different than the radiographic (planar) anteversion described by Murray.[19] Yao and colleagues[20] termed version measured from such lateral radiographs as "axiolateral version."

Woo and Morrey measured acetabular component version on a lateral-projection radiograph as the angle formed by the intersection of a tangential line to the opening of the acetabulum and a line drawn perpendicular to the horizontal plane (the film edge) of the radiograph (Fig. 3).[6] Arai and coworkers[8] used a similar method for measuring version but utilized a metal chain to impose a gravity line instead of the perpendicular line used by Woo and Morrey.[6] They noted that while anteversion measured using AP radiographs was correlated with what was measured using cross-table lateral radiographs, the differences between these two measuring techniques decreased as patient flexibility increased. Pelvic tilt (rotation in the flexion-extension plane) affects acetabular projection on radiographs, which decreases the comparability of the gravity line or a line perpendicular to the horizontal as a reference.[8]

Using a cross-table lateral view of the hip, Pollard and associates[7] measured the version of the acetabular component as the angle formed by a line drawn tangential to the face of the acetabular component and the horizontal plane. Using this method, they calculated a mean anteversion of 72.7° (SD ± 12.3°). Arai and colleagues[8] measured 97 other total hip arthroplasties and reported a mean anteversion of 21° (S.D. ± 6.5°) for the complement of the angle measured by Pollard and coworkers.[7] For these reasons, Tannest and associates[21] concluded that anteversion measurements on non-standardized radiographs without anatomic referencing is highly inaccurate. In their evaluation of acetabular anteversion on revised, cemented polyethylene cups, Hultmark and colleagues[22] measured anteversion as the angle between the anterior cortex of the ischial ramus and the cup. However, no analysis has been done to evaluate whether or not a skeletal landmark can be used to increase the consistency of acetabular measurements on lateral radiographs.

In the current study, we utilized a method of measuring acetabular component position on the Danelius-Miller[16] lateral radiograph, applying the ischial tuberosity as an anatomic reference point and comparing the measurement variability of this method to the horizontal film edge reference method of Woo and Morrey.[6] Additionally, we

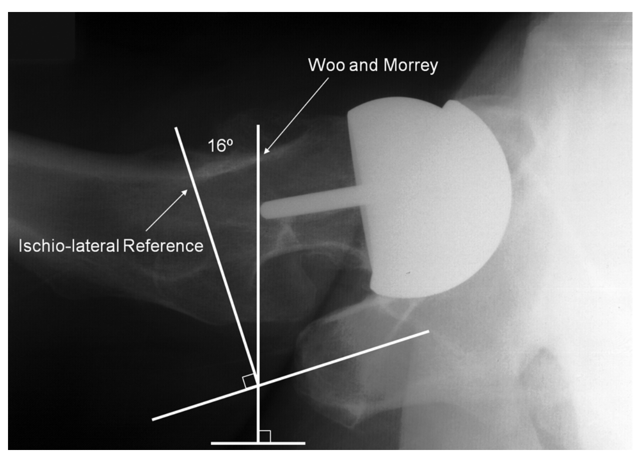

Figure 3 Danelius-Miller[16] lateral radiograph showing the external reference used by Woo and Morrey,[6] which is a line perpendicular to the horizontal film edge. A line perpendicular to the long axis of the ischial tuberosity is also drawn, demonstrating the ischio-lateral skeletal reference. The measured difference between these references in this example is 16°.

assessed the inter- and intra-observer variability of this new method.

Materials and Methods

Fifty-two hips in 51 patients, who were implanted with the same cobalt chromium alloy hip resurfacing prosthesis with a cementless acetabular component (Articular Surface Replacement/ASR™; DePuy, Leeds, UK), had at least three postoperative Danelius-Miller[16] lateral radiographs taken at different times (roughly 6 weeks, 6 months, and 1-year postoperative). Thirty-four hips had a fourth exam at approximately 2-years postoperatively. There were 31 males and 20 females. The mean age of the patients at surgery was 51 years (range, 30 to 69 years) and the average body mass index was 25.7 (range, 17.7 to 34.1). The diagnosis was osteoarthritis in 43 of the patients, osteonecrosis in three of the patients, posttraumatic arthritis in three of the patients, and hip dysplasia in two of the patients.

Acetabular component position was measured on each Danelius-Miller[16] lateral radiograph, using the Woo and Morrey[6] method: the angle between a line tangent to the opening of the acetabular component and a line drawn perpendicular to the horizontal plane (Fig. 3). For each hip, the mean lateral position angle and the standard deviation (SD) were calculated for the lateral radiographs taken at the different times.

To measure lateral component position using the ischial tuberosity as a reference, we measured the angle between a line tangential to the opening of the acetabular component and a line perpendicular to the ischial tuberosity. For this method, we drew a line parallel to the pitch of the ischial tuberosity when viewed on the Danelius-Miller[16] lateral radiograph. A line perpendicular to this skeletal reference was used in the angle measurement (Fig. 3). The mean lateral component position angle and the SD were calculated for the series of radiographs of each hip (Fig. 4).

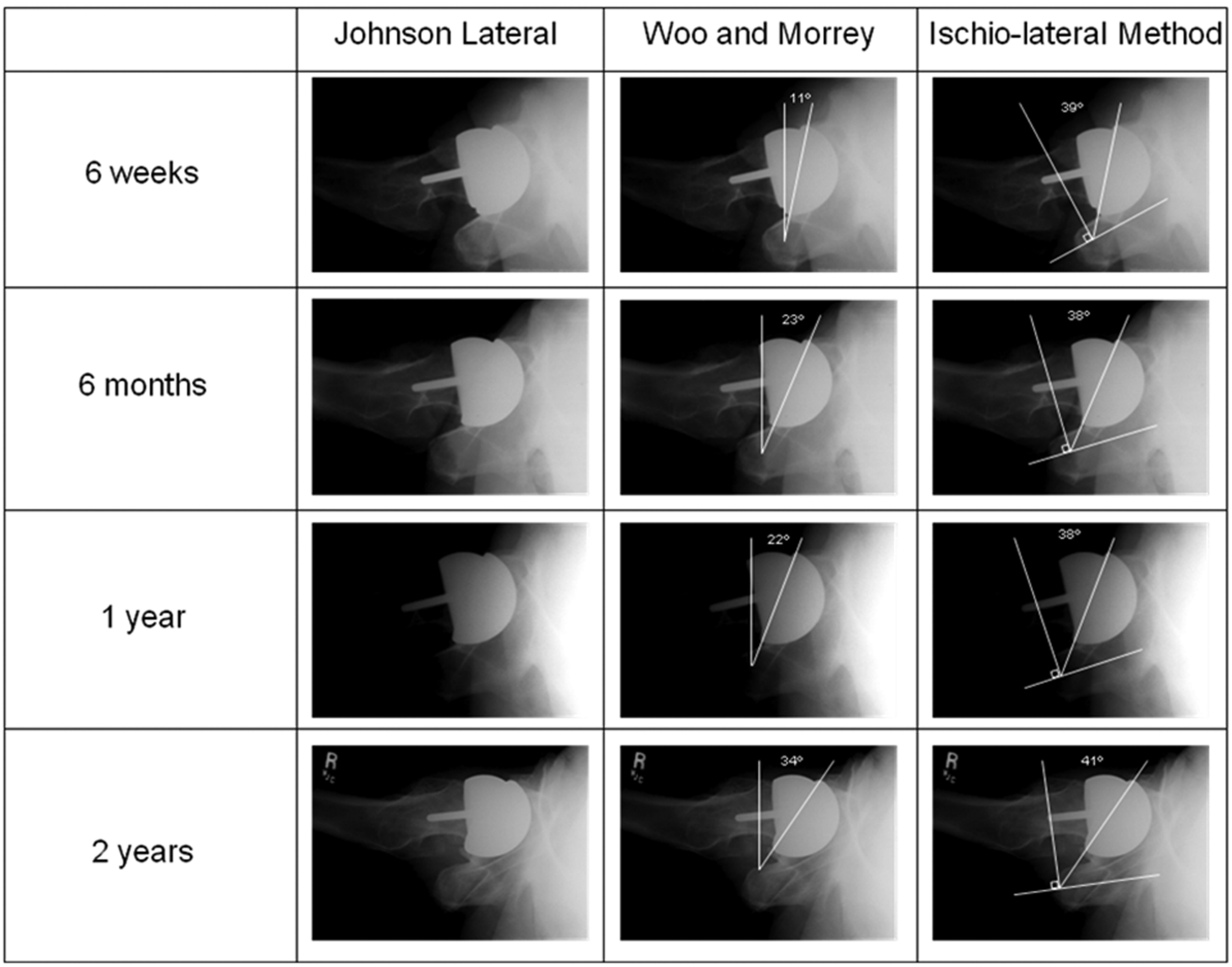

Figure 4 Lateral radiographic series of the same hip following hip resurfacing. Note the differences in projection for the four time periods. Using the Woo and Morrey[6] method, the mean lateral component position is 22.5°, with a SD of ± 9.4°. Using the long axis of the ischial tuberosity as a reference, the mean lateral component position is 39°, with a SD of only ± 1.4°.

To test the reproducibility and reliability of the ischio-lateral method, a subsample of 50 lateral radiographs was randomly selected to be read by two observers, who repeated the measurements on two separate occasions. Intra-class correlation coefficients (ICC) were calculated for both intra- and inter-observer reliability.[23]

The null hypothesis was that the difference between the SDs for each hip would be zero as a result of measurement error and pelvic tilt. Our alternative hypothesis was that measuring acetabular component position with the ischial tuberosity as a reference would yield a smaller SD. Statistical analysis was performed using the statistical package in Microsoft Excel. A paired two sample means t-test with a hypothesized mean difference of zero was used. Our paired variables were the SD of each hip using the Woo and Morrey[6] method and the SD of each hip using the ischio-lateral method. The test reported p-values using an alpha level of 0.05 as statistical significance.

Results

A total of 190 radiographs were analyzed. The mean of the SDs calculated for each patient using the Woo and Morrey[6] method was 3.7°. The mean of the SDs for the ischio-lateral method was 2.2°. This difference was statistically significant at $p < 0.001$. Using the Woo and Morrey[6] method, 19 (36.5%) hips had a SD greater than 4°, compared to 6 (11.5%) using the ischio-lateral method ($p < 0.001$). The number of measured angles that were greater than 4° from the mean was 24 (12.6%) using the Woo and Morrey[6] method and seven (3.8%) using the ischio-lateral method ($p = 0.002$). Figure 5 is a bar graph of the distribution of the range of angles measured for each series of radiographs.

The measurements from the two methods are strongly correlated ($p < 0.001$). The angles are increasing together, with the ischio-lateral method angle being 5° to 25° larger than the angle measured using the Woo and Morrey[6] method (Fig. 6). In seven (3.7%) films, the angle could not be measured with the ischio-lateral method; in five (2.6%) of these, the ischial tuberosity was outside the image, and in the remaining two (0.5%), there was insufficient contrast for the ischial tuberosity to be clearly seen. For the ischio-lateral measurement method, the ICC was 0.931 for intra-observer reliability and 0.854 for inter-observer reliability.

Discussion

The preferred method for evaluating acetabular component position on a lateral radiograph is the one least affected by variations in pelvic position and radiographic technique. The mean SD of acetabular component position measured using the historical method of Woo and Morrey[6] was ± 3.7°, for a mean anteversion of 29.7°. Pollard and coworkers[7] found a similar mean SD of ± 4°, for a mean anteversion of 17.3°, when measuring acetabular component position on serial radiographs of the same hip using the same method. Using a skeletal landmark, Massin and associates[1] found

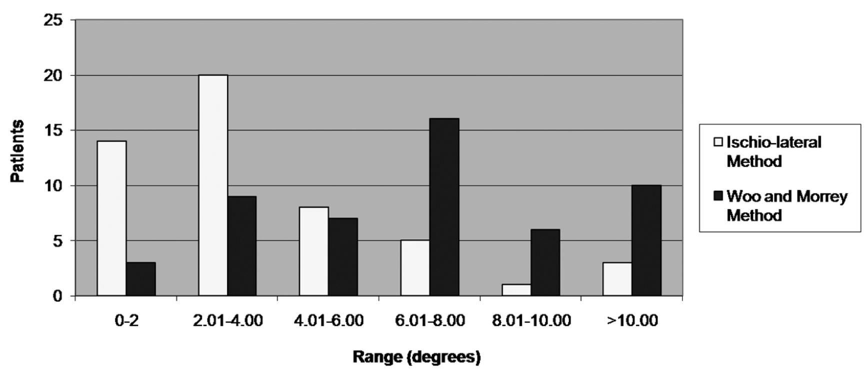

Figure 5 Bar graph comparing the range of the angles calculated for each hip by method. Only 23.5% of hip series had a measurement range of less than 4° using the Woo and Morrey[6] method, while 66.7% of hip series had a measurement range of less than 4° with the ischio-lateral method.

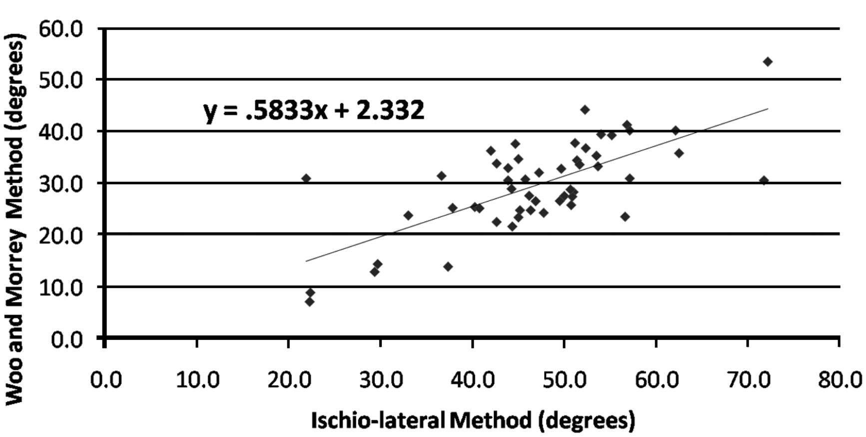

Figure 6 Component position on the lateral radiograph: the method of Woo and Morrey[6] versus the ischio-lateral method. The best-fit line has a correlation coefficient of $r^2 = 0.50$.

a SD of ± 4.4° when measuring the lateral opening angle on serial radiographs of the same hip. The ischio-lateral method of measuring acetabular component position of lateral radiographs had a mean SD of ± 2.2°, for a mean lateral component position of 46.9°.

The lateral component position angle measured by the ischio-lateral method is larger than the surgical anteversion observed in the operating room because surgical anteversion is measured as the angle between the frontal plane of the patient and the perpendicular to the face of the acetabular component (with no consideration of the ischium).[19,24]

Using an intra-class correlation coefficient in their study of hip resurfacing to show the reliability of radiologic measurements between observers, Hing and colleagues[25] used an ICC > 0.6 to represent substantial agreement and an ICC > 0.9 to represent excellent agreement, where ICC = 1.0 represents perfect agreement. Using these cut-offs, the intra-observer reliability of the ischio-lateral method was excellent, and the inter-observer reliability was substantial. Thus, the ischio-lateral method is a reliable way of measuring component position on lateral radiographs.

Clinically, this method is analogous to what has commonly been done on AP radiographs for the measurement of the acetabular component opening or abduction angle by Massin and coworkers.[1] An internal pelvic landmark, such as the inter-teardrop line, is used as a reference. Similarly, using the ischial tuberosity as a pelvic reference decreases variability of the lateral acetabular component position measurement due to differences in pelvic tilt, which can vary temporally with changes in patient flexibility and position on the X-ray table.[8] For example, using the Woo and Morrey[6] method, the lateral component position measured on one patient's lateral radiographs was 27.0°, 37.0°, and 36.0°, at 6 weeks, 6 months, and 1-year follow-up, respectively. Using the ischio-lateral method on the same set of films, lateral component position was measured as 53.0°, 53.0°, and 55.0°—the ischio-lateral method providing a more consistent measurement by decreasing the number of outlier angles (Fig. 5).

A limitation of our method is that the ischium must be visible on the lateral radiograph. For the films used in this series, the ischium was not a usable landmark on seven films (3.7%). The radiographs analyzed had been taken prior to the initiation of this study, and the technicians had not been given any special instructions regarding visualization of the ischium. Discussion with the technician regarding the importance of including the ischium on this view should reduce the number of unusable films. We recognize that computed tomography (CT) scanning can be used to determine acetabular anteversion. However, the goal of this study was to investigate a simple method using plain radiographs that improved on the current measurement standard and that required neither special equipment nor additional time or cost to the patient or payer.

Conclusion

Similar to what is commonly done with the inter-teardrop line on AP films, the long axis of the ischial tuberosity can be used as a skeletal landmark on a true lateral radiograph. The ischio-lateral method of measuring component position on a lateral radiograph significantly improved measurement consistency by reducing variation due to pelvic tilt. The high intra-class correlation coefficients for both intra- and inter-observer reliability indicated that the angle measured with this method is consistent and reproducible for multiple observers.

Disclosure Statement

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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