



Accuracy of plain antero-posterior radiographic-based methods for measurement of acetabular cup version

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Abstract

Introduction Acetabular cup version is crucial for successful total hip arthroplasty (THA). Many methods have been described for measurement of cup version angle. The aim of this study is to assess the accuracy of five commonly used methods for measurement of acetabular cup version in plain antero-posterior views of the pelvis and hip.

Material and methods Sixty primary THA cases were subjected postoperatively to plain A-P of the pelvis (AP-P), A-P view of the hip (AP-H), and computed tomography (CT) imaging. The acetabular cup version was measured in AP-P and AP-H by five methods (Lewinnek, Widmer, Hassan et al., Ackland et al., and Liaw et al.). These measurements were compared to the CT measurement.

Results All plain X-ray methods showed no significant differences from the CT, except those of Hassan et al. in AP-H, and Widmer and Ackland et al. in AP-P.

Conclusions and recommendations For measurement of acetabular cup version angle, we recommend the use of Lewinnek and Liaw et al. methods both in AP-P and in AP-H, while Hassan et al.'s method is recommended in AP-P only, and Widmer and Ackland et al.'s methods in AP-H only.

Keywords Total hip arthroplasty (THA) · Acetabular cup version · Antero-posterior view of the pelvis (AP-P) · Antero-posterior view of the hip (AP-H) · Computed tomography (CT)

Introduction

Acetabular cup orientation, including version and inclination, is a critical factor for successful total hip arthroplasty (THA). Surgeons have to pay effort and caution to place the acetabular cup in a proper position. Otherwise, adverse effects like instability [1–8], impingement with limited ROM [9–13], increased wear, osteolysis, and component migration [14] may occur increasing the need for revision surgery. Therefore, several methods have been advocated to enhance the surgeon's ability to place acetabular component accurately like the use of transverse acetabular

ligament as a guide [15], intra-operative radiographs [16], and using patient-specific instrumentations [17].

The ideal cup version is still controversial. However, most authors recommended anteversion between 5 and 30 degrees [1, 4].

Many methods have been postulated for post-operative measurement of acetabular cup anteversion using CT [18] and plain radiographs [1, 19–24]. CT has been proven to be the gold standard tool for measuring hip anatomy including the version angle [25]. Unlike radiographs [26], measurement of cup version using CT is accurate regardless of the patient's position [18]. However, CT measurements are expensive and demanding.

Plain radiographic-based methods of measurement may represent good alternatives for CT although they need equations or conversion tables. The reliability of these methods to measure the version angle accurately has been assessed in some previous studies. However, these studies did not test the possible differences in results which might be present between AP-P and AP-H as a result of the divergence of X-ray beams between the two imaging modalities.

Level of Evidence: Level III

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In this study, we tried to assess the accuracy of five common methods for measurement of acetabular cup anteversion using AP-P and AP-H plain radiographs, and comparing them with those of CT measurements which are considered to be the reference.

Patients and methods

Sixty primary THAs (37 uncemented and 23 cemented cups) performed at our centre between September 2015 and March 2016 were included in this study. There were 33 females and 27 males. The age varied between 22 and 80 years with the mean age of 43.

During patient selection, all cases were examined clinically and radiologically to exclude those with severe structural deformities of the back, pelvis, and lower limb that may interfere with proper positioning during imaging. Cases with severe acetabular abnormalities and patients who needed acetabular reconstruction or augmentation by metal implants that may cause fallacies during radiological interpretation were also excluded.

All patients included in this study were subjected on the second or third postoperative day to CT measurements of version, and then plain radiographic measurements were done one week later.

Techniques

Standardized plain A-P pelvic radiograph

A-P radiographs of the pelvis were obtained in the supine position at a source-to-film distance of 100 cm, with the X-ray beam centered on the superior aspect of the symphysis pubis and perpendicular to the patient, with the leg internally rotated 15 degrees to maximize the length of the femoral neck (Fig. 1).

Standardized plain A-P hip radiograph

The previous parameters were applied, with the beam focused on the hip centre (Fig. 2).

Multidetector CT imaging

The patients were subjected to CT imaging with the standard protocol as follows: 64-channel MDCT (G.E. light speed medical system), a collimation of 0.984 mm; the field of view at acquisition was 50 cm, and slice thickness was 0.6 mm with 40% section overlap.



Fig. 1 Plain A-P pelvic radiograph

Several steps were taken in order to minimize the bias during X-ray imaging:

- All patients had their imaging in the same department, by the same equipment, and by the same technician.
- All patients were carefully placed in the standard position for imaging.
- The image magnification was fixed to 100% to give a real-size photographs.
- All measurements were carried out by three independent observers with adequate knowledge of the technique of



Fig. 2 Plain A-P hip radiograph

radiographic and CT methods of measurement. The final figures of measurements represent the mean value of the numbers.

The obtained images were processed via the local PACS (picture archiving and collecting system) used in our hospital, and the PACS software (Paxera Ultima 360) was used to calculate the angles both in CT and in plain radiographs.

To avoid mental conflicts during the process of measurement, all measurements were done in a random order without any link to patient information or clinical data.

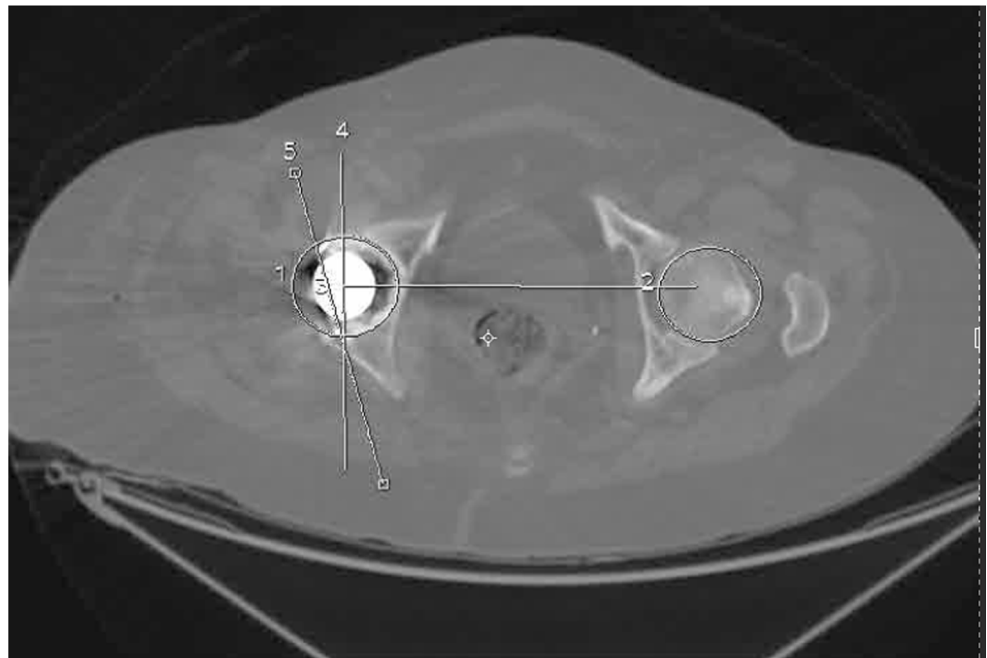
Measurement of cup anteversion in CT

Using the method described by Olivecrona et al. [18], the largest section of the acetabular component was selected in CT axial view. Then circles along the margin of the implant or of the acetabulum were drawn to set the true centre of both hips. Three lines were drawn, the first line connecting the centers of the two hips and a second line perpendicular to the first. Finally, a third line was drawn from the most anterior point of the component to its most posterior point. We then measured the angle between the second and third lines and calculated the version (Fig. 3).

Measurement of cup anteversion in plain A-P radiographs

In both hip and pelvis views, the version angle was calculated by the following five methods:

Fig. 3 CT measurement of cup anteversion



1. Lewinnek's method [1]

Version = arcsine (D1/D2); D1 is the distance of the short axis of an ellipse drawn perpendicular to the long axis of the acetabular component; D2 is the distance of the long axis, which is considered the maximal diameter of the implant (Fig. 4).

2. Widmer's method [19]

In this method, the short axis of the ellipse (S) and the total length (TL) of the projected cross section of the cup along the short axis are measured. The short axis S is related to the total length TL to get the S/TL ratio. By placing this ratio in the table designed by Widmer, the version is calculated (Fig. 5).

3. Ackland et al.'s method [20]

In this method, we measured the following:

- The distance of the long axis of the acetabular component (AC)
- The distance (AB) along the line AC
- DE which is an arbitrary tangent drawn at right angle to the diameter AC (Fig. 6)

Then we calculated the planar anteversion from the values of ratio AB/AC and ratio DE/AC using the conversion table developed by the authors.

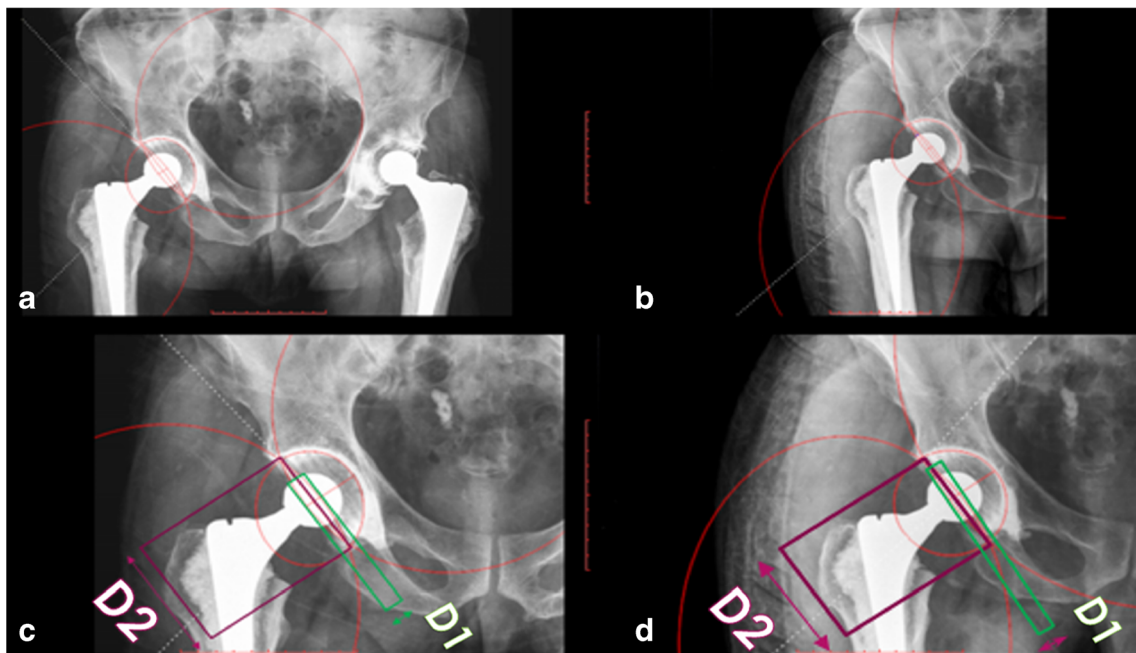


Fig. 4 Lewinnek's method of measurement of cup anteversion on plain AP radiogram **a** of the pelvis and **b** of the hip. **c** and **d** are magnified images of **a** and **b** respectively to clarify measurement method

4. Hassan et al.'s method [21]

In this method, D which represents the diameter of the acetabular cup was measured, m which is a distance along D that is not obscured by the femoral head, and h which is the length of the perpendicular dropped from the endpoint

of the distance m to the acetabular rim were also measured, then we calculated the anteversion from the values of ratio m/D and ratio h/D using the conversion table developed by the authors (Fig. 7).

5. Liaw et al.'s method [22]

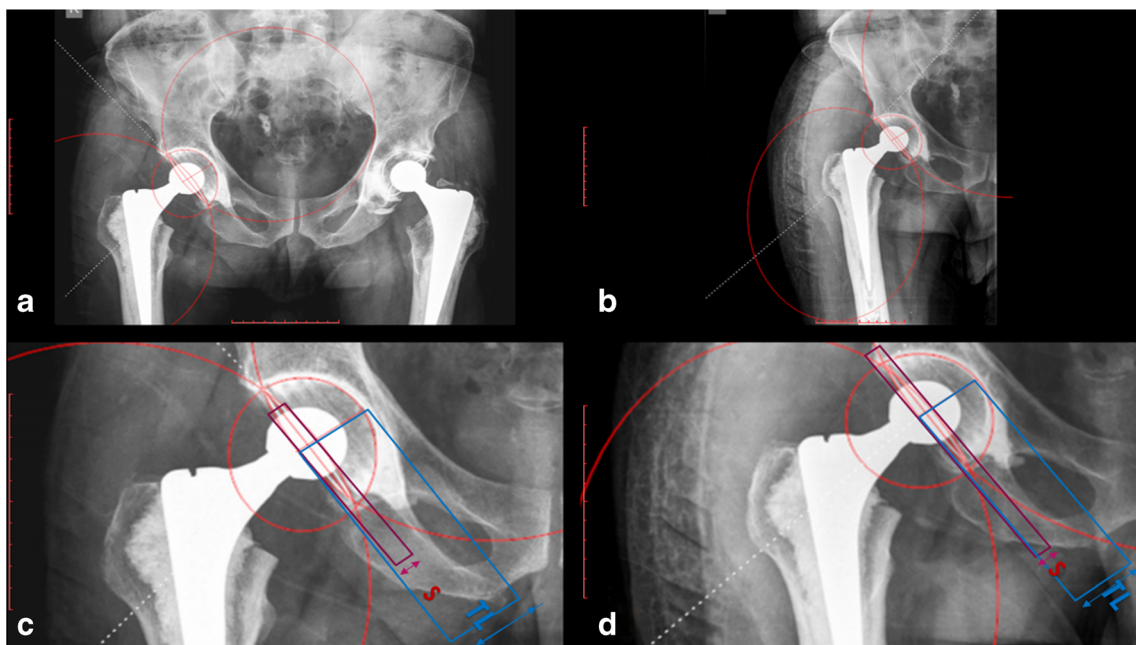


Fig. 5 Widmer's method of measurement of cup anteversion on plain AP radiogram **a** of the pelvis and **b** of the hip. **c** and **d** are magnified images of **a** and **b** respectively

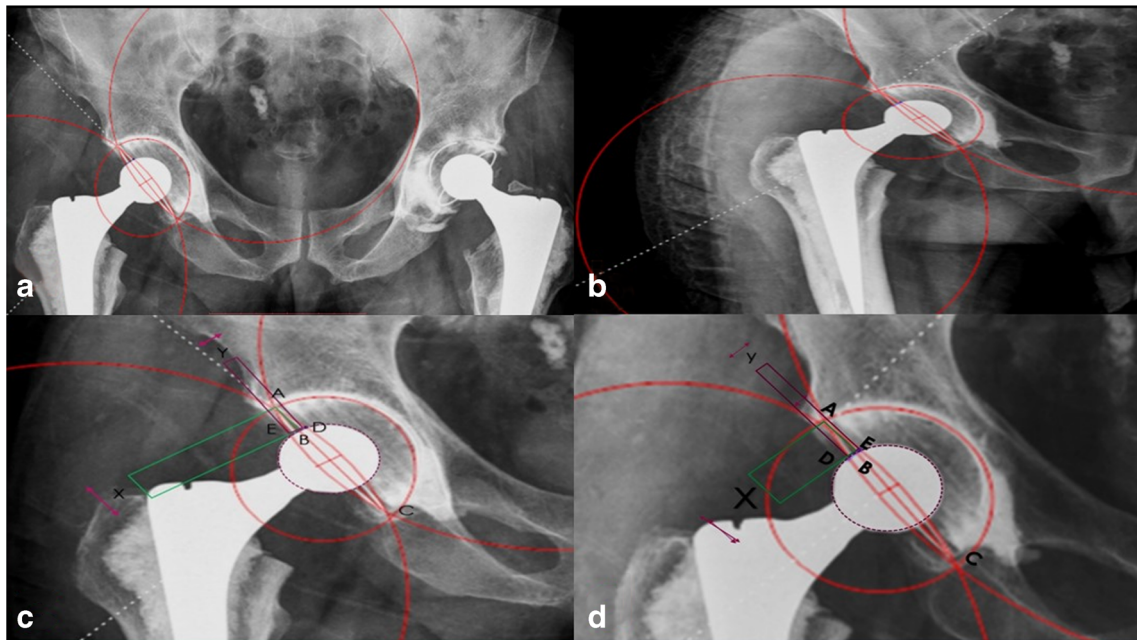


Fig. 6 Ackland's method of measurement of cup anteversion on plain AP radiogram **a** of the pelvis and **b** of the hip. **c** and **d** are magnified images of **a** and **b** respectively

In this method, the planar anteversion was used as follows:

- (a) A line across the maximal diameter of the ellipse in the AP radiograph, such as line AB, was drawn.

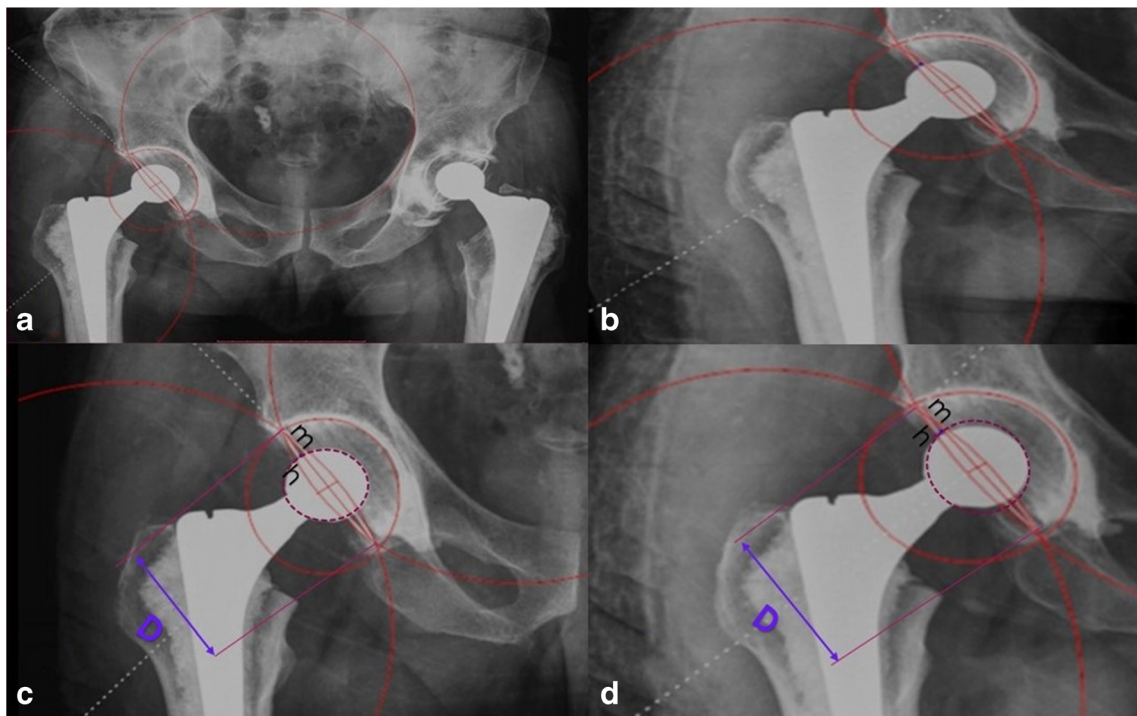


Fig. 7 Hassan et al. method of measurement of cup anteversion on plain AP radiogram **a** of the pelvis and **b** of the hip. **c** and **d** are magnified images of **a** and **b** respectively

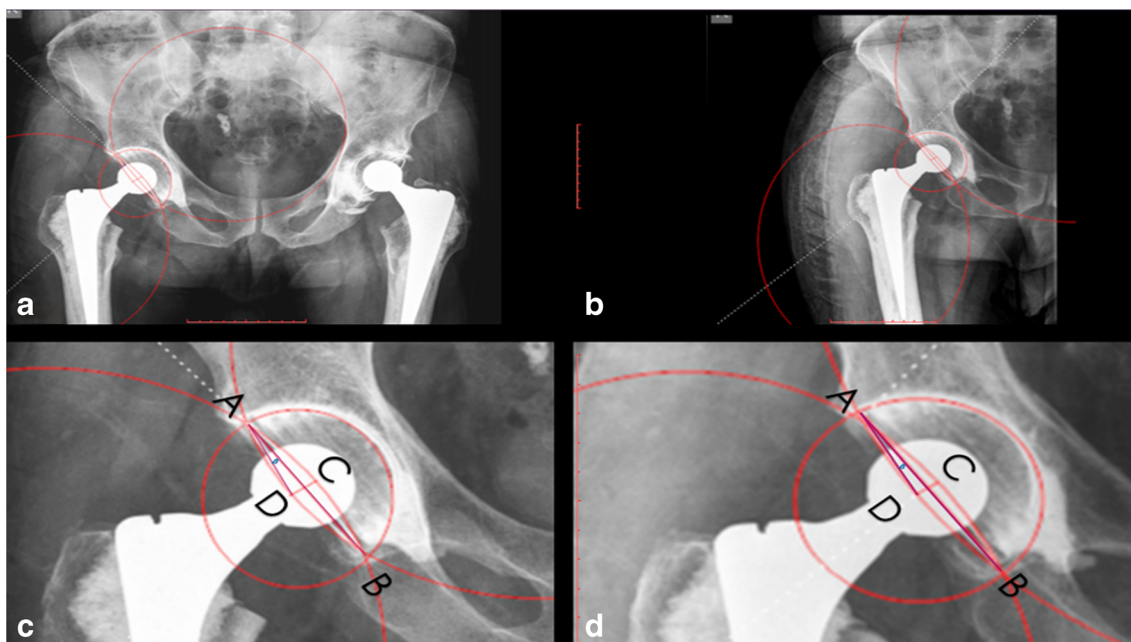


Fig. 8 Liaw method of measurement of cup anteversion on plain AP radiogram **a** of the pelvis and **b** of the hip. **c** and **d** are magnified images of **a** and **b** respectively

- (b) A point C, midway on the ellipse which is the intersection of the ellipse and the line perpendicular and going through the midpoint of AB, was determined.
- (c) Another line from the apex A to point C was drawn.
- (d) The angle β which is formed by lines AC and AB was measured (Fig. 8).
- (e) Version = $\sin^{-1} \tan \beta$.

differences between each method and CT. Such analysis was done via two tests, simple paired *t* test and two-way ANOVA, and statistical difference was considered significant if *P* value was < 0.05.

Statistical analysis

Patients included in this study were divided into two groups, uncemented and cemented groups. For each group, the statistical analyses were conducted using Graphpad Prism version 6 software, and the mean anteversion for every method was calculated, comparing results of each method separately in the pelvis A-P (AP-P) and in the hip A-P (AP-H) to results of CT as a reference. The accuracy of each method was assessed by presence or absence of significant statistical

Results

Uncemented cups

Measurements using the methods of Lewinnek and Liaw et al. had no statistical difference from CT measurements in both AP-P and AP-H. Measurements by Hassan et al. method had no statistical difference from CT measurements in AP-P only, while it had a highly significant statistical difference in AP-H view.

Measurements by Ackland et al. and Widmer had no statistical difference from CT measurements in AP-H only, while they had a highly significant statistical difference in AP-P view (Table 1).

Table 1 Results of version measurements for uncemented cups by different methods

| | CT | Lewennik | | Widmer | | Ackland | | Hassan | | Liaw | |
|----------------|-------|----------|--------|--------|---------|---------|---------|---------|--------|--------|--------|
| | | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis |
| Mean | 18.18 | 18.02 | 18.38 | 18.19 | 20.49 | 17.57 | 20.35 | 16.9 | 18.2 | 18 | 18.38 |
| <i>P</i> value | | 0.224 | 0.054 | 0.976 | <0.0001 | 0.105 | <0.0001 | <0.0001 | 0.7574 | 0.1126 | 0.3429 |

Table 2 Results of version measurements for cemented cups by different methods

| | CT | Lewennick | | Widmer | | Ackland | | Hassan | | Liaw | |
|---------|--------|-----------|--------|--------|----------|---------|--------|--------|--------|-------|--------|
| | | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis |
| Mean | 16.297 | 15.79 | 16.53 | 16.18 | 18.23 | 14.35 | 17.52 | 14.87 | 16.46 | 14.91 | 16.58 |
| P value | | 0.712 | 0.116 | 0.667 | < 0.0001 | 0.0697 | 0.0024 | 0.037 | 0.196 | 0.054 | 0.102 |

Cemented cups

Measurements using the methods of Lewinnek and Liaw et al. had no statistical difference from CT measurements in both AP-P and AP-H. Measurements by Hassan et al. method had no statistical difference to CT measurements in AP-P only, while it had a statistically significant difference in AP-H view.

Measurements by Ackland et al. and Widmer had no statistical difference from CT measurements in AP-H only while they had a statistically significant difference in AP-P view by Ackland et al. method, and a highly significant difference in AP-P view by Widmer method (Table 2).

Difference between AP-H and AP-P measurements

In uncemented cups, the lowest difference between mean values of measurements in AP-H and AP-P was in Lewennick method measurements (0.36 degrees), and the highest difference was in Ackland and Widmer measurements (2.78 and 2.3 degrees respectively) (Table 3).

In cemented cups, the lowest difference between mean values of measurements in AP-H and AP-P was in Lewennick method of measurements (0.74 degrees), and the highest difference was in Ackland and Widmer measurements (3.17 and 2.05 degrees respectively) (Table 4).

Discussion

In this study, the accuracy of measurement of acetabular cup version angle was assessed, using plain A-P radiographic-based five methods which are commonly used and proved by a previous study to have good inter- and intra-observer reliability [27].

The accuracy of these methods was assessed by comparing the results of their measurements using the pelvic and hip views separately to the measurements using CT imaging which are considered to be the reference. This was tested in both uncemented and cemented cup groups.

Compared to CT measurements, two methods (Lewinnek and Liaw et al.) had no statistically different measurements in both hip and pelvic views in both uncemented and cemented cups.

Two methods (Widmer and Ackland et al.) had no statistically different measurements in hip view only, and one method (Hassan et al.) had no statistically different measurements in pelvis view only.

Comparing measurements in plain radiographs with CT measurements in both uncemented and cemented cup groups showed that the results were nearly similar except for a higher statistically significant difference in measurements for only Ackland method in AP-P view and Hassan et al. method in AP-H view.

This can be explained by realizing that measurement of cup version is more difficult in uncemented cups.

In the study carried out by Nho et al. [27], the cup version was measured by CT and by six radiological methods, including the five methods used in the current study, in the A-P view of the pelvis. They concluded that the methods of Lewinnek, Hassan et al., and Liaw are accurate while those of the Ackland et al. and Widmer are not. So, they recommended not using the last two methods. However, they did not use the hip view and did not mention the use of these methods in hip view.

This study showed similar results to those of Nho et al. as regards the use of these methods in the A-P view of the pelvis. It was found in addition that the two methods that were inaccurate in the pelvic view can be used in the hip view accurately. This is consistent with the results of Ackland et al. who reported that their method was accurate only when the beam

Table 3 Difference between both views (AP-H and AP-P) in measurements of version of uncemented cups by the five methods

| Method | Lewennick | | Widmer | | Ackland | | Hassan | | Liaw | |
|------------|-----------|--------|--------|--------|---------|--------|--------|--------|------|--------|
| | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis |
| Mean | 18.02 | 18.38 | 18.19 | 20.49 | 17.57 | 20.35 | 16.9 | 18.2 | 18 | 18.38 |
| Difference | 0.36 | | 2.3 | | 2.78 | | 1.3 | | 0.38 | |

Table 4 Difference between both views (AP-H and AP-P) in measurements of version of cemented cups by the five methods

| Method | Lewennik | | Widmer | | Ackland | | Hassan | | Liaw | |
|------------|----------|--------|--------|--------|---------|--------|--------|--------|-------|--------|
| | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis | Hip | Pelvis |
| Mean | 15.79 | 16.53 | 16.18 | 18.23 | 14.35 | 17.52 | 14.87 | 16.46 | 14.91 | 16.58 |
| Difference | 0.74 | | 2.05 | | 3.17 | | 1.59 | | 1.67 | |

was centered over the hip, while when the radiographs were centered over the symphysis, an error was produced because the X-ray beam was oblique in relation to the opening of the ellipse. This error has been shown to be as much as 5 degrees. So, these authors stated that when the central beam passes through the hip, their method is highly accurate [20].

In this study, the difference between the mean measurements for version in AP hip and pelvis radiographic views was lowest in Lewennick method, while the highest difference was in Ackland and Widmer measurements. The highest value was 3.17 degrees in Ackland method measurements in cemented cups and 2.78 degrees in uncemented cups. Also, measurements by Widmer method showed a difference between AP-H and AP-P view of 2.3 and 2.05 degrees for uncemented and cemented cups respectively, and this can explain why these two methods were found inaccurate for measurement by Nho et al.

Although these methods could be beneficial, their use for the purpose of postoperative measurement of acetabular cup anteversion still has some limitations:

1. The most important limitation is the inability of the different methods that utilize the A-P view of plain X-ray to differentiate between anteversion and retroversion. Due to their two-dimensional nature, they cannot identify the direction of the cup without the need to do additional lateral or oblique views.
2. The accuracy of these methods depends strictly on the positioning of the patient at imaging. This standard positioning of the patient cannot be ensured at all times due to different patient or technician-related factors.
3. It was somewhat difficult to find the ellipse of the cup when anteversion of the uncemented cups was measured while it was easy in the cemented cups due to the presence of radio-opaque wire.

Conclusion and recommendations

Plain A-P radiographs can provide a simple, useful, and reliable tool for measuring the acetabular cup anteversion.

For most accurate radiographic measurements of cup version, this study shows that both Lewennick and Liaw methods are more accurate in both hip and pelvic views, while Hassan

et al. method gives more accurate measurements in the pelvis view and both Ackland et al. and Widmer methods are more accurate in the hip view.

The CT measurement of the acetabular cup anteversion still has some superiority as it does not depend on the patient's position and can differentiate the anteversion from retroversion.

Compliance with ethical standards

This study was approved by the institutional review board (ethical committee) of our institution. Informed consent was obtained from the patients following the guidelines set forth by our institution and by the Declaration of Helsinki and Good Clinical Practice. The consent included approval of the patients to undergo post-operative CT.

Conflict of interest The authors declare that they have no conflict of interest.

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