Reliability and validity of measuring version of the acetabular component

A variety of radiological methods of measuring version of the acetabular component after total hip replacement (THR) have been described. The aim of this study was to evaluate the reliability and validity of six methods (those of Lewinnek; Widmer; Hassan et al; Ackland, Bourne and Uighthoff; Liaw et al; and Woo and Morrey) that are currently in use. In 36 consecutive patients who underwent THR, version of the acetabular component was measured by three independent examiners on plain radiographs using these six methods and compared with measurements using CT scans. The intra- and interobserver reliabilities of each measurement were estimated. All measurements on both radiographs and CT scans had excellent intra- and interobserver reliability and the results from each of the six methods correlated well with the CT measurements. However, measurements made using the methods of Widmer and of Ackland, Bourne and Uighthoff were significantly different from the CT measurements (both p < 0.001), whereas measurements made using the remaining four methods were similar to the CT measurements. With regard to reliability and convergent validity, we recommend the use of the methods described by Lewinnek, Hassan et al, Liaw et al and Woo and Morrey for measurement of version of the acetabular component.

The orientation of the acetabular component in total hip replacement (THR) is defined by abduction, which is the angle between the face of the implant and the transverse axis; and version, which is the angle between the axis of the component and the coronal plane of the patient.1-3 Whereas abduction can easily be measured on anteroposterior (AP) radiographs, version is more difficult to measure. Version of the acetabular component can be measured accurately using CT scans, and there are a variety of methods of measuring it on plain AP or cross-table lateral radiographs.1-11 An ideal method should be both accurate and reproducible. Few studies have compared the reliability and validity of different methods of measuring version on plain radiographs.12-14 The aim of this study was to compare six current methods of measurement.

Materials and Methods

This prospective study was approved by our institutional review board, and informed consent was obtained from the patients. A power study using a Bonett’s approximation,15 and an intraclass correlation coefficient (ICC) at a target value of 0.8 and 95% confidence interval (CI) of 0.2 indicated that 36 hips were required.

A total of 36 consecutive patients who underwent primary cementless THR between August and October 2010 were recruited. There were 19 men and 17 women with a mean age of 52.5 years (27 to 74) (Table I). Image acquisition. Radiographs taken six weeks after THR were used to measure version of the acetabular component. All radiographs were taken in the same department using a standardised protocol. AP radiographs of the hip were obtained in the supine position at a source-to-film distance of 110 cm with the x-ray beam centred on the superior aspect of the pubic symphysis and perpendicular to the patient. Cross-table lateral radiographs were taken with the contralateral hip flexed at 90°. The direction of the x-ray beam was parallel to the examination table and 45° cephalad to the long axis of the body. The film was held perpendicular to the examination table using a cassette holder.6,16 All images were digitally acquired using the Picture Archiving and Communication System (PACS) (Impax: Agfa, Antwerp, Belgium), and all measurements on radiographs were subsequently made on a 19 inch LCD monitor using PACS software. CT scans were obtained three to seven days after THR with a 64-channel multi-detector CT system (Brilliance 64; Philips Medical Systems, The Netherlands). All measurements on both radiographs and CT scans were performed by three independent examiners.
Table I. Summary of patients (THR, total hip replacement)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male:female)</td>
<td>19:17</td>
</tr>
<tr>
<td>Mean age (yrs) (range)</td>
<td>52.5 (27 to 74)</td>
</tr>
<tr>
<td>Indication for THR (n, %)</td>
<td>62 (72.2)</td>
</tr>
<tr>
<td>Osteonecrosis</td>
<td>26 (72.2)</td>
</tr>
<tr>
<td>Primary osteoarthritis</td>
<td>3 (8.3)</td>
</tr>
<tr>
<td>Secondary osteoarthritis</td>
<td>7 (19.4)</td>
</tr>
</tbody>
</table>

Systems, Best, The Netherlands). The standard acquisition protocols were as follows: for 64-channel MDCT a collimation of 0.625 mm was used; the field of view at acquisition was 30 cm; and slice thickness was 0.67 mm with 0.33 mm increments (50% section overlap). This high-resolution isotropic CT volume allowed image reformation in any desired plane without degradation of image quality.

Measurement of acetabular component version on plain radiographs. Version was measured using six currently used methods on plain radiographs, as well as on CT scans. To avoid confusion before measuring the version, three consensus-building sessions were held by three orthopaedic surgeons (JHN, YCH and YKL), during which the definitions of each method of radiological measurement were identified and clarified.

Lewinne's method. 2

\[ \text{Version} = \text{arcsin} \left( \frac{D_1}{D_2} \right) \]

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 2 (Fig. 1a).

Widmer's method. 17

\[ \text{Version} = \text{arcsin} \left( \frac{\text{Short axis (S)}}{\text{Total length (TL)}} \right) = 48.05 \times \left( \frac{S}{TL} \right) - 0.3 \ (\text{if } 0.2 < S/TL < 0.6) \]

The short axis is the same distance as D1 above. Total length is the entire distance of the projected cross section of the acetabular component along the short axis (Fig. 2). This method shows linear correlation in the range of S / TL between 0.2 and 0.6. We used the second equation6 (Fig. 1b).

Hassan et al's method. 8

\[ \text{Version} = \text{arcsin} \left[ \frac{h}{D} / \sqrt{\left( \frac{m}{D} - \left[ \frac{m^2}{D^2} \right] \right)} \right] \]

In this method three measurements (D, m and h) should be made. D represents the maximum diameter of the acetabular component, m is the distance along D that is not obscured by the femoral head, and h is the length of the perpendicular dropped from the endpoint of the distance m to the acetabular rim8 (Fig. 1c).

Ackland, Bourne and Uhthoff's method. 9

\[ \text{Version} = \text{arcsin} \left[ \frac{2y}{2\sqrt{2ax - x^2}} \right] \]

Here, a is the distance of the long axis of the acetabular component (AC), x is the distance (AB) along the line AC. An arbitrary tangent is drawn at a right angle to the diameter, and y is the distance from the two-cup rims along this tangent (DE)9 (Fig. 1d).

Liaw et al's method. 5

\[ \text{Version} = \sin^{-1} \left( \frac{1}{\tan \beta} \right) \]

This is a method that uses the \( \beta \) angle formed by the long axis of the component (AB) and the line connecting the top point of the ellipse and the end-point of the long axis (AC) 5 (Fig. 1e).

Woo and Morrey's method. 1 This method uses cross-table lateral radiographs to measure version of the component, whereas the other methods use AP radiographs. This method needs no equations and distinguishes between anteversion and retroversion. The angle is directly measured between a line perpendicular to the table and a line tangential to the opening face of the acetabular component. This angle is defined as antversion from a cross-table lateral view1,16 (Fig. 1f).

Measurement of acetabular version on CT scan. In this study, the following methods, which were modified from Murray’s concept, were used to measure acetabular version. The largest section of the acetabular component was selected in CT axial view. We then drew circles along the margin of the implant or of the acetabulum to set the true centre of both hips. We drew a first line connecting the centres of the two hips and a second line perpendicular to the first. Finally, we drew a third line 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. The version from CT scans was regarded as the reference standard for acetabular version18 (Fig. 2).

Assessment of reliability and convergent validity. Reliability was defined as the consistency of the measurement. The six methods used to measure on plain radiographs were performed by three examiners (JHN, YCH and YKL) and each method independently used the same protocol.

The intra-observer reliability of each method was assessed using the values measured by one examiner (JHN), who performed the reassessment three weeks later. 19 The interobserver reliability of each method was assessed by the same three examiners. All measurements were made without any knowledge of the patient’s clinical information or the findings of the other examiners. The radiographs and scans were presented to each examiner in random order by a research assistant who did not participate in the reliability sessions.

Convergent validity was defined as proximity to the reference standard. It was assessed for each method by comparing the means of each method and means on CT scans. Correlations between the measurements on radiographs and those on CT scans were also analysed.

Statistical analysis. The ICCs and their 95% CIs were used to summarise the interobserver reliability in a single measurement. The ability of a test to show intra- and interobserver reliability was evaluated using the two-way random effects model assuming a single measurement and absolute agreement. An ICC of 1 means perfect reliability and an ICC of 0 means the opposite.

To determine the convergent validity of each method on radiographs with the CT measurements, paired t-tests and
Pearson's correlation coefficients were used. Pearson's correlation coefficient was characterised as poor (0.00 to 0.20), fair (0.21 to 0.40), moderate (0.41 to 0.60), good (0.61 to 0.80) or excellent (0.81 to 1.00).

Statistical analyses were conducted using SPSS for Windows version 15.0 (SPSS Inc., Chicago, Illinois) and statistical significance was set at p < 0.05.

Results

Reliability. In all six radiological measurements the intra- and interobserver reliabilities were > 0.90. Those of CT measurements were 0.954 (95% CI 0.909 to 0.976) and 0.982 (95% CI 0.970 to 0.990) (Table II).

Convergent validity. The radiological measurements of all six methods showed good positive correlations with the CT measurements. Whereas measurements made using Lewinnek's method, Hassan et al's method, Liaw et al's method for anteroposterior radiographs, and Woo and Morrey's method for cross-table lateral radiographs were similar to the CT measurements, those made by Widmer's method and those by Ackland, Bourne and Uhthoff's method were significantly different from the CT measurements (both p < 0.001, paired t-test) (Table III).

Discussion

The version and the inclination of the acetabular component in THR are crucial for movement and stability and to reduce wear. The ideal version remains controversial.
Charnley recommended no anteversion, but most studies recommend between 5° and 30° of anteversion. Various methods have been developed to measure version of the acetabular component, using radiographs, fluoroscopy or CT scans. Fluoroscopic methods involve time and radiation and CT measurements are expensive and involve a considerable amount of radiation. Accordingly, radiological methods are widely used even though they require complicated calculations or the use of conversion tables. However, only a few studies have assessed the reproducibility and accuracy of radiological methods.

We used version measured on CT as the reference standard, rather than anatomical version, which is practically unmeasurable. Previous studies have shown that version of the acetabular component could be measured accurately using CT scans.

Our study shows four radiological methods, Lewinnek’s, Hassan et al’s, and Liaw et al’s, which use AP radiographs, and Woo and Morrey’s, which requires cross-table lateral radiographs, to be reliable and valid for measuring anteversion.

However, the three measurements on AP radiographs have some limitations that should be addressed. First, retroversion cannot be detected on AP radiographs. To differentiate between ante- and retroversion, additional oblique or cross-table lateral radiographs are required.

Secondly, it is difficult to identify the apex of the ellipse on AP radiographs when a ceramic or metal liner is used and when the implant is excessively anteverted. When a cemented ultra-high molecular-weight polyethylene acetabular component, with a radio-opaque circumferential wire, is used, it is easy to identify the apex of the ellipse in AP radiographs.

It is easy to measure acetabular anteversion using Woo and Morrey’s method because it requires no equations or conversion tables. This method can also differentiate ante- and retroversion. It is widely used because it is convenient and fast, and is also safer and more economical than CT. However, it is inaccurate when the pelvis is tilted and when the contralateral hip joint or the lumbar spine is stiff.

We could not explain why Widmer’s method and Ackland, Bourne and Uhthoff’s method appeared inaccurate in our study. These two methods use linear regression to approximate the complicated non-linear relationship, which might have resulted in an inaccuracy, as previous studies have pointed out.

Despite their problems, these four methods of measurement using plain radiographs seem to be reproducible and accurate.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


