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The reliability of measuring acetabular component position on radiographs using everyday diagnostic imaging software

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Abstract

Background: It is standard practice for total hip arthroplasty (THA) patients to have post-operative imaging, and one of the reasons is to assess the adequacy of acetabular component position. Correct positioning of the acetabular component is important for successful outcome in THA. Acetabular component position can be measured from either computed tomography (CT) or plain radiographs. While CT is the gold standard for accurately measuring acetabular component position, radiographs are routinely used for post-operative evaluation. However, measurement of acetabular component position from plain radiographs is not straightforward and numerous methods have been proposed. As most imaging is now digital, the aim of this study was to investigate the reliability of one method to measure acetabular component position using a basic diagnostic imaging software program that is readily available to orthopaedic surgeons. **Methods:** We investigated the reliability Lewinnek's method using a basic Picture Archiving and Communication System program, *InteleViewer* ™. We measured 69 post-operative anteroposterior (AP) radiographs of patients who underwent primary THA. Intra-observer and inter-observer reliability for Lewinnek's method was calculated using the intraclass correlation coefficient. **Results:** Our results showed excellent intra- and inter-observer reliability for both inclination (0.99, 95% confidence interval (CI): 0.99–1.0; and 0.97, 95% CI: 0.95–0.99) and anteversion (0.99, 95% CI: 0.98–0.99; and 0.93, 95% CI: 0.89–0.96) measurements. **Conclusion:** This study has shown that using Lewinnek's method, acetabular component position can be reliably measured on post-operative AP digital radiographs using readily available software tools.

Keywords

acetabulum, arthroplasty, replacement, hip, software, tomography, X-ray computed, reproducibility of results

Introduction

It is standard practice for total hip arthroplasty (THA) patients to have post-operative imaging, and one of the reasons is to assess the adequacy of acetabular component position. Correct positioning of the acetabular component is important for successful outcome in THA. Malposition of the acetabular component is associated with numerous post-operative complications including decreased range of motion, impingement, increased wear and dislocation. It is therefore important for all surgeons to have a quick and reliable method for measuring acetabular component position.

Acetabular component position can be measured from either computed tomography (CT) or plain radiographs. While CT is the gold standard for measuring acetabular component position, it is not routinely used for post-operative evaluation.[1] Instead, plain radiographs remain the most common imaging modality for post-operative evaluation due to widespread availability, low cost and

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minimal radiation exposure. However, measurement of acetabular component position from plain radiographs is not straightforward. Acetabular component position can be described in terms of inclination and version, where inclination is the angle between the face of the component and the transverse axis and version is the angle between the axis of the component and the coronal plane of the patient.[2] While inclination can be measured simply from plain anteroposterior (AP) radiographs, calculating anteversion is more difficult and numerous methods have been proposed based on the ellipse projected by the acetabular component on the AP radiograph.[3,4] One of the first methods proposed is that described by Lewinnek et al[5] (Lewinnek's method). This method involves drawing an ellipse over the projection of the acetabular component and measuring the short and long axis of the ellipse to calculate anteversion. In the original study, these measurements were performed freehand on plain AP pelvic radiographs. With modern digital imaging, these measurements can be performed using the Picture Archiving and Communication System (PACS) software programs that are widely used in hospitals. These programs have electronic tools that allow various shapes and measurements to be superimposed over a digitally stored radiograph. There are also available specialized software programs that have been developed to measure acetabular component position on digital radiographs and they use methods such as component edge detection, pelvic reference point systems and complex mathematical curve-fitting techniques.[6–8] While these have been reported to be accurate when compared to CT, they are expensive and not widely available.

The aim of this study was to investigate the reliability of Lewinnek's method to measure acetabular component position using a basic diagnostic imaging software program that is readily available to orthopaedic surgeons.

Methods

Study population

The study population was 69 patients who underwent 69 primary THA procedures. These procedures were selected from a larger cohort of 1897 THA procedures that were performed from 1 January 2011 to 31 December 2013 at Epworth HealthCare, Richmond, that had their acetabular component position measured as part of a quality assurance project. Patient demographics were provided by the hospital's patient administration system data. Sample size was calculated using planning for precision analysis,[9,10] based upon the method described by Zou.[11] A 95% confidence interval (CI), a desired or target value of intraclass correlation coefficient (ICC) of 0.80, a precision or CI or half-width of 0.10 and an assurance of 80% (similar to the minimum statistical power required in power analyses involving p values) were specified. In other words, we wished to have 80% assurance of obtaining a 95% CI of no wider than 0.70–0.90, for a target ICC of 0.80. The table provided by Zou[11] indicated that a sample size of 69 procedures would be required for two raters.

Radiographic analysis

All post-operative AP pelvic radiographs were taken using a standardized protocol with the patients in the supine position, the radiation beam centred over the superior aspect of the pubic symphysis and a film-focus distance of 100 cm. Images were stored in digital format in the hospital's PACS program (*IntelePACS*^{TM}, Intelerad Medical Systems Inc) and available for viewing through *InteleViewer*^{TM} (Intelerad Medical Systems Inc) diagnostic imaging software.

Lewinnek's method[5] was used to determine the radiological anteversion angle (AV) of the acetabular component.[2] Using Lewinnek's method, anteversion was calculated as arcsin (short axis of the ellipse/long axis of the ellipse) from the ellipse projected by the circular opening of the acetabular component on to the AP pelvic radiograph. To measure the short and long axis of the ellipse, the digital drawing and measurement tools from the *InteleViewer*^{TM} software were used to draw an ellipse around the acetabular component's opening rim and then to measure the short axis and long axis (Figure 1). Where the version of the acetabular component was not clear on the AP radiograph, the lateral radiograph was used to determine whether the acetabular component was retroverted or anteverted. Inclination was measured as the angle between the line of the long axis of the ellipse and the inter-teardrop line and could be measured directly on the AP radiograph using the *InteleViewer*^{TM} software measurement tools (Figure 1).

To assess intra-observer reliability, the primary observer (first author) measured each of the 69 AP radiographs twice with a 3-week interval between the first and second measurements and blinded to the results. To assess inter-observer reliability, an experienced orthopaedic surgeon (second author) measured the same 69 AP radiographs, blinded to the primary observer's (JL) results. These results were compared to the primary observer's (JL) first measurements.

Statistical analysis

Intra-observer and inter-observer reliability for Lewinnek's method was calculated using the ICC[12] and a 95% CI. We used the one-way random-effect intraclass correlation model and absolute agreement to calculate the individual ICC. An ICC value of 1 means *perfect reliability* and a value of 0 means the opposite. An ICC > 0.80 conventionally represents excellent reliability. Statistical analysis was performed using Stata 13 (Stata Corporation, College

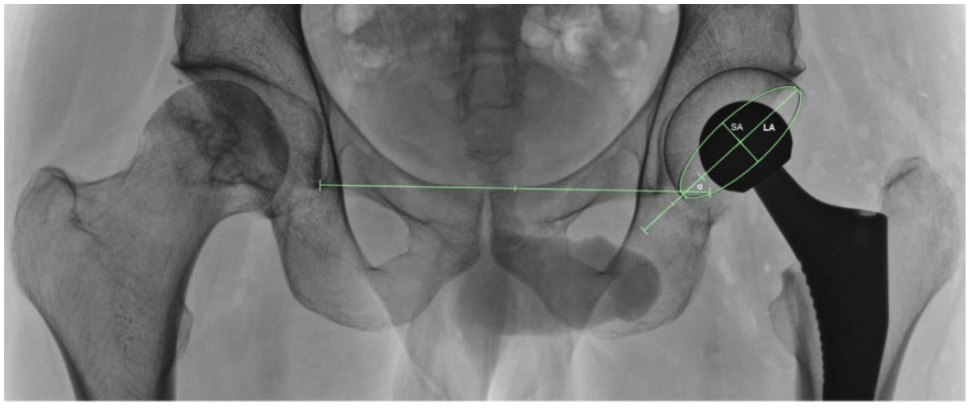

Figure 1. Example of an AP pelvic radiograph in a post-operative THA patient with the measurements used to calculate acetabular component position superimposed over the radiograph. AP: anteroposterior; α: inclination; LA: long axis; SA: short axis; THA: total hip arthroplasty.

Table 1. Results of intra- and inter-observer reliability.

	Intra-observer reliability		Inter-observer reliability	
	ICC	95% CI	ICC	95% CI
Anteversion	0.99	0.98–0.99	0.93	0.89–0.96
Inclination	0.99	0.99–1.0	0.97	0.95–0.99

ICC: intraclass correlation coefficient; CI: confidence interval.

Station, Texas, USA, 2013) software and statistical significance was defined as $p \leq 0.05$.

Results

Sixty-nine digital AP pelvic radiographs were selected for measurement and 17 different surgeons performed the THAs. The mean age of patients in the study population was 64.2 (SD: 12.1, range: 34–87 years). Thirty-seven procedures were performed in males and 41 procedures were right-sided.

The ICC for intra-observer reliability of anteversion measurements was 0.99 (95% CI: 0.98–0.99) and for inclination it was 0.99 (95% CI: 0.99–1.0). The ICC for inter-observer reliability of anteversion measurements was 0.93 (95% CI: 0.89–0.96) and for inclination it was 0.97 (95% CI: 0.95–0.99; Table 1).

Discussion

Using the *InteleViewer*^{TM} software, we found Lewinnek's method to be a reliable method for measuring acetabular component position. Intra-observer and inter-observer reliability was > 0.90 for both anteversion and inclination angle measurements, indicating excellent reliability. Previous studies have reported similar results when investigating the intra- and inter-observer reliability of Lewinnek's method using different imaging software programs (Table 2).

There was slightly higher inter-observer reliability when measuring the inclination angle compared to measuring the AV, and this was not surprising as this measurement relies only on identifying the inter-teardrop line and the long axis of the ellipse projected by the acetabular component. Variation between inclination measurements on the same radiograph is most likely due to minor variation in identifying the exact outline of the acetabular teardrop, which in some cases can be difficult to identify.

In comparison, when measuring the acetabular component anteversion, the main issue is identifying the outline of the ellipse. In some types of acetabular components, this is simple to do, such as when the component has a radiopaque metal ring (Figure 1). In other types of components, measurement is more difficult. This can be because the apex of the ellipse is harder to identify when the anteversion of the cup is high or when a large femoral head may obscure part of the ellipse. However, by using the drawing and measurement tools of *InteleViewer*^{TM}, this issue was largely overcome. Only a small section of the acetabular component edge needed to be clearly outlined on the digital radiograph for the drawing tools to be able to superimpose an ellipse over the remainder of the acetabular component. This is far simpler and more accurate than drawing the ellipse freehand.

Measuring acetabular component position using basic diagnostic imaging software and Lewinnek's method on post-operative AP radiographs was selected for a number of reasons. Firstly, while CT is the gold standard for measuring acetabular component position, radiographs are routinely used for post-operative imaging and so a method was needed that could be performed on digital radiographs. Secondly, previous studies have reported that Lewinnek's method is a reliable and accurate method for measuring acetabular component position on AP radiographs.[4,14] Although other methods for measuring acetabular component position have also been described,[4,6] some of these have been reported to be unreliable,[1,4] and our initial

Table 2. Comparison with recent studies investigating the reliability of Lewinnek's method for measuring acetabular component position.

Study	Number of hips measured in study	Method to measure anteversion	PACS software program used	Intra-observer reliability (ICC (95% CI))	Inter-observer reliability (ICC (95% CI))
Nomura et al.[13]	84	Lewinnek's	Not specified	AV: 0.93 (0.90–0.95) Inc: 0.97 (0.96–0.98)	AV: 0.95 (0.93–0.96) Inc: 0.98 (0.98–0.99)
Lu et al.[14]	60	Lewinnek's	PACS: Rogan-Delft View Pro-X™ (Rogan-Delft BV)	AV: 0.97 (0.95–0.98) Inc: 0.99 (0.99–1.0)	AV: 0.90 (0.85–0.93) Inc: 0.98 (0.98–0.99)
Nho et al.[4]	36	Lewinnek's	PACS: Impax: Agfa™ (Agfa HealthCare)	AV: 0.94 (0.86–0.97) Inc: NA	AV: 0.94 (0.91–0.97) Inc: NA

PACS: Picture Archiving and Communication System; ICC: intraclass correlation coefficient; AV: anteversion angle; Inc: inclination angle; NA: not applicable.

investigations of other methods found it was difficult to perform the required measurements on some types of acetabular components. Thirdly, Lewinnek's method can be performed using the digital measurement tools provided by basic diagnostic imaging software that is widely available in radiology departments. In our study, we used *InteleViewer™* software. The basic digital drawing and measurement tools in this software made it simple to superimpose the ellipse over the opening of the acetabular component and then to measure the long and short axis of the ellipse. Other recent studies have used specialized software such as *Ein-Bild-Roentgen-Analysis* (*EBRA*), *TraumaCad™* (Brainlab Inc) and *PolyWare™* (Draftware Developers Inc) that, while reportedly accurate, are expensive and not widely available.[6,7,15,16]

There are a number of limitations to this study. Firstly, we were unable to assess the accuracy of measuring acetabular component position on AP radiographs using Lewinnek's method by comparing to the gold standard of CT measurements because post-operative CTs were not available. The impact of pelvic tilt and pelvic rotation when measuring acetabular component position on AP radiographs is difficult to assess. It has been reported that for every 1° of pelvic tilt, anteversion is altered by 0.8°.[17] However, two recent, independent studies have reported that Lewinnek's method is an accurate method when compared to CT.[4,14] Secondly, femoral anteversion cannot be measured on AP radiographs. Recent studies have suggested that a target range based on combined femoral and acetabular anteversion position is more useful than a target range based on acetabular component position alone.[18,19] However, a study by Grammatopoulos et al.[16] stated that surgeons tend to implant the acetabular component before the femoral component and so need to have information about the acetabular component independently of the position of the femoral component.

Additional research investigating the accuracy of using *InteleViewer™* software to measure acetabular component position could be done by comparison with post-operative CT. This would allow the impact of pelvic tilt and rotation on radiographic measurements to be assessed.

Conclusion

Our study demonstrates that using a basic diagnostic imaging software program (*InteleViewer™*), acetabular component position can be reliably measured using Lewinnek's method. Given the widespread availability of such software, surgeons can be confident that they can consistently measure acetabular component position on digital AP pelvic radiographs. This method can be a simple and effective tool to audit the acetabular component position in THA.

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References

1. Kalteis T, Handel M, Herold T, et al. Position of the acetabular cup – accuracy of radiographic calculation compared to CT-based measurement. *Eur J Radiol* 2006; 58(2): 294–300.
2. Murray DW. The definition and measurement of acetabular orientation. *J Bone Joint Surg (Br)* 1993; 75(2): 228–232.
3. Liaw CK, Hou SM, Yang RS, et al. A new tool for measuring cup orientation in total hip arthroplasties from plain radiographs. *Clin Orthop Relat Res* 2006; 451: 134–139.
4. Nho JH, Lee YK, Kim HJ, et al. Reliability and validity of measuring version of the acetabular component. *J Bone Joint Surg (Br)* 2012; 94(1): 32–36.
5. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg (Am)* 1978; 60(2): 217–220.
6. Shin WC, Lee SM, Lee KW, et al. The reliability and accuracy of measuring anteversion of the acetabular component on plain anteroposterior and lateral radiographs after total hip arthroplasty. *Bone Joint J* 2015; 97-b(5): 611–616.
7. Westacott DJ, McArthur J, King RJ, et al. Assessment of cup orientation in hip resurfacing: a comparison of TraumaCad and computed tomography. *J Orthop Surg Res* 2013; 8: 8.

8. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. *Clin Orthop Relat Res* 2011; 469(2): 319–329.
9. Cumming G. *Understanding the new statistics: effect sizes, confidence intervals, and meta-analysis*. New York: Routledge; 2012.
10. Kelley K, Maxwell SE and Rausch JR. Obtaining power or obtaining precision. Delineating methods of sample-size planning. *Eval Health Prof* 2003; 26(3): 258–287.
11. Zou GY. Sample size formulas for estimating intraclass correlation coefficients with precision and assurance. *Stat Med* 2012; 31(29): 3972–3981.
12. Streiner DL, Norman GR and Cairney J. *Health measurement scales: a practical guide to their development and use*, 5th ed. Oxford: Oxford University Press, 2015.
13. Nomura T, Naito M, Nakamura Y, et al. An analysis of the best method for evaluating anteversion of the acetabular component after total hip replacement on plain radiographs. *Bone Joint J* 2014; 96-b(5): 597–603.
14. Lu M, Zhou YX, Du H, et al. Reliability and validity of measuring acetabular component orientation by plain anteroposterior radiographs. *Clin Orthop Relat Res* 2013; 471(9): 2987–2994.
15. Esposito CI, Gladnick BP, Lee Y-Y, et al. Cup position alone does not predict risk of dislocation after hip arthroplasty. *J Arthrop* 2015; 30(1): 109–113.
16. Grammatopoulos G, Thomas GE, Pandit H, et al. The effect of orientation of the acetabular component on outcome following total hip arthroplasty with small diameter hard-on-soft bearings. *Bone Joint J* 2015; 97-b(2): 164–172.
17. Malik A, Wan Z, Jaramaz B, et al. A validation model for measurement of acetabular component position. *J Arthrop* 2010; 25(5): 812–819.
18. Malik A, Maheshwari A and Dorr LD. Impingement with total hip replacement. *J Bone Joint Surg (Am)* 2007; 89(8): 1832–1842.
19. Ranawac CS and Maynard MJ. Modern technique of cemented total hip arthroplasty. *Techn Orthop* 1991; 6(3): 17–25.