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McWilliams, AB, Grainger, AJ, , O'Connor, PJ et al. (3 more authors) (2012) Assessing reproducibility for radiographic measurement of leg length inequality after total hip replacement. HIP International, 22 (5). pp. 539-544. ISSN 1120-7000

https://doi.org/10.5301/HIP.2012.9751

Assessing Reproducibility for Radiographic Measurement of Leg Length Inequality for Total Hip Replacement.

Running Title:

Assessing Reproducibility for Radiographic Measurement of LLI for THR.

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Financial Support

This work was supported by the NIHR (National Institute for Health Research) through funding of the Leeds Musculoskeletal Biomedical Research Unit. In addition this work was partially funded through WELMEC, a Centre of Excellence in Medical Engineering funded by the Welcome Trust and EPSRC, under grant number WT 088908/Z/09/Z.

Informed consent

All radiographs used were of patients who had given informed consent for the images to be used in research.

The project was part of a larger study for which ethical approval was sought and obtained from the Leeds West National Health Service Ethics Committee. Ref: 09/H1307/63

Conflict of interest

The Authors declare no conflict of interest

Presentation at meeting

The preliminary findings for this research were presented at the British Hip Society Annual meeting, Sheffield, U.K. 2010

Abstract

Leg length inequality (LLI) following total hip replacement (THR) can cause considerable morbidity Although it was described when the technique was popularized in the 1960s, it remains a significant challenge to arthroplasty surgeons . This study reviews the established practice for the measurement of LLI on plain AP radiograph, and compares these techniques to two methods used locally. The radiographs of 35 patients were measured using four techniques (Woolson, Williamson, 'Leeds' and 'Direct'). All four methods had an ICC of ≥ 0.90 for inter reader reliability. The intra observer reliability of repeat measures was higher for the Leeds and direct methods on remeasurement of the same films, while the Woolson and Williamson methods performed slightly better for serial radiographs. This study shows that the four methods are comparable, and the Leeds method provides extra information on component position as well as an overall measure of LLI.

Assessing Reproducibility for Radiographic Measurement of Leg Length Inequality for Total Hip Replacement.

Introduction

Leg length inequality following an otherwise successful arthroplasty can result in considerable morbidity and patient dissatisfaction[1]. Complications range from mechanical symptoms such as limp and early fatigue, to lower back pain, pelvic tilt, other joint pain, nerve palsy and increased wear of the implant[2-7]. Ultimately, symptomatic leg length inequality may require a revision operation, with all of the associated risk and further morbidity[7].

Leg length inequality has increasingly significant medico-legal consequences and is now one of the leading causes of litigation surrounding total hip arthroplasty (THR) in the USA. In recent years, LLI has become the third most common individual cause of THR related litigation in the UK, with the cost of individual claims as high as £600,000 GBP[7-10]

Assessment of leg length inequality is typically undertaken clinically by tape, ruler or block measurement of true and apparent leg length, although clinical measurement has been shown to be inaccurate by 10mm or more[11-13]. It is important therefore that any LLI is quantified accurately, usually using a plain AP radiograph of the pelvis and both hips ordered routinely as part of the consultation. Although other methods, such as CT scans, are considered the gold standard for the radiographic measurement of leg length inequality, the cost and increased exposure to ionising radiation make CT use unsafe and impractical to perform routinely, with this approach being reserved for exceptional circumstances such as when revision surgery is being actively considered.

It is also important when considering revision surgery to assess the cause of the post operative LLI. This has been classified by Parvizi et al. A type 1 structural LLI, exists where the components are directly responsible for the lengthening, for example when a stem has not been fully inserted and is proud. A type 2 structural LLI occurs when lengthening is accompanied by component malposition, for example when poor component version mandates increased soft tissue tension for stability with resulting lengthening[14]

It is therefore vital to accurately diagnose the cause of the LLI, as revision of the either the wrong component in a type 1 or a single component in a type 2 can result in an unstable prosthesis which will require further revision surgery.

A literature review identified 22 papers that specifically discussed the radiographic measurement of LLI. Nine of the 22 described the Williamson method[15-22] and 10 of the 22 papers used the Woolson method [23-33]. It is notable that while both methods are described as ‘validated’ there was very little documentation of the validation process.

LLI following THR remains a significant challenge to arthroplasty surgeons and is complicated by the fact that there is little agreement about many of its aspects.

This study therefore aims to assess the reliability of methods for quantifying post THR leg length inequality described in the literature and compare them with methods used in the Leeds Teaching Hospitals NHS Trust.

Methods

The radiographs of 35 patients, originally taken as part of the standard consultation, were extracted from the case notes of patients attending the senior author’s (MHS) outpatient arthroplasty clinic. Ethical approval was provided by the Leeds West NHS ethics committee and all images were obtained from patients who had given prior consent for use for research purposes. Radiographs were taken according to the local standardised operating protocol, with the patient in a supine position with both hips resting in internal rotation. A 25mm calibration ball (AGFA, Wilmington, MA) was placed in the groin at the same height above the table as the greater trochanter and the image centred on the pubic symphysis.

Four methods of quantifying LLI from AP radiograph were used. The Woolson, Hartford et al method [33] (Woolson method) (Fig 1), the Williamson and Reckling method [22] (Williamson method) (Fig 2) which are prominent in the literature, a

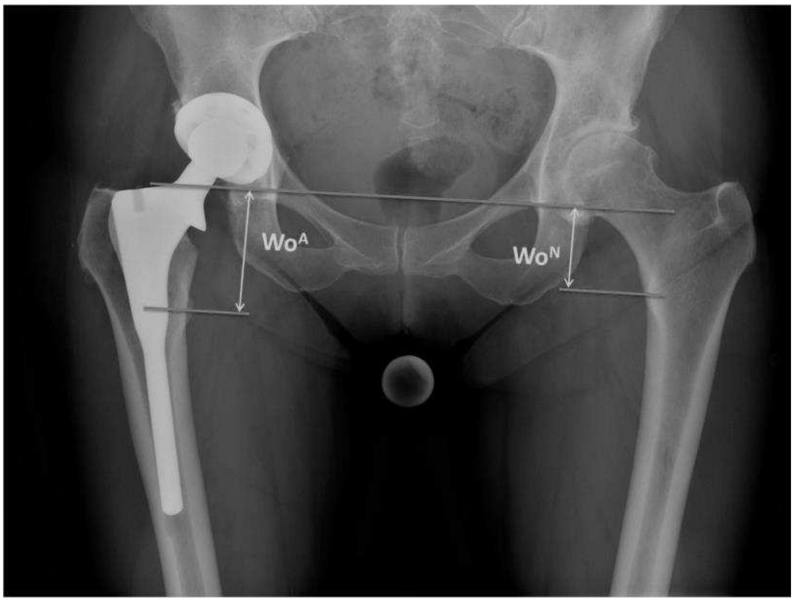

Fig 1 The Woolson method.

A reference line is drawn through the most inferior part of the acetabular tear drops. Two lines parallel to this are drawn through the centre of the lesser trochanter. The difference in the perpendicular distance between the two lines is defined as the leg length discrepancy

‘Direct’ method (Fig 3) and a locally developed ‘Leeds’ method (Fig 4).

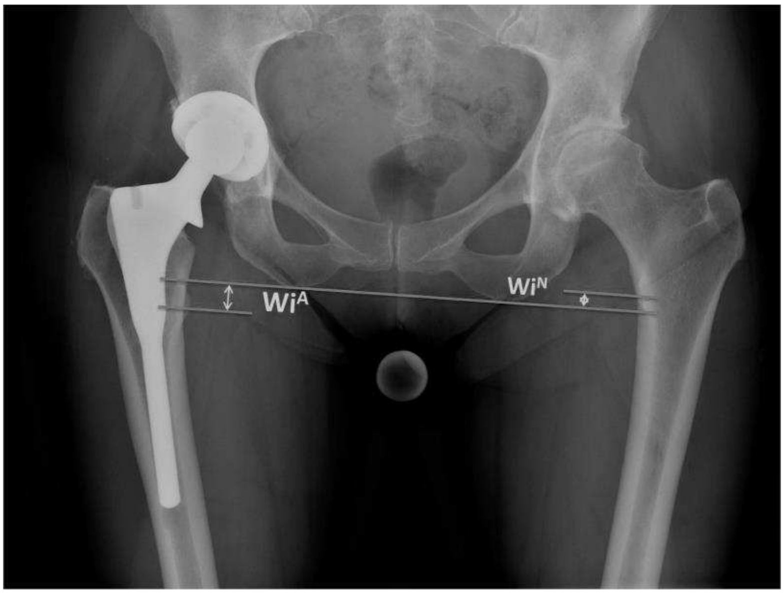

Fig 2 The Williamson method.

A reference line tangential and parallel to the most inferior portion of theischia. Two further parallel lines are drawn and the perpendicular distance between the lines measure, the difference between the two measurements is the discrepancy.

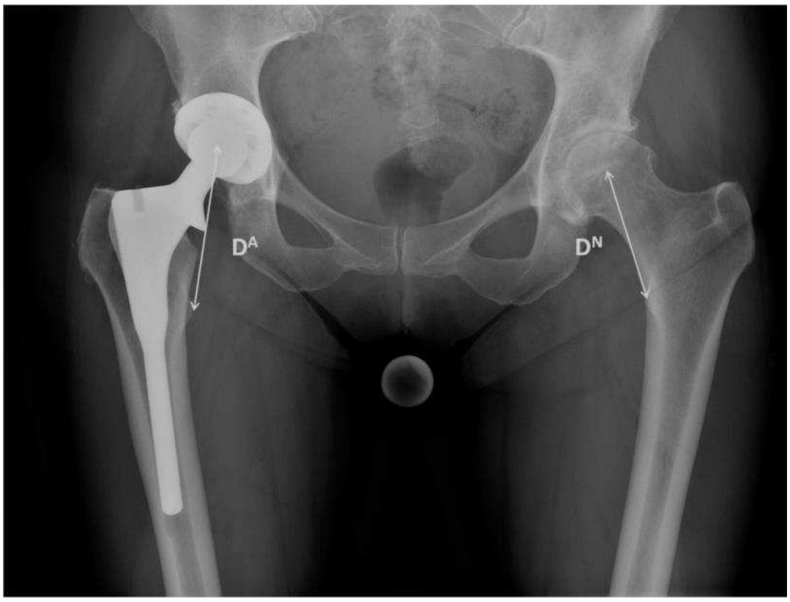

Fig 3 The Direct method

This is a measurement of the straight line distance between the femoral centre of rotation and the apex of the lesser trochanter. The difference in the measurement for both hips is the leg length discrepancy.

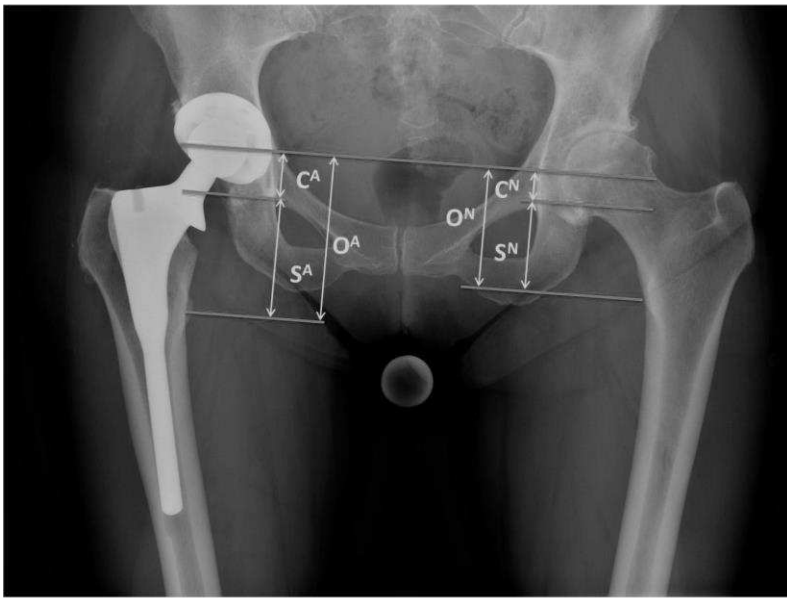

Fig 4 The Leeds Method

An initial reference line is drawn between the centres of femoral rotation. Two further line are drawn parallel to this. The first at the level of the most inferior part of the acetabular teardrop to give measurement C, which corresponds to any inequality due to the position of the cup. The second is at the level of the centre of the lesser trochanter to give measurement S, which corresponds to inequality due to position of the stem The sum of the two is measurement O which corresponds to the overall leg length inequality.

The measurements, to the nearest millimetre, were made by two senior consultant musculoskeletal radiologists (AJG and PJO) using the Leeds Teaching Hospitals NHS Trust PACS system (AGFA, Wilmington, MA). The original 35 radiographs were measured using the four methods. Subsequently 10 of these radiographs were picked at random and re-read after at least three months.

To explore the reliability of the acquisition protocol, in addition to reader consistency, in 24 radiographs of patients who had undergone serial imaging but no further surgery in the interim, follow-up images were also measured and compared with baseline radiographs.

Data were analysed using SPSS v16 and reliability was quantified through the generation of Intra Class Correlation Coefficients (ICC) and Limits of Agreement. ICC model 3,1 was used to determine inter-reader reliability and ICC model 1,1 was used to evaluate between-day reliability and consistency in measurement from serial images.

Results

Of the 35 patients in our sample, five patients (14%) had native hips 21 patients 60% had a undergone unilateral total hip replacement and nine patients (26%) had received bilateral hip replacements.

For the subset of 24 in whom serial radiographs were obtained, the mean time between the first and second x-ray was 393 days (0-7052 days).

The ICCs for inter-reader reliability are summarised in table 1. All four methods show high ICCs for inter-reader agreement (>0.9) and limits of agreement between raters of <10mm.

Table 1 Inter-reader reliability of leg length inequality measurement:

Leg Length Measure	Inter-reader $ICC_{(3,1)}$	Mean difference (mm)	95% LOA (mm)
Direct	0.91	1.00	±5.31
Leeds	0.90	0.60	±6.02
Williamson	0.90	0.26	±7.68
Woolson	0.91	-0.80	±8.26

When measuring intra-reader reliability for the same radiograph when assessed at two different time points, the Direct and Leeds methods performed slightly better

Table 2 Intra-reader reliability of leg length inequality measurement, same radiographs re-measured after 3 months:

	Intra-reader ICC$_{(1,1)}$ (Reader 1) n=10	Intra-reader ICC$_{(1,1)}$ (Reader 2)n=10
Leg Length Ineq. Measure		
Direct	0.96	0.97
Leeds	0.95	0.90
Williamson	0.87	0.88
Woolson	0.65	0.89

than the Williamson and Woolson method (table 2)

In the subset of 24 radiographs taken on two different occasions (Table 3), the variability of the acquisition protocol combined with reader variation increased error such that all four techniques exhibited only moderate reliability.

Table 3 Intra-reader reliability of leg length inequality measurement, radiographs taken at different occasions:

Leg Length Ineq. Measure	Intra-reader ICC$_{(1,1)}$ (Reader 1) n=24	Intra-reader ICC$_{(1,1)}$ (Reader 2) n=24
Direct	0.63	0.53
Leeds	0.63	0.50
Williamson	0.77	0.76
Woolson	0.77	0.71

Discussion

With the broadening of the indications for THA and increase in patient expectation, leg length inequality following total hip replacement is receiving more attention both clinically and medico-legally. LLI can result in significant patient morbidity and can require major revision surgery to correct.

While there is no single agreed method for the measurement of LLI on a plain radiograph, the literature has focused primarily on two methods, the Woolson and the Williamson methods. Despite the widespread use of these techniques in clinical practice and research there is little published validation of the method.

Woolson in his original paper describing the technique reported being able to determine LLI to within 0.5mm[33] . This has since been quoted as the accuracy of the measure[28]. We found no substantive data in the literature describing the error or reliability of the widely used techniques and, to our knowledge, ours is the first study to compare techniques directly.

In interpreting the agreement data, the radiologists reported qualitatively that it was occasionally difficult to identify the acetabular tear drop where, for instance, a cemented cup was used. Additionally it was felt harder to accurately identify the centre of rotation in the native, generally arthropathic, femoral head.

In this study, no allowance was made for the rotation of the pelvis, or for flexion, abduction or adduction and all measures were acquired and measured according to standard clinical practice. With two point measurement methods, trigonometry dictates that a fixed flexion deformity of 25° will result in a reduction in measured LLI of approximately 10%. Also when using the centre of femoral rotation as a reference, adduction and abduction deformities will introduce only minimal error when measuring relative to a fixed reference on the femur. Factors such as patient position when supine for the radiograph and the relative positions of the calibration ball, tube and radiographic plate are all potential sources of reduced reliability. It is clear that despite clinical protocols for AP Pelvic/Hip radiography direct comparison of measurements for LLI for any method should be made with caution. For this study, greater accuracy could probably have been achieved using a more highly protocolized approach but this study was intended to explore the real-world reliability of the techniques.

All four methods were comparable for inter-reader and intra reader reliability of measures taken from the same films, and for intra-reader reliability of radiographs taken at different occasions which was moderate. While all methods proved satisfactory for assessing LLI overall, the Leeds Method has the potential extra advantage of being able to distinguish between LLI due to cup position and LLI due to stem position. If the limb is left long (ie O^A is greater than O^N) and it is due to the stem, measurement S^A will be greater than S^N. However if the lengthening is due to the cup position, the measurement C^A will be smaller than C^N.

The Leeds Method for the measurement of leg length inequality has potential applications for the audit of practice. As it is able to quantify the problems due to either the cup, stem or both the Leeds method can provide vital information by aiding discrimination between a type 1 and 2 structural LLI. It is able therefore to assist in the planning of revision surgery and reducing the chances of inappropriate surgery.

In conclusion, we propose a novel method for evaluating post THR limb length inequality. We have provided the first direct comparison of the methods currently in common use and conclude that all the methods described previously, including the new method, demonstrate comparable reliability. The novel method has the added advantage of differentiating between cup or stem position as the cause of any LLI.

Acknowledgements

This work was supported by the NIHR (National Institute for Health Research) through funding of the Leeds Musculoskeletal Biomedical Research Unit. In addition this work was partially funded through WELMEC, a Centre of Excellence in Medical Engineering funded by the Welcome Trust and EPSRC, under grant number WT 088908/Z/09/Z. The authors wish especially to thank Dr Elizabeth M A Hensor PhD for her assistance with the statistical analysis of the data.

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