Accuracy of the relationship between the centre of the femoral head and tip of greater trochanter[☆]

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ABSTRACT

Introduction: There have been many techniques described to measure limb length discrepancy and methods to correct this during total hip arthroplasty; preoperative and intraoperative. These techniques have been either inconsistent, cumbersome or not readily available due to expense. There is a lack of evidence to support one particular approach. The aim of this study is to assess the accuracy of the relationship between the centre of the femoral head and tip of the greater trochanter.

Methods: A prospective observational cross-sectional study, with patients undergoing Positron emission tomography-CT (PET-CT) scan between 20th January 2016 to 31st December 2016. Exclusion criteria were patients undergoing PET-CT scan for musculoskeletal condition, those found to have existing pathology of the hip (including previous trauma) and those aged younger than 18 years and over 50 years.

Results: There was a total of 116 participants, giving 232 hips for assessment and 184 hips were measured by two observers. The mean age of the sample was 40.51 years. The mean distance of the centre of the femoral head from the tip of the greater trochanter was 8.53 mm distal (with a standard deviation of 4.97). Analysis of the right and left hip measurements gave a Pearson correlation coefficient of 0.87, suggesting a good correlation. Interobserver analysis demonstrated fair agreement with intra-class correlation coefficient of 0.52.

Conclusion: The evidence of this study and that in literature suggests that this landmark is unreliable and should no longer be used.

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1. Introduction

The National Joint Registry of England and Wales (NJR) reported that 83,886 primary total hip arthroplasty (THA) procedures and 8367 revision hip arthroplasty procedures were performed in 2015.¹ The most common indication for primary hip arthroplasty is osteoarthritis. Discrepancy of lower limb length is common within the general population, and may be exaggerated by osteoarthritic changes, however it is often not recognized by the individual due to compensatory mechanisms. The clinician must fully assess for leg length inequality as restoration of equality is an important

component of THA. It has been reported that the incidence of leg length discrepancy after THA is between 1 and 27%.² The limb length discrepancy that becomes perceivable to the patient varies, but may affect gait, posture, increase the risk of dislocation and impact on adjacent joints.^{3,4} Lengthening of the operative side is more common than shortening, however they both have implications. Patients are more likely to notice if a limb has been lengthened rather than shortened.⁴ A limb length discrepancy can lead to nerve palsy and back pain.⁵ Whilst a degree of limb length discrepancy is considered acceptable, and managed with shoe lifts, there is little consensus of the discrepancy deemed manageable.⁶ It is also a common cause for litigation after THA surgery, with the implication it impacts on outcome.³ The surgeon must have a thorough understanding of how to assess and adjust any discrepancy in the perioperative setting.

There have been many techniques described to measure limb length discrepancy and methods to correct this during THA;

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preoperative and intraoperative.^{7–11} Whilst preoperative templating using plain radiography has been used with both printed templates and computer templating software, this has not been found to be consistent and remains an unreliable method for correcting limb length discrepancy.¹² The use of intraoperative navigation systems to restore hip biomechanics has been touted, but this remains expensive and cumbersome, with a steep learning curve, and is not readily available.¹³

There have been a number of intraoperative techniques described, which rely on a measurement from the pelvis to the femur (typically the greater trochanter). These include iliac fixation pins, calipers, infracotyloid pins and using fixed suture lengths. However, all of these techniques rely on reproducibility of the operating table and patient position (hip abduction, flexion and rotation), and there is a lack of evidence to support either one.^{7,8,14–17}

A common intraoperative technique involves using the tip of the greater trochanter as a reference point for the centre of the femoral head. This is a 'surgical pearl' taught to many trainees for use in hip arthroplasty procedures. With an ever-increasing understanding of the kinematics of the hip there should be robust scientific evidence to support the use of this technique.

2. Method

In discussion with the radiology department at the study institution, it was identified that a greater number of patients undergo Positron emission tomography-computed tomography (PET-CT) scan that includes the hip joint and full-length femur, compared to computed tomography (CT) scan. It was agreed that patients undergoing PET-CT scan involving the pelvis for investigation of non-musculoskeletal pathology would be prospectively recruited. Between the 20th January 2016 and 31st December 2016, 304 patients attending a PET-CT scan were prospectively recruited into the study. On attending the scan appointment, they were given a patient information sheet, health questionnaire and consent form. The inclusion criteria included all patients undergoing PET-CT scan of the pelvis for non-musculoskeletal conditions. The participants must be between 18 and 50 years of age, so that subjects had minimal further skeletal growth left and to ensure changes present were not due to an osteoarthritic process. Exclusion criteria were patients undergoing PET-CT scan for a musculoskeletal condition, those found to have existing pathology of the hip (including previous trauma) and those aged younger than 18 years and over 50 years. The authors wanted the study population to be representative of an asymptomatic population. A patient referred for a PET-CT scan for musculoskeletal conditions would suggest pre-existing pathology that may impact on the results of the study, and it was agreed to exclude these patients. Participants with incomplete questionnaires were also excluded.

188 patients were excluded, leaving 116 patients and 232 hips participating in the study. Of the 188 patients excluded, the main reasons were hip pain documented on health questionnaire and incomplete questionnaires.

The PET-CT scans were performed using standard departmental protocol to ensure standardisation; however, the hip joints were reformatted by a single person to ensure standardisation. The reformatted triplanar images were then viewed on the Centricity™ (GE Medical Systems Ltd, Buckinghamshire, United Kingdom) picture archive and communication system (PACS) and the measurement carried out for the distance between the tip of the greater trochanter and centre of femoral head (Figs. 1–3). The measurements were performed by two observers, both of whom were specialty training registrars in their penultimate year of training. Each observer was to complete the measurements for all the

Fig. 1. An example of triplanar CT scans using three planes to identify the true midpoint of the femoral canal.

Fig. 2. An example of identifying the centre of the femoral head using coronal and axial CT planes, while maintaining the true long axis of the femur.

participants. Unfortunately, one observer was unable to complete 24 of the participants' measurements in time, thus these patients have only one set of measurements. These observers were only provided with a hospital number for the participant and access only to a folder with the anonymised PET-CT scan and no other imaging for the patient. Each observer inputted their measurements into a password protected spreadsheet that was amalgamated with the measurements from the other observer on completion of the study by another author.

Statistical analysis was performed using R software, which is a free software environment, and the 'psych' package.^{18,19}

Fig. 3. An example of the measurement of the distance from the tip of the greater trochanter to the femoral head centre, using the true long axis (Fig. 1) and the true centre of the femoral head (Fig. 2).

The study had Research Ethics Committee approval and local Research and Development approval (North West – Greater Manchester South Research Ethics Committee. Reference: RJ115/N131). There were no adverse events reported and the study was conducted in compliance with the principles of the Declaration of Helsinki (1996).

3. Results

There was a total of 116 participants with hips that had no identifiable pathology nor any symptoms related to possible pathology (Table 1). This gave a total of 232 hips to assess; observer one assessed all 232 hips, whilst observer two only assessed 184 hips. The mean age of the sample was 40.51 years (range from 20 to 50 years). There was a slight female predominance, with 64 females and 52 males participating. The mean distance of the centre of the femoral head from the tip of the greater trochanter was 8.53 mm (mm) distal (with a standard deviation of 4.97). The range of measurements was from –11.34 mm (the centre of the femoral head was proximal to the tip of the greater trochanter if a negative reading) to 21.73 mm.

Analysing the relationship between the measurements for the right hip and left hip performed, there was significant correlation. The mean difference between the measurements was -0.49 ± 2.55 mm (p -value <0.001), with a Pearson correlation coefficient of 0.87. With interobserver reliability analysis there was a fair agreement seen with an intraclass correlation coefficient of 0.52.

4. Discussion

This study has evaluated the relationship of the tip of the greater trochanter to the centre of the femoral head, whether there was any

correlation between measurements for right and left hips, and if the technique used had good interobserver reliability. This relationship has been utilized to ensure correct leg length during THA. It has been suggested that the tip of the greater trochanter is level in height with the centre of the femoral head, and thus can be used to position the femoral prosthesis.

There have been a number of techniques described to measure limb length discrepancy, preoperatively and intraoperatively.^{7–13} There has been no consensus as to the best technique, as they each have advantages and disadvantages. The decision is very surgeon dependent at the current time. Altering the limb length results in a change in the biomechanics of the hip joint, which may lead to poor functional outcome, instability and excessive wear of the components. Leg lengthening of one or more centimetres directly affects walking capacity, limping and patient satisfaction but not pain relief.²⁰

This study demonstrated that the tip of the greater trochanter is not an appropriate landmark for the position of the centre of the femoral head. The mean distance of the centre of the femoral head from the tip of the greater trochanter was 8.53 mm distal in this study. Thus, if surgeons were to use the tip of the greater trochanter as a landmark, this would result in inadvertent leg lengthening. As Table 2 demonstrates this result is comparative to other studies. There was a similar range of measurements in these studies. The study by Unnanuntana et al.²¹ reported a mean distance of 3.24 ± 5.66 mm for this measurement, which is a great deal less than the mean measurement in this study. However, it should be noted that this was a cadaveric study using unclaimed remains from a morgue between the period 1912 and 1938. These samples were retrieved after a significant period of time, and we do not know how well they were preserved and certainly over this time the architecture of the bone may have altered. Theivendran et al.²² also reported a mean measurement of 3.4 mm, but in patients with osteoarthritis awaiting THA. The presence of degenerative change within the joint, would make accurate measurements more difficult to obtain, and the use of radiographs relies on consistency of magnification correction and limb position. The other studies^{23–25} had a similar mean measurement and range of measurements as that obtained in this study.

A significant correlation was demonstrated between the left and right hips (Pearson correlation coefficient of 0.87), which has not been found in previous studies. This would suggest that measuring the contralateral hip could provide accurate assessment of the hip to be operated on, which is particularly useful in the trauma setting. Analysis suggested that interobserver reliability was fair for 184 hip measurements, with an intraclass correlation coefficient of 0.52. The study by Unnanuntana et al.²¹ looked at correlation of measurements between sides and interobserver reliability using Pearson's correlation coefficient. They reported poor correlation between sides, with a coefficient of 0.41, however a better interobserver reliability than my study, with a coefficient of 0.85. This may be related to the fact it was a cadaveric study, with measurements taken from a digital photograph, that may be easier to measure from than radiographic images on a computer screen. The architecture of the limbs may have altered at differing rates over the significant time period from the patient dying to the study commencing, which may explain the difference in measurements between sides.

The advantage of this study was the relatively young age of the sample, with a mean age of 40.51 years being lower than all other studies performed on living participants. This would reduce the risk of including patients with early degenerative changes, that would affect the measurements. The size of the study sample was also greater than the other studies, which should suggest greater representation of the population and strength of the results.

Table 1
Table of results.

Study number	Right GT-Centre of femoral head (mm) - 1 observer	Right GT-Centre of femoral head (mm) - 2 observer	Left GT-Centre of femoral head (mm)- 1 observer	Left GT-Centre of femoral head (mm)- 2 observer
2	11.15		9.51	
7	6.15		5.33	
10	4.43		-1.37	
14	2.26		3.07	
15	1.48		4.8	
18	14.14		12.84	
22	17.25		12.86	
24	9.63		6.32	
25	3.68		4.88	
27	11.72		6.32	
31	6.86		7.62	
34	9.51		7.08	
35	3.47		3.93	
38	7.55		11.11	
40	2.09		0.61	
42	13.79		9.34	
46	-11.34		-6.02	
49	6.18		7.73	
50	3.13		3.21	
53	10.85		11.42	
54	7.64		7.3	
57	7.75		9.22	
59	6.4		6.32	
60	4.43		7.39	
61	11.57	7.24	10.74	7.43
62	11.5	8.75	11.15	14.79
65	10.59	11.93	11.74	11.43
68	10.27	5.59	10.35	10.41
71	13.31	12.51	11.57	11.49
72	9.79	4.96	8.91	10.16
80	8.05	8.76	8.94	7.87
87	11.04	8.14	12.19	12.18
94	3	5.01	3.57	4.81
96	7.85	2.22	6.57	2.04
99	8.91	5.64	8.13	3.95
100	9.48	12.76	9.44	10.36
102	19.55	16.89	15.53	13.79
103	10.36	7.95	7.71	8.38
104	10.44	8.3	11.42	11.35
105	13.9	10.3	16.62	9.88
106	4.23	-0.87	9.33	5.49
108	10.49	5.28	11.73	8.51
109	13	7.71	12.88	11.56
110	17.53	12.82	16.54	10.76
111	9.1	7	11.15	9.26
112	16.09	13.29	15.12	12.31
113	16.8	13.3	13.64	11.4
114	8.61	9.35	7.95	8.26
118	1.9	-8.5	2.2	-5.7
120	9.34	2.4	3.41	-4.5
124	8.71	3.1	9.95	2
125	12.47	6.6	12.87	-5
126	11.52	-3.3	10.36	2.5
127	8.48	2.3	7.32	-1.5
128	17.68	6.1	11.68	7.5
130	16.4	10.46	13.32	9.72
131	17.91	125	13.63	9.4
132	13.73	12.3	12.25	11.5
133	12.88	6	17.21	9.1
134	10.88	7.5	6.91	7.96
135	12.04	9	9.84	8.55
136	10.27	8.83	14.34	10.9
137	12.04	8.83	10.53	7.1
139	12.14	8	12.68	9.5
140	10.36	7.6	11.82	5
141	7.65	6.2	6.39	6.5
142	14.25	6.4	12.56	7.25
145	9.8	7.99	8.27	4.7
148	3.57	2.4	3.87	1
149	7.98	4	7.53	1.6
152	6.38	5.4	6.94	-3.8
153	11.52	5.12	10.36	7.3
154	12.08	8.85	12.26	8.7
155	13.56	8.5	11.09	6.59

(continued on next page)

Table 1 (continued)

Study number	Right GT-Centre of femoral head (mm) - 1 observer	Right GT-Centre of femoral head (mm) - 2 observer	Left GT-Centre of femoral head (mm)- 1 observer	Left GT-Centre of femoral head (mm)- 2 observer
159	12.46	7.96	11.93	8.85
161	19.5	15.59	17.59	14.85
162	10.73	8.66	9.6	7.2
166	21.73	14.79	18.7	11.82
167	4.44	4	3.18	-5.6
168	13.3	9.6	10.19	7.96
171	20.68	13.6	13.39	12.1
173	13.12	9.5	12.69	9.82
174	7.29	-1.93	9.63	-7.42
175	7.72	11.87	4.5	7.07
183	10.24	12.36	14.42	14.06
187	4.15	3.19	3.8	6.14
188	7.82	8.73	12.66	10.29
191	3	1.83	4.94	-2.1
193	8.29	8.5	8.68	9.23
194	4.85	6.92	4.02	3.39
196	6.13	8.26	4.5	10.22
197	-1.74	-1.27	3.6	2.1
198	9.57	10.94	8.62	6.87
199	8.2	7.47	6.22	7.65
201	10.58	14.3	10.43	11.6
203	5.72	8.61	4.08	7.37
204	7.57	6.14	6.7	8.91
205	8.66	12.19	12.58	15.65
206	0.62	2.4	1.18	3.05
207	3.73	9.4	4.53	10.78
208	8.94	10.73	10.51	15.32
209	10.61	12.53	6.03	8.54
210	5.54	9.81	4.62	11.47
211	-1.77	3.19	-2.2	-4.56
212	-0.66	1.56	0	1.7
213	9.32	9.44	7.94	11.77
214	7.13	15.37	8.93	15.25
215	-3.29	-4.27	-2.04	-1.61
216	3.96	8.59	2.59	8.64
219	7.14	12.16	5.67	10.4
220	2.78	12.96	-5.05	11.36
221	15.27	17.99	11.32	17.51
222	5.59	10.81	6.54	10.28
223	1.11	4.51	0.8	3.61
224	4.26	6.65	6.27	9.17
228	2.97	7.46	3.71	8.72

Table 2

A table to collate study results with previous studies. Tip of greater trochanter (GT) and centre of femoral head (FH).

	This Study	Theivendran and Hart ²²	Memon et al. ²³	Unnanuntana et al. ²¹	Panichkul and Pinsornsak ²⁴	Antapur and Prakash ²⁵
Mean Age of patients (years)	40.51 (20–50)	67.2 (29–91)	71 (42–93)	29	67.3 (45–94)	Prior to THA
Study numbers	232	225	150	200	100	150
Mean GT-FH measurement (mm)	8.53 (-11.34–21.73)	3.4 (-10–20)	8.64 (-7.5–22.5)	3.24 (-12–22)	8 (-5–14)	9.5 (-9–24)
Method	PET-CT	Radiography	CT	Cadaveric	Radiographs	Radiographs
Correlation coefficient for right and left siderowhead	0.87	—	—	0.46	—	—
Interobserver reliability	0.52			0.85		

Unnanuntana et al.²¹ had a mean age of 29 years, however this was a cadaveric study of unclaimed remains from a morgue.

PET-CT scans were utilized in this study because computed tomography (CT) imaging has been shown to provide more reproducible measurements with accurately identifiable landmarks.²⁶ A greater number of appropriate PET-CT scans were performed than CT scans in my institution. Two-dimensional (2D) imaging, plain radiography, has historically been utilized to assess the hip joint for pathology and morphology.²⁶ The typical views utilized are anteroposterior and lateral. This modality is readily available in most hospitals and results are available almost instantly, with minimal

discomfort for the patient. For a skeletally mature patient plain radiographs can be used to assess hip joint space for potential degenerative change, the depth of the acetabulum, femoral neck-shaft angle, the femoral head-neck offset and femoral version.²⁶ However, with 2D imaging there continues to be inconsistency and lack of reproducibility of these measurements.²⁷ There is greater discrepancy between 2D imaging measurements of the proximal femur version and anatomic measurements, compared to CT imaging measurements.^{26,27}

The introduction of three-dimensional (3D) imaging, computed tomography (CT) and magnetic resonance imaging (MRI), has

provided the clinician with new and more accurate information regarding the proximal femur and acetabulum.^{27,28} CT imaging has the disadvantage of not being easily accessible in all hospitals, which makes standardisation and reproducibility of measurements difficult. Also, CT imaging involves an increased dose of radiation, with the radiation dose of the hip examination estimated to be ten to twenty times greater than for a single anteroposterior plain radiography.²⁸

The use of 2D imaging continues to be adequate for simple surveillance purposes, as long as the patient is correctly positioned, a standard technique and measurement protocol is utilized. However, for more detailed assessment of hip morphology and reliable measurements the use of 3D imaging is being advocated, where available. Given the concerns regarding radiation dosage, MRI is superseding CT imaging for the assessment of intra-articular hip pain, however this is not always as available in the acute scenario. CT imaging remains the first choice for osseous assessment and accurate measurement of the acetabulum and proximal femur.²⁸

Incomplete health questionnaires were the most common reason for exclusion of a participant. This could have been avoided if an investigator was present at the time of PET-CT scan, to ensure the form was completed to satisfaction. The study was reliant on the PET-CT scan receptionist distributing questionnaires and collecting them afterwards. This receptionist could be different from day-to-day and they had varying interests in completing this task; they were already busy with their own work and this task was not a priority for them; and they would not check to see if the health questionnaire was completed.

The fact that one of the observers did not complete all the measurements in time was also a factor that affected the results of this study and is something that would be addressed in the future. The interobserver reliability analysis was limited by having only 184 measurements to assess, which may have had an impact on the result.

5. Conclusion

Limb length discrepancy has been reported to occur in up to a third of patients after THA.⁴ This study has confirmed, with triplanar PET-CT imaging, that the height of the greater trochanter is not an accurate intraoperative landmark for the centre of the femoral head. This technique should not be used any longer based on the outcome of this study and current literature. Future work requires assessment and comparison of other methods to identify a 'gold standard' technique to reduce error and optimize patient outcomes.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jcot.2018.08.020>.

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