Influence of Acetabular and Femoral Version on Fractures of the Femoral Neck

A. Frost MRCS, G. Pavlou MRCS, P. J. Richards FRCR,
J. Belcher BSc MPhil PhD, V. Jasani FRCS

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Abstract

Background Fractures through the proximal femur are broadly grouped into intertrochanteric fractures and intracapsular fractures. It is not clear why a patient may sustain an intertrochanteric fracture as compared with an intracapsular fracture. There is an established relationship between relative hip retroversion and the development of osteoarthritis. We postulate retroversion also may be a risk factor for having intracapsular fractures develop.

Questions/purposes We looked specifically at the geometry of the hip to analyze the possibility of a relationship between acetabular version, femoral version, and Mckibbin's instability index and fracture type.

Patients and Methods We recruited 40 patients with fractures of the femoral neck for the study. There were 15

men and 25 women with a mean age of 80 years (range, 57–92 years). There were 14 intertrochanteric fractures and 26 intracapsular fractures. After treating their fracture, the contralateral hip was scanned in a CT scanner and assessed by two independent observers to establish the acetabular and femoral version.

Results We found no correlation between proximal femoral fracture type and the contralateral femoral version, femoral neck length, acetabular version, or Mckibbin's instability index or between fracture type and age or gender.

Conclusions There appears to be no correlation between proximal femoral fracture type and acetabular or femoral version.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

A. Frost (✉), G. Pavlou, V. Jasani
Department of Trauma and Orthopaedics, University Hospital
of North Staffordshire, Princes Road, Stoke-on-Trent ST4 7LN,
UK
e-mail: afrost@doctors.net.uk

P. J. Richards
Department of Radiology, University Hospital of North
Staffordshire, Stoke-on-Trent, UK

J. Belcher
Statistician, University Hospital of North Staffordshire,
Stoke-on-Trent, UK

Introduction

Fractures of the proximal femur are a substantial problem. Worldwide there are estimated to be more than one million patients with fractures of the proximal femur each year. This is estimated to increase to as many as 2.5 million by 2025 [13]. Fractures through the proximal femur are broadly grouped into intertrochanteric fractures and intracapsular (subcapital) fractures. Owing to vascular anatomy, prognostically, the two groups are very different. The intracapsular group often requires replacement of the femoral head especially when displaced [16, 24], whereas the extracapsular group usually can be treated by internal fixation and the femoral head can be preserved [4, 22].

Numerous studies have been done to establish why a patient may sustain an intertrochanteric fracture as

compared with an intracapsular fracture. Factors predisposing to the type of fracture might include mechanism of injury [20], gender [14], age [9, 14, 20], degree of osteoporosis [12], mineral quality and anisotropy of the bone matrix [7, 12], nutritional status of the patient [14], femoral neck length [1, 3, 6, 8, 18, 21], and degree of external rotation of the femoral head [1]. No studies have satisfactorily established any predisposition to one type of fracture over the other.

There is a relationship between hip retroversion and a predisposition to having osteoarthritis in the hip develop [5, 11, 15, 27]. This presumably is related to biomechanical factors. It seemed possible therefore there also is a relationship between fracture pattern and femoral version. It was suggested intracapsular fractures may occur during a fall when external rotation thrusts the femoral neck against the posterior margin of the acetabulum [1]. Therefore it seems logical a relatively more retroverted hip would be more prone to intracapsular fractures than a more anteverted joint that may be prone to intertrochanteric fractures.

Mckibbin's instability index is based on the assumption that the effects of femoral and acetabular anteversion may be additive or may offset each other. The index is calculated as the sum of the angles of the femoral and acetabular anteversion. The normal range is between 30° and 40° [17]. There is evidence that a normal instability index is associated with a balanced range of rotation of the hip and with relatively low rates of pain and osteoarthritis. As the index approaches its upper and lower limits, there are increasing degrees of rotational change, pain, and osteoarthritis [27]. We also postulate, as the upper or lower limits are reached, an intracapsular fracture is more likely owing to the increased likelihood of the femoral neck being forced against the posterior or even anterior wall of the acetabulum.

As yet, there has been no attempt to determine whether the type of fracture is determined by the bony geometry of the hip. There is cadaveric evidence that bilateral femurs are symmetric and do not have different cortical bone geometry [25]. For the purpose of this study, we therefore assumed the anatomic alignment of the contralateral hip was the same as the fractured hip. The bony geometry of the contralateral hip was analyzed to determine whether it influenced the type of fracture sustained.

We looked specifically at the geometry of the hip to analyze the possibility of a relationship between the acetabular version and fracture type, femoral version and fracture type, and Mckibbin's instability index and fracture type [17]. Our hypothesis was that intracapsular fractures are more likely to occur in relative retroversion compared with intertrochanteric fractures. We expected there would be no relationship between fracture type and gender. We

also expected the group of patients sustaining intertrochanteric fractures would be relatively older than the group sustaining intracapsular fractures.

Patients and Methods

Consecutive adult patients were recruited from those admitted to the unit with a fractured proximal femur who could give valid informed consent for the study in compliance with ethics committee guidelines. Ethics committee approval was obtained and restrictions adhered to. All patients sustained their injuries in low-energy falls from standing height. Patients were excluded if the fracture was sustained in any other way. Exclusion criteria included patients with a previous injury to the contralateral or ipsilateral femur or substantial degenerative changes in either knee or hip. This exclusion was necessary to allow accurate assessment of femoral and acetabular version on the contralateral side. Patients who could not give informed consent were excluded. Young patients with substantial traumatic incidents were excluded, as were patients with primary or metastatic bone tumors related to their fracture. A total of 40 patients were recruited to the study. There were 15 men and 25 women with a mean age of 80 years (range, 57–92 years). There were 14 intertrochanteric fractures and 26 intracapsular fractures.

A value of 21° of acetabular version was assumed to be normal, with a value of 14° or less representing retroversion as per Reynolds et al. [23]. On the basis of a power analysis, a minimum number of 20 intertrochanteric fractures and 20 intracapsular fractures were required to achieve 95% power. To detect a mean difference of 7° when the common SD of the response is 7.8°, using 80% power and 5% significance level, requires 20 subjects per group.

Each patient underwent the planned operative procedure for his or her fracture according to the admitting consultant's routine practice. In the recovery phase, each patient had a CT scan of the pelvis and knee performed to assess acetabular version (according to the method of Tönnis and Heinecke [27]) on the contralateral (noninjured) hemipelvis. Acetabular anteversion, as measured on CT scans, is the angle between the sagittal plane and a line drawn tangential to the anterior and posterior acetabular margins. Anterior pelvic tilt reduces acetabular anteversion whereas posterior pelvic tilt (an upright pelvic position) increases it. A neutral position of the pelvis is obtained by having the patient lie prone, with the anterior tips of the iliac crests and the symphysis pubis resting evenly on the table. A support placed beneath the ankles keeps the feet parallel to each other. Femoral version was

assessed according to standard methods as described by Tönnis and Heinecke [27]. Femoral anteversion is the angle between the transverse axis of the knee, which is best indicated by a line drawn tangential to the maximum posterior convexity of both femoral condyles, and the transverse axis of the femoral neck. The femoral neck cannot be seen in the transverse plane because of its anterior and cephalad orientation; however, images made at different levels can be superimposed to create a summation image, making it possible to draw a line through the center of the femoral head and along the central axis of the femoral neck. On proximal scans, the trochanteric fossa makes the neck appear to be more slender and more ventrally located than it appears on distal scans. On the summation image, the central axis is located more dorsally and there is increased anteversion. The lateral end of the line passing through the center of the femoral head should be located exactly between the anterior and posterior cortical margins but not in the trochanteric region. If there is any tibial torsion when the feet are placed parallel to each other with the patient in the prone position, the knees will appear to be rotated on the CT images. The knees are rotated inward when there is increased femoral anteversion and compensatory external tibial torsion, and they are rotated outward when there is decreased femoral anteversion and compensatory internal tibial torsion. If the femoral condyles are internally rotated on the images, the angle of rotation must be added to the angle of anteversion, and if they are externally rotated, this angle must be subtracted from the angle of anteversion. The femoral neck length also was recorded from the CT images, again on the noninjured femur. Measurements were made from the medial femoral cortex just above the lesser trochanter to the junction with the femoral head on the inferior cortex

of the femoral neck. The scanner used was a Toshiba Xpress-GX (Toshiba Medical Systems Ltd, Crawley, UK) using a standard departmental technique.

Measurements were taken by two separate assessors independently (AF, GP). Because of the obvious implant, it was impossible to blind the assessors to the fracture type.

Acetabular version, femoral version, and femoral neck length were recorded for each patient. Mckibbin's instability index was calculated from the acetabular and femoral version [17]. The sum of the femoral and acetabular version has been described as the instability index, the assumption being the effect on the hip may be additive. The lower the index, the more retroverted the acetabulum and femur are likely to be [17].

An interobserver reliability analysis was performed. Intraclass correlation coefficients were generated using a two-way random-effects ANOVA to assess absolute agreement. Associated 95% confidence intervals also were calculated. There was a high level of interobserver agreement in the measurements of femoral version, femoral neck length, acetabular version, and Mckibbin's instability index taken from the CT scans (Table 1). Statistical analysis also was performed to assess the relationship between age and gender and fracture type, acetabular version and fracture type, femoral version and fracture type, Mckibbin's instability index and fracture type, and femoral neck length and fracture type. For these measurements, normality was assessed using the one-sample Kolmogorov-Smirnov test and the independent *t* test subsequently was used under the assumption of equal variances for both groups. Statistical analyses were performed using SPSS® (SPSS Inc, Chicago, IL). The *t* test was used for independent groups for age and fracture type. Fisher's exact test was used to determine if a relationship existed between gender and fracture type.

Table 1. Interobserver agreement of measured parameters with 95% confidence intervals

Parameter	Intraclass correlation coefficient
Acetabular version	0.97 (0.95–0.99)
Femoral version	0.98 (0.97–0.99)
Instability index	0.98 (0.97–0.99)
Femoral neck length	0.97 (0.94–0.98)

Results

The measurements of femoral and acetabular version, along with the Mckibbin's instability index and femoral neck length, were similar in the patients with intertrochanteric fractures and intracapsular fractures (Tables 2, 3; Fig. 1), with Patients 17 and 36 appearing to be outliers in their respective groups (Fig. 1). According to independent-

Table 2. Measured parameters in the two fracture groups

Type of fracture	Femoral version (°)	Acetabular version (°)	Instability index	Femoral neck length (cm)
Intracapsular (n = 26)	14.6 ± 8.0	19.8 ± 6.1	34.3 ± 11.6	3.5 ± 0.3
Extracapsular (n = 14)	13.5 ± 7.3	19.4 ± 7.1	33.1 ± 7.8	3.6 ± 0.3

Values are expressed as mean ± SD.

Table 3. Summary of data

Parameter	Type of fracture	10th percentile	Lower quartile	Median	Upper quartile	90th percentile
Acetabular version (°)	Extracapsular	10.40	16.62	19.00	24.50	29.65
	Intracapsular	7.00	16.00	19.50	25.13	28.50
Femoral version (°)	Extracapsular	4.70	7.00	14.75	18.62	26.80
	Intracapsular	5.00	6.75	13.00	16.87	27.50
Instability index	Extracapsular	20.60	27.25	33.50	40.87	54.80
	Intracapsular	22.50	25.50	34.75	38.50	45.00
Femoral neck length (cm)	Extracapsular	3.18	3.28	3.40	3.67	4.05
	Intracapsular	3.25	3.35	3.45	3.80	4.10

Fig. 1A–D The box plots show (A) acetabular version, (B) femoral version, (C) Mckibbin's instability index, and (D) femoral neck length in the patients with intracapsular (Ic) and intertrochanteric (It) fractures. No major differences in distribution of the acetabular and femoral version measurements are seen between the two groups. Patients 17 and 36 appear to be outliers in their respective groups. The edges of the rectangular boxes represent the upper and lower quartiles whereas the solid line corresponds to the median. The upper and lower tails reflect the 90th and 10th percentiles, respectively. See Table 3 for numerical values.

Table 4. Results of the independent t test and associated 95% confidence intervals for group mean difference

Parameter	t Value	Degrees of freedom	p Value (2-tailed)	Mean difference	Standard error difference	95% confidence interval of difference	
						Lower	Upper
Acetabular version (°)	0.134	38	0.894	0.28571	2.13914	-4.04475	4.61618
Femoral version (°)	0.402	38	0.690	1.04121	2.58744	-4.19679	6.27921
Instability index	0.361	38	0.720	1.25549	3.47964	-5.78866	8.29965
Femoral neck length (cm)	-1.010	38	0.319	-0.10027	0.09926	-0.30121	0.10066

samples t tests, there were no significant differences in mean values between the two fracture patterns (Table 4). All observed significance levels (Table 4) easily exceed the 5% threshold and zero lies inside the 95% confidence intervals for the group differences. Therefore, we found

no correlation between fracture type and any of these measurements.

We found no relationship between gender and fracture type (Table 5) ($p = 0.089$) or between age and fracture type ($p = 0.555$).

Table 5. Contingency table of gender and fracture type

Gender	Intracapsular fracture	Extracapsular fracture
Male	7	8
Female	19	6

Discussion

Fractures through the proximal femur are broadly grouped into intertrochanteric fractures and intracapsular fractures. It is not clear why a patient may sustain an intertrochanteric fracture as compared with an intracapsular fracture. We looked specifically at the geometry of the hip to analyze the possibility of a relationship between acetabular version, femoral version, and Mckibbin's instability index and fracture type.

There are potential weaknesses of our study. We extrapolated the measurements of the contralateral hemipelvis in this study. This could be a potential flaw of our study, but obtaining preinjury CT scans in patients with potential fractures would not have been possible. Previous studies have suggested the contralateral limb sustains a similar fracture in 80% of patients, supporting the idea that the geometry on the opposite limb is likely to be similar with respect to femoral version, acetabular version and femoral neck length. There is cadaveric evidence that bilateral femurs do not have different cortical bone geometry [25]. It may be possible to obtain CT scans of patients who have had scans for other reasons and then experienced a hip fracture. We were unable to obtain sufficient CT scans for the patients in our hospital who had fractured their hips to make this a viable option. With the increased use of electronic radiographic files, this may become a viable option in the future. It is unclear how accurate our measurements of femoral and acetabular anteversion were. A previous study showed measurements made from CT scans may be as inaccurate as 6° [26], whereas another study suggests an accuracy closer to 3° can be obtained [19]. There are several potential sources of error in these measurements. The most accurate way to locate the sagittal plane is to draw an AP line exactly midway between the two halves of the pelvis. A transverse line drawn tangential to the ischial spine is accurate only when the pelvis is scanned at exactly the same height on both sides. Frequently, this is not the case. As the scanner moves distally from the level of the acetabular roof, the anterior part of the acetabulum begins to recede. The contact area between the femoral head and the anterior acetabular margin becomes smaller, until finally there is no congruence between the two. At this level, acetabular anteversion is increased, whereas when the femoral head is in full contact with the anterior margin, anteversion is less. In most departments, measurements are made on the scan

that shows the largest diameter of the femoral head. However, the deformation of the acetabulum in low or high anteversion is of influence only where the femoral head is fully congruent with the acetabulum posteriorly and anteriorly. This level has to be chosen for measurement. If it is not, the investigations will not be comparable. However, any inaccuracy presumably would affect intracapsular and extracapsular fractures equally. Added to this, the agreement between the two assessors was highly consistent, suggesting the measurements were accurate.

It is reported [2], in patients with sequential fractures of the femoral neck, greater than 80% sustain the same fracture type in a consequent injury in the contralateral hip. Binns et al. [1] described an increased external rotation in the contralateral limb in patients with intracapsular fractures as compared with extracapsular fractures. However, our study showed the geometry of the femoral neck is not implicated in determining which fracture type is likely to occur in low-trauma fracture of the femoral neck.

Adult acetabular version tends to anteversion as the norm (15°–20°) [27]. Previous investigators have implied relative retroversion (–2°–10°) could predispose to pain in adolescents and young adults [27] and also to osteoarthritis [23, 27]. A relationship between acetabular version and slipped upper femoral epiphyses in children has been established [10]. We have shown there is no relationship between femoral or acetabular version and fracture pattern.

We observed no relationship between the type of hip fracture and femoral version, acetabular version, or Mckibbin's instability index. We also confirmed there is no link between femoral neck length and type of hip fracture and between the age or gender of the patient and type of fracture. No literature exists regarding a relationship between type of fracture and hip geometry. However, based on our results, the bony geometry of the hip does not seem to predict what type of fracture an individual will sustain. It still is unclear why some patients sustain intracapsular fractures while others get extracapsular fractures.

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