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# Epidemiology of proximal femoral fractures

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A B S T R A C T

*Introduction:* With increasing age, the incidence of proximal femoral fractures increases steadily. Although the different treatments are investigated frequently, little is known about the seasonal variation and predisposing factors. The purpose of this study is to investigate the epidemiology, the impact of femoroacetabular impingement, as well as the presence of osteoarthritis.
*Methods:* We performed a retrospective review of all patients with pertrochanteric, lateral and medial femoral neck fractures between 2012 and 2019. Inclusion criteria consisted of patients older than 18 years old who presented with isolated proximal femoral fractures without any congenital or hereditary deformity. For analysis, we assessed the demographics, season at time of accident, Kellgren-Lawrence score and corner edge (CE) angle.
*Results:* In total, 187 patients were identified at a mean age of 75.1 ± 12.9 years old. Females consisted of 54.5% of this cohort. Most commonly, patients tend to present in winter with pertrochanteric fractures whereas no seasonal variation was found for medial femoral neck fractures. Significant correlations between season and age (regression coefficient −0.050 ± 0.021; $p < 0.05$) were identified. In medial neck fractures, the Gardner score was lower and Kellgren-Lawrence score higher for both female than males ($p < 0.05$). Patients with lateral neck fractures were significantly younger at 68.6 ± 12.5 years old ($p < 0.05$). In pertrochanteric fractures, the Kellgren-Lawrence score was significantly higher at 2.1 ± 0.8 ($p < 0.05$) with higher CE angle at 43.0 ± 7.6° ($p = 0.14$).
*Conclusion:* With increasing incidences of proximal femoral fractures, it is essential to recognize potential risk factors. This allows for development of new guidelines and algorithm that can aid in diagnosis, prevention, and education for patients.



## 1. Introduction

In older people, femoral neck fractures are the most common traumatic injuries which can lead to severe disability.[1,2] As society ages, the annual number is expected to steadily increase to between approximately 6.3 to 8.2 million cases in 2050.[2] The incidence of femoral neck fractures is approximately equal to the incidence of pertrochanteric fractures, in combination making up over 90% of all proximal femur fractures.[3,4,5,6] The remaining 5–10% consists of subtrochanteric fractures. In young adults, these kinds of fractures are rather uncommon with only 2% in patients under the age of 50 years, which mainly occur from traumatic etiology.[7] Above the age of 50 years old, there is a 2 to 3 times increase in incidence, preferentially affecting the female gender.[2] When looking for seasonal variation, higher incidence in the winter months have been reported, although no distribution among the type of proximal femur fractures have been described.[8,9]

Besides osteoporosis, other risk factors have been proposed. In literature, it is known that femoroacetabular impingement (FAI) predisposes patients to osteoarthritis. Specifically, femoroacetabular impingement can be divided into CAM and Pincer impingement morphology.[10] Furthermore, this morphology can predispose to other pathology as well. Beck et al. described a case series, where femoroacetabular impingement was thought to be

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the cause for non-union after femoral neck fracture fixation when all other known predisposing factors were excluded.[11] Based on this, the authors concluded that impingement should be addressed at the same time as the fracture fixation. In this context, a correlation between FAI and femoral neck stress fractures has also been described,[12] where the Pincer morphology was found to be associated with 78% of femoral neck fracture.[13]

It is also known that the femoroacetabular impingement is associated with posterior hip dislocation.[14] Center-edge angle and axial alpha angle are known to be higher in the posterior hip dislocation group than in the control group. In addition, a difference in Centrum-Column Diaphyseal (CCD) angle was identified to be significantly less in the control compared to the posterior hip dislocation group.

Although a variety of correlations between femoroacetabular impingement morphology and hip pathology have been described, no one has investigated FAI as risk factor for femoral neck fracture to our knowledge. We hypothesized that femoroacetabular impingement presents a fulcrum which predisposes patients to medial neck fractures (class 1 lever), whereas severe hip osteoarthritis causes pertrochanteric neck fractures related to a higher rigidity (class 2 lever). Therefore, patients presenting with pertrochanteric fractures should be older compared to the other two groups. The aim of our study was to investigate the epidemiology of medial, lateral femoral neck and pertrochanteric fractures with a focus on seasonal variation and predisposing conditions including femoroacetabular impingement and arthritic changes.

## 2. Methods

After obtaining internal review board approval (EA4/201/19), we performed a retrospective study and reviewed all charts and radiographs between 2012 and 2019. All patients 18 years old or older without congenital or hereditary deformity or femoral head necrosis who presented to the emergency room at a level I trauma center with an isolated, simple lateral, medial neck fracture or pertrochanteric fracture (A1.1 to A2.1) were included (Fig. 1). Patients suffering from comminuted as well as subtrochanteric fractures were excluded. The subtrochanteric region of the femur is of high stress concentration due to the muscular insertions (flexion – M. iliopsoas, abduction M. gluteus medius, external rotation – external rotators) which are mostly present in young male patients sustaining from high energy traumatic injuries.[15] Standard pelvic radiographic views were taken and medical records reviewed by a specialized orthopaedic surgeon. This is done for criteria including demographics, month of accident with respect to presentation to the emergency room and the fracture pattern.

The fractures were classified into lateral, medial neck fractures and pertrochanteric fractures. For the assessment of femoroacetabular impingement, we measured the center edge angle. In addition, we assessed the Kellgren-Lawrence score for the severity of osteoarthritis and Gardner score for medial neck fractures. Furthermore, demographic information including age, gender, ethnicity, and season at time of accident were recorded. Since radiographs in the emergency room are not perfectly anteroposterior view, we are not able to measure the Centrum-Column Diaphyseal (CCD) angle. Exclusion criteria consisted of patients younger than 18 years old as well as polytraumatized patients. All pathological femoroacetabular variations like hip dysplasia, coxa profunda, acetabular protusio or femoral head necrosis (FICAT classification > II) were excluded. For statistical analysis, we used Origin Lab for the ANOVA *t*-test and SPSS for the linear regression model.

## 3. Results

In total, we identified 187 patients at a mean age of 75.1 ± 12.9 years old (median 77 years; range 37–98 years). Female patients consists of 54.5% of cases (n = 102/187). Most commonly, pertrochanteric fractures were identified in 42.8% (n = 80/187), followed by medial neck fractures in 37.4% (n = 70/187) and lateral neck fractures in 19.8% of cases (n = 37/187). The overall CE angle was 40.8 ± 5.3° with a mean Kellgren-Lawrence score of 2.0 ± 0.6. Simple lateral neck fractures were fixed using a dynamic hip screw (DHS, Mahwah, NJ, USA). For pertrochanteric fractures, a proximal femoral nail was used (PFN, Raynham, MA, USA). Medial neck fracture were treated with either a proximal femoral nail (Garden type 1 and 2) or a total hip arthroplasty (Garden type 3 and 4).

Patients who suffered from a lateral femoral neck fracture were significantly younger (68.6 ± 12.5 years old; median 71 years; range 37–89 years) compared to pertrochanteric (77.0 ± 11.5 years old; median 78years; range 44–96 years) and medial neck fractures (76.0 ± 13 year old; median 78 years; range 37–98), with both p values at ≤0.01) (Fig. 2). For ethnicity, most patients were white

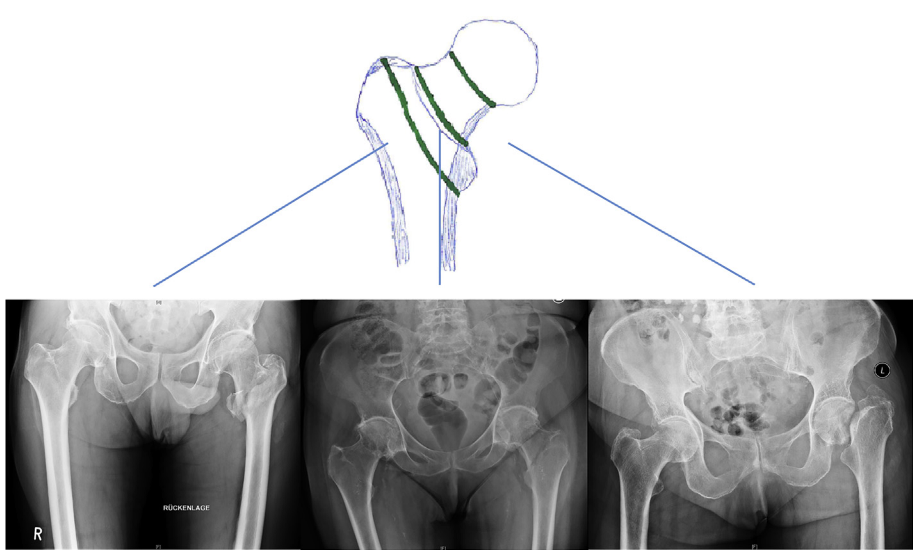


**Fig. 1.** Definition of pertrochanteric (A), lateral (B) and medial (C) neck fractures.

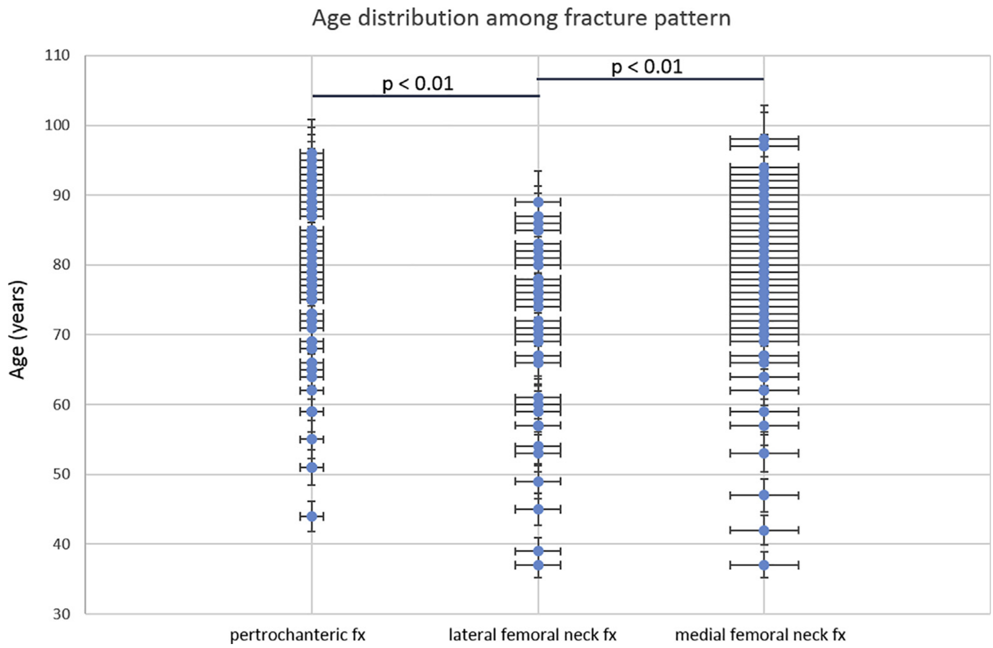


**Fig. 2.** Age distribution among fracture pattern.

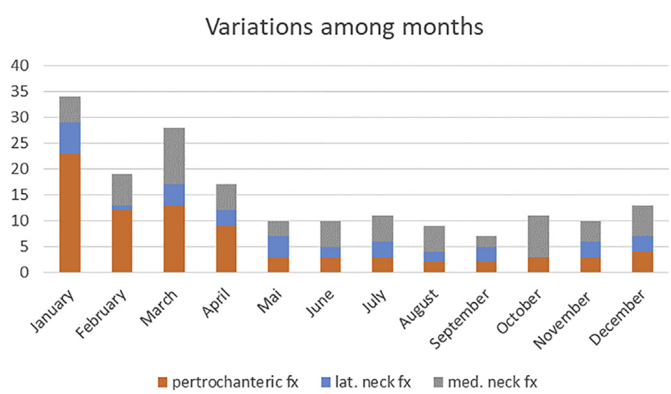


**Fig. 3.** Variations among months for pertrochanteric, lateral and medial femoral neck fractures; fx – fractures (the figure was drawn by the first author).

(84.5%) followed by African American (9.1%). The fracture patterns were the same between ethnicities. When looking at the timing of accidents, 18.2% of cases occurred in January ($n = 34/187$), followed by 15% in March ($n = 28/187$) and 10.7% in February ($n = 20/187$). Seasonally, the highest rate of injury was observed in winter with 45.8% of cases ($n = 82/187$; $p < 0.05$), followed by autumn with 22.3% ($n = 27/187$), spring with 21.2% ($n = 38/187$) and finally summer consisting of 15.1% ($n = 27/187$) (Fig. 3). After applying linear regression model, we found a significant correlation between the season and fracture pattern (regression coefficient $-1.176 \pm 0.296$; $p < 0.001$). Pertrochanteric fractures occurred significantly more in winter whereas lateral and medial neck fractures were equally distributed throughout the year. Additionally, significant difference between age and season was observed (regression coefficient $-0.050 \pm 0.021$; $p < 0.05$). Older patients tended to fall more frequently in winter.

For medial neck fractures, gender specific differences were identified. Female patients were significantly older (age $79.4 \pm 11.0$ years old vs. $71.5 \pm 14.2$; $p < 0.05$) and have notably higher Kellgren-Lawrence score ($2.1 \pm 0.7$ vs. $2.3 \pm 0.8$; $p < 0.05$). Furthermore, we identified a significant lower average Gardner score for females at $2.6 \pm 1.0$ versus a score of $0.1 \pm 0.9$ ($p < 0.05$) for males.

The corner edge angle for pertrochanteric fractures was highest at $43.0 \pm 7.6°$, compared to medial ($41.3 \pm 6.4°$), and lateral neck fractures ($40.5 \pm 8.7°$). Although no significances were identified, p value of 0.14 was found between medial and pertrochanertic fractures groups. Likewise, the Kellgren-Lawrence score was significantly higher for pertrochanteric fractures at $2.1 \pm 0.8$ ($p < 0.05$; regression coefficient of $-0{,}199 \pm 0091$) when compared to medial and lateral femoral neck fractures. The mean Kellgren-Lawrence score in medial neck fractures was $2.0 \pm 0.6$, and $1.9 \pm 0.5$ for lateral neck fractures. In medial neck fractures, the median Gardner score was $2.7 \pm 1.0$ without any further correlation.

For seasonal variation among fractures, no correlation between the season of accident and femoroacetabular impingement was found. ($p = 0.544$) Similarly, no correlation between Kellgren-Lawrence score and fracture and fracture patterns were found ($p = 0.235$). All findings are presented in Table 1.

## 4. Discussion

Femoral neck fractures are the most common traumatic injuries associated with increasing age.[1,2] Among fracture patterns, the incidence of femoral neck fractures is approximately equal to the incidence of pertrochanteric fractures.[3,4] Although a lot has been published about different treatment methods, little is known about predisposing factors such as the severity of pre-existing osteoarthritis and femoroacetabular morphology (CE-angle).

In this cohort, females sustain proximal femur fracture at a mean age of $68.6 \pm 12.5$ years. Isolated pertrochanteric fractures are most commonly see, consisting of 42.8% of cases. Lateral femoral neck fractures are relatively uncommon, consisting of only 19.8%. Patients with isolated pertrochanteric fractures tend to present with significantly higher severity of pre-existing osteoarthritis with a mean Kellgren-Lawrence score of $2.1 \pm 0.8$ as well as a CE angle of $43.0 \pm 7.6°$. These patients typically present in winter and significantly more so with pertrochanteric fractures.

**Table 1**
Differentiation between the fracture patterns; bold illustrates significant findings, * p-value <0.05

| | Total | Pertrochanteric fractures | Lateral neck fractures | Medial neck fractures |
|---|---|---|---|---|
| Numbers (n) | 187 | 80 | 37 | 70 |
| Age (years) | 75.1 ± 12.9 (range 37–98) | 77.0 ± 11.5 (range 44–96) | **68.6 ± 12.5*** (range 37–89) | 76.0 ± 13.1 (range 37–98) |
| Gender (females) | 54.5% (n = 102) | 52.5% (n = 42) | 54.1% (n = 20) | 57.1% (n = 40) |
| Ethnicity | 84.5 (n = 158) | 83.8, (n = 67) | 83.8, (n = 31) | 85.7, (n = 60) |
| - White | 9.1 (n = 17) | 8.8, (n = 7) | 5.4, (n = 2) | 11.4, (n = 8) |
| - African American | 0.5, (n = 1) | 1.3, (n = 1) | 0, (n = 0) | 0, (n = 0) |
| - Native American | 5.9, (n = 11) | 6.3, (n = 5) | 10.8, (n = 4) | 2.9, (n = 2) |
| - Asian | | | | |
| Kellgren-Lawrence Score | 2.0 ± 0.6 | **2.1 ± 0.8*** | 1.9 ± 0.5 | 2.0 ± 0.6 |
| Corner-edge (CE) angle | 40.8 ± 5.3° | 43.0 ± 7.6° | 40.5 ± 8.7° | 41.3 ± 6.4° |
| Gardner score | | | | 2.7 ± 1.0 |

Above the age of 50 years old, the incidence in proximal femoral fractures increases by 2–3 times.[2] This is related to hip joint rigidity from osteoarthritis which can causes falls.[16,17] In our cohort, the mean age was well above 50 with a female predominance. Additionally, we found significantly less lateral femoral neck fractures compared to pertrochanteric and medial neck fractures in this group. Most of the published studies only distinguished between intra- and extracapsular and not between medial and lateral neck fractures.[18] However, this is important as it has bearing on the femoral head perfusion and can dictate which surgical treatment is chosen. We believe epidemiological knowledge of proximal femur fracture pattern can help inform appropriate implant choice. Seasonally, pertrochanteric tends to happen in the winter whereas medial neck fractures occur evenly throughout the year. This consistent with the literature, where the winter is higher risk because of the slippery wintry conditions, although many of the fractures occurred indoor.[19–22] Possible explanations included a significantly poorer coordination in elderly during winter.[22,23] However, this may prevent more severe injuries as the mechanism of injury tend to be lower when falling from standing. Less active patients may be more likely to sustain isolated hip fractures whereas the active one tend to be polytrauma patients.[8] For intracapsular fractures, no seasonal predisposition was described.[9] For radiographic diagnosis of osteoarthritis, the imaging tools seem to impact on the joint space narrowing and therefore the classification.[24] This is why researchers have already questioned the applicable to women as it is more likely to find osteoarthritic changes and furthermore, have criticised the Kellgren-Lawrence score grades in general because of the reliability in joint space and the clinical reflection. However, radiographs still remains the gold standard as it is easy to perform in clinics and allows the treating physician to draw a conclusion.[25]

To date, femoroacetabular impingement has only been correlated with stress fractures, not pertrochanteric, medial or lateral neck fractures. Goldin et al. reported that among a cohort of 24 patients with femoral stress neck fractures, 42% exhibit a CAM morphology and 75% exhibit Pincer morphology. In addition, anatomical abnormalities like coxa profunda have been described as a predisposing factor also. However, we excluded this morphology in our study as this may limit the evaluation of the CE angle.[13] The measurement of alpha angle is limited by the fracture. Furthermore, there is still controversy as to what is the normal range for alpha angle, which has been reported anywhere from 46° to 49° and up to >55°.[26,27,28,29,30] On the other hand, lateral center-edge angle allows for precise determination of Pincer impingement morphology.[31] Armbuster et al. described a mean CE angle of 39° in his cohort of cadavers > 40 years old.[32]

In patients with pincer impingement, it is suggested that overcoverage creates a fulcrum that causes chronic deterioration of the femoral head.[13,10] This increases contact stress and may cause non-union due to abnormal biomechanics even after internal fixation.[11] We suggest a similar pathological mechanism where the combination of shorter lever (higher CE angle) and higher stiffness (higher Kellgren-Lawrence score) between the acetabular rim and intertrochanteric zone can potentially contribute to pertrochanteric fractures. In addition to the acetabular morphology, mechanism of injury also has a major impact on the fracture pattern which we did not investigate.

We acknowledge several limitations of this study. This study is of retrospective design where all radiographs were performed in the emergency room. Since patients with proximal femur fractures suffer from severe pain when moving, it is very difficult to perform a true anteroposterior plain radiography of the pelvis. It is unknown as to how the rotation of the pelvis influences the CE angle. Furthermore, we only included patients with isolated proximal femur fractures to exclude higher energy polytrauma patients. Additionally, no unified classification for the CAM or Pincer impingement exists. It is difficult to distinguish between Pincer impingement and ossifications in some cases.

Our study suggests that the most common proximal femur fracture occurs in an older female during winter. Most common fracture type is pertrochanteric fractures, which also showed highest severity of osteoarthritis and corner edge angles. As society ages, it is essential to identify potential risk factors as hip preserving surgeries may advance the care of these patients, or even potentially preventing some proximal femur fractures.

## Declaration of competing interestCOI

The authors have no conflict of interest directly related to this work.

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The figure was drawn by the first author.

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