ORIGINAL ARTICLE

Correlation between hip osteoarthritis and proximal femoral fracture site: could it be protective for intracapsular neck fractures? A retrospective study on 320 cases

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Abstract

Summary Proximal femoral fractures affect elderly people, showing high morbidity and mortality incidence resulting in a major economic burden on national healthcare systems. Understanding the causes of these injuries is of paramount importance to prevent the serious consequences of these fractures.

Introduction Hip osteoarthritis and proximal femoral fractures mainly affect elderly patients. Several authors, in their studies, tried to document a correlation between these conditions, but the results are conflicting. The aim of this study was to evaluate the relationship between hip osteoarthritis and the fracture site. Secondly, to evaluate if the grade of osteoarthritis could influence the fracture pattern.

Methods A retrospective study on 320 patients admitted for hip fracture between June 2015 and December 2016 was carried on. Radiographic images were evaluated, assessing the type of fracture, presence and grade of osteoarthritis according to Kellgren-Lawrence and Tönnis classifications, and their correlations.

Results Osteoarthritis was found to affect the fracture site showing a higher prevalence among subjects with extracapsular than those with intracapsular fractures ($p < 0.00001$). Patients with radiographic signs of arthritis had mainly trochanteric fracture. Conversely, patients without arthritis more frequently presented a femoral neck fracture. This correlation was even more significant as the severity of the OA increased.

Conclusions Results support the hypothesis that hip osteoarthritis could represent a protective factor for intracapsular fractures and a risk factor for trochanteric ones. The severity of arthritis is also associated with the fracture pattern.

Keywords Extracapsular fractures · Hip osteoarthritis · Intracapsular fractures · Proximal femur fractures

Introduction

Proximal femur fractures (PFF) show high morbidity and mortality incidence resulting in a major economic burden on national healthcare systems [1, 2]. In the USA, there are over 250,000 hip fractures every year [3]. Death risk in patients with PFF is about 5% in the acute phase and 15–25% at 1 year. Hip osteoarthritis (HOA), as well, is a typical condition of the elderly people affecting their morbidity [4]. In 1972, Foss and Byers hypothesized that HOA

could be a protective factor for PFF while Smith et al. in 2016 highlighted an increased risk of PFF in patients with HOA [5]. Chudyk et al. published a systematic review to determine the association between hip or knee OA and risk of hip fractures in people aged 45 years and older compared with people aged 45 years and older who do not have OA, finding that the presence of OA in the hip or knee should not be a predisposing factor [6].

Those contradictory data could be explained by the complexity of PFF- and HOA-related factors. Moreover, results are quite different if intracapsular fractures (ICF) and extracapsular fractures (ECF) are considered separately. Some authors assessed that there could be a positive relationship between HOA and ECF [7–9]. Calderazzi et al. recently showed a direct proportion between the degree of HOA, according to the radiological signs, and the probability of an ECF [10].

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The aim of the present study was, firstly, to evaluate the relationship between HOA and the PFF site and, secondly, to assess if the severity of HOA could affect the complexity of the fracture pattern.

Materials and methods

A retrospective study considering all patients ($n = 371$) who had been admitted for PFF from June 2015 to December 2016 at the Department of Orthopedics and Trauma Surgery of University Hospital was performed. The exclusion criteria were as follows: incomplete radiographic documentation ($n = 5$), age less than 65 years ($n = 33$), intertrochanteric ("reverse obliquity") fractures ($n = 13$). Three-hundred twenty patients met the inclusion criteria and were recruited. All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/ or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Radiographic assessments and classification of hip osteoarthritis

For each patient, the antero-posterior (AP) and lateral (LL) radiographs of the hip obtained in the emergency room were examined. According to the location of the hip fracture, two groups were distinguished: the first group included all patients affected by femoral ICF while the second group those affected by ECF (Figs. 1 and 2). PFF patterns according to AO and Garden's classifications for

Fig. 1 Typical case of an extracapsular proximal femur fracture with severe hip osteoarthritis

Fig. 2 Typical case of an intracapsular femoral neck without radiological signs of hip osteoarthritis

trochanteric and neck fractures respectively were considered [11] (Table 1). HOA radiological signs according to Kellgren and Lawrence (K/L) and Tönnis (Tön) radiological scales were evaluated [12, 13]. These scoring systems are described in Table 1. The Garden hip fracture and Kellgren-Lawrence HOA classifications have been widely studied; while the validation of the Garden score is still debated, the inter-observer reliability of the Kellgren-Lawrence scale has been demonstrated [14, 15] (Table 2). Each ICF and ECF group was therefore distinguished in three categories depending on the severity of HOA: absent (K/L = 0–1 or Tön = 0), mild (K/L = 2 or Tön = 1), severe (K/L = 3–4 or Tön = 2–3).

All these data were examined in order to evaluate the hypothesis that HOA could represent a risk factor for ECF and a protective factor for ICF and, furthermore, with the aim of understanding if the PFF pattern could be influenced by HOA severity. Therefore, the ICF group was further divided into two subgroups: the first represented by Garden I–II and the second by Garden III–IV type fractures. Likewise, the ECF group was split into the 3.1-A1 and the 3.1-A2/A3 groups, according to AO classification. Finally, HOA radiological signs in each subgroup were analyzed.

Table 1 Definition of femoral neck fracture severity according to Garden's classification

Type	Radiological findings
I	Incomplete, valgus impacted
II	Complete fracture, non-displaced
III	Complete, displaced < 50%
IV	Complete, displaced

Table 2 Definition of OA severity according to Kellgren-Lawrence and Tönnis classifications

Grade	Radiological findings	
	K/L	Tön
0	No radiological findings of OA	No radiological findings of OA
1	Doubtful narrowing of joint space and possible osteophyitic lipping	Increased sclerosis, slight joint space narrowing, no or slight loss of head sphericity
2	Definite osteophytes and possible narrowing of joint space	Small cysts, moderate joint space narrowing, moderate loss of head sphericity
3	Moderate multiple osteophytes, definite narrowing of joint space, small pseudocystic areas with sclerotic wales and possible deformity of bone contour	Large cysts, severe joint space narrowing, severe deformity of the head
4	Large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour	

Statistical analysis

The statistical analysis was performed using chi-squared test both to analyze the correlation between HOA and the fracture site and to evaluate some confounding factors such as the gender. Additionally, correlation was studied between HOA severity and fracture pattern with Poisson's distribution, which was corrected by patients' age and gender (included as covariates). Student's t test was applied to investigate the role of age. The data analysis was performed using STATA 14 software (StataCorp LLC, College Station, Texas, USA). Results were considered significant with a $p < 0.05$.

Results

Groups distribution

One hundred fifty-four (68.48% women, 30.52% men) out of the 320 recruited patients, with an average age of 84.95 years (range 65–101 years), had an extracapsular fracture. The intracapsular fracture group was represented by 166 patients (71.08% women, 28.92% men) with an average age of 83.45 years (range 65–98 years). There were not significant differences for age ($p = 0.69$) and gender ($p = 0.1$) between the two groups. Among the four additional subgroups generated by radiographical assessment, as previously described, in the extracapsular fracture group ($n = 154$), 79 cases (51.30%) were defined as 3.1-A1, while 75 cases (48.70%) as 3.1-A2. In the intracapsular fracture group ($n = 166$), 42 cases (25.3%) cases were classified as Garden type 1–2, while 124 fractures (74.7%) as Garden type 3–4.

Correlation between osteoarthritis and fracture site

The presence of hip osteoarthritis was established when K/L scored 2 or more and Tön 1 or more. Correlation between K/L and Tön, when associated to fracture site, was statistically highly significant in both cases, with a $p < 0.00001$ and = 0.0001 respectively. In fact, among patients with intracapsular fracture, 53.01% (88 patients) showed hip osteoarthritis signs, while 83.12% (128 patients) were affected by hip osteoarthritis in the extracapsular fracture group (Table 3). These data highlight that hip osteoarthritis is significantly less represented in the intracapsular fracture than in the extracapsular fracture (Fig. 3). Likewise, within hip osteoarthritis patient's group, 61.36% showed an extracapsular fracture and only the 38.64% had an intracapsular fracture (Fig. 4). Conversely, patients not affected by hip osteoarthritis presented an intracapsular fracture in the 76.11% of cases and an extracapsular fracture only in the 23.89% (Fig. 5, Table 3). This correlation is even more undeniable considering the patients affected by the most severe hip osteoarthritis grades (K/L = 3–4); in fact, 78.79% of them showed an extracapsular fracture and only 21.21% an intracapsular fracture. Correlation between hip osteoarthritis severity and fracture

**Table 3** Patients distribution and correlation between HOA severity and fracture pattern

	ECF $n = 154$	ICF $n = 166$
Male	30.52%	28.92%
Female	68.48%	71.08%
Age (years)	85 (65–101)	84 (65–98)
K/L 0–1, Tön 0	16.88%	46.99%
K/L ≥ 2, Tön ≥ 1	83.12%	53.01%

Fig. 3 Proximal femur fracture's distribution based on the grade of hip osteoarthritis
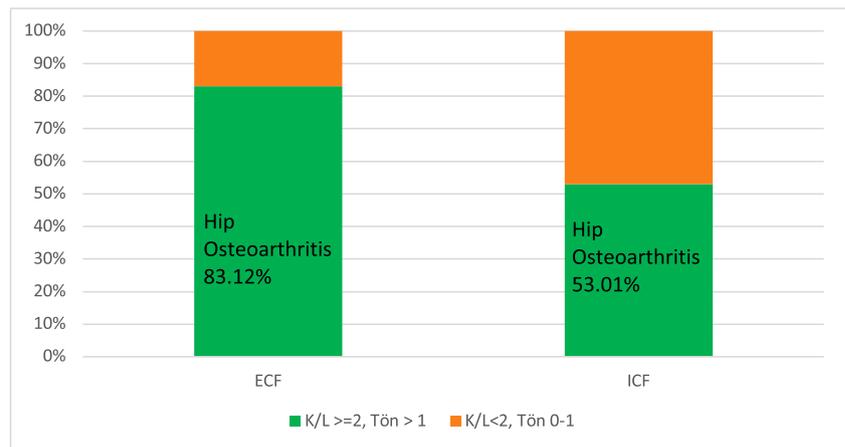

site was then analyzed using the Poisson regression method, adjusting the data for the effects of confounding factors such as age and gender. From this analysis, it clearly appeared that individuals with mild hip osteoarthritis (K/L 2) had a doubled risk of an extracapsular fracture compared with an intracapsular fracture (RR, 2.00; 95% CI, 1.27–3.14; p = 0.003); this risk triplicate is considering severe hip osteoarthritis (K/L 3–4) (RR, 3.13; 95% CI, 1.95–5.02; $p < 0.0001$). Those findings were confirmed even with Tönnis classification of mild hip osteoarthritis (Tön 1) (RR, 2.46; 95% CI, 1.57–3.86; $p < 0.0001$) and severe hip osteoarthritis (Tön 2–3) (RR, 3.52; 95% CI, 2.19–5.64; $p < 0.0001$). At the same time patients with mild hip osteoarthritis (K/L = 2) have a 34% lower risk of intracapsular fracture if compared to extracapsular fracture (RR, 0.66; 95% CI, 0.48–0.92; p =

0.014); this risk lowers even more in patients with severe hip osteoarthritis (K/L = 3–4) (RR, 0.28; 95% CI, 0.16–0.50; $p < 0.0001$). Tönnis classification gave comparable results (mild hip osteoarthritis: RR, 0.57; 95% CI, 0.41–0.80; $p = 0.001$; severe hip osteoarthritis: RR, 0.27; 95% CI, 0.15–0.58; $p < 0.0001$). Those findings highlight the protective role of hip osteoarthritis towards intracapsular fracture and evidence a directly proportional association between the severity of hip osteoarthritis and an extracapsular location of the fracture.
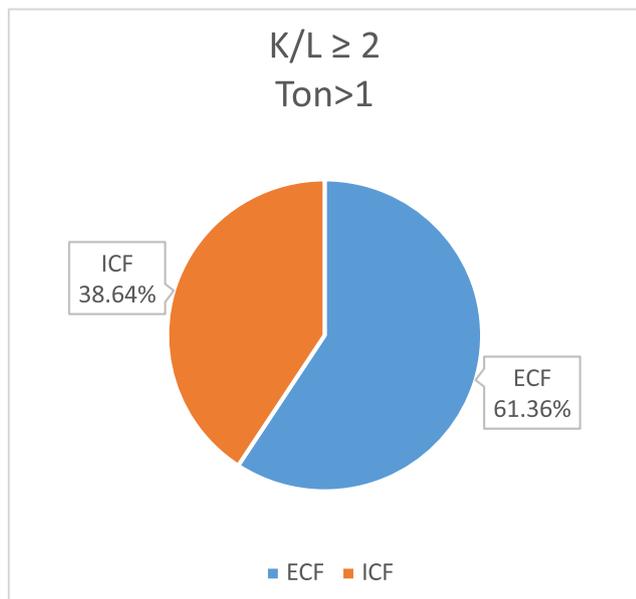
Fig. 4 Proximal femur fracture site distribution of patients affected by hip osteoarthritis
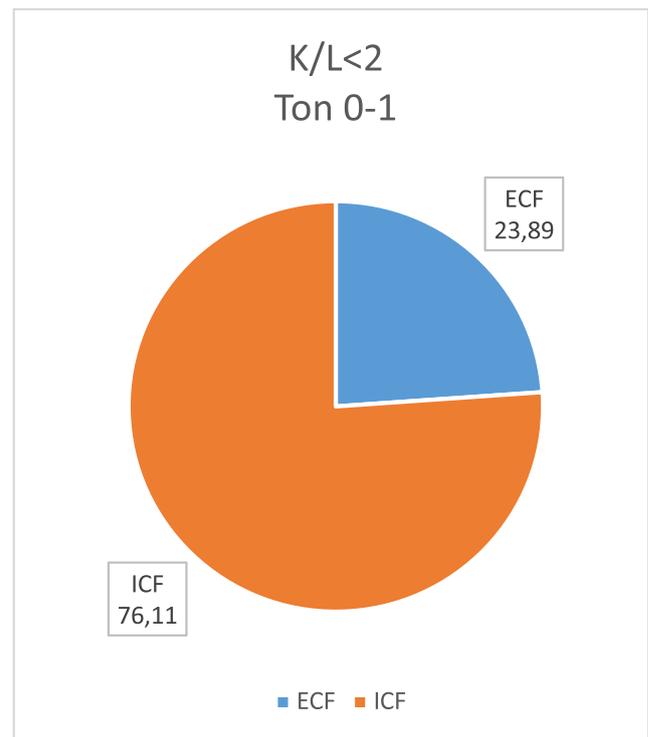
Fig. 5 Proximal femur fracture site distribution of patients without hip osteoarthritis

In the second part of the study, data investigating hip osteoarthritis severity and fracture pattern were evaluated. The previous findings allow a better knowledge of hip osteoarthritis influence also on the fracture pattern and therefore its severity. Whether this relation could also affect the complexity of the fracture and not only the fracture site was evaluated considering two more subgroups for each category, as above reported. The intracapsular fracture group was in fact divided into Garden 1–2 and 3–4 type fracture, while extracapsular fracture group was split in 3.1-A1 type and 3.1-A2 type. Results revealed an effect of hip osteoarthritis on the fracture pattern. In fact, the more hip osteoarthritis was severe, the more complex was the fracture. This trend is confirmed both in extracapsular fracture (3.1-A2>3.1-A1) and in intracapsular fracture (G3–4>G1–2), but differences among the groups were not statistically significant (in intracapsular fracture: $p = 0.20$ according to K/L and $p = 0.021$ according to Tönnis; in extracapsular fracture: $p = 0.11$ according to K/L and $p = 0.080$ according to Tönnis). Statistical analysis, therefore, did not confirm this latest hypothesis.

Discussion

This study demonstrates the hypothesis that hip osteoarthritis could influence the proximal femoral fracture site, being a protective factor for internal capsular fracture and a risk factor for external capsular fracture. Furthermore, this correlation appears to be stronger when hip osteoarthritis gets more severe. Data available in the literature are contradictory. Foss and Byers evidenced that patients undergoing total hip arthroplasty for an internal capsular fracture did not show hip osteoarthritis signs [5]. Later, Arden, Dretakis, and Robstad confirmed this association [7–9]. Aguado-Maestro et al. studied 1003 consecutive proximal femur fragility fractures in patients over 65 years old admitted in the first aid of their institution: patients presenting with severe hip osteoarthritis were found to have a statistically significant chance to present with an extracapsular fracture ($p < 0.01$) [16].

On the other side, Yamamoto and Franklin stated that this was valid only for the female population [17, 18]. There are several conditions that can affect relationships between hip osteoarthritis and proximal femoral fractures; therefore, the discrepancies found in the literature may rely on the multifactorial nature of this subject. In fact, the proximal femoral fracture incidence is obviously related to the bone quality and to the risk of falls [19, 20], but we should consider that there are multiple factors influencing a fall; among them, the most important are neurological diseases, dementia conditions, and, in general, a wheelchair confining but also an impairment due to a severe hip osteoarthritis [21, 22]. Arden et al. asses that there was no significant association between self-reported OA and radiographic hand OA with bone loss. No association between OA and incident nonvertebral fracture, hip fracture, or vertebral fracture was found but subjects with OA have a trend of reduced risk of femoral neck fractures in subjects with severe radiographic OA confirming our hypothesis [7].

A further cause of disagreement between different authors may be due to the considered hip osteoarthritis classification. In this study, the Kellgren-Lawrence and Tönnis classifications were adopted because of their semiquantitative criteria. The two scales are not superimposable, but they lead to the same conclusions and this gives further strength to our study.

There are few hypotheses in order to explain, with biomechanical argumentations, the association between hip osteoarthritis and fracture site. Wolf et al. in 2009 proved that patients with hip osteoarthritis have a higher bone mineral density (BMD) at the femoral neck if compared with controls, but the BMD decreases at the trochanteric region [23]. Other authors also evidenced in these patients a significant higher distribution of trabeculae, in terms of number and density, at the femoral neck [24, 25]. These factors could give mechanical strength to the neck bone structure resulting in more resistant to the impact forces than the trochanteric area. Moreover, the posterior-superior part of the femoral neck shows a thicker cortical in patients with hip osteoarthritis and the impact forces during a fall are often focused on this side [26].

Also, Detrakis et al. observed that a fall on the posterior aspect of the greater trochanter often leads to a femoral neck fracture, but if the trauma hits its lateral aspect, this will probably cause a trochanteric fracture [8]. Beginning with these considerations, it was hypothesized that hip osteoarthritis could affect also the fracture's biomechanical pathogenesis following a fall, protecting the femoral neck from the impact forces.

The present study, furthermore, hypothesized a possible association between the hip osteoarthritis severity and the proximal femoral fracture complexity, even if our results were not statistically significant to support it. Nevertheless, we found that, within the hip osteoarthritis group, Garden type 3 and 4 fractures were more frequent than type 1 and 2 fractures, the same applies for trochanteric fractures (3.1-A1>3.1-A2). This could mean that while the hip osteoarthritis is a protective factor for intracapsular fracture, in the case of femoral neck fracture, it should be expected a more severe fracture pattern.

Moreover, possible additional clinical implications could lead to consider an implementation of an extensive prevention of severe HOA onset with both an early surgical hip deformity correction, such as femoral-acetabular impingement removal in younger patients, and an earlier indication to a hip arthroplasty in the case of severe HOA, in order to prevent the risk of complex hip fractures, reducing their morbidity and costs [27]. Recent advances in the reliability of rheumatological therapies in HOA early stages could pursue the same purpose.

The limits of this study could be that the radiographs views and quality could be not fully reproducible and that the considered hip osteoarthritis classification criteria (K/L and Tön)

are just semiquantitative. Furthermore, some variables which can influence the onset of hip osteoarthritis and the risk of a fracture could have not been considered, among these are some important factors such as obesity, neurological diseases [19], and osteoporosis [28].

Compliance with ethical standards

Conflicts of interest   None.

Ethical approval   All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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