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Original Article

Radiographic anatomy of the proximal femur: femoral neck fracture *vs.* transtrochanteric fracture☆

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ABSTRACT

Objective: To evaluate the correlation between radiographic parameters of the proximal femur with femoral neck fractures or transtrochanteric fractures.

Methods: Cervicodiaphyseal angle (CDA), femoral neck width (FNW), hip axis length (HAL), and acetabular tear drop distance (ATD) were analyzed in 30 pelvis anteroposterior view X-rays of patients with femoral neck fractures ($n = 15$) and transtrochanteric fractures ($n = 15$). The analysis was performed by comparing the results of the X-rays with femoral neck fractures and with transtrochanteric fractures.

Results: No statistically significant differences between samples were observed.

Conclusion: There was no correlation between radiographic parameters evaluated and specific occurrence of femoral neck fractures or transtrochanteric fractures.

Anatomia radiográfica do fêmur proximal: fratura de colo *vs.* fratura transtrocantérica

Palavras-chave:
Fraturas do quadril
Colo do fêmur
Radiografia

RESUMO

Objetivo: Correlacionar parâmetros radiográficos do fêmur proximal com a ocorrência de fraturas do colo do fêmur ou fraturas transtrocantéricas do fêmur.

Métodos: Foram avaliados o ângulo cevicodiafisário (ACD), a largura do colo femoral (LCF), o comprimento do eixo do quadril (CEQ) e a distância entre as lágrimas acetabulares (DL) de radiografias de bacia em incidência anteroposterior de 30 pacientes com fratura de colo de fêmur ($n = 15$) e fratura transtrocantérica de fêmur ($n = 15$). A avaliação foi feita com a comparação dos pacientes com fratura de colo de fêmur com os pacientes com fratura transtrocantérica.

☆ Study conducted at Hospital Otávio de Freitas, Recife, PE, Brazil.

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Resultados: Não foram observadas diferenças estatisticamente significantes entre as amostras obtidas entre os dois grupos comparados.

Conclusão: Não houve correlação entre os parâmetros radiográficos avaliados e ocorrência específica de fraturas de colo de fêmur ou fraturas transtrocantéricas de fêmur.

Introduction

Advances in medicine and pharmacology have led to a significant increase in global life expectancy, reflected positively in the growing number of elderly people. However, there is a real concern about the quality of life of these aging adults, and especially, regarding how to adequately prevent and treat the complications inherent to this age group. Among these complications are low-energy fractures, or those that are a consequence of associated pathological complications.[1–3]

Hip fractures have serious impact on elderly patients, especially the very elderly (over 80 years).[3] This issue is relevant due to the high morbidity and mortality, high postoperative disability index, and increasing costs to society with less beneficial results related to treatment.[4] These fractures are considered one of the largest public health problems in the world.[4] According to American statistics, over 250,000 hip fractures occur each year; it is expected that over the next 30 years, there will be an increase of 100% in the number of cases/year. In Brazil, in 2010, the incidence was 100,000 fractures per year, and the mean mortality one year after the fracture was 30%. Femoral fractures, especially proximal fractures, are among the most relevant.[4]

Adequate surgical treatment is paramount for good prognosis; the method chosen is directly related to the type of hip fracture, specifically the types of femoral fractures (distal or proximal). Proximal fractures can be divided into two types: intracapsular and extracapsular. The first type includes fractures of the femoral neck, and the second type, transtrochanteric fractures. Both have low-energy trauma as the main etiology, and both have great influence in associated pathologies, such as osteoporosis.[5–7]

Osteoporosis, undoubtedly the most common of bone diseases, has become a burden of considerable economic significance. Factors such as ethnicity, gender, physical activity, and nutrition influence the maximum bone quality achieved by each individual, but are not the only determining factors for fractures. The specialized literature emphasizes that bone mineral density (BMD), an age-related predictor of fracture, is not always consistent: individuals with very low femoral neck BMD may not present fracture, while those with normal BMD might.[8] There may be other relevant variables that determine fractures and especially their types, such as bone anatomy.[8,9]

Bone geometry of the proximal femur has been studied[10] as a potential risk factor, and has been positively associated in the prediction of fracture risk. However, most hip fracture studies do not distinguish the predisposition between the two main types of fracture (femoral neck and transtrochanteric), which in clinical practice would be fundamental, since the surgical approach of choice can be different due to the high rate of hip arthroplasty indication in femoral neck fractures, which in turn has financial repercussions and affects patient recovery in the postoperative period.

Thus, this study is aimed at analyzing the influence of proximal femoral bone geometry in the type of femur fracture presented, by measuring standard pelvic radiographs.

Material and methods

This was a prospective, cross-sectional study performed in an orthopedic and trauma service in Brazil between August 10, 2015 and September 8, 2015. The study included 30 radiographs of patients with hip fractures, randomly selected as cases were admitted. The study followed the Declaration of Helsinki and was approved by the internal Ethics Committee (No. 1.221.094).

Radiographs were taken in the anteroposterior view, with the X-ray generator located one meter from the chassis. Patients were placed in a horizontal dorsal recumbent position, with the lower limbs rotated internally at 15°.

The inclusion criteria were panoramic radiographs of the hip of patients aged over 60 years, of both genders, with femoral neck and transtrochanteric fractures.

Exclusion criteria included radiographs of skeletally immature patients; bilateral hip fracture; and presence of tumor, infectious lesions, or metabolic diseases that could alter the hip and proximal femur anatomy.

After classification and selection, the radiographs were anatomically evaluated, according to the following measures:

- Cervicodiaphyseal angle (CDA): angle between the axis of the femoral neck and the diaphysis.
- Femoral neck width (FNW): distance between cortical lines, at the midpoint of the femoral neck, perpendicular to its axis.
- Hip axis length (HAL): the distance in a straight line between the base of the great trochanter to the end of the femoral head, following the line of the axis of the femoral neck.
- Acetabular tear drop distance (ATD): the distance in a straight line between the acetabular tear drops.

The choice of these measurement indexes was based on previous studies that conducted morphometric analyses of the proximal femur.[11] All measurements were made by two blinded examiners using a goniometer (MSD, Europe BVBA-Belgium).

The measurements were collected by manual marking of the aforementioned reference points. It was decided not to

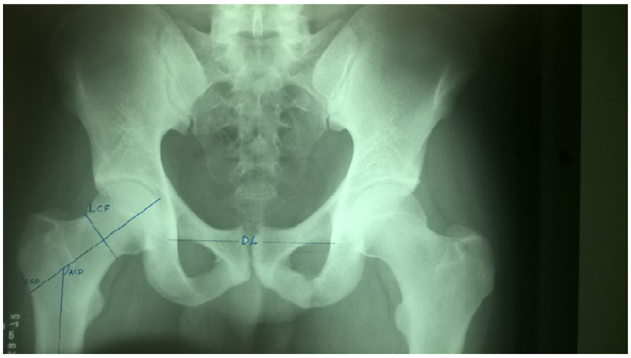

Fig. 1 – Representation of angles measured in an anteroposterior pelvic radiograph.

use computer programs for measuring, as the process of scanning the radiographs could lead to uneven magnification of the images and thus generate calibration bias, since the system available at this medical center is not digital (Fig. 1).

The Kolmogorov–Smirnov test was used to assess the intrinsic parameters of the sample regarding its normality and distribution. Data were expressed as mean, standard deviation, and percentage (SPSS Statistical Software).

The variables were analyzed descriptively through the mean, standard deviation, minimum and maximum values, and 95% confidence intervals. Student's *t*-test was used to compare the difference between the means of two variables, and Pearson's correlation coefficient was used to assess the correlation index. The level of significance was set at 5% (ROSNER, B. Fundamentals of Biostatistics. Boston, PWS Publishers, 2nd ed.)

Results

The study included 30 patients, male ($n=6$; mean age = 76, SD = 3.48) and female ($n=24$; mean age = 77.37, SD = 8.53), that were divided into two large groups of fractures with their respective anatomic evaluations, as shown in Table 1.

Parametric evaluation of the collected data

In order to establish reliable indexes in the comparisons, the normality of the samples was first determined according to the Kolmogorov–Smirnov test, *i.e.*, it was determined whether two underlying probability distributions would differ in relation to the normality hypothesis, in any one of the cases. The normality hypothesis was not rejected for the variables investigated with $p > 5\%$.

Then, to characterize possible interference biases between the angles measured by the observers of the study regarding gender and age, Pearson's correlation test was used. No positive association was observed between the variables, as shown in Table 2.

After determining the normality of the sample distribution and ruling out interference bias, the measurements made by the observers were compared to assess the difference between the types of fractures, represented by the measured angles, and whether these values were correlated. Although there were differences between the mean angles (around 3°–7°), Student's *t*-test indicated that they were not significant (Table 3, Figs. 2–5).

Table 1 – Characterization of the groups according to the evaluated angles.

Angles	Fractures							
	Transtrochanteric				Neck			
	CDA	FNW	HAL	ATD	CDA	FNW	HAL	ATD
Max	139	42	126	135	139	39	132	134
Min	125	30	99	110	120	29	90	114
M	131.7	34.7	110.2	125.1	131.8	33.2	112.6	122.1
SD	1.2	0.98	2.22	1.96	1.33	0.65	3.08	1.36
n	15	15	15	15	15	15	15	15

Max, maximum; Min, minimum; M, mean; SD, standard deviation; *n*, number of cases.

Table 2 – Pearson's correlation test to de-characterize the correlation between age, gender, and measurements.

Measurements		CDA	FNW	HAL	ATD
Age	Pearson's correlation	0.124	0.049	0.159	0.094
	p-value	0.392	0.735	0.116	0.318
Gender	Pearson's correlation	−0.094	−0.064	−0.225	−0.144
	p-value	0.387	0.516	0.657	0.318
Total	*n*	50	50	50	50

Table 3 – Numerical representation of the comparison data (unpaired *t*-test) between types of fractures for each pair of angles studied.

Pairs	*n*	MD	95% CI	R	*p*
CDA Trans × Neck	30	0.13 ± 1.7	−3.5 to 3.8	0.0001	0.69
FNW Trans × Neck	30	−1.46 ± 1.18	−3.89 to 0.95	0.05	0.14
HAL Trans × Neck	30	2.4 ± 3.8	−5.39 to 10.19	0.01	0.53
ATD Trans × Neck	30	−3 ± 2.3	−7.9 to 1.9	0.05	0.22

MD, mean deviation; *n*, number of patients; *p*, statistical value for significance of correlation; *r*, Pearson correlation index.

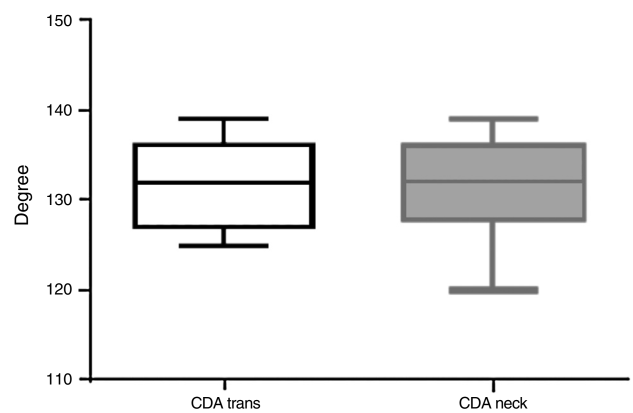

Fig. 2 – Representation of the statistical relationship of the paired *t*-test between CDA in transtrochanteric fractures and CDA in femoral neck fractures.

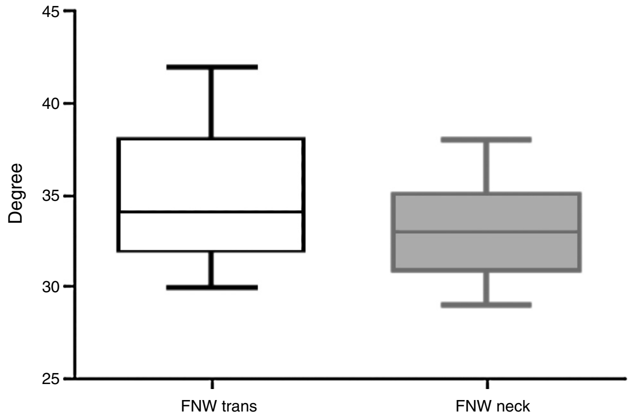

Fig. 3 – Representation of the statistical relationship of paired *t*-test between FNW in transtrochanteric fractures and FNW in femoral neck fractures.

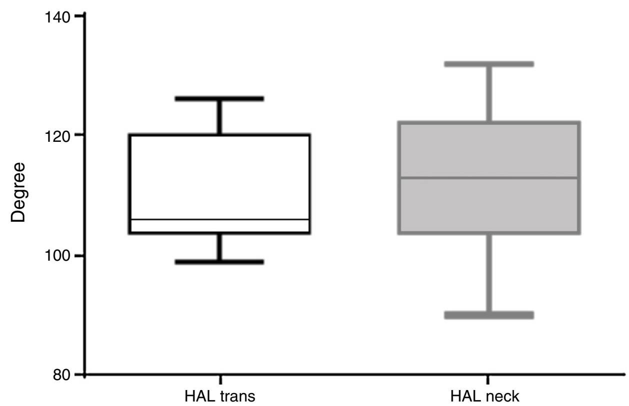

Fig. 4 – Representation of the statistical relationship of the paired *t*-test between HAL in transtrochanteric fractures and HAL in femoral neck fractures.

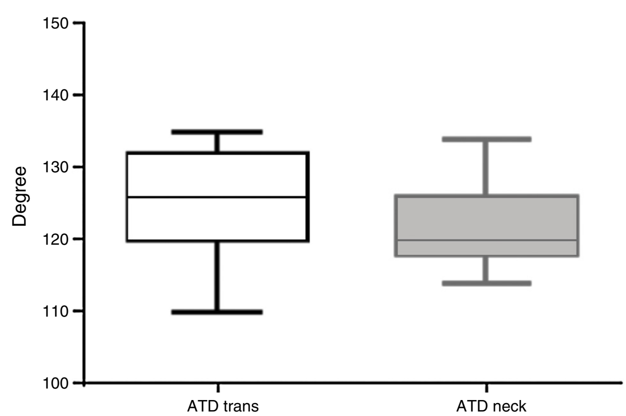

Fig. 5 – Representation of the statistical relationship of the paired *t*-test between DL in transtrochanteric fractures and DL in femoral neck fractures.

In order to establish a correlation between the variables measured according to the type of fracture, Pearson's correlation test was applied, which showed negativity and low correlation indexes, all of which were non-significant (Table 4, Figs. 6–9).

Table 4 – Numerical description of the values assigned to the Pearson correlation pairs between femoral neck and transtrochanteric fractures.

Pairs	*n*	*r*	95% CI	R	*p*
CDA Trans × Neck	30	0.38	−0.17 to 0.6	0.15	0.15
FNW Trans × Neck	30	0.394	−0.16 to 0.74	0.145	0.14
HAL Trans × Neck	30	0.04	−0.47 to 0.54	0.002	0.43
ATD Trans × Neck	30	−0.06	−0.55 to 0.46	0.003	0.82

n, number of patients; *p*, statistical value for significance of correlation; *r*, Pearson correlation index.

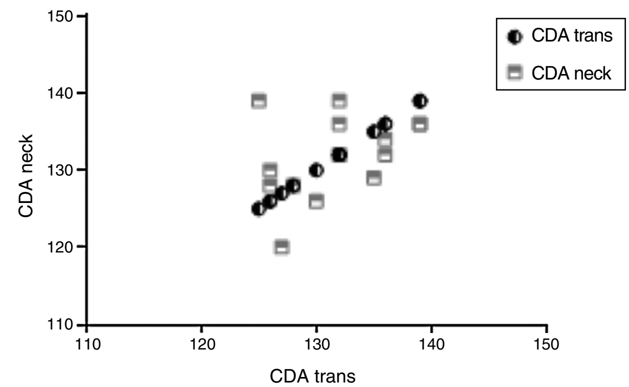

Fig. 6 – Representation of the negative correlation between CDA in transtrochanteric fractures and CDA in femoral neck fractures.

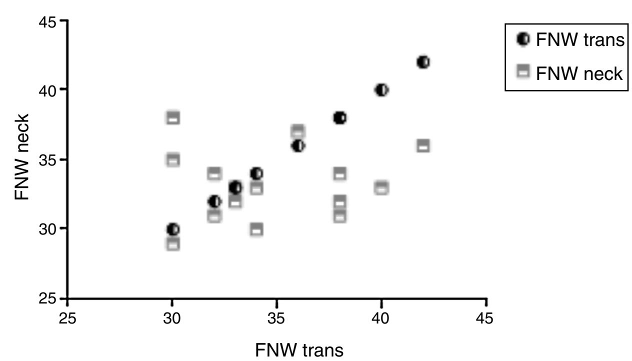

Fig. 7 – Graphic representation of the negative correlation between FNW in transtrochanteric and FNW fractures in femoral neck fractures.

Study limitations

A higher and more representative sampling of the population affected by hip fractures, a study in different groups with associated pathologies, and the addition of a healthy control group would be necessary.

Discussion

In the present study, it was demonstrated that, although radiography is a good method to evaluate bone structures and predict hip fractures, it was not sensitive enough to capture differences between femoral neck and transtrochanteric

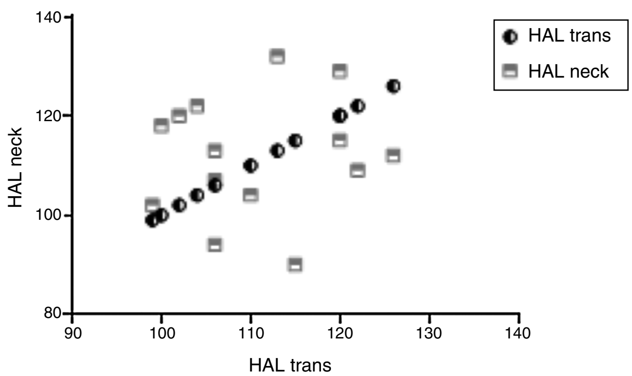

Fig. 8 – Graphic representation of the negative correlation between HAL in transtrochanteric fractures and HAL in femoral neck fractures.

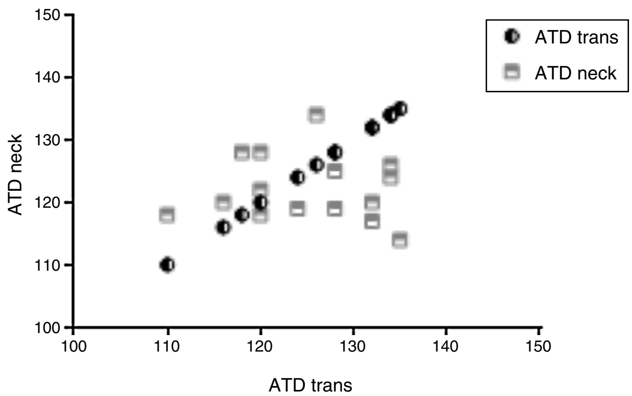

Fig. 9 – Graphical representation of the negative correlation between ATD in transtrochanteric and ATD fractures in femoral neck fractures.

fractures when compared with a healthy control group. No significant geometric difference was observed between the groups studied.

The increased risk of bone fractures due to loss of bone mass during a disease or aging process is a major clinical problem, which leads to an estimate of health costs of around US$ 17 billion in the United States alone.[12,13] In addition to the economic burden, non-vertebral fractures, especially those of the hip, are an important cause of morbidity and mortality in the aging population.[14,15] Over 4% of patients with pelvic fracture die during hospitalization, and 24% die within a year.[16] Thus, concentrated efforts are needed to identify treatment strategies that maintain skeletal health as patients age. However, it is of paramount importance to improve accuracy in identifying those at risk for bone fractures.

BMD measurements are widely used to assess bone mineral status, especially in women; they can account for up to 70% of bone strength. Although studies have demonstrated the correlation between BMD (commonly determined through dual-emission X-ray absorptiometry [DXA]) and fracture risk, predictive models based on DXA alone often present low sensitivity in identifying individuals susceptible to fractures, particularly in women of menopause age and in older populations.[2,17]

The structural integrity of this tissue in any mechanical loading environment is dependent on the spatial distribution of BMD, size, and shape, as well as the properties of bone material.[18,19]

In literature, several studies have demonstrated the clinical potential of bone texture analysis through pelvic radiographs in predicting the risk of femoral neck fractures. In a retrospective study, Thevenot et al.[10] observed a high intra- and interobserver reproducibility and reliability, and concluded that the structural analysis of pelvic radiographs allows the identification of patients with risk of femoral neck fractures. This finding corroborates with studies described in the literature, which suggest that the trabecular texture parameters, especially the entropic parameter, allow the separation of individuals at risk from the control individuals; however, no parameter suggests the ability to differentiate among the types of injury, as was studied in the present study.[20–22]

One of the great foes in bone injury is osteoporosis, the most common bone disease. It has become a burden of considerable economic significance. Factors such as ethnicity, gender, physical activity, and nutrition influence the maximum bone mass quality achieved by each individual. However, bone mass alone is not a determining factor.[3,4] A study by Cummengs et al.[22] found that Japanese women had lower BMD than their Caucasian peers; however, the former suffered fewer fractures. Likewise, age and BMI may not be directly related to loss in bone mass.[23]

Wheeler et al.,[8] in their study of the cross-sectional geometry of long bone diaphyses that correlated BMD, BMI, and age, demonstrated that bone strength is significantly higher in obese individuals when compared with those with normal BMI. However, the joint dimensions do not differ appreciably; older individuals with a higher BMI are less likely to develop a fracture than younger individuals with normal BMI.

In attempting to establish a risk assessment based on DXA, a multifactor tool was developed to determine hip fracture propensity, a method recommended by the World Health Organization. This tool takes into account different factors (anthropometric variables, medical history, and drug use) to evaluate the ten-year risk of fracture, using clinical risk factors with or without BMD values.[24] Nonetheless, this method still has low sensitivity for fracture prediction, since it is improved in a generic way, and cannot reflect the complexity of the personalized evaluation of individuals and/or specific populations.[25,26]

Different imaging methods such, as peripheral quantitative computed tomography and magnetic resonance imaging (MRI), can be used to obtain three-dimensional geometry and bone architecture *in vivo*. These methods may provide some relevant information in assessing bone quality.[27] However, the limited availability and high cost of these methods has led to the development of other types of low-cost analyses that may be clinically applicable, such as radiographs.

At present, the solution for a low-cost study of bone structures has been conventional radiography. It allows the evaluation of the geometry, the structure, and, eventually, the risk of bone fracture. Nonetheless, new prospective studies with geometric measurements are still needed to confirm the clinical capability of the bone texture analysis through this tool, as well as the possibility of predicting and defining risk groups for specific types of hip fractures, especially transtrochanteric and those of the femoral head.

Conclusion

In the present study, it was demonstrated that although radiography is a good method to evaluate bone structures and predict hip fractures, it was not sensitive enough to capture differences between femoral neck and transtrochanteric fractures when compared with a healthy control group. Further prospective studies are needed to establish parameters capable of measuring such differences.

Conflicts of interest

The authors declare no conflicts of interest.

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