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FEMORAL NECK FRACTURES – BIOLOGICAL ASPECTS AND RISK FACTORS.

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ABSTRACT

The strength of the bone is a function of its mechanical properties and bone geometry. The probability of the occurrence of femoral neck fracture is associated with both the trauma mechanism and magnitude of the acting forces as well as with the bone quality, the mental state, the incidence of falls, the use of medications, and other factors, the knowledge of which may help for better prevention of this devastating injury.

Key words: femoral neck fracture, intracapsular fractures, osteoporotic fractures, hip,

Biological aspects and risk factors.

Bone geometry.

The bone strength is closely related to the bone mass with a correlation coefficient of 0.6 to 0.8 between the bone mineral density and the force required to induce fracture [1]. Bone strength is also a function of geometry of the bone, of its microarchitecture and other parameters. *The mechanical quality* of the bone is determined by the bone *macroarchitecture* (shape and geometry), the degree of mineralization, the rate of bone turnover, the *microarchitecture* (trabecular and cortical), the degree of microdamage accumulation (microcracks and diffuse damage), and by the ultrastructure of bone collagen [2, 3]. These factors determine the material properties of the bone such as ***elasticity*** and ***rigidity*** [3]. All of these indicators are known as ***bone quality*** [4]. The mechanical properties of the bone are different according to the anatomic location and loading.

Significance of the bone geometry.

The mechanical strength of proximal femur depends on the size of the bone and the distribution of mass within the bone [5]. The length of proximal femur and the area of its cross-section may affect its strength [6]. Another factor for occurrence of femoral neck fractures is related to the length of the femoral neck. Reid et al.(1994) [7] found that the *length of the neck axis* (the distance from the center of the head to the cortex of the trochanter) is associated with increased incidence rate of neck fractures.

The diameter of the femoral neck is important for the bone strength, because, as with a solid bar, the contribution of a given part of bone to the bending strength is proportional to the fourth power of its distance from the neutral (central) axis of the bar. Thus the bending strength of the bar is determined by the material placed in the periphery of the bar, and if a similar load is applied to bones with equal cortical thickness and different diameters, the narrower bones will be exposed to a higher risk of fracture [3].

Brownbill and Ilich (2003)[8] described several components of the geometry of proximal femur which are possible risk factors for fracture. Three parameters of the proximal femur geometry are most important for fracture risk assessment. (1) The distance from below the lateral aspect of the greater trochanter through the femoral neck to the inner pelvic brim, is referred to as *Hip axis*. The length of this axis - *Hip axis length* (HAL), is a measure of the length of the “lever arm” of the femur. (2) *Femoral neck axis length* (FNAL) is determined as the length between the lateral border of the base of greater trochanter and the femoral head apex (HAL minus the pelvic portion). (3) The *femoral neck width* (FNW) is the shortest diameter of the femoral neck [8, 5].

The mechanism of femoral neck fracture, when there is a side fall and a direct impact on the trochanter, involves bending of the neck under the body weight (the femur shaft is in a horizontal position and the neck is pressed between the body and the floor). The strength of the bone at bending and torsion depend on its *section modulus* which depends on the bone diameter. The bending moment that breaks the femoral neck is a product of the femoral neck axis length (FNAL) and the bending component of the body weight. The bending component of the body weight is nearly perpendicular to the femoral neck axis and gets bigger as the femoral neck shaft angle (NSA) gets larger [3,9]. The larger the femoral neck shaft angle is, and the longer the femoral neck axis length (FNAL) is, the greater the bending moment acting on the femoral neck is, thus increasing the risk of fracture.

The femoral neck axis length (FNAL) and the femoral neck width (FNW) are correlated. A femoral neck fracture can occur in individuals with long femoral neck although at the same time their neck is wide [10].

From those parameters, Hip axis length (HAL) is the most important prognostic parameter for assessment of the fracture risk, and can be used independently of the age and BMD in older women. The average value of Hip axis length (HAL) is 10.5 cm among Caucasian women and is positively related to height [11].

The risk of hip fracture for white women is twice as high as the risk for black women. The greater strength of the proximal femur in blacks is due to more favourable geometric parameters such as shorter hip axis length (HAL) and a thicker femoral neck cortex [12]. Asian women also have twice as small hip fracture risk than whites due to the shorter HAL and the smaller neck-shaft angle (NSA) [13]. Each centimetre of extension of HAL increases the hip fracture risk in white older women by 50%. A longer hip axis length (HAL) and a greater neck-shaft angle (NSA) increase the risk of proximal femur fracture [8]. The fracture risk decreases when the femoral neck is wider, because the value of any type of stress depends on the area transmitting the load. For example, if the cross-section of a column that is subjected to pressure is doubled, then the value of the compressive stress is reduced by half. In the same way, if there is an eccentric load, with doubling of cross-section of the column, the bending stress is reduced to 1/3 [14].

The thinning and increased porosity reduce the cortical bone strength. At the same time, the thinning, perforation and loss of connectivity in cancellous trabeculae weakens the internal supporting structure of the proximal femur [15].

Osteoporosis.

The increase in incidence rate of femoral neck fractures with ageing is predominantly related to osteoporosis. *Osteoporosis* is a skeletal disease characterised by low bone mass and microarchitectural deterioration with a resulting increase in bone fragility and hence susceptibility to fracture [16].

Osteoporosis can be postmenopausal, surgical, senile, or caused by physical inactivity. In elderly patients, osteoporotic fractures are result mainly of reduced bone strength and increased incidence of falls.

The measurement of bone mineral density (BMD) is the most available_non-invasive method for assessment of the bone strength, but also should be taken into account the other characteristics of skeleton that contribute to bone strength, such as bone macroarchitecture, microarchitecture, matrix and mineral composition, as well as the degree of mineralization, accumulation of micro damages and the level of bone mineral turnover which can affect the structural and physical properties of the bone [17].

The measurement of bone mineral density for diagnosis of osteoporosis has been used since 1994. Low bone mineral density alone does not mean an individual will have a fracture. The accepted threshold for the presence of *osteoporosis* is T-score below -2.5, and for *osteopenia* the T-score range is between -1 and -2.5. *Osteomalacia* refers to the increase of the relative share of non-mineralized organic bone component (osteoid).

Irrespective of the value of BMD, the WHO has identified several risk factors for fracture occurence. These are: history of fracture, glucocorticoid use, family history of fracture, cigarette smoking, excessive alcohol consumption, and low body weight. The combined use of these risk factors together with age and bone mineral density allows the 10-year probability of hip and other fractures to be predicted [4].

Zuckerman [18] assumes that the risk factors for occurrence of hip fracture are: age, osteoporosis, white women, maternal history of hip fracture, excessive consumption of alcohol and caffeine, physical inactivity, low body weight, tall stature, previous hip fracture, use of psychotropic medications, residence in an institution, visual impairment, and dementia.

Age-related incidence of hip fractures is associated both with the increase of osteoporosis and the increase of the frequency of falls with advancing in age. 1% of all falls cause a fracture of the proximal femur [19] and 90% of the fractures of the proximal femur are due to falling [20]. The most common causes for falling are: balance impairment, reduced muscle strength, impaired vision, psychotropic medication, compromised gait, depression, dizziness or orthostatism, functional disorders (ADL), age over 80, female gender, low body-mass index, urinary incontinence, cognitive disorders, arthritis, diabetes, pain [21].

A downtrend of the annual incidence of hip fractures is observed in some countries such as Canada, Denmark and others, due to lifestyle changes. With women, the increase in the number of reproductive years and the related extension of the effect of endogenous hormones, the intake of calcium and vitamin D, stopping smoking, regular intensive exercises, fall prevention, and use of alcohol reduction probably contributed to the reduction of the frequency of these fractures [22].

With ageing in women, the proportion of trochanteric fractures increases more compared to the proportion of femoral neck fractures. There are indications that osteoporosis is a more important causative factor in pertrochanter fractures than in femoral neck fractures [23].

CONCLUSION

The knowledge of the factors predisposing the occurrence of femoral neck fractures could contribute to a better prevention of this devastating injury.

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