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Hip Fracture, Femoral Bone Mineral Density, and Protein Supply in Elderly Patients

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Osteoporosis is widely recognized as a major problem in public health. The most dramatic expression of this disease is represented by fractures of the proximal femur. In this chapter we shall consider the problem of malnutrition that can be observed in elderly patients with hip fracture and present two prospective studies indicating that daily oral dietary supplementation providing an adequate intake of protein can substantially improve the clinical course. However, before discussing our investigations on nutritional aspects, it seems appropriate to present briefly the magnitude of the hip fracture problem in our area and its relation to femoral mineral density, since malnutrition is considered as a risk factor in the maintenance of bone mass during adult life.

EPIDEMIOLOGICAL ASPECTS

Several studies (1–6) indicate that the number of hospital admissions of elderly patients with proximal femur fractures has increased considerably during the last 20 years. The same trend was observed in the University Hospital of Geneva (Switzerland). This prompted us to investigate (7) the incidence of all hip fractures as well as of those most likely to be due to osteoporosis, and the coinciding medical and social conditions, in the region of Geneva, which has the oldest population in Switzerland. The Geneva region seemed to be well suited to this kind of epidemiological study, since more than 90% of the patients with hip fractures are referred to one center, allowing a homogeneous evaluation. During 1987, 361 patients with hip fracture were recorded in the University of Geneva hospital, which is the main referral center for a population of about 376,000 inhabitants. This represented 94% of all hip fractures occurring in the region. Moderate trauma was reported in 329 cases (91.1%). The overall annual incidence was 96.1 per 100,000 population (146.9 for women and 39.8 for men). When only hip fractures following moderate trauma were considered, the incidence was 87.6 per 100,000 population (138.8 for women and 30.8 for men). Rare under the age of 65, hip fracture incidence increased exponentially later on. The mean age of patients with hip fracture was 82.0 in women and 75.7 years in men. The mean length of stay in the orthopedic ward was 30.5 days. During the stay in the orthopedic ward the mortality rate was 8.2% and about 55% of the patients displayed one or more severe complications such as bedsore, pneumonia, or pyelonephritis. The costs amounted to 8.8 million Swiss francs for hip fracture associated with moderate trauma. Forty-seven percent of subjects were transferred to another hospital for recovery or rehabilitation. Therefore, the overall cost of hospital admission exceeded 10 million Swiss francs. This survey emphasizes the high incidence and economic importance of hip fractures in a region of Switzerland where the population is particularly old. The problem will probably worsen with the progressive aging of the population. Therefore, it appears appropriate to study factors that could affect both the incidence of hip fractures and their dramatic consequences on the health of the elderly and on the economic burden of medical services in our region.

RELATION BETWEEN FEMORAL BONE MINERAL DENSITY AND HIP FRACTURE

Hip fracture incidence depends on several factors such as the propensity to fall and the insufficiency of protective mechanisms such as reaction time and muscle strength, which may decrease the force required to fracture a piece of the skeleton (8.9). It also depends on specific bone properties such as bone mass and bone architecture. As the breaking strength of bone is directly proportional to bone density (10,11), age-related bone loss should be a major determinant of the risk of fracture. Thus, the incidence of hip fracture has been found to be inversely correlated with femoral neck bone mineral content (12). However, direct determination of bone mineral density of the femoral neck has failed to show a significant difference between patients with hip fracture and age-matched normal individuals in some studies (13,14), but not in others (15,16). An interval between fracture and bone mineral density measurement of up to 5 years might have precluded the detection of a difference. Indeed, either overloading of the contralateral limb or undermobilization during the period following the fracture might have caused an increase or a decrease in femoral neck mineral density. In order to clarify this important issue, we measured bone mineral density in the femoral neck on the opposite side to the fracture, as well as in the femoral shaft and in the lumbar spine (L2–L4), by dual photon absorptiometry (17) in 68 patients (57 women and 11 men, mean age 78.8 ± 1.0 years, mean ± SEM) 12.4 ± 0.8 days after hip fracture following a moderate trauma (18). These values were compared to mineral density at the same bone sites in 93 nonfractured elderly control subjects (82 women and 11 men) measured during the same period. As compared with the controls, femoral neck bone mineral density was significantly lower in women with fractures (0.592 ± 0.013 *vs.* 0.728 ± 0.014 g/cm^2, $p < 0.001$) and also in men with fractures (0.697 ± 0.029 *vs.* 0.840 ± 0.052, $p < 0.05$). Expressed as standard deviations above or below the mean bone mineral density of age- and sex-matched normal subjects (Z score), the difference in femoral neck bone mineral density between women with fractures and controls was highly significant (−0.6 ± 0.1 *vs.* +0.1 ± 0.1, $p < 0.001$). As compared with mean value in young normal subjects, bone mineral density was decreased by 36.9 ± 1.4 and 22.4 ± 1.5% ($p < 0.001$) in women with fractures and controls, respectively. Femoral neck bone mineral density was lower than 0.705 g/cm^2 in 90% of the women with fractures. The prevalence of fracture increased with decreasing bone density, reaching 100% with values below 0.500 g/cm^2. Femoral shaft and L2–L4 bone mineral densities were significantly lower in women with hip fractures than in controls (1.388 ± 0.036 *vs.* 1.580 ± 0.030, $p < 0.001$, for femoral shaft; and 0.886 ± 0.027 *vs.* 0.985 ± 0.023, $p < 0.01$, for L2–L4), but these differences were not significant when expressed as a Z score. In men with a recent hip fracture, femoral shaft bone density was significantly lower than in controls (1.729 ± 0.096 *vs.* 2.069 ± 0.062, $p < 0.01$), but the difference at the lumbar spine level did not reach statistical significance. These results indicate that both women and men with a recent hip fracture had decreased bone mineral density of the femoral neck, femoral shaft, and lumbar spine. However, the difference appeared to be of greater magnitude in the femoral neck, suggesting a preferential bone loss at this site (18).

RELATION BETWEEN NUTRITION AND HIP FRACTURE

Malnutrition may well represent an important determinant of both incidence and complications of hip fractures in the elderly. The aging population is known to present a high prevalence of malnutrition and patients with fracture of proximal femur appear particularly undernourished, as pointed out by several authors (19–22). Therefore, malnutrition can be considered as a risk factor for hip fracture. Several reasons have been proposed to support this contention. First, malnutrition can be expected to accelerate the process of age-dependent bone loss, since diets deficient in calcium and/or protein are often associated with osteoporosis. Second, malnutrition can be expected to increase the propensity to fall by impairing the coordination of movements (23). Finally, malnutrition could affect the above-mentioned protective mechanisms, such as reaction time and muscle strength, which may decrease the power of impact required to fracture an osteoporotic hip (8,9). After the occurrence of the fracture, nutritional deficiencies may lead to an increase in complications and a greater mortality rate. It has been reported that either supplementary nasogastric tube feeding (24) or parenteral nutrition (25) may be associated with an improvement in clinical outcome following femoral neck fracture in elderly subjects.

BENEFITS OF ORAL DIETARY SUPPLEMENT ON CLINICAL OUTCOME IN PATIENTS WITH HIP FRACTURE

In an initial prospective randomized study (26) we assessed the clinical benefits of a simple oral dietary supplement taken by elderly patients after fracture of the proximal femur. The effects on clinical evolution of a simple dietary intervention provided as an oral protein-energy supplement were studied in elderly patients with femoral neck fractures due to moderate trauma.

Patients and Dietary Supplementation

Fifty-nine patients, mean age 82 years, were randomized in two groups when entering the orthopedic clinic. Twenty-seven patients received a daily oral nutritional supplement, in addition to the standard hospital diet. Thirty-two patients were used as controls. The oral nutritional supplement provided 254 kcal, 20.4 g protein, 29.5 g carbohydrate, 5.8 g lipid, 525 mg calcium, 750 IU vitamin A, 25 IU vitamin D_3, vitamins E, B_1, B_2, B_6, B_{12}, C, nicotinamide, folate, calcium-pantothenate, biotin, and minerals in 250 ml. It was started on admission to the orthopedic clinic and continued throughout the stay in the second (recovery) hospital. The supplement was given at 8 PM, so that it did not interfere with the scheduled meals, for a mean period of 32 days. It was well accepted, completely ingested, and no side effects were observed.

Nutritional Deficiencies on Admission

Anthropometric and biochemical evaluation confirmed the presence of nutritional deficiencies in a majority of patients on admission (19–22). Mean plasma concentration of 25-hydroxyvitamin D of the total study population was 18.9 nmol/l, below the lower limit of normal range (23 nmol/l), with as many as 80% of the subjects displaying poor vitamin D status. The mean concentrations of several nutritional indicators such as retinol-binding protein, vitamin A, and carotene were also below the normal range. This expression of undernutrition appeared to be more severe than that observed among the general aging population (19–22). It cannot be explained by one single cause, since medical, psychological, social, ethnic, and environmental factors probably play an intricate role.

Inadequate Food Intake During Hospital Stay

A precise dietary survey based on 50 daily determinations of the food intake, as assessed by the weighing method, confirmed that nutritional requirements were not covered while the patients were staying in the hospital, despite adequate quantities offered. The voluntary oral intake of energy was only 1,100 ± 300 kcal/day (mean

± SD), that of protein 34 ± 11 g/day, and that of calcium 400 ± 250 mg/day. Our dietary survey confirms that elderly patients in hospital only eat part of their meals at best (23). In this group of patients with femoral neck fractures, the energy intake during hospital stay was inadequate, with a mean value corresponding to about 60% of the recommended allowance for elderly people: energy 1,800 kcal/day, protein 60 g/day, and calcium 1,000 mg/day (27,28). The spontaneous food intake can therefore be expected to perpetuate malnutrition, as previously reported in this type of patient (23,24).

Effects of Dietary Supplementation

The dietary supplementation increased the intake of energy by 23%, of protein by 62%, and of calcium by 130%. Given at 8 PM, the supplement did not interfere with the scheduled meals and thus did not reduce the voluntary oral intake. The oral protein-rich nutritional supplement given daily increased the energy intake close to the recommended allowances. Its ingestion was associated with biochemical evidence of nutritional improvement, as assessed by the serum albumin levels, which showed a significant increase in the supplemented patients. Such an improvement was obtained previously by using either nasogastric tube feeding or parenteral nutrition (24,25). Our study demonstrated that it can be achieved by providing a simple oral dietary preparation. This simplicity has some obvious practical and psychological advantages.

The clinical follow-up was significantly better in the supplemented group, with 56% having a favorable clinical outcome as compared to 13% in the control group ($p < 0.05$) during their stay in the convalescent hospital. The rate of complications and deaths were significantly ($p < 0.05$) lower in the supplemented (44%) than in the control group (87%). Six months after the fracture, the rate of complications and mortality remained significantly lower ($p < 0.02$) in supplemented patients (40%) than in controls (74%). Similarly, the median duration of the overall hospital stay was significantly shorter ($p < 0.02$) in the supplemented group (24 days) than in the patients receiving dietary supplement (40 days). Although the mean duration of the dietary supplementation did not exceed one month, the significantly lower rate of complications and deaths was still observed at 6 months. When mortality is considered alone, no patient belonging to the supplemented group died between the discharge day from the second hospital and the 6-month control as compared to six fatal outcomes in the control group. Again, these results are in good agreement with two previous studies made in patients with femoral neck fractures receiving dietary supplementation provided either by nasogastric tube or intravenous infusion (24,25). In both trials improvement in anthropometric variables and clinical outcome was documented (24,25). In our study, the differences in the biochemical and clinical evolution between the two groups of patients suggest that the nutritional state was rapidly influenced by the oral supplementation, while its clinical benefit became clearly apparent only after the acute traumatic phase (fracture, operation, and early postoperative days) was passed.

The results of this first controlled study suggested that the clinical outcome of elderly patients with femoral neck fracture can be improved by a simple oral dietary supplementation. Among the various nutritional elements that could have played a role, an inadequate protein intake might have been particularly important for the risk of hip fracture.

ROLE OF PROTEIN IN THE BENEFITS OF DIETARY SUPPLEMENTATION

The major aim of this second prospective controlled study was to assess the clinical outcome of hip-fractured elderly patients receiving two different oral dietary supplements, which essentially differed by the presence or absence of protein. In addition, we also determined bone mineral density by dual photon absorptiometry (17) and followed its course at the lumbar spine, femoral neck, and femoral shaft levels in the two groups of patients.

Patients and Protein Supplementation

Sixty-two patients (mean age 82 years) admitted into the orthopedic ward for fracture of the proximal femur were randomized into two groups. One group comprised 33 patients aged 83.2 ± 1.3 years, who received 250 ml of an oral nutritional supplement containing protein (20.4 g), mineral salts (Ca 0.525 g), and vitamins (A = 750 IU; D_3 = 25 IU) daily for a mean of 38 days. A control group comprised 29 patients aged 81.3 ± 1.6 years and received 250 ml of an oral nutritional supplement containing the same amount of mineral salts and vitamins but no protein, for the same period of time. The evaluation of clinical outcome was based on the frequency of complications during the stay in both the orthopedic ward and the recovery hospital, as well as 7 months later.

Effects of Protein Supplementation

The clinical course was significantly better in the group receiving the protein-containing supplement, with 79% having a favorable course as compared to 36% ($p < 0.02$) in the control group during the stay in the recovery hospital. The rate of complications and deaths was also significantly lower in the protein-supplemented than in the control group (52% *vs.* 80%, $p < 0.05$) 7 months after hip fracture. The median duration of the hospital stay was significantly lower in the protein-supplemented group (69 *vs.* 102 days, $p < 0.05$). The present prospective randomized controlled investigation does not support the suggestion (29) that vitamin A could be the key nutritional element responsible for the favorable clinical outcome observed in the trial described above. The protein supplement provided a more than 60% increase in the overall daily protein consumption, taking into account that the supplement did not reduce the voluntary food intake. It should be stressed that the oral supplement increased the overall protein intake from a low to a normal level. A protein supplementation above the recommended allowance should be avoided since it may lead to a negative calcium balance (30–32).

Bone Mineral Density

On admission, both femoral neck and femoral shaft bone mineral density values were significantly lower in both groups as compared with age- and sex-matched healthy controls. Seven months after the fracture, no significant difference in bone mineral density between the protein-supplemented patients and the controls could be detected. However, the number of patients showing a significant decrease in femoral shaft density was significantly lower in the protein-supplemented group. This difference in bone density was associated with a greater increase in the plasma level of osteocalcin, taken as a reflection of osteoblastic activity.

CONCLUSION

A recent epidemiological survey emphasizes the high incidence, the dramatic consequences, and the important costs of osteoporotic fractures of the proximal femur in the Geneva region. Anthropometric and biochemical assessments confirm that elderly patients with hip fracture are often malnourished on admission. This malnutrition or undernutrition is more severe than that observed among the general elderly population. Bone mass measurement indicates that both women and men with hip fractures have a decreased mineral density at various sites of the skeleton. However, the difference appeared to be of higher magnitude for the femoral neck, suggesting a preferential bone loss at this site. Dietary survey indicates that nutritional requirements were not spontaneously met while the patients were in hospital, although adequate quantities of food were offered. In patients receiving a daily oral nutrition supplement for a mean period of 32 days (250 ml, 20 g protein, 254 kcal, 525 mg calcium, and various vitamins and minerals), the clinical outcome was significantly better, with reduction in both complication rate and median duration of hospital stay. The clinical benefits of this daily supplement appear to be essentially due to the increase in the protein intake as demonstrated in a prospective controlled randomized study where the effects of two dietary supplements that essentially differed by their protein content were compared. Finally, follow-up of bone mineral density suggests that normalization of the protein intake could prevent bone loss in undernourished elderly people after hip fracture, at least at the level of weight-bearing cortical bone. Further prospective studies are needed to confirm the possible benefit of protein supplementation to bone mass in undernourished elderly subjects.

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DISCUSSION

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Relationship between bone mineral density and dietary intakes in the elderly. Osteoporos. Int. 3, 242-248. Grimble, R. F. (1998). Nutritional modulation of cytokine biology. Nutrition 14, 634-640.Â Protein depletion and metabolic stress in elderly patients who have a fracture of the hip. J. Bone Joint Surg. 74A, 251-260. Quesada, J. M., Coopmans, W., Ruiz, B., Aljama, P., Jans, I., and Bouillon, R. (1992). Influence of vitamin D on parathyroid function in the elderly. J. Clin. Endocrinol. For bone mineral density and body composition assessment. The following States are Members of the International Atomic Energy AgencyÂ Dual energy X ray absorptiometry for bone mineral density and body composition assessment. â€" Vienna : International Atomic Energy Agency, 2010. p. ; 24 cm. â€" (IAEA human health series, ISSN 2075â€"3772 ; no. 15) STI/PUB/1479 ISBN 978â€"92â€"0â€"110610â€"0 Includes bibliographical references.Â Two examples are the femoral neck ROI and the forearm ROIs between the Hologic and GE systems. There have been some attempts to take out the systematic differences between systems for aBMD of the spine, total hip and femoral neck by using standardized BMD (sBMD) units [27].