Surgical prevention of femoral neck fractures in elderly osteoporotic patients. A literature review

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Summary

Fragility fractures of the femur are one of the major causes of morbidity and mortality worldwide. The incidence of new contralateral hip fractures in elderly osteoporotic patients ranges from 7 to 12% within 2 years after the first fracture.

Secondary prevention can be divided into: pharmacological therapy based on the prescription of anti-osteoporotic drugs with different mechanism of action and non-pharmacological therapy which is based on modification of environmental risk factors, on a healthy diet with daily supplements of calcium and vitamin D and calcium and on the use of hip protectors.

Recently a new form of prevention is becoming achievable: surgical prevention; the rationale of surgical reinforcement is the need to increase the resistance of the femoral neck to the compression and distraction forces acting on it.

In this paper we analyse all the experimental and “on the market” device available for the surgical prevention of femoral neck fracture.

KEY WORDS: osteoporosis; surgical prevention; femoral neck fractures.

Introduction

Osteoporosis is a skeletal disorder characterized by an increased risk of fractures due to a compromised bone strength (1, 2). The strength reflects both density and quality of bone, therefore the decrease of bone mass and the micro-architectural deterioration that occur in this disease cause bone frailty leading to low energy fractures (3-5).

Fragility fractures are one of the major causes of morbidity and mortality worldwide. In Italy there are 80,000 new femoral neck fractures due to osteoporosis every year, with a high prevalence in women (72%) (6). Moreover it is estimated that in 2012 the cost of femoral fractures was 1.1 billion euro (7).

Osteoporosis prevalence is likely to rise due to an aging population: people older than 60 will increase by 50% over the next 40 years. Although numbers are uncertain, the latest pessimistic estimates lead us to expect a doubling of fragility fractures by 2050 (8, 9).

Moreover hip fractures are associated with an increased mortality up to 25-30% within the first year (10) and an increase of 2.5 times risk of a new fracture (11). One year after a hip fracture 40% of patients is still unable to walk independently, 60% has difficulty in at least one of the normal daily living activities and 80% experiences limitations in other activities such as driving and shopping. In addition, 27% of patients is hospitalized in a long-term care facility following a hip fracture (12).

This scenario shows how osteoporosis and femoral neck fractures represent a tremendous concern in economic and social terms, therefore new strategies must be sought for the prevention and treatment of this pathology.

Prevention of the second contralateral femoral neck fracture

In literature, the incidence of a contralateral hip fracture in elderly osteoporotic patients ranges from 7 to 12% within 2 years after the first femoral neck fracture, with a high percentage of symmetry between the two fractures which varies from 70 to 83% (13, 14).

Therefore it is mandatory to adopt appropriate strategies to prevent the second fracture in these patients. Currently secondary prevention focuses on pharmacological and non-pharmacological therapy.

The pharmacological secondary prevention is based on the prescription of anti-osteoporotic drugs. In the market there are several classes of drugs with different mechanism of action: anti-absorbable, anabolic, hormone replacement, selective estrogen receptor modulators and monoclonal antibodies. Bisphosphonates are anti-absorbable drugs with high tropism for the mineralized tissues. They are able to concentrate electively on remodeling bone surfaces, blocking osteoclast activity (15-18).

Teriparatide (rh-PTH) is the first anabolic drug that stimulates bone formation and increases bone mineral density (19, 20).

Strontium ranelate is a drug with both anti-absorbable and anabolic actions and is able to un-couple the remodeling
process stimulating osteoblast differentiation and bone formation and on the other hand decreasing resorption by a reduction in osteoclastic activity (21, 22).

Hormone replacement therapy, as the name suggests, is based on the substitution of estrogens whose production decreases in menopausal women; however this class of drugs is associated with a high risk of uterine and breast cancer and increased cardiovascular risks (23-25). In order to overcome these complications, selective estrogen receptor modulators (SERMs) such as raloxifen and bazedoxifen were introduced. These drugs explicate their action on the estrogen receptors on the bone cells without having the negative effects on breast and uterus (26-28).

The last class of drug to be introduced in the marked are the monoclonal antibodies. Currently only denosumab is available; this is an IgG2 human monoclonal antibody directed against RANK-L which binds with high affinity and specificity. These bindings prevent the activation of its receptor RANK present on osteoclasts’ surface thereby inhibiting their activation thus reducing both cortical and trabecular bone resorption (29, 30).

Although there are so many drugs for the treatment and prevention of osteoporosis, it has been showed that none of these attain significant efficacy for the prevention of hip fractures below three years of continuous treatment (31, 32). This combined with poor patient compliance results in a lack of efficacy of drugs for the secondary prevention of femoral neck fractures (33). Recently some Authors argue that evidence for drug therapy to prevent hip fracture is insufficient to warrant the current approach. They believe that pharmacotherapy can achieve at best a marginal reduction in hip fractures at the cost of unnecessary psychological harms, serious medical adverse events, and forgone opportunities to have greater impacts on the health of older people. Therefore they propose to regret the current approach to hip fracture prevention because it is neither viable as a public health strategy nor cost effective (34).

The non-pharmacological prevention is based on modification of environmental risk factors, on a healthy diet with daily supplements of calcium and vitamin D and on the use of hip protectors. A Cochrane review on the use of hip protectors has demonstrated that their effectiveness in reducing fractures in nursing home patients but equally it has shown that they are less effective in patients living in community. These results are probably related to the adherence of patients in wearing hip protectors due to their discomfort (35).

Currently, in addition to pharmacological and non-pharmacological prevention we need to add a new type of prevention: the surgical one.

Surgical prevention of femoral neck fractures

Cortical thinning and trabecular bone loss are both important in the frail osteoporotic bone. The cortical thinning of long bones is due to endosteal resorption and normally is compensated by periosteal bone apposition, leading to an increase in the diameter of the bone. The femoral neck is not covered by periosteum because it is an intracapsular, and therefore there isn’t bone apposition (3). This may partially explain why in osteoporotic femur the neck is the “locus minoris resistentiae”. Moreover Holzer et al., in an *in vitro* study, show that in the femoral neck the cortical bone and its geometry are primarily responsible for the bone strength, whereas the trabecular bone gives a marginal contribution (less than 10%) due to morphological changes (36).

The rationale of surgical reinforcement is the need to increase the resistance of the neck to the compression and distraction forces acting on it (36, 37). During gait the major stresses occur in the subcapital and middle-cervical regions: high compressive stress occurs inferiorly and mild distraction stress occurs superiorly (38). During a fall to the side with impact on the greater trochanter the stresses are reversed: on the superior side of the femoral neck a huge compressive stress occurs while on the interior side there is a distraction stress (38, 39).

The concept of surgical reinforcement of the femoral neck was proposed for the first time in 1960 by Crockett (40) who described a reinforcement technique of the femoral neck characterized by percutaneous insertion of stainless-steel nails under local anesthesia. In the conclusion of his paper the Author affirmed that in case of a fracture in the reinforced neck, the patient would have a non-displaced fracture and therefore the treatment required was only rest and walking with 2 crutches.

More recently Heini et al. (41) in 2004 described another experimental technique called “femoroplasty” consisting of injection of poly-methyl-methacrylate (PMMA) inside osteoporotic femoral neck. The Author used 20 pairs of osteoporotic femurs, each pair as a case-control, to assess the surgical reinforcement. The Author inserted a low viscosity cement in a 4.5 mm hole on the lateral cortex at the base of the greater trochanter. Subsequently the femurs were tested by simulating a fall. Fracture type observed in control group matched those commonly seen *in vivo*; in the study group different fracture patterns were observed: trochanteric and medial fractures of the femoral neck and in three cases subtrochanteric fractures. Moreover all the fractures occurred at the bone-cement interface. In this study group femurs had an increased breaking load greater than 82% compared to controls and an increased absorbed energy of 188%. However the Author concluded that there is concerns in the application of this technique *in vivo* due to the high volume of PMMA necessary which generates enormous heat during polymerization (up to 60° *in vivo*) leading to necrosis of the femoral head. Moreover revision surgery in the event of fracture would be technically very difficult.

Other Authors (42) tested 10 pairs of osteoporotic human femurs, each pair as a case-control, augmented with about 40 ml of another low viscosity cement. They simulated a fall on the greater trochanter and confirmed the increase of breaking load and absorbed energy in the augmented femurs; however it was unknown if this increase would be enough to prevent fracture *in vivo*. Moreover they found that the stiffness was not significantly different between the 2 groups. They hypothesized that these results were due to the composite nature of the augmented femur: the bone governs the pre-yield behavior and once fracture occurs, it is likely that the composite formed by trabecular bone and cement determines the mechanical response.

To overcome the high temperature of polymerization, Beckmann et al. (43) tested a non-resorbable composite consisting of crosslinking resins and reinforcing glass ceramic particles already used for vertebral augmentation instead of PMMA. The Author used 9 pairs of femur as case-control, they recorded the temperature of polymerization and simulated a fall on the great trochanter. Subsequently the fractured fe-
murs were stabilized using either cannulated screws, a dynamic hip screw or a proximal femoral nail and they were then biomechanically tested again. As expected, breaking load and absorbed energy were significantly increased. The maximum temperature elevation (about 11 °) was lower if compared with PMMA but still high if compared to the near-isotermic polymerization cement based on calcium phosphate. However, the Authors expressed concern regarding the revision surgery of the reinforced femur especially in the drilling: the composite was even harder to drill than the PMMA. Moreover fenomoplasity may directly influence the subsequent fracture of the augmented region: a distal shift of the fracture location could be assumed for in vivo condition. Moreover De Bakker et al. (44), in a finite elements study, have shown how, reinforcing the femur with a Gamma nail, there was a 100% increase in the resistance to fracture. Currently, to our knowledge, there is only a device on the market, for the prevention of the femoral neck fractures. Recently it has been published a finite element analysis showing that this device has led to a decrease in the risk of femoral neck fracture (-28%) and trochanteric fracture (-52%) (45).

Conclusions
Surgical prevention could become a viable solution in the prevention of femoral neck fracture in patients at risk. The right selection of patients is mandatory but also randomized controlled trials should by designed in order to prove the efficacy of the treatment.

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