The orthopaedic treatment of fragility fractures

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Summary

The purpose of this review is the presentation of the proper orthopaedic treatment of the most frequent fragility fractures associated with low bone mineral density or established osteoporosis. In this particular group of patients, the surgical treatment is difficult for the poor quality of the broken bone that limits the reduction, the hardware fixation and the physiologic process of bone healing. Other important problems are the postoperative management of old patients with chronic diseases and more prone to develop local and general complications with big difficulties to conduct a good rehabilitation program.
Some considerations will be made, lastly, about the role of the orthopaedic surgeon on the treatment of osteoporosis and on the possibility to prevent further fractures.

KEY WORDS: osteoporosis, fracture, orthopaedic treatment, bone healing.

Introduction

Definition of osteoporosis

Osteoporosis has been defined by a Consensus Development Conference as a "skeletal sistemic disorder characterized by low bone mass and by a microarchitectural deterioration of bone with increased incidence of fragility fractures" (1).
Historically, this kind of bone loss has been recognized more than 150 years ago by Sir Astley Cooper that observed its correlation with hip fractures.
The term osteoporosis, however, has been used for the first time in Germany and France to describe the histological aspect of osteoporotic bone.
The diagnosis of osteoporosis is often made after a fracture following a low energy trauma, so a complete definition of osteoporosis should also include the risk of fracture.
The resistence of bone to trauma is due to a lot of factors including bone geometry, dimension and microarchitectural arrangement. An estimation of this resistance can be made measuring the bone mineral density (BMD) with the Dual Energy X-ray Absorptiometry (DEXA) exam. The World Health Organization (WHO) has published, in fact, an osteoporosis definition that include both the BMD value and the event fracture (4).
The value of BMD with DEXA technique is based on the definition of 2 parameters: the Z score and the T score.
The Z score is the risk of fracture of an individual compared to a same age group.
The T score is the standard deviation, adjusted for sex and race, of the bone mass peak in a 30 years old individual (reference value).
Based on the T score value there are 4 different groups of patients:
– normal: BMD not more than 1 standard deviation below the reference value;
– osteopenia: BMD between 1 and 2,5 standard deviation below the reference value;
– osteoporosis: BMD more than 2,5 standard deviations below the reference value;
– severe osteoporosis: BMD more than 2,5 standard deviations below the reference value with the presence of 1 or more fragility fractures.

Risk factors for osteoporosis

Risk factors can be divided as follows: the ones that affect the risk of falling and the response to trauma, the ones that affect BMD and the ones that influence the skeletal resistence but are indipendent from BMD (Tab. I).

Table I - Risk factors for osteoporosis and fracture.

Age
Female sex
Body mass index
Maternal family history of hip fracture
Prior fragility fractures
Low bone mineral density
Low birthweight
Genetic factors
Sex hormones
Premature menopause
Primary or secondary amenorrhoea
Primary and secondary hypogonadism in men
Diseases
Thyrotoxicosis, Cushing's disease, hyperparathyroidism
Stroke
Inflammatory arthritides
Drugs
Corticosteroids
Anti-convulsants
Heparin
Smoking
Alcohol
Dietary calcium and vitamin D deficiency

The main risk factors are the following: genetics, female sex, postmenopausal age, sex hormones deficiency, excessive smoke and alcohol abuse, very low physical activity, insufficient calcium and vitamin D dietary intake, low body wheight. Osteoporosis can also be secondary to chronic illnesses, amenorrhea, long time use of particular drugs, long term immobilization (5-8) (Tab. II).
All the above mentioned causes of osteoporosis can increase the risk of developing a fracture. In the elderly people, however, the most important cause of fracture is accidental fall in the domestic environment. There are many risk factors for accidental fall: reduction of view capacity and body balance, walking troubles, depression, postural hypotension, stroke history, Parkinson's disease, history of previous accidental fall.

Table II - Cause of secondary osteoporosis.

Drugs
Oral or intramuscular use of glucocorticoids for >3 mo
Excessive thyroxine doses
Aromatase inhibitors
Long-term use of certain anticonvulsants (eg., phenytoin)
Heparin
Cytotoxic agents
Gonadotropin-releasing hormone agonists or analogues
Intramuscular medroxyprogesterone contraceptive
Immunosuppressives (eg., cyclosporine)
Genetic disorders
Osteogenesis imperfecta
Thalassemia
Hypophosphatasia
Hemochromatosis
Disorders of calcium balance
Hypercalciuria
Vitamin D deficiency
Endocrinopathies
Cortisol excess
Cushing's syndrome
Gonadic insufficiency (primary and secondary)
Hyperthyroidism
Type 1 diabetes mellitus
Primary hyperparathyroidism
Gastrointestinal diseases
Chronic liver disease (eg., primary biliary cirrhosis)
Malabsorption syndromes (eg., celiac disease, Crohn's disease)
Total gastrectomy
Billroth I gastroenterostomy
Other disorders and conditions
Multiple myeloma
Lymphoma and leukemia
Systemic mastocytosis
Nutritional disorders (eg., anorexia nervosa)
Rheumatoid arthritis
Chronic renal disease

Incidence, prevalence and geographical variability of fragility fractures

Fragility fractures are more likely located in the lumbosacral spine, distal radium, hip region and proximal humerus.
The general incidence of fractures increases dramatically in the female sex above 35 years of age becoming the double of the male sex in the sixth decade of life (Fig. 1).

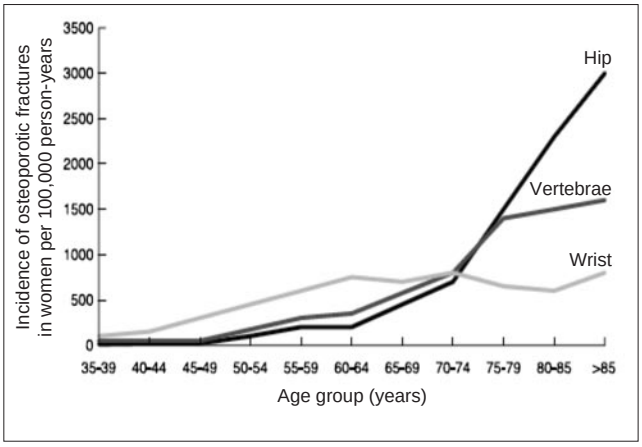

Figure 1 - Incidence of fragility fractures with age in women in different anatomic locations.

A study done in Minnesota has estimated that, at age 80, 27% of women were osteopenic and 70% osteoporotic at the levels of hip, lumbar spine or distal radius.
The same Authors have estimated that in all USA 54% of postmenopausal women were osteopenic and 30% osteoporotic. Considering the fractures rates, 40% of white women and 13% of white men above the age of 50 years will develop at least one fragility fracture during their life (12, 13).
In the world approximately 200 millions people are at risk of fragility fracture yearly. The incidence of fracture changes extremely in the different nations and is higher in USA and Scandinavia compared to Great Britain and central Europe.
In USA approximately 1,500,000 fractures per year are caused by osteoporosis.
The expense for the US health system is huge (10 billion dollar per year in 2001) and will rise in the next 10 years, when there will be 52 million people above 65 years of age (14).
In 2012 25% of the European population will be over 65 years old. The estimated number of fragility fractures was, one year ago, approximately 3 million with an expense of 32 billion euros that will rise to 77 billions in 2050 with the expected demographic variations (15).

Orthopaedic treatment of the most common fracture sites

Spine

Spine fractures are the most frequent fragility fractures and the second ones for morbidity and mortality in the elderly group after hip fractures.
The incidence rises with age becoming around 25% in postmenopausal women. A history of previous vertebral fragility fracture increases 4 times the probability of re-fracture (16, 17). The fracture prevalence is quite homogeneous in the world however it is very high in Asian and white women and much lower in the Afro-American and Hispanic population (18-21).
The most frequent site is the lumbar spine with the dorsolumbar passage being often interested.
The fractures happen for axial compression following a fall but, especially in the very old patients, also for simple lateral bending or weight lifting.
The fracture can interest each one of the 3 columns being the anterior column most likely interested with the typical wedge

deformation of the vertebral body. The fracture pattern can be, however, very broad going from the simple endplate disruption to the vertebral body burst fracture.
The definition of fracture based on the morphometric measures has lead, in the last years to a better characterization of such fractures creating a spinal deformity index (SDI) which is very important for fracture classification and treatment (22, 23).
The most frequent treatment is conservative because the majority of these fractures isn't unstable and doesn't have radicular or medullar involvement.
The conservative treatment leads to a long period of bed rest and walking with a corset for at least 3 months.
The indication to surgery depends on age, general conditions, fracture pattern and stability, involvement of medullary canal, bone quality, time elapsed from fracture.
The surgical options are vertebro-kyphoplasty with cement, vertebral stabilization and or fusion with eventual decompression of the medullary canal.
In presence of a simple wedge without instability a vertebro-kyphoplasty is recommendable, possibly with less invasive techniques (Fig. 2). This surgery is rapid, with low complications rates and with very promising early results in terms of pain and function.
In unstable or multilevel fractures with or without medullary involvement there's the need to perform a vertebral stabilization with bars and screws or plates and screws with or without interbody fusion (Fig. 3).

Proximal femur

Hip fractures are the most serious complication of osteoporosis. The cost of this fracture is huge with very high disability and complications rates. The incidence in women rises from 2 on 100000 per year under 35 years of age to 3032 on 100000 per year at 85 or more (24). The life risk of fracture has been estimated to be 17% in the white American women and 6% in white men (12). The incidence is higher in Scandinavian women respect to the North American or Oceanian ones (25, 26).
The percentage of fracture is much inferior in the Asian and Afro-American population (27-29).
The 5 years survival is 82% of expected with death being more frequent in the first 6 months following the fracture (30).
The orthopaedic treatment varies if the fracture is intra or extracapsular.
The Garden's classification, in particular, describes 4 types of intracapsular subcapital fractures with increasing gravity according to the degree of displacement in the AP x-ray view of the hip. The risk of avascular necrosis rises passing from grade I to grade IV of displacement (31, 32).
The conservative treatment is restricted to the incomplete undisplaced fractures or in case the patient or the family refuses the operation. In the complete undisplaced or slightly displaced fractures the preferred treatment is the osteosynthesis with 3 cannulated screws inserted percutaneously (Fig. 4).
In presence of complete displaced fractures the operation needed is a hip prosthetic replacement. The prosthesis substituting only the femoral part (endoprosthesis) is the most frequent operation in elderly patients (Fig. 5). In case of younger patients with quite good bone quality and radiographic signs of acetabular osteoarthritis the preferred operation is a total hip replacement with a metallic component inserted also in the pelvis.
The outcome of this surgery is very good and the weight bearing can be authorized from the first day after the operation.
The extracapsular fractures are localized at the proximal metaphyseal-epiphyseal junction of the femur. The classification has been made by Boyd e Griffin (33) and divides the fractures in 4 types with increasing instability levels:
– Type 1: intertrochanteric pure;
– Type 2: intertrochanteric pure with multiple fractures of the lateral cortical bone;

Figure 2 - L2 body fracture treated with vertebroplasty: x-ray immediate, at 3 and 6 months.

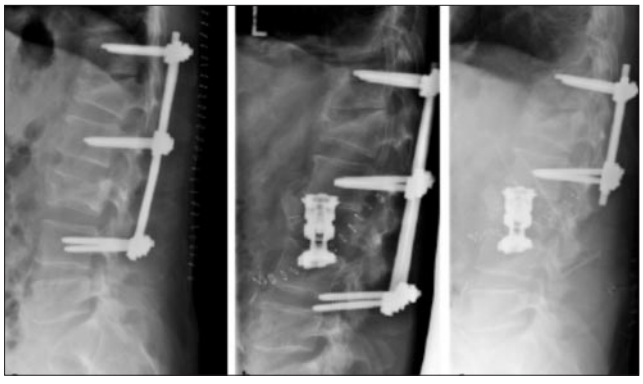

Figure 3 - Internal fixation of L1 and L3 fractures. Loosening of distal screws and revision of stabilization.

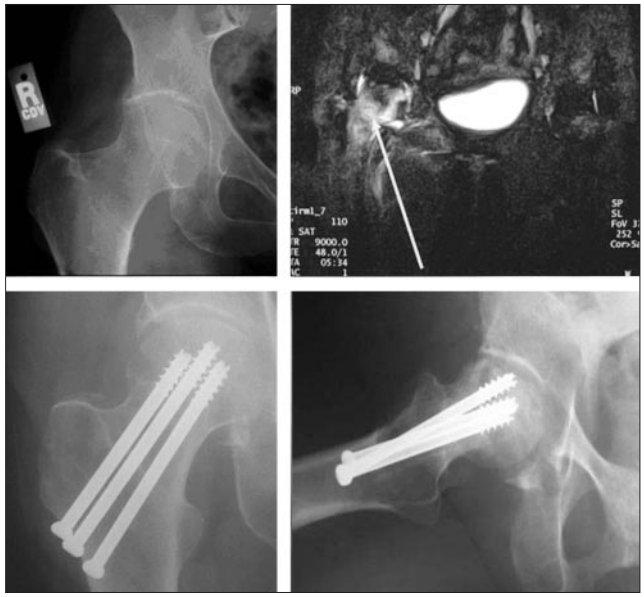

Figure 4 - Displaced femoral neck fracture: synthesis with 3 cannulated screws. Intraarticular migration of the screw at 3 months.

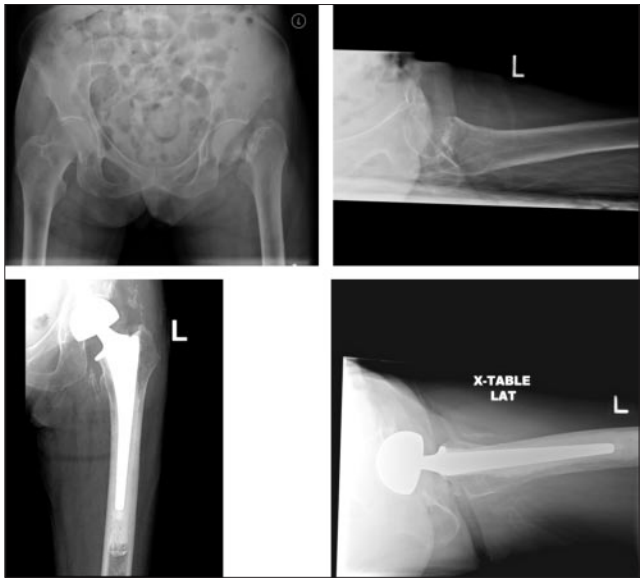

Figure 5 - Displaced femural neck fracture in 87 years old woman. Cemented endoprosthesis with biarticular cup.

Figure 7 - Subtrochanteric proximal femoral fracture in 87 years old woman treated with locked intramedullary nail.

– Type 3: subtrochanteric with at least one fracture line distal to lesser trochanter;
– Type 4: complex trochanteric and proximal metaphysis fracture with extension in at least two planes.

The intertrochanteric fractures are commonly treated with screw-plates such as the Dynamic Hip Screw (DHS) which is able to maintain a very good reduction of the fracture site with a fragment compression and a low rate of nonunion, cut-out and migration of the screw and loss of reduction (Fig. 6).
The unstable intertrochanteric, the reverse oblique and the subtrochanteric fractures can be efficiently treated with locked nail such as the gamma nail (Fig. 7).
The rehabilitation time required for these fractures is longer because the partial weight bearing is possible at 4-6 weeks from the operation with free deambulation after 3 months.

Distal radius fractures

The most common fractures in perimenopausal women (34).
The women-men ratio adjusted for age is 4 to1 with more than 80% of fractures in women (35) and peak of incidence around 65 years of age.
This fracture is more frequent in the Caucasian population than in the Asian or Afro-American ones (36, 37).
The fracture doesn't increase the mortality rate and is an unusual cause of hospital admission, however 1% of patients is not independent anymore after the fracture and only 50% report a satisfactory functional outcome at 6 months from trauma.
The classification is based on the American Society of Internal Fixation (ASIF) dividing them into extraarticular, partially articular and complex articular fractures (38) (Tab. III).
In the elderly the majority of fractures is treated by closed reduction and cast fixation for 4 to 6 weeks. The fracture site in osteoporotic bone can be unstable leading to the necessity to recur to surgery. This can vary from the insertion of Kirshner wires percutaneously and cast, the closed reduction and stabilization with external fixator to the open reduction and internal fixation with plate and screws.
The first technique can be used in extraarticular and simple ar-

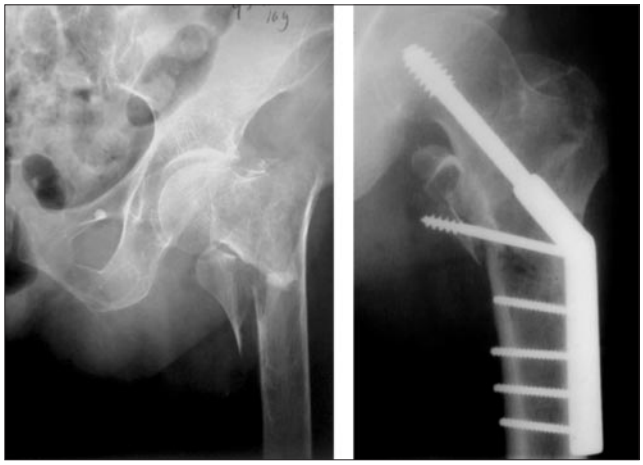

Figure 6 - Intertrochanteric fracture of proximal femur in 92 years old woman. Osteosynthesis with DHS plate.

Table III - American Society of Internal Fixation classification of distal forearm fractures

A	Extra-articular metaphyseal fracture	A1 Isolated Distal Ulna A2 Simple Radial Fracture A3 Radial Fracture with metaphyseal impaction
B	Intra-articular rim fracture (One cortex intact)	B1 Radial Styloid (Chauffeurs) B2 Dorsal rim (Dorsal Barton) B3 Volar rim (Volar Barton)
C	Complex Intra-articular (epiphysis and metaphysis involved)	C1 Radiocarpal joint congruity preserved C2 Articular displacement C3 Diaphyseal-metaphyseal involvement

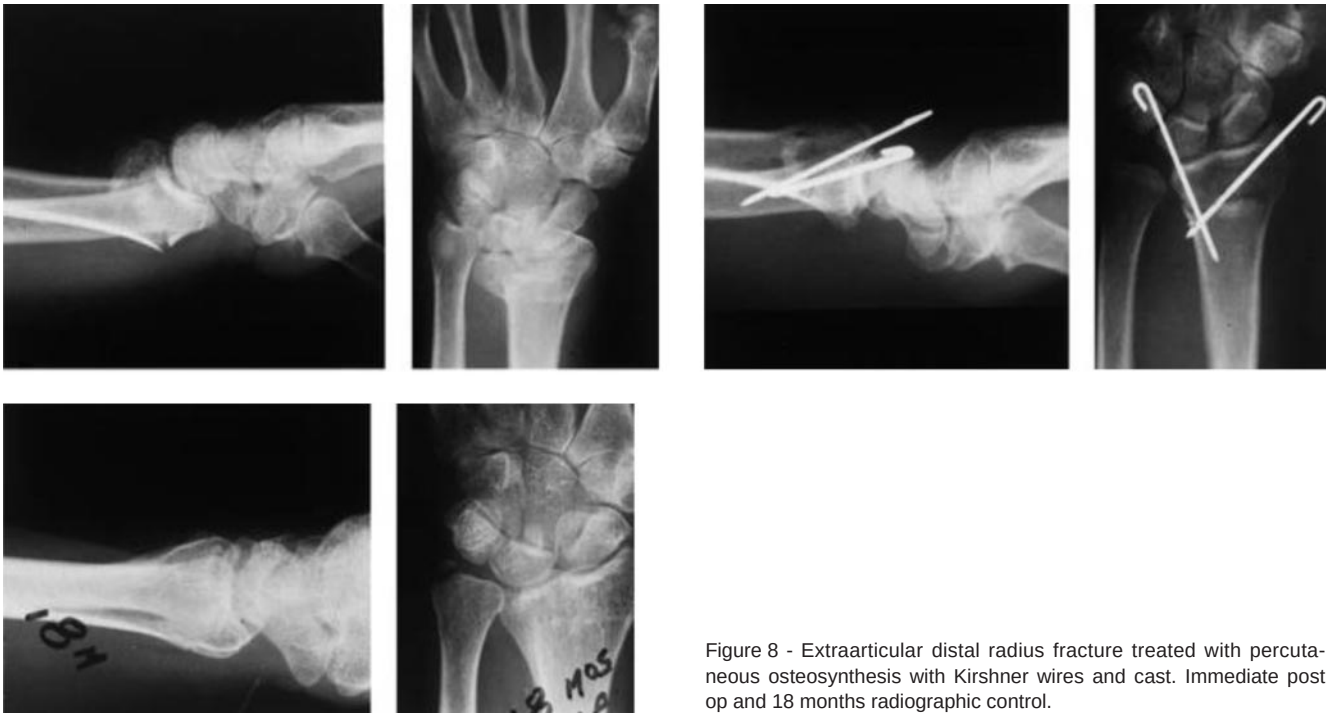

Figure 8 - Extraarticular distal radius fracture treated with percutaneous osteosynthesis with Kirshner wires and cast. Immediate post op and 18 months radiographic control.

ticular fractures when a bicortical fixation of the wires is achievable (Fig. 8).
The external fixator is particularly indicated in complex fracture patterns but should be limited to patients with good cognitive function who are able to take care of the pin tracts (Fig. 9).
Open reduction and internal fixation is indicated mainly for younger patients with intraarticular fractures with presence of big fragments useful for fixation of the plate and the screws (Fig. 10).

Figure 9 - Intraarticular complex fracture in 68 years old woman. Percutaneous Kirshner wires synthesis and external fixator.

Proximal humerus

5% of fractures in the ER department with only about 15% requiring surgical treatment.
This kind of fracture is very frequent in women over 65 years and is generally caused by low energy trauma such as direct shoulder trauma, fall on the outstretched arm, fall on the elbow.
The most used classification is the Neer one (Fig. 11) based on the 4 part concept (humeral head, lesser tuberosity, greater tuberosity, diaphysis) with capital importance to the degree of displacement and the risk of avascular necrosis (39).
Following this criteria 80% of all fractures are undisplaced with 2 or 3 fragments.
The conservative treatment is elective in the elderly with a simple arm holder or a Desault bandage. The results are generally acceptable in terms of range of motion and residual pain.
However the unstable or displaced fractures require surgical treatment.

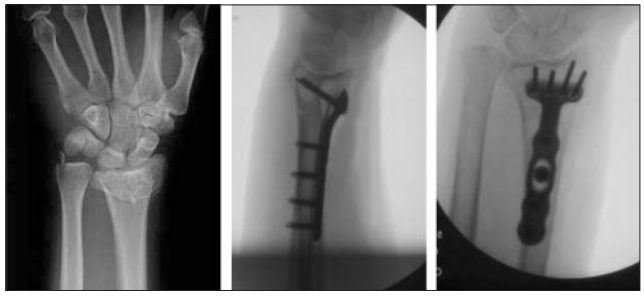

Figure 10 - Intraarticular complex fracture in an active 72 years old woman: osteosynthesis with plate and screws.

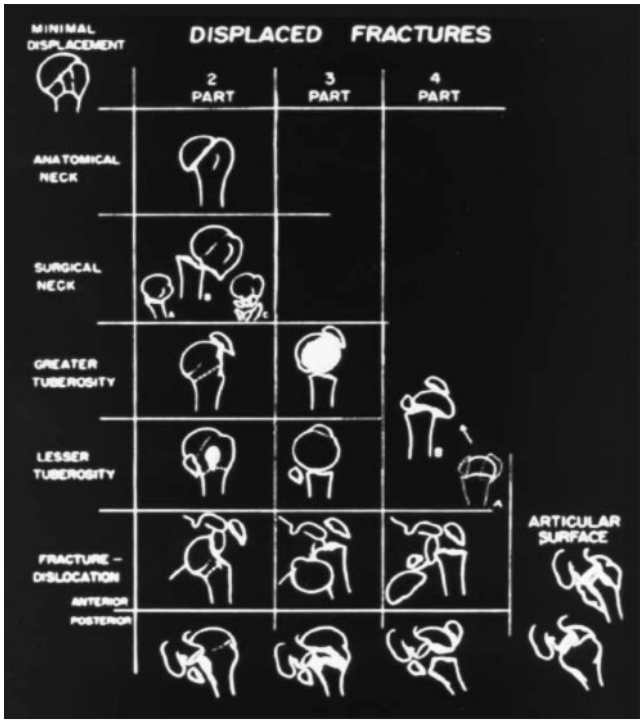

Figure 11 - Neer classification of proximal humeral fractures.

In the elderly, when possible, the preferred and less invasive technique is closed reduction and percutaneous pinning with Kirshner wires (Fig. 12).
In about 20% of the patients with displaced, complex fracture or fracture dislocations the open reduction and internal fixation or a primary humeral prosthetic replacement are indicated. In younger patients with bigger fragments an osteosynthesis with plate and screws is generally attempted although there's a high possibility of avascular necrosis (Fig. 13). The preferred treatment for 4 fragments displaced fractures is the prosthetic replacement of the humeral head with a stemmed implant (Fig. 14).

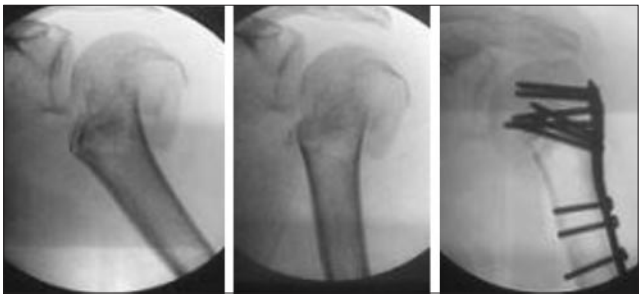

Figure 13 - Comminuted left proximal humeral fracture in male of 67 years old. Osteosynthesis with plate and screws.

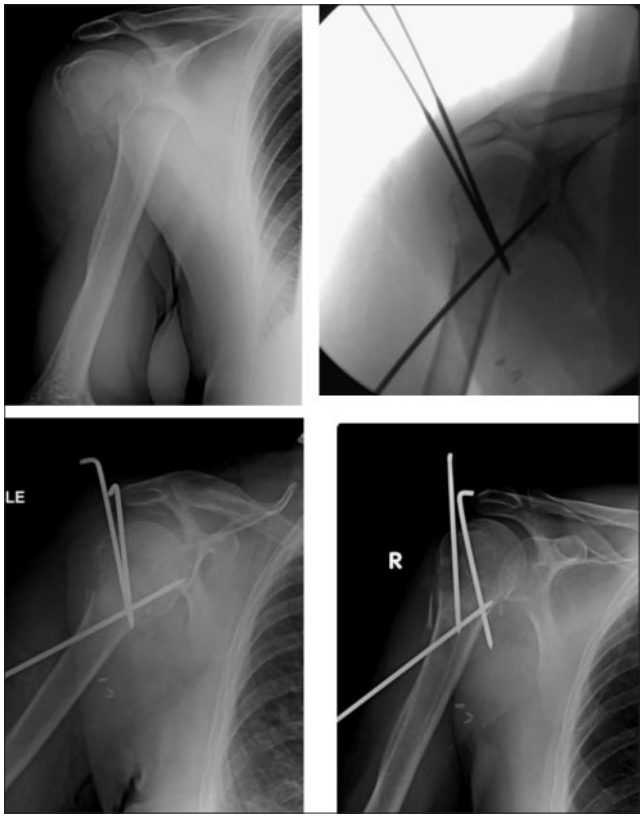

Figure 12 - Fracture-dislocation of right proximal humerus in 86 years old male. Reduction and osteosynthesis with Kirshner wires. X ray immediate and after 20 days.

Figure 14 - 4 parts fracture of right proximal humerus in a 74 years old male. Cemented endoprosthesis of the shoulder.

Discussion

Fragility fractures are a challenging problem both for patients and orthopaedic surgeons. The elderly is disabled and may present a reactivation of a previous illness or new medical problems related to the fracture, the surgical treatment or the period of immobilization. This is particularly true for the patients affected by a vertebral or a proximal femur fracture.

The vertebral fracture results in a long period of bed rest with restricted deambulation and progressive deformity with chronic low back pain.

The proximal femur fractures are life-threatening due to the long period of bed immobilization and the high risk of complications. For these fractures open reduction and internal fixation in the first days from trauma is a life-saving action. The early postoperative mobilization is also of capital importance in preventing skin and soft tissue complications. The patient has also to be carefully assessed from internal medicine specialist before and after the operation in order to assess the previous pathology and the eventual new ones. The rehabilitation protocol is often difficult to be carried out by the older patients that are depressed or unable to act or understand the medical orders.

For the surgeon the technical problems are obtaining and maintaining a proper reduction and stabilization of unstable fractures in a mechanically low resistant bone with the tendency to a slow healing process. The peri- and postoperative complications rate in the older group of patients is higher than in the younger population.

A proper reduction can be more important than the type of hardware used to treat the fracture (40). A non accurate reduction can increase the failure rate of the operation 3-fold and can delay the healing time of the fracture (41).

The surgical experience is very important to minimize the rate of complications (42). The choice of the hardware is very important too. The osteoporotic bone, having lower mechanical properties, presents more complex fracture patterns and reduced resistance to the holding power of the thread of the screws of the hardware. Many studies have shown that a low BMD is related to a lower holding power of the screws on the bone (43, 44). The force needed for the pullout of the implant is so ever inferior with possibility of microfractures and bone resorption at the bone-hardware interface and secondary failure of the construct (45, 46). In the osteoporotic bone the most common failure pattern of internal fixation is bone failure rather than implant failure.

In this group of patients the complication rate is higher than in the younger population: non-union or implant failure in 2-10% of fractures; mal-union in 4-40% of patients depending on the anatomical district; re-operation rates from 3 to 23% (47).

These problems have encouraged an extensive development of hardwares in terms of designs, materials, resistance and possibility to implant with a less invasive approach. In particular, in the Locked Compression Plates (LCP) the screws are fixed to the plate ensuring the angular stability with less importance to bone quality. Other implants, such as the Limited Invasive Surgical System (LISS), have got the same mechanical properties and the possibility to be implanted with a little surgical exposure with big advantages for the patient and the fracture healing.

Another technical possibility is bone augmentation with cement or corticomedullary allografts. The acrilic cement let a supplemental fixation of the screws at the fracture site or can simply have plastic function in case of bone defects.

The cortical strut grafts can be used as mechanical support when implanting a prosthesis or for containing a circumferential bone defect in case of complex fracture with loss of bone tissue. The medullary graft can be impacted in the medullary canal in case of implant of a cementless prosthesis or can have a plastic function in the contained bone defects.

Due to the excellent prosthetic implants available in the market, their use in case of articular complex fractures has increased in the last few years (48). The surfaces will be probably loaded, in the near future, with osteoinductive molecules such as Bone Morphogenetic Protein (BMP-2 and 7) to promote the cementless fixation of the implant.

The healing process of the fractured osteoporotic bone is similar to the non osteoporotic one. However, many studies have shown that this process is much slower particularly in the late phases of bone repair due to the altered composition of bone matrix and interaction osteoblast-bone matrix (49, 50).

Many times fracture is “time zero” of the diagnosis of osteoporosis and this event compromises the health of the elderly forever and is responsible for huge expenses for the health system. The only possible approach is, thereafter, prevention of fracture based on identification of groups at risk, proper medical therapy and patients education about the lifestyle risk factors.

A BMD assessment is suggested particularly in women over 65 years of age with or without risk factors, in younger postmenopausal women with one risk factor or more, in postmenopausal women that already suffered a fracture and in all patients with multiple risk factors.

In osteopenic or osteoporotic patients a proper medical therapy has to be started. Although the medical therapy is long term and expensive, a role of some drugs in hip fragility fractures prevention has been already shown.

The orthopaedic surgeon is sometimes the first doctor that diagnoses osteoporosis in the ER Department after the fracture and is supposed to follow up the patient. His role, therefore, is not only the treatment of the present condition, but also the prevention of future fractures. This can be done studying the patient clinically, with the education to lifestyle modifications, prescribing a proper medical therapy, or referring the patient to the metabolic disease specialist.

Patients affected by hip fracture have got 8-fold more possibility to fracture the contralateral hip respect to the general population but, today, less than 50% receive an adequate treatment for osteoporosis (52).

The orthopaedic surgeon needs to have a personalized therapeutic algorithm to use in primary and secondary fracture prevention. In general, a moderate physical activity and a diet rich in calcium, proteins and vitamin D are strongly suggested.

The prevention of domestic accidental falls is of paramount importance. The older patients living in nursing houses should wear hip protectors that have been shown to be very useful for hip fracture prevention (53).

The association of calcium and vitamin D has been shown to prevent hip and low back fractures especially in dependent patients that aren’t exposed so much to the sun. In this class the treatment can begin without a BMD assessment. In the indipendent patients a measure of hip and lumbar spine BMD is recommendable beginning immediately a treatment with calcium and vitamin D in the osteopenic ones.

The osteopenic-osteoporotic younger patients should be studied with blood test to rule out secondary causes of bone loss and begin a therapy just in case of normal markers or being referred to another specialist. Other than calcium and vitamin D, a bisphosphonate can be associated.

In postmenopausal women with biologic age up to 70 years old the treatment can be done with the association of estrogen to calcium and vitamin D. If the age is over 70 years old and if there’s contraindication to the estrogenic therapy, Selective Estrogen Receptor Modulators (SERMs) or bisphosphonates can be used (54).

Conclusion

The frequency, world distribution and high social costs of fragility fractures are a huge problem for the Health Systems. Due to the ageing process of industrialized country population and the population growth of developing countries, the incidence of these fractures can become epidemic in the next 50 years. Today, however, the possibility of prevention and excellent orthopaedic treatment exists. The primary and secondary prevention of fragility fracture can be done through the identification and screening of the groups at risk, with an appropriate medical therapy and the education of patients.
The results of orthopaedic treatment have improved in the last years thanks to a better knowledge of pathogenesis of osteoporosis and fracture repair pattern, hardware quality improvement, a more accurate surgical technique and rehabilitation protocols focused on this group of patients. The rate of complication though is still higher than in younger population, but dropping continuously.
The orthopaedic surgeon should participate to primary and secondary prevention of fractures through an adequate algorithm of study and treatment and should follow up the patient for a long period after the surgery.

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