# Fragility fractures

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24 Fragility fractures

1 Introduction

A fragility fracture is defined as a fracture that occurs following a fall from a standing height or less. These fractures occur with minimal trauma, yet may demonstrate a significant fracture pattern. The fragility fracture confirms a diagnosis of osteoporosis regardless of the bone-density measurement.

Typical examples are a vertebral compression fracture that occurs while bending forward, a distal radial fracture occurring with a simple fall, and a low-energy hip fracture. According to recent studies, in the elderly, fractures of the hip, proximal humerus, and radius occur with the same frequency whereas, spine fractures are rarer [1–3].

In 2000, the World Health Organization Scientific Group on the Assessment of Osteoporosis at primary health care level estimated a worldwide number of osteoporotic fractures in people aged 50 years or older to be at 8,950,000, of which 1,672,000 were hip fractures [4]. Many patients who experience a fragility fracture will suffer morbidity, disability, or death.

Life expectancy is dramatically increasing globally and the population is aging at an unprecedented rate. By 2050, people aged 60 years or older will exceed the number of younger people. This trend is believed to be irreversible and is coupled with lower birth rates and lower fertility. This is a worldwide trend. The fastest growing subsegment of the world population is those over 80 years old.

2 Etiology

2.1 Osteoporosis

Primary osteoporosis involves a loss of bone mass because bone formation becomes imbalanced with bone resorption. There are many types of secondary osteoporosis besides the typical primary osteoporosis seen with aging. Other causes of osteoporosis are termed secondary osteoporosis [5]. Secondary osteoporosis may be the result of altered calcium metabolism or altered collagen make-up of bone. Type I collagen is the primary collagen found in bone. Many mineral metabolism problems may cause a secondary osteoporosis including vitamin D deficiency, hyperparathyroidism, hyperthyroidism, renal disease, anticonvulsant use, and Paget’s disease. Collagen-based bone structure problems can be the result of osteogenesis imperfecta, vitamin C deficiency, and steroid use [5].

According to the US National Osteoporosis Foundation, 80% of those affected by osteoporosis are women and 20% are men. Kanis et al have shown the femoral neck bone density decreases with age in men and women [6, 7]. Osteoporosis in men is common with aging and is often overlooked and undertreated [8]. All ethnic groups can be affected, although rates of osteoporosis are affected by ethnicity. Osteoporosis influences the emergence of fractures and their treatment.
2.2 Reduction in the quality of bone

Osteoporosis involves both a loss of bone mass, reduction in bone quality by microarchitectural deterioration of bone tissue, and reduced ability of bone to withstand loading. It is important to understand the difference between bone mineral density (BMD)—which reflects the calcium content—and the deterioration of bone quality measurable in reduced resistance to loading. Usually, the quality of bone reduces much more with age in cancellous bone than in cortical bone (Table 24-1).

Bone is a living tissue with three main cell types: osteoblast, osteoclast, and osteocyte. Each cell line has an important role in maintenance of healthy bone. The osteoblast forms new bone in areas that were previously resorbed by the osteoclasts. Osteocytes are believed to provide the chemical signaling to osteoclasts and osteoblasts through the canaliculi found in lamellar bone. Peak bone mass is achieved between 25 and 30 years and is believed to decline thereafter. A state of equilibrium exists in the bone of young adults; bone is resorbed and replaced at even rates. This is important to heal minor bone damage that occurs with daily activity. By middle age, bone resorption continues but bone accretion is reduced. At menopause, the antiresorptive effects of estrogen are reduced and a rapid loss of bone mass occurs during the first 7 years after menopause. After 7 years the rate of bone loss slows but continues until death.

Bone can be divided into cortical and cancellous types. Both types change significantly with age. Cortical bone is normally found in the diaphyseal areas of long bones and the perimeter of flat bones. Cancellous bone predominates in the metaphyseal and epiphyseal areas of long bones, vertebrae, and flat bones. Distinctive changes to cortical and cancellous bones are described below.

It is well established that aging humans lose a substantial amount of bone mass that was present at 25 years. It is also documented that women over 40 lose more bone and at a faster rate than men [5, 8, 9]. Cortical bone at 25 years is dense, thick, and strong. The pattern of age-related cortical bone loss involves thinning long-bone cortices or cortical thickness loss with concomitant increase in medullary diameter, particularly in women (Fig 24-1). Women show significant ($P < .05$) decreases in cortical thickness, bone mineral content, and cortical bone density when plotted against age. Men exhibit slight nonsignificant declines for cortical thickness, bone mineral content, and cortical bone density. Both men and women exhibit significant ($P < .05$) age-related increases in summed Haversian canal area values and Haversian canal number [10, 11]. The human body increases the diameter of the osteoporotic bone to give some increase in its bending and torsional strength. The osteoporotic skeleton increases the outer diameter to increase the bending stiffness. With the reduced bone mass, the inner diameter is also augmented because the bone volume and bone mass may not be enlarged. If we assume a diaphyseal bone is a tube, the formula $\Pi/4(R^4-r^4)$ describes the calculation of the bending stiffness of a tube. Bending stiffness depends on the inner and outer radius of the tube. Dependence is as strong as exponent 4.

### Table 24-1 Age-related changes in mechanical properties of bone tissue between 30 and 80 years. Note that the deterioration of the elastic modulus, ultimate strength, and toughness are much more pronounced in cancellous bone than in cortical bone.

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<tr>
<th></th>
<th>Cortical bone</th>
<th>Cancellous bone</th>
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<tr>
<td>Elastic modulus (E)</td>
<td>-8%</td>
<td>-64%</td>
</tr>
<tr>
<td>Ultimate strength (S)</td>
<td>-11%</td>
<td>-68%</td>
</tr>
<tr>
<td>Toughness</td>
<td>-34%</td>
<td>-70%</td>
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![Fig 24-1a-b](image) Schematic sketches of cross sections of the femur of a 30-year-old patient (a) and an 80-year-old patient (b). Note the larger internal diameter and the decrease of cortical thickness and increased porosity in the elderly bone.
Cancellous bone undergoes many changes with both aging and osteoporosis. The trabeculae undergo osteoclast-mediated resorption with a diminished rate of osteoblastic bone deposition. This results in thinning of the trabeculae and disconnection of the trabeculae from each other and from the surrounding cortical bone. With aging, the bone trabeculae change in shape from flatter structures to more rod-like structures. These changes weaken the internal architecture of the cancellous bone making it more likely to fracture with minor trauma (Fig 24-2).

Biomechanically the reduction of bone quality has been demonstrated for many different failure modes, implants, and bones [12].

**Fig 24-2a–b** Micro-CT scans showing differences between young, healthy cancellous bone (a) and osteoporotic, thinned trabeculae (b). Note also that the geometry of the trabeculae changes (courtesy of Ralph Müller, ETH Zürich).

### 2.3 Mechanisms of injury

There is a wide variety of injury mechanisms, from the usual low-energy fall from standing or sitting height to severe motor vehicle injuries.

Why are fragility fractures more frequent with age? Many factors contribute. Most fragility fractures occur after a low-energy fall. Falls occur in one third of community-dwelling people per year older than 65 years. 10% of falls in the elderly result in serious injury [6]. Women are more likely to sustain a fracture than men. Risk factors for falls are similar to those of fractures: previous falls, weakness, poor balance, gait disorders, and taking certain medications, such as psychoactive drugs, anticonvulsants, and antihypertensives [13–15].

In geriatric polytrauma patients, for each 1-year increase in age over 65 years, the probability of dying increases by 6.8%. Hepatic and renal diseases, cancer, and long-term steroid use have greatest negative impact on patient survival [16]. For care of the injured elderly patient, trauma centers have shown significantly better outcomes than acute care hospitals [17]. Therefore, triage of the injured elderly patient to a trauma center from the scene of injury is critical to improving outcomes.

In demographic studies, 28% of all traumatic deaths occur in the geriatric group despite being only 12% of the population. When controlled for severity, the elderly were six times as likely to die as their younger counterparts [18].

As people are living longer, they are also more active when older. In the elderly population motor vehicle collisions, being struck by a car as a pedestrian, falls from high, and burns are all increasingly common injuries.
Preexisting comorbidities have a significant impact on outcomes with geriatric trauma patients [16–22]. One possible definition of a fragility fracture patient is:

- Acute injury
- Older than 80 years, or
- Older than 70 years with three or more comorbidities, reduced general health status, dementia, and so on

3.1 Comorbidities
The fragility fracture is only one part of the problem. Fragility fractures are much more common in patients with preexisting medical conditions—comorbidities. These comorbidities may contribute to the cause of the fracture and frequently complicate patient care. Comorbidities may dominate the situation in some cases and the fragility fracture may be secondary in importance. Some fracture survival scores use the presence of specific comorbidities to help predict patient outcomes [23, 24].

Common comorbidities in patients with fragility fractures include cardiac disease, dementia, renal dysfunction, pulmonary disease, hypertension, and diabetes. Each of these conditions is likely to be treated with at least one medication which leads to a situation referred to as polypharmacy. When more than three drugs are used, many patients will experience some level of drug-drug interaction. A consultation with a geriatrician or physician is useful in these situations to assist the orthopaedic trauma surgeon with management of these conditions and medications.

3.2 Compliance/adherence
The natural aging process limits the elderly in their ability to respond to injury. Many patients have difficulty being compliant with instructions because of frailty and/or dementia. Dementia is a common comorbidity in the fragility fracture population. Dementia is a chronic, fatal illness with relentless progression of decline in cognitive status. The patient with dementia finds it difficult or impossible to follow instructions given in physical therapy.

Delirium is much more common in patients who have dementia and up to 61% of patients with a hip fracture have delirium in the perioperative period [25]. Delirium is an acute and fluctuating alteration in mental status with inattention, confusion, and lack of mental clarity. There are hypoactive, hyperactive, and mixed forms of delirium. The hyperactive form often involves agitation, irritability, confusion, hallucinations, and loud verbal communications. The hypoactive form is notable for somnolence, diminished responsiveness, little or no speech, or reduced movement of the patient. The mixed variety involves a fluctuating course between these two forms. Delirium indicates a poor prognosis for the patient with fragility fracture. Hospital stay is lengthened and it becomes more likely that the delirious patient will have a complication. Delirious patients cannot effectively participate in their rehabilitation following fracture [25, 26].

3.3 Functional demands
The functional demands of the elderly are unique. Many elderly have little or no support from family and this varies from region to region. Elderly patients often require use of their upper extremities to assist with ambulation by using a cane or walker. It is impossible for most elderly patients to limit their weight bearing on an injured extremity. Both upper and lower extremities can be weight-bearing limbs. Therefore, any treatment plan devised for the older fracture patient must also consider their unique functional needs, preinjury living situation, and preinjury function.
4 Preoperative assessments

Usually the general preparation for surgery of the geriatric fracture patients has to be separated from medical stabilization that may become necessary in selected, medically unstable cases. The preoperative assessment of most elderly patients should not consume more time than in younger patients if organized well and consented to by all stakeholders.

Another important concept is that fragility fracture patients should not stay longer than absolutely necessary in the emergency department. Disorientation and fear in this noisy, unfamiliar, and chaotic environment causes them problems that could be avoided. A well-organized “fast track” should limit the time in the emergency department to a maximum of 2 hours [27].

4.1 Risk of surgery

At this stage the status of the patient should only be optimized if the measure lowers the risk of surgery. However, if the risk of surgery cannot be altered surgery should be performed without further delay. Delaying surgery would otherwise add additional, unnecessary risk that is.

4.2 Standard preoperative evaluation

The standard evaluation process follows a predefined and consented pathway [17] (Table 24-2).

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<thead>
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<th>Notes</th>
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<td>Orthopaedic diagnostics</td>
<td>Plain films, CT scan, MRI accessible to local practice and injury</td>
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<tr>
<td>X-ray thorax</td>
<td>Although there is no significant evidence, chest x-rays are usually taken preoperatively</td>
</tr>
<tr>
<td><strong>Electrocardiogram</strong></td>
<td></td>
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<tr>
<td>“Geriatric laboratory tests”</td>
<td>Preselected set of orders</td>
</tr>
<tr>
<td>Include geriatrician</td>
<td>Geriatric medical assessment</td>
</tr>
<tr>
<td>Anesthesiology assessment</td>
<td>Should not cause any delay</td>
</tr>
<tr>
<td>Definition of operating-room timing</td>
<td>Surgeon, geriatrician, and anesthetist agree on earliest possible time</td>
</tr>
<tr>
<td><strong>Definition when to start with thrombosis prophylaxis</strong></td>
<td></td>
</tr>
<tr>
<td>Fluid and electrolyte management</td>
<td>Immediate infusion therapy according to local guidelines while replacing decreased intravascular volume</td>
</tr>
<tr>
<td>Pain management</td>
<td>Immediate pain management according to local guidelines</td>
</tr>
<tr>
<td>Fixation of relevant geriatric-medical comorbidities</td>
<td>According to recommendation of geriatrician</td>
</tr>
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Provide important medical and surgical information for patients and relatives

Table 24-2 Checklist for preoperative evaluation and treatment of geriatric fracture patients.
4.3 Optimizing the medical situation
In few and clearly defined situations, the patient will need additional preoperative preparation and medical stabilization. As a rule the time needed should not exceed 72 hours. Any delay of surgery for more than 72 hours causes a significant increase in complications.

Conditions that need a more time-consuming medical stabilization before surgery are “active” geriatric-medical conditions:
- Heart failure, acute cardiac ischemia
- Unclear systolic ejection heart murmur, with examination, which suggests aortic stenosis
- Acute stroke
- Acute infection, such as pneumonia or septicemia
- Unstable angina pectoris
- Severe hypotension
- Severe chronic obstructive pulmonary disease
- Rhabdomyolysis

4.4 Anesthesia
The role of anesthetic assessment remains an area of much concern to the surgeon. The anesthesiologist looks for the patient’s physiological age. Physiological age is more important than chronological age. The patient’s preinjury functional capacity is evaluated, including cognitive function and daily activities. Preoperative functional capacity may be the single best predictor of the patient’s risk of in-hospital mortality. The medication list and the preoperative preparation for surgery are also assessed. The patient is risk stratified and then a decision is made about type of anesthesia and whether to proceed as planned with surgery. Preoperative hydration and restoration of a normothermic state (36–37.5°C) is essential for success.

When deciding on the type of anesthesia to be used, the anesthesiologist will consider the procedure planned and its duration, preoperative anticoagulation, possibility of delirium, and feasibility of neuraxial anesthesia. Neuraxial blockade is associated with a reduced risk of delirium, thromboembolic events, pneumonia, and bleeding complications [22]. Presence of antiplatelet agents, such as clopidogrel, may preclude use of neuraxial anesthesia. In most cases proper preoperative rehydration will reduce the risk of hypotension during surgery. Critical aortic stenosis may also preclude use of spinal anesthesia. Use of femoral nerve blockade in the lower extremity or supraclavicular blockade in the upper extremity may provide excellent anesthesia and postsurgical analgesia.

5 Postoperative management
From the orthopaedic surgeon’s perspective, the fracture fixation should permit weight bearing as tolerated, especially for the proximal femoral fracture. From the geriatrician’s standpoint, stability concerns treating comorbidities.

In the first postoperative phase, early mobilization and avoidance of complications are vital. Prolonged bed rest is associated with increased risk of deep vein thrombosis (DVT), pulmonary embolism, skin breakdown, infection, and de-conditioning in elderly patients [28, 29]. Early physical therapy enables activation of the respiratory and cardiovascular system. The authors encourage early full range-of-motion exercises of the adjacent joints.

Postoperatively the following points are very important and must be addressed:
- Sufficient pain management (see 5.1 Pain treatment)
- Routine laboratory testing on the first postoperative day
- Early administration of blood units when hemoglobin < 8 g/dL
- Respiratory therapy in all bedridden or limited-mobility patients from the first postoperative day
- Avoidance of prolonged use of surgical drains
- Early removal of urine catheter (within 24–48 hours)
- Early mobilization with weight bearing as tolerated (within 24 hours)
- Protein-enriched nutrition, contingently with additional food, control of intake
- Close communication between geriatrician and surgeon
- Early discharge planning
5.1 Pain treatment

Standard algorithms for pain management should not to be applied in geriatric patients because they are more vulnerable, and many systems do not work as well as in younger patients.

The provision of good pain relief for postoperative patients is generally associated with reduced cardiovascular, renal, respiratory, and gastrointestinal tract morbidity. Good pain management enhances mobilization, lowers delirium rate, and may decrease length of hospital stay. Nevertheless troublesome medications, like nonsteroidal antiinflammatory medications, should be avoided because of potential side effects of renal insufficiency and peptic ulcers. Paracetamol, morphine, metamizol, and piritramide are used as first-line therapy intravenously and soon changed to orally administered paracetamol, metamizol, oxycodone, or hydromorphone. When using morphine, laxatives should be prescribed regularly. In addition, formal assessment and charting of pain scores helps with pain management.

There is evidence that local catheters and blocks with continuous administration of local anesthetics (3-in-1 femoral nerve block, installed with the help of sonography) are helpful to provide good pain treatment and mean that administration of additional analgesics with potentially negative side effects specifically in this patient population can be reduced [30, 31].

Other issues:

- Many geriatric patients tend to have renal dysfunction; therefore routine administration of nonsteroidal antiinflammatories (NSAIDs) is not justified.
- Elderly patients, specifically with dementia, are not able to articulate pain sufficiently; consequently, they are often not given enough analgesics. Unrecognized or undertreated pain on the other hand predisposes the development of delirium, and limits mobilization which leads to an increased morbidity.
- An early change to oral administration of analgesics is preferred and helps to avoid delirium.

A regular formal charting of pain scores in the patient’s medical chart should be adopted as routine practice. It helps to address pain therapy specifically and prevents undertreatment, which is common in these patients [32]. Furthermore, an adapted pain-therapy protocol should be used.

The following recommendations are offered:

- Intravenous (IV) pain therapy directly postoperatively:
  - Paracetamol/acetaminophen 1,000 mg 3–4 times daily (first choice). Possibly adapt to body weight 15 mg/kg
  - Metamizole 1,000 mg up to 3 times daily, additionally if needed
- Piritramide 3.75–7.5 mg subcutaneously (sc) or morphine 2.5–5 mg sc (or IV) in acute pain
- Morphine 1–2 mg intravenously every 2 hours as needed for pain
- Early switch to oral pain medication postoperatively:
  - Paracetamol/acetaminophen 500 mg 3–4 times daily (first choice)
  - Metamizole 500 mg 3–4 times daily postoperatively, additionally if needed
  - Hydromorphone 2–4 mg postoperatively or piritramide 3.75–7.5 mg sc in acute pain

Oxycodone 5 mg orally every 3 hours as needed for pain

- On constant demand for opiate analgesics:
  - Haloperidol 0.5mg daily to prevent nausea
  - Macrogol for regulation of bowel movements

Opioids should only be used in low dosages first, specifically in patients at risk of delirium. When patients are cachectic or sarcopenic, dosages should be generally reduced, which is also true for patients with reduced renal function.

Metamizole is not approved in some countries, like the United States or Sweden, because of a certain risk of agranulocytosis. The drug has low rates of adverse effects and high pain-killing potential. Oxycodone is a satisfactory alternative medication.

5.2 Fluid and electrolyte balance

Electrolyte imbalance, especially hypokalemia and hyponatremia, are common in the postoperative period and reflect the limited reserves of the patients [33]. This situation may worsen with diuretics and inappropriate IV fluid application and can also encourage delirium. Therefore isotonic fluids should be used exclusively and electrolyte management should be monitored regularly and adjusted appropriately.
5.3 **Prophylaxis with antibiotics**

Gillespie et al [34] reported (8,307 patients) that a single-dose prophylaxis significantly reduces superficial and deep wound infections, and urinary and respiratory tract infections, whereas multiple-dose prophylaxis did not show an effect on urinary and respiratory tract infections. Thus prophylactic antibiotics should be given preoperatively and in case of verified infection. Prolonged antibiotic use is of no proven benefit for prophylaxis of wound or visceral infections.

The following recommendations may be given:
- **First- or second-generation cephalosporins** are first choice
- Single-dose cephalosporin 2 grams or vancomycin 1 gram in surgical fracture fixation
- 24 hours prophylaxis (2–3 times) cephalosporin or vancomycin in arthroplasties
- 48 hours prophylaxis (3 times/day): open fractures until smear test is sterile
- Bedridden patients from nursing homes should be tested preoperatively with a smear test from the nose for methicillin-resistant Staphylococcus aureus (MRSA). The result is available within 24 hours. If positive, perioperative antibiotic therapy with vancomycin is indicated.

5.4 **Anticoagulation and thromboprophylaxis**

Perioperative thromboprophylaxis should be a routine aspect in the care of geriatric fracture patients. Commonly, low-molecular-weight heparins are used. Mechanical devices may be reserved for patients with contraindications for anticoagulants and antiplatelet agents [35]. Many older patients are chronically anticoagulated. Warfarin is typically reversed to safely permit surgery. Postoperatively, patients using oral warfarin on admission to hospital are restarted on warfarin the day of surgery and may require perioperative “bridging therapy” with low-molecular-weight heparin or unfractionated heparin depending on the individual indication for anticoagulation therapy [35].

Venous thromboembolism is one of the leading reasons for postoperative morbidity and mortality in patients with hip fracture or other immobilizing fracture. Up to 7.5% of all patients with hip fracture sustain fatal pulmonary embolism within 3 months postoperatively.

- Administration of thromboprophylaxis on admission depends on timing of surgery, type of anesthesia, and preexisting anticoagulation.
- If the time between admission and surgery exceeds 2–3 hours, thromboprophylaxis with unfractionated heparin (5,000 units subcutaneously) should be started preoperatively.

In cases of preexisting anticoagulation or antithrombotic therapy or if thromboprophylaxis has been initiated preoperatively, certain therapy interruptions have to be respected if the use of regional anesthetic procedures is planned [35].

5.4.1 **Unfractionated heparin**

In case of prophylactic doses of unfractionated heparin, the recommended therapy interruption of 3 hours has to comply with elective interventions. In acute cases with indication for regional anesthesia, peripheral blocks or single-shot spinal anesthesia are possible before expiration of the recommended interruption period. In case of therapeutic dosing the normalization of a partial thromboplastin time or activated coagulation time in the laboratory tests should be additionally ensured preoperatively.

5.4.2 **Low-molecular-weight heparins**

In case of prophylactic doses of low-molecular-weight heparins the therapy interruption of >11 hours has to be observed. Because of the recommended long-therapy interruption of 24 hours, in case of therapeutic doses the indication for regional anesthetic techniques should be carefully weighed in each case. Bridging therapy with unfractionated heparin is possible.

5.4.3 **Oral anticoagulants** (warfarin, vitamin K antagonists)

The use of neuroaxial anesthetic techniques without a therapy interruption is contraindicated due to the long and variable half-life periods of oral anticoagulants. In the case of any interruption, bridging therapy with low-molecular-weight heparins or unfractionated heparin may be recommended, especially in patients with atrial fibrillation, valvular heart disease, or recurrent thromboembolic events. Reversal of oral anticoagulants with low-dose oral vitamin K (1–5 mg) is possible, the use of coagulation factor concentrate (prothrombin complex concentrates (PPSB), prothrombin, prokonvertin, Stuart-Prower-Factor, antihemophiles globulin B, prothrombincomplex) or fresh frozen plasma is not usually indicated for the limited purpose of regional anesthetic administration. Postoperatively anesthetic catheters should be removed before reestablishment of oral anticoagulation.
5.4.4 Acetylsalicylic acid (aspirin)
For patients taking aspirin not combined with other anti-coagulants and a normal-bleeding history compliance with therapy, delay before the use of regional anesthesia is no longer urgently recommended. In case of abnormal bleeding histories or combination therapies, eg, with low-molecular-weight heparins, a 48-hour delay in aspirin intake is recommended before single-shot spinal anesthesia with atraumatic “Touhy” needle, while a 72-hour interruption is recommended before all other neuroaxial procedures.

5.4.5 Nonsteroidal antiinflammatory drugs
In patients with normal bleeding history receiving pain medication with NSAIDs as a monotherapy, no therapy interruptions have to be observed before the use of regional anesthetic procedures similar to the case with aspirin. With the use of regional anesthetic catheters postoperatively a window of two half-life periods for the NSAID is suggested before removing the catheter if patients receive additional postoperative thromboprophylaxis. During this phase pain medication should be changed to agents without antiplatelet activity.

5.4.6 Dual antiplatelet therapy
In patients receiving dual antiplatelet therapy with clopidogrel and aspirin, eg, after coronary artery stenting, no neuroaxial anesthetic techniques should be performed under ongoing effect of clopidogrel because of possible spontaneous and perioperative bleedings requiring transfusion. In those patients, an individual, interdisciplinary risk-benefit analysis is recommended before starting any therapy interruption because of the high risk of possibly life-threatening thrombotic complications (eg, stent thrombosis). If clopidogrel is interrupted, regional anesthesia can be performed after an interval of 7 days during ongoing monotherapy with aspirin. Preoperatively monitoring platelet function with aggregometry is recommended. Thromboprophylaxis with low-molecular-weight heparins should not be initiated until after the puncture, and appropriate therapy interruption times also have to be respected before catheter removal. Postoperatively a rapid readministration of the clopidogrel therapy is recommended to reduce risk of stent thrombosis [36, 37]. The authors do not recommend a delay in patient care when clopidogrel is being used.

5.5 Delirium
There are four key features that characterize delirium [38]:
• Disturbance of consciousness with reduced ability to focus, sustain, or shift attention
• A change in cognition or the development of a perceptual disturbance that is not better accounted for by a preexisting, established, or evolving dementia
• The disturbance develops over a short period (usually hours to days) and tends to fluctuate during the course of the day
• There is evidence from the history, physical examination, or laboratory findings that the disturbance is caused by a medical condition, substance intoxication, or medication-adverse effects

Additional features that may accompany delirium include:
• Psychomotor behavioral disturbances, such as hypoactivity, and impairment in sleep duration, euphoria, and architecture
• Variable emotional disturbances, including fear, depression, euphoria, or perplexity

Conversation with the patient may elicit memory difficulties, disorientation, or speech that is tangential, disorganized, or incoherent. The clinician should be aware of superficially appropriate conversation that follows social norms but is poor in content. This sort of “vacuous” conversation is one of the most important indicators of delirium, but up to 70% of patients with delirium remain unrecognized by healthcare providers.

Distractibility, one of the hallmarks of delirium, is often evident in conversation. It is essential that clinicians are sensitive to the patient’s flow of thought and do not attribute tangential or disorganized speech to age, dementia, or fatigue.

Delirium is an independent risk factor for length of hospitalization, an increase of functional impairments, complications, such as urinary incontinence, falls, or decubitus ulceration, and admission to a nursing home [39]. The mortality rate is still high, up to 30%. Only one third recover from delirium, the other two thirds retain a decline in cognitive function. Delirium is always an acute medical emergency. It requires an adequate diagnostic process. The best and only medical treatment for delirium is avoidance. Guidelines for diagnosis of delirium can be useful when an experienced clinician is not available.
5.5.1 Causes, risk factors, and triggers

Common causes of delirium are:
- Brain disorders (e.g., dementia, hematoma, Parkinson’s disease)
- Metabolic derangements (e.g., hypoglycemia, hyponatremia)
- Systemic organ failure (e.g., heart failure, renal failure)
- Toxins (e.g., alcohol, prescription medications)
- Physical disorders (e.g., trauma with systemic inflammatory response system, hypothermia)
- Sensory deprivation (e.g., taking away glasses and hearing aids)

Particularly in the elderly, long-term alcohol abuse is a rare cause of delirium. More common in this age group is the abuse of benzodiazepines. An immediate withdrawal of this medication can induce delirium. Consequently, because of the above-listed reasons, delirium is one of the most prevalent complications among hospitalized geriatric patients, evident in up to 61% of patients with hip fractures [25].

Common risk factors are:
- Older age
- Preexisting cognitive impairment
- Severe comorbidities
- Visual and/or hearing impairment
- Major fractures (e.g., hip fracture)

Triggers may be:
- Physical restraints (e.g., extension, bed grids)
- Impaired perception of the environment (e.g., glasses, hearing aids)
- Urinary catheters, drainages
- Medical complications
- Polypharmacy (more than three medications)
- Malnutrition
- Dehydration and derangement of electrolytes
- Pain
- Anesthesia
- Withdrawal of benzodiazepines or alcohol

5.5.2 Prevention

Treatment strategies are less effective than preventive measures. A general medicinal prophylaxis of geriatric patients is not recommended.

Prevention is based on four principles [40]:
- If possible, avoid triggers and worsening factors.
- Identify and treat possible causes.
- Care for an optimal reactivating care and rehabilitation to avoid further physical and cognitive decline.
- Take care of dangerous and disturbing behavior of the patient and try to control them to make the other principles possible.

Early surgery and a proactive geriatric treatment are crucial. The following steps can be taken in clinical practice:
- Early volume and electrolytes repletion (if necessary)
- Avoid hypoxemia
- Sufficient pain therapy
- Review medication; look for inadequate drugs (e.g., Beers List, a list of medications that are inappropriate for the elderly) [41]
- Management of bowel and bladder function
- Adequate nutrition
- Early mobilization
- Minimize use of physical restraints for patient with limited mobility
- Early detection and treatment of postoperative complications
- Environmental modification and nonpharmacological sleep aids for patients with insomnia
- Orientation protocol and cognitive stimulation for patients with cognitive impairment
- Managing disruptive behavior, particularly agitation and combative behavior
- Monitoring high-risk patients with validated scores, like the confusion assessment method

5.5.3 Therapy

There is no true treatment for delirium. Symptom control may be necessary to prevent harm or to allow evaluation and treatment. Delirium symptoms are still managed empirically and at this time there is no evidence in the literature to support change to current practice.

In older hospitalized patients after hip surgery, low-dose haloperidol did not reduce the incidence of delirium but did reduce the severity and duration of episodes [42]. So haloperidol is effective as a symptomatic but not a preventive therapy. The newer atypical antipsychotic agents, quetiapine, risperidone, ziprasidone, and olanzapine have fewer side effects, and in small studies they appear to have similar efficacy to haloperidol [43]. If there is any uncertainty of head injury, cerebral CT should be obtained.
Slight or moderate delirium (oral medication is possible):
• Risperidon 0.5–1 mg postoperatively
• Quetiapine 25–100 mg postoperatively
• Haloperidol 0.5–1 mg postoperatively

Disruptive behavior:
• Haloperidol 2–5 mg IV in a short infusion, followed by oral medication

Medication must be reduced or discontinued as soon as possible.

5.6 Polypharmacy
As mentioned above, this issue should be carefully addressed and resolved by an experienced geriatrician. Drug-related illnesses are an important medical problem, resulting in 3–5% of all hospital admissions and are associated with a substantial increase in morbidity and mortality. Older patients are particularly vulnerable to drug-related illnesses because they are usually receiving multiple-drug regimens, leading to a higher risk of drug interactions, and because age is associated with changes in pharmacokinetics and pharmacodynamics [44]. Drug toxicity accounts for approximately 30% of all cases of delirium [45]. Other important drug-related medical problems may be disturbances of electrolytes, nausea, renal failure, hypotension, heart failure, gastritis, and bleeding.

There is also a relationship between polypharmacy and under prescription [46]. Usually underprescription or undertreatment is defined as lack of an indicated drug, while no reason could be found for not prescribing it. Examples are osteoporosis, pain treatment, or oral anticoagulation therapy in patients with atrial fibrillation.

The management of medication in elderly trauma patients is a challenge for all clinical physicians and needs, besides substantial experience, a particular type of comanagement.

5.7 Other complications
Urinary tract infection is best prevented by avoiding catheterizing the patient, except in presence of urinary incontinence, or when monitoring cardiac/renal function. Intermittent catheterization has been shown not to increase the infection rate [47].

The use of laxatives, increased fluid intake, and mobility can reduce constipation. Special low-pressure mattresses, nutrition management, and early mobility may help to avoid development of decubitus ulceration.

Wound care should be standardized with daily occlusive wound dressings in the first few days. The rate for wound infection in patients with hip fracture is approximately 1–3% [48]. Deep wound infections are devastating for the patient with a mortality rate approaching 50%.

5.8 Malnutrition
The nutritional status should be checked in all fragility fracture patients postoperatively. The Mini-Nutritional Assessment tool is a useful diagnostic device for identifying patients at risk of malnourishment [49]. The most common problem is protein deficiency. For malnourished patients with hip fracture, oral supplements are recommended and may reduce unfavorable outcomes [50, 51], and may also influence mortality [52].

Settings with interdisciplinary care and standardized order sets improve the outcome in geriatric fracture patients and are therefore highly recommended [27, 53–55].

5.8.1 Assessment
The following symptoms help to diagnose a poor nutritional status:
• Weight loss: > 5% within 3 months or > 10% within 6 months
• Body mass index < 20 kg/m²
• Albumin < 3.5 g/dL
• Mini-Nutritional Assessment < 1 points

5.8.2 Step-by-step approach of malnourishment
• Identify and treat possible causes
• Focus the nursing staff on malnourishment
• Dietary supplements
• Feeding tube or parenteral nutrition

5.8.3 Recommendations for elderly people
• 1,500–2,000 kcal/day
• Protein: 12–14% of overall feed charge (0.9–1.1 g/kg body weight/day)
• Fat: maximum 30% of overall feed charge
• Carbohydrate: minimum 50% of overall feed charge
• Dietary fiber: minimum 30 g/day
• Fluids: 1.5–2 l/day

In case of malnourishment liquid dietary supplements should be given early. Oral dietary supplements are known to decrease mortality in geriatric patients. In case of a geriatric hip fracture, postoperative oral dietary supplements may reduce overall complications.
5.9 Rehabilitation

After the stay in the orthopaedic ward, treatment within an acute geriatric unit with rehabilitation seems to be most effective to reintegrate patients. Initially, a geriatric assessment should be done. Assessment of cognition, depression, mobility, fall risk, nutritional status, incontinence, and visual function are recommended and lead to an individual rehabilitation concept [56, 57]. An interdisciplinary rehabilitation program improves physical outcomes, quality of life, and instrumental daily activities, reduces readmission rates and depression, and may also be associated with fewer falls [58, 59].

If rehabilitation takes place within an acute geriatric hospital, polypharmacy and comorbidities can be addressed properly. Polypharmacy is most common in elderly patients. Use of antidepressants and benzodiazepines are risk factors for future hip fractures [60]. Drug-drug interactions and changes in metabolism of elderly individuals may also contribute to falls. Few studies on physiology in elderly patients have been done and pharmacological studies on subjects 85 years or older are usually not performed for ethical reasons.

Most fragility fracture patients have three or more comorbidities which increase the postoperative complication rate [48] and influence the overall outcome and mortality. Geriatricians are specialized in treating these conditions and therefore need to be included in the multidisciplinary team. It is essential to improve patients’ self-confidence in their own abilities, lessen disability, avoid overdependence, and restore social integration.

5.10 How to avoid complications

Complications following fragility fracture surgery can have devastating effects on the patients. A total-quality-management approach to the patient is helpful. Here, each detail of care is studied and the harmful and wasteful processes are lessened or eliminated. This allows creation of a system of care that will benefit the patient. In surgery, meticulous positioning helps avoid skin breakdown. Meticulous hemostasis helps avoid tipping the patient out of equilibrium. Avoiding crushing reduction forceps helps avert worsening the comminution. The four AO Principles certainly apply to the care of fragility fractures and should be carefully adhered to [61].

They are:
1. Fracture reduction and fixation to restore anatomical relationships
2. Stability by fixation or splinting, as the personality of the fracture and the injury requires
3. Preservation of blood supply to soft tissues and bone by careful handling and gentle reduction techniques
4. Early and safe mobilization of the part and the patient

5.11 How to prevent secondary fractures

5.11.1 Fall prevention

A comprehensive falls assessment program for all patients with a fragility fracture is an essential tool for prevention of subsequent fractures. An excellent review of falls prevention in community-dwelling people was published by Tinetti and Kumar [13]. Consideration should be given to the patient’s medications, particularly to antihypertensive, psychoactive drugs and anticonvulsants. Careful adjustment or replacement of these medications may be necessary and should be referred to the patient’s primary care physician. Evaluation of the patient’s gait can be performed with clinical examination or with a formal gait study to help understand the etiology of falls. Falls can be predicted using gait studies and some of these gait disorders can be improved with physical therapy or with reconstructive surgery. Tai Chi in particular has been shown to reduce falls in older adults [13].

Additionally, the patient’s vision should be corrected with glasses or surgery. An assessment for alcohol use can also be helpful. There is an increased incidence of late-life alcoholism, particularly in men who have lost their spouse. A cognitive assessment by the primary care physician should be performed to check for early dementia which can be a cause of falls and disordered gait.

A thorough home assessment for hazardous conditions can be undertaken by a physical therapist or visiting nurse. This assessment should check for missing rails on stairs, poor lighting, loose rugs or carpets, issues with pets, and other potential situations that place an older person at risk of falling. Many of these environmental factors are easily correctable, for example, a nightlight by the patient’s bedside can reduce the risk of falls at night when using the toilet.

Proper footwear is also an essential factor. Comfortable shoes that fit properly and have appropriate traction for the environment can reduce risk of falling.
5.1.1.2 Diagnostics of osteoporosis
The following principles should be applied:

• DEXA scan is a bone density study performed with dual energy photons. It is presently the standard study performed to determine bone density. Availability of this technique varies by region. Indications for DEXA scan vary with the country. General good indications for obtaining a DEXA scan are long-term steroid use, early surgical menopause, postmenopausal women with a family history of fractures, alcoholism, heavy tobacco use, or a body mass index < 18.5.

• A DEXA study is appropriate for all patients to get a baseline for monitoring the therapy.

• DEXA follow-up studies after 1 year are recommended to follow the progress of treatment with pharmacotherapy.

If the indication for a specific treatment is unclear or if only minor fractures, like distal radial fractures, have occurred, the FRAX tool may be used (this may be accessed at www.FRAX.org). Therapy should be started with a 10-year probability for a hip fracture > 3% or for a 10-year probability of “major osteoporotic fracture” > 15–20%.

5.1.1.3 Medical therapy
All older patients with a fragility fracture should be suspected of having a low level of vitamin D. Serum 25-hydroxy vitamin D levels below 32 ng/dL are considered insufficient, and below 10 ng/dL are considered deficient [62]. Repletion in most cases is accomplished with oral vitamin D. Vitamin D is a fat-soluble vitamin and large doses for a prolonged period may be required. Vitamin D deficiency is typically accompanied by elevated levels of parathyroid hormone and a low-serum calcium level (secondary hyperparathyroidism). Fractures may not heal with low vitamin D levels as the body is unable to mineralize the osteoid deposited at the fracture site. Thus a fine surgical effort may prove unsuccessful.

Dosage of vitamins for maintenance is vitamin D3 1,200–2,000 IU per day orally. Patients with renal disease may require calcitriol (Rocaltrol) but this treatment should be administered by the patient’s renal specialist to avoid hypercalcemia.

Calcium should only be consumed with vitamin D for proper absorption. Oral calcium supplementation: 1,500 mg/dL in three divided doses is the typical requirement for most postmenopausal women [63]. Most patients can safely consume calcium carbonate, which is inexpensive. However, patients who are being treated with antacid therapies should use calcium citrate which does not require a gastric acid environment for absorption. Calcium level checked prior to starting therapy is necessary to avoid worsening the condition of a patient with hypercalcemia. In case of a severe vitamin D deficiency (25-hydroxy vitamin D < 10 ng/dL) a loading with 50,000 IU vitamin D3 once or twice a week administered orally for 5–6 weeks is recommended [5]. Typically large doses of vitamin D2 or D3 are well tolerated and will not cause hypercalcemia. Depending on availability, large oral doses of vitamin D2 can be given once or twice a week for 6–12 weeks and in most cases will begin to replete the patient’s levels [5].

Osteoporosis therapy should be prescribed centered on patient-based factors, regional factors, and availability of drugs in all patients with a fragility fracture. Typically oral bisphosphonate can be safely started immediately after fracture repair. The antifracture effects of these medications are typically not reached until after at least 6 months of therapy [64]. Oral bisphosphonates will not interfere with secondary bone healing but do interfere with bone remodeling. In many studies compliance is reported to be low by 6 months with oral bisphosphonate therapy due to upper gastrointestinal tract upset and an asymptomatic condition—osteoporosis. Intravenous bisphosphonate therapy can provide protection against a second fracture for 1 year (zoledronic acid); and one study showed a reduced mortality rate at 1 year when zoledronic acid was given [65]. Intravenous treatment should be delayed at least 3 weeks postoperatively to prevent uptake of all medications at the fracture site.

Intravenous therapy assures compliance and has an immediate onset of fracture protection but is costly and requires medical personnel to infuse the dose:

• First choice: oral bisphosphonates alendronate or risidronate
• Second choice: strontium ranelate in patients with bisphosphonates intolerance
• SERMs for postmenopausal women include raloxifene
• In case of serious osteoporotic fractures, eg, after treatment with bisphosphonates: anabolic hormone teriparatide is recommended
• IV bisphosphonates (zoledronic acid) only after special consideration
• Following a fragility fracture, in every medical report the diagnosis of osteoporosis and recommendations of how to proceed should be communicated to the patient and primary care physician.
6  General principles of surgical treatment

There are several key principles to remember when preparing an elderly patient for surgery:

- **Keep operating time as brief as possible**: Although speed should not be a surgeon’s primary goal, a brief surgery is generally preferred to reduce stresses of surgery and its burdens on the patient.
- **Correct positioning to avoid pressure sores and skin damage**: It is essential to carefully position the patient on the surgical table. Avoidance of pressure sores is of particular importance as sores significantly interfere with recovery. An infected pressure sore may actually result in sepsis and death in the elderly fracture patient. During positioning and draping, the surgeon must remember that the elderly patient’s skin is fragile and can tear or be avulsed with minimal shear stresses.
- **Preference for supine position**: In most cases a supine position is preferred in the elderly to allow for overall care by the anesthetist. When under regional anesthesia, the patient can breathe easier when supine and is usually more comfortable.
- **Minimize blood loss**: To keep older patients in “equilibrium”, the surgeon must take great care to lose as little blood as possible. Otherwise the patient’s equilibrium may be disturbed to an extent which he/she can no longer tolerate. At that point, a series of events may follow that can result in serious harm or death.
- **Need for immediate weight bearing and full function**: If possible, the selected surgical procedure should permit immediate unrestricted weight bearing. The benefits of immediate weight bearing are numerous. The likelihood of delirium is reduced and the functional outcomes have been shown to be better with immediate weight bearing. In cases when immediate weight bearing is not possible, early functional range of motion is preferred to prevent joints from stiffening.
- **Many patients have an incision from previous surgery which should be respected and used if possible**.
- **During the removal of surgical drapes, great care must also be exercised to prevent injury to the patient’s skin**.

6.1  The fracture

Classification of fragility fractures is often challenging because of different fracture patterns. Many fracture classifications exist in an attempt to describe fracture patterns. These classification schemes may provide treatment recommendations and offer prognostic information to surgeons. Osteoporotic fractures often occur in patterns not described in the currently used classification schemes. This frustrates attempts to classify the fractures and may result in incorrect procedure or implant selection. The Müller AO Classification of Fractures is useful for many, but not all, fragility fractures.

- **Soft-tissue considerations**: As people age, their bone and soft tissues also age. The skin becomes thinner and less elastic. The skin of an older patient may tear away from underlying tissues if handled roughly. The muscles also are frequently atrophied and weaker than in younger patients. The loss of muscle tissue is referred to as sarcopenia. Sarcopenia has many negative implications for the older fracture patient. Besides weakness, it may reflect poor nutritional status.

When caring for the fragility fracture, the surgeon must be gentle. Forceful reduction maneuvers and aggressive handling of the bone may result in extension of the fracture beyond the original injury pattern or new fractures. The use of clamps and other instruments applied directly to the bone must be performed cautiously to avoid additional damage. The thinned cortex may break just by closing a clamp with too much force.

6.2  Indications for operative treatment

Almost all fractures of the lower extremity should be surgically managed. Treatment of fractures with nonoperative care in elderly patients will almost always mean they will require nursing home care. In many cases early surgery can lessen this need. On the upper extremity the need to preserve function should be considered to allow the patient to accomplish activities of daily living—eating, self-care, grooming, and ambulation.

6.2.1  Paradigm shift

Universally, it is important to adjust our attitudes toward elderly patients. They must be considered as valuable members of society who deserve prompt attention when injured. It is no longer appropriate to relegate the elderly to second- or third-class care, as has been done in many places in the past. Changing attitudes toward the elderly takes time and for some surgeons this may only occur as they personally age.

The elderly specifically benefit from surgical stabilization of their fractures. They do not tolerate bed rest well, as many serious complications may develop. This should be shunned in nearly all cases. Stabilization of fractures should be accomplished as soon as the patient has been optimized for surgery.
Aggressive care delivers better outcomes. Comparison of a comprehensive approach to the elderly fracture patient with respect to usual care has been studied. Results of this comparison reveal dramatic improvements in time to surgery, length of hospital stay, readmission rates, and numerous complications. Rates of delirium are reduced as are bleeding complications and infection rates. This approach seems to offer many benefits to patients and health-care systems adopting it [27, 53, 54].

The entire patient must be considered including his/her medical problems, medications, living situation, and goals for care. Overall, the following issues assume prominence in care of the elderly with a fracture:

- Pain relief
- Prevention of functional decline
- Need to maintain independence
- Prevention of complications, such as pneumonia, pressure sores, urinary tract infection, and delirium

Careful attention to each of these issues will significantly improve the patient’s care. Many of these patients want their full function back. A healed fracture is not the only goal for the patient. Patients want to return to their preinjury living situation. This is also society’s goal.

6.2.2 Plaster immobilization

Plaster immobilization should be avoided. A cast on any extremity in an elderly person is disabling. The cast will likely prevent a patient from accomplishing daily activities, walking, and the patient may therefore require placement in a nursing home. Casts and braces tend to exacerbate delirium in the elderly.

6.2.3 Preoperative traction

Being treated in traction confuses elderly patients and may only be indicated, if necessary, for pain relief. In this patient population long-term traction is not a treatment option. The traction pin may also cut through the osteoporotic bone causing great damage.

6.2.4 Overall risk

Attaining these goals may involve taking more surgical and overall risk. In many cases, fractures in severely osteoporotic bone can be daunting to the surgeon and may require further planning or effort to stabilize them. It is important to consider the patient’s global needs in choosing the right procedure. In general, an operation that allows immediate postoperative function should be the correct choice.

6.3 Timing of surgery

Much has been written about the timing of surgery in the elderly patient with hip fracture. The literature remains somewhat confusing on how much delay is safe. However, most studies recommend performing surgery within the first 24–48 hours of admission to reduce risks of complications and mortality. Delays longer than 72 hours are associated with an increased risk of mortality. The recommendation is to perform surgery as soon as the patient is optimized and operating time is available.

6.4 Implants

Biomechanically, the purchase of implants in bone structures depends on the BMD. Apart from the content of bone minerals, structural changes of cortical and cancellous bone also weaken the anchorage. Implant anchorage significantly depends on the overall contact area between the implant surface and bone structures. Implants with increased contact area therefore are beneficial and withstand more cycles to failure in biomechanical experiments. Blade-like head-neck elements for proximal femoral fixations, for example, like the proximal femoral nail antirotation (PFNA), trochanteric fixation nail, or the dynamic helical hip system work according to this principle. The same applies to locking head screws (LHSs) in comparison to regular cortex screws, as LHSs have a much thicker core diameter and a finer thread pitch.

Locking plates have special benefits for osteoporotic bone, although were not designed specifically for osteoporotic bone. These plates have revolutionized operative care of the fragility fracture. Locking plates with their angular stable screws allow for successful bridge plating of many fractures not previously possible with standard implants. At the metaphyseal ends of bones, locking plates help to prevent varus collapse in many fractures and allow for anatomical joint reconstruction.

Certain fracture types remain challenging to treat despite the locking plate technology. These include the proximal humeral fracture and proximal tibial fracture. Negative aspects of the locking implants include higher costs and excessive rigidity in some instances.

Standard implants in osteoporotic bone: In some cases standard implants, such as dynamic hip screw (DHS), blade plate, and dynamic condylar screw can be used successfully in osteoporotic bone. These fixed-angle implants still offer advantages for many fractures, and their costs are less. Of these
Implants, the DHS is applied most often in stable pertrochanteric fractures. The DHS is cost effective and successful when inserted correctly. The 95° condylar blade plate remains a good implant choice for some distal femoral fractures, periprosthetic fractures above a total knee replacement, and for nonunited fractures. It has vast strength but requires a high level of technical expertise to insert properly. The dynamic condylar screw has few modern applications and has been largely supplanted by locked nails and locking periarticular plating systems.

Implants may be too stiff, and special techniques are required for a successful outcome: In some cases, the plate may be too stiff for the construct being considered. This has been pointed out clearly by Stephan Perren [66], when discussing newer implants. He has advised that surgeons consider using more flexible fixation techniques to achieve better success with osteoporotic fractures. The technique of bridge plating is one such concept. This technique involves placement of screws more distant from the fracture site and use of longer implants to distribute stress further from the fracture zone. In some cases, use of smaller implants may also help to achieve flexible fixation.

Fig 24-3a–i  A 78-year-old woman with periprosthetic fracture of her right femur (Vancouver type B1).

a  Pelvic x-ray 6 months before the fracture.

b–c  Almost nondisplaced but painful fracture around the stem.

d–g  MIPO with long-splinting curved femoral locked plate. Note the locking attachment plate at the tip of the stem and the set of screws passing posteriorly behind the proximal part of the stem.

h–i  Result after 1 year.
6.5 Fixation principles in MIPO

The following fixation principles should be applied in minimally invasive plate osteosynthesis (MIPO) of osteoporotic fractures:

- **Locking head screws**: A thicker core diameter and less sharp thread pitches result in an increased contact area to the surrounding bone. Another relevant advantage of LHSs is the fact that they cannot be overtightened; thus, a destruction of the thread in the bone is less likely. Locking head screws do not loosen sequentially like conventional screws.

- **Bicortical screw purchase**: It has been shown in biomechanical experiments that the screw purchase of LHSs almost doubles in comparison to a conventional cortex screw while inserted bicortically. Since the “working length” of a screw depends on the thickness of the cortex, and cortices become thinner with age, bicortical screw anchorage is mandatory in osteoporotic fracture treatment.

- **Long-spanning plates**: Long plates lead to a better stress distribution than short plates. They also avoid stress risers and fractures at the end of the implant.

- **No mix of principles**: The osteosynthesis should be planned and accomplished according to well-defined principles.

A mix of principles, like absolute and relative stability, should be avoided.

- **No compression and lag screws**: Fixation principles that aim for absolute stability do not work in osteoporotic bone because the deteriorated bone quality cannot withstand the forces exerted when applying these principles (Fig 24-4).

- **No mix of principles**: The osteosynthesis should be planned and accomplished according to well-defined principles. A mix of principles, like absolute and relative stability, should be avoided.

- **No compression and lag screws**: Fixation principles that aim for absolute stability do not work in osteoporotic bone because the deteriorated bone quality cannot withstand the forces exerted when applying these principles (Fig 24-3). When bicortical screw fixation is not possible, a longer plate with unicortical screws and cerclage wires may be required.

- **Long-spanning plates**: Long plates lead to a better stress distribution than short plates. They also avoid stress risers and fractures at the ends of the implant. Fig 24-4 demonstrates the use of a long-spanning plate to fix a periprosthetic fracture.
6.6 Fracture reduction
Fracture reduction may be among the most critical points in fragility fracture fixation:
- “Functional” reduction should be the goal, ie, restoration of the axis of the bone.
- Shortening of metaphyseal sections may be acceptable in some cases.
- The usual reduction tools may cause additional damage to the bone, ie, the collinear clamp.
- Reduction with the help of plates.
- In simple fracture types, like transverse or oblique fractures with two fragments, only the fracture gap should be reduced as much as possible, as for fixations with relative stability.

6.7 MIPO in fragility fractures
Selected indications exist for MIPO. When deciding on the procedure and approach, it is necessary to ask which procedure will serve the patient’s needs best. Considerations include soft-tissue trauma (existing and iatrogenic), operative time, expected blood loss, wound-healing issues, intraoperative-positioning needs, and anesthetic considerations.

Open procedures are not necessarily worse. In many cases, an open procedure will meet the patient’s needs adequately and thus should be used. Ankle and distal radial fractures are well served with open approaches.

6.7.1 Indications and contraindications
Indications and contraindications for MIPO are similar to indications in “normal” fractures. Special indications and contraindications apply to the elderly patient. Skin problems, such as chronic venous stasis changes or ulcerations, may preclude plating in some patients.

Intramedullary fixation options are frequently the best option and are also minimally invasive. The nailing option can be minimally invasive for the tibial diaphysis, femoral diaphysis, and humeral diaphysis, and represents an excellent alternative in many cases. Usually, if an intramedullary implant is a good option for a fracture, it should be used. The locked intramedullary nail is a better choice when it is biomechanically superior and technically feasible. The new angular stable locking system extends nailing indications specifically in osteoporotic bone.

There are limited indications for external fixation and percutaneous pinning in the elderly. In some instances, such as severely comminuted metaphyseal (radial and proximal humeral) fractures, it can be considered as an alternative. Overall this option is not well tolerated by the elderly—particularly if they suffer from delirium or dementia.

Some cases that could be considered for MIPO technique are listed (not comprehensive):
- In many cases distal femoral fractures can be well served with a MIPO approach. The incision and soft-tissue trauma is reduced with acceptable fracture reduction and functional outcomes.
- Selected periprosthetic fractures can be considered for MIPO techniques. These are covered in more detail below.
- Compression hip pinning: Placement of a sliding-hscrew can be accomplished in several cases with MIPO techniques. As with open surgery, choice of the correct implant for the specific fracture pattern is vital. The fracture reduction must be correctly performed with indirect techniques, and proper lag screw or helical blade placement is essential for a good outcome.
- Selected humeral fractures: Humeral fractures may involve placement of the implant proximate to a major nerve. When considering MIPO approach, a limited exposure and protection of the radial nerve is necessary to avoid iatrogenic injury (Fig 24-5).
- Proximal tibia: The proximal tibial fracture can be properly managed with limited exposures or MIPO approaches. Indirect reduction techniques are necessary so that fracture reduction is correctly achieved. Image intensifier guidance is helpful for screw placement and crucial for visualization of the joint and reduction. With MIPO techniques one must also be careful to avoid iatrogenic injury to the common and superficial peroneal nerves.
- The distal tibial fracture is one fracture where MIPO approach should be strongly considered. The limited incision is highly beneficial at this location. Careful preoperative planning is valuable here and accurate plate positioning will often allow for a good reduction.
6.8 MIPO in periprosthetic fractures

In most cases when plate fixation is indicated to fix periprosthetic fractures, MIPO approaches should be considered. Periprosthetic distal femoral fractures have been treated for a long time with MIPO less invasive stabilization system distal femur (LISS-DF), locking compression plate distal femur (LCP-DF), or distal femur plate (DFP). This history of successful use of MIPO techniques with periprosthetic fractures has been accomplished using the LISS plate system. Published results indicate that this is a safe and useful technique [67, 68].

6.8.1 Prerequisites

The prosthetic implant needs to be secure. This is frequently an issue with the proximal femoral periprosthetic fracture. Fixation of the fracture with a loose stem has been shown to have a higher failure rate. To make this determination, if necessary, a limited exposure of the stem could be performed. Ideally, this is decided before surgery, for example, by comparing with older x-rays.

The fracture needs to be reducible by closed means. A critical element for successful treatment of the periprosthetic fracture is fracture reduction. If the fracture cannot be reduced by closed means, a limited exposure is preferred and necessary. The essential feature for success is a good reduction.

6.8.2 Technical considerations

In most cases bridge plating is the appropriate technique to use. It may be helpful to use a reversed distal femoral plate of the opposite side (Fig 24-6). This implant often lets screws pass posteriorly to the prosthesis. Sometimes the use of non-locked screws is advantageous, thus enabling choosing the direction of screws.

The following specific implants are at the surgeon’s disposal:

- Monocortical LHSs: Usually these short screws do not provide reliable fixation in only one cortex. They work best if they may be anchored in the cement mantle of the prosthetic stem.
- Special cerclage and cable systems with the option to fix these implants to the plate: If bicortical proximal screw fixation is not possible, consideration should be given to placement of one or more cerclage cables to supplement fixation. These can be placed with no muscle stripping and this should be planned into the surgical approach.
- Locking attachment plate: This is a versatile and indispensable implant. To safely implant the locking attachment plate, a limited surgical approach is required.
Fig 24-6a–l  An 89-year-old woman with a pertrochanteric/subtrochanteric fracture of her right femur and a cemented long-stem knee arthroplasty on the same side.

a–b  Fixation with a reversed left distal femoral plate to overlap the stem.

c  Periprosthetic screws were anchored in the cement mantle. Note the wide tube and thin cortex of the femur.

d–e  Two months later another fall with periprosthetic fracture around the stem and loosening of the plate distally. All short screws and the most distal long screw were removed.

f  Reduction and adaptation of the plate with the collinear clamp.

g–h  Periprosthetic fixation with two locking attachment plates, one nonlocked slightly oblique cortex screw anchored in the cement and a conventional cerclage.

i–l  Follow-up 14 months later.
Damaging vessels should be avoided as they are much more fragile in the elderly than in younger patients. When placing the plate, screws, or cables, the vascular anatomy must be considered. The distal profunda femoris artery is particularly at risk when drilling screw holes in the distal femur. The perforating branches of the profunda femoris artery is also at risk when exposing and plating the femur. Injury can be avoided in most cases with protective drill sleeves and meticulous technique.

Collateral flow if the main vessels are occluded: In elderly patients, the superficial femoral artery may be occluded with arterial plaques. Thus the limb is perfused with collateral blood flow from the profunda femoris artery which then reconstitutes the vascular tree below the knee. This makes MIPO approaches desirable but highlights the need to avoid collateral vascular injury.

6.9 Augmentation

In most instances, augmentation is not necessary because acceptable fixation can be achieved with implants alone. There is no standardized way of using augmentation with MIPO, or for that matter, in open surgery. The augmentation techniques are currently being developed.

The augmentation material increases the surface area between implant and bone, thus providing a better purchase. In biomechanical investigations at the AO Research Institute, a highly significant increase of cycles until failure could be demonstrated with small amounts of polymethylmethacrylate (PMMA) cement only (2–3 cc) ([Fig 24-7] and [Fig 24-8]) [69, 70].

6.9.1 Void filling

Void filling is well known and accepted for vertebroplasty/kyphoplasty. Cements, particularly the biological cements, offer an opportunity to fill metaphyseal bone voids below an articular fracture. These voids should be filled only after fracture reduction and fixation has been accomplished. The void filler should offer strong compressive strength and should be kept at least 6 mm away from subchondral bone to reduce risks of cartilage injury or intraarticular extrusion. Before using cement, other options like autogenous or allogeneous bone grafting should be considered.

6.9.2 Implant augmentation

Standardized applications are currently under evaluation mainly for fixation of the proximal femur. At the distal femur, if there is little cancellous bone and drilling for LHSs shows no resistance, cement injection may be considered ([Fig 24-7] and [Fig 24-8]). There is no clinical tool yet on the market to determine the need for augmentation (although at the time of publication one has been developed by the AO Foundation). Failure to achieve stable fixation with screws or blades would then prompt the surgeon to consider augmentation. Polymethylmethacrylate cement as well as biological alternatives are available presently but there is no well-accepted clinically validated technique.

6.9.3 Prophylactic augmentation

Again, in spine surgery, prophylactic augmentation of unaffected vertebral bodies adjacent to broken ones is well accepted to prevent future vertebral collapse. In other areas of the musculoskeletal system prophylactic augmentation is not presently used. It may become an option to lower the risk of secondary hip fractures on the opposite side while fixing a broken proximal femur.
A 101-year-old woman with a pertrochanteric fracture of the left proximal femur and an undisplaced three-part fracture of the left proximal humerus.

**a–d** Three years before her injuries she sustained a pertrochanteric fracture on the right side which was fixed with PFNA.

**e–f** Closed reduction with traction table, fixation with PFNA, positioning and locking of the perforated blade, and augmentation with PMMA cement.

**g–j** Postoperative x-ray and CT scan after immediate mobilization. The patient was unable to use her right arm due to the humeral fracture. She performed full weight bearing from day 1 and did not complain about pain.

**k–l** Follow-up after 3 months shows some subsidence of the head-neck fragment without change of the implant position in the femoral head.
7 Outcome of treatment of fragility fractures

7.1 Bone healing
Early and complete healing via secondary bone healing: As people age, their fracture healing ability diminishes. There is a diminished regenerative capacity of the bone [71]. Fractures in the elderly primarily heal with endochondral fracture healing with callus. Fracture healing is believed to require the migration of mesenchymal stem cells into the fracture callus. The number of stem cells is reduced in the elderly patient. The periosteum itself is less responsive with aging. There also seems to be a decreased rate of new bone formation, prolonged cartilage phase of healing and slower remodeling [71].

Largely because of osteoporosis, the aging adult must rely on endochondral fracture healing rather than intramembranous fracture healing. In most cases the aged bone cannot participate in compression fixation.

7.2 Mortality
It is difficult to compare results due to different outcome variables and inclusion criteria, such as type of fracture, age, gender, exclusion of pathological fractures, and cognitively impaired patients, follow-up intervals, methodical features, and differences in the social systems. Furthermore, most studies concentrate on hip fractures with only a few publications investigating other typical geriatric fractures concerning outcome and mortality.

Giversen [72] reported a constant cumulative mortality of 26.5% at 1 year and 36.2% at 2 years after fracture in his register-based study of 2,674 first hip fractures over a 10-year period. Despite significantly advanced age at admission during that time, no changing time trend of mortality was observed, nor was mortality influenced by the type of proximal femoral fracture.

Recently, in a long-term observational study of fracture patients, Blinc et al [73] reported an increased mortality risk for all low-trauma fractures for 5–10 years in a sample of older men and women. A subsequent osteoporotic fracture was associated with an increased mortality risk for another 5 years.

Briefly, in the literature mortality rates range from 12 to 35% in the first year after a hip fracture, but the cause for these findings still remains unclear. Mortality from hip fracture is higher in men than in women and increases with age, the number of comorbidities, low prefracture functional status, and also low BMD is reported to be a risk factor [74, 75].
### 7.3 Functional outcomes

Most publications concerning functional outcome and quality of life focus on hip fractures and there is little evidence concerning the effect of other fragility fractures on functional abilities of geriatric fracture patients. Einsiedel et al [76] investigated the outcome of geriatric distal radial fractures and proximal humeral fractures, each with 52 cases, after a 4-month period. They found no significant changes in the ability of daily living management according to the Instrumental Activities of Daily Living score by Lawton and Brody, even though 6% of patients with distal radial fractures and 17% with proximal humeral fractures had to give up their own housekeeping. Interestingly, both groups showed a high incidence of fear of falling and a significant decline in the ability to walk after the incident.

In summary, geriatric fractures and, in particular hip fractures, constitute a major source of disability and diminished quality of life for the elderly. Age, gender, comorbid conditions, prefracture functional abilities, and fracture type have an impact on the outcome regarding ambulation, daily activities, and quality of life [20]. Of course, the quality of the surgical management and the fracture type and dislocation are also significant on patients’ outcomes [77].

### 8 References


