REVIEW ARTICLE

Patient-specific risk factors for adverse outcomes following geriatric proximal femur fractures

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Abstract

Background Proximal femur fractures (PFFs) occur frequently among geriatric patients due to diverse risk factors, such as a lower bone mineral density and the increased risk of falls.

Methods In this review, we focus on recent literature of patient-specific risk factors and their impact on common complications and outcome parameters in patients with PFF.

Results Patient- and treatment related factors have a significant impact on outcome and are associated with an increased risk of mortality, impairments in functional rehabilitation and complicative courses.

Conclusion Geriatric patients at high risk for complications are nursing home inhabitants suffering from severe osteoporosis, dementia and sarcopenia. The early and ongoing assessment for these individual risk factors is crucial. Strategies including interdisciplinary approaches, addressing comorbidities and facilitating an optimal risk factor evaluation result in a beneficial outcome. The ongoing ambulant assessment and therapy of complicating factors (e.g., malnutrition, sarcopenia, frailty or osteoporosis) have to be improved.

keywords Geriatric trauma · Proximal femur fracture · Risk factors · Complications

Introduction

Proximal femur fractures are common injuries in elderly patients. Based on the anatomic classification, PFFs are subdivided into fractures of the femoral head, the femoral neck, and intertrochanteric or subtrochanteric fractures. For the specific fracture region, several suitable surgical treatment options are described and include arthroplasty and external or internal fixation (such as intramedullary nailing or sliding hip screws). The optimal surgical strategy has been reviewed extensively elsewhere and is determined based on international guidelines [1, 2]. In addition to the fracture patterns, this strategy also has to consider the patients’ comorbidities, prognosis and potential risk factors.

The etiology of PFF differs between younger patients, who usually suffer high-impact injuries, and older patients, who usually have lower bone mineral density and suffer low-impact injuries such as falls from standing height [3]. The vast majority of cases are seen in elderly patients, which is also reflected by an age-dependent increase in the annual incidence of PFFs. White et al. examined a British population and found that the majority of cases occur in the age group of 85–89 years, with an annual age-related incidence of 2237 per 100,000 inhabitants [4]. Taking the increasing life expectancy into account, the total number of PFFs is estimated to increase tremendously within the next decades. In 1992, Cooper et al. predicted a total global number of hip fractures of 3.94 million in 2025 and 6.26 million in 2050 [5]. More recent studies come to similar results, with a predicted increase of total numbers by 36.7% until 2031 [4].

In addition to the individual consequences, this development also brings a relevant socioeconomic burden to the health care systems caused by the direct costs of hospitalization, surgery and rehabilitation. Additional costs result from impaired functional recovery and decreased mobility, which can lead to the need for long-term care [6].

In addition to the enhanced total number of PFFs in the aging population, an associated increase in patients with significant comorbidities is expected, thus complicating the peri- and postoperative treatment of geriatric patients.

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More than 95% of all patients with PFF present with at least one comorbidity, while the majority of patients have two or three comorbidities. Despite hypertension as the most common comorbidity, anemia, fluid and electrolyte disorders and chronic pulmonary diseases are seen in over 20% of all patients presenting with PFF [7]. Furthermore, distinct comorbidities are known to negatively affect 30-day mortality after PFF, including dementia, cardiac disease, chronic obstructive pulmonary disease (COPD) and renal dysfunction [8]. This becomes even more relevant when looking at the overall outcomes of the large group of patients with PFF. Up to 7% of these patients are affected by early death within 30 days after the fracture [9], and 20–28% face death within the first year after the injury [10]. In addition to the high mortality rates, it must be considered that a high percentage of patients suffering from PFF are not able to continue their lives as independently as before the trauma, leading to serious changes within daily life for the majority of the injured patients once the acute phase passes. This is reflected by a significantly reduced quality of life (QOL) after a PFF [10]. One key factor influencing QOL in geriatric patients is the living situation. In this context, approximately one out of six patients who live at a home-dwelling location before the fracture need to permanently move to a nursing home, resulting in a significantly reduced QOL [11, 12].

The main factors leading to fractures in elderly individuals are the elevated risk of falling and the increased incidence of osteoporosis [13]. Therefore, preventative measures focused on these risk factors should be optimized to make the best use of their potential. In addition to treatment options for osteoporosis, strategies to reduce the risk of falls are therefore of utmost importance. The increasing fall risk of patients over the age of 65 years is of multifactorial genesis. Reduced physical resources, declining cognitive capacities, sensorimotor and sight disorders combined with an environment unsuitable to elderly individuals result in the prevalence of annual falls ranging from 28 to 35% among individuals aged 65 and above [14]. Various assessments are available for identifying individuals at risk of falling. These tools focus on their current living situation. Tests for hospitalized patients differ from tests predicting the hazard of patients in a community-dwelling setting [14]. Approaches to reduce falls in geriatric patients were analyzed in a meta-analysis including 159 trials [15]. A significant reduction in the risk of fall and fall-related fractures was achieved by using multiple component groups or home-based exercise, including balance and functional training, strength training, 3D training (such as Tai Chi) or general physical activity. Especially in patients with sight disorders and a higher risk of falls, home safety assessments were sufficient to reduce the rate of falls [15]. Furthermore, programs including these strategies were shown to have the potential to reduce the resulting costs for the health care system [16].

Despite the necessary efforts to prevent PFF, the total number of PFF in elderly individuals is nevertheless predicted to increase. Thus, the importance of adequate management of geriatric patients will further increase within the coming decades. The assessment of risk factors leading toward a compromised clinical outcome is, therefore, essential to reduce mortality and morbidity by optimized treatment concepts.

**Risk factors**

**Frailty**

Frailty, defined as the reduced physiologic capacity of geriatric patients to react to an acute stressor affecting several organ systems, is a major risk factor for both the occurrence of PFF and a complicated clinical course after PFF. Therefore, the presence of frailty should be assessed in every geriatric patient [17–19]. The individual nature of frailty makes the diagnosis difficult and is one reason for the lack of an international unified classification. Recent methods to identify frailty are often only reliable in a specific setting, such as primary care, hospital care, or long-term care [19]. Here, we concentrate on studies including patients suffering an acute fracture.

The clinical frailty scale (CFS) is a baseline category grading system that classifies patients over the age of 65, ranging from very fit to severely frail [20], focusing on the clinical impression and the need for help in daily life before the acute injury. Although potentially biased by the examining clinician [21], it can be assessed easily and rapidly. When classified in a higher category of frailty, the patient’s mortality rate is significantly increased following PFF [22–25]. Low et al. found that a higher CFS category is associated with poorer recovery of mobility, lower functional recovery and lower return rates to a community-dwelling setting [26].

In contrast to the clinical assessment by the CFS, the modified frailty index (mFI) concentrates on 19 preexisting deficits, e.g., impaired cognition, history of falls or syncope, thyroid disease, depression or renal diseases [27]. When patients with PFF present with an mFI of 4 or greater, the odds ratio for 1-year mortality is 4.97, as described by Patel et al. [27]. This correlation of the mFI with mortality after PFF has been confirmed by others [28, 29]. Inoue et al. also demonstrated a correlation of an elevated mFI with the occurrence of postoperative complications such as delirium, deep thrombophlebitis, pneumonia, urinary tract infection and pressure sores, lower rates of functional recovery and the new need for institutional care taking [30]. In addition to the CFS and the mFI, an additional way of initially assessing frailty is the usage of simple scores, such as the Identification of Seniors at Risk (ISAR) score [31], which was designed in
the setting of an emergency department and offers the opportunity to detect endangered patients at an early stage. Other less frequently used diagnostic frailty instruments describe additional correlations between a higher level of frailty and fracture-associated mortality, complications, reduced activity of the daily life (ADL), longer hospital stay, and a reduced QOL [17, 32–36]. Thus, independent from the method used to assess the level of frailty, the majority of the reviewed studies describe frailty as an independent risk factor for post-fracture mortality and an adverse outcome.

However, despite the relevance of frailty, the therapeutic options are limited. The main aspects of the management of frailty include slowing the progression of physical frailty, optimizing the management of comorbidities, improving the remaining organ function and their medication, strengthening intrinsic capacities such as vision and hearing, assessing psychosocial resources, individually discussing possible outcomes and the patient’s will, and reducing the risk of falls [19]. These interdisciplinary strategies are already implemented in modern approaches to orthopedic care in the perioperative setting for patients with PFF and include regular interdisciplinary consultation and revision of patient-specific factors in a geriatric trauma section.

### Living situation

The living situation before the fracture has an impact on the prevalence of PFF and the patient’s outcome. Patients with the need for care have a higher risk of developing a PFF than patients who are independent in a community-dwelling living situation. Patients with a need for care (home dwelling or at nursing homes) account for up to 50% of patients with PFF [37–39]. Furthermore, the hazard ratio for mortality of patients who were living in nursing homes before the injury is 1.8 compared to patients not living in such an institution [40]. The prefracture resident status also affects the functional recovery within the first year. Thus, institutionalized patients showed lower improvements in their functional and cognitive tests at the 12-month follow-up [41].

### Comorbidities

#### Osteoporosis

Osteoporosis is one of the main factors for the increasing incidence of PFF in geriatric patients and is defined as reduced bone mass with an impaired microstructure [42]. The diagnosis is made by assessing the bone mineral density by dual energy X-ray absorptiometry (DXA) or quantitative computed tomography (QCT). New approaches include bone turnover markers to evaluate the therapeutic response [43] or genetic analysis [44]. Among elderly individuals, osteoporosis is particularly prevalent in postmenopausal women, mainly due to estrogen deficiency [45]. However, long-term corticoid treatment and systemic diseases affecting bone formation and turnover (such as diabetes, chronic kidney diseases, multiple myeloma, primary hyperparathyroidism or immobilization) are also relevant factors leading to osteoporosis [46].

The prevalence of concomitant osteoporosis in patients with PFF varies in the recent literature but can reach 74.9% [47], making the PFF an indicator for manifest osteoporosis. Therefore, when patients are admitted with a PFF, screening for osteoporosis in the perioperative setting should become a standard procedure, as it can greatly improve the rate of diagnosed osteoporosis [48]. The presence of osteoporosis must also be considered when deciding between fracture stabilization or arthroplasty, as demonstrated by Kim et al., who reported an elevated rate of osteosynthesis failure in patients with unstable fractures and osteoporosis who were treated with a dynamic hip screw [49].

It is well known that the diagnosis of osteoporosis is associated with diverse complications after PFF. In this context, an increased fracture-associated mortality has been described [50], which was shown to be attenuated after the prescription of an anti-osteoporotic therapy [51–53]. Furthermore, a significantly enhanced risk for a secondary fracture after a previously undergone osteoporotic fracture as well as a reduction in both hip functional scores and QOL has been reported in cases of osteoporosis and the absence of adequate treatment [54]. Despite these beneficial effects, adherence to anti-osteoporotic therapy decreases in the postoperative phase [55, 56]. Therefore, patients should undergo ongoing screening for their anti-osteoporotic therapy at every follow-up examination.

The basic anti-osteoporotic treatment consists mainly of two groups of drugs, bisphosphonates and vitamin D plus calcium, which can be complemented or exchanged by denosumab, parathyroid hormone and parathyroid hormone-related protein analogs, selective estrogen receptor modulators, menopausal hormone therapy and tibolone or calcitonin, depending on the patients’ characteristics [57]. Many studies highlight the preventive effects of anti-osteoporotic drugs on fracture risk in postmenopausal women [58], while recent studies also describe beneficial effects of bisphosphonates and vitamin D and calcium in men with osteoporosis [59].

Bisphosphonates belong to a group of antiresorptive drugs that reduce the activity of osteoclasts and the associated remodeling rate, thereby inducing secondary mineralization of the bone and increasing bone mineral density [60]. Adverse events from bisphosphonate usage include the risk of atypical femur fractures, which is particularly present in cases of an intake of this type of medication for longer than 5 years. However, the benefits of bisphosphonates in the prevention of osteoporotic fractures greatly outweigh the risk of
rates of readmissions to hospital compared to patients with recovery of mobility to a prefracture level and increased ing back in their community-dwelling homes, an impaired significantly associated with a diminished rate of patients return-

with adverse outcomes in geriatric patients with PFF. Distinct neurologic diseases are known to patients with PFF. Aside from the general reduction in cognitive capacities, Cognitive disorders

calcium with or without vitamin D can increase the risk of beneficial in other subpopulations. These considerations recommendation for postmenopausal women is also population of patients benefiting from therapy with calcium

and vitamin D. It has to be assessed whether the standard treatment of osteoporosis and the associated effect on the fracture risk are not that clear for all subgroups of patients. Beneficial effects were described by Tang et al. in a meta-

analysis, reporting a reduced overall fracture risk by 12% and a reduced hip bone loss of 0.54% in patients over 50 years of age using more than 1200 mg calcium plus 800 international units (IE) of vitamin D per day [63]. The reduced risk for PFF was confirmed by other studies that reported a 16% decrease in the risk of PFF in patients with a combined daily intake compared to patients with no therapy or placebo. This significant reduction was not seen in patients using mono-

therapy with vitamin D or calcium alone [64, 65]. However, the reduced risk for PFF by the aforementioned combined therapy was not confirmed in a specific sub-analysis of the high-risk group of community-dwelling geriatric patients [66], consistent with findings of other trials describing benefits, especially in institutionalized elderly individuals [67].

More studies are needed to investigate the optimal sub-

population of patients benefiting from therapy with calcium and vitamin D. It has to be assessed whether the standard recommendation for postmenopausal women [67] is also beneficial in other subpopulations. These considerations should also respect the possible side effects, as the intake of calcium with or without vitamin D can increase the risk of both cardiovascular insults [68] and lithiasis [64].

Cognitive disorders

Aside from the general reduction in cognitive capacities, mental disorders complicate the treatment of geriatric patients with PFF. Distinct neurologic diseases are known to increase the risk of refracturing after PFF [50]. In particular, dementia and delirium have been described to be associated with adverse outcomes in geriatric patients with PFF.

A preexisting dementia in patients with a PFF is signifi-
cantly associated with a diminished rate of patients return-

ing back in their community-dwelling homes, an impaired recovery of mobility to a prefracture level and increased rates of readmissions to hospital compared to patients with no known history of dementia [26, 69–71]. A diagnosed dementia was also identified as an independent risk factor for 6-month mortality following PFF [72]. Thus, special consider-

ations must be taken to improve the situation of hospital-

ized patients with dementia.

Regarding the treatment of demented subpopulations with PFF, there is low-quality evidence of a benefit for patients treated in an interdisciplinary manner in a geriatric ward

[73]. However, high-quality trials that address the treatment of the growing population of these patients are missing. The current general concepts mainly focus on educational train-

ing for caregivers [74], while these strategies must be con-

tinuously analyzed and adapted with respect to the predicted increasing incidences within the coming decades. In particular, since patients with dementia are prone to developing complicative delirium, an optimized treatment of dementia has the potential to reduce rates of delirium as well [75–77].

Delirium is defined as acute and fluctuant disturbance in attention and awareness [78] and is common in geriat-

ric patients who suffer an acute injury. The incidence of postoperative delirium in patients with PFF ranges from 17 to up to 50% [79, 80]. In these patients, delirium is a serious risk factor for an adverse outcome. Its development correlated with an impaired recovery of mobility, reduced functional recovery [26], discharge into a nursing home and an increased one-year mortality [77]. Moreover, the early detection of delirium is challenging, particularly in patients with mental disorders. Therefore, a rough initial assessment can be performed by short and easy assessment tools such as the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) score [81].

While the underlying treatment options are limited, efforts to prevent and recognize delirium early are key factors when treating geriatric patients. The recognition of potentially treatable triggers is crucial and should be routinely realized. These triggers include sepsis, hypoglycemia, stroke, liver failure, dehydration, pain, psychological stress, overdosed delirogenic drugs or day–night disorientation [82]. Measurements addressing these triggers, including reorientation, assisted and monitored fluid intake, aided sitting and walking, optimized pain management, medication and reduced opioid use, have been shown to effectively reduce the risk of delirium. These promising strategies might help to reduce the incidence of delirium, a complication representing an additional psychological burden for patients, relatives and caregivers [78, 80].

Nutrition

Malnutrition is an additional independent risk factor for adverse postoperative outcomes in patients with PFF. Guimeiro et al. found an association between malnutrition assessed by the Mini Nutritional Assessment (MNA) and increased mortality after 6 months [83]. This association has been confirmed in other studies [84, 85]. Furthermore, malnutrition negatively affects the ADL, rates of postop-

erative complications, length of hospital stay, mobility, and readmission rates [17]. The reported prevalence of malnutrition in patients with PFF varied widely, mostly depending on the survey method used. Helminen et al. reported a prevalence of 7% for concomitant malnutrition
Sarcopenia

Sarcopenia is one of the independent, yet often underdiagnosed, comorbidities influencing the postoperative outcome. Several studies have demonstrated significant negative outcomes after PFF associated with sarcopenia, including reduced ADL and a reduced QOL [91, 92]. Moreover, a significant association between sarcopenia and increased mortality has been demonstrated in a systematic meta-analysis [93]. Kim et al. observed a significantly elevated 5-year mortality of 82.7% among patients with sarcopenia and PFF compared to 52.7% among patients without additive sarcopenia [94].

Data about the incidence of sarcopenia vary between 11 and 76.4% of the overall population with PFF [17], emphasizing the relevance of sarcopenia in this vulnerable population [95]. The syndrome itself is characterized by progressive deterioration of skeletal muscle mass and function. The widely accepted and 2018 revised criteria and cutoff values of the European Working Group on Sarcopenia in Older People (EWGSOP2) define sarcopenia by a reduced grip strength (male < 26 kg, female < 16 kg) and a reduced muscle mass (appendicular skeletal muscle mass divided by height in square; for male patients below 7 kg/m², for female patients below 5.5 kg/m²) [96]. To assess the general muscle mass, the usage of dual energy X-ray absorptiometry (DXA) represents the current gold standard. Alternatively, cross-sectional computed tomography (CT), magnetic resonance imaging (MRI) or bioelectrical impedance analysis (BIA) with adjustments for age, ethnicity, and hydration status can be performed [96]. By assessing physical performance (e.g., gait speed), sarcopenia can be further subdivided by its severity. Despite the known negative impact of sarcopenia on the clinical outcome, sarcopenia remains severely under-diagnosed and is rarely considered in the clinical routine [97]. A possible explanation for this might be that to date, there are no approved pharmacologic therapies for sarcopenia due to inadequate efficacy or severe side effects [97]. Once the diagnosis is made, the treatment is predominantly limited to an increase in physical activity [98]. The effect of nutritional supplementation, especially increased protein intake, is controversial [99]. However, some research groups endorse a multimodal approach of a combined nutritional intervention with rehabilitation exercise [100].

The multiple adverse short- and long-term outcomes emphasize the need for sufficient sarcopenia screening and early consistent treatment in the elderly population.

Selection of treatment

Additionally, international guidelines suggest an operation, in patients with a limited overall prognosis and severe comorbidities as well, to improve pain control and enable mobilization. Therefore, surgical treatment is performed in 95% of all patients with PFF. Hence, large comparative trials on nonsurgical treatment are lacking, leaving only retrospective approaches. A Dutch meta-analysis assessed 2615 patients with nonoperative treatment. In two-thirds of these cases, the surgery was denied due to unfit patients with low pretraumatic function; in the remaining cases, the surgery was denied due to nonmedical reasons (such as the patient or their relatives refusing surgical treatment). The outcome of conservatively treated patients was significantly worse with respect to overall mortality and recovery [101]. Thus, the decision for a conservative treatment should only be made in exceptional cases.

When focusing on the surgical therapy of PFF, patients’ comorbidities and overall status as well as fracture morphology are important factors for the choice of treatment option (e.g., arthroplasty or osteosynthesis). Aside from complications such as infections or osteosynthesis failure, various complications have been reported to occur due to technical mistakes, e.g., malalignment, malrotation or elongation of the femur. Potential operative complications have been extensively reviewed elsewhere and should be carefully considered when determining the optimal surgical strategy [1, 102, 103].

Time to surgery

A well-described and widely accepted risk factor highly affecting patient mortality and the overall outcome is the time from admission until surgical treatment. Most studies have described that a delay between injury and surgery
of 48 h is associated with an increased risk for an adverse outcome [9, 104–107]. A more rapid approach was analyzed by Fu et al., who described further benefits on mortality for patients receiving surgical treatment within 24 h after admission [108]. In addition to mortality, surgery within 24 h correlated with a reduced rate of wound infections compared to delayed surgery [109]. Interestingly, no additional significant differences in mortality or the development of major complications were found by a recent study comparing an even faster approach with surgery within six hours after admission compared to 24 h [110]. However, this study also included patients under the age of 65, while patients receiving their surgery within 48 h were not included [110, 111]. Taken together, more studies are needed to assess the optimal time point of operative treatment in general. Despite the mentioned considerations, special attention should be devoted to the individual’s comorbidities, as the beneficial effects of early surgery on outcomes are not consistent for all patients. In this context, some authors demand a preoperative optimization of comorbidities, as distinct disease patterns and the associated overall status of the patient can lead to increased mortality in patients undergoing early surgery [112]. It is of upmost importance to identify subpopulations that can benefit from delayed surgery, as the majority of trials describe a clear general advantage in the majority of patients undergoing early fracture stabilization [104, 113, 114].

Conclusion

The reduced physiologic capacities in elderly individuals lead to an increased risk of falling. Often, these low-impact falls result in PFF induced by osteoporosis and other comorbidities. Geriatric patients suffering a PFF are at high risk to have a complicate course. Patients at high risk for complications are nursing home inhabitants suffering from severe osteoporosis, dementia and sarcopenia. The early and ongoing assessment for these individual risk factors is crucial and should be a standard procedure in the care of geriatric patients. Various strategies have already been implemented, including interdisciplinary approaches, thus addressing comorbidities and facilitating an optimal risk factor evaluation and resulting in a beneficial outcome. It must also be emphasized that the ongoing ambulant assessment and therapy of many complicating factors (e.g., malnutrition, sarcopenia, frailty or osteoporosis) have to be improved, as the long-term adherence to therapeutic approaches is low.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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References

1. Bhandari M, Swiontkowski M. Management of acute hip fracture. N Engl J Med. 2017;377(21):2053–62.
2. Fischer H, et al. Management of proximal femur fractures in the elderly: current concepts and treatment options. Eur J Med Res. 2021;26(1):86.
3. Augat P, Bliven E, Hackl S. Biomechanics of femoral neck fractures and implications for fixation. J Orthop Trauma. 2019;33(Suppl 1):S27–32.
4. White SM, Griffiths R. Projected incidence of proximal femoral fracture in England: a report from the NHS Hip Fracture Anaesthesia Network (HIPFAN). Injury. 2011;42(11):1230–3.
5. Cooper C, Campion G, Melton LJ 3rd. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2(6):285–9.
6. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury. 2018;49(8):1458–60.
7. Nikkel LE, et al. Impact of comorbidities on hospitalization costs following hip fracture. J Bone Jt Surg Am. 2012;94(1):9–17.
8. Khan MA, et al. Predictors of early mortality after hip fracture surgery. Int Orthop. 2013;37(11):2119–24.
9. Pincus D, et al. Association between wait time and 30-day mortality in adults undergoing hip fracture surgery. JAMA. 2017;318(20):1994–2003.
10. Alexiou KI, et al. Quality of life and psychological consequences in elderly patients after a hip fracture: a review. Clin Interv Aging. 2018;13:143–50.
11. Olsen C, et al. Differences in quality of life in home-dwelling persons and nursing home residents with dementia—a cross-sectional study. BMC Geriatr. 2016;16:137.
12. Schoeneberg C, et al. Four-month outcome after proximal femur fractures and influence of early geriatric rehabilitation: data from the German Centres of Geriatric Trauma DGU. Arch Osteoporos. 2021;16(1):68.
13. Benzinger P, et al. The impact of preventive measures on the burden of femoral fractures - a modelling approach to estimating the impact of fall prevention exercises and oral bisphosphonate treatment for the years 2014 and 2025. BMC Geriatr. 2016;16:75.
14. Park SH. Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. Aging Clin Exp Res. 2018;30(1):1–16.
15. Gillespie LD, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012;9:CD007146.
16. Saunders H, et al. Cost-utility analysis of the Ontario fracture screening and prevention program. J Bone Jt Surg Am. 2021;103(13):1175–83.
17. Inoue T, et al. Undernutrition, sarcopenia, and frailty in fragility hip fracture: advanced strategies for improving clinical outcomes. Nutrients. 2020;12(12):3743.
18. Li G, et al. Frailty and risk of fractures in patients with type 2 diabetes. Diabetes Care. 2019;42(4):507–13.
19. Dent E, et al. Management of frailty: opportunities, challenges, and future directions. Lancet. 2019;394(10206):1376–86.
20. Rockwood K, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005;173(5):489–95.
21. Theou O, et al. A classification tree to assist with routine scoring of the Clinical Frailty Scale. Age Ageing. 2021;50(4):1406–11.
22. Narula S, et al. Clinical frailty scale is a good predictor of mortality after proximal femur fracture: a cohort study of 30-day and one-year mortality. Bone Jt Open. 2020;1(8):443–9.
23. Church S, et al. A scoping review of the Clinical Frailty Scale. BMC Geriatr. 2020;20(1):393.
24. Chen CL, et al. Frailty is associated with an increased risk of major adverse outcomes in elderly patients following surgical treatment of hip fracture. Sci Rep. 2019;9(1):19135.
25. Lu W, et al. Comparison of two frailty indexes in hip fractures. J Orthop Surg (Hong Kong). 2020;28(1):2309499020901891.
26. Low S, Wee E, Dorevitch M. Impact of place of residence, frailty and other factors on rehabilitation outcomes post hip fracture. Age Ageing. 2021;50(2):423–30.
27. Patel KV, et al. Association of a modified frailty index with mortality after femoral neck fracture in patients aged 60 years and older. Clin Orthop Relat Res. 2014;472(3):1010–7.
28. Krishnan M, et al. Predicting outcome after hip fracture: using a frailty index to integrate comprehensive geriatric assessment results. Age Ageing. 2014;43(1):122–6.
29. Pizzonia M, et al. Frailty assessment, hip fracture and long-term clinical outcomes in older adults. Eur J Clin Invest. 2021;51(4):e13445.
30. Inoue T, et al. Frailty defined by 19 items as a predictor of short-term functional recovery in patients with hip fracture. Injury. 2019;50(12):2272–6.
31. McCusker J, et al. Detection of older people at increased risk of adverse health outcomes after an emergency visit: the ISAR screening tool. J Am Geriatr Soc. 1999;47(10):1229–37.
32. Kistler EA, et al. Frailty and short-term outcomes in patients with hip fracture. Geriatr Orthop Surg Rehabil. 2015;6(3):209–14.
33. Gleason LJ, et al. FRAIL questionnaire screening tool and short-term outcomes in geriatric fracture patients. J Am Med Dir Assoc. 2017;18(12):1082–6.
34. Choi JY, et al. Prediction of mortality and postoperative complications using the hip-multidimensional frailty score in elderly patients with hip fracture. Sci Rep. 2017;7:42966.
35. Winters AM, et al. Relationship between clinical outcomes and Dutch frailty score among elderly patients who underwent surgery for hip fracture. Clin Interv Aging. 2018;13:2481–6.
36. Zhao H, Wei P, Feng Y. Association between frailty and clinical outcomes and quality of life in older adults following hip fracture surgery: a retrospective cohort study. Anesth Analg. 2021;10:1213.
37. Gamboa-Arango A, et al. Prognostic factors for discharge to home and residing at home 12 months after hip fracture: an Anoia hip study. Aging Clin Exp Res. 2020;32(5):925–33.
38. Finsterwald M, et al. Gender-specific hip fracture risk in community-dwelling and institutionalized seniors age 65 years and older. Osteoporos Int. 2014;25(1):167–76.
39. Rapp K, et al. Femoral fracture rates in people with and without disability. Age Ageing. 2012;41(5):653–8.
40. Harris IA, et al. A prospective study of the effect of nursing home residency on mortality following hip fracture. ANZ J Surg. 2010;80(6):447–50.
41. Balzer-Geldsetzer M, et al. Association between longitudinal clinical outcomes in patients with hip fracture and their pre-fracture place of residence. Psychogeriatrics. 2020;20(1):11–9.
42. Hui SL, Slemenda CW, Johnston CC Jr. Age and bone mass as predictors of fracture in a prospective study. J Clin Invest. 1988;81(6):1804–9.
43. Eastell R, Szulc P. Use of bone turnover markers in post-menopausal osteoporosis. Lancet Diabetes Endocrinol. 2017;5(11):908–23.
44. Nethander M, et al. BMD-related genetic risk scores predict site-specific fractures as well as trabecular and cortical bone microstructure. J Clin Endocrinol Metab. 2020;105(4):e1344–57.
45. Cheng CH, Chen LR, Chen KH. Osteoporosis due to hormone imbalance: an overview of the effects of estrogen deficiency and glucocorticoid overuse on bone turnover. Int J Mol Sci. 2022;23(3):1376.
46. Miller PD. Management of severe osteoporosis. Expert Opin Pharmacother. 2016;17(4):473–88.
47. Farouk O, et al. Osteoporosis among hospitalized patients with proximal femoral fractures in Assiut University Trauma Unit Egypt. Arch Osteop. 2017;12(1):12.
48. Roy A, Heckman MG, O’Connor MI. Optimizing screening for osteoporosis in patients with fragility hip fracture. Clin Orthop Relat Res. 2011;469(7):1925–30.
49. Kim Wy, et al. Failure of intrtrochanteric fracture fixation with a dynamic hip screw in relation to pre-operative fracture stability and osteoporosis. Int Orthop. 2001;25(6):360–2.
50. Pantho S, et al. Predictors of mortality and fracture in patients older than 65 years with a proximal femur fracture. J Clin Rheumatol. 2022;28(1):e49–55.
51. Nurmi-Luthje I, et al. Post-fracture use of prescribed calcium plus vitamin D or vitamin D supplements and antosteoporotic drugs is associated with lower mortality: a nationwide study in Finland. J Bone Miner Res. 2011;26(8):1845–53.
52. Brozek W, et al. Antiresorptive therapy and risk of mortality and fracture in osteoporosis-related hip fracture: a nationwide study. Osteoporos Int. 2016;27(1):387–96.
53. Dobre R, et al. Adherence to anti-osteoporotic treatment and clinical implications after hip fracture: a systematic review. J Pers Med. 2021;11(5):341.
54. Makridis KG, et al. The effect of osteoporotic treatment on the functional outcome, re-fracture rate, quality of life and mortality in patients with hip fractures: a prospective functional and clinical outcome study on 520 patients. Injury. 2015;46(2):378–83.
55. Radvenda V, et al. Low incidence of anti-osteoporosis treatment after hip fracture. J Bone Jt Surg Am. 2008;90(10):2142–8.
56. Kanis JA, et al. A meta-analysis of previous fracture and subsequent fracture risk. Bone. 2004;35(2):375–82.
57. Eastell R, et al. Pharmacological management of osteoporosis in postmenopausal women: an endocrine society* clinical practice guideline. J Clin Endocrinol Metab. 2019;104(5):1595–622.
58. Barriomuevo P, et al. Efficacy of pharmacological therapies for the prevention of fractures in postmenopausal women: a network meta-analysis. J Clin Endocrinol Metab. 2019;104(5):1623–30.
59. Vescini F, et al. Management of osteoporosis in men: a narrative review. Int J Mol Sci. 2021;22(24):13640.
60. Compston JE, McClung MR, Leslie WD. Osteoporosis. Lancet. 2019;393(10169):364–76.
61. Black DM, et al. Atypical femur fracture risk versus fragility fracture prevention with bisphosphonates. N Engl J Med. 2020;383(8):743–53.
Masud T, McClung M, Geusens P. Reducing hip fracture risk with risedronate in elderly women with established osteoporosis. Clin Interv Aging. 2009;4:445–9.

Tang BM, et al. Use of calcium or calcium in combination with vitamin D supplementation to prevent fractures and bone loss in people aged 50 years and older: a meta-analysis. Lancet. 2007;370(9588):657–66.

Jackson RD, et al. Calcium plus vitamin D supplementation and the risk of fractures. N Engl J Med. 2006;354(7):669–83.

Yao P, et al. Vitamin D and calcium for the prevention of fracture: a systematic review and meta-analysis. JAMA Netw Open. 2019;2(12):e1917789.

Zhao JG, et al. Association between calcium or vitamin D supplementation and fracture incidence in community-dwelling older adults: a systematic review and meta-analysis. JAMA. 2017;318(24):2466–82.

Black DM, Rosen CJ. Clinical practice. Postmenopausal osteoporosis. N Engl J Med. 2016;374(3):254–62.

Bolland MJ, et al. Calcium supplements with or without vitamin D and risk of cardiovascular events: reanalysis of the Women’s Health Initiative limited access dataset and meta-analysis. BMJ. 2011;342:d2040.

Yoshii I, et al. Relationship between dementia degree and gait ability after surgery of proximal femoral fracture: review from Clinical pathway with regional alliance data of rural region in Japan. J Orthop Sci. 2016;21(4):481–6.

Harboun M, et al. Impact of hip fracture, heart failure and weight loss on the risk of institutionalization of community-dwelling patients with dementia. Int J Geriatr Psychiatry. 2008;23(12):1245–52.

Kates SL, et al. Hospital readmission after hip fracture. Arch Orthop Trauma Surg. 2015;135(3):329–37.

Ha YC, et al. Effect of dementia on postoperative mortality in elderly patients with hip fracture. J Korean Med Sci. 2021;36(38):e238.

Smith TO, et al. Enhanced rehabilitation and care models for adults with dementia following hip fracture surgery. Cochrane Database Syst Rev. 2020;2:CD010569.

Karrer M, et al. A systematic review of interventions to improve acute hospital care for people with dementia. Geriatr Nurs. 2021;42(3):657–73.

Mosk CA, et al. Dementia and delirium, the outcomes in elderly hip fracture patients. Clin Interv Aging. 2017;12:421–30.

Lee HB, et al. Predisposing factors for postoperative delirium after hip fracture repair in individuals with and without dementia. J Am Geriatr Soc. 2011;59(12):2306–13.

de Jong L, et al. Delirium after hip hemiarthroplasty for proximal femoral fractures in elderly patients: risk factors and clinical outcomes. Clin Interv Aging. 2019;14:427–35.

Marcantonio ER. Delirium in hospitalized older adults. N Engl J Med. 2017;377(15):1456–66.

Wu J, et al. The risk factors for postoperative delirium in adult patients after hip fracture surgery: a systematic review and meta-analysis. Int J Geriatr Psychiatry. 2021;36(1):3–14.

Marcantonio ER. Postoperative delirium: a 76-year-old woman with delirium following surgery. JAMA. 2012;308(1):73–81.

Ely EW, et al. Delirium in mechanically ventilated patients: validity and reliability of the confusion assessment method for the intensive care unit (CAM-ICU). JAMA. 2001;286(21):2703–10.

Wilson JE, et al. Delirium. Nat Rev Dis Primers. 2020;6(1):90.

Gumieiro DN, et al. Mini nutritional assessment predicts gait status and mortality 6 months after hip fracture. Br J Nutr. 2013;109(9):1657–61.

van Wissen J, et al. Mini nutritional assessment and mortality after hip fracture surgery in the elderly. J Nutr Health Aging. 2016;20(9):964–8.

Zanetti M, et al. Poor nutritional status but not cognitive or functional impairment per se independently predict 1 year mortality in elderly patients with hip-fracture. Clin Nutr. 2019;38(4):1607–12.

Helminen H, et al. Comparison of the mini-nutritional assessment short and long form and serum albumin as prognostic indicators of hip fracture outcomes. Injury. 2017;48(4):903–8.

Inoue T, et al. Pre-fracture nutritional status is predictive of functional status at discharge during the acute phase with hip fracture patients: a multicenter prospective cohort study. Clin Nutr. 2017;36(5):1320–5.

Guigoz Y, Vellas B, Garry PJ. Assessing the nutritional status of the elderly: the mini nutritional assessment as part of the geriatric evaluation. Nutr Rev. 1996;54(1 Pt 2):S59-65.

Avenell A, et al. Nutritional supplementation for hip fracture aftercare in older people. Cochrane Database Syst Rev. 2016;11:CD001880.

Malafarina V, et al. Nutritional status and nutritional treatment are related to outcomes and mortality in older adults with hip fracture. Nutrients. 2018;10(5):555.

Landi F, et al. The association between sarcopenia and functional outcomes among older patients with hip fracture undergoing in-hospital rehabilitation. Osteoporos Int. 2017;28(5):1569–76.

Chen YP, et al. The high prevalence of sarcopenia and its associated outcomes following hip surgery in Taiwanese geriatric patients with a hip fracture. J Formos Med Assoc. 2020;119(12):1807–16.

Beaudart C, et al. Health outcomes of sarcopenia: a systematic review and meta-analysis. PLoS ONE. 2017;12(1):e0169548.

Kim YK, et al. Effect of sarcopenia on postoperative mortality in osteoporotic hip fracture patients. J Bone Metab. 2018;25(4):227–33.

Gonzalez-Montalvo JI, et al. Prevalence of sarcopenia in acute hip fracture patients and its influence on short-term clinical outcome. Geriatr Gerontol Int. 2016;16(9):1021–7.

Cruz-Jentoft AJ, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16–31.

Cruz-Jentoft AJ, Sayer AA. Sarcopenia. Lancet. 2019;393(10191):2636–46.

Dent E, et al. International clinical practice guidelines for sarcopenia (ICFSR): screening, diagnosis and management. J Nutr Health Aging. 2018;22(10):1148–61.

Woo EC, Rodis B. Sarcopenia in elderly surgery. Ann Acad Med Singap. 2019;48(11):363–9.

Martone AM, et al. Exercise and protein intake: a synergistic approach against sarcopenia. Biomed Res Int. 2017;2017:2672435.

Loggers SAI, et al. Prognosis of nonoperative treatment in elderly patients with a hip fracture: a systematic review and meta-analysis. Injury. 2020;51(11):2407–13.

Mavrogenis AF, et al. Complications after hip nailing for fractures in the elderly: a retrospective cohort study. Injury. 2016;47(10):2060–4.

Simunovic N, et al. Effect of early surgery after hip fracture on mortality and complications: systematic review and meta-analysis. CMAJ. 2010;182(15):1609–16.

Kristiansson J, Hagberg E, Nellgard B. The influence of time-to-surgery on mortality after a hip fracture. Acta Anaesthesiol Scand. 2020;64(3):347–53.

Sasabuchi Y, et al. Timing of surgery for hip fractures in the elderly: a retrospective cohort study. Injury. 2018;49(10):1848–54.

Neufeld ME, et al. Timing of hip fracture surgery and 30-day outcomes. Orthopedics. 2016;39(6):361–8.
108. Fu MC, et al. Surgery for a fracture of the hip within 24 hours of admission is independently associated with reduced short-term post-operative complications. Bone Jt J. 2017;99B(9):1216–22.
109. Cordero J, Maldonado A, Iborra S. Surgical delay as a risk factor for wound infection after a hip fracture. Injury. 2016;47(Suppl 3):S56–60.
110. Investigators HA. Accelerated surgery versus standard care in hip fracture (HIP ATTACK): an international, randomised, controlled trial. Lancet. 2020;395(10225):698–708.
111. Wenk M, Frey S. Elderly hip fracture patients: surgical timing and factors to consider. Curr Opin Anaesthesiol. 2021;34(1):33–9.
112. Yonezawa T, et al. Influence of the timing of surgery on mortality and activity of hip fracture in elderly patients. J Orthop Sci. 2009;14(5):566–73.
113. Swift C, et al. Interdisciplinary management of hip fracture. Clin Med (Lond). 2016;16(6):541–4.
114. Brox WT, et al. The American Academy of Orthopaedic Surgeons evidence-based guideline on management of hip fractures in the elderly. J Bone Jt Surg Am. 2015;97(14):1196–9.