Geriatric Hip Fractures

A Practical Approach

Nicholas C. Danford
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Chapter 1
Introduction: History of Geriatric Hip Fracture Treatment

Samir Sabharwal and Nicholas C. Danford

History of Geriatric Hip Fracture Treatment

The Early Years: Non-operative Treatment

In his 1936 address to the American Orthopaedic Association, William Arthur Clark said, "Because the mechanical factors in [hip] fractures were the same in the first century as they are in the twentieth century, the methods of treatment in ancient times are found to be similar, not only in principle but in practice, to those of our own day" [1]. Hippocrates applied traction to hip fractures in ancient Greece, and Ambroise Paré treated a hip fracture in sixteenth-century France with spica casting, both of which were practices not dissimilar from those of early twentieth-century America [1]. Treatment of hip fractures from Hippocrates to the early twentieth century was thus non-operative, with very rare exceptions. In addition to traction and spica casting, treatment included months of manipulative bandaging, weighted traction with the goal of maintaining the hip in extension, and binding of both feet together so that the foot of the uninjured limb helped maintain the injured hip in extension [2].

In 1954, the orthopaedic surgeon Charles Heck summarized these early treatments and recovery from hip fracture for elderly patients as "long periods of recumbency, bedsores, low morale, a high mortality rate and often an extremity unfit for satisfactory function" [2]. The difficulty and protracted treatment required to obtain

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acceptable functional outcomes in the case of displaced intracapsular hip fractures led Coales in 1845 to ask, “Shall we then attempt to produce a cure, or only assist nature in palliating the condition of the patient, for each aim will require a different treatment?” Coales continues: “Considering the age of the patients generally subject to this lesion, how much we should subject them to becomes a question of importance.” He concludes that “if the patient is old—over 60—it is true you may produce a bony union, but the chance is so small that it is unjustifiable to resort to the means necessary to effect it” [3]. Sir Astley Cooper, writing in nineteenth-century London, believed that bony union of intracapsular hip fractures was impossible to achieve [4].

These difficulties of treatment stem in part from underlying deficiency in bone quality and strength. Geriatric hip fractures typically arise from low-velocity falls, the impact of which is enough to fracture fragile bone. Cooper found that these fractures “most frequently occur when persons, walking on the edge of the elevated footpath, slip upon the carriage pavement,” propagating through bone characterized by “lightness and softness…though the descent be only a few inches” [5]. His observation prompted work in the physiology of what eventually was termed metabolic bone disease or osteoporosis. Harris and Heaney, over 100 years after Cooper, said that fractures “occur with increasing frequency in the elderly because of decreasing strength of the skeleton. This weakness is due largely to a reduction in skeletal mass caused by an imbalance between the formation and the resorption of bone” [6]. They were among the earliest physicians to describe the mechanisms of skeletal renewal, hormonal controls of bone resorption and formation, and optimization of bone mineral health, a topic discussed in detail in Chap. 11: Post-operative Bone Mineral Health Optimization in Geriatric Hip Fracture Patients.

The mid-twentieth century marked a change from mostly non-operative to mostly operative treatment of geriatric hip fractures. When Clark gave his American Orthopaedic Association address in 1936, he spoke at a transitional time. The “mechanical factors” of fractures indeed were constant throughout history, but in the ensuing years, the principles and practice of geriatric hip fracture management changed rapidly.

Moving Toward Modern Treatment: Early Operative Techniques

Although internal fixation for hip fracture was attempted as early as 1850, by Von Langenbeck, successful operative treatment eluded surgeons, most often due to lack of sufficient rotational control of fracture fragments or corrosion of the implant due to poor material selection [7]. The tides began to turn in 1931, with the development of Smith-Peterson’s four- and later three-flanged nail [7].

Almost 30 years later, in a 1960 survey of recent progress in the management of intra-capsular (femoral neck) fractures, Banks and Quigley said that “the treatment of femoral-neck fractures has continued to be a major problem although much progress has been made” [8]. In the case of “truly impacted” femoral neck fractures, which demonstrated evidence of healing without operative intervention, Banks and

Quigley stated a preference for "screw fixation even though the procedure may be largely prophylactic." Displaced neck fractures presented a greater challenge. While the results of internal fixation for displaced femoral neck fractures proved superior to spica casting, nonunion and aseptic necrosis still occurred "too often." Early replacement prostheses—such as those introduced by Judet and Moore—represented a potential salvage for those fractures that went on to nonunion and were beginning to see use in the settings of "irreducible fresh fractures" [8]. However, naysayers abounded—as Nicoll wrote in a 1963 editorial, "the best place for a prosthesis is still in the instrument cupboard, just as the best place for a viable femoral head is on the neck of the femur. So let us pause a little longer before embarking on a policy of wholesale decapitation" [9]. Primary prosthetic replacement for displaced, intracapsular geriatric hip fractures eventually gained traction after Charnley introduced his low-friction hip prosthesis, the predecessor for the implants used today.

While the main trouble with intracapsular fractures was one of obtaining bony union, the issue with extra-capsular (intertrochanteric fractures), as Hudson and Giliberty pointed out in 1957, was "a matter of residual varus deformity at the fracture site" [10]. They observed that varus deformity impaired function and the degree of dysfunction correlated to degree of deformity. With varying levels of success, Hudson and Giliberty used three methods of treatment in their series of intertrochanteric fractures: fixed-angle plate fixation, traction, and a technique called Bartel's osteoclasis in which the femoral shaft was medialized with respect to the intertrochanteric region in a closed manner, with the goal of preventing varus collapse [10].

One year later, in 1958, McKeever published a case series demonstrating the promise of intramedullary fixation for intertrochanteric fractures, highlighted by success in a 96-year-old woman who "regained rapidly the ability to walk without assistance" postoperatively [11]. He described the design for a fixed-angle cephalomedullary implant, a predecessor for the device used today. His design stood in contrast to a device proposed by Pugh that was similar to a dynamic hip screw (DHS). In this way, McKeever anticipated future failures of unstable intertrochanteric fractures fixed with a DHS: "Sliding is accompanied by a shearing action. The only device that will avoid all the biomechanical faults and permit rapid healing is a self-retaining total intramedullary fixation."

Hudson and Giliberty realized that while a more biomechanically suitable implant improves fracture alignment and promotes return to function, by itself it "is not sufficient to ensure a good end-result" [10]. Overton agreed, saying in his 1958 treatise "Fractures of the Hip in the Aged and Disabled" that "the most important first consideration in each elderly patient with a fracture of the hip is not the fracture but, rather, the patient as a whole. What is the general physical and mental condition of the patient? This must be determined and evaluated; then the complicating factors must be corrected in so far as possible prior to surgery if postoperative complications are to be avoided and the mortality reduced to the lowest reasonable percentage" [12]. With that prescient statement, Overton prefigured the large, forthcoming body of work in preoperative evaluation, risk stratification, and perioperative medical optimization of geriatric patients with hip fractures, which is discussed in Chap. 3: Peri-operative Medical Co-management of Patients with Geriatric Hip Fractures.

In summary, the middle of the twentieth century set the field of orthopaedic surgery on a path toward modern techniques that included in situ fixation for non-displaced intra-capsular fractures, arthroplasty for displaced intra-capsular fractures, and extra- or intramedullary-based screw fixation for extra-capsular hip fractures in geriatric patients. Fahey, Kilfoyle, and Shortell reported to the American College of Surgeons (ACS) in 1949:

> In sharp contrast to the attitude of a few years back, hip nailing in aged people suffering from various medical disabilities has become accepted surgical practice. Penicillin, carefully controlled anesthesia, the use of blood and standard physiologic fluids, refinements of surgical technic and early ambulation have permitted feats of major surgery previously believed impossible, especially in the aged. In the cases of hip fracture, traction or a plaster spica was used by choice under the impression that operation was too great a risk in this age group. This attitude is now reversed, and nailing is performed to avoid the many evils of prolonged bed rest and traction, to diminish the burdens on an already overtaxed nursing staff and, most important, to lower an appalling mortality rate [13].

In the eyes of the ACS in 1949, just a little more than a decade after Clark's 1936 address to the American Orthopaedic Association, orthopaedic surgeons and their treatment of geriatric hip fractures had evolved. The paradigm had shifted from mostly non-operative to mostly operative treatment of these injuries. Progress has since continued in improving those operative modalities presented in detail throughout this book.

References

1. Clark WA. History of fracture treatment up to the sixteenth century. JBJS. 1937;19(1):47–63.
2. Heck CV. Management of hip fracture in the geriatric patient. J Am Geriatr Soc [Internet]. 1955 Feb 1 [cited 2021 Jan 29];3(2):113–6. Available from: http://doi.wiley.com/10.1111/j.1532-5415.1955.tb00109.x
3. Dr. Coale's Prize Dissertation on Fractures. Bost Med Surg J [Internet]. 1845 Aug 27 [cited 2021 Feb 4];33(4):69–76. Available from: https://www.nejm.org/doi/full/10.1056/NEJM184508270330401
4. Cooper A. A treatise on dislocations and on fractures of the joints. London: Cox & Son; 1824.
5. A treatise on dislocations and on fractures of the joints: Cooper, Astley, Sir, 1768–1841: Free download, borrow, and streaming: Internet archive [Internet]. [cited 2021 Jan 29]. Available from: https://archive.org/details/treatiseondisloc00coop/page/110/mode/2up
6. Harris WH, Heaney RP. Skeletal renewal and metabolic bone disease. N Engl J Med. 1969;280(4):193–202.
7. Lowell JD. Fractures of the hip. N Engl J Med. 1966;274(25):1418–25.
8. Banks H, Quigley TB. Treatment of fractures and dislocations, 1950–1960. N Engl J Med. 1960;263(9):444–52.
9. Nicoll EA. The unsolved fracture. J Bone Joint Surg Br. 1963;45(2):239–41.
10. Hudson OC, Giliberty RP. Intertrochanteric fractures. Clin Orthop Relat Res. 1957;10:282–8.

11. McKeever DC. The intramedullary internal fixation of intertrochanteric fractures. Clin Orthop Relat Res. 1958;12:300–6.
12. Overton LM. Fractures of the hip in the aged and disabled: a study of the relation of pre-operative evaluation and preparation to morbidity and mortality. Clin Orthop Relat Res. 1958;11:51–5.
13. Fahey RJ, Kilfoyle RM, Shortell JH. Medical considerations in the care of elderly patients with hip fractures. N Engl J Med. 1949;241(9):325–30.

Chapter 2
Initial Workup, Diagnosis, and Fracture Classification for Geriatric Hip Fractures

Matthew M. Levitsky, Roshan P. Shah, and Alexander L. Neuwirth

Initial Workup and Diagnosis

History

Geriatric patients presenting to the emergency department (ED) with suspected hip fractures require a thorough history from the emergency room providers, orthopaedic surgeons, and internal medicine physicians. Elderly patients can be limited with regard to memory and cognitive ability. The estimated prevalence of dementia in elderly patients with hip fractures is approximately 19%, and cognitive impairment is present in approximately 40% of these patients [1]. An essential part of the history is determining if the patient has any caregivers or close relatives that know the patient and his or her medical conditions well. The phone numbers for these caregivers should be documented in any consult notes and in the patient's chart as well. Contact information for the patient's primary care physician or specialists (such as a cardiologist, pulmonologist, or nephrologist) should also be documented to ensure that inpatient providers can obtain a better sense of the patient's full medical picture.

It is important to establish the patient's baseline function and social setting as well as to identify any witnesses of the injury. A witness who observed the injury can detail the mechanism of injury, as well as formulate a timeline with information such as down time, which may facilitate risk stratification for venous thromboembolic events, ulcers, and predict postoperative recovery. Patients who don't quickly present to the emergency room after injury are at an increased risk of having preoperative deep vein thromboses (DVTs). Approximately 3% of elderly patients with hip fractures have asymptomatic DVTs at the time of presentation, and this risk

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increases to nearly 15% if patients present to the emergency room more than 72 h after injury [2].

Pre-injury cognitive function offers a glimpse into how a patient will progress following surgery. Patients with cognitive impairment, along with patients who have both cognitive impairment and depression, improve significantly less from an ambulatory standpoint compared to those patients without cognitive impairments [3]. Having a sense of a patient's cognitive function and decision-making ability allows medical teams to involve family members early on and also offer insight into what a patient and his or her family could expect postoperatively. Pre-injury ambulatory status can predict postoperative recovery. Approximately 18% of elderly patients with hip fractures are able to return to their baseline level of ambulatory function, and 25% of patients do not regain the ability to ambulate [4]. Patients with poor baseline ambulatory function and those who live in skilled nursing facilities are significantly less likely to regain their baseline ambulatory function postoperatively. It is, therefore, critical to assess in detail the patient's pre-operative ambulatory status and the use of ambulatory gait aids.

A thorough review of the patient's past medical and surgical history will help in their management both during and after hospitalization. Patients with three or more medical comorbidities, respiratory disease, or malignancy are at significantly increased risk of mortality within 30 days of surgery [5]. A history of previous fragility fractures such as a vertebral compression fracture or distal radius fracture might indicate that the patient is at risk for suffering additional fragility fractures and might necessitate the involvement of metabolic bone disease specialists. A review of a patient's home medications will allow treating physicians to ensure that the patient is appropriately medically managed while in the hospital and is on a suitable anticoagulation regimen.

Examination

When examining an elderly patient with a suspected hip fracture, a focus only on the injured extremity can lead clinicians to ignore other important injuries. Approximately 5% of patients with geriatric hip fractures have fractures elsewhere, most commonly proximal humerus and distal radius fractures [6]. In patients who hit their heads or have no memory of the fall, it is important to perform a neurological examination and cervical spine examination. Patients who are mostly bedbound or spend time in nursing homes should be checked for any pressure sores or decubitus ulcers. Inspecting and palpating lower extremities can reduce the incidence of an undiagnosed preoperative DVT.

Patients with a hip fracture often present to the emergency department with their affected lower extremity shortened and externally rotated depending on the extent of displacement. A pulse and sensory exam should be performed, along with checking the skin around the hip and pelvis. Provocative tests for hip fractures include the log roll and heel strike. A log roll test can be performed with the clinician grabbing the patient's thigh and ankle before internally and externally rotating the extremity. Pain in the groin raises suspicion for hip fracture. A heel strike test involves applying axial compression to the ankle, leading to pain in the groin if a fracture is present. The patient can also be asked to perform an unassisted straight leg raise of the affected extremity—if the patient is unable to do so, this also increases suspicion for a hip fracture.

Imaging

Appropriate imaging of the affected extremity includes an AP radiograph of the pelvis, along with full-length X-rays of the affected femur including an AP and cross-table lateral view of the affected hip. Traction-internal rotation radiographs of the affected hip have been proven to offer improved resident and attending agreement on fracture location and morphology and often lead to changes in implant selection based on the additional information that this radiographic view provides [7]. A computerized tomography (CT) scan of the affected hip can also be used to evaluate femoral neck fractures to identify the degree of displacement if a lateral radiograph cannot adequately accomplish this.

If a patient has a femoral neck fracture, then an AP pelvic radiograph with a marker ball is useful because it allows for preoperative templating in cases treated with arthroplasty. Full-length femur films are useful in investigating the extent of anterior femoral bowing that a patient might have, especially considering femoral bowing increases with age [8]. In cases of a suspected pathologic due to malignancy, full-length femur radiographs also allow surgeons to further investigate if there are any additional lesions in the bone. If a patient has previously had surgery to the affected femur, then full-length films are useful for fully visualizing the entire implant.

While the patient is receiving his or her extremity-specific radiographs, it is important to remember to obtain a chest X-ray for preoperative medical risk stratification and co-management. While many anesthesia and preoperative clearance teams require X-rays in order to obtain a more robust clinical picture of the patient, the chest X-ray can diagnose possible medical ailments or even alert the clinical team that the patient has had a history of thoracic surgery that they might not have reported (pacemaker, sternotomy wires, etc.).

Laboratory Workup and Preoperative Clearance

In addition to obtaining relevant preoperative imaging, it is important to collect preoperative laboratory studies. These laboratory values are especially useful when they can be compared to baseline values for a patient. Elderly patients with hip fractures who were found down after a prolonged period might have an acute kidney injury or a metabolic acidosis, and these values should be closely monitored throughout the patient's care. Elevated serum glucose values might indicate poorly controlled or undiagnosed diabetes, and close regulation of serum glucose can lead to fewer complications and a reduced risk of mortality [9].

A complete blood count in elderly patients with hip fractures often reveals preoperative anemia, and preoperative anemia has been associated with an increased risk of 30-day readmission and mortality [10]. A type and screen will facilitate a blood transfusion if needed, and approximately 20–40% of elderly patients with hip fractures will end up receiving a blood transfusion during their hospitalizations [11–13]. Coagulation studies such as prothrombin time/international normalized ratio (PT/INR) and partial thromboplastin time (PTT) can ensure that patients are safe for surgery from a coagulation standpoint, especially those who take medications such as warfarin and those who might require additional preoperative optimization with vitamin K or fresh frozen plasma.

An often forgotten preoperative laboratory study is the urinalysis. Nearly a quarter of all elderly patients with hip fractures had a urinary tract infection (UTI) during their hospitalizations, and patients diagnosed with UTIs had poorer functional outcomes and longer hospital stays [14]. Preoperative EKG and an echocardiogram also offer additional information for cardiopulmonary clearance as well as for perioperative fluid resuscitation. However, the decision to order an echocardiogram should be at the discretion of the internal medicine service.

Fracture Classification

Femoral Neck

Complete radiographs will allow the surgical team to classify the fracture and subsequently decide on an appropriate treatment plan. Femoral neck fractures can be classified on their location within the femoral neck, their amount of displacement, and the orientation of their fracture lines. In terms of location, femoral neck fractures can be subcapital (just lateral to the femoral head), transcervical (middle of the femoral neck), or basicervical (at the base of the femoral neck) (Fig. 2.1) [15]. While subcapital and transcervical fractures are intracapsular, basicervical fractures are often extracapsular, placing them at a lower risk of osteonecrosis and nonunion. For this reason, basicervical fractures can often be treated more like an intertrochanteric fracture and fixed with either a dynamic hip screw (DHS) or intramedullary nail (IMN).

The most commonly used classification for femoral neck fractures is the Garden classification, which divides femoral neck fractures into four subgroups based on fracture displacement [16]. Type I fractures are incomplete, valgus-impacted fractures. Type II fractures are complete fractures of the femoral neck without

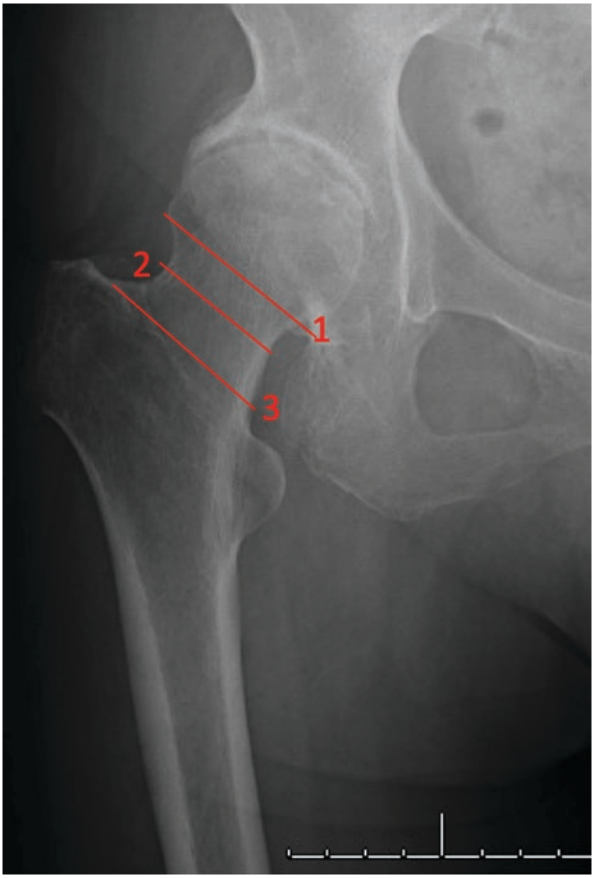

Fig. 2.1 Radiograph demonstrating the different anatomic areas at which a femoral neck fracture can occur. Fractures can either be subcapital (line *1*, lateral to the head), transcervical (line *2*, middle of the femoral neck), or basicervical (line *3*, base of the femoral neck)

displacement. Type III fractures are complete fractures that are partially displaced, whereas type IV fractures are completely displaced. This system can be further simplified by categorizing these femoral neck fractures as nondisplaced/minimally displaced (types I and II) versus displaced (types III and IV).

The Müller-AO classification can be used as well for femoral neck fractures, with the proximal femur beginning with the label 31 (Fig. 2.2). Femoral neck fractures are 31-B fractures (intertrochanteric fractures are 31-A and femoral head fractures are 31-C). The Pauwels classification system for femoral neck fractures is based on the orientation of a fracture line. With this system, a fracture is classified based on its angle with a horizontal line. Type I fractures are up to 30° from horizontal, type II fractures are between 30° and 50° from horizontal, and type III fractures are over 50°, making them the most vertical. While Pauwels believed that more vertical fractures were more prone to nonunion due to increased shear stresses across the fracture, additional research has failed to confirm this claim [17]. Therefore, the Pauwels classification system is rarely used.

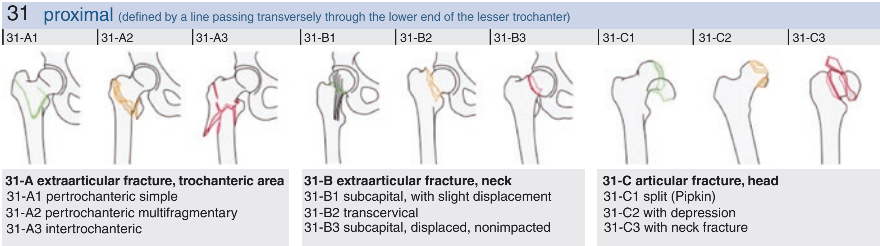

Fig. 2.2 Müller-AO classification for proximal femur fractures. Peritrochanteric fractures are 31-A, femoral neck fractures are 31-B, and femoral head fractures are 31-C

Peritrochanteric

As mentioned above and in Fig. 2.2, intertrochanteric fractures are 31-A in the Müller-AO classification system, though this system is mostly used for research purposes. The two most commonly used classification systems are the Boyd and Griffin system, along with the Evans classification [18]. There are four types of fractures in the Boyd and Griffin system [19]. Type I fractures have a fracture line along the intertrochanteric line, and type II fractures also contain a major fracture line along the intertrochanteric line but with additional comminution. Type III fractures are at the level of the lesser trochanter and extend into the subtrochanteric region (reverse obliquity). Type IV fractures extend into the subtrochanteric region. The Evans classification system is divided into stable and unstable fracture patterns, with stability dependent on continuity of the posteromedial cortex. With this classification system, reverse obliquity fractures are inherently unstable.

Subtrochanteric fractures can similarly be classified by the Müller-AO classification system, and they are designated as 32.1 (3 = femur, 2 = diaphysis, 0.1 = subtrochanteric). Simple fractures are type A, wedge fractures are type B, and complex fractures are type C. The Russel-Taylor classification was devised to differentiate between fractures that would be amenable to intramedullary fixation. Type I fractures do not extend into the piriformis fossa, whereas type II fractures do. However, this system is no longer of much relevance given that advances in both piriformis and trochanteric entry nails allow all subtrochanteric fractures to be treated with intramedullary fixation.

When assessing subtrochanteric fractures, it is important to pay attention to the mechanism of injury and if any radiographic parameters are present that would lead the clinical team to suspect an atypical fracture. These atypical fractures can be seen in patients with a history of long-term bisphosphonate use or other anti-resorptive medications. The American Society for Bone and Mineral Research (ASBMR) has devised major and minor criteria for diagnosing atypical femur fractures [20]. Major features include fracture location from the lesser trochanter to the supracondylar flare, minimal or no trauma, transverse or short oblique fracture pattern, and fracture through both cortices with a medial spike. Minor features include localized periosteal reaction of the lateral cortex, increased cortical thickness of the diaphysis, prodromal symptoms, bilateral symptoms or fractures, delayed healing, comorbid conditions, or use of pharmaceutical agents.

Periprosthetic

The Vancouver classification system is useful when discussing periprosthetic fractures of the hip [21]. This system takes account the stability of the femoral component and the location of the fracture. The first part of the classification is a letter to designate where the fracture is—zone A is the proximal metaphysis and often involve the greater (A_G) or lesser trochanter (A_L), zone B is the diaphysis surrounding the stem, and zone C is distal to the prosthesis such that it can be treated independently of the prosthesis. Within type B, there are three subtypes to indicate the stability of the femoral component. B1 indicates a stable component, B2 fractures have an unstable femoral component, and B3 fractures have unstable stems with poor bone quality. Management of these fractures will be discussed in respective chapters later in this book.

References

1. Seitz DP, Adunuri N, Gill SS, Rochon PA. Prevalence of dementia and cognitive impairment among older adults with hip fractures. J Am Med Dir Assoc. 2011;12(8):556–64. https://doi.org/10.1016/j.jamda.2010.12.001.
2. Cho YH, Byun YS, Jeong DG, Han IH, Park YB. Preoperative incidence of deep vein thrombosis after hip fractures in Korean. Clin Orthop Surg. 2015;7(3):298–302. https://doi.org/10.4055/cios.2015.7.3.298.
3. Feng L, Scherer SC, Tan BY, Chan G, Fong NP, Ng TP. Comorbid cognitive impairment and depression is a significant predictor of poor outcomes in hip fracture rehabilitation. Int Psychogeriatr. 2010;22(2):246–53. https://doi.org/10.1017/S1041610209991487.
4. Ko Y. Pre- and perioperative risk factors of post hip fracture surgery walking failure in the elderly. Geriatr Orthop Surg Rehabil. 2019;10. Published 2019 Jun 4 https://doi.org/10.1177/2151459319853463.
5. Roche JJ, Wenn RT, Sahota O, Moran CG. Effect of comorbidities and postoperative complications on mortality after hip fracture in elderly people: prospective observational cohort study. BMJ. 2005;331(7529):1374.
6. Buecking B, Wack C, Oberkircher L, et al. Do concomitant fractures with hip fractures influence complication rate and functional outcome? Clin Orthop Relat Res. 2012;470:3596–606. https://doi.org/10.1007/s11999-012-2419-z.
7. Koval KJ, Oh CK, Egol KA. Does a traction-internal rotation radiograph help to better evaluate fractures of the proximal femur? Bull NYU Hosp Jt Dis. 2008;66(2):102–6.
8. Karakaş HM, Harma A. Femoral shaft bowing with age: a digital radiological study of Anatolian Caucasian adults. Diagn Interv Radiol. 2008;14(1):29–32.
9. Marchant MH Jr, et al. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. JBJS. 2009;91(7):1621–9.
10. Ryan G, Nowak L, Melo L, et al. Anemia at presentation predicts acute mortality and need for readmission following geriatric hip fracture. JB JS Open Access. 2020;5(3):e20.00048. Published 2020 Sep 28. https://doi.org/10.2106/JBJS.OA.20.00048.

11. Morris R, Rethnam U, Russ B, Topliss C. Assessing the impact of fracture pattern on transfusion requirements in hip fractures. Eur J Trauma Emerg Surg. 2017;43(3):337–42.
12. Carson JL, Duff A, Berlin JA, Lawrence VA, Poses RM, Huber EC, et al. Perioperative blood transfusion and postoperative mortality. JAMA. 1998;279(3):199–205.
13. Kadar A, Chechik O, Steinberg E, Reider E, Sternheim A. Predicting the need for blood transfusion in patients with hip fractures. Int Orthop. 2013;37(4):693–700.
14. Bliemel C, Buecking B, Hack J, Aigner R, Eschbach DA, Ruchholtz S, Oberkircher L. Urinary tract infection in patients with hip fracture: an underestimated event? Geriatr Gerontol Int. 2017;17(12):2369–75. https://doi.org/10.1111/ggi.13077. Epub 2017 Jun 16.
15. Koval K, Zuckerman J. Hip fractures: a practical guide to management. New York: Springer; 2000.
16. Garden RS. Low-angle fixation in fractures of the femoral neck. J Bone Joint Surg Br. 1961;43:647–64.
17. Parker MJ, Dynan Y. Is Pauwels classification still valid? Injury. 1998;29(7):521–3.
18. Kim JO, Kim TH. Surgical treatment of femur intertrochanteric and subtrochanteric fracture. J Korean Hip Soc. 2010;22(1):1–12. https://doi.org/10.5371/jkhs.2010.22.1.1.
19. Sonawane DV. Classifications of intertrochanteric fractures and their clinical importance. Trauma Int. 2015;1(1):7–11.
20. Boskey AL, van der Meulen MCH. The duration and safety of osteoporosis treatment. Riverside: Springer; 2006.
21. Rayan F, Dodd M, Haddad FS. European validation of the Vancouver classification of periprosthetic proximal femoral fractures. J Bone Joint Surg. 2008;90(12):1576–9.

Chapter 3
Perioperative Medical Co-management of Patients with Geriatric Hip Fractures

William C. Turner

Introduction

Every year in the United States, over 300,000 patients of age 65 and older are hospitalized for hip fractures [1]. More than 95% of hip fractures are due to falling, usually sideways, and women suffer three-quarters of all hip fractures [2]. Hip fractures may have devastating consequences in elderly patients in particular and can be associated with a poor outcome. One-third of elderly patients with hip fracture are deceased a year later, and in surviving patients, hip fractures have a negative effect on daily life activities and can lead to a substantial loss of healthy life-years [2, 3]. Historically, studies of in-hospital mortality after hip fracture ranged from 2.3% to 13.9%, with risk persisting beyond the immediate surgical period and 6-month mortality rates ranging from 12% to 23% [4]. The mortality risk is increased in the first 6 months postoperatively, then starts to decrease, and is higher in men. When compared to elective hip replacements, patients presenting with hip fracture have a 6- to 15-fold greater mortality risk [5]. A more recent review of Medicare databases show a relatively low rate of in-hospitality mortality associated with intertrochanteric hip fractures at 1.70% and suggests that mortality risk is actually greatest after patients have been released from the hospital [6].

Based on data from the Framingham Heart Study, however, there has been an overall decrease in hip fracture incidence over the past 40 years in the United States. This population-based cohort study including >105,000 person-years in follow-up over 40 years found that those born more recently experienced a lower incidence of hip fracture for a given age. Decreases in the prevalence of smoking and heavy drinking were associated with the decrease in the incidence of hip fracture.

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Individuals born more recently appeared to have a low risk for hip fracture. Attributing the decrease in hip fracture incidence up to 2010 solely to better treatment is not supported by these data, emphasizing the need to treat patients with osteoporosis while continuing to encourage public health interventions for smoking cessation and heavy drinking [7].

Excellent and comprehensive medical management is critical during the perioperative period of hip fracture in elderly patients as three in four hip fracture-associated deaths may be related to preexisting medical conditions rather than the fracture itself. In fact, one of the first questions a physician must pose is what caused the fall and whether an acute medical process, such as arrhythmia, stroke, or change in medicine, provoked the fall leading to the fracture [8]. Generally, the emergency physician will have performed the initial workup, including labs and electrocardiogram, but a comprehensive history, including collateral history and medication history, is paramount to understanding the cause of a fall. Identification of contributors to falls and mitigation of these factors may help prevent future fracture. This chapter is written by a general internist and hospitalist and is intended for a primary audience of orthopaedic surgeons who aim to understand the fundamentals of medical management of geriatric hip fracture and the most frequent consultation questions for an internist.

Initial Medical Workup for Hip Fracture

Over the last two decades, there has been a concerted effort to examine and reassess over-testing in medicine, and this includes in the perioperative period. Historically, extensive preoperative testing was performed to stratify risk, direct anesthetic choices, and guide postoperative management [9]. Since 2012, national medical societies and organization have created evidence-based, specialty-specific lists to limit over-testing. Ultimately, the decision to order preoperative tests should be guided by the patient's clinical history, comorbidities, and physical examination findings, and the degree to which test results would change management.

Geriatric hip fractures are viewed as complex, medium- to high-risk surgical operations and repair should be performed urgently within 48 hours for a mortality benefit, and most testing should not delay the operation.[1] We will review the

[1] The ASA (American Society of Anesthesiologists) Physical Status Classification System is a simple scale describing fitness to undergo anesthesia. The ASA states that it does not endorse any elaboration of these definitions but internists in the United States often relate these grades as relating to functional capacity – that is, comorbidity that does not (ASA 2) or that does (ASA 3) limit a person's activity.

Most patients undergoing urgent hip fracture repair are considered ASA3 or 4.

ASA 1: A normal healthy patient

ASA 2: A patient with mild systemic disease

ASA 3: A patient with severe systemic disease

ASA 4: A patient with severe systemic disease that is a constant threat to life evidence for preoperative medical workup. Table 3.1 summarizes the initial evaluation for the geriatric patient undergoing hip fracture repair.

Laboratory Evaluation

A complete blood count is indicated as significant perioperative blood loss is anticipated. Electrolyte and creatinine testing should be performed in patients with underlying chronic disease and those taking medications that predispose them to electrolyte abnormalities or renal failure. Coagulation studies are reserved for patients with a history of bleeding or medical conditions that predispose them to bleeding and for those taking anticoagulants. Random glucose testing should be performed in patients at high risk of undiagnosed diabetes mellitus. In patients with diagnosed diabetes, A1c testing is recommended only if the result would change perioperative management. Preoperative urinalysis is recommended only for patients undergoing invasive urologic procedures [10].

Preoperative N-terminal pro-B-type natriuretic peptide (BNP) levels predict postoperative adverse cardiovascular events. In theory, preoperative BNP levels also could help guide surgical or anesthetic approaches and more precisely intensify or lessen postoperative monitoring. However, whether additional diagnostic and therapeutic interventions triggered by routine perioperative measurement of BNP would lower postoperative morbidity and mortality is unclear [11]. Preoperative BNP greater than 600 pg/mL is independently associated with postoperative cardiac complications in patients with hip fracture without renal dysfunction and is recommended. Future studies are underway to develop a simple index for prediction of postoperative cardiac complication including cutoff values of BNP [12].

Table 3.1 Initial preoperative workup for geriatric patients undergoing hip fracture repair

Test	Considerations
Extensive history	Did patient have syncope or trip and fall? Baseline exercise tolerance: i.e. can patient walk up a flight of stairs? Exhaustive medication review
Auscultation for severe aortic stenosis murmur	Is systolic murmur increased over proximal right clavicle?
Complete blood count	
Basic metabolic profile	
Prothrombin time	For patients predisposed to bleeding
N-terminal pro-B-type natriuretic peptide	
Electrocardiogram	
Use risk assessment calculators	GSCRI and ACS-NSQIP risk calculators

GSCRI geriatric-sensitive perioperative cardiac risk index, *ACS-NSQIP* American College of Surgeons-National Surgical Quality Improvement Program

In a 2014 study, investigators showed that even modestly elevated high-sensitivity troponin T (hsTnT) levels during the 3 days after non-cardiac surgery were associated independently with excess 30-day mortality [13]. Among 4000 patients with peak postoperative hsTnT between 20 and 65 ng/L, 30-day mortality was 3%. Mortality increased further at higher peak hsTnT levels, and several nonfatal cardiac outcomes correlated with elevated hsTnT. Relatively modest elevations in hsTnT during or just after non-cardiac surgery can represent potentially clinically important ischemic myocardial injury that is often initially asymptomatic or unrecognized. However, the question of drawing routine troponin levels (or in selected high-risk subgroups) after non-cardiac surgery is still debated among different cardiology societies and there is no consensus. Evidence-based interventions shown to improve outcomes in such patients with asymptomatic perioperative troponin elevations are also lacking, but a clinical trial examining use of dabigatran for this purpose is underway [14].

Other Studies

A baseline electrocardiography is recommended for patients undergoing high-risk surgery and those undergoing intermediate-risk surgery who have additional risk factors [15]. Routine chest radiography is reasonable for patients at risk of postoperative pulmonary complications if the results would change perioperative management, but generally not for orthopaedic surgery [16]. Patients with signs or symptoms of active cardiovascular disease should be evaluated with appropriate testing, regardless of their preoperative status. Avoid echocardiograms for preoperative/perioperative assessment of patients with no history or symptoms of heart disease. Resting left ventricular (LV) function is not a consistent predictor of perioperative ischemic events; even reduced LV systolic function has poor predictive value for perioperative cardiac events [17].

Since orthopaedic intervention within 48 hours is the standard of care for patients who are hospitalized with hip fractures, researchers retrospectively reviewed data from more than 1000 older patients (age, ≥65) with acute hip fractures to determine the association between use of preoperative noninvasive cardiac testing and several outcomes. Preoperative pharmacological stress testing was rare (<1%), and transthoracic echocardiogram (TTE) was relatively common (33%). After adjustment for potentially confounding factors including comorbidities, patients admitted to the medical service had 3.5 times greater odds of undergoing TTE than those admitted to the orthopaedic service. Patients at community hospitals had almost three times greater odds of receiving preoperative TTE than those at tertiary centers. Preoperative TTE was associated with longer time to surgery (37 vs. 24 hours) [18] and was not associated with reduced in-hospital mortality or postoperative complications [19]. Because bone is an excellent conductor of aortic valve murmurs, concern for severe aortic stenosis can be reliably excluded in most situations on physical exam, by the absence of murmur radiation to the right clavicle [20]. Stress testing should not be performed unless the patient has an indication for a stress test, such as concern for unstable angina.

Medication Reconciliation

Polypharmacy, prescription of an average of five or more daily drugs, is often associated with potentially inappropriate medications (PIMs) such as benzodiazepines and glucocorticoids and leads to a higher risk of serious health consequences in elderly patients and an increased risk of falls and resultant hip fracture [21]. Antihypertensive drugs are associated with an immediate increase in hip fracture risk during the initiation of treatment in hypertensive community-dwelling elderly patients. Caution is advised when initiating antihypertensive drugs in the elderly [22]. There is an association between antidepressant drug use and hip fracture before and after the initiation of therapy [23].

A full review of preoperative medicines is critical, as they may be a contributor to the etiology of the fall, fracture, and/or cause of perioperative morbidity. For patients undergoing non-cardiac surgery, rates of death, stroke, and myocardial injury are reduced when angiotensin-converting enzyme (ACE) inhibitors and angiotensin II receptor blockers (ARBs) are discontinued 24 hours before the procedure. ACE inhibitors and ARBs are both known to cause hypotension during anesthesia, but it has not been determined whether they lead to adverse outcomes [24]. Internists generally recommend holding diuretics, weight loss medications, potassium supplements, and vitamins on the day of surgery. See Perioperative Diabetes Management for further details, but oral diabetes medications are typically held on the day of surgery. Basal insulin (e.g., Lantus) is taken at half dose (on the night before or morning of surgery), while bolus insulin (e.g., Lispro) is held while the patient is nil per os (NPO).

Risk Assessment Tools

There are numerous national and international societies that have published guidelines relating to perioperative assessment and management of geriatric hip fractures. While the details of each of these guidelines are beyond the scope of this orthopaedic textbook, recommendations from major societies are summarized. There are three major society guidelines for the perioperative setting: American College of Cardiology/American Heart Association (ACC/AHA) [25], European Society of Cardiology ESC/EHA [26], and the Canadian Cardiovascular Society (CCS) guidelines [27]. There are other useful guidelines from the American Society of Anesthesiology (ASA) that examine preoperative testing, obstructive sleep apnea (OSA), and fluid management [28]. The American College of Chest Physicians (ACCP) provides excellent guidelines on perioperative anticoagulation and prophylaxis [29].

The ACC and ESC guidelines are quite similar compared to the CCS guidelines and give slightly different recommendations on preferred risk assessment tools and use of preoperative laboratories, such as troponin, TTE, and stress testing. The calculators are excellent at predicting morbidity and mortality. Infrequently, the risk may be prohibitively high and operation should be aborted. If a patient is deemed high risk, it allows for shared decision-making with the patient/surrogate, internist, anesthesiologist, and surgeon and an individualized risk/benefit analysis and helps to identify which comorbidities to manage and optimize preoperatively. Given the emergent nature of hip fracture surgery, these calculators generally do not lead to additional testing that would further delay surgery.

The 2014 American College of Cardiology/American Heart Association Perioperative Guidelines suggest using the revised cardiac risk index (RCRI), myocardial infarction or cardiac arrest (MICA), or American College of Surgeons-National Surgical Quality Improvement Program (ACS) calculators for combined patient-surgical risk assessment. Cohn et al. attempted to compare these risk calculators with a reconstructed RCRI in predicting postoperative cardiac complications, both during hospitalization and 30 days after operation, in a patient cohort who underwent select surgical procedures in various risk categories. Cardiac complications occurred in 14 of 663 patient (2.1%) and 11 of the 14 had their complications during the actual hospitalization. Only 3 of the 663 patients (0.45%) had a myocardial infarction or cardiac arrest. Because these calculators used different risk factors, different outcomes, and different durations of observation, a true direct comparison was not possible. They found that all four risk calculators performed well in the setting they were originally studied and were useful in defining low-risk patients in whom further cardiac testing was unnecessary, but the MICA calculator may be the most reliable in selecting higher risk patients [30].

However, many of these risk prediction models had poor performance in geriatric patients. In 2017, Alrezk et al. investigated the performance of the RCRI and Gupta MICA perioperative cardiac risk models in a geriatric population and developed a geriatric-sensitive perioperative cardiac risk index (GSCRI) optimized for use with geriatric patients and sensitive to the clinical and physiologic uniqueness of this population and also conducted a comparative performance analysis of the GSCRI, RCRI, and Gupta MICA models [31]. Every internist and orthopedist should be acquainted with one or two clinical risk calculators for cardiac complications and have them accessible on a smart phone. The two most "user friendly" and pertinent to a geriatric hip fracture are the GSCRI [32] and ACS risk calculator [33]. There is good evidence that these surgical risk calculators are simple and cost-effective assessment methods and suitable for predicting the incidence of postoperative complications in elderly patients with hip fractures, are well matched with the actual complication rate, and predict 30-day mortality in elderly patients with hip fractures [34].

For postoperative pulmonary complications, the Gupta Postoperative Respiratory Failure Risk Calculator most efficiently predicts the risk of mechanical ventilation for longer than 48 hours postoperatively or reintubation within 30 days [35]. The American College of Physicians (ACP) has published a guideline to reduce the risk of postoperative pulmonary complications and found that those patients with chronic obstructive pulmonary disease, age older than 60, American Society of Anesthesiologists class II or greater, functional dependence, congestive heart failure, and low serum albumin level (<3.5 g/dL) were at greatest risk. Obesity and moderate asthma are not risk factors for postoperative pulmonary complications. Spirometry and chest radiography should not be used routinely to assess risk and right heart catheterization and total enteral or parenteral nutrition should not be used solely for reducing postoperative pulmonary complications. The ACP recommends postoperative interventions for those at risk, including deep breathing exercises or incentive spirometry, and use of nasogastric tubes in cases of nausea and vomiting, inability to tolerate oral intake, or symptomatic abdominal distention [36].

Perioperative Considerations

To optimize outcomes, it is imperative to consider preventive measures to reduce complications in the perioperative period such as pain, infection, thromboembolic events, and delirium. Major recommendations regarding perioperative management are shown in Table 3.2.

Analgesia

At least two-thirds of patients with a hip fracture will experience moderate or severe pain, but this is often underdiagnosed, particularly in those with cognitive impairment. Extracapsular fractures are more painful than intracapsular injuries due to the greater degree of periosteal damage. It is therefore vital that adequate pain relief be provided as soon as possible, although careful consideration should be given to the regimen used due to the risk of potentially serious side effects in elderly patients. Inappropriate pain control may increase postoperative delirium and patients with delirium may also receive inadequate analgesia. Acetaminophen is both a safe and effective analgesic and is an excellent potentiating adjunct to opiates.

Table 3.2 Perioperative medical management

Analgesia	Acetaminophen, intravenous morphine, nerve blocks
Perioperative antibiotic prophylaxis	Cefazolin 2 g intravenously once
Venous thromboembolic prophylaxis	Enoxaparin 1 mg/kg every 12 hours
Delirium precautions	Monitor for alcohol withdrawal, frequent orientation, sleep management, ensure the patient has glasses and/or hearing aids on, fluid and electrolyte management, and effective pain management

In the emergency department, as well as in the post-anesthesia recovery room (PACU), intravenous morphine titration is a very simple and efficient analgesic and is considered first line, but it has a propensity to cause nausea, constipation, and sedation, especially in the geriatric population and/or patients with renal and/or cognitive impairment. Non-steroidal anti-inflammatory drugs (NSAIDs) can provide effective pain relief following a hip fracture, but they carry a significant risk of acute kidney injury (AKI) and fluid retention, particularly in the geriatric population. Nerve blocks can also be easily performed either in the emergency department or in the PACU and reduce the need for breakthrough analgesia and opiates [37]. Their use is also shown to have improved outcomes, including reduced incidence of delirium, risk for pneumonia, time to first mobilization, cost of the analgesic regimen, length of stay, and mortality [38]. From the evidence available, the routine use of traction (either skin or skeletal) prior to surgery for a hip fracture does not appear to have any benefit [39].

Perioperative Antibiotic Prophylaxis

Preoperative prophylactic antibiotics are effective in reducing the incidence of wound infection (combined superficial and deep) after hip fracture surgery, when compared with placebo [40]. A meta-analysis by Southwell et al. found that the overall incidence of infections in the treatment group was 5.39% (67 of 1244) and in the control group was 10.40% (122 of 1173). This gave an absolute risk difference of wound infection when treated with prophylactic antibiotics of 5.01%. Therefore, to prevent one such infection from developing, 20 patients need to be treated. One dose of antibiotics, usually 1 or 2 g of a cephalosporin, given intravenously at the time of induction of anesthesia seems to be as effective as multiple doses of antibiotics. Prophylactic antibiotics also result in a significant reduction in urinary tract infections after surgery; however, there was no significant difference in mortality [41].

The evidence is inconclusive regarding the clinical effectiveness of postoperative prophylactic antibiotics for patients following hip fracture repair surgery. Two systematic reviews (based on low-quality studies) did not find a statistically significant difference in infection rates for patients who received postoperative prophylactic antibiotics compared with those who did not. One retrospective cohort study found a statistically significant reduction in infection rates following hip arthroplasty in patients who had an elevated risk of infection to begin with (e.g., diabetes, chronic kidney disease, and smoking) and who received postoperative prophylactic antibiotics compared with those who did not. There are currently no evidence-based guidelines regarding the use of prophylactic antibiotics for patients following hip fracture repair surgery [42].

DVT Prophylaxis

Hip fracture patients are at high risk for venous thromboembolism (VTE) and pulmonary embolism. For patients undergoing hip fracture surgery, ACCP guidelines recommend the use of low molecular weight heparin (LMWH), low-dose unfractionated heparin (UFH), warfarin (VKA), fondaparinux, aspirin (all grade 1B), or an intermittent pneumatic compression device (IPCD) (grade 1C) for at least 10–14 days and up to 35 days. The use of LMWH is recommended in preference to the other agents (grade 2B and 2C when it comes to adjusted-dose VKA or aspirin). When LMWH is used for VTE prophylaxis in patients undergoing hip fracture surgery, it is recommended to begin administration either 12 hours or more preoperatively or 12 hours or more postoperatively, rather than within 4 hours or less preoperatively or 4 hours or less postoperatively [43]. During hospitalization, the use of dual prophylaxis with an IPCD device for at least 18 hours daily along with an antithrombotic agent is recommended [43]. In addition to ACCP, the British Orthopaedic Association [44] and NICE guidelines [45] suggest administration of heparin (UFH or LWMH) 6–12 hours after surgery for 4 weeks, early mobilization of the frail patient, and simultaneous use of IPCD [46]. The Scottish Intercollegiate Guidelines Network (SIGN) guidelines for VTE prophylaxis in patients with hip fractures recommend that heparin (UFH or LMWH) or fondaparinux may be used for pharmacological VTE (grade A) and do not recommend aspirin monotherapy as an appropriate pharmacological VTE prophylaxis after hip fracture surgery (grade D). Regarding LMWH, SIGN guidelines suggest that patients without a contraindication should receive fondaparinux for 28 days starting 6 hours after surgery (grade A) [47].

Hip fracture surgery should be performed as soon as possible after the fracture has occurred. However, surgery sometimes is delayed to address unstable medical problems or for logistical reasons. A likely consequence of delayed surgery is excess risk for venous thromboembolism (VTE). In one study from Korea, researchers determined the prevalence of VTE among 208 consecutive hip fracture patients whose surgery was performed more than 24 hours after injury. All patients began prophylactic LMWH and IPCD shortly after admission. Twenty-three patients (11%) had VTE: twelve had deep venous thrombosis alone, seven had pulmonary embolism alone, and four had both. All VTE cases were asymptomatic. This study demonstrates a nontrivial incidence of preoperative VTE in hip fracture patients whose surgery is delayed, even though these patients were receiving standard VTE prophylaxis. Because all these VTEs reportedly were asymptomatic, the clinical implications are unclear. The authors believe that patients whose surgery is delayed should undergo preoperative screening for VTE routinely; however, that conclusion seems premature in the absence of evidence that routine screening improves clinical outcomes [48].

Postoperative Complications

This section will review common medical complications of hip fracture repair and how to mitigate them. Older patients with fractures commonly have comorbidities that require evaluation prior to and after surgery. The road to recovery for hip fracture patients is long and most patients may not regain their pre-fracture functional status. Understanding, anticipating, and delivering evidence-based medical care in the geriatric patient with a hip fracture are critical to maximize patient recovery [49]. Internists are helpful in managing these patients with orthopaedic surgeons during the postoperative period. Sufficient evidence exists for most recommendations for fracture patients, but further and robust research is needed in most areas [50].

The World Hip Trauma Evaluation (WHiTE) study is a multicenter, prospective cohort study conducted in National Health Service (NHS) hospitals in England and Wales. Participants were 60 years and older who received operative treatment for a hip fracture. The study reported the incidence of complications recorded by hospital staff until discharge from hospital and by participants at 120-day post-surgery: signs of wound infection (3.1%), dislocation (0.5%), failure of fixation (0.6%), periprosthetic fracture (0.3%), overall revision surgery (0.9%), blood loss requiring transfusion (6.1%), chest infection (6.3%), urinary tract infection (5.0%), deep vein thrombosis/pulmonary embolus (1.8%), cerebrovascular accident (0.6%), acute coronary syndrome/myocardial infarction (0.6%), and acute kidney injury (1.3%) [51].

To help mitigate these complications, major clinical abnormalities including coagulopathy, respiratory failure, electrolyte disturbances, and heart failure should be addressed prior to surgery as discussed [52]. There are multiple studies showing that early surgery resulted in decreased pain, shorter length of stay, and fewer major postoperative complications [53]. In a cohort study of 367 hip fracture patients, a surgical delay of more than 2 days from admission approximately doubled the risk of 1-year mortality; however, the mortality excess was no longer present after controlling for comorbid conditions that delayed the surgery [54].

Cardiac

In 2007, the ACC/AHA Guidelines on Perioperative Cardiovascular Evaluation and Care for Non-cardiac Surgery estimated less than 5% risk of cardiac complication postoperatively after all orthopaedic major surgeries, but the 1-year recorded mortality exceeded 20% in patients specifically with hip fracture [55]. The main reasons for in-hospital cardiac-related mortality after hip fracture are heart failure and myocardial ischemia, which normally occur within first 5 days and in patients with known underlying heart disease [56]. The general incidence of perioperative myocardial ischemia in geriatric patients hip fracture surgery in other studies has been estimated at 35–42% [57].

Perioperative myocardial infarction remains a life-threatening complication in non-cardiac surgery, and even an isolated troponin rise (ITR) can be associated with significant mortality in some studies. One cohort study was conducted on a dedicated geriatric hip fracture postoperative unit to assess the prognostic value of an isolated troponin rise postoperatively. There was no significant difference for any postoperative complications, 6-month mortality and/or re-hospitalization, between ITR and the control groups. However, atrial fibrillation, acute heart failure, hemorrhage, ICU admission, and 6-month mortality were significantly more frequent in patients with an actual and clinical acute coronary syndrome [58]. One population-based study revealed that heart failure represents a prevalent and serious comorbidity in patients undergoing hip fracture repair and may carry higher postoperative risk than guidelines may suggest. It is essential that all members of the team caring for perioperative hip fracture patients pay particular attention to symptoms and signs of new or recurrent heart failure [59].

Pulmonary

Postoperative pulmonary complications (PPC) are quite common (~4% of patients) and increased the length of stay, morbidity, and mortality in patients who had undergone hip fracture surgery. Clinically important PPC include exacerbation of chronic lung disease, atelectasis, respiratory failure, pneumonia, pulmonary thromboembolism, hypoxia, and acute respiratory distress syndrome. Pneumonia is one of the common pulmonary complications of hip fracture. One study aimed to evaluate the risk factors and constructed a nomogram to predict postoperative pneumonia specifically in elderly hip fracture patients to improve prognosis and reduce mortality [60]. The impact of a comprehensive postoperative pulmonary rehabilitation program in elderly hip fracture patients after hip surgery showed a lower incidence of pneumonia (6 patients, 5.9%) compared to the standard care group (19 patients, 13.9%) and was the first trial to demonstrate the benefits of a postoperative pulmonary rehabilitation program in hip surgery patients [61]. This should be pursued in addition to standard prophylactic postoperative interventions, such as liberal use of incentive spirometry, pulmonary toilet techniques, and early ambulation. Internists are consulted frequently for postoperative hypoxia. Postoperative hypoxia has a broad differential and is often multifactorial. Pulmonary embolism is a common diagnosis that should remain high on the differential after trauma, regardless of timing or atypical features, but fat embolism should always be a consideration in the hip fracture patient. Although small fat emboli occur in many patients with long bone fractures, they are usually asymptomatic, but they rarely can cause multisystem dysfunction referred to as fat embolism syndrome [62].

The clinical presentation of fat embolism syndrome can be highly variable. Classically, the triad of presenting symptoms is hypoxemia, neurologic abnormality, and petechial rash in the setting of recent trauma or surgical treatment. However, this triad is not present in all patients, with neurologic dysfunction present in 86%

of patients, pulmonary dysfunction (tachypnea, dyspnea, and hypoxemia) in 75%, and a petechial rash on the conjunctiva, axilla, chest, or neck in 60%. Half of patients with fat embolism syndrome have development of hypoxemia that warrants mechanical ventilation, with 5–8% of patients having progression to ARDS [63]. Treatment of fat embolism syndrome is supportive. The most common cause of mortality is acute right-sided heart failure. The use of corticosteroids and albumin therapy is controversial, and their benefit is not well established [64].

Historically, large amounts of IV fluids were given during and after surgery, particularly for abdominal surgery, because of perceived third space and insensible losses [65]. Over the years, the term "restrictive fluid management" has gained popularity, particularly with the widespread adoption of Enhanced Recovery After Surgery pathways, with recent guidelines advocating a restrictive approach [66]. However, the amount of fluid given with restrictive fluid management has gradually decreased, and the term "zero balance" was introduced to describe a restrictive regimen aiming to avoid postoperative fluid retention (as indicated by weight gain) [67]. One of the most frequent postoperative medical consultations is for hypoxia related to perioperative fluid overload from standing maintenance fluids, and surgeons should be vigilant in not overhydrating the patient, particularly if the patient already received perioperative blood transfusions [68].

Neuro-Delirium

Delirium is by far the most common postoperative neurological complication following hip fracture surgery and is associated with significant mortality and morbidity. Delirium is characterized by impairments in the level of thinking, memory, and consciousness and by changes in behavior, perception, and emotion. These impairments are usually worse in the evening and during times of decreased environmental stimuli [69, 70]. A prolonged course of delirium has been associated with the development or worsening of underlying dementia [71]. An orthopedist should suspect delirium in a patient who has new or profound inattention. The prevalence of preoperative delirium ranges from 35% to 65%. The numerous risk factors for delirium include advanced age, infection, endocrinopathies, electrolyte disturbances, medications, poor nutritional status, and underlying cognitive impairment. Greater awareness and early intervention of delirium can reduce prevalence by up to 50% [70].

No single intervention has been shown to cure delirium, but the most accepted means of treatment, after removing deliriogenic triggers and medications, is the use of antipsychotic medications, particularly haloperidol [72]. A starting dose of 1–2 mg haloperidol parenterally twice daily and as needed every 4 hours has proven effective. With a concern for a paradoxical delirium exacerbation, benzodiazepines should be used with extreme caution in the elderly population [73]. In 2016, the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) developed a simple risk prediction model for post-hip fracture delirium (PHFD). A risk score based on 9 of 20 preoperative risk factors can predict PHFD in older adult patients with fairly good accuracy [74].

The STRIDE study was a double-blind randomized clinical trial that assessed geriatric patients undergoing non-elective hip fracture repair with spinal anesthesia and propofol sedation. In the primary analysis, limiting the level of sedation provided no significant benefit in reducing incident delirium [75] or return to pre-fracture ambulation up to 1 year after surgery [76]. In a population-based cohort study of 68,131 adults, however, increasing surgery duration was associated with a higher risk-adjusted likelihood of postoperative delirium (6% increase in delirium risk per additional half hour of surgery). This risk was higher in patients who received a general anesthetic [75].

In the perioperative course, alcohol withdrawal syndrome (AWS) can occur in any setting, especially in acute trauma surgery, and is often under-recognized. The overlap of other forms of delirium in perioperative and intensive care settings as well as general anesthesia that masks the onset of withdrawal symptoms is a common diagnostic challenge. In contrast to other etiologies of delirium, the pathophysiology and thus treatment strategy of AWS is different, so team members must have a high index of suspicion, especially in patients who have known alcohol use, elevated blood alcohol concentration at hospital admission, and past AWS episodes. Patients considered at risk for severe AWS should be treated with prophylactic benzodiazepines before the onset of symptoms. Thiamine supplementation is required for all malnourished alcohol-dependent patients. The backbone of AWS therapy is the symptom-triggered administration of intravenous benzodiazepines (BZO) in escalating doses until the aimed revised Clinical Institute Withdrawal Assessment for Alcohol Scale (CIWA-Ar) is achieved. AWS must be considered in the postoperative delirious patient, and benzodiazepines are first-line drugs, but they would not be the treatment of choice in other etiologies of delirium, so clinical acumen is critical [77]. Based on the quality of evidence provided, comprehensive geriatric care working alongside orthopaedic surgeons may reduce the incidence of perioperative delirium [78].

Gastrointestinal

Common postoperative gastrointestinal complications after hip fracture surgery include dyspepsia, abdominal distention, and constipation. Gastrointestinal postoperative stress ulcer and secondary bleeding are well documented as medical complications after hip surgery, especially in patients with a history of previous gastroduodenal ulcers. Prevention of gastrointestinal bleeding with pump inhibitors, antacids, etc., is extremely important in this clinical situation, in order to minimize the morbidity and mortality associated with it [79]. Swallowing disorders represent a strong risk factor of aspiration pneumonia, and their detection may lead to modification of food consistencies and careful survey. Constipation due to opioids and immobility are quite common and must be addressed aggressively [4]. Early ambulation, liberal use of polyethylene glycol 3350, and vigilant use of methylnaltrexone bromide are preferred regimens for postoperative and opioid-induced constipation. Stool impaction frequently occurs and represents a source of discomfort, a risk factor of bladder retention, and may cause a delay in rehabilitation and life-threatening complications.

Renal

The incidence of acute kidney injuries (AKI) among aging patients undergoing arthroplasty for femoral neck fractures ranges from 16% to 24.4%. Postoperative AKI is often multifactorial, with pre-renal, renal, and/or post-renal causes and is often related to perioperative medico-surgical factors (i.e., age, emergency surgery or longer preparation time, dehydration, malnutrition, nephrotoxic drug use, including NSAID, type of surgical procedure, congestive heart failure, and preexisting chronic kidney disease). AKI represents a frequent complication after hip fracture surgery and is associated with longer hospital stay and higher treatment costs with increased morbidity. Baseline preoperative renal function is an independent predictor of AKI [80].

Infectious

Urinary Tract Infection

The most common infectious postoperative complication is urinary tract infection [81]. The risk of a urinary tract infection increases an estimated 5–10% for every 48 hours of indwelling urinary catheter placement, and patients who are discharged to a skilled nursing facility with an indwelling urinary catheter have a greater chance of readmission for urinary tract infections [82]. Urinary tract infections are considered an important delirium factor risk, prolong length of stay, and increase mortality rate. Controlled trials have found that patients who had scheduled intermittent catheterization immediately after surgery or their catheter removed the morning after surgery had lower rates of urinary retention [83]. Urinary catheters are the single most important risk related to this type of postoperative infection. Therefore, indwelling catheters should be preferably removed within 24 hours after insertion [84].

Wound

The prevalence of wound infections ranges from 2% to 17% in patients with acute hip fracture. Deep wound infections impair functional ability and increase mortality in elderly patients [85]. *Staphylococcus aureus* was the most common pathogen associated with deep wound infections and 1-year mortality increased by 57% when *S. aureus* is involved compared to infections involving other bacteria. Oral steroid use and surgeries lasting more than 4 hours conferred the highest statistically significant risk for postoperative wound infection. Diabetes and renal disease showed a slightly increased risk [86].

COVID

In 2020, a UK-based multi-center study examined predictors of mortality in 34 consecutive Corona Virus Disease (COVID-19)-positive patients with hip fractures. This study reported that 12% of those presenting with a hip fracture were COVID positive and the mortality rate was 41.2% among COVID-positive patients. This study suggests that the mortality following surgery for a hip fracture in COVID-positive patients is strikingly high and is associated with higher age and male gender. The highest mortality was observed for extracapsular fracture operated with intramedullary nailing. In the immediate postoperative period, rapid deterioration of chest imaging, higher oxygen requirement, and early pulmonary complications can serve as warning signs and predictive factors for higher mortality [87, 88].

Clostridium difficile

Patients with geriatric hip fractures may be at increased risk for postoperative *Clostridium difficile* colitis, which can cause severe morbidity and is associated with 15% mortality. Patients at high risk, such as those admitted from any type of chronic care facility, those who had preoperative anemia and hypoalbuminemia, and current smokers, should be targeted with preventative measures. Standard measures include the judicious use of antibiotics, thorough hand washing between patient contacts, and isolation of the patient. Future prospective studies aim to determine the best prophylactic antibiotic regimens, probiotic formula, and discharge timing that minimize postoperative *C. difficile* colitis in patients with hip fractures [89].

Hematologic

Anemia, defined as hemoglobin <12 mg/dL in women and <13 mg/dL in men, is a common finding in patients with acute hip fracture and is a strong negative prognostic marker [90]. Severe anemia, defined as hemoglobin <8 mg/dL, is associated with increased postoperative mortality, poor physical performance, and poor functional recovery [91]. Perioperative anemia has been consistently linked to adverse outcomes in patients undergoing hip fracture surgery and is associated with increased length of hospitalization, readmission rates, and death. The prevalence of perioperative anemia ranges from 24% to 44%, and the prevalence of postoperative anemia is even higher at 51–87% [90].

Recent studies have validated the use of tranexamic acid in primary total hip arthroplasty, showing reduced blood loss and decreased number of allogenic blood transfusions. Based on this study, preoperative administration of intravenous tranexamic acid in revision hip arthroplasty reduces allogenic blood transfusions and perioperative blood loss [92]. Historically, allogenic transfusion has been the mainstay treatment of anemia in this patient population. The main factors affecting perioperative blood transfusion are age, fracture type, and admission hemoglobin [93]. The FOCUS trial was a randomized, unblinded multicenter trial that assessed whether an aggressive transfusion strategy in patients with cardiovascular risk factors who underwent hip fracture surgery improved functional outcomes and reduced postoperative adverse events. The researchers randomized patients into two groups: a 10 mg/dL hemoglobin transfusion threshold group and a group transfused for symptoms alone. Patients with cardiovascular risk factors benefitted from lower transfusion thresholds [94]. However, most clinical guidelines recommend a restrictive red blood cell (RBC) transfusion threshold. Indications for transfusion in patients with a hip fracture remain controversial. One large meta-analysis looking at seven eligible randomized controlled trials (RCTs) involving 3575 patients in total undergoing hip fracture surgery found no differences in frequency of delirium, mortality, the incidence rates of all infections, pneumonia, wound infection, all cardiovascular events, congestive heart failure, thromboembolic events, or length of hospital stay between restrictive and liberal thresholds for RBC transfusion ($P > 0.05$). However, they found that the use of restrictive transfusion thresholds is associated with higher rates of acute coronary syndrome ($P < 0.05$), while liberal transfusion thresholds increase the risk of cerebrovascular accidents ($P < 0.05$). Ultimately, in patients undergoing hip fracture surgery, clinicians should evaluate the patient's condition in detail and adopt different transfusion strategies according to the patient's specific situation rather than merely using a certain transfusion strategy [95].

Endocrine

Despite perceived risks associated with diabetes mellitus, there is little difference in terms of perioperative risk among geriatric patients with hip fracture with non-insulin-dependent or insulin-dependent diabetes relative to patients without diabetes [96]. However, insulin-requiring patients have a longer hospital stay, more complications within both 30 and 90 days after hip surgery, and a higher 1-year mortality rate compared to patients on only oral antidiabetic drug and nondiabetic patients [97]. For patients who require insulin preoperatively, prompt endocrine consultation is critical. Please see Chap. 11 for other endocrine considerations postoperatively including treatment of osteoporosis.

Nutrition

Serum albumin level is one of the most well-established serum markers of malnutrition, and a serum albumin concentration <3.5 g/dL is considered by many to be suggestive of malnutrition. In a retrospective study of 29,377 geriatric patients undergoing a hip fracture repair, there was hypoalbuminemia in 45.9%. In comparison with patients with normal albumin concentration, patients with hypoalbuminemia had higher rates of death (9.94% compared with 5.53%), sepsis (1.19% compared with 0.53%), and unplanned intubation (2.64% compared with 1.47%). Hypoalbuminemia is a powerful independent risk factor for mortality following a surgical procedure for geriatric hip fracture. These data suggest that further investigation into postoperative nutritional supplementation is warranted to decrease the risk of complications [98]. Myint et al. recently observed that perioperative nutritional supplements induced some clinical benefits (less weight loss, reduced rate of infections, and length of stay), but they were not associated with significant rehabilitation improvement. The precise nutrition strategy required remains to be determined [99].

Decubiti Ulcers

Decubitus ulcers are also detrimental postoperative complications resulting from extrinsic mechanical forces on the skin and soft tissue plus the intrinsic susceptibility of tissue to break down. Acute hip fractures are among the most frequent causes of these lesions. About 35% of ulcers occur by the end of the first week of hospitalization [100]. Risk factors of decubiti include age, malnutrition, history of smoking, and systemic illnesses. The use of foam or alternating pressure mattresses, special beds to relieve pressure, aggressive skin care, preventative nursing, and good nutrition help prevent the evolution to ulceration [101].

Perioperative Co-management

Various approaches have been proposed to integrate orthopaedic and geriatric care for elderly patients with hip fracture, an initiative also known as orthogeriatrics. Some of these measures have included an orthopaedic ward with geriatric consultation, an orthopaedic ward with daily geriatric/hospitalist management, and a geriatric ward under the specialist care of an orthopaedic consultant. Evidence from patients undergoing colorectal surgery, who also have increased age and medical complexity, demonstrated that co-management with internists was associated with a decrease in transfers to the intensive care unit (ICU), length of stay, medical consultations, and cost, but had no significant difference in medical complications, patient satisfaction, or 30-day readmission rate [102]. While closer cooperation between specialties seems like an intuitive solution to improving care, the actual evidence for co-management teams treating hip fracture patients has been somewhat mixed.

A retrospective analysis of the American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) found no evidence that a dedicated medical co-management team improves postoperative morbidity and mortality in the hip fracture population [103]. However, the authors noted that selection bias at the individual patient level may have affected the results, as sicker patients are more likely to be assigned the medical service. Many variables specific to individual institutions may affect the relationship between co-management and outcomes [104]. In fact, individual hospitals and health systems have shown more promising results with co-management. Data from Yale New Haven's Hospital Integrated Fragility Hip Fracture program showed a decrease in 30-day mortality from 8% to 2.8% during the first 3 years of the program's implementation [105].

Simply implementing co-management does not necessarily ensure improved outcomes as successful programs tend to invest significant time upfront to develop standardized protocols, building teams, and tailoring care processes to the specific needs of the hospital. One large health care system's co-management program demonstrated the need for an engaged steering committee to oversee the program, the importance of standardizing order sets and documentation, the utilization of hospitalists as co-managers, the benefit of developing and actively using a data dashboard, the challenge of ensuring wide uptake of education modules, and the need to take proactive steps to improve multidisciplinary communication [106]. Other co-management programs, such as the American Geriatric Society (AGS) CoCare: Ortho® that optimizes perioperative care of older adults, have demonstrated improved outcomes. Yet there is still substantial variation in hip fracture care nationally and there is no "one-size-fits-all" approach.

One meta-analysis that reviewed 14 studies (with one randomized clinical trial) involving 35,800 patients showed no significant association between length of stay and mortality, but multidisciplinary team involvement was associated with significant reduction in length of stay (mean difference, −2.03 days; 95% CI, −4.05 to −0.01 days; $P = 0.05$) and mortality (odds ratio (OR), 0.67; 95% CI, 0.51–0.88; $P = 0.004$). There was no difference in 30-day readmissions (odds ratio, 0.89; 95% CI, 0.68–1.16; $P = 0.39$). Overall, evidence has been of low quality, and well-designed prospective studies are still needed [107]. Baroni et al. in 2019 compared the clinical outcomes of persons with hip fracture cared according to orthogeriatric co-management (OGC), orthopaedic team with the support of a geriatric consultant service (GCS), and usual orthopaedic care (UOC). They found that patients in the OGC (OR 2.62; CI 95% 1.40–4.91) but not those in the GCS (OR 0.74; CI 95% 0.38–1.47) showed a higher probability of undergoing surgery within 48 hours compared with those in the UOC. Moreover, the OGC (β, − 1.08; SE, 0.54, $p = 0.045$) but not the GCS (β, − 0.79; SE, 0.53, $p = 0.148$) was inversely associated with length of stay. Ultimately, patients in the OGC (OR 0.31; CI 95% 0.10–0.96) but not those in the GCS (OR 0.37; CI 95% 0.10–1.38) experienced a significantly lower 1-year mortality rate compared with those in the UOC. All analyses were independent of several confounders [108]. *Swart* et al. conducted an economic analysis to determine whether implementation of a co-management model of care for geriatric patients with osteoporotic hip fractures would be cost-effective at hospitals with moderate volume. They calculated what annual volume of cases would be needed for a co-management program to "break even," and evaluated whether universal or risk-stratified co-management was more cost effective. Swart et al. found that universal co-management was more cost effective than traditional care and risk-stratified co-management (incremental cost effectiveness ratios of USD 41,100 per quality-adjusted life-year and USD 81,900 per quality-adjusted life-year, respectively). Co-management was more cost effective than traditional management as long as the case volume was more than 54 patients annually (range, 41–68 patients based on sensitivity analysis) and resulted in cost savings when there were more than 318 patients annually (range, 238–397 patients). The optimum patient population for a co-management strategy is still being defined [109].

Patients with hip fracture managed by hospitalist vs. non-hospitalist services had lower odds of 30-day readmission after discharge, suggesting a benefit to hospitalist co-management of hip fracture patients [110]. Early multidisciplinary daily geriatric care reduces in-hospital mortality and medical complications in elderly patients with hip fracture, but there is not a significant effect on the length of hospital stay or long-term functional recovery. Hospitalists can help screen for dementia, delirium, and perform a medication reconciliation that will help identify medications that frequently cause confusion perioperatively, specifically, benzodiazepines, anticholinergics, and antipsychotics. Hospitalists help avoid unnecessary consults. Recent literature has assessed the use of preoperative specialty consults, in addition to hospitalist co-management, which are often requested for preoperative risk assessment. There is good evidence that specialty consults do not meaningfully influence management and outcomes in hip fracture patients, while being co-managed by hospitalists, and may have potentially increased morbidity by delaying surgery [111]. Cardiologists should be consulted if there is a clinical concern for acute coronary syndrome, acute congestive heart failure, severe valvular disease, or uncontrolled arrhythmia. When looking specifically at postoperative delirium, which was discussed earlier, one randomized trial in an orthopaedic surgery service at an academic hospital examined whether proactive geriatrics consultation can reduce delirium after hip fracture and found that geriatrics consultation reduced delirium by over one-third and reduced severe delirium by over one-half [73].

With a vigilant orthopaedic team, hospitalists have expertise in providing support to managing underlying medical conditions and optimizing all medications. They have expertise in following population-specific protocols and pathways for VTE prevention, pain management, and prevention of aspiration and CAUTI. They will help with the management of diabetes mellitus and COPD, which can change outcomes and length of stay, after hip fracture. While the evidence is mixed, it stands to reason that a robust and collaborative co-management team that is significantly resourced will improve patients' outcomes.

References

1. Boddaert J, Raux M, Khiami F, Riou B. Perioperative management of elderly patients with hip fracture. Anesthesiology. 2014;121(6):1336–41. https://doi.org/10.1097/ALN.0000000000000478. PMID: 25299743.
2. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. JAMA. 2009;302(14):1573–9. https://doi.org/10.1001/jama.2009.1462. PMID: 19826027; PMCID: PMC4410861.
3. Papadimitriou N, Tsilidis KK, Orfanos P, Benetou V, Ntzani EE, Soerjomataram I, Künn-Nelen A, Pettersson-Kymmer U, Eriksson S, Brenner H, Schöttker B, Saum KU, Holleczek B, Grodstein FD, Feskanich D, Orsini N, Wolk A, Bellavia A, Wilsgaard T, Jørgensen L, Boffetta P, Trichopoulos D, Trichopoulou A. Burden of hip fracture using disability-adjusted life-years: a pooled analysis of prospective cohorts in the chances consortium. Lancet Public Health. 2017;2(5):e239–46. https://doi.org/10.1016/S2468-2667(17)30046-4. Epub 2017 Apr 11. PMID: 29253489.
4. Boddaert J, Cohen-Bittan J, Khiami F, Le Manach Y, Raux M, Beinis JY, Verny M, Riou B. Postoperative admission to a dedicated geriatric unit decreases mortality in elderly patients with hip fracture. PLoS One. 2014;9(1):e83795. https://doi.org/10.1371/journal.pone.0083795. PMID: 24454708; PMCID: PMC3893076.
5. Cram P, Lu X, Kaboli PJ, Vaughan-Sarrazin MS, Cai X, Wolf BR, Li Y. Clinical characteristics and outcomes of Medicare patients undergoing total hip arthroplasty, 1991-2008. JAMA. 2011;305(15):1560–7. https://doi.org/10.1001/jama.2011.478. PMID: 21505134; PMCID: PMC3108186.
6. Kiriakopoulos E, McCormick F, Nwachukwu BU, Erickson BJ, Caravella J. In-hospital mortality risk of intertrochanteric hip fractures: a comprehensive review of the US Medicare database from 2005 to 2010. Musculoskelet Surg. 2017;101(3):213–8. https://doi.org/10.1007/s12306-017-0470-3. Epub 2017 Mar 2. PMID: 28255840.
7. Swayambunathan J, Dasgupta A, Rosenberg PS, Hannan MT, Kiel DP, Bhattacharyya T. Incidence of hip fracture over 4 decades in the Framingham heart study. JAMA Intern Med. 2020;180(9):1225–31. https://doi.org/10.1001/jamainternmed.2020.2975. PMID: 32730556; PMCID: PMC7385683.
8. Penrod JD, Litke A, Hawkes WG, Magaziner J, Doucette JT, Koval KJ, Silberzweig SB, Egol KA, Siu AL. The association of race, gender, and comorbidity with mortality and function after hip fracture. J Gerontol A Biol Sci Med Sci. 2008;63(8):867–72. https://doi.org/10.1093/gerona/63.8.867. PMID: 18772476; PMCID: PMC3807236.
9. Feely MA, Collins CS, Daniels PR, Kebede EB, Jatoi A, Mauck KF. Preoperative testing before noncardiac surgery: guidelines and recommendations. Am Fam Physician. 2013;87(6):414–8.
10. National Institute for Clinical Excellence. Preoperative tests: the use of routine preoperative tests for elective surgery. https://www.nice.org.uk/guidance/ng45/chapter/Recommendations#table-2-intermediate-surgery. Accessed 12 Dec 2020.
11. Duceppe E, Patel A, Chan MTV, Berwanger O, Ackland G, Kavsak PA, Rodseth R, Biccard B, Chow CK, Borges FK, Guyatt G, Pearse R, Sessler DI, Heels-Ansdell D, Kurz A, Wang CY, Szczeklik W, Srinathan S, Garg AX, Pettit S, Sloan EN, Januzzi JL Jr, McQueen M, Buse GL, Mills NL, Zhang L, Sapsford R, Paré G, Walsh M, Whitlock R, Lamy A, Hill S, Thabane L, Yusuf S, Devereaux PJ. Preoperative N-terminal pro-B-type natriuretic peptide and cardiovascular events after noncardiac surgery: a cohort study. Ann Intern Med.

2020;172(2):96–104. https://doi.org/10.7326/M19-2501. Epub 2019; Dec 24. PMID: 31869834.
12. Ushirozako H, Ohishi T, Fujita T, et al. Does N-terminal pro-brain type natriuretic peptide predict cardiac complications after hip fracture surgery? Clin Orthop Relat Res. 2017;475(6):1730–6. https://doi.org/10.1007/s11999-017-5245-5.
13. Botto F, Alonso-Coello P, Chan MT, Villar JC, Xavier D, Srinathan S, Guyatt G, Cruz P, Graham M, Wang CY, Berwanger O, Pearse RM, Biccard BM, Abraham V, Malaga G, Hillis GS, Rodseth RN, et al. Vascular events In noncardiac Surgery patIents cOhort evaluatioN (VISION) Writing Group, on behalf of The Vascular events In noncardiac Surgery patIents cOhort evaluatioN (VISION) Investigators; Appendix 1. The Vascular events In noncardiac Surgery patIents cOhort evaluatioN (VISION) Study Investigators Writing Group; Appendix 2. The Vascular events In noncardiac Surgery patIents cOhort evaluatioN Operations Committee; Vascular events In noncardiac Surgery patIents cOhort evaluatioN VISION Study Investigators. Myocardial injury after noncardiac surgery: a large, international, prospective cohort study establishing diagnostic criteria, characteristics, predictors, and 30-day outcomes. Anesthesiology. 2014;120(3):564–78. https://doi.org/10.1097/ALN.0000000000000113. PMID: 24534856.
14. Brett AS. Reviewing writing committee for the VISION study investigators. JAMA. 2017; Apr 25.
15. Fleisher LA, Beckman JA, Brown KA, et al. American College of Cardiology. American Heart Association Task Force on Practice Guidelines (writing committee to revise the 2002 guidelines on perioperative cardiovascular evaluation for noncardiac surgery); American Society of Echocardiography; American Society of Nuclear Cardiology; Heart Rhythm Society; Society of Cardiovascular Anesthesiologists; Society for Cardiovascular Angiography and Interventions; Society for Vascular Medicine and Biology; Society for Vascular Surgery. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery [published corrections appear]. J Am Coll Cardiol. 2007;50(17):e242. J Am Coll Cardiol. 2008;52(9):793–794. J Am Coll Cardiol. 2007;50(17):e159–e241.
16. Qaseem A, Snow V, Fitterman N, et al.; Clinical Efficacy Assessment Subcommittee of the American College of Physicians. Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery. Ann Intern Med. 2006;144(8):575–80.
17. Douglas PS, Garcia MJ, Haines DE, Lai WW, Manning WJ, Patel AR, Picard MH, Polk DM, Ragosta M, Ward RP, Weiner RB. ACCF/ASE/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 appropriate use criteria for echocardiography: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, and Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr. 2011;24:229–67.
18. Sinvani L, et al. Preoperative noninvasive cardiac testing in older adults with hip fracture: a multi-site study. J Am Geriatr Soc. 2020;68(8):1690–7.
19. Sugawara A, Hanada S, Hayashi K, Kurosawa A, Suno M, Kunisawa T. Anesthetic management using effect-site target-controlled infusion of dexmedetomidine. J Clin Anesth. 2019;55:42. https://doi.org/10.1016/j.jclinane.2018.12.022. Epub 2018 Dec 27. PMID: 30594679.
20. McGee S. Etiology and diagnosis of systolic murmurs in adults. Am J Med. 2010;123(10):913–921.e1. https://doi.org/10.1016/j.amjmed.2010.04.027. PMID: 20920693.
21. Park HY, Kim S, Sohn HS, Kwon JW. The association between polypharmacy and hip fracture in osteoporotic women: a nested case-control study in South Korea. Clin Drug Investig. 2019;39(1):63–71. https://doi.org/10.1007/s40261-018-0716-3. PMID: 30306340.

22. Butt DA, Mamdani M, Austin PC, Tu K, Gomes T, Glazier RH. The risk of hip fracture after initiating antihypertensive drugs in the elderly. Arch Intern Med. 2012;172(22):1739–44. https://doi.org/10.1001/2013.jamainternmed.469. PMID: 23165923.
23. Brännström J, Lövheim H, Gustafson Y, Nordström P. Association between antidepressant drug use and hip fracture in older people before and after treatment initiation. JAMA Psychiat. 2019;76(2):172–9. https://doi.org/10.1001/jamapsychiatry.2018.3679. PMID: 30601883; PMCID: PMC6440395.
24. Roshanov PS, Rochwerg B, Patel A, Salehian O, Duceppe E, Belley-Côté EP, Guyatt GH, Sessler DI, Le Manach Y, Borges FK, Tandon V, Worster A, Thompson A, Koshy M, Devereaux B, Spencer FA, Sanders RD, Sloan EN, Morley EE, Paul J, Raymer KE, Punthakee Z, Devereaux PJ. Withholding versus continuing angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers before noncardiac surgery: an analysis of the Vascular events In noncardiac Surgery patIents cOhort evaluatioN prospective cohort. Anesthesiology. 2017;126(1):16–27. https://doi.org/10.1097/ALN.0000000000001404. PMID: 27775997.
25. Fleisher LA, Fleischmann KE, Auerbach AD, Barnason SA, et al. ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. J Am Coll Cardiol. 2014;64(22):e77–e137.
26. Kristensen SD, Knuuti J, Saraste A, Anker S, Bøtker HE, Hert SD, Ford I, Gonzalez-Juanatey JR, Gorenek B, Heyndrickx GR, Hoeft A, Huber K, Iung B, Kjeldsen KP, Longrois D, Lüscher TF, Pierard L, Pocock S, Price S, Roffi M, Sirnes PA, Sousa-Uva M, Voudris V, Funck-Brentano C, Authors/Task Force Members. 2014 ESC/ESA guidelines on non-cardiac surgery: cardiovascular assessment and management: the joint task force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). Eur Heart J. 2014;35(35):2383–431. https://doi.org/10.1093/eurheartj/ehu282. Epub 2014 Aug 1. PMID: 25086026.
27. Duceppe E, Parlow J, MacDonald P, Lyons K, McMullen M, Srinathan S, Graham M, Tandon V, Styles K, Bessissow A, Sessler DI, Bryson G, Devereaux PJ. Canadian Cardiovascular Society guidelines on perioperative cardiac risk assessment and management for patients who undergo noncardiac surgery. Can J Cardiol. 2017;33(1):17–32. https://doi.org/10.1016/j.cjca.2016.09.008. Epub 2016 Oct 4. Erratum in: Can J Cardiol. 2017 Dec;33(12):1735. PMID: 27865641.
28. American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea. Practice guidelines for the perioperative management of patients with obstructive sleep apnea: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Management of patients with obstructive sleep apnea. Anesthesiology. 2014;120(2):268–86. https://doi.org/10.1097/ALN.0000000000000053. PMID: 24346178.
29. Douketis JD, Spyropoulos AC, Spencer FA, Mayr M, Jaffer AK, Eckman MH, Dunn AS, Kunz R. Perioperative management of antithrombotic therapy: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of chest physicians evidence-based clinical practice guidelines. Chest. 2012;141(2 Suppl):e326S–50S. https://doi.org/10.1378/chest.11-2298. Erratum in: Chest. 2012 Apr;141(4):1129. PMID: 22315266; PMCID: PMC3278059.
30. Cohn SL, Fernandez Ros N. Comparison of 4 cardiac risk calculators in predicting postoperative cardiac complications after noncardiac operations. Am J Cardiol. 2018;121(1):125–30. https://doi.org/10.1016/j.amjcard.2017.09.031. Epub 2017 Oct 13. PMID: 29126584.
31. Alrezk R, Jackson N, Al Rezk M, Elashoff R, Weintraub N, Elashoff D, Fonarow GC. Derivation and validation of a geriatric-sensitive perioperative cardiac risk index. J Am Heart Assoc. https://doi.org/10.1161/JAHA.117.006648. Originally published15 Nov 2017.
32. Geriatric-Sensitive Perioperative Cardiac Risk Index | GSCRI | QxMD. Accessed 16 Jan 2021.
33. ACS Risk Calculator - Home Page (facs.org). Accessed 16 Jan 2021.

34. Wang X, Zhao BJ, Su Y. Can we predict postoperative complications in elderly Chinese patients with hip fractures using the surgical risk calculator? Clin Interv Aging. 2017;12:1515–20. https://doi.org/10.2147/CIA.S142748. PMID: 29026289; PMCID: PMC5626238.
35. Gupta Postoperative Respiratory Failure Risk Calculator (mdapp.co). Accessed 16 Jan 2021.
36. Smetana GW, Lawrence VA, Cornell JE. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144:581–95. [Epub ahead of print 18 April 2006]. https://doi.org/10.7326/0003-4819-144-8-200604180-00009.
37. Sieber FE, Mears S, Lee H, Gottschalk A. Postoperative opioid consumption and its relationship to cognitive function in older adults with hip fracture. J Am Geriatr Soc. 2011;59(12):2256–62. https://doi.org/10.1111/j.1532-5415.2011.03729.x. Epub 2011 Nov 7. PMID: 22092232; PMCID: PMC3245376.
38. Dixon J, Ashton F, Baker P, Charlton K, Bates C, Eardley W. Assessment and early management of pain in hip fractures: the impact of paracetamol. Geriatr Orthop Surg Rehabil. 2018;9:2151459318806443. https://doi.org/10.1177/2151459318806443. PMID: 30377550; PMCID: PMC6202735.
39. Handoll HH, Queally JM, Parker MJ. Pre-operative traction for hip fractures in adults. Cochrane Database Syst Rev. 2011;12:CD000168. https://doi.org/10.1002/14651858.CD000168.pub3. Affiliations expand
40. Southwell-Keely JP, Russo RR, March L, Cumming R, Cameron I, Brnabic AJ. Antibiotic prophylaxis in hip fracture surgery: a metaanalysis. Clin Orthop Relat Res. 2004;419:179–84. https://doi.org/10.1097/00003086-200402000-00029. PMID: 15021151.
41. Southwell-Keely JP, Russo RR, March L, Cumming R, Cameron I, Brnabic AJM. Antibiotic prophylaxis in hip fracture surgery: a metaanalysis. Clin Orthop Relat Res. 2004;419:179–84.
42. Antibiotic prophylaxis in patients with orthopedic implants undergoing dental procedures: a review of clinical effectiveness, safety, and guidelines [Internet]. Ottawa: Canadian Agency for Drugs and Technologies in Health; 2016. PMID: 27030856.
43. Falck-Ytter Y, Francis CW, Johanson NA, et al. Prevention of VTE in orthopedic surgery patients: antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2012;141:e278S–325S.
44. British Orthopaedic Association. The care of patients with fragility fracture. http://www.fractures.com/pdf/BOA-BGS-Blue-Book.pdf. Last accessed 16 Jan 2021.
45. National Institute for Health and Clinical Excellence. Venous thromboembolism in over 16s: reducing the risk of hospital-acquired deep vein thrombosis or pulmonary embolism. https://www.nice.org.uk/guidance/ng89. Last accessed 21 Jan 2021.
46. Flevas DA, Megaloikonomos PD, Dimopoulos L, Mitsiokapa E, Koulouvaris P, Mavrogenis AF. Thromboembolism prophylaxis in orthopaedics: an update. EFORT Open Rev. 2018;3(4):136–48.
47. Scottish Intercollegiate Guidelines Network (SIGN). Management of hip fractures in older people. Edinburgh: SIGN; 2009. http://www.sign.ac.uk/pdf/sign111.pdf. Last accessed Jan 2021.
48. Shin WC, Woo SH, Lee SJ, Lee JS, Kim C, Suh KT. Preoperative prevalence of and risk factors for venous thromboembolism in patients with a hip fracture: an indirect multidetector CT venography study. J Bone Joint Surg Am. 2016;98(24):2089–95. https://doi.org/10.2106/JBJS.15.01329. PMID: 28002372.
49. Hung WW, Egol KA, Zuckerman JD, Siu AL. Hip fracture management: tailoring care for the older patient. JAMA. 2012;307(20):2185–94. https://doi.org/10.1001/jama.2012.4842. PMID: 22618926.
50. Chong CP, Savige JA, Lim WK. Medical problems in hip fracture patients. Arch Orthop Trauma Surg. 2010;130(11):1355–61. https://doi.org/10.1007/s00402-009-1038-y. Epub 2010 Jan 5. PMID: 20049603.
51. Goh EL, Lerner RG, Achten J, Parsons N, Griffin XL, Costa PML. Complications following hip fracture: results from the world hip trauma evaluation cohort study. Injury.

2020;51(6):1331–6. https://doi.org/10.1016/j.injury.2020.03.031. Epub 2020 Mar 30. PMID: 32268962; PMCID: PMC7322551.

52. McLaughlin MA, Orosz GM, Magaziner J, Hannan EL, McGinn T, Morrison RS, Hochman T, Koval K, Gilbert M, Siu AL. Preoperative status and risk of complications in patients with hip fracture. J Gen Intern Med. 2006;21(3):219–25. https://doi.org/10.1111/j.1525-1497.2006.00318.x. Epub 2005 Dec 22. PMID: 16390507; PMCID: PMC1828089.
53. Orosz GM, Magaziner J, Hannan EL, Morrison RS, Koval K, Gilbert M, McLaughlin M, Halm EA, Wang JJ, Litke A, Silberzweig SB, Siu AL. Association of timing of surgery for hip fracture and patient outcomes. JAMA. 2004;291(14):1738–43. https://doi.org/10.1001/jama.291.14.1738. PMID: 15082701; PMCID: PMC1454713.
54. Vidán MT, Sánchez E, Gracia Y, Marañón E, Vaquero J, Serra JA. Causes and effects of surgical delay in patients with hip fracture: a cohort study. Ann Intern Med. 2011;155(4):226–33. https://doi.org/10.7326/0003-4819-155-4-201108160-00006. PMID: 21844548.
55. Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof EL, Fleischmann KE, Freeman WK, Froehlich JB, Kasper EK, Kersten JR, Riegel B, Robb JF, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Buller CE, Creager MA, Ettinger SM, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Hunt SA, Lytle BW, Nishimura R, Ornato JP, Page RL, Riegel B, Tarkington LG, Yancy CW. American College of Cardiology; American Heart Association task force on practice guidelines (writing committee to revise the 2002 guidelines on perioperative cardiovascular evaluation for noncardiac surgery); American Society of Echocardiography; American Society of Nuclear Cardiology; Heart Rhythm Society; Society of Cardiovascular Anesthesiologists; Society for Cardiovascular Angiography and Interventions; Society for Vascular Medicine and Biology; Society for Vascular Surgery. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (writing committee to revise the 2002 guidelines on perioperative cardiovascular evaluation for noncardiac surgery) developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. J Am Coll Cardiol. 2007;50(17):e159–241. https://doi.org/10.1016/j.jacc.2007.09.003. Erratum in: J Am Coll Cardiol. 2007 Oct 23;50(17):e242. Erratum in: J Am Coll Cardiol. 2008 Aug 26;52(9):793–4. Chaikof, Elliott [corrected to Chaikof, Elliott L]. PMID: 17950140.
56. Smeets SJ, Poeze M, Verbruggen JP. Preoperative cardiac evaluation of geriatric patients with hip fracture. Injury. 2012;43(12):2146–51. https://doi.org/10.1016/j.injury.2012.08.007. Epub 2012 Sep 18. PMID: 22995981.
57. Huddleston JM, Gullerud RE, Smither F, Huddleston PM, Larson DR, Phy MP, Melton LJ, Roger VL. Myocardial infarction after hip fracture repair: a population-based study. J Am Geriatr Soc. 2012;60:2020–6.
58. Vallet H, Breining A, Le Manach Y, et al. Isolated cardiac troponin rise does not modify the prognosis in elderly patients with hip fracture. Medicine. 2017;96(7):e6169. https://doi.org/10.1097/md.0000000000006169.
59. Cullen MW, Gullerud RE, Larson DR, Melton LJ 3rd, Huddleston JM. Impact of heart failure on hip fracture outcomes: a population-based study. J Hosp Med. 2011;6(9):507–12. https://doi.org/10.1002/jhm.918. Epub 2011 Oct 31. PMID: 22042721; PMCID: PMC3230699.
60. Xiang G, Dong X, Xu T, Feng Y, He Z, Ke C, Xiao J, Weng YM. A nomogram for prediction of postoperative pneumonia risk in elderly hip fracture patients. Risk Manag Healthc Policy. 2020;13:1603–11. https://doi.org/10.2147/RMHP.S270326. PMID: 32982518; PMCID: PMC7502327.
61. Chang SC, Lai JI, Lu MC, Lin KH, Wang WS, Lo SS, Lai YC. Reduction in the incidence of pneumonia in elderly patients after hip fracture surgery: an inpatient pulmonary rehabilitation program. Medicine (Baltimore). 2018;97(33):e11845. https://doi.org/10.1097/MD.0000000000011845. PMID: 30113476; PMCID: PMC6113002.

62. Fabian TC, Hoots AV, Stanford DS, Patterson CR, Mangiante EC. Fat embolism syndrome: prospective evaluation in 92 fracture patients. Crit Care Med. 1990;18(1):42–6. PMID: 2293968.
63. Shaikh N. Emergency management of fat embolism syndrome. J Emerg Trauma Shock. 2009;2(1):29–33. https://doi.org/10.4103/0974-2700.44680. PMID: 19561953; PMCID: PMC2700578.
64. Li CT, Reddy YN, Bonnichsen CR. 62-year-old woman with acute hypotension and hypoxia after surgical repair of hip. Mayo Clin Proc. 2016;91(8):e111–6. https://doi.org/10.1016/j.mayocp.2016.03.011. Epub 2016 May 26. PMID: 27236427.
65. Miller TE, Myles PS. Perioperative fluid therapy for major surgery. Anesthesiology. 2019;130(5):825–32. https://doi.org/10.1097/ALN.0000000000002603. Erratum in: Anesthesiology. 2020 Feb;132(2):405. PMID: 30789364.
66. Feldheiser A, Aziz O, Baldini G, Cox BP, Fearon KC, Feldman LS, Gan TJ, Kennedy RH, Ljungqvist O, Lobo DN, Miller T, Radtke FF, Ruiz Garces T, Schricker T, Scott MJ, Thacker JK, Ytrebø LM, Carli F. Enhanced Recovery After Surgery (ERAS) for gastrointestinal surgery, part 2: consensus statement for anaesthesia practice. Acta Anaesthesiol Scand. 2016;60:289–334.
67. Varadhan KK, Lobo DN. A meta-analysis of randomised controlled trials of intravenous fluid therapy in major elective open abdominal surgery: getting the balance right. Proc Nutr Soc. 2010;69:488–98.
68. Brandstrup B, Svendsen PE, Rasmussen M, Belhage B, Rodt SA, Hansen B, Moller DR, Lundbech LB, Andersen N, Berg V, Thomassen N, Andersen ST, Simonsen L. Which goal for fluid therapy during colorectal surgery is followed by the best outcome: near-maximal stroke volume or zero fluid balance? Br J Anaesth. 2012;109:191–9.
69. Kyziridis TC. Post-operative delirium after hip fracture treatment - a review of the current literature. Psychosoc Med. 2006;3:Doc01. PMID: 19742275; PMCID: PMC2736510.
70. Robertson BD, Robertson TJ. Postoperative delirium after hip fracture. J Bone Joint Surg Am. 2006;88(9):2060–8. https://doi.org/10.2106/JBJS.F.00049. PMID: 16951125.
71. Furlaneto ME, Garcez-Leme LE. Delirium in elderly individuals with hip fracture: causes, incidence, prevalence, and risk factors. Clinics (Sao Paulo). 2006;61(1):35–40. https://doi.org/10.1590/s1807-59322006000100007. Epub 2006; Mar 10. PMID: 16532223.
72. Lundström M, Olofsson B, Stenvall M, Karlsson S, Nyberg L, Englund U, Borssén B, Svensson O, Gustafson Y. Postoperative delirium in old patients with femoral neck fracture: a randomized intervention study. Aging Clin Exp Res. 2007;19(3):178–86. https://doi.org/10.1007/BF03324687. PMID: 17607084.
73. Marcantonio ER, Flacker JM, Wright RJ, Resnick NM. Reducing delirium after hip fracture: a randomized trial. J Am Geriatr Soc. 2001;49(5):516–22. https://doi.org/10.1046/j.1532-5415.2001.49108.x.
74. Kim EM, Li G, Kim M. Development of a risk score to predict postoperative delirium in patients with hip fracture. Anesth Analg. 2020;130(1):79–86. https://doi.org/10.1213/ANE.0000000000004386. PMID: 31478933; PMCID: PMC6917900.
75. Sieber FE, Neufeld KJ, Gottschalk A, Bigelow GE, Oh ES, Rosenberg PB, Mears SC, Stewart KJ, Ouanes JP, Jaberi M, Hasenboehler EA, Li T, Wang NY. Effect of depth of sedation in older patients undergoing hip fracture repair on postoperative delirium: the STRIDE randomized clinical trial. JAMA Surg. 2018;153(11):987–95. https://doi.org/10.1001/jamasurg.2018.2602. PMID: 30090923; PMCID: PMC6583071.
76. Sieber F, Neufeld KJ, Gottschalk A, Bigelow GE, Oh ES, Rosenberg PB, Mears SC, Stewart KJ, Ouanes JP, Jaberi M, Hasenboehler EA, Wang NY. Depth of sedation as an interventional target to reduce postoperative delirium: mortality and functional outcomes of the strategy to reduce the incidence of postoperative delirium in elderly patients randomised clinical trial. Br J Anaesth. 2019;122(4):480–9. https://doi.org/10.1016/j.bja.2018.12.021. Epub 2019 Feb 4. PMID: 30857604; PMCID: PMC64359.

77. Ungur AL, Neumann T, Borchers F, Spies C. Perioperative management of alcohol withdrawal syndrome. Visc Med. 2020;36(3):160–6. https://doi.org/10.1159/000507595. Epub 2020 Jun 9. PMID: 32775345; PMCID: PMC7383285.
78. Wang Y, Tang J, Zhou F, Yang L, Wu J. Comprehensive geriatric care reduces acute perioperative delirium in elderly patients with hip fractures: a meta-analysis. Medicine (Baltimore). 2017;96(26):e7361. https://doi.org/10.1097/MD.0000000000007361. PMID: 28658156; PMCID: PMC5500078.
79. Carpintero P, Caeiro JR, Carpintero R, Morales A, Silva S, Mesa M. Complications of hip fractures: a review. World J Orthop. 2014;5(4):402–11. https://doi.org/10.5312/wjo.v5.i4.402. PMID: 25232517; PMCID: PMC4133447.
80. Ulucay C, Eren Z, Kaspar EC, Ozler T, Yuksel K, Kantarci G, Altintas F. Risk factors for acute kidney injury after hip fracture surgery in the elderly individuals. Geriatr Orthop Surg Rehabil. 2012;3(4):150–6. https://doi.org/10.1177/2151458512473827. PMID: 23569709; PMCID: PMC3598517.
81. Merchant RA, Lui KL, Ismail NH, Wong HP, Sitoh YY. The relationship between postoperative complications and outcomes after hip fracture surgery. Ann Acad Med Singap. 2005;34(2):163–8. PMID: 15827663.
82. Wald H, Epstein A, Kramer A. Extended use of indwelling urinary catheters in postoperative hip fracture patients. Med Care. 2005;43(10):1009–17. https://doi.org/10.1097/01.mlr.0000178199.07789.32. PMID: 16166870.
83. Schneider MA. Prevention of catheter-associated urinary tract infections in patients with hip fractures through education of nurses to specific catheter protocols. Orthop Nurs. 2012;31(1):12–8. https://doi.org/10.1097/NOR.0b013e3182419619. PMID: 22278644.
84. Gould CV, Umscheid CA, Agarwal RK, Kuntz G, Pegues DA, Healthcare Infection Control Practices Advisory Committee. Guideline for prevention of catheter-associated urinary tract infections 2009. Infect Control Hosp Epidemiol. 2010;31(4):319–26. https://doi.org/10.1086/651091. PMID: 20156062.
85. Versluysen M. Pressure sores in elderly patients. The epidemiology related to hip operations. J Bone Joint Surg Br. 1985;67(1):10–3. https://doi.org/10.1302/0301-620X.67B1.3968129. PMID: 3968129.
86. Partanen J, Syrjälä H, Vähänikkilä H, Jalovaara P. Impact of deep infection after hip fracture surgery on function and mortality. J Hosp Infect. 2006;62(1):44–9. https://doi.org/10.1016/j.jhin.2005.04.020. Epub 2005 Oct 10. PMID: 16221508.
87. Kayani B, Onochie E, Patil V, Begum F, Cuthbert R, Ferguson D, Bhamra J, Sharma A, Bates P, Haddad FS. Infographic: the effects of COVID-19 on perioperative morbidity and mortality in patients with hip fractures. Bone Joint J. 2020;102-B(10):1279–80. https://doi.org/10.1302/0301-620X.102B10.BJJ-2020-1774. PMID: 32993335.
88. De C, Wignall A, Giannoudis V, Jimenez A, Sturdee S, Aderinto J, Pandit H, Palan J, Gulati A. Peri-operative outcomes and predictors of mortality in COVID-19 positive patients with hip fractures: a multicentre study in the UK. Indian J Orthop. 2020;54(Suppl 2):1–11. https://doi.org/10.1007/s43465-020-00272-7. Epub ahead of print. PMID: 33052147; PMCID: PMC7545153.
89. Bovonratwet P, Bohl DD, Russo GS, Ondeck NT, Nam D, Della Valle CJ, Grauer JN. How common-and how serious- is Clostridium difficile colitis after geriatric hip fracture? Findings from the NSQIP dataset. Clin Orthop Relat Res. 2018;476(3):453–62. https://doi.org/10.1007/s11999.0000000000000099. PMID: 29443839; PMCID: PMC6260047.
90. Spahn DR. Anemia and patient blood management in hip and knee surgery: a systematic review of the literature. Anesthesiology. 2010;113(2):482–95. https://doi.org/10.1097/ALN.0b013e3181e08e97. PMID: 20613475.
91. Foss NB, Kristensen MT, Kehlet H. Anaemia impedes functional mobility after hip fracture surgery. Age Ageing. 2008;37(2):173–8. https://doi.org/10.1093/ageing/afm161. PMID: 18349013.

92. Peck J, Kepecs DM, Mei B, et al. The effect of preoperative administration of intravenous tranexamic acid during revision hip arthroplasty: a retrospective study. J Bone Joint Surg Am. 2018;100(17):1509–16. https://doi.org/10.2106/jbjs.17.01212.
93. Dai CQ, Wang LH, Zhu YQ, Xu GH, Shan JB, Huang WC, Wei LH, Zhou FL, Li Y. Risk factors of perioperative blood transfusion in elderly patients with femoral intertrochanteric fracture. Medicine (Baltimore). 2020;99(15):e19726. https://doi.org/10.1097/MD.0000000000019726.
94. Carson JL, Terrin ML, Magaziner J, Chaitman BR, Apple FS, Heck DA, Sanders D, FOCUS Investigators. Transfusion trigger trial for functional outcomes in cardiovascular patients undergoing surgical hip fracture repair (FOCUS). Transfusion. 2006;46(12):2192–206. https://doi.org/10.1111/j.1537-2995.2006.01056.x. PMID: 17176334.
95. Zhu C, Yin J, Wang B, Xue Q, Gao S, Xing L, Wang H, Liu W, Liu X. Restrictive versus liberal strategy for red blood-cell transfusion in hip fracture patients: a systematic review and meta-analysis. Medicine (Baltimore). 2019;98(32):e16795. https://doi.org/10.1097/MD.0000000000016795.
96. Golinvaux NS, Bohl DD, Basques BA, Baumgaertner MR, Grauer JN. Diabetes confers little to no increased risk of postoperative complications after hip fracture surgery in geriatric patients. Clin Orthop Relat Res. 2015;473(3):1043–51. https://doi.org/10.1007/s11999-014-3945-7. Epub 2014 Sep 20. PMID: 25238805; PMCID: PMC4317441.
97. Lee T, Lee Y, Chen J, et al. Impact of type 2 diabetes on postoperative outcome after hip fracture: nationwide population-based study in Taiwan. BMJ Open Diabetes Res Care. 2020;8:e000843. https://doi.org/10.1136/bmjdrc-2019-000843.
98. Bohl DD, Shen MR, Hannon CP, Fillingham YA, Darrith B, Della Valle CJ. Serum albumin predicts survival and postoperative course following surgery for geriatric hip fracture. J Bone Joint Surg Am. 2017;99(24):2110–8. https://doi.org/10.2106/JBJS.16.01620. Erratum in: J Bone Joint Surg Am. 2018 Mar 21;100(6):e41. PMID: 29257017.
99. Myint MW, Wu J, Wong E, Chan SP, To TS, Chau MW, Ting KH, Fung PM, Au KS. Clinical benefits of oral nutritional supplementation for elderly hip fracture patients: a single blind randomised controlled trial. Age Ageing. 2013;42(1):39–45. https://doi.org/10.1093/ageing/afs078. Epub 2012 Jun 8. PMID: 22685164.
100. Haleem S, Heinert G, Parker MJ. Pressure sores and hip fractures. Injury. 2008;39(2):219–23. https://doi.org/10.1016/j.injury.2007.08.030. Epub 2008 Jan 29. PMID: 18234201.
101. Qaseem A, Humphrey LL, Forciea MA, Starkey M, Denberg TD, Clinical Guidelines Committee of the American College of Physicians. Treatment of pressure ulcers: a clinical practice guideline from the American College of Physicians. Ann Intern Med. 2015;162(5):370–9. https://doi.org/10.7326/M14-1568. PMID: 25732279.
102. Rohatgi N, Wei PH, Grujic O, Ahuja N. Surgical comanagement by hospitalists in colorectal surgery. J Am Coll Surg. 2018;227(4):404–410.e5.
103. Maxwell BG, Mirza A. Medical comanagement of hip fracture patients is not associated with superior perioperative outcomes: a propensity score-matched retrospective cohort analysis of the national surgical quality improvement project. J Hosp Med. 2020;15(8):468–74. https://doi.org/10.12788/jhm.3343. PMID: 31869291.
104. Colwell J. Helping hip fractures: is comanagement the answer? ACP Hospitalist, December 2020, p. 8.
105. Morris JC, Moore A, Kahan J, Shapiro M, Li J, Spadaccino B, Baumgaertner M, O'Connor MI. Integrated fragility hip fracture program: a model for high quality care. J Hosp Med. 2020;15(8):461–7. https://doi.org/10.12788/jhm.3365. PMID: 32118555.
106. Sinvani L, Goldin M, Roofeh R, Idriss N, Goldman A, Klein Z, Mendelson DA, Carney MT. Implementation of hip fracture co-management program (AGS CoCare: Ortho®) in a large health system. J Am Geriatr Soc. 2020;68:1706–13.
107. Shaw M, Pelecanos AM, Mudge AM. Evaluation of internal medicine physician or multidisciplinary team comanagement of surgical patients and clinical outcomes: a systematic

review and meta-analysis. JAMA Netw Open. 2020;3(5):e204088. https://doi.org/10.1001/jamanetworkopen.2020.4088. PMID: 32369179; PMCID: PMC7201311.
108. Baroni M, Serra R, Boccardi V, Ercolani S, Zengarini E, Casucci P, Valecchi R, Rinonapoli G, Caraffa A, Mecocci P, Ruggiero C. The orthogeriatric comanagement improves clinical outcomes of hip fracture in older adults. Osteoporos Int. 2019;30(4):907–16. https://doi.org/10.1007/s00198-019-04858-2. Epub 2019 Feb 4. PMID: 30715561.
109. Swart E, Vasudeva E, Makhni EC, Macaulay W, Bozic KJ. Dedicated perioperative hip fracture comanagement programs are cost-effective in high-volume centers: an economic analysis. Clin Orthop Relat Res. 2016;474(1):222–33. https://doi.org/10.1007/s11999-015-4494-4. Epub 2015 Aug 11.
110. Stephens JR, Chang JW, Liles EA, Adem M, Moore C. Impact of hospitalist vs. nonhospitalist services on length of stay and 30-day readmission rate in hip fracture patients. Hosp Pract (1995). 2019;47(1):24–7. https://doi.org/10.1080/21548331.2019.1537850. Epub 2018 Oct 26. PMID: 30328742.
111. Bellas N, Stohler S, Staff I, Majk K, Lewis C, Davis S, Kumar M. Impact of preoperative specialty consults on hospitalist comanagement of hip fracture patients. J Hosp Med. 2020;15(1):16–21. https://doi.org/10.12788/jhm.3264. Epub 2019. Aug 16. PMID: 31433780.

Chapter 4
Applied Anatomy for Treatment of Geriatric Hip Fractures

Justin E. Hellwinkel, Austin C. Kaidi, and H. John Cooper

Introduction

The hip is a complex articulation between the proximal femur and pelvis that is surrounded by an elegant array of static and dynamic stabilizers to allow for weight bearing through the lower extremities. Through the early years of life, bones become strong, ligaments thicken to support the joint, and muscles learn to contract in a coordinated fashion that allow for ambulation and movement. As physiologic reserve deteriorates with aging, significant changes occur that weaken bone quality, ligamentous strength, muscular coordination, and healing potential. Fractures of the hip in the elderly are a common consequence of these changes. Variables such as baseline functional status, physical demands, and patient goals are assessed to help guide treatment strategies. Optimal surgical treatment of these injuries requires a thorough understanding of local anatomy to restore motion and minimize complications for patients.

Part 1: Anatomic Considerations in Geriatric Patients

Both the bone of the proximal femur and soft tissues surrounding the hip joint undergo significant age-related changes which have an impact on the management of geriatric hip fractures. These changes will be reviewed here.

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Age-Related Osseous Changes of the Proximal Femur

The proximal aspect of the femur is formed from three distinct ossification centers, which coalesce with the primary ossification center of the shaft by age 18 [1]. The three ossification centers within the femoral head, greater trochanter, and lesser trochanter begin ossification at 6 months, 4 years, and 14 years, respectively. The bony architecture of the proximal femur is influenced through articulation with the acetabulum and the associated muscular strain and weight bearing. In early age, a dense trabecular network of lamellar bone develops along lines of compressive and tensile stress in accordance with Wolff's law (Fig. 4.1) [2]. Medial and lateral principal trabeculae begin forming around 18 months of age, both extending from the femoral head to transmit compressive forces [2]. The secondary trabecular network and greater trochanteric trabeculae form later, around 9 years of age. A dense column of bone, the calcar femorale, lies along the posteromedial femoral neck and is the primary region for transmission of weight-bearing forces to the shaft.

The bone of the proximal femur undergoes dynamic deformation and remodeling throughout its lifespan, and the effects of aging have been well studied [3–5]. Subchondral bone continues to increase in density in the superior portion of the femoral head in response to weight bearing throughout adult years [6]. Cortical strength reaches maximum capacity at approximately 30 years of age for both males and females before a steady decline into the sixth decade of life, followed by a more rapid deterioration in the seventh through ninth decades of life [7, 8]. The natural progression of aging results in decreasing bone mineral density (BMD), most notably in postmenopasual females, and is thought to largely contribute to the risk of fragility fractures [9]. Geometric studies demonstrate that elderly female bone has thinner cortices and reduced capacity to resist compressive and bending forces [8]. These differences in structural fragility become more pronounced with greater age into the eighth and ninth decades of life. The proximal femoral osseous material is remodeled with aging to concentrate along primary trabecular lines of compression and along the cortex to maximize strength [10]. As a consequence, trabecular bone in the elderly ultimately only contributes to approximately 10% of the strength of

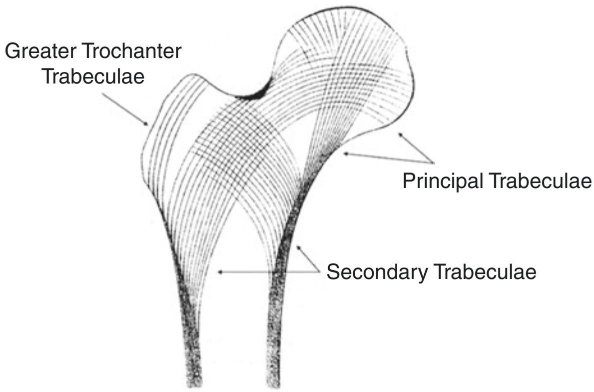

Fig. 4.1 Principle and secondary compressive and tensile groups of the proximal femur. (Reproduced from Hammer et al. [98])

the femoral neck [10]. Each of these osseous changes increases risk of proximal femur fractures in the geriatric population. Distally, the anterior bow of the femoral diaphysis is exaggerated with aging, which increases the risk for subtrochanteric femur fractures [11, 12].

Age-related osseous changes affect not only the susceptibility for fractures but also healing potential, which can dictate treatment strategies. Elderly patients who sustain hip fractures have significantly lower viability of osteocytes within the femoral head compared to younger patients, with some areas of bone containing no live osteocytes [13, 14]. Osteocyte viability likely starts declining after 30 years of age, with more precipitous decline in later years. Lack of osteocytes precludes normal bone healing processes and is suspected to be responsible for the relatively higher rate of osteonecrosis after hip fracture in elderly patients, particularly among females. Animal studies demonstrate a four- to sevenfold increase in osteocyte apoptosis in models of estrogen insufficiency [15]. Weight-bearing exercise increases bone strength, as osteocytes respond to mechanical loading in a U-shaped curve. When bone is completely unloaded or overloaded, both cortical and trabecular osteocytes undergo apoptosis. Intermittent periods of mechanical loading help reduce osteocyte apoptosis and improves turnover [16]. However, aging bone is less responsive to mechanical stimulation and does not undergo the robust remodeling seen in younger bone [17, 18]. These factors should be considered for both fracture prevention and rehabilitation after internal fixation for proximal femur fractures.

Age-Related Changes to Muscle

Muscle mass diffusely decreases with age [19, 20]. This “sarcopenia of aging” is a well-established phenomenon that is explained by social, nutritional, and metabolic factors [21–25]. Although irreversible, adequate nutrition and regular resistance training can slow or prevent the progression of sarcopenia [26–29]. Age-related sarcopenia may be an indicator of underlying bone health, since decreased lower limb muscle mass has been associated with decreases in femoral neck bone density [30].

Although sarcopenia of aging can affect all parts of the body, it more significantly affects the hind limbs [22, 31, 32]. This is not unique to humans and is seen in all mammals, including quadrupeds [33–35]. Lower extremity sarcopenia, and the resultant weakness, has been associated with increased elderly fall risks [36–38]. This is likely due to decreased balance and recovery capabilities in the setting of decreased efficacy of the dynamic stabilizers. Age-related weakness in hip adductor and abductor strength has been associated with more difficulty balancing and recovering while ambulating [39, 40]. Within elderly patients with hip fractures, lower cross-sectional area and higher percent of fatty infiltration of gluteus medius and minimus have been observed on the fractured hip compared to the healthy hip [41]. Abductor tendon degeneration is present in approximately 20% of elderly patients and likely responsible for lateral imbalance in the elderly as well, increasing risk for falls and fracture [42]. For these reason, postoperative rehabilitation protocols for geriatric hip fracture patients should not under-estimate the importance of adductor-abductor strengthening exercises, similar to what is often recommended for patients undergoing elective total hip arthroplasty [43, 44]. In addition to the adductor-abductor muscles, the quadriceps also decrease in size and strength as patients age and should be an area of focus for postoperative rehabilitation [45, 46].

Part 2: Applied Surgical Anatomy of the Hip

The anatomy of the hip has several important considerations that influence the management of geriatric hip fractures, including the vascular anatomy of the proximal femur, hip capsular anatomy, and anatomy of the surrounding soft tissue attachments to the proximal femur.

Vascular Supply and Risk of Osteonecrosis

Vascular anatomy of the proximal aspect of the femur plays a critical role in the treatment of hip fractures. The primary blood supply to the adult proximal femur begins with the femoral artery as it emerges below the inguinal ligament and through the femoral triangle, between the sartorius and adductor longus muscles. The femoral artery travels medial to the proximal femur, where its deep branch, the profunda femora artery, divides into three to four perforating arteries, which penetrate the adductor magnus along its length. Proximally, the profunda femora artery branches to supply the medial (MFCA) and lateral (LFCA) femoral circumflex arteries in approximately 50% of specimens, with approximately 30% of MFCA branching from the common femoral artery (Fig. 4.2) [47, 48]. The MFCA travels between iliopsoas and pectineus muscle bellies before diving posteriorly around the proximal femur toward the intertrochanteric crest. Here, it supplies a branch to the greater trochanter before crossing the obturator externus to join a pericapsular ring [48]. The LFCA arises from the profunda femora artery and travels anteriorly to join the pericapsular ring of the MFCA.

In early development, the MFCA and LFCA equally contribute to supply the proximal femur, followed by regression of the LFCA as the MFCA becomes the dominant blood supply to the femoral head [49]. In the adult, the MFCA contributes approximately 82% of the vascular contribution to the femoral head and 67% to the femoral neck, whereas the LFCA contributes 18% to the head and 33% to the neck, most notably along the anteroinferior aspect of the neck [50]. The MFCA and LCFA form an extracapsular ring at the base of the femoral neck, which receives additional minor contributions from the superior and inferior gluteal arteries [51]. Collateral circulation to the pericapsular ring is provided by the first perforating branch of

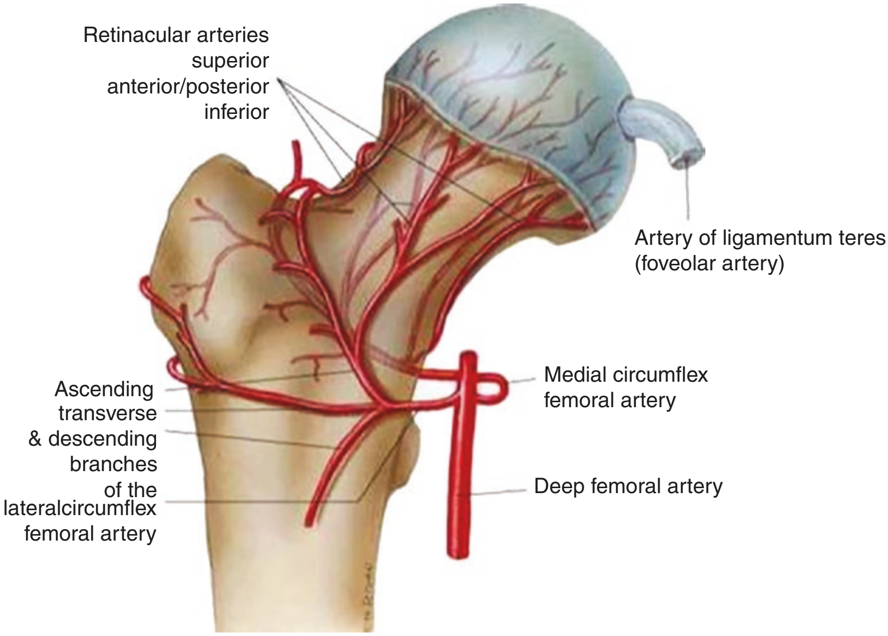

Fig. 4.2 Vascular anatomy of the proximal femur. The deep femoral artery branches to form the medial femoral circumflex artery (MFCA) and lateral femoral circumflex artery (LFCA), which create a pericapsular anastomotic ring. Retinacular vessels arising from this ring perforate the capsule to supply the femoral neck and terminate in the head region. (Courtesy of ALPF Medical Research, annotations added by authors. (https://www.alpfmedical.info/femoral-head/vascular-supply-to-the-femoral-head.html))

femora profunda and the inferior gluteal artery. These create a cruciate anastomosis about the posterior aspect of the femoral neck. Ascending cervical branches arise from the extracapsular arterial ring in line with the femoral neck and contribute to the metaphyseal region. There are four primary branches that penetrate the capsule and form an intraarticular anastomotic ring at the margin of the articular cartilage. Epiphyseal arterial branches arise from this intraarticular ring and enter the femoral head. The deep branch of the MFCA provides the lateral epiphyseal artery postero-superiorly, which is the major contributor of blood supply to the weight-bearing portion of the femoral head [48, 52].

The artery of the ligamentum teres arises within the acetabulum as a terminal branch of the obturator artery and travels within the ligamentum teres, attaching to the fovea capitis of the femur. The artery of the ligamentum teres is the primary blood supply to the epiphysis of the femoral head during development, eventually creating an anastomosis with the distal metaphyseal artery after physeal closure. In adults, there is negligible contribution of this vessel to the femoral head. The smallest contribution of vascular supply to the femoral head arises from the intraosseous supply of trabecular sinusoids. When the hip is fractured, this supply, and therefore its ability to contribute to healing, is compromised.

Approximately one-half of all hip fractures are intracapsular where blood supply is tenuous, resulting in considerable risk for development of osteonecrosis and decreased potential for healing. Extracapsular hip fractures have a much more robust vascular supply as outlined above, which very rarely results in osteonecrosis of the femoral head (ONFH), even in the elderly [53].

It is theorized that disruption of periarticular perforating vessels or the deep branch of the MFCA through shear forces at the time of fracture is responsible for the development of ONFH. Subsequent increased intracapsular pressure secondary to fracture hematoma and kinking of the MFCA likely exacerbate vascular compromise in the subacute phase of injury [54]. Surgically, the quality of internal fixation plays a significant role in the risk of osteonecrosis and nonunion as well [55]. The overall incidence of ONFH for nondisplaced intracapsular femoral neck fractures across all age groups is approximately 4%, although this increases to 9–16% for displaced femoral neck fractures [56]. The risk of development of osteonecrosis decreases with increasing age, likely due to the relatively lower energy required to sustain a femoral neck fracture in older patients. Patients younger than 60 years of age with displaced femoral neck fractures exhibit a 20% incidence of osteonecrosis. This declines to approximately 12% in the elderly population with displaced femoral neck fractures treated with internal fixation; however, the reoperation rate in this treatment group is as high as 35%, due to high rates of nonunion [57–59]. In a subgroup analysis of 1023 patients, timing of surgical fixation did not affect the development of ONFH in elderly patients [56]. Increased nonunion rates and ONFH in the elderly population are very closely related to vascular supply and largely responsible for the high revision rate after internal fixation. Despite the relatively common outcome of ONFH after femoral neck fracture, many patients still have acceptable functional outcomes, but revision surgery rates can be as high as 30% in the elderly population [60].

Early detection or prediction of patients who will develop ONFH after a femoral neck fracture can be helpful in providing appropriate treatment and reducing the risk of postoperative femoral head collapse and revision surgery. Numerous imaging modalities have attempted to quantify the risk of osteonecrosis development for femoral neck fractures. Early enthusiasm was garnered for magnetic resonance imaging, but these studies are expensive and not always readily available [61]. In elderly hip fracture patients, Park et al. demonstrated 100% sensitivity and 63.6% specificity in predicting osteonecrosis of the femoral head with single-photon emission computed tomography/computed tomography (SPECT/CT) [62].

With specialized intraoperative instruments, the risk of ONFH may also be evaluated intraoperatively. Wantanabe et al. utilized intramedullary oxygen gradients at the time of internal fixation to predict osteonecrosis with 100% sensitivity and 82% specificity [63].

The Hip Capsule

The synovial-lined hip capsule is a complex heterogeneous structure composed primarily of type I collagen in longitudinally oriented retinacular fibers along the neck of the femur [64]. The hip capsule originates from just proximal to the rim of the acetabulum where fibers are contiguous with the acetabular periosteum. Distally, the anterior capsule attaches to the intertrochanteric line of the femur, while the inferior aspect attaches just proximal to the lesser trochanter. Superiorly the capsule attaches in the saddle point where the base of the greater trochanter meets the lateral neck (Fig. 4.3). The posterior fibers of the capsule blend with the zona orbicularis, a series of fibers oriented perpendicular to the femoral neck and inserting medial to the intertrochanteric crest of the femur. The zona orbicularis supports the posterior capsular attachment and creates a collar-type mechanism to provide capsular stability and medialization of the femoral head into the acetabulum. Three extracapsular ligaments arranged in a helical fashion help support the joint and provide stability in three planes of motion. These ligaments (iliofemoral, ischiofemoral, pubofemoral) envelope and blend with the hip capsule, with each having a distinct biomechanical role in maintaining hip stability (Fig. 4.3). The iliofemoral ligament (of Bigelow) comprises a superior and an inferior band, both originating just inferior to the anterior inferior iliac spine and acetabular rim and inserting broadly along the superior and inferior intertrochanteric lines, respectively. This ligament is most taut in hip extension and external rotation, providing robust support to the anterior capsule. Posteriorly, the ischiofemoral ligament comprises a superior and an inferior band, both originating from the posterior acetabular rim and attaching to the superior and inferior zona orbicularis fibers, respectively, to resist hip internal rotation [65]. The pubofemoral ligament travels from the inferior aspect of the acetabulum and inserts just near the lesser trochanter, noted to be tightest in abduction.

The hip capsule is thicker and contains more layers on the anterior and superior aspects, whereas the posterior and inferior aspects are thinner and less complex. The anterior ligaments are biomechanically able to withstand greater tensile forces than posterior ligaments, implicating their role in anterior stability [66]. In the setting of hemiarthroplasty for hip fractures, a posterior-based approach has a significantly greater odds of dislocation compared to anterior or lateral approaches [67]. Capsular ligaments undergo biochemical and functional changes resulting in loss of tissue strength with aging, loss of fiber organization, and greater cell senescence. In a biomechanical cadaveric study of the three primary ligaments of the hip, Schleifenbaum et al. demonstrated greater strain for iliofemoral and pubofemoral ligament in specimens greater than 55 years old. When stratified by age, there was also a notable decrease in pubofemoral elastic modulus and thus greater stiffness. Surgical considerations for soft tissue balance will be discussed in more detail below.

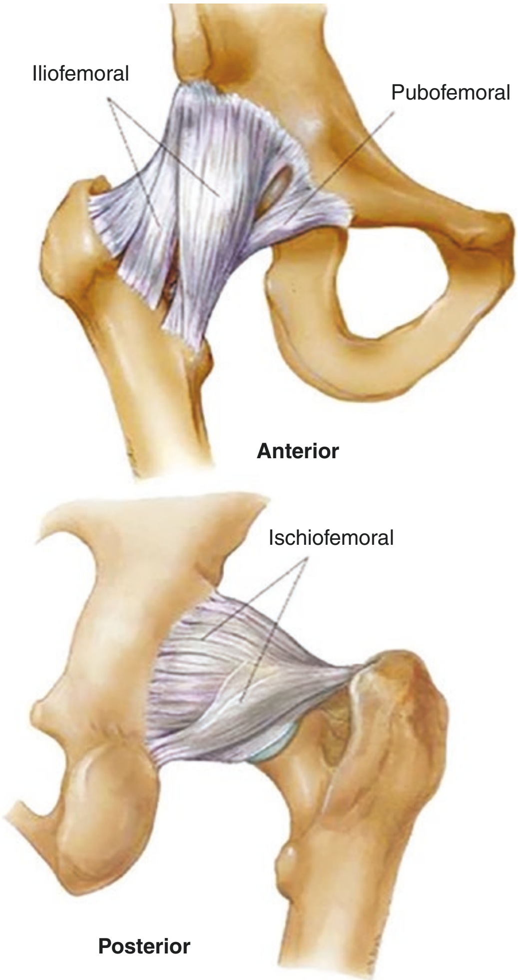

Fig. 4.3 Hip capsule and surrounding ligaments. The iliofemoral, ischiofemoral, and pubofemoral ligaments arranged in a helical pattern allow for movement and stability of the hip through all planes of motion. (Courtesy of ALPF Medical Research (https://www.alpfmedical.info/femoral-head/capsular-and-joint-architecture.html))

Pericapsular Anatomy

Soft tissue structures around the hip joint and hip capsule also play a critical role in the stabilization of the hip joint and management of fractures in the elderly [68]. While the hip's capsular ligaments play a critical role in static stabilization of the hip joint, muscular attachments onto the proximal femur provide important dynamic stabilization. Moreover, they can act as deforming forces that must be considered when managing hip fractures [69–71].

The majority of the hip's dynamic stabilizers originate on the pelvis and insert onto aspects of the greater trochanter of the femur. These include the gluteus medius, gluteus minimus, and short external rotators of the hip (piriformis, obturator internus, superior and inferior gemelli, and obturator externus). The greater trochanter is also the site of origin for the vastus lateralis and vastus medialis. Other muscular insertions onto the proximal femur include the iliopsoas onto the lesser trochanter of the femur, quadratus femoris onto the intertrochanteric crest, and some fibers of the gluteus maximus onto the gluteal tuberosity. More distally, the adductors (longus, brevis, and magnus) insert along the linea aspera of the femur. The iliopsoas plays a particularly significant role in stabilization of the hip, as it wraps around a majority of the anterior hip capsule [70].

These muscular attachments onto the proximal femur explain physical examination findings and guide treatments in hip fracture patients, as the force vectors of these structures can result in classic and predictable deformities depending on the location of the fracture lines. In patients with proximal femur fractures, unopposed action of the short-external rotators and abductors (gluteus muscles) results in a shortened and externally rotated leg [72]. Subtrochanteric fractures can commonly be difficult to reduce because the proximal fragment can be flexed, abducted, and externally rotated relative to the shaft by the iliopsoas, gluteus medius and minimus, and the short external rotators, respectively. The adductors can also externally rotate the leg, and the broad, incontiguous insertions of the adductors along the linea aspera can make reduction difficult in intertrochanteric and subtrochanteric fractures with significant medial comminution [73]. Comminuted fractures with lesser trochanteric fragments are also particularly challenging to anatomically reduce because of the anterior force created by the iliopsoas. Research has found equivalent functional outcomes in patients with non-reduced lesser trochanter fragments; however, research has not looked into long-term hip stability in these patients (Figs. 4.4 and 4.5) [74, 75].

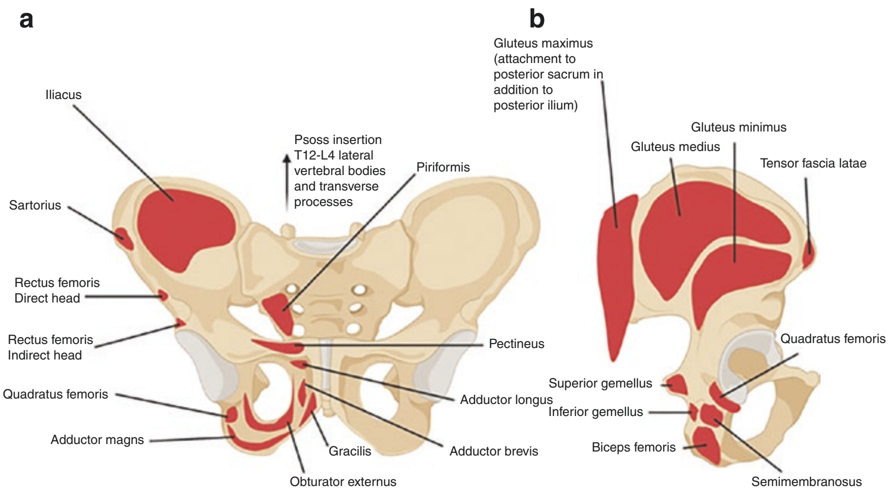

Fig. 4.4 (**a**) and (**b**): Muscular attachments of the innonimate bone and sacrum. Muscles that originate on the innonimate bone and cross the hip joint act as dynamic stabilizers of the joint. (**a**) AP view of the pelvis. (**b**) Lateral view of the innonimate bone. (Created with biorender.com)

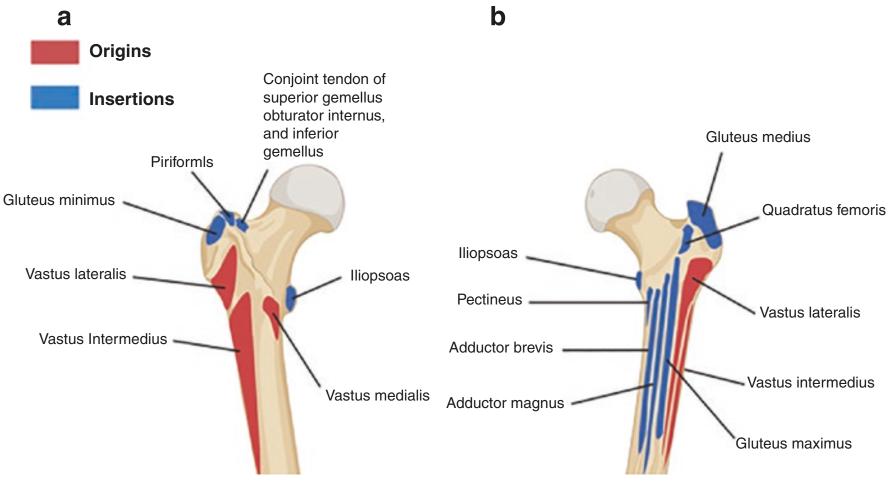

Fig. 4.5 (**a**) and (**b**) Muscular attachments of the proximal femur. Muscles that insert on the proximal femur and cross the hip joint act as dynamic stabilizers of the joint. (**a**) AP view of the femur. (**b**) Posterior view of the femur. (Created with biorender.com)

Part 3: Surgical Decision-Making

Understanding the relevant anatomical considerations covered above will allow surgeons to choose the most appropriate treatment for the patient and will inform details of surgical technique. Hip fracture management relies upon choosing the procedure that, when possible, will enable stable fixation or replacement of the fracture fragments based on the physiologic and chronologic age of the patient, lifestyle factors, and medical comorbidities, all of which contribute to variations in bone quality.

Intracapsular Versus Extracapsular Fractures

Fracture location in relation to the hip capsule is the first major factor in dictating choice of treatment. As described above, extracapsular fractures, including subtrochanteric, intertrochanteric, and basicervical femoral neck fractures, have diffuse and redundant vascular supply. With reliable healing potential, they are generally treated with fracture reduction and stabilization to allow for healing using fixed angle devices such as intramedullary rods, sliding hip screws, and helical blades. Intracapsular fractures are bathed in synovial fluid and have tenuous blood supply, both of which significantly impact bone-healing potential [76]. For this reason, displaced intracapsular fractures in the geriatric population are typically addressed with arthroplasty.

Minimally Displaced Intracapsular Fractures

If the fracture is located inside the hip capsule, the next relevant anatomical consideration is the degree of displacement. Minimally displaced and valgus-impacted femoral neck fractures within the hip capsule can often be successfully treated with internal fixation, commonly with in situ cannulated screws or a sliding hip screw (SHS). In a review of elderly patients treated with internal fixation for non-displaced femoral neck fractures, Conn et al. noted an overall nonunion rate of 4.3% and ONFH rate of 2.2% after 1 year [77]. Optimal placement of internal fixation devices should aim to maximize their support along strong cortical bone. As described above, remodeling of remaining bone in older age tends to preferentially concentrate away from trabeculae and along the cortex of the femoral neck. The posterior and inferior (calcar) aspects of the femoral neck retain the strongest bone, which is ideally where implant placement should be focused to maximize strength with weight bearing. Biomechanically, three cannulated screws in a parallel inverted triangle pattern yield the strongest construct [78]. The addition of a fourth screw in a diamond pattern does not have additional benefit in regard to complications, patient-reported outcomes, or clinical prognosis [79]. More recent data demonstrate the use of arthroplasty for treatment of valgus-impacted, or minimally displaced femoral neck fractures in the elderly can decrease the risk of reoperation by approximately 60–70% compared to internal fixation and may portend a mortality benefit over internal fixation [80, 81]. Similar patient satisfaction and patient-reported outcome scores have been reported with both modes of treatment [82].

Displaced Intracapsular Fractures

Due to unacceptably high risk of nonunion and osteonecrosis, displaced intracapsular femoral neck fractures in the geriatric population should be treated with prosthetic replacement to provide patients a stable weight-bearing construct to return them to functional ambulatory status [83]. Hemiarthroplasty and total hip arthroplasty performed for displaced femoral neck fractures both yield excellent outcomes which are superior to internal fixation. These procedures have relative risks and benefits, which will be explored in depth in Chap. 6: Surgical Treatment of Femoral Neck Fractures [71, 84]. Primary anatomic considerations for surgical management with arthroplasty include surgical approach, soft tissue tension, capsular management, and use of cement.

Arthroplasty for hip fracture is a significant procedure for elderly patients who often come to surgery with minimal physiologic reserve. Many surgical approaches have been described to date, with the posterolateral approach consistently the most widely utilized. This is probably reflective of training patterns of surgeons performing these procedures, as well as the relative ease of exposure of the hip joint. However, the use of relatively extensive exposures, increased intraoperative blood loss, and increased intraoperative time can produce excess surgical risk and prolong rehabilitation in the elderly population, who often have other medical comorbidities complicating their course. Less-invasive approaches allow for less muscular and capsular dissection and have been advocated in this population. Muscle-sparing approaches are beneficial in elderly patients with age-related sarcopenia to maximize muscular reserve and decrease bleeding and pain after surgery [85]. Mueller et al. utilized magnetic resonance imaging (MRI) and showed that use of a direct lateral approach for hip arthroplasty results in significantly greater fatty muscle atrophy of the gluteus medius in elderly patients at 3 and 12 months postoperatively compared to younger patients [86]. Muscle atrophy was correlated with worse clinical outcome scores in this population. The use of a minimally invasive lateral approach for elderly patients resulted in significantly better clinical outcome scores, less pain, and much less fatty atrophy, no different from the young cohort of patients. Bel et al. further noted that use of a 7 cm or smaller incision with a direct lateral (Hardinge) approach yielded less blood loss, less postoperative analgesia requirement, and faster time to walking without any additional surgical complication or compromise of implant placement [85]. The authors note the more technically demanding aspects of minimally invasive surgery benefit from experienced surgeons and strong knowledge of hip anatomy. Many high-volume centers aim for these patients to be treated by surgeons with specialty training in hip arthroplasty. Novel muscle-sparing modifications to the posterolateral approaches that maintain the short external rotators through small incisions result in less blood loss, less hospitalization time and cost, and quicker functional recovery [87].

Direct anterior (DA) muscle-sparing approaches have gained popularity in recent years in the fracture setting. Use of an intramuscular plane with the DA approach for hip fractures in elderly can allow full return of hip flexion power by 3 months and hip abduction by 6 weeks [88]. When compared to the posterolateral approach, DA approach for femoral neck fracture in elderly patients results in a shorter operation time, less risk of blood transfusion, less postoperative pain, and a shorter duration of hospitalization [89]. Additionally, when compared to the lateral (Hardinge) approach, the DA approach was found to be superior for earlier mobilization, less blood transfusions, and decreased pain [90]. In a systematic review comparing the DA approach to other approaches for hip fracture treatment, the DA approach resulted in a statistically significantly decreased dislocation rate [91]. There was also an overall trend toward greater functional recovery in the DA group, without difference in complications, intraoperative fracture, infections, reoperation rate, and perioperative blood loss.

Capsular, ligamentous, and muscular attachments of the hip provide stability for the native joint and are of particular interest in the arthroplasty setting for displaced femoral neck fractures. Recreating soft tissue balance is critical for hip stability when selecting the type, size, and position of implants for arthroplasty. Surgical approach largely determines the portion of the capsule most disrupted. Cadaveric studies demonstrate that posterior capsulotomy and repair results in increased range of motion of the hip in deep flexion compared to anterior capsulotomy and repair, suggesting greater instability with a posterior-based approach [92]. It is suspected that the zona orbicularis contributes to posterior stability and should be preserved when possible. Arthroplasty head size and neck length are additionally important to maintain proper length-tension relationships of capsular tissue to maximize mobility and decrease risk of dislocation. A smaller head size results in more laxity to the capsule, most notably along the posterior aspect [93]. For patients with a greater risk of postoperative dislocation, including patients with dementia or Parkinson's disease, hemiarthroplasty provides a relatively larger head size to promote stability within the articulation. Further implant designs including bipolar hemiarthroplasty and dual-mobility liners contribute to this stability. Femoral stability after arthroplasty is largely contingent upon the interface between bone and implant.

In elderly patients who have suffered age-related osseous changes described earlier in this chapter, cement is generally recommended to decrease the risk of periprosthetic fracture and reoperation [94, 95]. Implant design and patient factors should influence the decision to use cement for patients with adequate bone stock.

Extracapsular Fractures

Muscular attachments to the proximal femur produce the characteristic deformity seen in peritrochanteric femur fractures. The location of fracture pattern determines how much each force vector will contribute to the overall displacement of a fracture. Short external rotators attached to the greater trochanter will externally rotate the proximal segment, hip abductors will abduct the greater trochanteric fragment, and the iliopsoas will flex the fracture fragments attached to the lesser trochanter. Each of these deforming forces contribute to fracture displacement, the pattern of which will vary based on the number and location of fracture fragments as well as the energy of the fracture. Geriatric bone generally fractures in less predictable patterns with more comminution; however, fracture stability is not dependent on age, gender, or BMI in older patients [96]. Extracapsular fractures can often be successfully reduced with the aid of a traction table or intraoperative assistant to maintain leg positioning. Reduction maneuvers should aim to reverse the deforming forces as needed to manipulate proximal displaced fragments. Internal fixation of these fractures is most often done with sliding hip screws and intramedullary nails. There are specific anatomical considerations where one device might be favored over another, and they will be discussed in detail in Chap. 5: Surgical Treatment of Peritrochanteric Fractures.

Open Reduction Techniques

When open reduction of extracapsular fractures is needed, it is preferable to minimize incisions and dissection to decrease blood loss, pain, and iatrogenic muscular injury. Maintenance of blood supply to the femoral head is paramount during internal fixation of the proximal femur. The MFCA and anastomotic tributaries should be preserved and always protected, in particular during open reduction techniques. During open reduction, vascular supply is most at risk along the medial femoral shaft, just inferior to the lesser trochanter, and along the posterior aspect of the femoral neck where the deep branch of the MFCA pierces the capsule [48, 97]. Open reduction technique through a direct lateral approach should expose only as much femur as necessary to obtain a reduction, with avoidance of excessive medial or posterior exploration and maintenance of instrument contact with bone where visualization is difficult. Reduction clamps and sharp bone hooks typically used for reduction of these fractures have a risk of perforation or comminution in elderly patients with lower cortical bone mineral density and should be used judiciously. Alternative reduction instruments and cerclage cables can be helpful to avoid these complications.

Conclusions

Knowledge of applied surgical anatomy of the hip helps surgeons to best care for elderly patients with hip fractures. Consideration of natural changes with aging of osseous, muscular, ligamentous, and vascular structures can direct treatment strategies and optimize outcomes for a population at risk for significant complications surrounding these injuries. Additional characteristics of fracture patterns and location, specifically in relation to the joint capsule and vascular supply, are important to identify due to the substantial risk of osteonecrosis of the femoral head. Optimal surgical approaches, such as the direct anterior approach, should respect anatomic intervals and impart minimal damage to soft tissue to allow for quicker recovery and ambulation.

References

1. Baumgart M, Wisniewski M, Grzonkowska M, Badura M, Malkowski B, Szpinda M. Quantitative anatomy of the primary ossification center of the femoral shaft in human fetuses. Surg Radiol Anat. 2017;39(11):1235–42. https://doi.org/10.1007/s00276-017-1861-8.
2. Osborne D, Effmann E, Broda K, Harrelson J. The development of the upper end of the femur, with special reference to its internal architecture. Radiology. 1980;137(1 Pt 1):71–6. https://doi.org/10.1148/radiology.137.1.7422864.
3. Kaptoge S, Dalzell N, Loveridge N, Beck TJ, Khaw KT, Reeve J. Effects of gender, anthropometric variables, and aging on the evolution of hip strength in men and women aged over 65. Bone. 2003;32(5):561–70. https://doi.org/10.1016/s8756-3282(03)00055-3.
4. Russo CR, Lauretani F, Seeman E, Bartali B, Bandinelli S, Di Iorio A, et al. Structural adaptations to bone loss in aging men and women. Bone. 2006;38(1):112–8. https://doi.org/10.1016/j.bone.2005.07.025.
5. Szulc P, Duboeuf F, Schott AM, Dargent-Molina P, Meunier PJ, Delmas PD. Structural determinants of hip fracture in elderly women: re-analysis of the data from the EPIDOS study. Osteoporos Int. 2006;17(2):231–6. https://doi.org/10.1007/s00198-005-1980-7.
6. Wright D, Whyne C, Hardisty M, Kreder HJ, Lubovsky O. Functional and anatomic orientation of the femoral head. Clin Orthop Relat Res. 2011;469(9):2583–9. https://doi.org/10.1007/s11999-010-1754-1.
7. Tommasini SM, Nasser P, Jepsen KJ. Sexual dimorphism affects tibia size and shape but not tissue-level mechanical properties. Bone. 2007;40(2):498–505. https://doi.org/10.1016/j.bone.2006.08.012.

8. Yates LB, Karasik D, Beck TJ, Cupples LA, Kiel DP. Hip structural geometry in old and old-old age: similarities and differences between men and women. Bone. 2007;41(4):722–32. https://doi.org/10.1016/j.bone.2007.06.001.
9. Tarantino U, Rao C, Tempesta V, Gasbarra E, Feola M. Hip fractures in the elderly: the role of cortical bone. Injury. 2016;47(Suppl 4):S107–S11. https://doi.org/10.1016/j.injury.2016.07.058.
10. Holzer G, von Skrbensky G, Holzer LA, Pichl W. Hip fractures and the contribution of cortical versus trabecular bone to femoral neck strength. J Bone Miner Res. 2009;24(3):468–74. https://doi.org/10.1359/jbmr.081108.
11. Zhang JZ, Zhao K, Li JY, Zhu YB, Zhang YZ. Age-related dynamic deformation of the femoral shaft and associated osteoporotic factors: a retrospective study in Chinese adults. Arch Osteoporos. 2020;15(1):157. https://doi.org/10.1007/s11657-020-00834-0.
12. Papaioannou I, Pantazidou G, Baikousis A, Korovessis P. Femoral bowing and femoral neck-shaft angle evaluation can reduce atypical femoral fractures in osteoporotic patients: a scientific report. Cureus. 2020;12(10):e10771. https://doi.org/10.7759/cureus.10771.
13. Dunstan CR, Evans RA, Hills E, Wong SY, Higgs RJ. Bone death in hip fracture in the elderly. Calcif Tissue Int. 1990;47(5):270–5. https://doi.org/10.1007/BF02555908.
14. Wong SY, Kariks J, Evans RA, Dunstan CR, Hills E. The effect of age on bone composition and viability in the femoral head. J Bone Joint Surg Am. 1985;67(2):274–83.
15. Emerton KB, Hu B, Woo AA, Sinofsky A, Hernandez C, Majeska RJ, et al. Osteocyte apoptosis and control of bone resorption following ovariectomy in mice. Bone. 2010;46(3):577–83. https://doi.org/10.1016/j.bone.2009.11.006.
16. Jilka RL, Noble B, Weinstein RS. Osteocyte apoptosis. Bone. 2013;54(2):264–71. https://doi.org/10.1016/j.bone.2012.11.038.
17. Noble BS, Peet N, Stevens HY, Brabbs A, Mosley JR, Reilly GC, et al. Mechanical loading: biphasic osteocyte survival and targeting of osteoclasts for bone destruction in rat cortical bone. Am J Physiol Cell Physiol. 2003;284(4):C934–43. https://doi.org/10.1152/ajpcell.00234.2002.
18. Javaheri B, Pitsillides AA. Aging and mechanoadaptive responsiveness of bone. Curr Osteoporos Rep. 2019;17(6):560–9. https://doi.org/10.1007/s11914-019-00553-7.
19. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol. 1998;147(8):755–63. https://doi.org/10.1093/oxfordjournals.aje.a009520.
20. Gallagher D, Ruts E, Visser M, Heshka S, Baumgartner RN, Wang J, et al. Weight stability masks sarcopenia in elderly men and women. Am J Physiol Endocrinol Metab. 2000;279(2):E366–75. https://doi.org/10.1152/ajpendo.2000.279.2.E366.
21. Volpi E, Sheffield-Moore M, Rasmussen BB, Wolfe RR. Basal muscle amino acid kinetics and protein synthesis in healthy young and older men. JAMA. 2001;286(10):1206–12. https://doi.org/10.1001/jama.286.10.1206.
22. Larsson L, Degens H, Li M, Salviati L, Lee YI, Thompson W, et al. Sarcopenia: aging-related loss of muscle mass and function. Physiol Rev. 2019;99(1):427–511. https://doi.org/10.1152/physrev.00061.2017.
23. Verlaan S, Maier A, Cederholm T. Re: Letter to the editor – comment on: ‘Sufficient levels of 25-hydroxyvitamin D and protein intake required to increase muscle mass in sarcopenic older adults – the PROVIDE study’. Clin Nutr. 2018;37(6 Pt A):2300. https://doi.org/10.1016/j.clnu.2018.08.026.
24. Evans WJ, Campbell WW. Sarcopenia and age-related changes in body composition and functional capacity. J Nutr. 1993;123(2 Suppl):465–8. https://doi.org/10.1093/jn/123.suppl_2.465.
25. Roubenoff R, Castaneda C. Sarcopenia-understanding the dynamics of aging muscle. JAMA. 2001;286(10):1230–1. https://doi.org/10.1001/jama.286.10.1230.
26. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians. Effects on skeletal muscle. JAMA. 1990;263(22):3029–34.
27. Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med. 1994;330(25):1769–75. https://doi.org/10.1056/NEJM199406233302501.

28. Danneskiold-Samsoe B, Kofod V, Munter J, Grimby G, Schnohr P, Jensen G. Muscle strength and functional capacity in 78-81-year-old men and women. Eur J Appl Physiol Occup Physiol. 1984;52(3):310–4. https://doi.org/10.1007/BF01015216.
29. Bamman MM, Clarke MS, Feeback DL, Talmadge RJ, Stevens BR, Lieberman SA, et al. Impact of resistance exercise during bed rest on skeletal muscle sarcopenia and myosin isoform distribution. J Appl Physiol. 1985;1998;84(1):157–63. https://doi.org/10.1152/jappl.1998.84.1.157.
30. Gentil P, Lima RM, Jaco de Oliveira R, Pereira RW, Reis VM. Association between femoral neck bone mineral density and lower limb fat-free mass in postmenopausal women. J Clin Densitom. 2007;10(2):174–8. https://doi.org/10.1016/j.jocd.2007.01.004.
31. Stalberg E, Fawcett PR. Macro EMG in healthy subjects of different ages. J Neurol Neurosurg Psychiatry. 1982;45(10):870–8. https://doi.org/10.1136/jnnp.45.10.870.
32. Oertel G. Changes in human skeletal muscles due to ageing. Histological and histochemical observations on autopsy material. Acta Neuropathol. 1986;69(3–4):309–13. https://doi.org/10.1007/BF00688309.
33. Fujisawa K. Some observations on the skeletal musculature of aged rats. Part 2. Fine morphology of diseased muscle fibres. J Neurol Sci. 1975;24(4):447–69. https://doi.org/10.1016/0022-510x(75)90170-7.
34. Hashizume K, Kanda K. Differential effects of aging on motoneurons and peripheral nerves innervating the hindlimb and forelimb muscles of rats. Neurosci Res. 1995;22(2):189–96. https://doi.org/10.1016/0168-0102(95)00889-3.
35. McDonagh MJ. Mechanical properties of muscles from Xenopus borealis following maintenance in organ culture. Comp Biochem Physiol A Comp Physiol. 1984;77(2):377–82. https://doi.org/10.1016/0300-9629(84)90077-x.
36. Blake AJ, Morgan K, Bendall MJ, Dallosso H, Ebrahim SB, Arie TH, et al. Falls by elderly people at home: prevalence and associated factors. Age Ageing. 1988;17(6):365–72. https://doi.org/10.1093/ageing/17.6.365.
37. Mahoney J, Sager M, Dunham NC, Johnson J. Risk of falls after hospital discharge. J Am Geriatr Soc. 1994;42(3):269–74. https://doi.org/10.1111/j.1532-5415.1994.tb01750.x.
38. Luke E, Norton W, Denbigh K. Medical and social factors associated with psychological distress in a sample of community aged. Can J Psychiatr. 1981;26(4):244–50. https://doi.org/10.1177/070674378102600409.
39. Inacio M, Creath R, Rogers MW. Effects of aging on hip abductor-adductor neuromuscular and mechanical performance during the weight transfer phase of lateral protective stepping. J Biomech. 2019;82:244–50. https://doi.org/10.1016/j.jbiomech.2018.10.040.
40. Johnson ME, Mille ML, Martinez KM, Crombie G, Rogers MW. Age-related changes in hip abductor and adductor joint torques. Arch Phys Med Rehabil. 2004;85(4):593–7. https://doi.org/10.1016/j.apmr.2003.07.022.
41. Erinc S, Bozca MA, Bankaoglu M, Cakirturk S, Yahsi Y, Ozdemir HM. Association of abductor hip muscle atrophy with fall-related proximal femur fractures in the elderly. Injury. 2020;51(7):1626–33. https://doi.org/10.1016/j.injury.2020.04.054.
42. Howell GE, Biggs RE, Bourne RB. Prevalence of abductor mechanism tears of the hips in patients with osteoarthritis. J Arthroplast. 2001;16(1):121–3. https://doi.org/10.1054/arth.2001.19158.
43. Di Monaco M, Vallero F, Tappero R, Cavanna A. Rehabilitation after total hip arthroplasty: a systematic review of controlled trials on physical exercise programs. Eur J Phys Rehabil Med. 2009;45(3):303–17.
44. Messier SP, Mihalko SL, Beavers DP, Nicklas BJ, DeVita P, Carr JJ, et al. Strength training for arthritis trial (START): design and rationale. BMC Musculoskelet Disord. 2013;14:208. https://doi.org/10.1186/1471-2474-14-208.
45. Letocart AJ, Mabesoone F, Charleux F, Couppe C, Svensson RB, Marin F, et al. Muscles adaptation to aging and training: architectural changes - a randomised trial. BMC Geriatr. 2021;21(1):48. https://doi.org/10.1186/s12877-020-02000-0.
46. Marshall RN, Morgan PT, Martinez-Valdes E, Breen L. Quadriceps muscle electromyography activity during physical activities and resistance exercise modes in younger and older adults. Exp Gerontol. 2020;136:110965. https://doi.org/10.1016/j.exger.2020.110965.

47. Zlotorowicz M, Czubak-Wrzosek M, Wrzosek P, Czubak J. The origin of the medial femoral circumflex artery, lateral femoral circumflex artery and obturator artery. Surg Radiol Anat. 2018;40(5):515–20. https://doi.org/10.1007/s00276-018-2012-6.
48. Lazaro LE, Klinger CE, Sculco PK, Helfet DL, Lorich DG. The terminal branches of the medial femoral circumflex artery: the arterial supply of the femoral head. Bone Joint J. 2015;97-B(9):1204–13. https://doi.org/10.1302/0301-620X.97B9.34704.
49. Ogden JA. Changing patterns of proximal femoral vascularity. J Bone Joint Surg Am. 1974;56(5):941–50.
50. Dewar DC, Lazaro LE, Klinger CE, Sculco PK, Dyke JP, Ni AY, et al. The relative contribution of the medial and lateral femoral circumflex arteries to the vascularity of the head and neck of the femur: a quantitative MRI-based assessment. Bone Joint J. 2016;98-B(12):1582–8. https://doi.org/10.1302/0301-620X.98B12.BJJ-2016-0251.R1.
51. Grose AW, Gardner MJ, Sussmann PS, Helfet DL, Lorich DG. The surgical anatomy of the blood supply to the femoral head: description of the anastomosis between the medial femoral circumflex and inferior gluteal arteries at the hip. J Bone Joint Surg Br. 2008;90(10):1298–303. https://doi.org/10.1302/0301-620X.90B10.20983.
52. Boraiah S, Dyke JP, Hettrich C, Parker RJ, Miller A, Helfet D, et al. Assessment of vascularity of the femoral head using gadolinium (Gd-DTPA)-enhanced magnetic resonance imaging: a cadaver study. J Bone Joint Surg Br. 2009;91(1):131–7. https://doi.org/10.1302/0301-620X.91B1.21275.
53. Mallina R, Dinah F. Avascular necrosis of femoral head: a rare complication of a common fracture in an octogenarian. Geriatr Orthop Surg Rehabil. 2013;4(3):74–7. https://doi.org/10.1177/2151458513507771.
54. Crawfurd EJ, Emery RJ, Hansell DM, Phelan M, Andrews BG. Capsular distension and intracapsular pressure in subcapital fractures of the femur. J Bone Joint Surg Br. 1988;70(2):195–8. https://doi.org/10.1302/0301-620X.70B2.3279041.
55. Barnes R, Brown JT, Garden RS, Nicoll EA. Subcapital fractures of the femur. A prospective review. J Bone Joint Surg Br. 1976;58(1):2–24. https://doi.org/10.1302/0301-620X.58B1.1270491.
56. Loizou CL, Parker MJ. Avascular necrosis after internal fixation of intracapsular hip fractures; a study of the outcome for 1023 patients. Injury. 2009;40(11):1143–6. https://doi.org/10.1016/j.injury.2008.11.003.
57. Gregersen M, Krogshede A, Brink O, Damsgaard EM. Prediction of reoperation of femoral neck fractures treated with cannulated screws in elderly patients. Geriatr Orthop Surg Rehabil. 2015;6(4):322–7. https://doi.org/10.1177/2151458515614369.
58. Rogmark C, Johnell O. Primary arthroplasty is better than internal fixation of displaced femoral neck fractures: a meta-analysis of 14 randomized studies with 2,289 patients. Acta Orthop. 2006;77(3):359–67. https://doi.org/10.1080/17453670610046262.
59. Parker MJ, Pryor G, Gurusamy K. Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures: a long-term follow-up of a randomised trial. Injury. 2010;41(4):370–3. https://doi.org/10.1016/j.injury.2009.10.003.
60. Han SK, Song HS, Kim R, Kang SH. Clinical results of treatment of garden type 1 and 2 femoral neck fractures in patients over 70-year old. Eur J Trauma Emerg Surg. 2016;42(2):191–6. https://doi.org/10.1007/s00068-015-0528-6.
61. Mitchell MD, Kundel HL, Steinberg ME, Kressel HY, Alavi A, Axel L. Avascular necrosis of the hip: comparison of MR, CT, and scintigraphy. AJR Am J Roentgenol. 1986;147(1):67–71. https://doi.org/10.2214/ajr.147.1.67.
62. Park SJ, Ko BS, Moon KH, Lee M. Prediction value of SPECT/CT in avascular necrosis of femoral head after femur neck fracture. Geriatr Orthop Surg Rehabil. 2019;10:2151459319872943. https://doi.org/10.1177/2151459319872943.
63. Watanabe Y, Terashima Y, Takenaka N, Kobayashi M, Matsushita T. Prediction of avascular necrosis of the femoral head by measuring intramedullary oxygen tension after femoral neck fracture. J Orthop Trauma. 2007;21(7):456–61. https://doi.org/10.1097/BOT.0b013e318126bb56.

64. Buckwalter J, Woo SY. Age-related changes in ligaments and joint capsules implications for participation in sports. Sports Med Arthrosc Rev. 1996;4(3):250–62.
65. Martin HD, Savage A, Braly BA, Palmer IJ, Beall DP, Kelly B. The function of the hip capsular ligaments: a quantitative report. Arthroscopy. 2008;24(2):188–95. https://doi.org/10.1016/j.arthro.2007.08.024.
66. Hewitt JD, Glisson RR, Guilak F, Vail TP. The mechanical properties of the human hip capsule ligaments. J Arthroplast. 2002;17(1):82–9. https://doi.org/10.1054/arth.2002.27674.
67. van der Sijp MPL, van Delft D, Krijnen P, Niggebrugge AHP, Schipper IB. Surgical approaches and Hemiarthroplasty outcomes for femoral neck fractures: a meta-analysis. J Arthroplast. 2018;33(5):1617–27. e9. https://doi.org/10.1016/j.arth.2017.12.029.
68. Shindle MK, Ranawat AS, Kelly BT. Diagnosis and management of traumatic and atraumatic hip instability in the athletic patient. Clin Sports Med. 2006;25(2):309–26., ix-x. https://doi.org/10.1016/j.csm.2005.12.003.
69. Ng KCG, Jeffers JRT, Beaule PE. Hip joint capsular anatomy, mechanics, and surgical management. J Bone Joint Surg Am. 2019;101(23):2141–51. https://doi.org/10.2106/JBJS.19.00346.
70. Shahrdar C, Smidt KP. Hip Arthroplasty instability after implantation of a spinal cord stimulator. J Am Acad Orthop Surg Glob Res Rev. 2020;4(7):e2000004. https://doi.org/10.5435/JAAOSGlobal-D-20-00004.
71. Investigators H, Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, et al. Total hip Arthroplasty or Hemiarthroplasty for hip fracture. N Engl J Med. 2019;381(23):2199–208. https://doi.org/10.1056/NEJMoa1906190.
72. Lu Y, Uppal HS. Hip fractures: relevant anatomy, classification, and biomechanics of fracture and fixation. Geriatr Orthop Surg Rehabil. 2019;10:2151459319859139. https://doi.org/10.1177/2151459319859139.
73. Rizkalla JM, Nimmons SJB, Jones AL. Classifications in brief: the Russell-Taylor classification of subtrochanteric hip fracture. Clin Orthop Relat Res. 2019;477(1):257–61. https://doi.org/10.1097/CORR.0000000000000505.
74. Schenkel M, Kaniewska M, Buhler T, Anderson S, Eid K. No difference in flexion power despite iliopsoas fatty degeneration in healed hip fractures with large lesser trochanter displacement. Eur J Orthop Surg Traumatol. 2018;28(7):1313–9. https://doi.org/10.1007/s00590-018-2200-4.
75. Xiong WF, Zhang YQ, Chang SM, Hu SJ, Lesser Trochanteric DSC. Fragments in unstable Pertrochanteric hip fractures: a morphological study using three-dimensional computed tomography (3-D CT) reconstruction. Med Sci Monit. 2019;25:2049–57. https://doi.org/10.12659/MSM.913593.
76. Mirhadi S, Ashwood N, Karagkevrekis B. Factors influencing fracture healing. Trauma. 2013;15(2):140–55.
77. Conn KS, Parker MJ. Undisplaced intracapsular hip fractures: results of internal fixation in 375 patients. Clin Orthop Relat Res. 2004;421:249–54.
78. Selvan VT, Oakley MJ, Rangan A, Al-Lami MK. Optimum configuration of cannulated hip screws for the fixation of intracapsular hip fractures: a biomechanical study. Injury. 2004;35(2):136–41. https://doi.org/10.1016/s0020-1383(03)00059-7.
79. Guo J, Dong W, Yin Y, Zhang R, Hou Z, Zhang Y. The effect of configuration of rhombic cannulated screws on internal fixation of femoral neck fractures. Orthopedics. 2020;43(2):e72–e8. https://doi.org/10.3928/01477447-20191212-03.
80. Afaq S, O'Hara NN, Schemitsch EH, Bzovsky S, Sprague S, Poolman RW, et al. Arthroplasty versus internal fixation for the treatment of undisplaced femoral neck fractures: a retrospective cohort study. J Orthop Trauma. 2020;34(Suppl 3):S9–S14. https://doi.org/10.1097/BOT.0000000000001940.
81. Richards JT, Overmann AL, O'Hara NN, D'Alleyrand JC, Slobogean GP. Internal fixation versus arthroplasty for the treatment of nondisplaced femoral neck fractures in the elderly: a systematic review and meta-analysis. J Orthop Trauma. 2020;34(1):42–8. https://doi.org/10.1097/BOT.0000000000001656.

82. Mukka S, Sjoholm P, Aziz A, Eisler T, Kadum B, Krupic F, et al. A cohort study comparing internal fixation for undisplaced versus hip arthroplasty for displaced femoral neck fracture in the elderly: a pilot study for a clinical trial. Pilot Feasibility Stud. 2020;6:98. https://doi.org/10.1186/s40814-020-00642-w.
83. Gao H, Liu Z, Xing D, Gong M. Which is the best alternative for displaced femoral neck fractures in the elderly?: a meta-analysis. Clin Orthop Relat Res. 2012;470(6):1782–91. https://doi.org/10.1007/s11999-012-2250-6.
84. Tang X, Wang D, Liu Y, Chen J, Zhou Z, Li P, et al. The comparison between total hip arthroplasty and hemiarthroplasty in patients with femoral neck fractures: a systematic review and meta-analysis based on 25 randomized controlled trials. J Orthop Surg Res. 2020;15(1):596. https://doi.org/10.1186/s13018-020-02122-6.
85. Bel JC, Carret JP. Total hip arthroplasty with minimal invasive surgery in elderly patients with neck of femur fractures: our institutional experience. Injury. 2015;46(Suppl 1):S13–7. https://doi.org/10.1016/S0020-1383(15)70005-7.
86. Muller M, Tohtz S, Dewey M, Springer I, Perka C. Age-related appearance of muscle trauma in primary total hip arthroplasty and the benefit of a minimally invasive approach for patients older than 70 years. Int Orthop. 2011;35(2):165–71. https://doi.org/10.1007/s00264-010-1166-6.
87. Wang XD, Lan H, Hu ZX, Li KN, Wang ZH, Luo J, et al. SuperPATH minimally invasive approach to total hip arthroplasty of femoral neck fractures in the elderly: preliminary clinical results. Orthop Surg. 2020;12(1):74–85. https://doi.org/10.1111/os.12584.
88. Chulsomlee K, Sa-Ngasoongsong P, Kulachote N, Sirisreetreerux N, Tuntiyatorn P, Vasaruchapong S, et al. Hip muscle power recovery after hip replacement using anterior-based muscle-sparing approach in elderly femoral neck fracture: a prospective study in 40 patients. Orthop Res Rev. 2018;10:31–9. https://doi.org/10.2147/ORR.S153451.
89. Neyisci C, Erdem Y, Bilekli AB, Bek D. Direct anterior approach versus posterolateral approach for hemiarthroplasty in the treatment of displaced femoral neck fractures in geriatric patients. Med Sci Monit. 2020;26:e919993. https://doi.org/10.12659/MSM.919993.
90. Saxer F, Studer P, Jakob M, Suhm N, Rosenthal R, Dell-Kuster S, et al. Minimally invasive anterior muscle-sparing versus a transgluteal approach for hemiarthroplasty in femoral neck fractures-a prospective randomised controlled trial including 190 elderly patients. BMC Geriatr. 2018;18(1):222. https://doi.org/10.1186/s12877-018-0898-9.
91. Kunkel ST, Sabatino MJ, Kang R, Jevsevar DS, Moschetti WE. A systematic review and meta-analysis of the direct anterior approach for hemiarthroplasty for femoral neck fracture. Eur J Orthop Surg Traumatol. 2018;28(2):217–32. https://doi.org/10.1007/s00590-017-2033-6.
92. Logishetty K, van Arkel RJ, Ng KCG, Muirhead-Allwood SK, Cobb JP, Jeffers JRT. Hip capsule biomechanics after arthroplasty: the effect of implant, approach, and surgical repair. Bone Joint J. 2019;101-B(4):426–34. https://doi.org/10.1302/0301-620X.101B4.BJJ-2018-1321.R1.
93. van Arkel RJ, Ng KCG, Muirhead-Allwood SK, Jeffers JRT. Capsular ligament function after Total hip Arthroplasty. J Bone Joint Surg Am. 2018;100(14):e94. https://doi.org/10.2106/JBJS.17.00251.
94. Kristensen TB, Dybvik E, Kristoffersen M, Dale H, Engesaeter LB, Furnes O, et al. Cemented or uncemented hemiarthroplasty for femoral neck fracture? Data from the Norwegian hip fracture register. Clin Orthop Relat Res. 2020;478(1):90–100. https://doi.org/10.1097/CORR.0000000000000826.
95. Veldman HD, Heyligers IC, Grimm B, Boymans TA. Cemented versus cementless hemiarthroplasty for a displaced fracture of the femoral neck: a systematic review and meta-analysis of current generation hip stems. Bone Joint J. 2017;99-B(4):421–31. https://doi.org/10.1302/0301-620X.99B4.BJJ-2016-0758.R1.
96. Chen PH, Wu CC, Chen WJ. Factors affect stability of intertrochanteric fractures when elderly patients fall. Biom J. 2016;39(1):67–71. https://doi.org/10.1016/j.bj.2015.08.007.
97. Gautier E, Ganz K, Krugel N, Gill T, Ganz R. Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg Br. 2000;82(5):679–83. https://doi.org/10.1302/0301-620x.82b5.10426.
98. Hammer A. The calcar femorale: a new perspective. J Orthop Surg (Hong Kong). 2019;27(2):2309499019848778. https://doi.org/10.1177/2309499019848778.

Chapter 5
Surgical Treatment of Pertrochanteric Hip Fractures

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In current practice, operative management is the mainstay of treatment for pertrochanteric (intertrochanteric) hip fractures, in order to allow full weight bearing and early mobilization. Even in patients with limited mobility, surgical treatment of these highly unstable fractures can improve pain control and facilitate better nursing care [1].

Timing of Surgery

Evidence from numerous studies has demonstrated that surgery should be performed as soon as possible after judicious medical optimization within a reasonable timeframe (i.e., within 36–48 hours) [2–4]. Surgical delays for extensive medical workup are associated with increased 30-day and 1-year mortalities, prolonged hospitalization, and complications from immobilization (e.g., venous thromboembolism, atelectasis, pneumonia, pressure sores, and urinary tract infections) [4–7].

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Hip Fracture Medical Co-management

Medical co-management of hip fracture patients generally encompasses one of three forms [8]. The first is routine geriatric consultation, where the patient is on the orthopaedic service and the internist or geriatrician is a consultant. Another form of co-management is the geriatric ward, where the patient is on the medicine or geriatric service and the orthopaedic surgeon serves as a consultant. Shared care, the third form, is a more-integrated care model with the patient on the orthopaedic service; however, both the orthopaedic team and the medical team share responsibility for the patient. While most of the proposed models have been associated with improved outcomes, the shared care model, with geriatric/medicine and orthopaedic co-management, has been the latest trend and has particularly been shown to significantly reduce the length of stay, as well as decrease in-hospital and long-term mortality [8–10].

Implant Selection

Implants utilized for operative treatment of pertrochanteric hip fractures fall within several categories and include internal fixation implants (intramedullary nail (IM) nails or plates and screws), hip arthroplasty (hemi and total), and, rarely, external fixation. In general, the evidence supporting the use of one implant over another is fairly weak and based on historical literature [11]. Early randomized trials and meta-analyses suggested an increased risk of subsequent peri-implant femoral shaft fractures with short cephalomedullary nails compared to sliding hip screws. However, more recent studies have demonstrated no significant difference in the risk of peri-implant fractures between the two implant choices, which has largely been attributed to improved implant design and improved learning curves [12]. Sliding hip screws are less expensive than cephalomedullary nails; however, they require an open technique and have a higher estimated blood loss and thus their cost effectiveness is called into question. In certain fracture patterns (e.g., reverse obliquity fractures), the use of a sliding hip screw may lead to excessive slide at the fracture site and diminish compression. This may result in excessive medialization of the femoral shaft in relation to the femoral neck (i.e., lateralization of the proximal femoral fragment). This potentially results in varus collapse and subsequently shortening of the limb. In summary, stable intertrochanteric fractures may be treated with a sliding hip screw or a cephalomedullary nail, depending on surgeon preference and capability, while unstable intertrochanteric fracture patterns should be managed with a cephalomedullary device to prevent the resultant deformity.

Plates and Screws

Fixed Angle Plates

Blade plates or 95-degree condylar screw plates are generally no longer employed for the primary treatment of a hip fracture. They afford more rigid fixation without control of collapse at the fracture site [13]. These plates are generally indicated for unique fracture patterns (e.g., reverse obliquity intertrochanteric fractures), some subtrochanteric fractures, or in the case of revision in failed fixation cases [13, 14], since theoretically they provide resistance to rotation of the proximal fragment and resist lateral sliding when compared to other devices. Another form of fixed angle fixation, proximal femoral locking plates, may be used for complex fractures in younger patients with adequate bone stock where anatomic reduction is preferable. They allow locked screw placement at various angles around the proximal femur without subsequent controlled collapse. However, placement of these implants entails a more extensive dissection, and they are associated with an increased risk of plate breakage, nonunion, malunion, and varus collapse [15–18].

Sliding Hip Screw

Originally developed in 1950, the sliding hip screw (Fig. 5.1) is indicated for intertrochanteric hip fractures and was largely thought to be the gold standard for treatment of these injuries. These devices allow dynamic interfragmentary compression

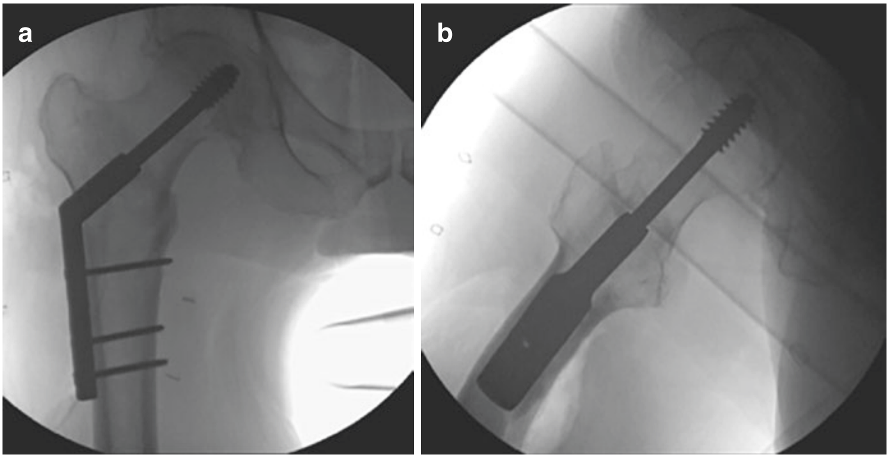

Fig. 5.1 An 80-year-old male sustained a stable right intertrochanteric hip fracture. AP (**a**) and lateral (**b**) radiographs of a left hip demonstrate treatment with a sliding hip screw. The lag screw is placed central and deep

at the fracture site. Available plate angles range from 130 to 150 degrees. The steeper angle allows for better sliding characteristics, while lower angles are more anatomic. Thus, most surgeons tend to choose 130- or 135-degree side plates. More recent literature shows equivocal outcomes when treating stable fractures with these implants compared to cephalomedullary nails [19–22]. While they require an open technique and are associated with a higher estimated blood loss, the surgical approach spares the hip abductors, and they are the lowest cost implants available for treatment of stable intertrochanteric hip fractures. Today, these implants are reserved for the most stable fracture patterns as a cost-saving measure.

Medoff Sliding Plate

The Medoff sliding plate serves as a modification of the sliding hip screw and is composed of two interdigitating femoral plates and a lag screw [23]. These implants can be used for the management of unstable fractures [23, 24]. In addition to allowing dynamic compression along the axis of the femoral neck, these devices also provide dynamic compression along the axis of the femoral shaft. This implant has been replaced by the use of intramedullary nails in the case of an unstable fracture pattern.

Lateral Trochanteric Stabilizing Plate

The lateral trochanteric stabilizing plate (Fig. 5.2) is another modification of the sliding hip screw which provides additional support for the disrupted lateral femoral wall [25–27]. It is composed of a lateral (side) plate that clips to a standard sliding hip screw to buttress an incompetent lateral wall and greater trochanter. It helps diminish excessive slide seen in unstable patterns by providing a “metal lateral wall.” This device can also be used as a reconstructive adjunct for fractures of the greater trochanter.

Intramedullary Nails

Cephalomedullary Nail

Cephalomedullary nails (Fig. 5.3) became widely available in the 1980s and have undergone extensive design modifications since that time. Earlier implant designs were associated with femur fractures around the tip of the nail or distal interlocking screw insertion point, extrusion of the head screw (i.e., screw-cutout), and breakage

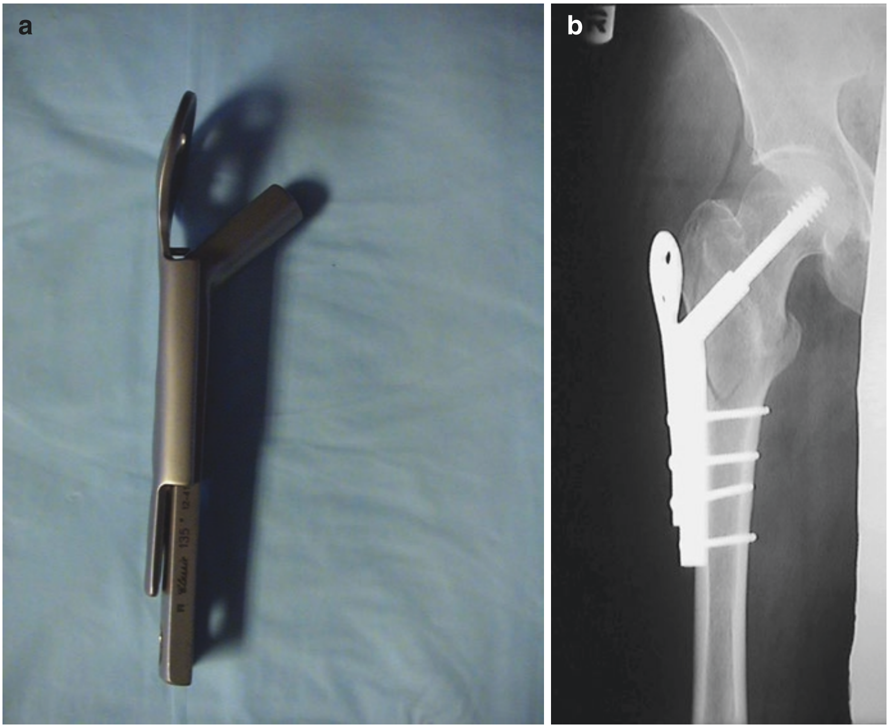

Fig. 5.2 (**a**) Side profile of a lateral trochanteric stabilizing plate (TSP) attached to a standard barrel hip screw side plate. (**b**) AP radiograph of a right hip demonstrating treatment of a pertrochanteric hip fracture with lateral wall incompetence with a TSP

of the implant. There has been a significant increase in the use of cephalomedullary nails in the last decade and a half [28]. With the modern cephalomedullary nail designs, equivalent outcomes have been demonstrated when compared to sliding hip screws for treating stable fracture patterns [19–22, 29]. These devices come in several options, varying in nail length and diameter, static or dynamic distal locking, or uniaxial versus biaxial proximal fixation. Generally, short nails are used for stable fracture patterns and long nails are used for unstable fracture patterns. Compared to sliding hip screws, these implants can be placed percutaneously and as such have a lower estimated intraoperative blood loss. However, they are more costly, and the surgical approach violates the hip abductors.

Short Nails

In general, the indications for a short cephalomedullary nail are intertrochanteric hip fractures and basicervical femoral neck fractures (discussed in Chap. 6). A long cephalomedullary nail is indicated in pathologic fractures, metabolic bone disease,

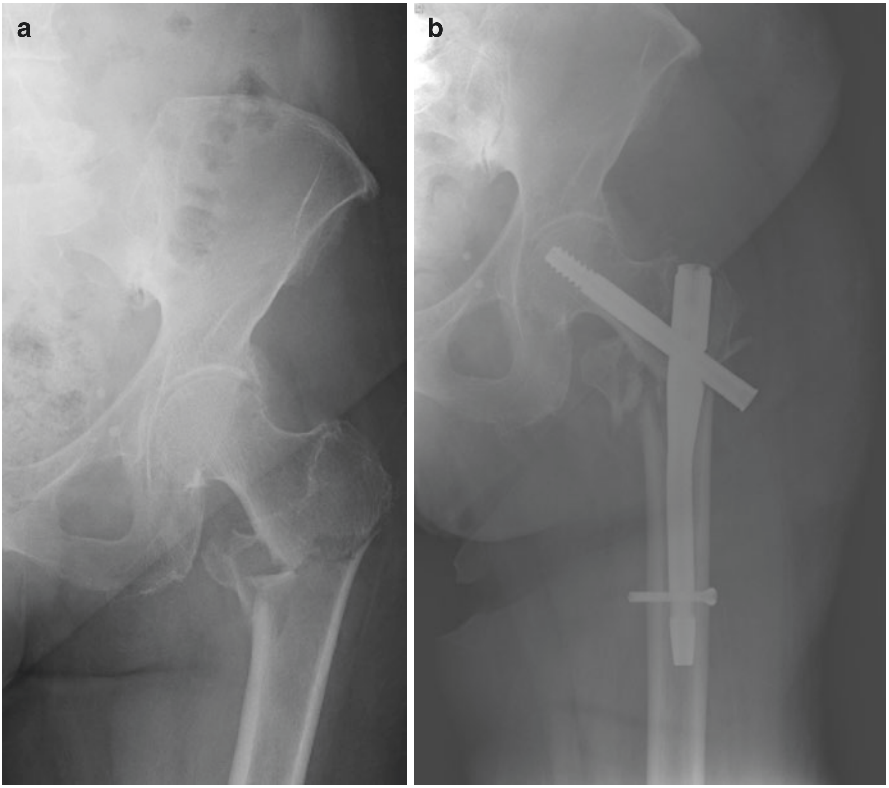

Fig. 5.3 (**a**) AP radiograph of a left hip demonstrating an unstable intertrochanteric hip fracture. The posteromedial cortex is comminuted. (**b**) AP radiograph after treatment with a short cephalomedullary nail. Note the amount of fracture impaction or "slide" with this unstable pattern

and fracture extension >3 cm below the lesser trochanter. It was previously thought that short nails provided inadequate fixation of the diaphysis compared to long nails (e.g., in the case of subtrochanteric fracture extensions); additionally, stress risers present at the tip of the short nails may pose a risk of developing future stress fractures [30, 31], especially in osteoporotic bone. Long cephalomedullary nails are more expensive devices and require a longer operation (secondary to distal intramedullary reaming that is not necessary when inserting short nails) [30, 32]. There have been extensive studies comparing short and long cephalomedullary nails and the consensus is that there is no significant difference in the development of complications (i.e., periprosthetic fractures about the nail tip) or functional outcomes [33–36].

Other Options

External Fixator

This option has been described, but for a number of reasons, including the risk of secondary repeat fracture, this technique is not utilized in the United States. It may be an option in resource-poor areas of the world, however. A trochanteric external fixator consists of two pins across the intertrochanteric fracture into the cancellous bone of the femoral head and two pins distally that engage cortical bone. The four pins are then connected to an external fixator frame, which must be in place for ~3 months. While this treatment option affords less surgery, minimal blood loss, and reduced operative times [24, 37, 38], the inconvenience of the fixator and the risk of pin tract infections make it a less attractive treatment and as such is infrequently used. Additionally, following removal of the fixator pins, there is no long-term protection and patients may fracture the same hip again. Hydroxyapatite-coated pins should be used, as recent studies have reported better results with this material [39].

Arthroplasty

Because these fractures tend to involve the greater and lesser trochanters, replacement arthroplasty for pertrochanteric (i.e., extracapsular) hip fractures is generally only indicated when there is severe, preexisting symptomatic hip arthritis in the setting of a hip fracture, as a salvage for failed internal fixation, or in the setting of severely osteoporotic bone [11, 39]. Historically, a long stem cemented hemiarthroplasty was most commonly used (in conjunction with cerclage wires about the proximal femur) and a calcar-replacing prosthesis was often necessary due to the level of these fractures. With the advent of modern arthroplasty implant designs, pertrochanteric fractures are more commonly managed today with long, tapered stems with distal flutes that allow for improved diaphyseal fixation (Fig. 5.4). Replacement arthroplasty is associated with increased blood loss and the need for blood transfusion [40, 41]. This procedure also carries the added risk of postoperative prosthetic hip dislocation.

Preoperative Checklist

The preoperative checklist for internal fixation of pertrochanteric hip fractures generally includes a fracture table, intraoperative fluoroscopy with an image intensifier, and the standard surgical equipment for fracture cases (e.g., reduction clamps).

Fig. 5.4 AP radiograph of a right hip demonstrating a total hip arthroplasty with a long, tapered stem with ample diaphyseal fixation

Some surgeons prefer to use a standard radiolucent table (e.g., Jackson Flat Top). Additionally, we recommend a preoperative plan that includes measuring the isthmus of the medullary canal, templating with the intended implant of choice, and ensuring availability of specific equipment (e.g., reamers) with operating room personnel and vendor representatives.

Positioning

The patient should be placed supine on a fracture table, secured by a groin post and with the injured foot held in a traction boot that is strapped in and fixed to the fracture table (Fig. 5.5). The contralateral, uninjured limb should be placed out of the way and can be held in a stirrup or scissored. Historically, the well leg was placed in the hemilithotomy position (i.e., hip and knee flexion, hip abduction, and hip external rotation); however, reports of well leg compartment syndrome (WLCS) have discouraged the use of such positioning [42, 43]. Another option available with

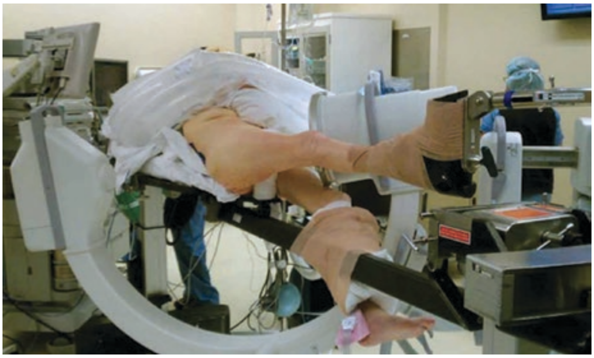

Fig. 5.5 Positioning of a patient on a fracture table. The well leg is scissored and secured to the table with a "pillow sling"

certain fracture tables is to detach the distal aspect of the table and to create a "pillow sling" by scissoring the well leg to the table's support bar with a pillow and adherent compression bandage (e.g., Coban). The image intensifier should be positioned on the side of the uninjured extremity.

Reduction of Fracture

Prior to prepping and draping, fracture reduction should be performed. Adequate reduction of the fracture is one of the most important aspects of surgical treatment of these fractures. The fracture must be reduced such that the cortical bone is line-to-line in order to prevent excessive collapse at the fracture site and ultimately, delayed fracture healing and deformity. Inadequately reduced fractures (most commonly in varus) will be mechanically unstable and result in collapse, screw cut-out, and limb shortening. Reduction is performed by application of longitudinal traction, adduction (especially for cephalomedullary devices), and slight internal rotation. The patella should generally be facing the ceiling in order to avoid a rotational deformity. Once an adequate reduction is obtained on the AP radiograph (i.e., anatomic or slightly valgus), the reduction is verified on the lateral view, and ideally the femoral head, neck, and trochanteric region should be in a straight line (Fig. 5.6). There should be no posterior sag or angulation of the femoral neck. A valgus reduction is associated with the lowest risk of screw cut-out and mitigates postoperative implant shortening [26, 44]. If the standard reduction maneuvers (as mentioned above) fail to adequately reduce the fracture, various reduction aids may be utilized to apply upward pressure at the fracture site. This can be achieved by the use of a posterior reduction aid (some may be attached directly to the fracture table), the use of a vertical crutch to provide upward pressure at the fracture site, placement of a bone lever below the fracture site, or by elevation of the femur at the site of the sag with a bone clamp. Pertrochanteric fractures rarely need to be opened.

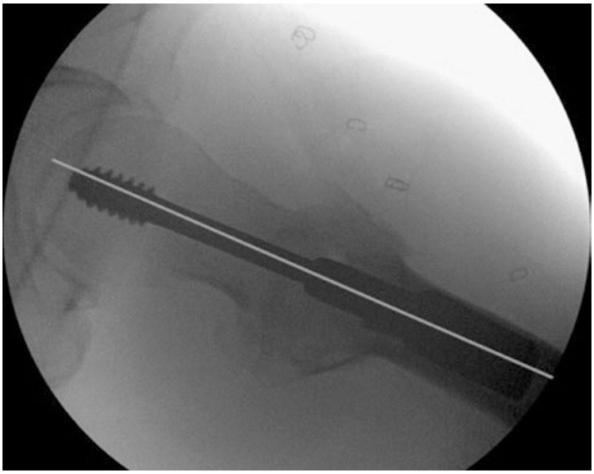

Fig. 5.6 A lateral radiograph of the hip demonstrating reduction of the fracture. Reduction of the fracture on the lateral should be approximately 180° between the neck and shaft

Lag Screw Position

Proper positioning of the lag screw is extremely important and should only be undertaken after an adequate reduction of the fracture is achieved. For example, a fracture reduced in a varus position will lead to superior placement of the lag screw within the femoral head. This leads to an increased risk of screw cut-out as the fracture falls further into varus. A slight opening above the fracture site medially is preferred to ensure a slightly valgus reduction. The ideal position of the lag screw is low to central on the AP view and central on the lateral radiograph and is placed within 1 cm of subchondral bone [45–48]. The tip-apex distance (TAD) (Fig. 5.7), expressed in millimeters, is the sum of the distance from the tip of the lag screw to the apex of the femoral head on both the AP and lateral radiographs. The TAD is used to assess adequate placement of the lag screw and should be less than 25 mm summed on both the AP and lateral image views [45, 49]. Radiographic magnification must be taken into account. Values greater than the 25 mm cutoff has been associated with increased risk of lag screw cut-out [49, 50].

Surgical Techniques

Sliding Hip Screw

Following positioning of the patient on a traction table and adequate fluoroscopy-guided fracture reduction, standard sterile skin preparation and draping are performed. A 5–7 cm lateral skin incision is made just distal to the vastus ridge in line with the femoral shaft. The incision may be lengthened if a longer plate is used.

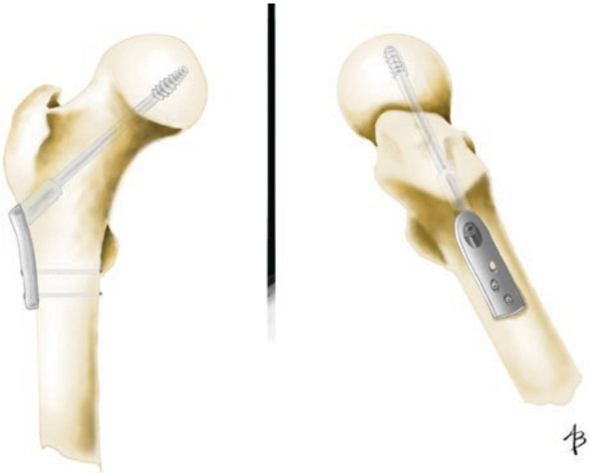

Fig. 5.7 An illustration of the tip-apex distance (TAD). It is measured as the sum of the distance from the tip of the lag screw to the apex of the femoral head on both the AP and lateral radiographs, in millimeters

Subcutaneous fat is incised to expose the fascia lata. The fascia lata is then incised in line with the skin incision, ensuring to stay posterior to the muscle fibers. Deep to the fascia lata, the vastus lateralis is bluntly exposed and retracted anteriorly to expose the lateral femur. Care should be taken to not inadvertently divide the first perforating vessels, which may be encountered ~5 cm below the vastus ridge [51]. Splitting the vastus should be avoided as this will cause more bleeding.

With a retractor placed anteriorly, the lateral femoral shaft is exposed with a periosteal elevator, carefully elevating the vastus lateralis off the intermuscular septum. Utilizing fluoroscopy, a guidewire may be placed anteriorly and positioned parallel to the axis of the femoral neck. This guidewire serves as an "anteversion pin" and allows for proper placement of the definitive guidewire, in terms of femoral neck anteversion, neck-shaft angle, and the sliding hip screw angle. Once the guide pin is in place, the sliding hip screw angle guide is selected to allow for the highest angle that will allow central placement of the screw and is placed along the axis of the femoral shaft. A guide wire is then placed through the sliding hip screw angle guide and should be parallel to the anteversion pin, lie along the axis of the femoral neck on both AP and lateral radiographs, and directed toward the center of the femoral head. As outlined above, ideal placement of the guidewire should be low to central on the AP radiograph and central on the lateral view [45–48]. The wire should be no less than 5 mm from the joint line to avoid penetration of the hip [49, 50]. After placement of the guidewire, the depth gauge is used to determine the appropriate length of the lag screw.

Following the determination of screw length, the lag screw hole is reamed with a triple diameter reamer (inner and outer lag screw diameter and the barrel). The screw is then inserted over the guidewire and advanced to the desired position. A tap may be used to precut the thread for the screw to avoid rotating the proximal fragment by reducing torsional forces as the screw is advanced. This is especially relevant for younger patients with good-quality bone.

After lag screw placement, the sliding hip screw plate can be applied. The plate with the appropriate angle is slid over the screw with an impactor. A 2- to 4-hole plate is generally chosen and sufficient for stable intertrochanteric fractures, based on evidence from biomechanical and clinical studies [52–54]. The plate is then fixed to the femoral shaft via standard drilling and cortical screw placement. Finally, the guidewire is removed, final plate and screw(s) position is verified on both AP and lateral views, and the wound is copiously irrigated. Closure will be discussed below.

Cephalomedullary Nail

Positioning of the patient and reduction are carried out in a similar manner to screw and side plate use. The nail diameter and length should be determined preoperatively to ensure its availability. The nail diameter is determined by measuring the diameter of the medullary cavity at the narrowest segment (i.e., the isthmus), and the nail length options are generally based on the specific implant manufacturer. Following positioning of the patient on a fracture table and adequate fluoroscopy-guided fracture reduction, standard sterile skin preparation and draping are performed.

Approximately 5 cm proximal to the tip of the greater trochanter, a 2–3 cm skin incision is made in line with the femoral shaft. The gluteal fascia is incised and the subcutaneous tissues are dissected to allow access to the trochanter. The entry point of the guidewire may vary based on the particular implant, but in general the entry point should be just medial to the tip of the greater trochanter. The guidewire is inserted through the tip of the trochanter in line with the center of the femoral neck (which is anterior to the shaft) and slightly lateral to the anatomical axis of the shaft. The position of the wire is checked with orthogonal views using fluoroscopy.

After satisfactory guidewire position, with the use of a soft tissue protection sleeve, an opening reamer is used to open the proximal femur and trochanteric area. Reaming may be done by hand (e.g., in elderly patients) or with power (e.g., young patients). Further reaming of the femur may be required to accommodate the nail depending on the determined diameter. It is generally advised to ream to 1–1.5 mm greater than the predetermined nail diameter. An assistant may apply a medial-directed force to the proximal lateral thigh during reaming to prevent displacement of the fracture and maintenance of an acceptable reduction. Sometimes, the guidewire sits within the fracture line. In these cases, it is important to ream slowly while a lateral force is applied to avoid pushing the reamer through the fracture site without creating a channel for the nail. If this is not achieved, nail slide might be affected.

With the nail of appropriate diameter and length mounted on the insertion device; it is inserted manually by gentle advancement to a depth that allows placement of the lag screw in the center of the femoral neck. Following placement of the nail, with the use of the alignment jig, a small skin incision is made for placement of the wire. The guidewire is inserted to a central to low position on the AP radiograph and a central position on the lateral view, ~5 mm from the joint line. The measuring device is then used to measure the length of the screw.

A dual diameter reamer (inner and outer lag screw diameters only) is applied over the guidewire and the lateral cortex and screw path are reamed to accommodate the lag screw. The lag screw is inserted over the guidewire to the appropriate position, with judicious use of fluoroscopy. The lag screw should protrude just slightly out of the lateral cortex to avoid "jamming." The guidewire is removed. If distal locking is desired, a stab incision is made at the appropriate level and the drill bit (with protection sleeve) is inserted through the designated hole (for short cephalomedullary nails). Bicortical drilling is performed and the screw is placed in standard fashion. Static locking is sufficient for pertrochanteric fractures. Final nail and lag screw position is verified on both AP and lateral views, and the wound is copiously irrigated.

Long cephalomedullary nails may be used for unstable fractures (e.g., subtrochanteric extension). The technique is as described above; however, the guidewire (e.g., ball tip) must be advanced to the level of the femoral condyles, and distal reaming is performed to an appropriate diameter. Distal locking is performed freehand with two screws rather than one.

Wound Closure

Closure of the wound(s) should begin after copious irrigation with saline and cauterization of any bleeding vessels. The fascia lata and iliotibial band are closed with 0-vicryl. In larger patients with excess soft tissue, dead space can be minimized by closure of the subcutaneous fat with 1-0 or 2-0 vicryl. The subcutaneous layer is closed with 2-0 vicryl and the skin is closed with sutures or staples in a tension-free manner. Care should be taken to avoid protrusion of any tissue from the wound. A sterile dressing should be applied and ideally left in place for at least 5 days postoperatively to avoid contamination of the wound.

Postoperative Protocol

Postoperatively, patients are all made weight bearing as tolerated. Prophylaxis against venous thromboembolism should be administered by both mechanical (e.g., sequential compression devices) and pharmacologic (e.g., Lovenox) methods. Standard postoperative orders should be placed, including pain control with a multimodal regimen, a diet, and labs (e.g., hemoglobin) as deemed necessary by the medical co-management team. Early rehabilitation is extremely important and should be facilitated in conjunction with physical therapy and occupational therapy goals. Optimal postoperative care and rehabilitation involve sound coordination by a multidisciplinary team, including the orthopaedic surgery team, a geriatrician or an internist, social workers and case managers, physical therapists, and occupational therapists. A follow-up appointment should be scheduled at the 2-week mark for a surgical wound check and at the 6-week mark for radiographic evaluation.

Hemoglobin/Hematocrit Monitoring and Transfusion Threshold

Particular attention should be given to the pre- and postoperative hemoglobin (Hgb) levels for geriatric patients undergoing surgical treatment of hip fractures. Despite the percutaneous nature of modern techniques for insertion of cephalomedullary nails, blood loss may be underestimated for these procedures given that a significant portion of it is lost from intramedullary reaming and thus may not be readily apparent intraoperatively. As such, it is imperative to check the Hgb at least once postoperatively and to compare it to the patients' baseline level. Particularly in patients who may have difficulty mobilizing due to orthostasis or symptoms of anemia, it is important to have a low threshold to transfuse packed red blood cells to a goal Hgb of >7 g/dL. In patients with underlying cardiac history, it is recommended that postoperative Hgb be kept above 8 g/dL.

Subtrochanteric Femur Fractures

Subtrochanteric femur fractures pose additional challenges with respect to surgical treatment of pertrochanteric hip fractures. They have a higher susceptibility to malreduction (i.e., varus and procurvatum) compared to intertrochanteric hip fractures. Surgical treatment may be achieved with cephalomedullary nailing or a fixed angle plate. The advantage of the cephalomedullary nail remains the preservation of vascularity (due to decreased surgical dissection) and the load-sharing characteristic of the implant, allowing the patient to bear weight immediately postoperatively. Disadvantages of nailing include difficulty in achieving an adequate reduction, compared to plating, which requires more extensive surgical dissection, and thus disrupts vascularity of the fracture fragments, but can better control for varus malalignment. Particularly with cephalomedullary nailing of these fractures, percutaneous (indirect) and open (direct) reduction techniques (described above) may be more required in order to get an adequate reduction prior to insertion of the nail.

Complications

Lag Screw Cut-Out

Lag screw cut-out is the most common complication after surgical treatment of intertrochanteric hip fractures and usually occurs within the first 3 months postoperatively [39]. The incidence is 1–3% [55]. Lag screw cut-out may occur as one of two forms: superior screw cut-out (Fig. 5.8) or medial screw migration. Superior screw cut-out is attributed to inadequate reduction of the fracture resulting in poor (eccentric) placement of the lag screw (e.g., superiorly within the femoral head) as

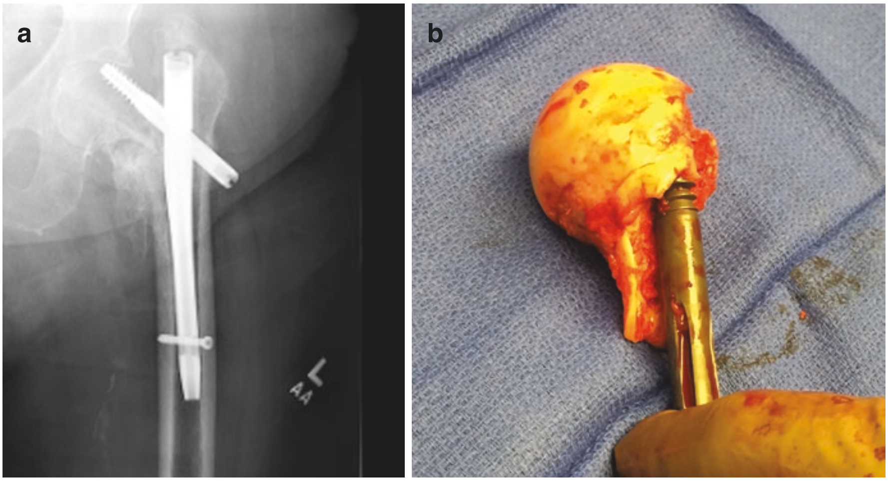

Fig. 5.8 (**a**) AP radiograph of a left hip demonstrating superior lag screw cut-out following treatment of a pertrochanteric hip fracture with a short cephalomedullary nail. (**b**) Clinical demonstration of the superior lag screw cut-out in this patient

well as a TAD >25 mm [45, 49, 50]. Other contributing factors are improper intraoperative reaming that creates a second channel or insufficient engagement of the screw-barrel mechanism, which prevents sliding. Medial screw migration is precipitated by varus collapse of the fracture as well as repetitive axial loading and resultant nail toggling within the femoral intramedullary canal in significantly poor bone [56, 57]. Penetration of the femoral head and migration into the pelvis is more likely to be seen with osteoporotic bone. This complication may be managed by observation if the patient is asymptomatic and the fracture can be allowed to heal. If the cut-out is significant and/or the patient is symptomatic, revision of the implant, removal of the hardware, or conversion to hip arthroplasty will be necessary. The choice of the revision implant will be dependent on the amount of intact bone in the femoral head and the status of the femoral canal (tube).

Nonunion

Fracture nonunion after pertrochanteric hip fractures (Fig. 5.9) occurs less commonly compared to femoral shaft or subtrochanteric fractures, at a rate of ~2% [20, 21]. Persistence of hip pain and lucency about the fracture site 4–7 months after surgical fixation should raise concern for nonunion. Removal of the distal locking screw and nail dynamization to facilitate fracture union may be employed for initial treatment. A persistent nonunion should be addressed by revision fixation with bone grafting (in younger patients with adequate bone stock) or conversion to arthroplasty (in elderly patients with osteoporotic bone).

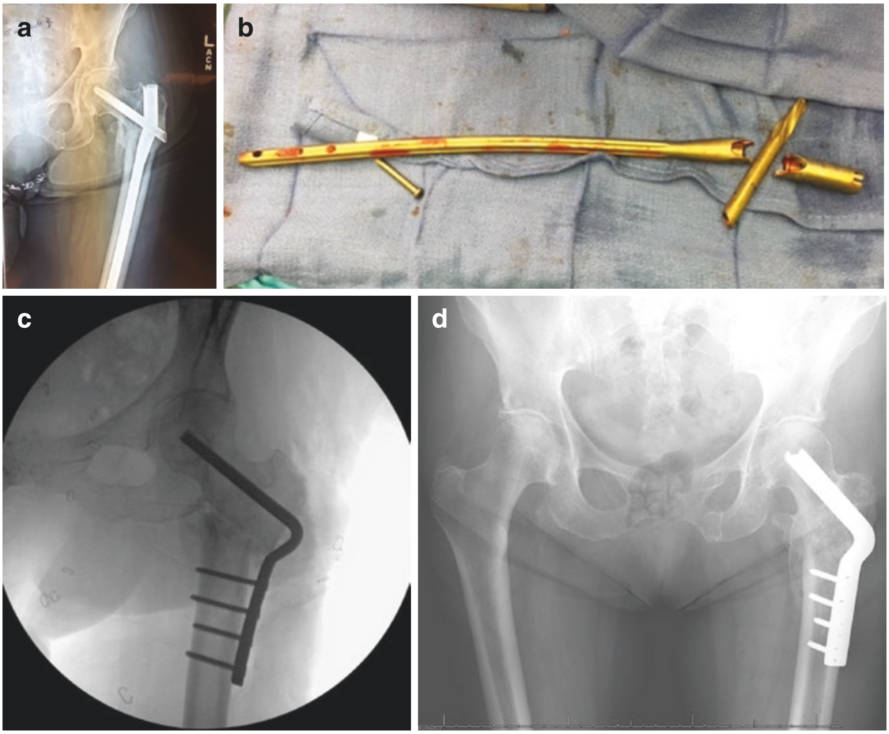

Fig. 5.9 An 80-year-old female who is one year status post treatment of a pertrochanteric hip fracture with a long IM Nail. (**a**) AP radiograph demonstrating fracture nonunion with hardware failure. (**b**) Intraoperative photo demonstrating nail failure at the lag screw hole. (**c**) AP intraoperative radiograph following osteotomy and nonunion repair with a blade plate. (**d**) AP pelvis radiograph at 1 year following nonunion repair. There is complete union and an excellent clinical result

Fracture-Related Infection

The incidence of a wound infection after treatment of a pertrochanteric hip fracture is about 1% [24]. Standard sterile technique should always be practiced to minimize wound complications. As discussed above, meticulous, layered wound closure also decreases the risk. Prophylactic antibiotics prior to incision are standard of care and additionally reduce this risk. The literature on the effect of topical vancomycin on fracture-related infection rates have focused on arthroplasty for the treatment of pertrochanteric fractures and have shown no advantage in reducing the incidence of infection [58]. Historically, there have been concerns about the systemic levels and nephrotoxicity associated with topical vancomycin powder in fracture surgery; however, recent studies have shown relatively low serum levels postoperatively and an overall low risk of nephrotoxicity [59, 60]. While these findings may pave the way for future investigation on the efficacy of local vancomycin use in fracture surgery, there is currently no known benefit [60, 61]. In short, local vancomycin use is not recommended when surgically treating pertrochanteric hip fractures.

Refracture

The incidence of delayed peri-implant fracture is ~0.1% for sliding hip screws [21] and 0.5–1% for cephalomedullary nails [62, 63]. Earlier nail designs were associated with much higher rates (up to 10%) of fractures at the tip of the nail; however, advancements in nail designs have significantly reduced the incidence to rates comparable to that of sliding hip screws [12, 64]. A peri-implant fracture may be addressed with exchange to a long nail (i.e., if it occurs around a short nail) or with overlapping plate fixation.

Anterior perforation of the distal femur, particularly with long cephalomedullary nails, is another form of peri-implant fracture. Historically, impingement or perforation of the anterior femoral cortex was of particular concern due to a mismatch between the radius of curvature of the femur (shorter radius of curvature) and the implant (longer radius of curvature) [39]. Modern implant designs have mitigated this potential complication by reducing the radius of curvature such that it closely matches that of the femur [65].

Implant Breakage

The rate of implant breakage (Fig. 5.9b) with modern nail designs is approximately 1% [66]. It is generally related to nonunion or delayed union of the fracture. Treatment involves implant removal, revision fixation, or conversion to arthroplasty (e.g., in the setting of severe preexisting hip osteoarthritis).

Avascular Necrosis of the Femoral Head

Femoral head avascular necrosis following pertrochanteric hip fractures is much lower than after a femoral neck fracture given the extracapsular location of the intertrochanteric region. The incidence is 1–2% [67]. This complication may be observed if the patient is asymptomatic, otherwise arthroplasty is the definitive treatment.

Vascular Injury

Vascular injury rarely can occur in the form of injury to the superior gluteal artery during the surgical approach (for a cephalomedullary device) or with the formation of a pseudoaneurysm [39, 68]. The treatment is surgical repair of the vessel or embolization of the pseudoaneurysm.

Summary

Pertrochanteric (intertrochanteric) hip fractures are treated with surgery in the majority of patients as soon as possible to prevent complications of immobility and recumbency. A medical co-management team should be closely involved with the hip fracture patient's preoperative medical optimization as well as perioperative surveillance. Surgery involves insertion of a sliding hip screw or a short cephalomedullary device for stable fracture patterns and a short or long cephalomedullary device for unstable fracture patterns. In the case of severely osteoporotic bone or severe, preexisting symptomatic osteoarthritis, arthroplasty may be performed. Meticulous preoperative planning, adequate reduction of the fracture (for surgical fixation), and implant positioning are most important to achieve stable fixation and to prevent complications, most commonly implant failure and lag screw cut-out. Substantial improvements in implant design over the last few decades have led to more minimally invasive techniques, fewer complications, and shorter surgical times. As the population of elderly, fragile patients continue to increase, we can expect a concomitant increase in the total number of hip fractures, which may pose new challenges. High-quality, randomized research focused on outcomes should tailor future practices.

References

1. Hay D, Parker MJ. Hip fracture in the immobile patient. J Bone J Surg Br. 2003;85:1037–9.
2. Bretherton CP, Parker MJ. Early surgery for patients with a fracture of the hip decreases 30-day mortality. Bone Joint J. 2015;97:104–8.
3. Khan SK, Kalra S, Khanna A, et al. Timing of surgery for a hip fracture; a systematic review of 52 published studies involving 291,413 patients. Injury. 2009;40:692–7.
4. Shiga T, Wajima Z, Ohe Y. Is operative delay associated with increased mortality of hip fracture patients? Systematic review, meta-analysis, and meta-regression. Can J Anaesth. 2008;55:146–54.
5. Siegmeth AW, Gurusamy K, Parker MJ. Delay to surgery prolongs hospital stay in patients with fracture of the proximal femur. J Bone Joint Surg Br. 2005;87:1123–6.
6. Simunovic N, Devereaux PJ, Sprague S, et al. Effects of early surgery after hip fracture on mortality and complications: systematic review and meta-analysis. CMAJ. 2010;182:1609–16.
7. Zuckerman JD, Skovron ML, Koval KJ, Aharonoff G, Frankel VH. Postoperative complications and mortality associated with operative delay in older patients who have a fracture of the hip. J Bone Joint Surg Am. 1995;77:1551–6.
8. Grigoryan KV, Javedan H, Rudolph JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. J Orthop Trauma. 2014;28:49–55.
9. Vidan M, Serra JA, Moreno C, Riquelme G, Ortiz J. Efficacy of a comprehensive geriatric intervention in older patients hospitalized for hip fracture: a randomized, controlled trial. J Am Geriatr Soc. 2005;53:1476–82.
10. Gonzalez-Montalvo JI, Alarcon T, Gil-Garay E, Gotor P, Martin-Vega A, Mauleon JL. The orthogeriatric unit for acute patients: a new model of care that improves efficiency in the management of patients with hip fracture. Hip Int. 2010;20:229–35.

11. Rockwood CA, Green DP, Bucholz RW. Rockwood and green's fractures in adults. 6th ed. Philadelphia: Lippincott Williams & Wilkins; 2006. p. 2284–317.
12. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisted: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. J Orthop Trauma. 2009;23:460–4.
13. Pelet S, Arlettaz Y, Chevalley F. Osteosynthesis of per- and subtrochanteric fractures by blade plate versus gamma nail: a randomized prospective study. Swiss Surg. 2001;7:126–33.
14. Sadowski C, Lubbeke A, Saudan M, et al. Treatment of reverse oblique and transverse intertrochanteric fractures with use of an intramedullary nail or a 95 degree screw-plate. J Bone Joint Surg Am. 2002;84:371–81.
15. Haq RU, Manhas V, Pankaj A, et al. Proximal femoral nails compared with reverse distal locking plates in intertrochanteric fractures with a compromised lateral wall: a randomized controlled trial. Int Orthop. 2014;38:1443–9.
16. Streubel PN, Moustoukas MJ, Obremskey WT. Mechanical failure after locking plate fixation of unstable intertrochanteric femur fractures. J Orthop Trauma. 2013;27:22–8.
17. Wirtz C, Abbassi F, Evangelopoulos DS, et al. High failure rate of trochanteric fracture osteosynthesis with proximal femoral locking compression plate. Injury. 2013;44:751–6.
18. Glassner PJ, Tejwani NC. Failure of proximal femoral locking compression plate: a case series. J Orthop Trauma. 2011;25:76–83.
19. Liu M, Yang Z, Pel F, et al. A meta-analysis of the Gamma nail and dynamic hip screw in treating peritrochanteric fractures. Int Orthop. 2010;34:323–8.
20. Parker MJ, Bowers TR, Pryor GA. Sliding hip screw versus the Targon PF nail in the treatment of trochanteric fractures of the hip: a randomised trial of 600 fractures. J Bone Joint Surg Br. 2012;94:391–7.
21. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2010:9.
22. Yu J, Zhang C, Li L, et al. Internal fixation treatment for intertrochanteric fractures: a systematic review an meta-analysis of randomized evidence. Sci Rep. 2015;5:1–11.
23. Lunsjo K, Ceder L, Thorngren KG, et al. Extramedullary fixation of 569 unstable intertrochanteric fractures: a randomized multicenter trial of the Medoff sliding plate versus three other screw-plate systems. Acta Orthop Scand. 2001;72:133–40.
24. Parker MJ, Das A. Extramedullary fixation implants and external fixators for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2013.
25. Babst R, Renner N, Biedermann M, et al. Clinical results using the trochanter stabilizing plate (TSP): the modular extension of the dynamic hip screw (DHS) for internal fixation of selected unstable intertrochanteric fractures. J Orthop Trauma. 1998;12:392–9.
26. Hsu CE, Chiu YC, Tsai SH, et al. Trochanter stabilizing plate improves treatment outcomes in AO/OTA 31-A2 intertrochanteric fractures with critical thin femoral lateral walls. Injury. 2015;46:1047–53.
27. Madsen JE, Næss L, Aune AK, et al. Dynamic hip screw with trochanteric stabilizing plate in the treatment of unstable proximal femoral fractures: a comparative study with the Gamma nail and compression hip screw. J Orthop Trauma. 1998;12:241–8.
28. Anglen JO, Weinstein JN. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. J Bone Joint Surg Am. 2008;90:700–7.
29. Wynne Jones H, Johnston P, Parker M. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop. 2006;30:69–78.
30. Haidukewych GJ. Intertrochanteric fractures: ten tips to improve results. J Bone Joint Surg Am. 2009;91:712–9.
31. Kanis JA, Melton LJ, Christiansen C 3rd, Johnston CC, Khaltaev N. The diagnosis of osteoporosis. J Bone Miner Res. 1994;9:1137–41.

32. Hou Z, Bowen TR, Irgit KS, et al. Treatment of pertrochanteric fractures (OTA 31-A1 and A2): long versus short cephalomedullary nailing. J Orthop Trauma. 2013;27:318–24.
33. Bellabarba C, Herscovici D, Jr Ricci WM. Percutaneous treatment of peritrochanteric fractures using the Gamma nail. Clin Orthop Relat Res. 2000;375:30–42.
34. Bojan AJ, Beimel C, Speitling A, et al. 3066 consecutive Gamma Nails. 12 years experience at a single centre. BMC Musculoskelet Disord. 2010;11:133.
35. Calvert PT. The Gamma nail--a significant advance or a passing fashion? J Bone Joint Surg Br. 1992;74:329–31.
36. Kukla C, Heinz T, Gaebler C, Heinze G, Vécsei V. The standard Gamma nail: a critical analysis of 1,000 cases. J Trauma. 2001;51:77–83.
37. Kazemian GH, Manafi AR, Najafi F, et al. Treatment of intertrochanteric fractures in elderly high risk patients: dynamic hip screw vs external fixation. Injury. 2014;45:568–72.
38. Moroni A, Faldini C, Pegreffi F, et al. Dynamic hip screw compared with external fixation for treatment of osteoporotic pertrochanteric fractures: a prospective, randomized study. J Bone Joint Surg Am. 2005;87:753–9.
39. Egol KA, Koval KJ, Zuckerman JD. Handbook of fractures. Lippincott Williams & Wilkins; 6th edition. USA. p. 395–405.
40. Ozkan N, Okcu G, Aktuglu K. Intertrochanteric femur fractures in the elderly treated with either proximal femur nailing or hemiarthroplasty: a prospective randomised clinical study. Injury. 2015;46:3–8.
41. Parker MJ, Handoll HH. Replacement arthroplasty versus internal fixation for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2006.
42. Anglen J, Banovetz J. Compartment syndrome in the well leg resulting from fracture-table positioning. Clin Orthop Relat Res. 1994;301:239–242.
43. Dugdale TW, Schutzer SF, Deafenbaugh MK, Bartosh RA. Compartment syndrome complicating use of the hemi-lithotomy position during femoral nailing. A report of two cases. J Bone Joint Surg Am. 1989;71:1556–7.
44. Parker MJ. Valgus reduction of trochanteric fractures. Injury. 1993;24:313–6.
45. Hsu CE, Huand KC, Lin TC, et al. Intergraded risk scoring model for predicting dynamic hip screw treatment outcome of intertrochanteric fracture. Injury. 2016;47:2501–6.
46. Kyle RF, Gustilo RB, Premer RF. Analysis of six hundred and twenty-two intertrochanteric hip fractures. J Bone Joint Surg Am. 1979;61:216–21.
47. Parker MJ. Cutting-out of the dynamic hip screw related to its position. J Bone Joint Surg Br. 1992;74:625.
48. Pervez H, Parker MJ, Pryor GA, et al. Classification of trochanteric fracture of the proximal femur; a study of the reliability of current systems. Injury. 2002;33:713–5.
49. Baumgaertner MR, Curtin SL, Lindskog DM, et al. The value of the tip-apex distance in predicting failure of fixation of pertrochanteric fractures of the hip. J Bone Joint Surg Am. 1995;77:1058–64.
50. Baumgaertner MR, Solberg BD. Awareness of tip-apex distance reduces failure of fixation of pertrochanteric fractures of the hip. J Bone Joint Surg Br. 1997;79:969–71.
51. Hoppenfeld S, Buckley R. Surgical exposures in orthopaedics: the anatomic approach. Lippincott Williams & Wilkins; 4th edition. USA. 2017.
52. Davey MS, Flynn SO, Hayes J, et al. Two-hole versus four-hole plate dynamic hip screw: a systematic review of current evidence. Ir J Med Sci. 2020;189:1317–22.
53. Rog D, Grigsby P, Hill Z, Pinette W, Inceoglu S, Zuckerman L. A biomechanical comparison of the two- and four-hole side-plate dynamic hip screw in an osteoporotic composite femur model. J Orthop Surg. 2017;25:2309499017717199.
54. McLoughlin SW, Wheeler DL, Rider J, Bolhofner B. Biomechanical evaluation of the dynamic hip screw with two- and four-hole side plates. J Orthop Trauma. 2000;14:318–23.
55. Chirodian N, Arch B, Parker MJ. Sliding hip screw fixation of trochanteric hip fractures: outcome of 1024 procedures. Injury. 2005;36:793–800.

56. Weil Y, Gardner M, Mikhail G. Medial migration of intramedullary hip fixation devices: a biomechanical analysis. Arch Orthop Trauma Surg. 2008;128:227–34.
57. Strauss E, Kummer F, Koval K. The "Z-effect" phenomenon defined: a laboratory study. J Orthop Res. 2007;25:1568–73.
58. Erken HY, Nusran G, Karagüven D, Yilmaz O, Kuru T. No decrease in infection rate with the use of local vancomycin powder after partial hip replacement in elderly patients with comorbidities. Cureus. 2020;12:e10296.
59. O'Toole R, Degani Y, Carlini AR, Castillo R, O'Hara N, Joshi M, METRC. Systemic absorption and nephrotoxicity associated with topical vancomycin powder for fracture surgery. J Orthop Trauma. 2021;35:29–34.
60. Metsemakers WJ, Fragomen AT, Moriarty TF, Morgenstern M, Egol KA, Zalavras C, Obremskey WT, Raschke M, McNally MA. Evidence-based recommendations for local antimicrobial strategies and dead space management in fracture-related infection. J Orthop Trauma. 2020;34:18–29.
61. Hanada M, Nishikino S, Hotta K, et al. Intrawound vancomycin powder increases post-operative wound complications and does not decrease periprosthetic joint infection in primary total and unicompartmental knee arthroplasties. Knee Surg Sports Traumatol Arthrosc. 2019;27:2322–7.
62. Dunn J, Kusnezov N, Bader J, et al. Long versus short cephalomedullary nail for trochanteric femur fractures (OTA 31-A1, A2 and A3): a systematic review. J Orthop Traumatol. 2016;17:361–7.
63. Norris R, Bhattacharjee D, Parker MJ. Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. Injury. 2012;43:706–11.
64. Queally JM, Harris E, Handoll HH, et al. Intramedullary nails for extracapsular hip fractures in adults. Cochrane Database Syst Rev. 2014.
65. Shetty A, Shenoy PM, Swaminathan R. Mismatch of long Gamma intramedullary nail with bow of the femur: does radius of curvature of the nail increase risk of distal femoral complications? J Clin Orthop Trauma. 2019;10:302–4.
66. Cruz-Sanchez M, Torres-Claramunt RT, Alier-Fabrego A, et al. Salvage for nail breakage in femoral intramedullary nailing. Injury. 2015;46:729–33.
67. Barquet A, Ayora G, Guimaraes JM, et al. Avascular necrosis of the femoral head following trochanteric fractures in adults: a systematic review. Injury. 2014;45:1848–58.
68. Kakarala GK, Van Rensburg L, Parker M. Pseudo-aneurysm of the lateral circumflex femoral artery. Eur J Trauma. 2006;32:480–1.

Chapter 6
Surgical Treatment of Femoral Neck Fractures

Michael B. Held, William K. Crockatt, Kyle L. McCormick, and Jeffrey A. Geller

Epidemiology of Femoral Neck Fractures in Geriatric Patients

Economic Impact and Incidence

Fractures of the femoral neck account for over 50% of all hip fractures and have a significant economic burden on the healthcare system [2]. With an increasing population of elderly individuals, it is expected that the number of femoral neck fractures and associated healthcare costs will substantially rise over the coming decades. In 2010, the direct medical cost of managing all geriatric hip fractures was estimated to be US$17–20 billion, and projections are estimated to rise to as much as US$446.3 billion worldwide by the year 2050. Patients typically spend US$40,000 in the first year following hip fracture mostly for medical treatment and rehabilitation costs, and nearly $5000 in the each of the years to follow [3–5].

Despite these predictions, the incidence of femoral neck fractures in patients ≥65 years of age has fallen over recent years. In a nationwide analysis of femoral neck fractures in elderly patients, there was a steady decrease in total fractures (86,978 in 2003 to 65,130 in 2013) as well as national age-adjusted incidence of

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femoral neck fractures (242 per 100,000 US adults in 2003 to 146 in 2013), consistent with trends identified across the literature. Additionally, the rate of operative fixation has steadily increased from 89.2% in 2003 to 92.1% in 2013, with the choice of total hip arthroplasty rising in popularity [6, 7].

Age Distribution

Hip fracture patterns tend to vary based upon age at injury. Young adults typically have greater bone density than elderly individuals and tend to suffer basicervical or vertically oriented distal femoral neck fractures from high-energy mechanisms. On the other hand, elderly individuals tend to have subcapital or transcervical femoral neck fractures from low-energy mechanisms, such as a fall from standing [8]. Of patients ≥65 years old undergoing operative fixation of a femoral neck fracture in 2013, 20,945 (34.9%) were aged 65–79 years, while 39,020 (65.1%) were ≥80 years [6].

Risk Factors

Risk factors for femoral neck fracture in the geriatric population include, but are not limited to, osteoporosis, inadequate home safety or supervision, and associated medical conditions that may increase the prevalence of falls, such as diabetes, impaired vision, and impaired physical function or balance, as well as neurologic disorders such as Parkinson's disease, neuropathy, spinal stenosis, or dementia [5]. Factors that may be protective against femoral neck fracture include bisphosphonate use, decreased smoking rates, bone density screening, proper nutrition, and weight-bearing exercise [3, 6].

Morbidity and Mortality

Femoral neck fractures are a major cause of morbidity and mortality in the geriatric population, and elderly patients are at increased risk of short- and long-term complications. In the perioperative period, patients are at risk of surgical site infection, venous thromboembolism, acute kidney injury or renal insufficiency, urinary tract infection (particularly with use of indwelling urinary catheter), peripheral nerve injury, graft/implant failure, reoperation within 30 days, and death, among many other complications [4, 9]. In a recent multivariate analysis utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database, predictors of adverse events in the perioperative period included American Society of Anesthesiologist (ASA) Class 3 or 4, older age, dependent functional status, longer operative time, medical comorbidities like hypertension and diabetes, and cases deemed to be emergent operations [4]. Conversely, delay in surgical treatment longer than 48 hours has also been shown to increase complication rates following femoral neck fracture [4].

Additionally, the mortality risk following femoral neck fracture is significantly higher among geriatric patients than individuals of similar age without fracture, both in the perioperative period and at 1 year postoperatively. In a 2019 multicenter study evaluating predictive factors for mortality in the geriatric hip fracture population, approximately 5% of patients died within 30 days after admission [10]. At 1 year, mortality rates remain high, ranging 18–33%, suggesting that patients sustaining these fractures suffer from continued complications and additional medical comorbidities resulting in declining health status compared to their peers [11, 12]. Important risk factors for increased mortality include albumin <3.5 g/dL (hazard ratio [HR] 0.36), urinary retention (HR 0.4), dependence with activities of daily living (ADLs) (HR 0.29), and cognitive disorder (HR 0.65) [10]. Moreover, those patients with recent hospital admission prior to the fracture are also at higher risk for poor functional outcomes and increased mortality rates [13].

Impact on Quality of Life

Geriatric patients frequently achieve poor physical, psychological, and social outcomes following fracture of the femoral neck. These patients are often unable to return to previous ambulatory status, require increased level of care and supervision, and report lower health-related quality of life and functional outcome measures. On average, 40–60% of survivors recover their pre-fracture level of mobility, while nearly 35% are incapable of walking independently [1, 12]. Approximately 70% of patients return to basic ADLs, while roughly half regain pre-fracture independence with ADLs. Recovery may take up to a year; however, most patients who show improvement with basic ADLs do so within 6 months of injury [1]. Additionally, 20% of patients will permanently enter a long-term care facility within the first year after fracture [12].

A number of factors are associated with worse functional outcomes in the geriatric population after femoral neck fractures, including pre-fracture ADLs, initial fracture displacement, decreased preoperative cognitive status, and concomitant psychiatric disorders. Level of dependence with ADLs prior to the fracture has been shown to be an important determinant of EuroQol-5D (EQ-5D) scores upon hospital discharge, with increased dependence correlating to lower EQ-5D scores; in general, higher EQ-5D scores suggest better self-reported overall health outcomes in the five areas of mobility, self-care, usual activities, pain/discomfort, and anxiety/depression [2]. Elderly patients with displaced femoral neck fractures have significantly lower EQ-5D scores at 26 months following injury than those with non-displaced femoral neck fractures when treated with wither sliding hip screws or cancellous screws [2]. Moderate cognitive impairment, with Mini Mental Status Examination (MMSE) score between 10 and 19, has also been associated with a lower EQ-5D index at hospital discharge and a greater decrease in EQ-5D during hospitalization [14]. Since depression is commonly underdiagnosed and undertreated in the elderly population, all geriatric hip fracture patients should be routinely screened for psychiatric disorders. Depressive patients not receiving antidepressant medication experienced a greater decrease in the EQ-5D during hospitalization as compared to those who were receiving medication [14].

An orthogeriatric model of care pathway may be beneficial to optimize the functional outcomes of elderly patients with femoral neck fractures. These systems emphasize overall assessment of patient health, medical co-management with a hospitalist team, medication review and reconciliation, appropriate pain control, adequate nutrition, depression screening, delirium prevention, return to ambulation and ADLs, and home safety and prevention of falls. By utilizing a large interdisciplinary team of medical, orthopaedic, and rehabilitation providers, orthogeriatric models have shown positive benefits in the rate of discharge directly to home; ADLs, fear of falling, and quality of life at 4 and 12 months; mobility and cognition at 12 months; and overall mortality [12].

Applied Surgical Anatomy of the Proximal Femur

Osteology of the Femoral Neck

The femoral neck is composed of both dense cortical and cancellous trabecular bone, and its osseous architecture is determined by the forces generated during normal weight bearing and ambulation. Stress-induced bone remodeling results in thickening of the compressive and tensile groups of trabeculae within the femoral neck (Fig. 6.1). A region of low bone density and relative weakness, called Ward triangle, is located at the inferomedial aspect of the femoral neck between the primary and secondary compressive groups [8, 15, 16]. There is also a notable thickening of the inferomedial cortex at the medial compression buttress. Adjacent to this, a dense ridge of cortical bone called the calcar femorale can be identified at the posteromedial femoral neck, deep to the lesser trochanter and projecting toward the greater trochanter superolaterally [8, 15, 16]. The calcar femorale is an important structural support that distributes force through the hip joint into the proximal femur, and disruption of the calcar has significant consequences on the choice of surgical procedure and implant selection [15].

The change in femoral neck architecture with normal aging plays an important role in the mechanism of geriatric fractures. Over time, the superior aspect of the femoral neck experiences less load than the inferior aspect and undergoes cortical thinning, thereby increasing risk of fracture. Cortical bone also increases

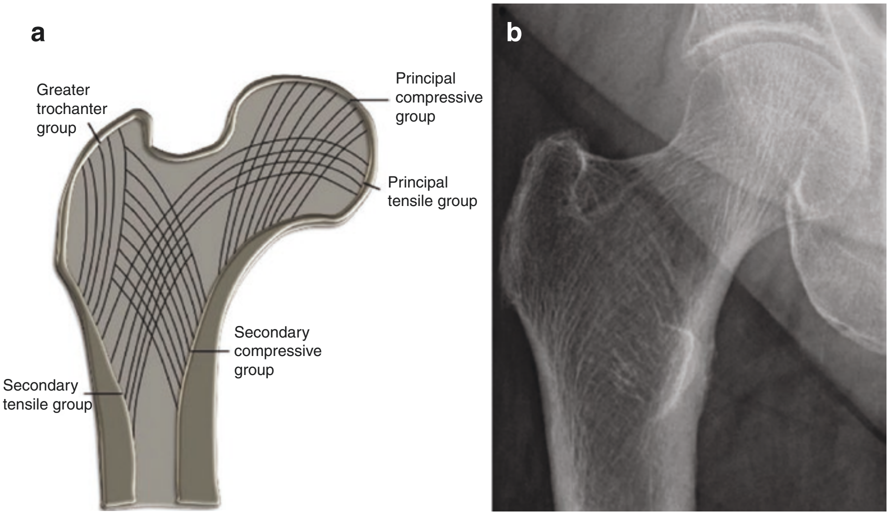

Fig. 6.1 Bone density of the proximal femur. (**a**) Illustration of the compressive and tensile trabeculae of the femoral neck, (**b**) anteroposterior hip radiograph with trabeculae visible. (Reprinted with permission by Springer Nature: Springer Nature, Kani et al. [16] COPYRIGHT 2018. license #4976570377385)

in porosity with age, from 4% in young adults to nearly 50% in the elderly patients. Furthermore, age-related nonenzymatic cross-linking of collagen can reduce the elasticity, load to failure, and energy required to fracture cortical bone [15].

In addition to age-related changes in cortical bone, geriatric patients with osteoporosis are at increased risk of fragility fracture due to further loss of trabecular bone, particularly in the area of Ward triangle [8]. The occurrence of femoral neck fractures has also been shown to correlate with degeneration of compressive and tensile trabeculae on multi-detector CT [8, 15], and a 1 standard deviation decrease in femoral neck bone mineral density has an odds ratio of hip fracture ~4.5 [17].

Vascular Supply of the Proximal Femur

The primary vascular contributions to the femoral neck and head include the medial and lateral femoral circumflex arteries and the inferior gluteal artery. Together, these vessels form an extracapsular anastomotic ring, from which the ascending intracapsular cervical branches arise (Fig. 6.2) [8, 15]. These branches enter the neck anteriorly at the intertrochanteric line and posteriorly at the intertrochanteric crest, before traveling toward the femoral head. A subsynovial intracapsular ring, formed by the retinacular and epiphyseal arteries, lies at the junction of the articular surface

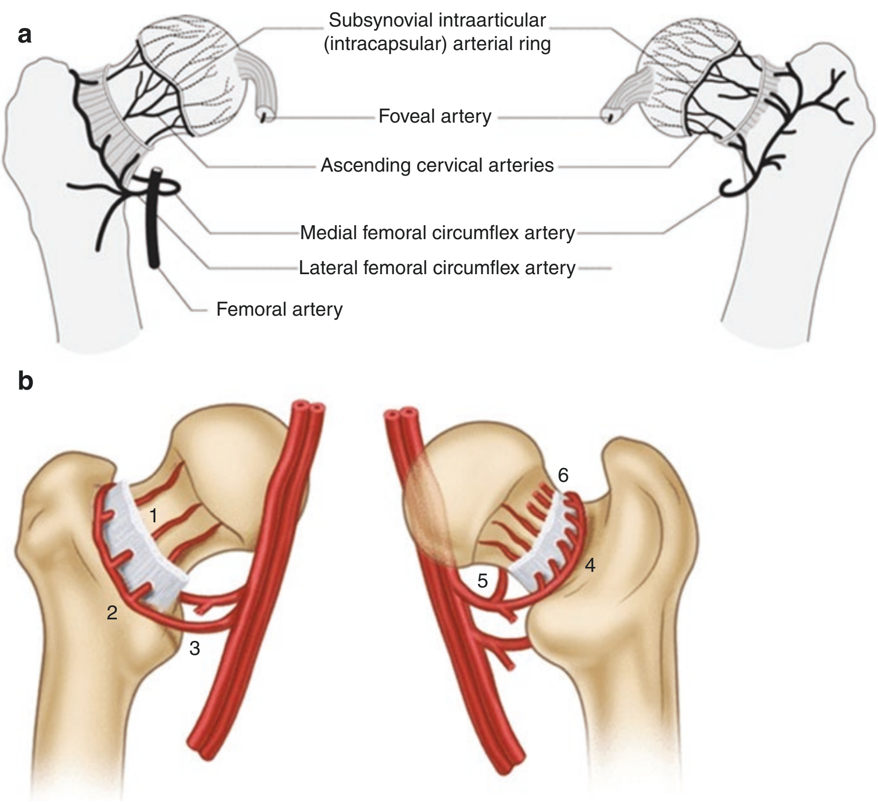

Fig. 6.2 Vascular anatomy of the proximal femur. (Reprinted with permission by Springer Nature: Springer Nature, Thorngren [65]. COPYRIGHT 2014. License #4976580028265)

of the head and neck [8]. Additional minor contributions come from the superior gluteal artery, obturator artery, and acetabular branch of the obturator artery within the ligamentum teres [15].

There is a high risk of vascular compromise and resulting avascular necrosis (AVN) of the femoral head following displaced femoral neck fractures due to the intracapsular and intraosseous course of the vessels. The ascending intracapsular cervical branches and vessels of the subsynovial ring are at particular risk in subcapital and transcervical fractures. Therefore, the orthopaedic surgeon must give strong consideration to the appropriate treatment options and account for maintenance or restoration of blood flow with internal fixation or consider implantation of a prosthesis as more definitive management [8]. Furthermore, fractures with posteromedial comminution or fracture line extension through the lateral femoral head-neck junction place patients at higher risk of vascular compromise. Conversely, basicervical and intertrochanteric fractures have minimal risk of disruption to vascular flow and AVN [8].

Surgical Approaches to the Hip

Direct Anterior

The direct anterior approach, or Smith-Petersen approach, has become popular in elective hip arthroplasty and is increasingly used during treatment of femoral neck fractures. This approach utilizes the superficial internervous plane between the sartorius and tensor fasciae latae muscles and deep interval between the rectus femoris and gluteus medius muscles (Fig. 6.3). Important considerations during the approach include ligation of the ascending branch of the lateral femoral circumflex artery and protection of the lateral femoral cutaneous nerve in the superficial plane. The direct anterior approach provides the potential advantages of reduced dislocation risk, faster recovery, less pain, and fewer surgical complications. However, it has been shown to have a significant learning curve, may have poor skin healing in obese patients, and presents complications not often seen in other approaches, like breach of the femoral canal and intraoperative periprosthetic fracture [18].

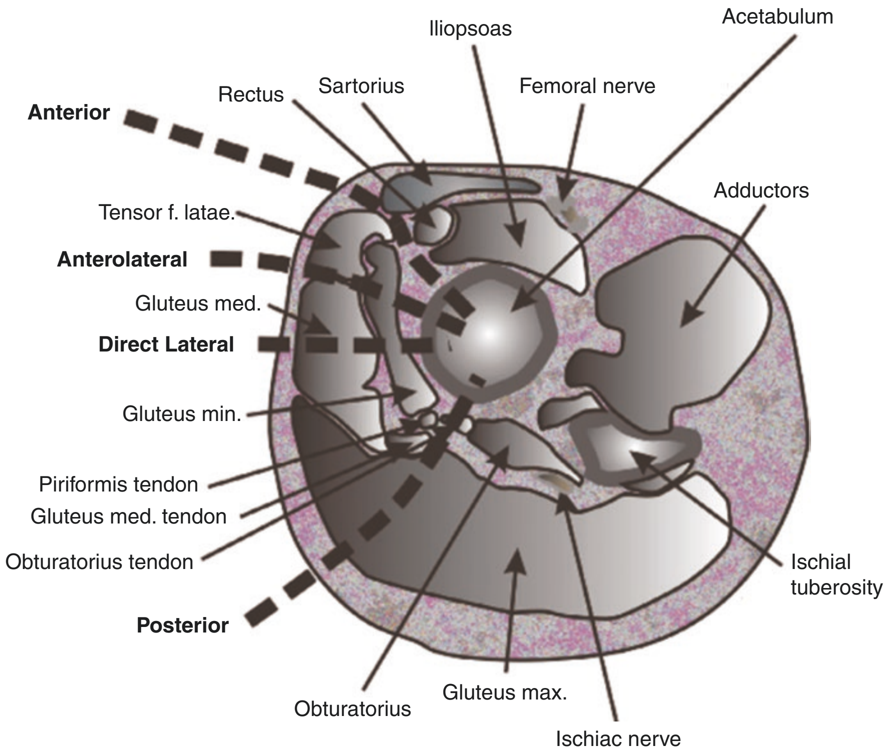

Fig. 6.3 Surgical approaches to the hip. (Reprinted with permission by Springer Nature: Springer Nature, Krismer [66]. COPYRIGHT 2009. License #4976580252779)

Anterolateral

The anterolateral, or Watson-Jones, approach can be performed in either the supine or lateral decubitus positions. Relatively recent advancements in the technique endorse an abductor sparing approach with many of the same recovery and pain benefits of the direct anterior approach. Skin incision is made 2.5 cm posterior and distal to the ASIS and runs distally over the greater trochanter. This approach utilizes the intramuscular plane between the tensor fasciae latae and the gluteus medius muscles (Fig. 6.3). Additional care must be taken to protect the femoral nerve, artery, and vein, which can be injured with placement of retractors, much like the direct anterior approach [18].

Direct Lateral

Similar to the anterolateral approach, the direct lateral approach, also known as the Hardinge or transgluteal approach, can be performed with the patient in supine or lateral decubitus positions. Incision is made 5 cm proximal to the tip of the greater trochanter and extended distally along the length of the femur. As there is no true internervous plane, this approach splits the gluteus medius and vastus lateralis muscles and releases the gluteus minimus attachment to provide exposure to the anterior joint capsule (Fig. 6.3). Injury to the superior gluteal nerve may occur with proximal extension of the gluteus medius split, resulting in postoperative Trendelenburg gait [18, 19].

Posterior

The posterior approach is performed with the patient in the lateral decubitus position with the surgical hip up. Skin incision is made approximately 7 cm superior and posterior to the greater trochanter, curving just posterior to the greater trochanter and continuing down the shaft of the femur. This approach utilizes the intermuscular and vascular plane of the gluteus maximus muscle, which is split in the interval of the superior and inferior gluteal arteries, as indicated by a fat stripe on the surface of muscle (Fig. 6.3). The posterior approach does not violate the hip abductor muscles; however, the short external rotators are detached during deep dissection. The sciatic nerve should be identified overlying the external rotator muscles; gentle retraction and patient positioning with hip extension and knee flexion may reduce traction on the nerve and decrease risk of injury [18].

Comparison of Approaches

Each of the major surgical approaches can be used safely and effectively in hip arthroplasty for the treatment of femoral neck fractures, but each provides its own advantages and disadvantages. For hip hemiarthroplasty, there is no significant difference in operative time, postoperative pain, blood loss, and length of stay among the approaches [20]. The direct anterior and posterior approaches also show similar rates of infection, postoperative periprosthetic fracture, and revision in total hip arthroplasty [21]. However, there do appear to be differences in dislocation, early functional mobility, and familiarity with the respective approaches. Current evidence shows a lower rate of dislocation with the direct lateral and direct anterior approaches as compared to the posterior approach [5, 18, 20]. The direct anterior approach has also shown improved functional outcome measures at early term follow-up for hemiarthroplasty and decreased mortality rates at 1 year following total hip arthroplasty [18, 20, 21]. Ultimately, patient-specific factors and surgeon experience with each approach must be considered for treatment of femoral neck fractures with hip arthroplasty.

Clinical Presentation and Initial Management

History and Physical Exam

In the geriatric population, femoral neck fractures most commonly occur as a result of a low-energy fall. This may be due to a fall directly onto the hip, a rotational injury with the foot planted, or spontaneous completion of an insufficiency fracture. The etiology of the fall (i.e., syncopal, mechanical, etc.) should be thoroughly evaluated in the history, and patients should be assessed and treated for any additional injuries.

On physical examination, patients with displaced femoral neck fractures tend to present with external rotation, abduction, and shortening of the injured extremity, while those with nondisplaced fractures may have no obvious visual deformity. Pain can be elicited with direct palpation over the greater trochanter or with movement like internal or external rotation of the hip. Range of motion will typically be severely limited due to pain, and patients are often unable to perform a straight leg raise. A thorough neurovascular examination should also be performed and documented during initial evaluation. Similarly, an evaluation of the soft tissue skin envelope should be done as it may affect the surgeon's choice of surgical approach if/when surgery is indicated. Finally, a full body survey for any areas of bruising, deformity, or pain should be done as secondary injuries are not uncommon in this more frail population and may be overlooked by distracting pain from the hip injury.

Radiographic Evaluation

Plain Film Radiographs

Initial imaging for geriatric femoral neck fractures should include radiographs with an anteroposterior (AP) view of the pelvis, AP and cross-table lateral view of the affected hip, and a full length femur view. Ideally, X-rays should be taken with a scaling marker ball positioned either between the thighs or at the greater trochanter for the AP views and mid-thigh at the level of the femoral shaft for lateral views for surgical planning if arthroplasty is necessary. Findings significant for femoral neck fracture may include disruption of the cortex, sclerosis at the site of impaction, loss of contour of Shenton's line, disruption in the alignment of the trabeculae, and valgus or varus angulation of the femoral head-neck junction [16]. Radiographs should also be evaluated for concomitant femoral shaft or distal femur fractures, as well as hip osteoarthritis.

A traction radiograph of the hip may add in accurately classifying intracapsular versus extracapsular femoral neck fractures. The traction view places the patient in a supine position, with a gentle, controlled traction force applied through the foot and ankle, up to a maximum of 10–15 kg. The leg is also brought into slight internal rotation for the traction view. Traction should be slowly released after the image is obtained to prevent additional pain or injury [22].

Role of Advanced Imaging

Plain film radiographs may demonstrate false-negative findings of geriatric femoral neck fracture in up to 10% of cases, in part due to patient age and bone mineral density [9, 16]. AAOS Clinical Practice Guidelines for Management of Hip Fractures in the Elderly supports MRI as the advanced imaging modality of choice for diagnosis of occult femoral neck fracture not apparent on initial radiographs [5, 8]. On MRI, occult fractures appear as T1 hypointense lines with surrounding hyperintense edema and has the added benefit of evaluating for other potential causes of hip pain [8, 16]. For those patients contraindicated for MRI, thin slice multidetector CT has shown similar sensitivity and specificity to MRI in evaluating occult femoral neck fractures [23]. Bone scans are no longer indicated as a modality of choice for detecting occult femoral neck fractures.

Fracture Classification

Intracapsular and Extracapsular Fractures

The intra- or extracapsular nature of femoral neck fractures has significant implications for the choice of surgical treatment. Subcapital and transcervical femoral neck fractures are considered intracapsular and treated with either open reduction internal fixation or closed reduction percutaneous pinning if non-displaced or arthroplasty if displaced; basicervical fractures occur at the junction of the base of the femoral neck and the intertrochanteric crest. Though basicervical femoral neck fractures may be intracapsular, the risk of vascular injury is lower, and they may be treated like extracapsular fractures given great healing potential. Intertrochanteric fractures are considered extracapsular in nature and treatments vary accordingly [2, 8].

Garden Classification

The Garden classification is the most commonly used classification scheme for geriatric hip fractures. It divides femoral neck fractures into one of four categories based on fracture displacement as seen on an AP radiograph (Fig. 6.4). Garden type 1 fractures are described as incomplete, valgus impacted, while type 2 fractures are

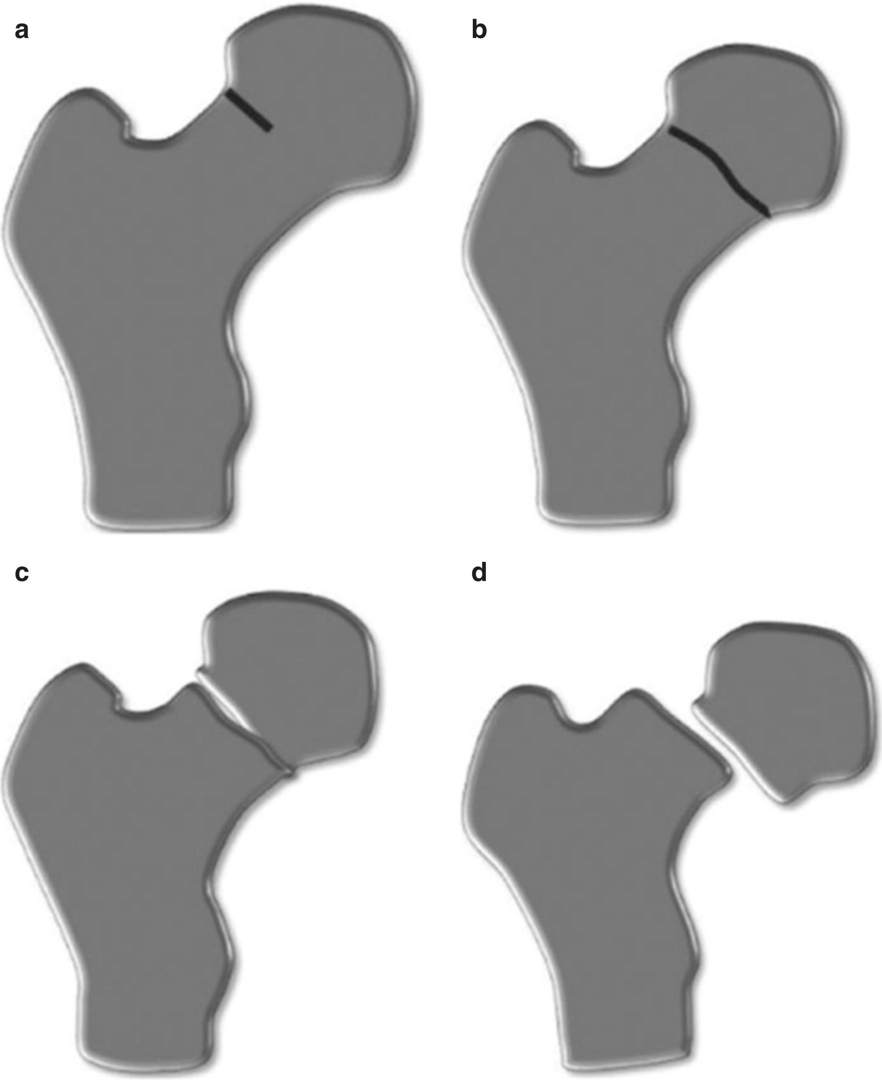

Fig. 6.4 Garden classification of femoral neck fractures. (**a**) Garden type 1, incomplete, valgus impacted; (**b**) Garden type 2, complete, nondisplaced; (**c**) Garden type 3, complete, partially displaced; (**d**) Garden type 4, complete, fully displaced. (Reprinted with permission by Springer Nature: Springer Nature, Kani et al. [16] COPYRIGHT 2018. license #4976570377385)

complete, nondisplaced. Type 3 fractures are complete, partially displaced, and type 4 fractures are complete, fully displaced [8, 15]. Type 1 valgus-impacted fractures are often missed on initial radiographs because of minimal cortical disruption and mild fracture angulation. When femoral neck fracture is part of the differential diagnosis, it is important to assess for a sclerotic lateral cortical impaction triangle, which may signal a Garden type 1 fracture. The modified Garden classification, which categorizes femoral neck fractures simply as nondisplaced or displaced, has been shown to have greater interobserver reliability than the original system [15].

Pauwels Classification

The Pauwels classification system is less frequently used in the geriatric population and typically helps categorize high-energy femoral neck fractures in younger adults. This system is based upon the vertical angulation of the fracture line using Pauwels angle, which is the angle between a line through the fracture and a line tangential to the superior aspect of the femoral head. Type I fractures have a Pauwels angle less than 30°, type II fractures between 30° and 50°, and type III fractures greater than 50° [8, 15]. A greater Pauwels angle results in increased shear forces across the fracture, potentially causing complications with fracture stability and risk of varus collapse.

AO/OTA

The AO/OTA classification system is an alphanumeric system with the ability to classify any fracture by bone, segment, joint involvement, and fracture pattern and geometry. Femoral neck fractures are classified as 31-B. These fractures can be further divided into subcapital (31B1), transcervical (31B2), or basicervical (31B3). Subcapital fractures are described as valgus impacted (31B1.1), nondisplaced (31B1.2), and displaced (31B1.3), while transcervical fractures are considered simple (31B2.1), multifragmentary (31B2.2), or shear (31B2.3) [15].

Non-operative Treatment of Femoral Neck Fractures

Indications for Non-operative Treatment

Although the overwhelming majority of geriatric patients with femoral neck fractures are treated surgically, there is a small subset of patients who may be treated non-operatively. Surgical intervention does not guarantee a return to previous function and/or quality of life. Even with operative treatment, there is only a 46% chance that a geriatric patient will return to previous functionality and mobility [24] and 15–20% do not return to their original residences following a femoral neck fracture [25, 26]. Given this high rate of morbidity, non-operative treatment may be considered after discussion and shared decision-making between the surgeon, geriatrician, and patient with his/her healthcare proxy (if patient lacks capacity). A large Canadian registry study found that the incidence of non-operative treatment of hip fractures has significantly declined over time, from 8.3% to 5.1% (1990–1994, 2010–2014, $p < 0.001$, respectively) [27].

Indications for non-operative, palliative treatment of femoral neck fractures include patients with minimal to no baseline ambulatory status, patients on hospice with poor short-term prognosis, unacceptable surgical risk, and those who decide to not undergo surgical intervention. If a patient was bedbound and not ambulatory prior to injury, it is extremely unlikely that surgical intervention will change this. Furthermore, it has been demonstrated by Hossain et al. that medically unfit patients do not have a significant difference in functionality and mortality when comparing operative and non-operative treatment [28]. However, palliative surgery should be carefully considered as this may improve pain and quality of life for both patients and caretakers.

Relative Indications for Non-operative Treatment
- Prior bedbound patients
- Baseline limited ambulator
- Hospice patients
- Medically unfit patients
- Patient/family decision
- Non-displaced fracture in elderly patient

Complications of Non-operative Treatment

The complications of non-operative treatment of femoral neck fracture are mainly secondary to prolonged bed rest and immobility despite proper medical and nursing care. This includes pressure sores on the sacrum and heel, respiratory compromise from aspiration and/or pneumonia, deep vein thrombosis (DVT) and pulmonary embolus (PE), urinary tract infection (UTI), and increased pain during transfer [29]. Nonetheless, surgery does not necessarily prevent all of the aforementioned complications.

Complications of Non-operative Treatment
- DVT
- PE
- Pneumonia
- Aspiration
- Pain during transfer
- Sacral pressure ulcers
- Heel pressure ulcers
- UTI

Prevention of Non-operative Complications

Vigilant nursing care is essential to preventing complications following non-operative treatment of femoral neck fractures. Constant turning and repositioning is needed to prevent pressure-induced skin necrosis [30]. Specialty mattresses, as well as padding or elevation of the heels, can be used to prevent skin breakdown. Adequate nutrition can also help prevent long-term skin breakdown [31]. Combined mechanical and pharmacologic DVT prophylaxis is critical to minimize risk of pulmonary embolus (PE). Incentive spirometry and elevation of the head of bed can help prevent aspiration and pneumonia. Additionally, multi-disciplinary management with palliative care physicians and geriatricians can lead to improved pain scores, using multimodal pain control techniques while minimizing opioid consumption and its potential complications.

Closed Reduction Percutaneous Pinning

General Principles and Indications

Closed reduction percutaneous pinning (CRPP) is an important surgical consideration when treating non-displaced and valgus-impacted femoral neck fractures in geriatric patients. The goals of CRPP are to return a patient to his/her baseline ambulatory level and to prevent malunion and avascular necrosis (AVN) of the femoral head. CRPP is a minimally invasive technique, which utilizes cannulated screws (partially threaded or fully threaded) to fix stable fracture patterns that have a lower risk of AVN and do not require more than minimal reduction of fracture fragments. Ideal fracture patterns amenable to CRPP include Garden 1 femoral neck fractures and valgus-impacted length stable fracture patterns (Fig. 6.5). Careful evaluation must also be made to the lateral radiograph to confirm that the fracture pattern is not more displaced than it seems on the AP projection.

In the geriatric population, completely displaced or varus fracture patterns are not amenable to CRPP. In these circumstances, arthroplasty should be the treatment due to high rates of malunion, nonunion, and AVN with closed or open reduction and fixation. This is especially true in geriatric patients with limited life expectancy to avoid the morbidity of a second conversion procedure. In a randomized controlled trial by Tidermark et al., the rate of complication and reoperation was much lower for arthroplasty compared to CRPP for displaced femoral neck fractures (4% versus 36% and 4% versus 42% respectively; $p < 0.001$) [32]. Thus, one must be selective in which patients are most suited for CRPP versus arthroplasty.

Surgical Technique

CRPP with cannulated screws can be performed on a regular radiolucent table or a specialized fracture table. It is the senior author's preference to perform CRPP of the proximal femur on a fracture table either with the legs scissored (contralateral hip extended) or with the contralateral leg flexed at the hip to make room for the lateral fluoroscopic image. Prior to the start of the procedure, it is imperative to check fluoroscopically that positioning allows for perfect AP and lateral X-ray of the hip. Thus, it is important to have arthroplasty equipment on backup in the case of displacement during transfer to the operating room.

Geriatric non-displaced and valgus impacted fractures generally do not require large reduction maneuvers. The majority of these fractures can be pinned in situ. However, if a reduction is needed, one may utilize the Whitman technique on the fracture table. The hip is slightly extended and the leg is externally rotated in the

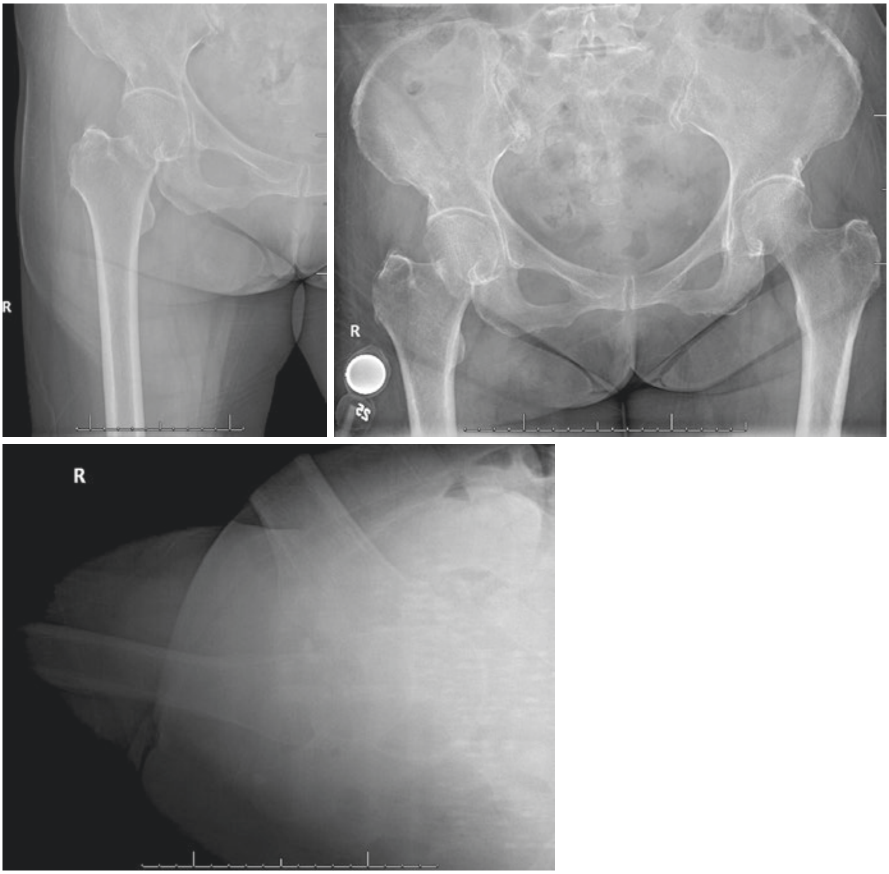

Fig. 6.5 Example of valgus-impacted femoral neck fracture

footplate and abducted to roughly 20 degrees. Traction is then applied, and the leg is internally rotated around 20–30 degrees, judging off the patella. Fluoroscopy confirms reduction or the need for further adjustments.

The anterior, posterior, superior, and inferior femoral neck are marked utilizing fluoroscopy. An important landmark to identify is the lesser trochanter. It is imperative that the start point of the most inferior screw is not distal to this, as this may lead to a stress riser which can lead to future sub-trochanteric fracture. Utilizing fluoroscopy, Kirschner wires (K-wires) are percutaneously placed through the skin, with or without a limited skin incision, and fascia in an inverted triangle configuration (Fig. 6.6). The configuration is started by placing the most inferior wire, as this generally provides the most robust bone stock for fixation in elderly osteoporotic patients. The senior author aims to place this screw just superior and anterior to the calcar to ensure that the threads engage cortical bone to prevent future collapse. The remaining k-wires can be passed either with the aid of a pin guide or using a freehand technique in an inverted triangle or diamond configuration.

The wires are passed retrograde to subchondral bone, ensuring that they do not penetrate into the joint space. A small incision is made through the skin and fascia and the length of the screws is determined utilizing a calibrated measuring device. It is important to ensure that the guide is down to bone to prevent aberrant measurements. Generally, 5 mm is subtracted off of the measurement to ensure that the screw does not penetrate into the joint. The lateral cortex is opened with a cannulated drill and the screws are then placed over the K-wires. These screws are typically self-tapping, so it is not necessary to tap with the drill, especially in osteoporotic bone.

Different screw sizes are available; however, it is our practice to either use 6.5 mm or 7.3 mm partially threaded screws depending on the available space within

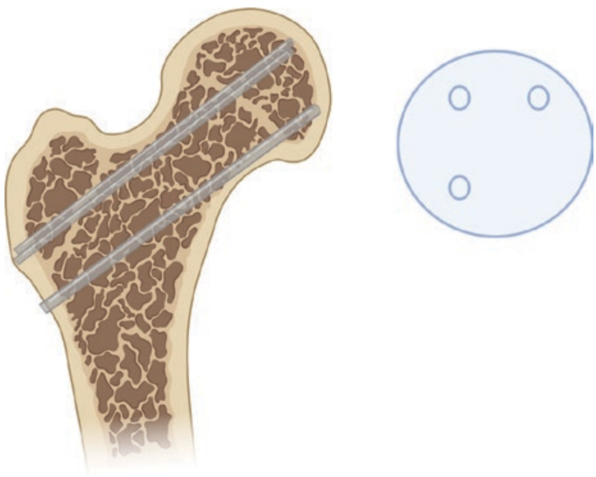

Fig. 6.6 Preferred pin configuration

the individual's femoral neck anatomy. It is important that the threads completely cross the fracture site to aid in gentle compression if using partially threaded screws. Washers can be utilized on all or some of the screws to prevent screwhead penetration. In the event that the neck is in too much valgus, one may use a combination of partially threaded and fully threaded screws to aid in reduction. The most inferior screw should be partially threaded and placed first. Utilizing the lag-by-design technique, this screw is compressed to tilt the neck out of valgus. Next, one or two, fully threaded, superior screws are then placed to aid in fixation. An example of three partially threaded screws placed in an inverted triangle configuration can be seen in Fig. 6.7. It is important that your screws do not converge to aid in mechanical stability.

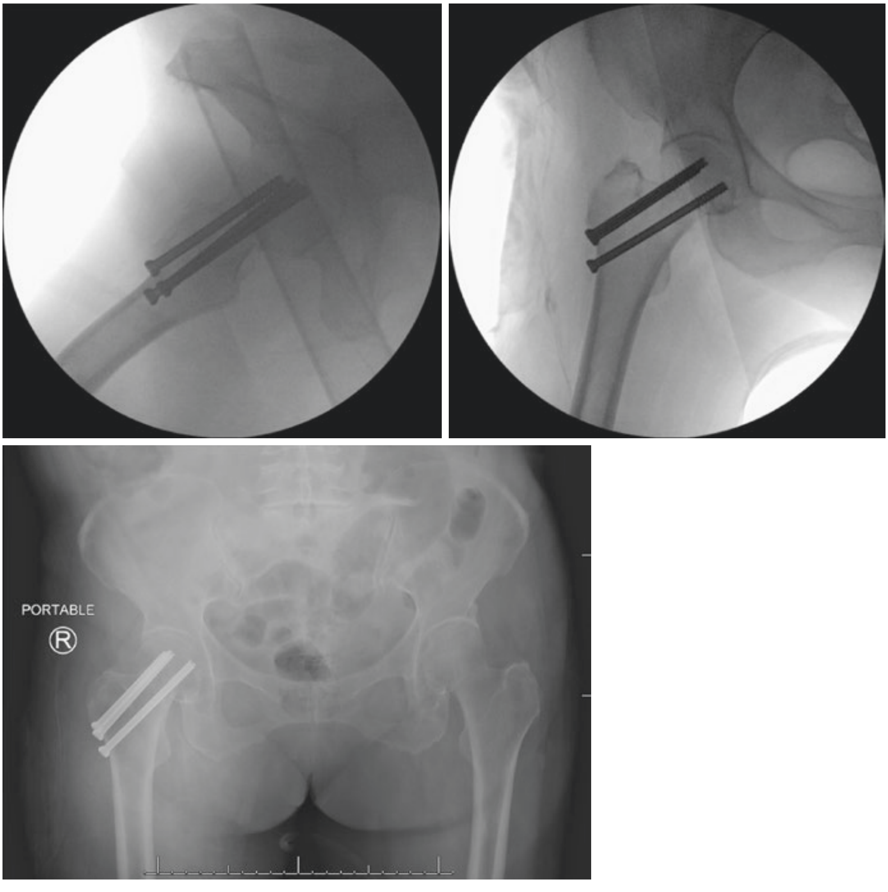

Fig. 6.7 Postoperative X-rays following closed reduction percutaneous pinning

Technical Pearls to CRPP

- Always obtain perfect AP and lateral X-rays prior to incision.
- Have arthroplasty equipment available as backup.
- Ensure that none of the starting points of your screws are distal to the lesser trochanter to prevent future stress riser.
- Start by placing the most inferior, posterior screw to ensure good screw-to-bone purchase in the geriatric population.
- Utilize an inverted triangle pin configuration.
- Ensure that screws do not converge.

Perioperative Care

Following CRPP, we obtain postoperative flat plate radiographs in the recovery room. Perioperative antibiotics are given for 24 hours postoperatively. Patients are generally made weight bearing as tolerated with no restrictions. We focus on early mobilization of these patients to encourage prompt removal of the urinary catheter, combined with mechanical and pharmacologic DVT prophylaxis to reduce the risk of bed-bound complications. Our postoperative protocol to prevent VTE complications consists of sequential compression devices while in the hospital and aspirin 81 mg twice daily for 28 days. For patients at higher risk, enoxaparin 40 mg once daily or apixaban 2.5 mg twice daily for 28 days is utilized. Patients are co-managed with the medical service and multimodal pain control is utilized to minimize opiate consumption. Patients are seen by physical therapy on postoperative day (POD) 0 and are assessed for safe discharge disposition. Generally, elderly patients stay in the hospital for 1–2 days followed by subacute rehab for 1–2 weeks, but this varies depending on individual patient progress and needs.

Postoperative Outcomes and Complications

Failure rates of CRPP for femoral neck fracture in the geriatric population occur in 5–19% of cases [33]. Reasons for failure include AVN, failure of fixation, screw penetration, screw cut-out and nonunion. The surgical treatment for failure following CRPP is typically a conversion to total hip arthroplasty (THA) or hemiarthroplasty (HA) as revision open reduction with internal fixation is generally unsuccessful in this patient population. Conversion rates have been documented to be 10–20% at 12 months postoperatively [33, 34].

Additionally, when fixation is chosen over replacement, AVN, screw back–out, and collapse become major concerns (Fig. 6.8). The rate of AVN following CRPP for nondisplaced femoral neck fracture has been cited at 7.2% [35]. Thus, given this high rate of conversion and potential for AVN following CRPP, many advocate for an initial arthroplasty in all circumstances to prevent necessitating a secondary, more complex revision procedure.

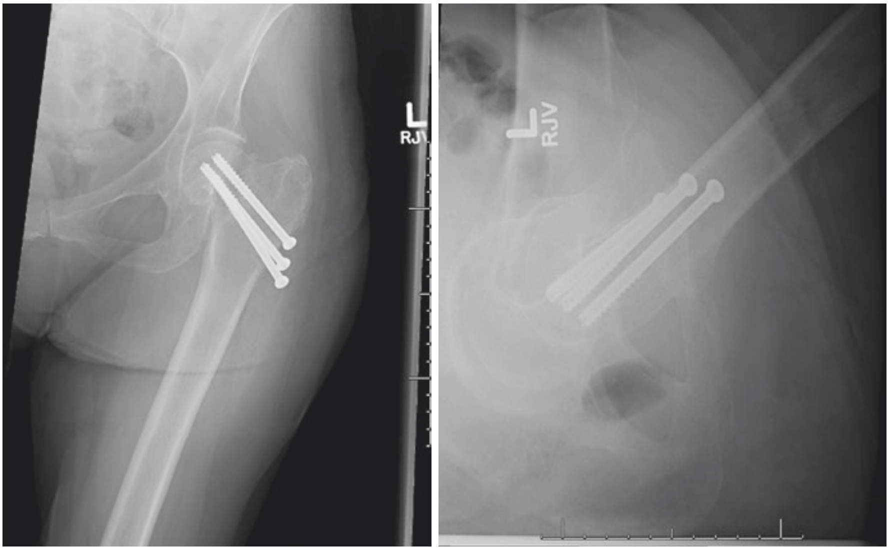

Fig. 6.8 Screw backout and shortening after CRPP

Nonetheless, CRPP does offer some benefits as compared to arthroplasty. This includes a lower dislocation rate, lower infection rate, and a lower rate of heterotopic ossification [36]. Increasing age over 80 and obesity are risk factors for failure and reoperation following CRPP [36, 37]. Thus, the elderly, morbidly obese patient may not be the ideal candidate for CRPP.

Postoperative Complications Following CRPP

- Avascular necrosis
- Fixation failure
- Screw penetration
- Screw cut-out
- Nonunion
- Subtrochanteric fracture

Open Reduction Internal Fixation (ORIF)

General Principles and Indications

Although ORIF is a frequently utilized treatment option for younger patients with femoral neck fractures, it is rarely indicated in the geriatric patient population. Conventional dogma states that in younger patients, less than 50 years old, attempts should be made to save the femoral head and preserve the native joint as this is more desirable in this patient population compared to early arthroplasty. If these patients ultimately progress to failure of fixation or AVN, they are converted to total hip arthroplasty. In fact, the rate of AVN in a patient population <50 years of age with displaced femoral neck fractures is up to 27% [38]. Given the already high rate of AVN in younger, healthy patients, the same dogma of initial fixation does not apply to the geriatric population, who have poorer bone quality, decreased vascularity, less ability to heal, and limited life expectancy. In order to minimize a more complex, conversion surgery, geriatric patients more commonly undergo arthroplasty as the procedure of choice for displaced femoral neck fracture.

There are narrow indications for a true ORIF of the femoral neck in the geriatric population. Non-displaced basicervical femoral neck fractures can be treated with a fixed angle device, such as a sliding-hip screw, proximal femoral locking plate, an intramedullary nail, or cannulated screws (Fig. 6.9). It is our preference to use sliding-hip screws when performing ORIF in the geriatric population. We do not recommend the use of proximal femoral locking plate, given the high incidence of catastrophic failure with this technique [39]. In summary, the high risk of AVN, failure of fixation, and need for conversion to arthroplasty limit the indications for ORIF of the femoral neck in an elderly patient. Initial treatment with THA or HA should always be considered in the geriatric patient population.

Relative Indications for ORIF in Geriatric Patients

- Non-displaced basicervical femoral neck fracture
- Non-displaced transcervical femoral neck fracture
- Garden 1 femoral neck fracture
- Valgus-impacted femoral neck fracture
- High Pauwels angle, nondisplaced femoral neck fracture

Surgical Technique

This technique will be more thoroughly described in Chap. 5, and in this chapter, we will only briefly describe the technique of ORIF utilizing the sliding hip screw. It is the senior author's practice to position the patient on a fracture table with a perineal post. It should be noted that this technique can also be performed in the lateral decubitus position with a bean bag. Proper AP and lateral X-rays are obtained, and if reduction is indicated, the Whitman technique, as described earlier in this chapter, is utilized. The tip of the greater trochanter, femoral neck, and longitudinal axis of the femur are marked using fluoroscopic guidance. Skin incision is marked, centered on the lateral femur, starting proximally at the vastus ridge and extending distally roughly 7 cm. Incision is taken down to the iliotibial band, and this is sharply divided. The vastus is carefully elevated from its posterolateral attachment to the femur in a subvastus fashion. Care is taken to coagulate any perforating vessels of the vastus at the distal end of the incision, as these may cause major bleeding

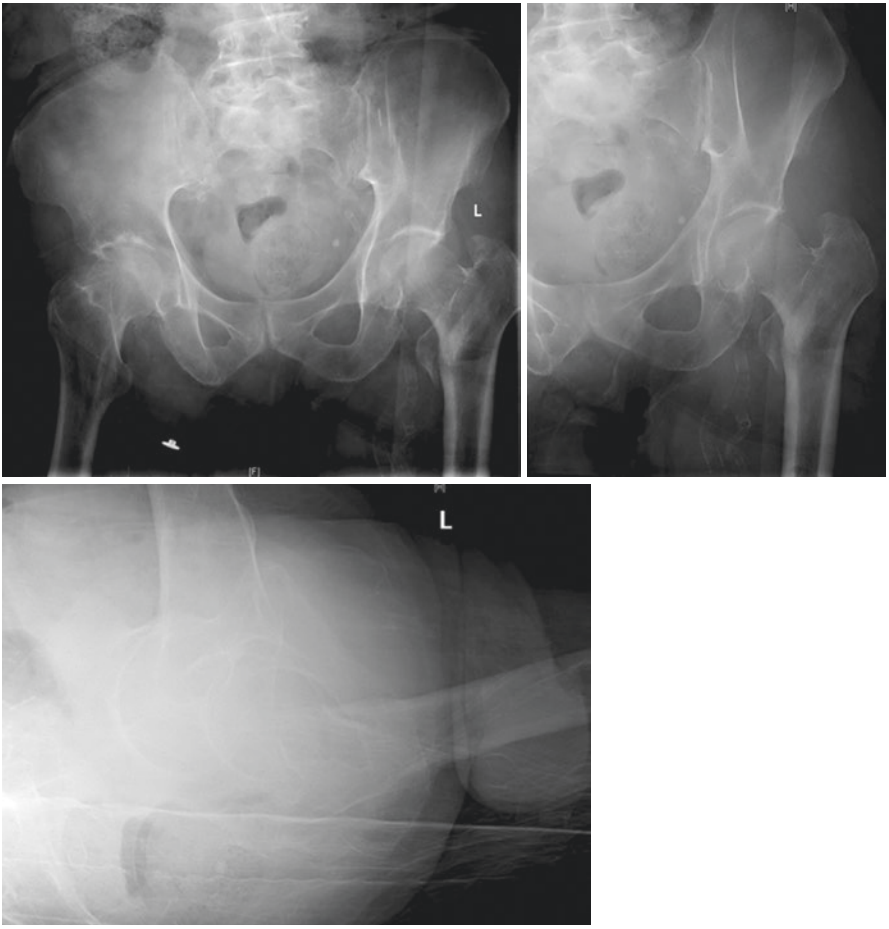

Fig. 6.9 Non-displaced femoral neck fracture amenable to sliding hip screw

if inadvertently damaged. Exposure of the lateral femur is obtained by placing blunt retractors over the anterior aspect of the femoral shaft.

C-arm fluoroscopy is utilized for guide pin placement. If a reduction is needed, a variety of instruments including a bone hook, Cobb Elevator, ball-spikes, and k-wires can be used to aid in indirect reduction. The guide pin should be placed in the center-center position of the femoral head to minimize the tip-apex distance, and ideally place the pin less than 5 mm from the joint surface, on both the AP and lateral X-ray. We aim to place the guide wire slightly more inferior than superior to prevent screw cut-out. After measuring the length of the wire, we generally subtract 5 mm from the triple reamer to avoid joint penetration. We aim for a tip-to-apex distance of <25 mm to decrease the risk of screw cut-out [40]. When reaming for the lag screw, care is taken to avoid advancing the guide wire through the femoral head and acetabulum into the pelvis. Generally, tapping is

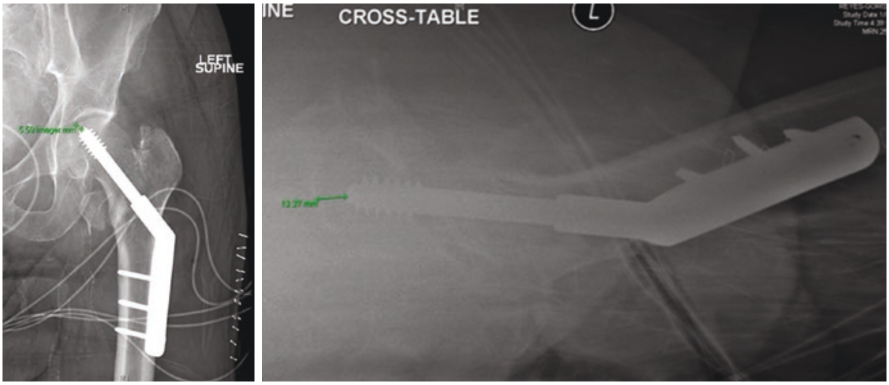

Fig. 6.10 Postoperative X-rays following sliding hip screw

not required given the osteoporotic bone quality in elderly patients. During the surgical planning phase, the contralateral neck-shaft angle is measured in order to restore anatomic alignment, and optimal sizing of the plate is determined. Generally, this is with a 130-degree or 135-degree neck-shaft plate. The lag screw, with a 2-, 3-, or 4-hole plate, is inserted, and the plate is fixed with two 4.5-mm bicortical screws. There is no mechanical advantage of utilizing a 4-hole versus 2-hole plate [41]. After confirming hardware placement with fluoroscopy, the fascia and skin are closed (Fig. 6.10).

Tips for Sliding Hip Screw Placement

- Measure the contralateral neck shaft angle to help plan proper plate angle selection (125, 130, 135 degrees).
- During approach, care must be taken to avoid perforators from the vastus muscle.
- Avoid superior placement of the lag screw, it is optimal to be more inferior than superior to avoid cut-out.
- When placing lag screws, especially on left hips, consider placing an anti-rotation screw to prevent fracture displacement.
- Tip-to-apex distance should ideally be <25 mm on AP and lateral X-rays.
- There is no mechanical advantage between 2- and 4-hole plates.

Perioperative Care

Refer to section "Perioperative Care" for perioperative care following ORIF. Postoperative care following CRPP is identical to ORIF.

Postoperative Outcomes and Complications

Compared to arthroplasty, ORIF of femoral neck fractures in the geriatric population is associated with a lower risk of wound infection, reduced length of stay, lower risk of dislocation, lower blood loss, and transfusion rates [42, 43]. Conversely, ORIF is associated with higher rates of nonunion and failure of fixation compared to arthroplasty, which leads to a more complex conversion surgery. Rates of AVN following ORIF have been demonstrated to be up to 39%, especially with initial displacement [44, 45]. Moreover, rates of nonunion range from 17% to 33% [46]. Given the high rates of conversion, proponents of arthroplasty advocate for its initial use in most geriatric femoral neck fractures. Additionally, evidence supports that patients who undergo arthroplasty have higher Harris hip scores than ORIF patients by 1-year follow-up [43].

Given the similar indications for CRPP with cancellous screws and ORIF with sliding hip screw, investigators have sought to determine whether one technique is superior to another. From a biomechanical perspective, sliding hip screws have superior tensile strength. However, clinical outcomes are mixed [47]. In the Fracture Fixation in the Operative Management of Hip Fractures (FAITH) randomized controlled trial, there was no difference in reoperation rates between cancellous screws and sliding hip screws [47]. However, patients who smoked or had displaced fractures requiring a limited reduction showed a slight advantage when treated with sliding hip screw versus cancellous screw [47].

Although there is no uniform consensus regarding ORIF of geriatric femoral neck fractures, one must carefully evaluate the individual patient and fracture characteristics to ensure that it is amenable to ORIF and not better suited for an initial arthroplasty. Younger geriatric patients with higher functional demands and displaced fractures may benefit from primary arthroplasty due to the high risk of AVN and conversion associated with ORIF.

Hemiarthroplasty and Total Hip Arthroplasty

General Principles and Indications

Historically, HA had been the gold standard for displaced femoral neck fractures in geriatric patients (>65 years old). Recently, due to advances in implant material science, surgical technique, and approach selection, THA has become increasingly utilized when treating geriatric patients with acute femoral neck fractures. Both HA and THA are reliable and reproducible operations for treatment of these fractures in this patient population.

HA and THA can be utilized for any femoral neck fracture but are primarily indicated for displaced femoral neck fractures: Garden 3 and 4 fractures in a geriatric patient should be treated with arthroplasty. Furthermore, there is evidence supporting arthroplasty for nondisplaced fractures due to its reliability, 70% lower risk of reoperation, and improved functional outcomes as compared to CRPP and ORIF [48, 49].

The decision to perform a HA or THA in geriatric patients is highly debated, with no uniform consensus at this time. Traditionally, HA was considered superior over THA for low demand, elderly patients due to less blood loss, decreased operative duration, and lower risk of dislocation [50]. However, with the recent resurgence of anterior-based approaches, enhanced implant materials, dual mobility femoral heads, and improvements in anesthesia techniques, the perceived benefit, and possibly lower risk of complications with HA, is not as profound as it once was. Generally speaking, patient characteristics that may drive a surgeon to pursue THA over HA include younger geriatric patients (between 65 and 80 years old), preexisting osteoarthritis, higher functional demand, and fewer medical comorbidities. Conversely, older patients with lower functional demands, higher risk for dislocation, and greater medical comorbidities may be more likely to undergo a HA than THA. Based on the more recent literature citing higher functional outcomes and less pain, our preference is to perform THA more commonly than HA in most cases at the current time.

When to Consider HA
- Patients age >85
- Low functional demand
- Higher risk of dislocation (Parkinson's disease, seizures, spasticity, and rigidity)
- Increased medical comorbidities
- Short life expectancy
- No preexisting hip arthritis

When to Consider THA
- "Younger" geriatric patients (65–80 years old)
- Higher functional demand
- Few medical comorbidities
- Long life expectancy
- Preexisting hip arthritis
- Availability of fellowship-trained arthroplasty surgeon
- Anterior-based approach

Surgical Technique

An AP pelvis X-ray with a marker ball should be obtained preoperatively for surgical templating and planning. The surgeon can then estimate the size of implants that need to be available for the procedure. The senior author's preference is to utilize an abductor sparing anterolateral (AL) approach for both HA and THA, supine, on a regular radiolucent table with the use of intraoperative fluoroscopy. However, at our institution, HA and THA are also performed through direct-anterior (DA) and posterior approaches with and without fluoroscopy.

Skin incision is marked two finger widths distal and posterior to the anterior-superior iliac spine. The incision is centered over the posterior border of the tensor fasciae latae muscle (TFL) with the distal end of the incision aimed at the fibular head, roughly 8–12 cm in length. The internervous Watson-Jones interval is utilized splitting the interval between the TFL and gluteus medius. An important landmark is the white-red-white fascial junction of the sartorius (white-appearing), TFL (red-appearing), and abductors (white-appearing). Identifying this as a landmark for the correct interval, the fascia is sharply incised just posterior (0.5 cm) to the white-red junction posterior to the muscle belly of the TFL. Care is then taken to identify and cauterize crossing retinacular vessels off of the ascending branches of the lateral femoral circumflex vessels, which are located at the distal end of the incision.

After coagulation of the vessels, blunt cobra retractors are placed around the superior and inferior necks, outside of the capsule. Pre-capsular fat is removed and the capsule is identified. Both options of either full capsulectomy or capsulotomy with tagging stitches for capsular repair at the conclusion of the procedure may be done. After wide capsulotomy, the retractors are replaced around the neck and good visualization of fracture should be obtained. Hematoma should be evacuated with suction and irrigation. It is important to take care not to inadvertently cut the labrum during capsulectomy for HA, as this may lead to instability and postoperative pain, and possibly increasing the risk of subsequent prosthetic dislocation. If THA is being performed the labrum should be excised, facilitating removal of the femoral head. Depending on fracture pattern, an additional clean-up neck osteotomy can be made with an oscillating saw utilizing the lesser trochanter as a reference if necessary. Care should be taken to not cut into the greater trochanter during this step. Using a corkscrew, the head is dislocated and removed. It is the policy of our institution to send the head for pathology evaluation, which may be a beneficial practice for detection of any pathologic bony process as the true etiology of the fracture.

If performing a THA, attention is next taken to the acetabulum. Retractors are placed around the anterior and posterior walls of the acetabulum. The labrum is fully excised at this stage. With or without utilizing fluoroscopy, the acetabulum is sequentially reamed, ensuring medialization to the base of the cotyloid fossa. The cup is inserted at the desired abduction (40 degrees) and anteversion (10 degrees) angles. The senior author prefers to place screws in the posterior-superior "safe-zone," especially in geriatric patients. The polyethylene liner is impacted, and attention is moved the femur.

If performing HA, the acetabulum does not need to be prepared, and the cut femoral head may be used for sizing of the prosthetic head.

At this point, the steps are the same for both THA and HA. The femur is elevated by removing superolateral capsular tissue inside the saddle of the greater trochanter. Care is taken to not damage abductors in the anterior based approach. The insertion of the obturator internus and piriformis muscles can be recessed to allow for proper femoral exposure. This allows for elevation and exposure of the proximal femoral metaphysis to ensure proper access to the femur during broaching and to avoid damaging the skin and abductors. The operative leg is adducted, externally rotated, and extended to aid with visualization. After the femur is elevated, the surgeon can start preparing the femur. A box osteotome and femoral canal finder are used to open up access to the femoral shaft and prevent errant perforation during broaching. The femur is sequentially broached, and when proper sizing is achieved, a c-arm is used to confirm the provisional construct. Proper femoral version of the broach must be obtained to ensure that it matches the native version of the femur. Care must be taken to avoid fracturing the femur during broaching in geriatric patients with osteoporosis. Length may be adjusted at this point by exchanging the broach for a larger or smaller size to lengthen or shorten the leg respectively and make appropriate adjustments to the femoral head size to match the preoperative template and contralateral anatomy as optimally as possible and finalize the trialing. Generally, patients over the age of 70 are cemented to help prevent intraoperative periprosthetic fracture.

If cementing, the canal is irrigated and prepared. Vaginal packing soaked in epinephrine is placed down the canal. A cement restrictor is placed 1 cm distal to the tip of the prosthesis stem. Anesthesiologist is informed that cementing is about to take place to ensure adequate monitoring of blood pressure and pulmonary function. Cement is placed into the canal and pressurized. The stem is inserted and held in place until the cement has hardened. The appropriate head size, from trialing, is impacted and the hip is relocated and taken through a full range of motion to assess stability and leg length both clinically and fluoroscopically. The fascia and skin are closed, and final flat plate radiographs are taken in the recovery room (Fig. 6.11).

Technical Pearls During HA and THA

- AL and DA approaches have lower rates of dislocation compared to posterior approach (for fracture?).
- Ensure proper coagulation of the retinacular branches of the ascending lateral circumflex vessel to avoid blood loss.
- Intraoperative fluoroscopy can aid in proper component sizing and positioning.
- Remove all remaining superior neck to avoid aberrant placement of the stem into varus.
- Cement if poor bone quality and/or if patient age >70.
- No postoperative restrictions if AL or DA approach is taken.
- The electrocautery cord and fluoroscopy may be useful in helping determine leg length and allows for final fine tune adjustments.

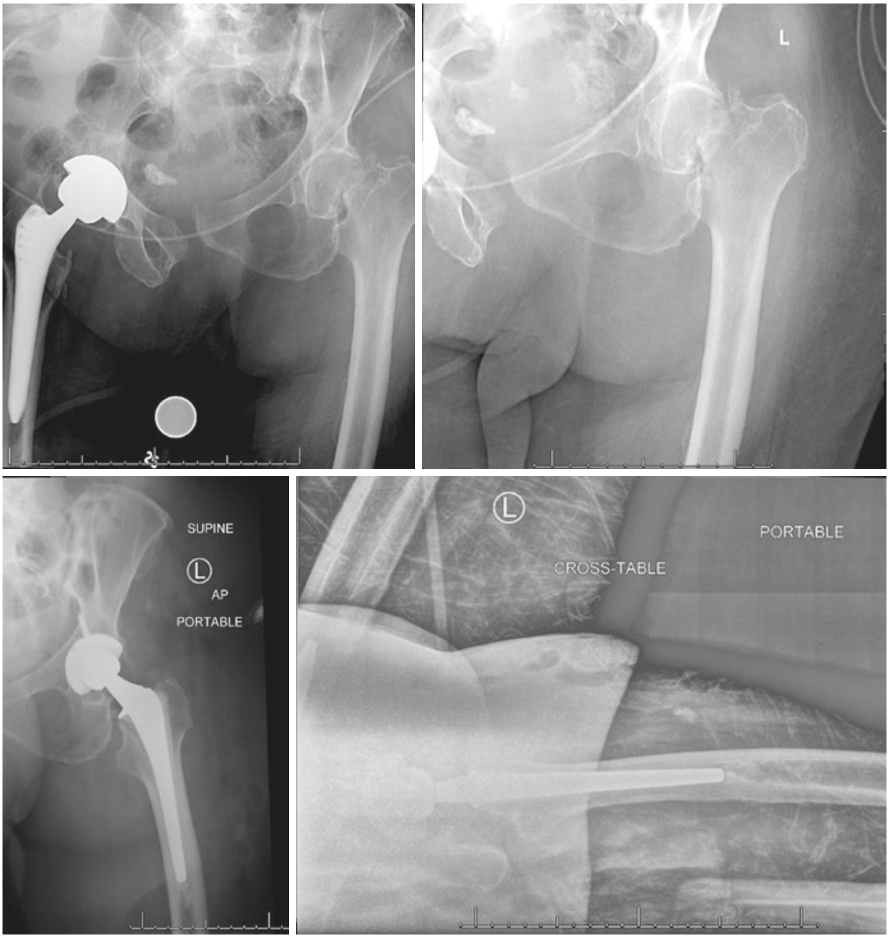

Fig. 6.11 Left displaced femoral neck fracture status post left THA

Perioperative Care

Refer to section "Perioperative Care" for perioperative care following HA and THA. Postoperative care following CRPP is similar to HA and THA. For those patients undergoing arthroplasty through a posterior approach, we typically endorse postoperative posterior hip precautions to avoid deep flexion, adduction, and internal rotation. We generally do not recommend any postoperative precautions with range of motion when we utilize the AL or DA approach for these reconstructions. In-hospital physical therapy is started on POD 0; however, active hip strengthening exercises are avoided until at least 2 weeks after surgery to avoid injury to the convalescing anterior hip muscles in the initial postoperative period.

Postoperative Outcomes and Complications

Overall, outcomes following arthroplasty for geriatric femoral neck fractures are successful. However, it should be noted that many of these patients suffer from significant medical comorbidities and carry nearly 10 times the risk of 30-day mortality compared to elective arthroplasty patients [51]. Parvizi et al., in a study of 7774 patients, found the 30-day mortality rate to be 2.4% with no significant difference in mortality between HA and THA [51]. Whether to perform HA or THA for displaced geriatric femoral neck fracture remains a debated topic, with no uniform consensus at this time. Although HA is associated with shorter operative duration, less blood loss, and lower rates of dislocation compared to THA, it has also been found to have higher rates of revision, increased pain scores, worse implant survivorship, and worse mobility [52]. On the contrary, Ogawa et al. found that THA had higher rates of revision, with no difference in overall complications when compared to HA. Thus, THA has gained popularity when compared to HA among younger, more active geriatric patients with or even without much preexisting hip arthritis [53, 54].

Complications following arthroplasty for geriatric femoral neck fractures are common and can be severe. Fragility fractures, such as femoral neck fracture, signal end-organ damage and a systemic decrease in one's health. Nearly one-third of patients suffer from a postoperative complication that increases postoperative hospital duration [55]. Older patients with more preexisting medical comorbidities and dementia are at greater risk of suffering an adverse event following replacement. The 3-year mortality has been cited to be as high as 40% [56]. Common minor complications following arthroplasty include delirium, pneumonia, surgical site infection, and UTI. Major events include cardiovascular or respiratory compromise, VTE, fall, periprosthetic joint infection, and new fractures.

Implant Considerations

Femoral Stems Selection

Femoral stem selection is an important consideration in the preoperative planning of HA or THA for geriatric femoral neck fracture. Femoral stems can have either a fixed-neck or modular-neck design, with or without a collar. Fixed-neck designs are most popular in this patient population due to lower risk of junctional component failure and fretting corrosion and trunnionosis [57].

Both THA and HA femoral stems can either be cementless or cemented. Due to the overall poor bone quality and increased risk for periprosthetic fracture, the gold standard for geriatric femoral stems has been cemented femoral stems [58–60]. Additionally, cemented femoral stems have been shown to have lower implant-related complication and better function and mobility when compared to cementless stems. While cementing offers some advantages, it is associated with certain catastrophic complications. In particular, intraoperative cardiopulmonary compromise is an extremely rare occurrence, but it may occur due to systemic cement extravasation and cement emboli, although new generations of cementing technique have substantially lowered this risk [51].

Cementless femoral stems can be used in the geriatric population but do carry an increased risk of failure, including intraoperative and postoperative periprosthetic fracture, subsidence, or lack of bony in-growth. Due to the increased hoop-stresses of this technique, poor bone quality may make this patient population more prone to fracture or failure [61].

Femoral Head Component Selection

Either unipolar or bipolar (modular) femoral heads may be utilized in both HA and THA. While the theoretical advantage of bipolar heads for HA is decreased risk of dislocation and acetabular erosion, its use has been debated and scrutinized due to the associated increase in cost. The evidence is mixed whether bipolar heads offer significant clinical advantages compared to unipolar heads [62, 63]. There are studies that both support and refute the use of unipolar versus bipolar HA with respect to risk of dislocation. Additionally, bipolar heads have been associated with delayed acetabular erosion and increased health-related quality of life for patients undergoing HA for femoral neck fracture [63].

As for THA, bipolar heads have been shown to provide no meaningful difference in outcomes and complications. However, there is limited evidence to support its use due to improved hip function outcomes despite no real difference in morbidity and mortality [64]. Further randomized controlled trials are necessary to further assess the benefits of bipolar versus unipolar heads in both HA and THA.

Arthroplasty Versus Fixation

In summary, the question of fixation versus arthroplasty for geriatric patients with femoral neck fractures may continue to be debated. With close, careful scrutinization of the fracture pattern, the evidence supports a clear treatment algorithm based on an accurate fracture classification. Arthroplasty should always be considered in the case of a displaced femoral neck fracture in the geriatric population, whereas non-displaced and valgus-impacted femoral neck fractures can be treated with CRPP. Despite these general guidelines, successful management of geriatric patients with femoral neck fractures requires a well-coordinated team approach; however, this population remains at high risk for complications. Patient and family education and engagement in the treatment process are extremely important for setting realistic expectations when a patient sustains a femoral neck fracture.

Conclusion and Authors Recommendations

In conclusion, the authors recommend arthroplasty for all displaced femoral neck fracture in the geriatric population. HA should be reserved for the less active older geriatric patients with increased risks of dislocation. The use of bipolar heads should also be considered in this patient population. THA should be utilized for the more active, healthier patient, especially when preexisting degenerative joint disease is present. For non-displaced femoral neck fractures, we recommend a closed reduction percutaneous pinning with three cannulated cancellous screws in an inverted triangle configuration. For non-displaced basicervical femoral neck fractures, we recommend the use of a sliding hip screw.

References

1. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, et al. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr. 2016;16(1):158.
2. Sprague S, Bhandari M, Heetveld M, Liew S, Scott T, Bzovsky S, et al. Factors associated with health-related quality of life, hip function, and health utility after operative management of femoral neck fractures. Bone Joint J. 2018;100(3):361–9.
3. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. JAMA. 2009;302(14):1573–9.
4. Konda SR, Pean CA, Goch AM, Fields AC, Egol KA. Comparison of short-term outcomes of geriatric distal femur and femoral neck fractures: results from the NSQIP database. Geriatric Orthopaedic Surgery & Rehabilitation. 2015;6(4):311–5.
5. Surgeons AAoO. Management of hip fractures in the elderly: evidence-based clinical practice guideline. Rosemont: American Academy of Orthopaedic Surgeons; 2014.
6. Ju DG, Rajaee SS, Mirocha J, Lin CA, Moon CN. Nationwide analysis of femoral neck fractures in elderly patients: a receding tide. JBJS. 2017;99(22):1932–40.
7. MacKinlay K, Falls T, Lau E, Day J, Kurtz S, Ong K, et al. Decreasing incidence of femoral neck fractures in the Medicare population. Orthopedics. 2014;37(10):e917–e24.
8. Sheehan SE, Shyu JY, Weaver MJ, Sodickson AD, Khurana B. Proximal femoral fractures: what the orthopedic surgeon wants to know. Radiographics. 2015;35(5):1563–84.
9. Sadro CT, Sandstrom CK, Verma N, Gunn ML. Geriatric trauma: a radiologist's guide to imaging trauma patients aged 65 years and older. Radiographics. 2015;35(4):1263–85.
10. Forni C, Gazineo D, D'Alessandro F, Fiorani A, Morri M, Sabattini T, et al. Predictive factors for thirty day mortality in geriatric patients with hip fractures: a prospective study. Int Orthop. 2019;43(2):275–81.
11. Goldacre MJ, Roberts SE, Yeates D. Mortality after admission to hospital with fractured neck of femur: database study. BMJ. 2002;325(7369):868–9.
12. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623–33.
13. Aigner R, Buecking B, Hack J, Eschbach D, Oberkircher L, Ruchholtz S, et al. Pre-fracture hospitalization is associated with worse functional outcome and higher mortality in geriatric hip fracture patients. Arch Osteoporos. 2017;12(1):32.
14. Buecking B, Struewer J, Waldermann A, Horstmann K, Schubert N, Balzer-Geldsetzer M, et al. What determines health-related quality of life in hip fracture patients at the end of acute care?—a prospective observational study. Osteoporos Int. 2014;25(2):475–84.

15. Lu Y, Uppal HS. Hip fractures: relevant anatomy, classification, and biomechanics of fracture and fixation. Geriatr Orthop Surg Rehabil. 2019;10:2151459319859139.
16. Kani KK, Porrino JA, Mulcahy H, Chew FS. Fragility fractures of the proximal femur: review and update for radiologists. Skeletal Radiol. 2019;48(1):29–45.
17. Alonso CG, Curiel MD, Carranza FH, Cano RP, Pérez AD. Femoral bone mineral density, neck-shaft angle and mean femoral neck width as predictors of hip fracture in men and women. Osteoporos Int. 2000;11(8):714–20.
18. Meermans G, Konan S, Das R, Volpin A, Haddad F. The direct anterior approach in total hip arthroplasty: a systematic review of the literature. Bone Joint J. 2017;99(6):732–40.
19. Xie J, Zhang H, Wang L, Yao X, Pan Z, Jiang Q. Comparison of supercapsular percutaneously assisted approach total hip versus conventional posterior approach for total hip arthroplasty: a prospective, randomized controlled trial. J Orthop Surg Res. 2017;12(1):1–8.
20. Kunkel ST, Sabatino MJ, Kang R, Jevsevar DS, Moschetti WE. A systematic review and meta-analysis of the direct anterior approach for hemiarthroplasty for femoral neck fracture. Eur J Orthop Surg Traumatol. 2018;28(2):217–32.
21. Cichos KH, Mabry SE, Spitler CA, McGwin G Jr, Quade JH, Ghanem ES. Comparison between the direct anterior and posterior approaches for total hip arthroplasty performed for femoral neck fracture. J Orthop Trauma. 2020;35(1):41–8.
22. Khurana B, Mandell JC, Rocha TC, Duran-Mendicuti MA, Jimale H, Rosner B, et al. Internal rotation traction radiograph improves proximal femoral fracture classification accuracy and agreement. Am J Roentgenol. 2018;211(2):409–15.
23. Thomas RW, Williams HL, Carpenter EC, Lyons K. The validity of investigating occult hip fractures using multidetector CT. Br J Radiol. 2016;89(1060):20150250.
24. Rashidifard CH, Romeo N, Richardson M, Muccino P, DiPasquale T, Bush CM. Palliative management of nonoperative femoral neck fractures with continuous peripheral indwelling catheters: case–control series. Geriatr Orthop Surg Rehabil. 2019;10:2151459319827470.
25. Parker M, Khan R, Crawford J, Pryor G. Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures in the elderly: a randomised trial of 455 patients. J Bone Joint Surg. 2002;84(8):1150–5.
26. Tidermark J, Zethraeus N, Svensson O, Törnkvist H, Ponzer S. Quality of life related to fracture displacement among elderly patients with femoral neck fractures treated with internal fixation. J Orthop Trauma. 2003;17(8):S17–21.
27. Cram P, Yan L, Bohm E, Kuzyk P, Lix LM, Morin SN, et al. Trends in operative and nonoperative hip fracture management 1990–2014: a longitudinal analysis of Manitoba administrative data. J Am Geriatr Soc. 2017;65(1):27–34.
28. Hossain M, Neelapala V, Andrew J. Results of non-operative treatment following hip fracture compared to surgical intervention. Injury. 2009;40(4):418–21.
29. Parker MJ. Current concepts in the treatment of hip fracture. Z Gerontol Geriatr. 2001;34(1):74–7.
30. Voeten SC, Arends AJ, Wouters MW, Blom BJ, Heetveld MJ, Slee-Valentijn MS, et al. The Dutch Hip Fracture Audit: evaluation of the quality of multidisciplinary hip fracture care in the Netherlands. Arch Osteoporos. 2019;14(1):28.
31. Citty SW, Cowan LJ, Wingfield Z, Stechmiller J. Optimizing nutrition care for pressure injuries in hospitalized patients. Adv Wound Care. 2019;8(7):309–22.
32. Tidermark J, Ponzer S, Svensson O, Söderqvist A, Törnkvist H. Internal fixation compared with total hip replacement for displaced femoral neck fractures in the elderly: a randomised, controlled trial. J Bone Joint Surg. 2003;85(3):380–8.
33. Kahlenberg CA, Richardson SS, Schairer WW, Cross MB. Rates and risk factors of conversion hip arthroplasty after closed reduction percutaneous hip pinning for femoral neck fractures—a population analysis. J Arthroplasty. 2018;33(3):771–6.
34. Hui A, Anderson G, Choudhry R, Boyle J, Gregg P. Internal fixation or hemiarthroplasty for undisplaced fractures of the femoral neck in octogenarians. J Bone Joint Surg. 1994;76(6):891–4.

35. Chiu F-Y, Lo W-H, Yu C-T, Chen T-H, Chen C-M, Huang C-K. Percutaneous pinning in undisplaced subcapital femoral neck fractures. Injury. 1996;27(1):53–5.
36. Griffin J, Anthony TL, Murphy DK, Brennan KL, Brennan ML. What is the impact of age on reoperation rates for femoral neck fractures treated with internal fixation and hemiarthroplasty? A comparison of hip fracture outcomes in the very elderly population. J Orthop. 2016;13(1):33–9.
37. Masson MA, Parker MJ, Schoelzel S. Internal fixation versus arthroplasty for intracapsular proximal femoral fractures in adults. Cochrane Database Syst Rev. 2003;(2).
38. Liporace F, Gaines R, Collinge C, Haidukewych GJ. Results of internal fixation of Pauwels type-3 vertical femoral neck fractures. JBJS. 2008;90(8):1654–9.
39. Berkes MB, Little MT, Lazaro LE, Cymerman RM, Helfet DL, Lorich DG. Catastrophic failure after open reduction internal fixation of femoral neck fractures with a novel locking plate implant. J Orthop Trauma. 2012;26(10):e170–e6.
40. Fujii T, Nakayama S, Hara M, Koizumi W, Itabashi T, Saito M. Tip-apex distance is most important of six predictors of screw cutout after internal fixation of intertrochanteric fractures in women. JBJS Open Access. 2017;2(4):e0022.
41. McLoughlin SW, Wheeler DL, Rider J, Bolhofner B. Biomechanical evaluation of the dynamic hip screw with two-and four-hole side plates. J Orthop Trauma. 2000;14(5):318–23.
42. Parker MJ, Pryor GA. Internal fixation or arthroplasty for displaced cervical hip fractures in the elderly: a randomised controlled trial of 208 patients. Acta Orthop Scand. 2000;71(5):440–6.
43. Johansson T, Jacobsson S-A, Ivarsson I, Knutsson A, Wahlström O. Internal fixation versus total hip arthroplasty in the treatment of displaced femoral neck fractures: a prospective randomized study of 100 hips. Acta Orthop Scand. 2000;71(6):597–602.
44. Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE. Outcomes after displaced fractures of the femoral neck. A meta-analysis of one hundred and six published reports. J Bone Joint Surg Am. 1994;76(1):15–25.
45. Jakob M, Rosso R, Weller K, Babst R, Regazzoni P. Avascular necrosis of the femoral head after open reduction and internal fixation of femoral neck fractures: an inevitable complication? Swiss Surg. 1999;5(6):257–64.
46. Nikolopoulos K, Papadakis S, Kateros K, Themistocleous G, Vlamis J, Papagelopoulos P, et al. Long-term outcome of patients with avascular necrosis, after internal fixation of femoral neck fractures. Injury. 2003;34(7):525–8.
47. Nauth A, Creek AT, Zellar A, Lawendy A-R, Dowrick A, Gupta A, et al. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet. 2017;389(10078):1519–27.
48. Richards JT, Overmann AL, O'Hara NN, D'Alleyrand J-C, Slobogean GP. Internal fixation versus arthroplasty for the treatment of nondisplaced femoral neck fractures in the elderly: a systematic review and meta-analysis. J Orthop Trauma. 2020;34(1):42–8.
49. Overmann A, Richards J, O'Hara N, D'Alleyrand J, Slobogean G. Outcomes of elderly patients with nondisplaced or minimally displaced femoral neck fractures treated with internal fixation: a systematic review and meta-analysis. Injury. 2019;50(12):2158–66.
50. Haynes MS, Ondeck NT, Ottesen TD, Malpani R, Rubin LE, Grauer JN. Perioperative outcomes of hemiarthroplasty versus total hip arthroplasty for geriatric hip fracture: the importance of studying matched populations. J Arthroplasty. 2020;35(11):3188–94.
51. Parvizi J, Ereth MH, Lewallen DG. Thirty-day mortality following hip arthroplasty for acute fracture. JBJS. 2004;86(9):1983–8.
52. Lee BP, Berry DJ, Harmsen WS, Sim FH. Total hip arthroplasty for the treatment of an acute fracture of the femoral neck. Long-term results. JBJS. 1998;80(1):70–5.
53. Ogawa T, Yoshii T, Moriwaki M, Morishita S, Oh Y, Miyatake K, et al. Association between hemiarthroplasty vs total hip arthroplasty and major surgical complications among patients with femoral neck fracture. J Clin Med. 2020;9(10):3203.
54. Investigators H. Total hip arthroplasty or hemiarthroplasty for hip fracture. N Engl J Med. 2019;381(23):2199–208.

55. Merchant R, Lui K, Ismail N, Wong H, Sitoh Y. The relationship between postoperative complications and outcomes after hip fracture surgery. Ann Acad Med Singapore. 2005;34(2):163–8.
56. Berggren M, Stenvall M, Englund U, Olofsson B, Gustafson Y. Co-morbidities, complications and causes of death among people with femoral neck fracture–a three-year follow-up study. BMC Geriatr. 2016;16(1):120.
57. Pastides PS, Dodd M, Sarraf KM, Willis-Owen CA. Trunnionosis: a pain in the neck. World J Orthop. 2013;4(4):161.
58. Taylor F, Wright M, Zhu M. Hemiarthroplasty of the hip with and without cement: a randomized clinical trial. JBJS. 2012;94(7):577–83.
59. Jameson SS, Jensen CD, Elson DW, Johnson A, Nachtsheim C, Rangan A, et al. Cemented versus cementless hemiarthroplasty for intracapsular neck of femur fracture—a comparison of 60,848 matched patients using national data. Injury. 2013;44(6):730–4.
60. DeAngelis JP, Ademi A, Staff I, Lewis CG. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: a prospective randomized trial with early follow-up. J Orthop Trauma. 2012;26(3):135–40.
61. Gjertsen J, Lie S, Vinje T, Engesaeter L, Hallan G, Matre K, et al. More re-operations after uncemented than cemented hemiarthroplasty used in the treatment of displaced fractures of the femoral neck: an observational study of 11 116 hemiarthroplasties from a national register. J Bone Joint Surg. 2012;94(8):1113–9.
62. Enocson A, Hedbeck CJ, Törnkvist H, Tidermark J, Lapidus LJ. Unipolar versus bipolar Exeter hip hemiarthroplasty: a prospective cohort study on 830 consecutive hips in patients with femoral neck fractures. Int Orthop. 2012;36(4):711–7.
63. Inngul C, Hedbeck C-J, Blomfeldt R, Lapidus G, Ponzer S, Enocson A. Unipolar hemiarthroplasty versus bipolar hemiarthroplasty in patients with displaced femoral neck fractures. A four-year follow-up of a randomised controlled trial. Int Orthop. 2013;37(12):2457–64.
64. Fahad S, Khan MZN, Aqueel T, Hashmi P. Comparison of bipolar hemiarthroplasty and total hip arthroplasty with dual mobility cup in the treatment of old active patients with displaced neck of femur fracture: a retrospective cohort study. Ann Med Surg. 2019;45:62–5.
65. Thorngren KG. Fractures of the femoral neck and proximal femur. In: Bentley G, editor. European surgical orthopaedics and traumatology. Berlin, Heidelberg: Springer; 2014.
66. Krismer M. Total hip arthroplasty: a comparison of current approaches. In: Bentley G, editor. European instructional lectures. European Federation of National Associations of Orthopaedics and Traumatology, vol. 9. Berlin, Heidelberg: Springer; 2009.

Chapter 7
Periprosthetic Femur Fractures After Total Hip Arthroplasty

Alirio J. deMeireles, Nana O. Sarpong, and H. John Cooper

Introduction

Total hip arthroplasty (THA) is often regarded as the most effective treatment of painful hip arthritis. In 2007, Learmonth and colleagues recognized THA as the "operation of the century" [1]. One potentially devastating complication of an otherwise extremely successful surgery is a periprosthetic fracture. The rate of fracture after total hip arthroplasty ranges from 0.1% to 18% [2]. In a landmark study using data from the Swedish Hip Arthroplasty Register, Lindahl and colleagues found the annual incidence of periprosthetic fractures to be 0.4% after primary THA and 2.1% after revision THA [3]. Using the Mayo Clinic Joint Replacement Database, Berry and colleagues analyzed 23,980 primary THAs and 6349 revision THAs and found an incidence of 1% in primary THA and 4% in revision THA [4].

The prevalence of periprosthetic fractures after THA is increasing [4–8]. There are multiple proposed reasons for the observed increase in complication rate. First, the annual number of THAs performed worldwide is increasing – this is accompanied by a concomitant rise in the absolute volume of known surgical complications, including periprosthetic fracture [9]. Second, the increase in volume of primary procedures inevitably leads to an increase in revision THAs, which have been shown to have higher rate of periprosthetic fracture [8]. Third, as medical therapies advance and patients live longer, they are at higher risk of developing osteoporosis and subsequently a low-energy periprosthetic fracture.

Treatment of periprosthetic fractures can be complex, as it often requires the surgeon to concurrently address multiple problems, including osteolysis, fracture reduction, and implant stability. Accordingly, periprosthetic fractures are generally managed

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by surgeons with specialized training in revision arthroplasty. However, given the popularity of THA, all orthopaedic surgeons should be aware of the initial workup, management principles, and indications for referral to a specialized center. Thus, the purpose of this chapter is to provide a comprehensive overview of periprosthetic hip fractures, including initial presentation, clinical evaluation, treatment modalities, and expected outcomes. Though periprosthetic hip fractures may involve the acetabulum, the femur is most commonly affected and will therefore be the focus of this review [10].

Risk Factors

Risk factors for periprosthetic fracture can be grouped into patient factors, surgical factors, and anatomical factors. Patient-specific factors associated with increased rate of periprosthetic fracture include older age, female gender, and higher body mass index (BMI) [11–13]. Notably, however, while older age and female gender are commonly listed as independent risk factors of periprosthetic fracture, the data supporting these conclusions are often confounded by the presence of osteoporosis [13]. Other patient-specific factors to consider include initial indication for THA, as patients undergoing THA for hip fracture have been shown to be at higher risk of subsequent periprosthetic fracture than patients who undergo a THA for osteoarthritis (OA) [14, 15]. This difference is likely secondary to the higher rate of osteoporosis seen in the hip fracture patient population versus the OA patient population. Any systemic illness known to be associated with reduced bone mineral density, such as chronic corticosteroid use, alcoholism, substance abuse, or rheumatoid arthritis, increases patients' risk of periprosthetic fracture [16]. Similarly, neuromuscular disorders which predispose patients to falls, such as dementia or Parkinson's disease, increase risk of periprosthetic fracture [17, 18].

Surgical factors associated with higher risk of periprosthetic fracture are largely related to implant type and method of fixation. For both primary and revision surgery, risk of periprosthetic fracture is significantly increased with the use of uncemented femoral components [4, 12, 19–21]. Abdel et al. found a 14-fold increased risk of intraoperative periprosthetic fracture when a cementless femoral component was used in primary THA [8]. Herndon et al. found that increasing Dorr ratio, defined as inner canal diameter 10 cm distal to the midportion of the lesser trochanter divided by inner canal diameter at the midportion of the lesser trochanter, was associated with a higher rate of periprosthetic fracture [22]. In a recent systematic review and meta-analysis, Carli et al. found single-wedge and double-wedge femoral implants to be associated with a threefold increase in periprosthetic fracture rate as compared with anatomical, fully coated and tapered stems [21]. Additionally, the authors noted that among cemented stems, Exeter stems (loaded-taper) were associated with higher rate of periprosthetic fracture than Charnley stems (composite-beam) [21].

Anatomical factors associated with higher risk of periprosthetic fracture include anatomic abnormalities of the proximal femur, tumor, and prior surgery involving the ipsilateral proximal femur [18]. Additionally, osteolysis of the greater trochanter has been shown to be associated with an increased rate of periprosthetic fracture [11, 23].

Clinical Evaluation

History and Physical Examination

A thorough history and physical exam is a mandatory aspect of the workup in a patient with a suspected periprosthetic fracture. Low-energy falls from a sitting or standing position have been shown to cause 75% of periprosthetic femur fractures after primary THA and 56% of fracture after revision THA [11, 24, 25]. Patients with low-energy injury mechanisms should be evaluated for possible medical causes of their fall, such as syncope, acute coronary syndrome, arrhythmia, head injury, or cerebrovascular accident. As such, "mechanical fall" should be a diagnosis of exclusion, particularly in the geriatric patient population with multiple medical comorbidities. Contributing medical conditions, when identified, should be co-managed with the appropriate medical specialty. Less commonly, younger patients with higher levels of activity may experience fracture secondary to high-energy trauma, but this comprises <10% of reported cases [26].

It is important to determine pre-injury functional status, including the presence or absence of thigh pain, or pain with initiation of motion after sitting ("start-up" pain) as these symptoms can indicate a loose femoral component. If possible, the surgeon should obtain the patient's medical record, including prior operative reports and radiographs, as they are helpful to properly identify the devices currently implanted as well as pertinent prior surgical details such as abnormal anatomy or intraoperative complications. If outside records are not available, consultation with senior surgeons or experienced industry representatives is often successful in identifying the patient's implants. Recently, Karnuta et al. have shown that artificial intelligence can be used to identify arthroplasty implants using hip radiographs with 99% accuracy [27].

After a general assessment, a secondary survey, and, if appropriate, completion of Advanced Trauma Life Support (ATLS) protocols, attention should be turned to the exam of the affected extremity. Given the robust soft tissue sleeve of the surrounding area, gross deformity is not often seen. However, as with all orthopaedic patients, exam and documentation of the skin and distal neurovascular status are mandatory.

Imaging Studies

An anteroposterior (AP) pelvis and standard AP and lateral radiographs of the affected hip should be obtained. These views allow for determination of important fracture characteristics, component positioning, degree of osteolysis, adequacy of bone stock, and implant stability. It is also important to obtain full-length femur radiographs as they better allow full assessment of fracture propagation distally, the presence of distal femur hardware, and any complicating femoral anatomy. Furthermore, these images should be compared and scrutinized against previous radiographs, whenever available, to elucidate progression in loosening or osteolysis and assess for any subtle subsidence or shift in implant position. Routinely obtaining advanced imaging such as computed tomography (CT) scans, magnetic resonance imaging (MRI), or ultrasound is not warranted, though the improved detail provided by CT scans can be helpful for surgical planning. CT can occasionally be helpful in identifying subtle nondisplaced fracture extension from the stem tip and may provide further insight into osteointegration of uncemented implants when radiographs are not definitive.

Laboratory Investigations

In the setting of a fracture, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) level are not sensitive indicators of infection, as they are increased with trauma due to the inherent inflammation [13]. In a retrospective review of 204 patients with periprosthetic hip fracture, Chevillotte et al. found a false-positive rate for infection of 43% for CRP level and 31% for ESR [28]. Therefore, Pike et al. argue that in the absence of evidence of infection on history and exam, and with radiographs that demonstrate a stable THA, surgeons may proceed with operative intervention without further infectious workup [13]. Shah and associates evaluated the efficacy of common diagnostic tests for periprosthetic joint infection and found synovial white blood cell (WBC) count with a cutoff of 2707 WBC/uL and differential cutoff of 77% polymorphonuclear cells to be the best diagnostic predictors of infection [29]. Surgeons may choose to send frozen section specimens if suspicions of infection based on patient history, physical exam, or imaging [13]. The patient may be further evaluated with image-guided hip joint aspiration with subsequent gram stain and culture, though this delays operative intervention by 5–7 days. Routine tissue cultures for permanent analysis should be sent in the setting of all revision arthroplasty procedures.

Classification

The Vancouver classification, initially proposed in 1995 by Duncan and Masri, is considered one of the most useful classification systems in orthopaedics due to its ability to direct treatment and prognosis [30, 31]. The classification system was initially designed to describe postoperative periprosthetic femur fractures but has since been modified by Masri et al. to include both intraoperative and postoperative fractures [32]. The intraoperative fracture classification focuses primarily on fracture location, pattern, and stability, while the postoperative classification emphasizes not only fracture location but also implant stability and adequacy of femoral bone stock (Tables 7.1 and 7.2). The Vancouver classification has been validated by multiple investigators [33, 34]. In the European validation of the Vancouver classification system, Rayan et al. found excellent intra- and interobserver reliability among medical students, surgical trainees, and senior orthopaedic surgeons [34]. Similarly, in a review of 45 radiographs of patients with periprosthetic femur fractures, Naqvi et al. found an 81% interobserver agreement with a κ value of 0.68 when classifying B1, B2, and B3 fractures [35].

Intraoperative Vancouver Classification

Intraoperative periprosthetic fractures are first defined by their location and then subclassified based on fracture type. Type A fractures are located at the proximal metaphysis, Type B fractures are located at the proximal diaphysis, and Type C fractures are distal to the tip of the femoral component. Each fracture is then assigned a subtype: Type 1 is a simple cortical breach, Type 2 is a nondisplaced fracture line, and Type 3 is a displaced fracture.

Table 7.1 Intraoperative Vancouver classification

Type	Fracture pattern
A1	Metaphysis; cortical breach
A2	Metaphysis; nondisplaced linear crack
A3	Metaphysis; displaced, unstable fracture
B1	Diaphysis; cortical breach
B2	Diaphysis; nondisplaced linear crack
B3	Diaphysis; displaced, unstable fracture
C1	Distal to stem tip; cortical breach
C2	Distal to stem tip; nondisplaced linear crack
C3	Distal to stem tip; displaced, unstable fracture

Table 7.2 Postoperative Vancouver classification

Type	Fracture pattern	Subtype	Stem	Bone stock
A	Involving the greater trochanter	AG	N/A	N/A
	Involving the lesser trochanter	AL	N/A	N/A
B	Fracture around or just below the femoral component	B1	Stable	Adequate
		B2	Unstable	Adequate
		B3	Unstable	Inadequate
C	Fracture well distal to the tip of the femoral stem	N/A	Stable	N/A

Postoperative Vancouver Classification

Type A fractures represent fractures involving the greater or lesser trochanters and are subclassified as A_G and A_L, respectively. Fractures through the greater trochanter are usually the result of particle-induced osteolysis secondary to polyethylene wear [36]. Type B fractures involve the proximal metaphysis or diaphysis around the implanted stem. Type B fractures are further classified based on the stability of the femoral component as well as the femoral bone quality. Stable fractures are classified as Type B1, unstable fractures with adequate bone quality are classified as Type B2, and unstable fractures with poor bone quality are classified as Type B3. Data from the Swedish Hip Arthroplasty Register demonstrated that more than 80% of periprosthetic fractures are Type B fractures [3]. Lindahl and colleagues reported that for Type B fractures after primary THA, approximately 25% of fractures were stable (i.e., Type B1), while approximately 75% of fractures were associated with a loose stem (i.e., Type B2 or B3) [3]. In contrast, for periprosthetic fractures occurring after revision THA, data from the Swedish Hip Arthroplasty Register found that 50% of stems were loose while 50% of stems were stable [3]. Lastly, Type C fractures occur distal to the tip of the femoral stem.

It is crucial to appropriately differentiate between Type B1 and Type B2/B3 fractures as an unstable femoral component necessitates revision arthroplasty techniques [25]. In fact, data from the Swedish Hip Arthroplasty Register demonstrated a 30% revision rate for B1 fractures treated with open reduction and internal fixation (ORIF), while there was an 18.5% revision rate for B2 fractures treated with revision arthroplasty [7]. The authors suggested that some of their B1 fractures were initially misclassified and were actually B2 fractures, in which case ORIF alone would have been an inappropriate management [7, 25, 37, 38].

A thorough history and physical exam can aid the surgeon in determining whether the femoral component is loose. Preexisting anterior thigh pain, start-up pain, pain with non-weight-bearing range of motion, or a progressive limb length discrepancy can all be signs of a loose femoral component [25]. Furthermore, radiographic signs such as femoral component subsidence, circumferential radiolucent lines in the Gruen zones, and cement mantle failure are all suggestive of a loose femoral stem [25]. Ultimately, however, femoral component stability is confirmed during intraoperative assessment, highlighting the importance of surgical planning for all possible operative scenarios.

Management

Vancouver Type A

For Type A_G fractures, when there is less than 2 cm of displacement of the greater trochanter, Marsland et al. argue that nonoperative management is sufficient due to the stabilization imparted by the tendons of the vastus lateralis and abductor musculature [38]. If nonoperative management is pursued, patients should limit active abduction to decrease the deforming forces of the abductor tendon on the greater trochanter. With significant displacement about the greater trochanter, progression of displacement on serial radiographs, or abductor musculature weakness, operative management should be considered. If there is a high suspicion of particle-induced osteolysis of the greater trochanter, the polyethylene liner should be exchanged. Surgical fixation of the greater trochanter can occur with wires, cables, or claw plates [39]. Ricci and colleagues advocate for the use of trochanteric claw plates followed by partial weight bearing with or without an abduction brace for 8–12 weeks [40].

Fractures through the lesser trochanter (Type A_L) are rare and may often be managed nonoperatively. They are generally the result of an avulsion of the lesser trochanter and do not need to be addressed unless there is significant distal extension with involvement of the medial cortex, as this could result in destabilization of the stem. If the implant is determined to be at risk of destabilization, cerclage wire fixation provides adequate implant stability [38]. Abdel et al. recommend patients avoid full weight bearing and active hip abduction for 6–12 weeks [41]. Orthopaedic surgeons should be wary of concomitant nondisplaced A_G and A_L fractures, as this pattern may be contiguous, may signify a loose femoral component, and should be treated as such.

There is minimal data reporting directly on outcomes after operative management of Type A periprosthetic fractures. Most recommendations stem from studies examining outcomes after greater trochanteric osteotomies or nonunions [42, 43]. Lindahl reported on a series of 31 cases of claw plate fixation of the greater trochanter, 8 of which were for acute fracture. The authors noted union in 28 out of 31 patients, with 3 patients going on to fibrous union [42].

Vancouver Type B1

Type B1 periprosthetic fractures occur about the femoral component and are defined by the presence of a well-fixed femoral component. In the past, these injuries were treated with nonoperative management or skeletal traction, but these techniques are no longer recommended given the significant complications associated with prolonged immobilization [44]. After transition away from nonoperative management, open reduction and internal fixation (ORIF) became a common treatment for

Vancouver Type B1 fractures [13]. Most recently, however, to minimize the soft tissue dissection that accompanies standard ORIF techniques, minimally invasive plate osteosynthesis (MIPO) techniques with standard compression plates or locking plates have gained popularity [45] (Fig. 7.1).

In an excellent review of surgical management of Type B1 injuries, Pike et al. highlighted their current recommendation for Type B1 fractures with MIPO techniques using either a compression plate or a locking plate [13] (Fig. 7.2). The use of locking plates provides surgeons with an important mechanical advantage in osteopenic bone inherent in the geriatric patient population. If the femoral bone stock is inadequate, a locked plate augmented with cortical strut allograft is used [46]. Lastly, if there is a Type B1 fracture with an ipsilateral stemmed total knee arthroplasty (TKA), a locked plate spanning the TKA and THA femoral stems should be used. Haddad et al. note that while MIPO techniques are recommended as the standard of care for most B1 fractures, transverse or short oblique fractures at the tip of the femoral stem are not appropriate to treat with plating alone [10]. In these cases, revision to a long stem femoral implant which bypasses the distal fracture line by at least two cortical diameters is a more appropriate method of treatment [47]. Postoperatively, Marino et al. recommend non-weight bearing on the affected extremity until radiographic evidence of fracture callus is present [48].

Vancouver Type B2

In Type B2 periprosthetic fractures, the fracture occurs about a loose femoral component, with adequate femoral bone stock. These fractures therefore necessitate revision arthroplasty with a long cementless femoral component which bypasses the

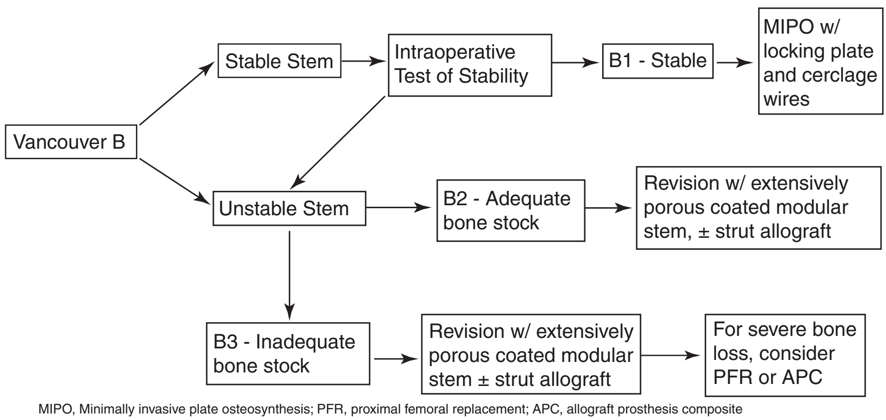

Fig. 7.1 An algorithm for Vancouver Type B periprosthetic fractures. MIPO Minimally invasive plate osteosynthesis, PFR proximal femoral replacement, APC allograft prosthesis composite

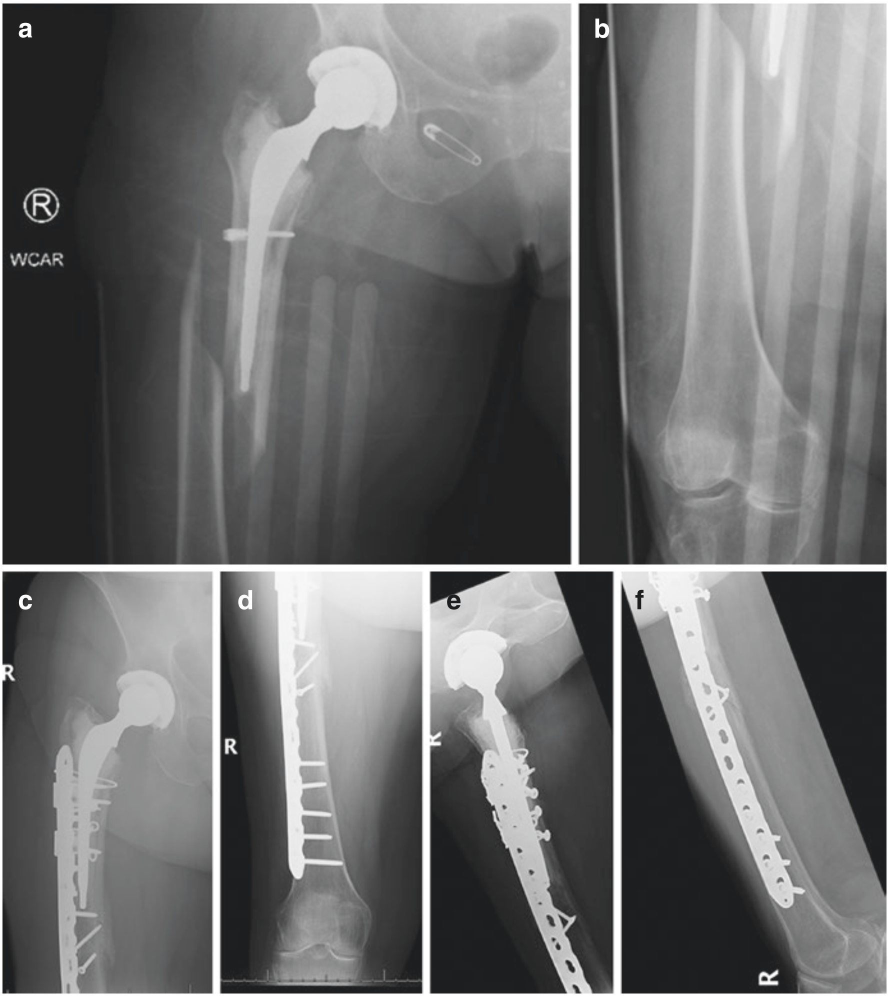

Fig. 7.2 (**a**) Anteroposterior (AP) radiograph of an 87-year-old female patient with a history of right THA demonstrating a right Vancouver Type B1 periprosthetic fracture which occurred after a ground-level fall; (**b**) AP radiograph of the right femur again demonstrating a Vancouver Type B1 periprosthetic fracture; (**c**, **d**) AP radiographs demonstrating open reduction and internal fixation (ORIF) of a Vancouver Type B1 periprosthetic fracture with a spanning plate and cerclage wires; (**e**, **f**) lateral radiographs of the same patient again demonstrating ORIF of a Vancouver Type B1 periprosthetic fracture

distal fracture line by at least two cortical diameters along with fixation of the fracture (Fig. 7.3). Given the high rate of osteoporosis in patients with periprosthetic fractures, early literature focused on the use of cemented long-stem prosthesis. However, likely due to the tendency for cement to interpose between fracture fragments and prevent union, mid- and long-term outcome studies for cemented stems demonstrated high failure rates [49].

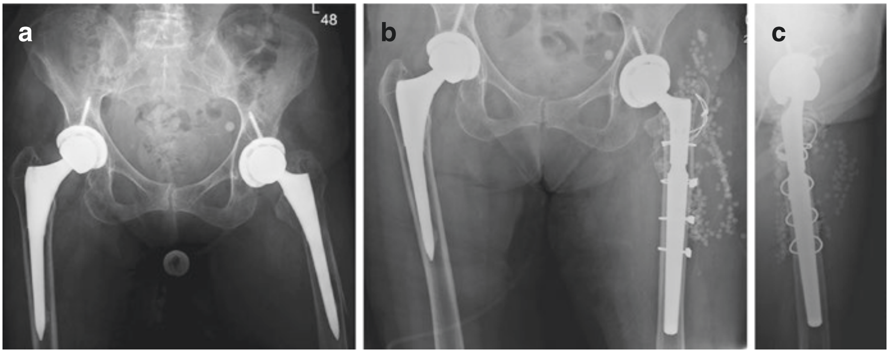

Fig. 7.3 (**a**) Anteroposterior (AP) radiograph of a 92-year-old female patient with a history of bilateral THA demonstrating a left Vancouver Type B2 periprosthetic fracture which occurred after a ground-level fall; (**b**, **c**) AP and lateral radiographs demonstrating a revision arthroplasty with a modular fluted tapered stem and cable fixation. Note an extended trochanteric osteotomy was used for removal of the index femoral component

Extensively Porous-Coated Stems

There was a period when surgeons preferred to use extensively porous-coated long-stem implants for periprosthetic femur fractures, which provide excellent distal diaphyseal fixation and demonstrate significantly improved outcomes compared to cemented stems [50]. For maximal distal interference fit, a minimum of 4–6 cm of intact distal diaphysis is recommended for femoral reconstruction prior to fracture fixation [25] when using these types of stems. If cortical bone is determined to be inadequate, cortical allograft struts are used to augment fixation and provide additional rotational stability [51]. Postoperatively, Ding et al. recommend patients be made partial weight bearing for 1–4 weeks after surgery, with progression to full weight bearing by 1–3 months, depending on the severity of the bone defect [52].

In a series of 20 patients with Type B2 fractures treated with extensively porous-coated long stems, Garcia-Rey et al. reported a 100% union rate and no thigh pain at an average follow up of 8.3 years [53]. In a review of 118 Type B fractures, Springer et al. found that extensively porous-coated stems performed significantly better with regard to survival rate and rate of nonunion as compared with proximally coated stems or cemented stems [54].

Several complications associated with extensively porous-coated stems have been described. In a review of 21 patients with Type B2 and B3 fractures treated with extensively coated steams, Sheth et al. report complications in 33% of patients including nonunion, infection, subsidence, and instability. Similarly, Garcia-Rey et al. found that 50% of patients with Vancouver B2 fractures treated with extensively porous-coated stems had subsidence of >1 cm [53]. Further, six patients (15%) were noted to have a leg-length discrepancy of >1 cm, and two patients had a discrepancy of >2 cm [53].

Modular Tapered Stems

Another option that allows for distal diaphyseal engagement in the setting of a loose femoral component (Vancouver B2), and one which has taken over as the predominant stem type used in this setting, is the modular tapered fluted stem. The tapered design of the stem allows for axial stability, while the splines allow for rotational stability of the femoral implant. The modular proximal component of these stems mates via a Morse taper and allows the surgeon to exercise greater control over limb length, offset, and femoral version. Additionally, modular tapered fluted stems can achieve stability with <4 cm of engagement with the distal diaphysis [55]. The selected implant should be of sufficient length to bypass the distal aspect of the fracture line by at least two femoral cortical diameters.

There are multiple described techniques for insertion of modular tapered stems; however, the author's preferred technique is to first reconstruct the femur and then proceed with fracture reduction. A prophylactic cable should be placed 1 cm distal to the distal aspect of the fracture line to prevent distal fracture propagation during femoral component revision. Next, manual sequential tapered reamers are used to reduce the risk of iatrogenic cortical perforation. The selected modular tapered fluted stem is then impacted into the distal femur, and trial components are used to obtain the desired limb length, stability, and version. Two to three cables or wires are then used to secure the proximal fracture fragments. Some authors choose to augment the intramedullary fixation with cortical strut grafts depending on specific fracture characteristics (i.e., transverse fracture) [56]. Postoperatively, patients may be protected weight bearing with no abduction for 4–6 weeks.

Outcomes for the use of modular fluted tapered stems in the setting of periprosthetic fracture have been largely positive. In a review of 44 patients with Type B2 and B3 fractures, Abdel et al. reported a 2% nonunion rate and a mean Harris Hip score of 83 at 4.3 year average follow-up [57]. The authors note, however, that 7 of 44 patients went on to reoperation, 5 for recurrent instability, and 2 for deep infection [57]. Similarly, Munro et al. reported on 55 patients (38 Type B2, 17 Type B3) treated with modular fluted tapered stems. At mean follow-up of 54 months, the authors found only one radiographic nonunion and two revision operations, one for subsidence and one for deep infection [55]. Additionally, the authors reported excellent patient-reported outcome scores [55]. Recently there has been interest in using non-modular titanium tapered fluted stems for periprosthetic fractures, with good short-term results reported [58].

Subsidence is the most common complication seen with the use of modular fluted tapered stems. Munro et al. noted a 24% rate of subsidence in their cohort, though only 1 patient out of 55 required revision [55]. Hernandez-Vaquero noted a 50% rate of subsidence in their cohort, with a mean subsidence of 3.9 mm [59]. The authors note that none of the patients who experience subsidence required revision surgery [59]. To combat subsidence, Patel and colleagues recommend choosing a stem that is one or two sizes bigger than the final reamer [60].

Vancouver Type B3

Type B3 fractures are defined by a loose femoral stem and severely deficient femoral bone stock. Several of the implant options used in Type B2 fractures (i.e., extensively porous-coated stems, modular tapered stems) are also used in Type B3 fractures. It is important to note that bone loss visualized intraoperatively is likely to be more severe than estimated with standard preoperative radiographs [61]. In the setting of severe bone loss extending beyond the femoral isthmus, some Type B3 fractures may not be amenable to treatment with modular tapered stems, as these constructs rely on distal diaphyseal fixation, although there have been several reports of success using this stem design for Type B3 fractures [55]. In particularly challenging cases where these are not a viable option, the surgeon has three main options: impaction grafting, replacement with an allograft-prosthesis composite (APC), or a tumor mega prosthesis such as a proximal femoral replacement (PFR).

Impaction grafting can be used to create a "neo-endosteum" and assist in diaphyseal fixation in patients with an otherwise wide femoral canal. Additionally, impaction grafting can assist in addressing fracture comminution, which is often significant with Type B3 fractures. Tsiridis et al. describe their technique wherein they impact morselized fresh-frozen allograft bone chips into the femoral canal prior to cementing their implant. The authors describe a series of 106 patients with B2 or B3 fractures and report that those treated with impaction grafting had four times the rate of radiographic union compared to those treated without impaction grafting. However, given the risk of subsidence and subsequent loosening, impaction grafting is not frequently utilized.

Allograft-prosthesis composites have fallen out of favor due to mixed clinical outcomes and the significant technical demands of the operation. Proximally, the construct consists of a long stem cemented into a proximal femur allograft. Distally, the long stem is impacted into the distal femur of the host bone. Min et al. note the 10-year survival rate of APCs to be 65–85% [62]. Maury and colleagues describe a series of 25 patients with Type B3 fractures treated with APC and report that in 20% of patients, the graft did not incorporate with host bone [63]. Additionally, the authors reported radiographic graft resorption in 6 of 25 hips [63]. Given the concerns for graft resorption, Shah et al. note that the APC is a mechanically weaker construct as compared with a tumor mega prosthesis such as a PFR [25].

A PFR can be utilized in low-demand patients with severely compromised proximal bone stock often extending to the level of the trochanters. Clinical outcomes for PFRs are mixed, and the use of a PFR should be considered a salvage operation. One of the main benefits of PFR is the lack of weight-bearing restriction in the immediate postoperative periods. This is of particular importance for the geriatric patient who would otherwise be significantly impacted by the morbidity of prolonged non-weight-bearing status. However, one of the main drawbacks of the PFR is the inability to secure soft tissue attachments proximally, leading to a high incidence of abductor weakness (consequently a Trendelenburg gait) and increased dislocation rate. Outcome studies for PFRs after Type B3 fractures are sparse and sample sizes limited. Of those published, the most common complications include dislocation, aseptic loosening, and low functional outcomes [64–66]. After PFR, options for further revision surgery are extremely limited beyond a total femur replacement.

Vancouver Type C

Type C fractures occur well distal to the tip of the femoral component and may be treated as isolated fractures (i.e., without femoral component) with closed reduction and MIPO techniques or ORIF following standard fracture fixation principles (Fig. 7.4). For Type C fractures, an important consideration is the length of the plate

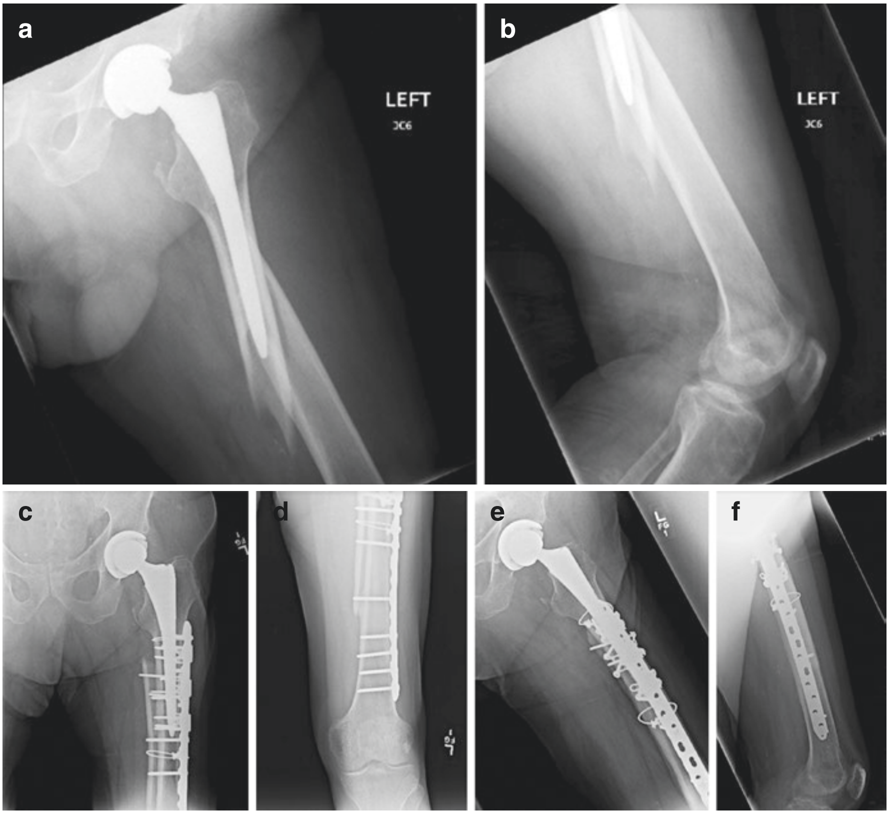

Fig. 7.4 (**a**) Anteroposterior (AP) radiograph of an 81-year-old male patient with a history of left primary THA demonstrating a Vancouver Type C periprosthetic fracture which occurred after a ground-level fall; (**b**) lateral radiograph again demonstrating a Vancouver Type C periprosthetic fracture; (**c**, **d**) AP radiographs demonstrating open reduction and internal fixation (ORIF) of a Vancouver Type C periprosthetic fracture with a spanning plate, cerclage wires, and strut allograft; (**e**, **f**) lateral radiographs of the same patient again demonstrating ORIF of a Vancouver Type C periprosthetic fracture

used to treat the fracture as it is important to not create a stress riser between the proximal aspect of the plate and the distal aspect of the femoral stem. The plate should be of sufficient length to cover two cortical diameters above the distal aspect of the stem tip while also being able to secure four to six cortices of fixation distally [67]. Almost all modern plates have the option for locking screw placement, which is useful for osteoporotic bone [40]. Unicortical locking screws, cerclage wires, or both can also assist with proximal fixation [67]. Loosen et al. note that postoperative weight-bearing restrictions following plate fixation of Type C fractures vary by surgeon, with most opting for non-weight bearing for 6 weeks [68]. O'Toole et al. describe a series of 12 patients with Type C fractures treated with lateral locking plates and report 10 of 11 patients healed without complication, while 1 patient experienced plate pullout requiring revision [67].

Given the significant potential morbidity associated with prolonged non-weight bearing in the geriatric patient population, Langenhan et al. advocate for treatment of Type B and C fractures with a novel distally locked modular prosthesis nail, irrespective of stem stability. In a review of 52 patients with Type B1/B2/B3 and Type C fractures, immediate full weight bearing seen with use of a distally locked modular prosthesis nail resulted in a significant decrease in mortality versus ORIF [69]. The authors argue that irrespective of stem stability, surgeons should consider the use of a distally locked modular prosthesis nail given the benefits of full weight bearing in the immediate postoperative period [69].

Another option for the treatment of Type C fractures includes the use of a retrograde intramedullary nail (rIMN) and lateral plate combination technique as described by Liporace and Yoon [70]. The authors advocate for the placement of a rIMN followed by a lateral plate which extends proximally to the base of the greater trochanter. The plate is linked to the nail using the perfect circle technique [70]. Using this combination construct, patients can fully bear weight on the affected extremity in the immediate postoperative period.

Outcomes and Complications

Overall, the risk of complications after periprosthetic femoral fractures is high. In a review of 1049 patients from the Swedish Hip Arthroplasty Register, Lindahl et al. report an overall complication rate of 18%, a reoperation rate of 23%, and a 1-year mortality of 9.4% [71]. Common complications from their study were bleeding (3.4%), early dislocation (3.2%), and stroke (1.0%) [71]. Additionally, the authors report a 60% rate of chronic pain seen in their surviving patient sample [71]. Bhattacharyya et al. found that 1-year mortality rate after surgical treatment of periprosthetic fracture was similar to the 1-year mortality rate seen after hip fracture (11.0% and 16.5%, respectively) [72]. Additionally, this study demonstrated a significantly higher mortality rate (11.0%) seen in patients with periprosthetic fracture as compared with age- and sex-matched patients undergoing primary THA (2.9%) [72]. Early mobilization in the geriatric patient population is of the utmost importance and can prevent some of these complications.

Conclusions

As the number of total hip arthroplasty procedures continues to rise, periprosthetic fractures present an increasingly common and complex problem for orthopaedic surgeons. Periprosthetic fracture of the femur requires the surgeon to simultaneously address bone loss, implant stability, and the fracture itself. Particularly for geriatric patients, the goal of treatment is stable fracture fixation with early mobilization. Determining femoral component stability is one of the most important aspects of management. A periprosthetic femoral fracture with a loose stem is the most common scenario. In these situations, the current literature supports treatment with an uncemented long revision stem. There are several other less commonly performed reconstruction options that surgeons may perform based on bone quality and fracture characteristics. Complication and morbidity rate after periprosthetic fracture is high, with mortality rates approaching those of hip fracture patients [73].

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References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370(9597):1508–19.
2. Sarvilinna R, Huhtala HSA, Sovelius RT, Halonen PJ, Nevalainen JK, Pajamäki KJK. Factors predisposing to periprosthetic fracture after hip arthroplasty: a case (n = 31)-control study. Acta Orthop Scand. 2004;75(1):16–20.
3. Lindahl H. Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. Injury. 2007;38(6):651–4.
4. Berry DJ. Epidemiology: hip and knee. Orthop Clin North Am. 1999;30(2):183–90.
5. Bottle A, Griffiths R, White S, Wynn-Jones H, Aylin P, Moppett I, et al. Periprosthetic fractures: the next fragility fracture epidemic? A national observational study. BMJ Open. 2020;10(12):e042371.
6. Duwelius PJ, Schmidt AH, Kyle RF, Talbott V, Ellis TJ, Butler JBV. A prospective, modernized treatment protocol for periprosthetic femur fractures. Orthop Clin North Am. 2004;35(4):485–92. vi
7. Lindahl H, Garellick G, Regnér H, Herberts P, Malchau H. Three hundred and twenty-one periprosthetic femoral fractures. J Bone Joint Surg Am. 2006;88(6):1215–22.
8. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties: a 40-year experience. Bone Joint J. 2016;98-B(4):468–74.
9. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89(4):780–5.
10. Yasen AT, Haddad FS. Periprosthetic fractures: bespoke solutions. Bone Joint J. 2014;96-B(11 Suppl A):48–55.

11. Della Rocca GJ, Leung KS, Pape H-C. Periprosthetic fractures: epidemiology and future projections. J Orthop Trauma. 2011;25(Suppl 2):S66–70.
12. Sidler-Maier CC, Waddell JP. Incidence and predisposing factors of periprosthetic proximal femoral fractures: a literature review. Int Orthop. 2015;39(9):1673–82.
13. Pike J, Davidson D, Garbuz D, Duncan CP, O'Brien PJ, Masri BA. Principles of treatment for periprosthetic femoral shaft fractures around well-fixed total hip arthroplasty. J Am Acad Orthop Surg. 2009;17(11):677–88.
14. Moazen M, Jones AC, Jin Z, Wilcox RK, Tsiridis E. Periprosthetic fracture fixation of the femur following total hip arthroplasty: a review of biomechanical testing. Clin Biomech (Bristol, Avon). 2011;26(1):13–22.
15. Schwarzkopf R, Oni JK, Marwin SE. Total hip arthroplasty periprosthetic femoral fractures: a review of classification and current treatment. Bull Hosp Jt Dis. 2013;71(1):68–78.
16. Thien TM, Chatziagorou G, Garellick G, Furnes O, Havelin LI, Mäkelä K, et al. Periprosthetic femoral fracture within two years after total hip replacement: analysis of 437,629 operations in the nordic arthroplasty register association database. JBJS. 2014;96(19):e167.
17. Singh JA, Jensen MR, Harmsen SW, Lewallen DG. Are gender, comorbidity, and obesity risk factors for postoperative periprosthetic fractures after primary total hip arthroplasty? J Arthroplast. 2013;28(1):126–131.e2.
18. Mayle RE, Della Valle CJ. Intra-operative fractures during THA. J Bone Joint Surg. 2012;94-B(11_Supple_A):26–31.
19. Holley K, Zelken J, Padgett D, Chimento G, Yun A, Buly R. Periprosthetic fractures of the femur after hip Arthroplasty: an analysis of 99 patients. HSS J. 2007;3(2):190–7.
20. Lee S-R, Bostrom MPG. Periprosthetic fractures of the femur after total hip arthroplasty. Instr Course Lect. 2004;53:111–8.
21. Carli AV, Negus JJ, Haddad FS. Periprosthetic femoral fractures and trying to avoid them: what is the contribution of femoral component design to the increased risk of periprosthetic femoral fracture? Bone Joint J. 2017;99-B(1 Suppl A):50–9.
22. Herndon CL, Nowell JA, Sarpong NO, Cooper HJ, Shah RP, Geller JA. Risk factors for periprosthetic femur fracture and influence of femoral fixation using the mini-anterolateral approach in primary total hip arthroplasty. J Arthroplast. 2020;35(3):774–8.
23. Tsiridis E, Haddad FS, Gie GA. The management of periprosthetic femoral fractures around hip replacements. Injury. 2003;34(2):95–105.
24. Jakubowitz E, Seeger JB, Lee C, Heisel C, Kretzer JP, Thomsen MN. Do short-stemmed-prostheses induce periprosthetic fractures earlier than standard hip stems? A biomechanical ex-vivo study of two different stem designs. Arch Orthop Trauma Surg. 2009;129(6):849–55.
25. Shah RP, Sheth NP, Gray C, Alosh H, Garino JP. Periprosthetic fractures around loose femoral components. J Am Acad Orthop Surg. 2014;22(8):482–90.
26. Cooke PH, Newman JH. Fractures of the femur in relation to cemented hip prostheses. J Bone Joint Surg Br. 1988;70(3):386–9.
27. Karnuta JM, Haeberle HS, Luu BC, Roth AL, Molloy RM, Nystrom LM, Piuzzi NS, Schaffer JL, Chen AF, Iorio R, Krebs VE, Ramkumar PN. Artificial Intelligence to Identify Arthroplasty Implants From Radiographs of the Hip. J Arthroplasty. 2021;36(7S):S290–S294.e1. https://doi.org/10.1016/j.arth.2020.11.015. Epub 2020 PMID: 33281020.
28. Chevillotte CJ, Ali MH, Trousdale RT, Larson DR, Gullerud RE, Berry DJ. Inflammatory laboratory markers in periprosthetic hip fractures. J Arthroplast. 2009;24(5):722–7.
29. Shah RP, Plummer DR, Moric M, Sporer SM, Levine BR, Della Valle CJ. Diagnosing infection in the setting of periprosthetic fractures. J Arthroplast. 2016;31(9 Suppl):140–3.
30. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect. 1995;44:293–304.
31. Gaski GE, Scully SP. In brief: classifications in brief: Vancouver classification of postoperative periprosthetic femur fractures. Clin Orthop Relat Res. 2011;469(5):1507–10.
32. Masri BA, Meek RMD, Duncan CP. Periprosthetic fractures evaluation and treatment. Clin Orthop Relat Res. 2004;420:80–95.
33. Brady OH, Garbuz DS, Masri BA, Duncan CP. The reliability and validity of the Vancouver classification of femoral fractures after hip replacement. J Arthroplast. 2000;15(1):59–62.

34. Rayan F, Dodd M, Haddad FS. European validation of the Vancouver classification of periprosthetic proximal femoral fractures. J Bone Joint Surg Br. 2008;90(12):1576–9.
35. Naqvi GA, Baig SA, Awan N. Interobserver and intraobserver reliability and validity of the Vancouver classification system of periprosthetic femoral fractures after hip arthroplasty. J Arthroplast. 2012;27(6):1047–50.
36. Roffman M, Mendes DG. Fracture of the femur after total hip arthroplasty. Orthopedics. 1989;12(8):1067–70.
37. Lindahl H, Malchau H, Odén A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. J Bone Joint Surg Br. 2006;88(1):26–30.
38. Marsland D, Mears SC. A review of periprosthetic femoral fractures associated with total hip arthroplasty. Geriatr Orthop Surg Rehabil. 2012;3(3):107–20.
39. Jarit GJ, Sathappan SS, Panchal A, Strauss E, Di Cesare PE. Fixation systems of greater trochanteric osteotomies: biomechanical and clinical outcomes. J Am Acad Orthop Surg. 2007;15(10):614–24.
40. Ricci WM. Periprosthetic femur fractures. J Orthop Trauma. 2015;29(3):130–7.
41. Abdel MP, Cottino U, Mabry TM. Management of periprosthetic femoral fractures following total hip arthroplasty: a review. Int Orthop. 2015;39(10):2005–10.
42. Lindahl H, Oden A, Garellick G, Malchau H. The excess mortality due to periprosthetic femur fracture. A study from the Swedish national hip arthroplasty register. Bone. 2007;40(5):1294–8.
43. Guidera KJ, Borrelli J, Raney E, Thompson-Rangel T, Ogden JA. Orthopaedic manifestations of Rett syndrome. J Pediatr Orthop. 1991;11(2):204–8.
44. Fredin HO, Lindberg H, Carlsson AS. Femoral fracture following hip arthroplasty. Acta Orthop Scand. 1987;58(1):20–2.
45. Sen R, Prasad P, Kumar S, Nagi O. Periprosthetic femoral fractures around well fixed implants: a simple method of fixation using LC-DCP with trochanteric purchase. Acta Orthop Belg. 2007;73(2):200–6.
46. Haddad FS, Duncan CP, Berry DJ, Lewallen DG, Gross AE, Chandler HP. Periprosthetic femoral fractures around well-fixed implants: use of cortical onlay allografts with or without a plate. J Bone Joint Surg Am. 2002;84(6):945–50.
47. Schmotzer H, Tchejeyan GH, Dall DM. Surgical management of intra- and postoperative fractures of the femur about the tip of the stem in total hip arthroplasty. J Arthroplast. 1996;11(6):709–17.
48. Marino DV, Mesko DR. Periprosthetic proximal femur fractures. In: StatPearls [internet]. Treasure Island, FL: StatPearls Publishing; 2020. [cited 2020 Dec 22]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK557559/.
49. Incavo SJ, Beard DM, Pupparo F, Ries M, Wiedel J. One-stage revision of periprosthetic fractures around loose cemented total hip arthroplasty. Am J Orthop (Belle Mead NJ). 1998;27(1):35–41.
50. Paprosky WG, Greidanus NV, Antoniou J. Minimum 10-year-results of extensively porous-coated stems in revision hip Arthroplasty. Clin Orthop Relat Res. 1999;369:230–42.
51. Canbora K, Kose O, Polat A, Aykanat F, Gorgec M. Management of Vancouver type B2 and B3 femoral periprosthetic fractures using an uncemented extensively porous-coated long femoral stem prosthesis. Eur J Orthop Surg Traumatol. 2013;23(5):545–52.
52. Ding Z, Ling T, Yuan M, Qin Y, Mou P, Wang H, et al. Minimum 8-year follow-up of revision THA with severe femoral bone defects using extensively porous-coated stems and cortical strut allografts. BMC Musculoskelet Disord [Internet]. 2020 Apr 8 [cited 2021 Feb 6];21. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7140549/.
53. García-Rey E, García-Cimbrelo E, Cruz-Pardos A, Madero R. Increase of cortical bone after a cementless long stem in periprosthetic fractures. Clin Orthop Relat Res. 2013;471(12):3912–21.
54. Springer BD, Berry DJ, Lewallen DG. Treatment of periprosthetic femoral fractures following total hip arthroplasty with femoral component revision. JBJS. 2003;85(11):2156–62.
55. Munro JT, Garbuz DS, Masri BA, Duncan CP. Tapered fluted titanium stems in the management of Vancouver B2 and B3 periprosthetic femoral fractures. Clin Orthop Relat Res. 2014;472(2):590–8.

56. Rodriguez JA, Fada R, Murphy SB, Rasquinha VJ, Ranawat CS. Two-year to five-year follow-up of femoral defects in femoral revision treated with the link MP modular stem. J Arthroplast. 2009;24(5):751–8.
57. Abdel MP, Lewallen DG, Berry DJ. Periprosthetic femur fractures treated with modular fluted, tapered stems. Clin Orthop Relat Res. 2014;472(2):599–603.
58. Clair AJ, Cizmic Z, Vigdorchik JM, Poultsides LA, Schwarzkopf R, Rathod PA, et al. Nonmodular stems are a viable alternative to modular stems in revision total hip arthroplasty. J Arthroplast. 2019;34(7):S292–6.
59. Hernandez-Vaquero D, Fernandez-Lombardia J, de los Rios JL, Perez-Coto I, Iglesias-Fernandez S. Treatment of periprosthetic femoral fractures with modular stems. Int Orthop. 2015;39(10):1933–8.
60. Patel PD, Klika AK, Murray TG, Elsharkawy KA, Krebs VE, Barsoum WK. Influence of technique with distally fixed modular stems in revision total hip arthroplasty. J Arthroplast. 2010;25(6):926–31.
61. Learmonth ID. The management of periprosthetic fractures around the femoral stem. J Bone Joint Surg. 2004;86-B(1):13–9.
62. Min L, Peng J, Duan H, Zhang W, Zhou Y, Tu C. Uncemented allograft-prosthetic composite reconstruction of the proximal femur. Indian J Orthop. 2014;48(3):289–95.
63. Maury AC, Pressman A, Cayen B, Zalzal P, Backstein D, Gross A. Proximal femoral allograft treatment of Vancouver type-B3 periprosthetic femoral fractures after total hip arthroplasty. J Bone Joint Surg Am. 2006;88(5):953–8.
64. McLean AL, Patton JT, Moran M. Femoral replacement for salvage of periprosthetic fracture around a total hip replacement. Injury. 2012;43(7):1166–9.
65. Malkani AL, Settecerri JJ, Sim FH, Chao EY, Wallrichs SL. Long-term results of proximal femoral replacement for non-neoplastic disorders. J Bone Joint Surg Br. 1995;77(3):351–6.
66. Klein GR, Parvizi J, Rapuri V, Wolf CF, Hozack WJ, Sharkey PF, et al. Proximal femoral replacement for the treatment of periprosthetic fractures. JBJS. 2005;87(8):1777–81.
67. O'Toole RV, Gobezie R, Hwang R, Chandler AR, Smith RM, Estok DM, et al. Low complication rate of LISS for femur fractures adjacent to stable hip or knee arthroplasty. Clin Orthop Relat Res. 2006;450:203–10.
68. Loosen A, Fritz Y, Dietrich M. Surgical treatment of distal femur fractures in geriatric patients. Geriatr Orthop Surg Rehabil [Internet]. 2019 Jul 2 [cited 2021 Feb 6];10. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6607559/.
69. Langenhan R, Trobisch P, Ricart P, Probst A. Aggressive surgical treatment of periprosthetic femur fractures can reduce mortality: comparison of open reduction and internal fixation versus a modular prosthesis nail. J Orthop Trauma. 2012;26(2):80–5.
70. Liporace FA, Yoon RS. Nail plate combination technique for native and periprosthetic distal femur fractures. J Orthop Trauma. 2019;33(2):e64.
71. Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures classification and demographics of 1049 periprosthetic femoral fractures from the Swedish national hip Arthroplasty register. J Arthroplast. 2005;20(7):857–65.
72. Bhattacharyya T, Chang D, Meigs JB, Estok DM, Malchau H. Mortality after periprosthetic fracture of the femur. J Bone Joint Surg Am. 2007;89(12):2658–62.
73. Boddapati V, Grosso MJ, Sarpong NO, Geller JA, Cooper HJ, Shah RP. Early morbidity but not mortality increases with surgery delayed greater than 24 hours in patients with a periprosthetic fracture of the hip. J Arthroplast. 2019;34(11):2789–2792.e1.

Chapter 8
Pathologic Hip Fractures in the Geriatric Patient

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Introduction

Pathologic fractures are a subset of hip fractures in the elderly which occur for a number of reasons. Primary cancers of bone, benign lesions, metastatic disease, or metabolic disease can all be causes of pathologic fractures. The goals of treatment of geriatric pathologic hip fractures are similar to any other hip fracture, but the care of pathologic fractures is complicated by additional diagnostic steps, clinical considerations, and coordination with other physicians. Fortunately, evidence-based guidelines have simplified and standardized the process of preoperative workup and allow orthopaedic surgeons of all subspecialties to safely care for patients with suspected metastatic disease.

Etiology

Geriatric pathologic hip fractures occur due to disturbance of the structural integrity of the proximal femur, a portion of the bone which experiences significant stresses with weight bearing and ambulation [1]. Whether the structural integrity of the bone is affected by neoplastic invasion, irregularities in bone metabolism, or a combination of the two, there is a pathologic process which serves to increase the

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susceptibility of the bone to fracture. Prior pain in the affected area is often present, and the goal for the surgeon prior to completion of the fracture is to assess the risk of fracture prior to it happening and apply prophylactic fixation as needed.

There are two theories, which are not regarded as mutually exclusive, as to the propensity for cancerous cells to metastasize to specific anatomic locations (such as the proximal femur), developed by Paget and Ewing. Stephen Paget in 1889 described a "seed and soil" hypothesis, which stated that certain tumor cells are able to survive and grow in compatible end-organ environments that have the optimal concentration of oxygen and other nutritional factors. This may explain why certain types of carcinoma (e.g., breast, prostate, thyroid, lung, kidney) have predilection for bone and not others [2]. This theory may also explain why certain types of cancer exhibit different anatomic predilections, such as proximal humerus (for renal cell carcinoma) and distal phalanges (for lung). This theory has been supported by later basic science findings that cancellous bone naturally allows space for metastatic cells to reside and interact with osteoclasts and osteoblasts based on the RANK/RANKL signaling system [3].

Later in 1928, James Ewing suggested that the direction of the blood supply from sites of carcinoma to specific bony locations – for instance, via Batson's vertebral plexus to the vertebral bodies, pelvis, and proximal limb girdles – is what explains the likelihood for cancer to arrive at certain locations within the skeleton [4]. In this theory, organs are essentially passive receptacles, and tumor cells simply tend to migrate to where the circulation takes them first.

The true etiology behind the geographic pattern of metastatic disease is likely a combination of both theories; cancer cells travel primarily by hematogenous spread, but the final deposition and growth of metastatic cells do depend on the localized tissue environment [5].

The surgical implication of these theories is that there are predictable locations in which bony metastases tend to present. Knowledge of these patterns, and appropriate workup for other potential sites of disease, can have profound effects on decisions about intubation (if cervical spine disease is found), positioning in the operating room, and additional sites requiring prophylactic fixation. Furthermore, because of their progressive etiology, many of the diseases that cause pathologic fractures will continue to progress despite best efforts to treat them, which informs the surgical tactics used to treat these fractures.

Epidemiology

Metastatic lesions are more prevalent in the elderly (over 65) population. In fact, the most common cause of a destructive, lytic bone lesion in a person over 40 years of age is metastatic carcinoma. While it is much rarer for primary bone tumors to lead to pathologic fracture, it is always a possibility that must be considered, even in a patient with known metastatic cancer [6]. Of the approximately 1.7 million people who will develop cancer each year in the United States, about 5% of these will develop metastatic disease to bone at some point in their disease course, and a subsequent 8% will sustain a pathologic fracture [7–9]. While all tumors are capable of metastasizing to bone, the most common primary cancers to do so are breast, prostate, lung, kidney, and thyroid, in order of most to least common. Breast and prostate cancer together represent about 80% of bone metastases, due to a combination of their high prevalence and favorable prognosis with modern therapies [10]. Primary bone cancers are less common in this age group [11], but they must always be considered as part of the differential diagnosis, as the treatment of primary bone cancers is significantly different from metastatic disease, and the results of missing this diagnosis can be catastrophic.

Pathophysiology

When considering the pathologic fracture in any disease setting, it is important to understand the biological underpinning of the mechanical failure leading to fracture. The balance of bony turnover and structural integrity is governed by the RANK/RANK ligand (RANKL)/osteoprotegerin (OPG) pathways [12]. The cells involved in bone metabolism – osteoblasts, osteoclasts, and osteocytes – all participate and respond to this signaling pathway. Bone formation is promoted by osteoblast stimulation and osteoclast inhibition, while bone resorption occurs by activated osteoclasts, typically with RANKL in normal processes.

Tumor cells themselves do not directly destroy bone. Instead, they express cytokines which influence bone turnover. Metastatic breast cancer is the classic prototype of this process, which is characterized by parathyroid hormone-related protein (PTHrP) manipulation of the RANKL pathway. TGF-β, which is normally stored in the bone and released during normal bone turnover, will stimulate breast cancer cells to secrete PTHrP. PTHrP from cancer cells acts as a potent activator of the RANKL pathway, causing RANKL release from osteoblasts which in turn stimulates osteoclast precursors and increases the number of osteoclasts. Osteoclasts destroy bone, which in turns releases more TGF-β, and the cycle of destruction repeats [13].

Knowledge of the mechanism by which metastatic carcinoma destroys bone has led to the development of therapeutic agents that can aid in the fight to slow and reverse bony destruction. The RANKL pathway is a critical therapeutic target in treating metastatic bone disease, and bisphosphonates and denosumab (an anti-RANKL monoclonal antibody) have both been found to delay time to skeletal-related events (SREs) such as pathologic fracture, spinal cord compression, and/or need for radiation therapy/surgery [14–16]. In pathologic hip fractures affecting locations where surgical treatment is of limited utility (i.e., acetabulum), bisphosphonates in conjunction with radiation therapy can be quite effective (Fig. 8.1).

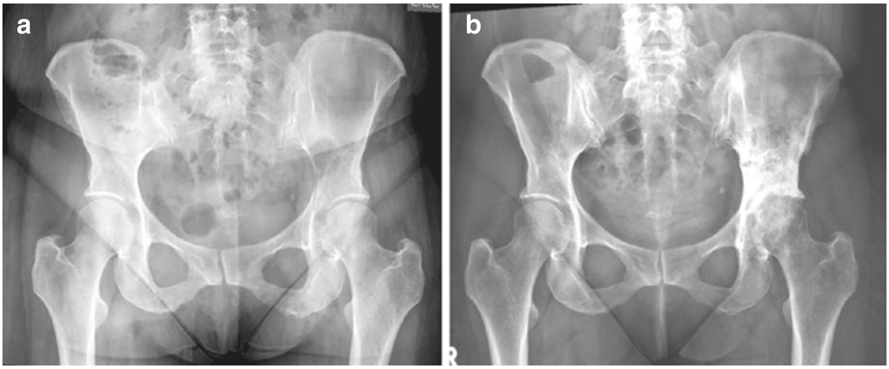


Fig. 8.1 Initial (**a**) radiograph of a 44-year-old woman who presented with a destructive lesion and pathologic fracture of the left supraacetabular region. Three-year follow-up (**b**) radiograph demonstrating reconstitution of the bone with bisphosphonates and radiation therapy alone

Evaluation

There is a specific and systematic process for the workup of a destructive bone lesion without a known primary cancer, which was originally described by Michael Simon et al. in 1986 [17]. This process consists of a history and physical, laboratory evaluation, radiographic evaluation of the affected bone, whole-body bone scan (WBBS), CT scans of the chest/abdomen/pelvis (CT CAP), and biopsy of the most accessible site found after the above. This strategy will both yield the correct diagnosis and correctly identify the location of the primary cancer, with 85% effectiveness.

Even if a patient has a history of prior carcinoma, one cannot assume that a bony lesion represents the first instance of metastatic disease. Approximately 15% of the time, a new bony lesion in a patient with known localized carcinoma is found to be a new tumor as opposed to the first presentation of metastatic carcinoma. This occurs most frequently with breast and prostate cancer [18]. Therefore, even if a patient endorses a cancer history, it is critical to never assume that a new bony lesion is metastatic carcinoma and treat it as such without confirmation of the diagnosis.

History and Physical

In evaluating a patient who presents with a pathologic hip fracture, a quality history will aid in the diagnosis and subsequent treatment of the patient. In the geriatric patient with a pathologic hip fracture, metastatic disease is statistically the single most likely diagnosis. There is an 11-fold increase incidence of cancer in the age group over 65, 56% of all cancer diagnoses occur in the greater than 65 year old population, and the incidence of cancer in the 65 year old population has increased 26% in the last 30 years [19]. Specific questions about history of cancer, constitutional symptoms, and physical exam can help elucidate the cause of pathologic fracture.

As with any good history, determination of the patient's pain onset, location, severity, antecedent pain, and radiation of pain is helpful in discerning involvement of other areas of the body, and whether or not this process has been progressive over a set amount of time prior to fracture. It is also important to note the patient's functional status, both before the onset of any pain and before the fracture itself. These two points will assist in directing treatment with a goal of return to reasonable functional status.

Physical exam can also provide important information upon initial evaluation. Aside from mental status evaluation during the history, palpation of the axial and appendicular skeleton is important in identifying any other bony lesions that may be less symptomatic in the setting of a distracting injury. Any areas of pain within the musculoskeletal system should be appropriately imaged. Visceral masses and skin cancers can sometimes be appreciated on exam, yielding clues to the etiology of pathologic fracture.

Following history and physical examination, laboratory and imaging evaluation provide a significant amount of information in the further narrowing of a differential diagnosis.

Laboratory Evaluation

Complete blood count (CBC) with a differential is obtained to evaluate for leukopenia or leukocytosis as well as anemia. This can be helpful in the case of leukemia or lymphoma diagnosis. Complete metabolic panel (CMP) is obtained for the evaluation of general electrolyte imbalances, but the CMP also evaluates calcium, for which a derangement can be a life-threatening metabolic abnormality from metastatic disease or multiple myeloma. The sedimentation rate (ESR) and C-reactive protein (CRP) levels are obtained to evaluate for infectious processes as some lesions of bone can appear abnormal, but in fact are infection. Thyroid-stimulating hormone (TSH) and free T4 are helpful for thyroid diagnosis, and urinalysis can aid in renal or urothelial cancer with microhematuria. Serum and urine protein electrophoresis panels (SPEP/UPEP) are very important in the metastatic/pathologic fracture workup as this is the diagnostic test for multiple myeloma. Alkaline phosphatase (ALP) is a helpful marker in the evaluation of malignancy, as ALP has been shown to be a surrogate of bony disease in several carcinomas and even primary tumors of bone [20–22]. Other laboratory markers can be obtained if the patient has a history of prior malignant disease such as prostate cancer, ovarian cancer, or pancreatic cancer.

Imaging

Imaging is of the utmost importance in further development of the differential diagnosis. The primary imaging modality is the radiograph and, for hip fractures, should consist of a pelvic radiograph as well as two views of the femur. A chest radiograph should also be obtained, both for preoperative evaluation and for metastatic evaluation. Further plain films should be obtained if the physical exam or history indicates other areas of bony pain or tenderness. All radiographs should be two orthogonal views of the entire bone.

Computed tomography (CT) of the chest, abdomen, and pelvis should be obtained to evaluate for possible primary site of disease and can additionally help determine metastatic disease burden. This will also cover the area of the fracture and help with further bony characterization in the area of the pathologic fracture.

A whole-body bone scan is also essential in evaluating for other metastatic lesions to bone that may have been overlooked or missed and is especially crucial to rule out cervical spine or other metastases which can affect the ability to appropriately intubate and position patients in the operating room. These whole-body bone scans may either be performed via nuclear scintigraphy or by PET-CT, depending on institutional preferences. However, recent studies suggest that while PET/CT may be useful in assessing overall metastatic burden, it does not outperform standard evaluation for identification of the primary cancer in patients with a skeletal metastasis of unknown primary [23].

MRI is a more specific study that may be indicated in order to better delineate the soft tissue component of a bony lesion or to differentiate a primary bone malignancy from other causes of impending or completed pathologic fracture. This is not typically included in the workup of a metastatic lesion of unknown origin.

Biopsy

The next stage of diagnosis is biopsy of the most accessible lesion based on the workup. Often this will be the site of the fracture itself, but even if another non-bony site is biopsied first, it is advised to still perform a biopsy of the fracture site in case it represents a different process.

Biopsy planning is an important process, and care must be taken to take biopsies that are longitudinally oriented and in line with the incision necessary for subsequent surgical intervention [24]. The challenge with fractured proximal femoral lesions is that treatment options can vary widely – between intramedullary nail fixation, hemiarthroplasty, total hip arthroplasty, proximal femoral replacement, hip disarticulation, and hemipelvectomy – depending on the type of lesion and location of the fracture. The site and orientation of the biopsy should thus be carefully planned, such that even if a resection is necessary (such as in cases of a newly discovered primary bone tumor), the biopsy tract can be removed as part of the incision. It is also essential to limit contamination as a result of the biopsy, and the biopsy tract should involve as few compartments as possible and avoid important neurovascular structures.

For hip fractures specifically, the approach that generally works the best for biopsy is in on the lateral portion of the greater trochanter, just large enough to insert a tool for bone specimens. This can be a core biopsy needle/Jamshidi needle, or a pituitary rongeur. Fluoroscopy is essential for biopsy to localize the lesion and confirm intraosseous material is taken. The pathologic fracture often serves as an easy and safe access point for obtaining material from a bony lesion.

If for some reason the location of the fracture does not allow for this method, an approach through the lateral cortex of the greater trochanter allows for sampling of most lesions about the proximal femur, and the hole created by the biopsy is more favorable in terms of reducing the risk of creating a stress rise as compared to a subtrochanteric location (Fig. 8.2).

If a cortical window is necessary to gain access to the lesion, an oblong window as reported by Clark et al. is the safest [25]. Biopsy should be sent immediately for frozen section and evaluation by a musculoskeletal pathologist. The decision point that dictates proceeding with surgical fixation or not is whether the lesion is definitively of a cell lineage where fixation is safe (i.e., metastatic carcinoma, benign bone lesion, or disseminated hematopoietic malignancy such as lymphoma or multiple myeloma). If the lesion is consistent with either a primary or sarcoma or indeterminate from frozen section, further pathologic evaluation is necessary and definite fixation should be deferred. Depending on the clinical scenario, there can be a role for limited internal fixation prior to closure to stabilize the bone, as long as the procedure does not cause excessive contamination or preclude proper management with resection even if the lesion ultimately returns as consistent with a primary malignancy.

Prognosis

Historically [26], literature suggested that a life expectancy of greater than 1 month can clinically benefit from reconstruction. A more current approach does not dictate a cutoff but does take into consideration the location of the pathologic fracture and functional status of the patient and includes the patient in the decision-making process. There is movement toward more accurate life expectancy prediction for the purposes of treatment and patient information. Physicians are typically poor judges of prognosis, and survival models rely on several information points including disease-specific variables [27], performance status [28], and laboratory values, among other inputs [29]. This is important from a patient care perspective due to the interest in effect metastasis has on patient survival and the outcomes of surgical intervention, largely if the recovery period from surgical intervention is a reasonable risk for the improved quality of life following recovery. Forsberg et al. developed prognostic models evaluating the validity of three prognostic models for

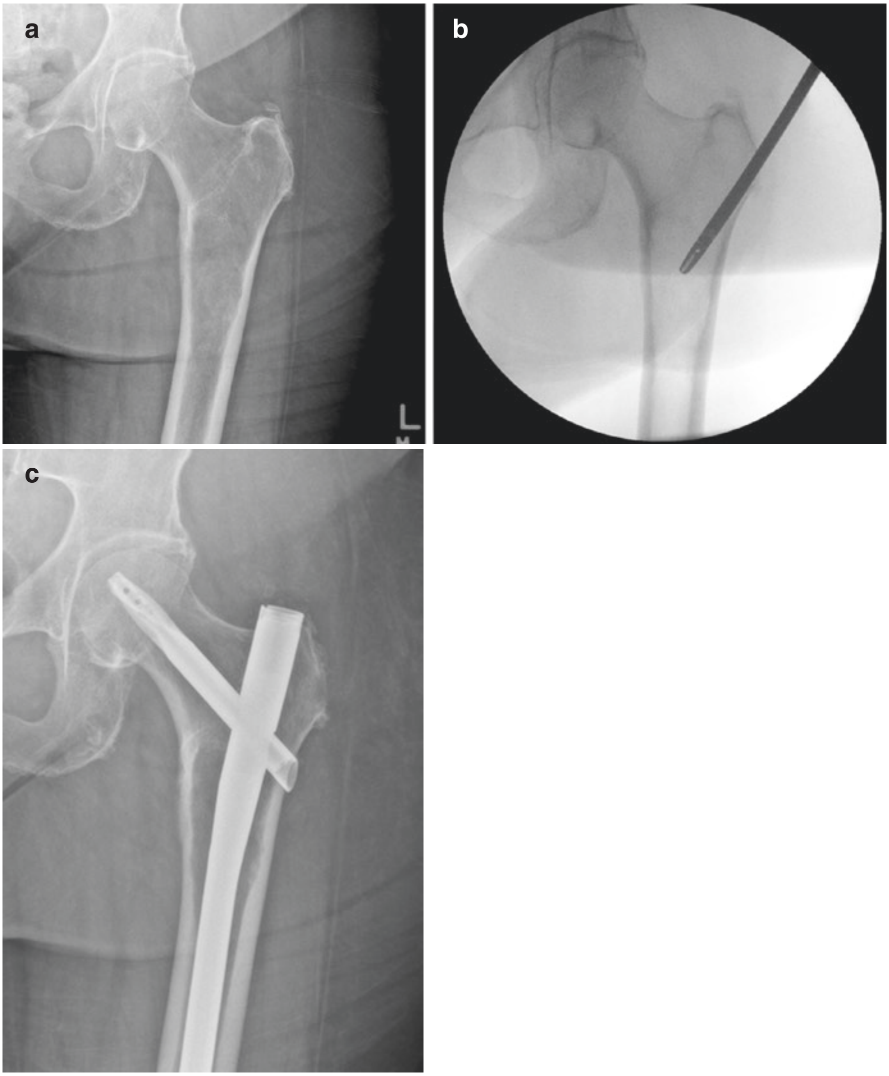


Fig. 8.2 (**a**) Preoperative AP radiograph of an impending pathologic fracture through a lesion in the subtrochanteric region (ultimately found to be B-cell lymphoma). In order to avoid a stress rise in a vulnerable area, a (**b**) trans-trochanteric biopsy of the lesion was performed prior to (**c**) prophylactic long cephalomedullary nail fixation

patients who underwent surgical intervention for pathologic fractures. These included a Bayesian belief network, artificial neural network, and logistic regression models and found that the artificial neural networks most effectively predicted 3 and 12 months survival [30]. This study shows promising new avenues in the accurate prediction of survival and can contribute better to decision-making of pathologic fracture fixation.

Management

Nonsurgical

Nonsurgical treatment of a pathologic hip fracture is appropriate for patients who are unable to undergo anesthesia or those with extremely short life expectancy. For patients of this category, pain control and palliation become the primary goals of care. Perineural femoral catheters or epidural catheters with infusions of bupivacaine can be extremely effective in improving a patient's pain while in bed and during toileting and hygiene. There are risks associated with these interventions such as catheter infection, but in situations involving short life expectancy, the risk-benefit ratio may favor this type of intervention [31]. Other palliative measures can include radiation therapy, bone-seeking radiopharmaceuticals, palliative chemotherapy, embolization, electrochemotherapy, radiofrequency ablation, and high-frequency ultrasound delivery [32].

Surgical

Management of the pathologic fracture of the proximal femur, whether in the femoral head, neck, peritrochanteric region, or subtrochanteric region, is largely surgical. Some considerations that are important in surgical planning include life expectancy, expectations of activity level, and the need for immediate stability. Pathologic fractures are, by nature, fractures of abnormal bone, in which healing potential may be limited or nonexistent due to malignant infiltration [33]. In modern times, patients with metastatic cancer generally have an increased life expectancy due to improvements in medical management, chemotherapeutic, and radiation options for systemic and localized treatment [1]. As patients survive longer with disease, quality of life should be taken more as a priority in the treatment of pathologic fractures. Surgical intervention must therefore assume not only longevity of the patient but also progression of disease, which creates unique challenges in planning surgical interventions.

Won-Sik Choy et al. advocate for management of the pathologic fracture based on the anatomic location of the lesion. Hemiarthroplasty (Fig. 8.3) was historically favored over total hip arthroplasty for femoral neck (intra-capsular) fractures because of the desire to limit dislocation risk and surgical time in this population, as well as a relatively lower life expectancy [34]. However, in more recent years, a survey of MSTS members showed no consensus between treatment with hemiarthroplasty and total hip arthroplasty given several case vignettes, perhaps signaling a shifting trend as patients continue to live longer with metastatic carcinomas [35].

Peritrochanteric and subtrochanteric fractures are better served by intramedullary nail fixation, and most would traditionally advocate for protecting the neck and head with a cephalomedullary device, anticipating the possibilities of progression of

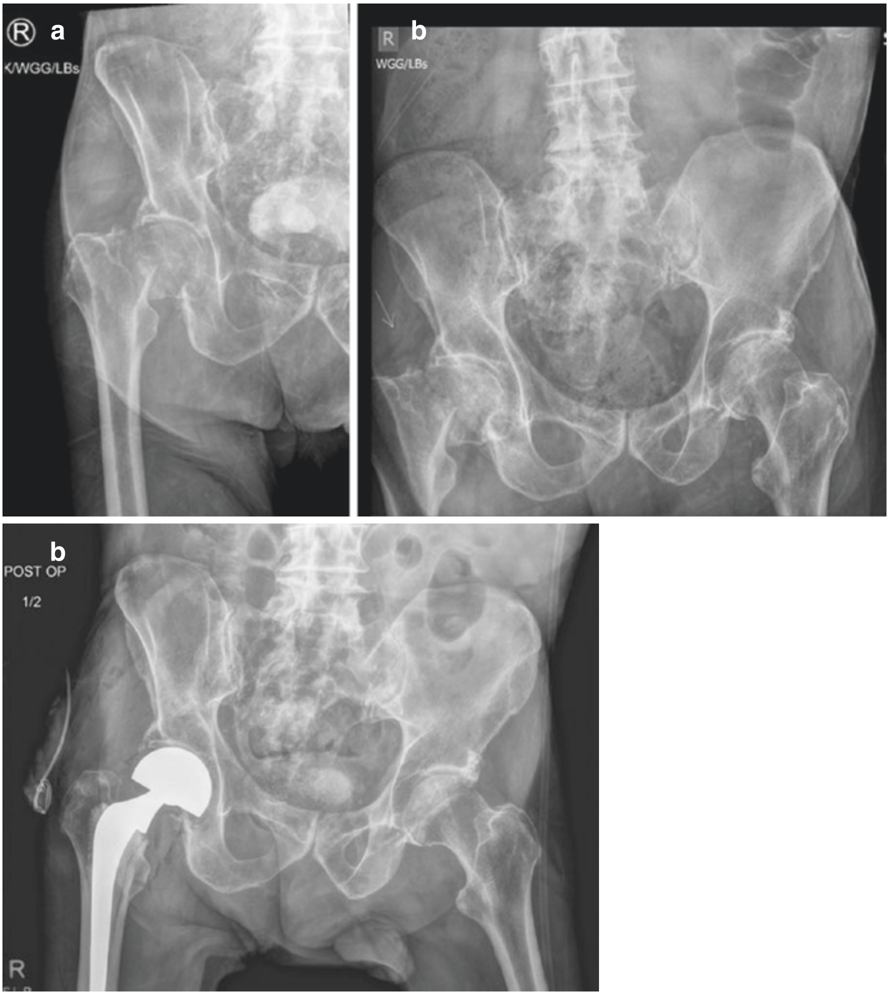


Fig. 8.3 (**a**) AP of the hip and (**b**) AP of the pelvis demonstrating a femoral neck pathologic fracture and a (**c**) postoperative radiograph demonstrating resection and reconstruction with a long stem cemented hemiarthroplasty

metastatic disease in the femoral neck and future injury (Fig. 8.4). While a long-standing tenet of orthopaedic oncology, "one bone, one surgery," has historically prescribed cephalomedullary nail or long-stem hemiarthroplasty as the treatments of choice for this reason, recent evidence has challenged this truism. Proponents of less invasive modalities may suggest that there is a role for intramedullary nails without fixation of the neck, or short-stemmed arthroplasty options [36].

Resection of the proximal femur and reconstruction with a proximal femur is indicated in certain types of pathologic hip fracture. This intervention is more suited for larger, destructive lesions that would make stability of a typical arthroplasty

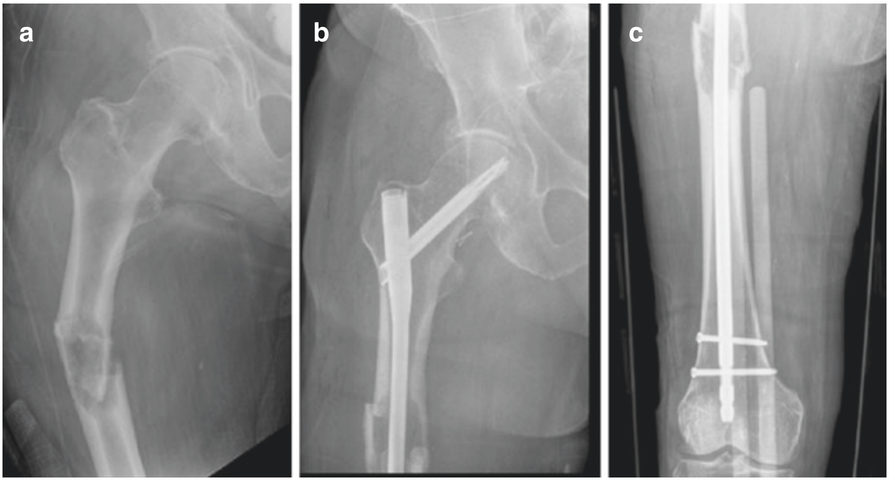
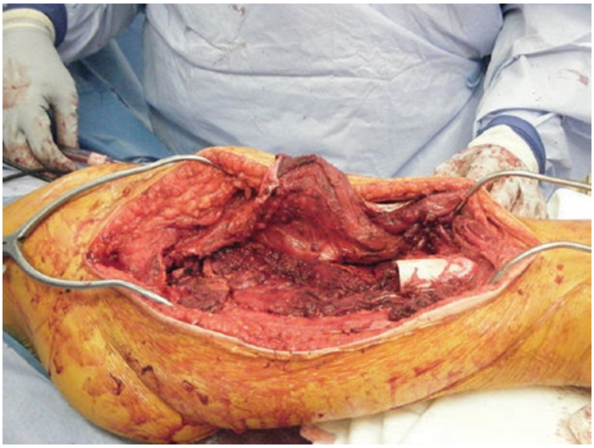


Fig. 8.4 (**a**) Preoperative AP, alongside postoperative AP (**b**) and lateral (**c**) radiographs demonstrating intramedullary fixation of subtrochanteric pathologic fracture

Fig. 8.5 Proximal femoral resection (BennyK95, Public domain, via Wikimedia Commons)



component unfeasible [37]. Another indication for large modular replacement is the documented failure of intramedullary fixation of proximal femoral fractures due to weakness of the tumor region, heavy loading of the proximal femur, systemic effects of the primary failure, and failure of healing due to adjuvant radiation [38], although radiation of the metastatic lesion will often allow the normal bony healing to return in the majority of cases. These dissections are large and contribute to longer surgical time (Figs. 8.5 and 8.6). Some would advocate for resection and reconstruction in certain disease types, such as renal cell carcinoma, in which progressive destruction is anticipated in the future, although this is a controversial issue at present time [39–42].

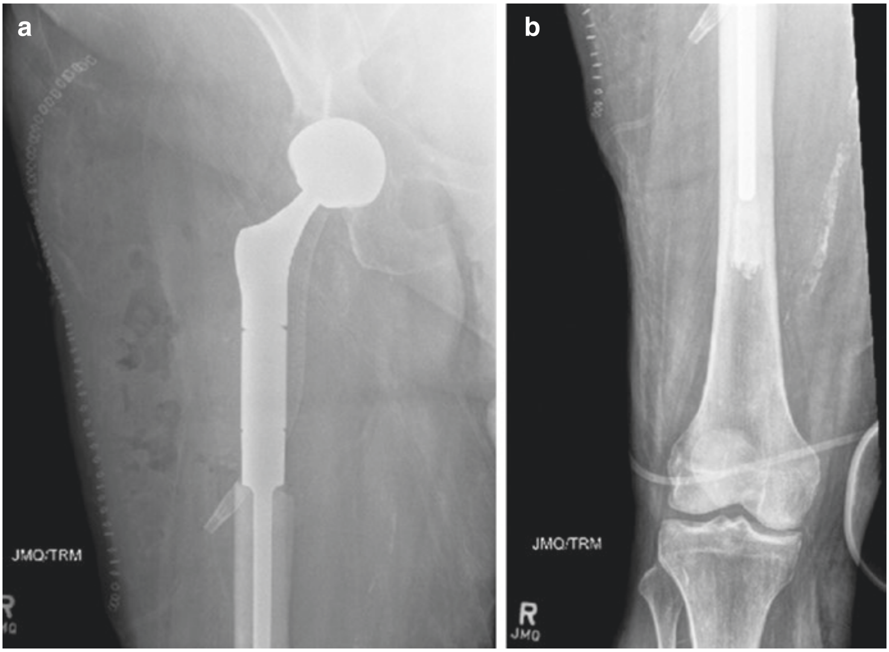


Fig. 8.6 AP and lateral radiographs of a cemented proximal femoral replacement performed for pathologic fracture

A final alternative is simple resection of the metastatic lesion and wound closure alone. This is an option in a patient that has other functional limitations, whether they be musculoskeletal, metabolic, or neurologic. Patients who undergo this treatment also have shorter surgical times, with the primary goal being pain relief for this treatment method. One comparative, retrospective study evaluated the difference between stabilization and resection with no statistical significance in survival or complication, but did have a higher frequency of complications with the resection group [43].

Neoadjuvant

In certain rare cases, preoperative treatment of pathologic lesions is indicated. Patients who have metastatic thyroid, renal, or pheochromocytoma should be considered for preoperative embolization to limit blood loss during the eventual surgical management. A case-control study evaluated patients with renal cell and thyroid carcinoma evaluating blood loss with and without preoperative embolization. Those who underwent embolization had less estimated blood loss (EBL), less need for transfusion, and shorter operative time [44]. If the workup for unknown primary cancer suggests one of these primary types, embolization should be considered prior to surgical intervention.

Adjuvant

Surgical fixation of a pathologic hip fracture generally marks the commencement of the treatment course for the patient, rather than the conclusion.

Radiation is the single most important adjuvant therapy in many tumors that are radiosensitive like myeloma, lymphoma, prostate, breast, ovarian, and neuroendocrine tumors. Radiation is useful in improving duration and quality of life for patients with metastatic disease [39, 40]. The radiation therapy to metastatic lesions after fixation assists by inducing cell death and decreasing overall malignant burden in the area of fracture. With restoration of a more normal balance of osseous cells, normal bone healing can proceed without as much competition from malignant cells. Ultimately, radiation adjuvant to metastatic pathologic fracture improves the likelihood of achieving better functional status postoperatively and decreases the risk of requiring additional orthopaedic procedures of the same site. Furthermore, radiotherapy has been suggested to potentially increase survival in some scenarios, likely from decreased malignant burden as well. One study showed survival of 3.3 months in the surgery alone group, compared to 12.4 months in the surgery plus radiation group [45].

The Mirels score (Table 8.1) is also a useful tool for generalizing treatment of patients with pathologic fractures. The score, which is a simple clinical and radiographic stratification schema based on the site of lesion, size of lesion, nature of lesion, and pain, has been used for criteria for prophylactic fixation, but the original publication was directed at whether or not lesions would eventually fracture after irradiation without fixation. The mean score of 7 in the non-fracture group led to the Mirels score of greater than 8 being considered an indication for prophylactic fixation prior to radiation [46]. Those with a score of 7 or less would be better served with radiation and may be considered for prophylactic fixation after radiation if symptoms persist.

For disseminated cancers, chemotherapy may sometimes be indicated. Chemotherapy should be directed by medical oncology colleagues familiar with

Table 8.1 Mirels' criteria, with a total score of >8 being an indication for prophylactic fixation prior to radiation therapy

Mirels' criteria			
Score	1	2	3
Site	Upper limb	Lower limb	Peritrochanteric
Size (width of bone)	<1/3	1/3–2/3	> 2/3
Nature	Blastic	Mixed	Lytic
Pain	Mild	Moderate	Functional

various cytotoxic, immunotherapeutic, and directed chemotherapy options. This is typically initiated postoperatively after wound healing is completed, as the goal of bony stabilization and pain reduction are the most time sensitive priorities in the patient with the pathologic fracture. A patient's functional status can sometimes play an important role in eligibility for chemotherapy trials, so the orthopaedic intervention can have a long-lasting impact on the patient's outcome.

Bisphosphonates play a key role in bone metastases and an even more important role in pathologic fractures [47, 48]. It is recommended that bisphosphonates be instated early in the clinical course of a patient with lytic lesions. Similarly, the patient with a completed pathologic fracture should receive bisphosphonate therapy postoperatively. Much research for bisphosphonate therapy in metastatic disease is in breast cancer [14], but the metabolic advantage translates to all lytic lesions. In a placebo-controlled study for pamidronate in patients with bony metastasis from breast cancer, monthly infusions of pamidronate led to statistically significant reductions in the rate of skeletal complications and delays in mean time to skeletal-related events [49].

Previously, there were concerns for delayed union of fractures with the use of bisphosphonates [50, 51], but a double-blind randomized controlled trial showed that there was no significant delay in union of fractures treated with bisphosphonates compared to placebo, demonstrating the safety and efficacy of early bisphosphonate use in the pathologic fracture [52]. It is important to keep in mind the risks associated with extended bisphosphonate use, which include subtrochanteric alteration of the femoral cortex and high risk of pathologic subtrochanteric fracture. These often require prophylactic fixation as seen in Fig. 8.7.

Complications

Although complications can present throughout the perioperative period, the single most dreaded preoperative complication of the treatment of pathologic hip fractures is misdiagnosis, which occurs when a lesion is assumed to be metastatic disease and therefore is not biopsied. If this assumption is incorrect, surgical fixation will seed tumor cells into adjacent or distant parts of the body, significantly and negatively impacting the patient's prognosis. In the case of intramedullary fixation, cancerous cells are seeded throughout the femoral canal and into the abductor musculature. Although primary bone tumors are rare (0.2% of all new cases of cancer), the surgeon should always know the etiology of a bone lesion before proceeding with surgical treatment [53]. A patient with a proximal femur lesion that is assumed to be metastatic disease but is in fact sarcoma, for example, could potentially undergo intramedullary nail fixation as treatment. This error may ultimately lead to the patient requiring a hemi-pelvis resection because tumor cells are assumed to have seeded the entire thigh and hip. Had the correct diagnosis been made via biopsy, a limb sparing surgery would have been curative.

Fig. 8.7 Pre- and postoperative radiographs of impending pathologic femur fracture from extended bisphosphonate use

Other perioperative complications can include failure to anticipate or treat lesions that would benefit from preoperative embolization such as renal cell or thyroid metastatic carcinoma. Significant blood loss, at times leading to the need to abort surgical intervention, can result and could be avoided by preoperative embolization. Reaming of the medullary canal during treatment with either cephalomedullary nails or long-stem arthroplasty can lead to not only the typical reaming-related complications such as fat embolism and pulmonary embolism, but recent studies have suggested that there is a systemic spread of cancer cells that occurs during this process which have led some to advocate against using long-stem implants unless there are clearly other lesions distal to the hip [54, 55].

Postoperative complications are numerous. Fixation failure, periprosthetic fracture, wound dehiscence, infection, and hematoma causing a compressive neuropathy are complications that can affect pathologic and non-pathologic fractures alike. There are additionally many mechanisms of failure of fixation or replacement that are relatively unique to pathologic fracture. These can be generally categorized as soft tissue failure, aseptic loosening, structural failure, periprosthetic infection, and tumor progression [56]. Systemic complications are also numerous and include pneumonia, venous thromboembolic event including pulmonary embolism, deconditioning and sarcopenia, sepsis, acute cardiac syndrome, and acute kidney failure.

Outcomes

With respect to timing of fixation of pathologic geriatric hip fractures, the first instinct may be to treat the patient with the same urgency as a non-pathologic hip fracture, for which traditional literature dictates that there is a survival benefit if surgical fixation occurs within 48 hours of injury [57–60]. In contrast, patients with pathologic fracture were found to have no difference in 30-day complications if surgical treatment was delayed more than 48 hours [61]. This study found that delayed surgery was only associated with increased length of stay and that the risk of major complications and mortality was solely dependent upon preexisting medical conditions. Therefore, having a correct diagnosis or treatment plan is more important than surgical expediency for pathologic fractures. Delayed time to surgical fixation allows for appropriate discussion with the patient and family, multidisciplinary coordination and deliberation, and other preoperative activities such as biopsy, vascular embolization, and advanced imaging.

There is very little data regarding the risk factors for mortality for patients with pathologic fractures, but one retrospective study for patients with non-small cell lung cancer suggests that intertrochanteric location, lower serum albumin, an availability of chemotherapeutic, reconstruction with endoprosthesis, elevated leukocyte count, and elevated alanine aminotransferase are predictive of higher mortality. Intertrochanteric location is associated with larger bony involvement and worse prognosis compared with femoral head or neck. Albumin levels are indicative of overall nutrition and physiologic reserve, indicative of the patient's ability to recover from surgical intervention [62].

In addition to patient survival, survival of implants is an important consideration, especially when choosing the fixation method. Evaluation of cephalomedullary nail placement for proximal femoral lesions with intact femoral head and neck bone found only a 10% loss of stability necessitating revision surgery. The same group favored hemiarthroplasty for femoral head or neck lesions. Overall, cumulative incidence of revision surgery was 5% and 9% at 1 and 5 years, respectively [63]. One group evaluated durability (number of treatment failures) with respect to intertrochanteric and subtrochanteric fractures between intramedullary nailing, open reduction with internal fixation, and endoprosthetic reconstruction and found that endoprosthetic had significantly fewer treatment failures (any reoperation). Endoprosthetic reconstruction had a failure rate of 3.1%, while intramedullary nailing and open reduction with internal fixation had failure rates of 6.1% and 42.1%, respectively [64]. Arthroplasty as a salvage procedure for failed internal fixation of a pathologic fracture is another important consideration. Revision to arthroplasty demonstrated significant improvement in Harris hip scores and had 90% implant survivorship at 5 years [6].

Function

Overall function of patients with metastatic disease is shown to improve after surgical management. Enneking proposed a six-category scoring system for functional evaluation after surgical treatment of tumors. This varied for upper and lower extremities but encompassed pain, function, and emotional acceptance. In the lower extremity, supports, walking, and gait completed the six categories. The upper extremity categories included hand positioning, dexterity, and lifting ability [65].

Intramedullary fixation of proximal femoral pathologic fracture was evaluated using the MSTS score, and postoperative scores were found to be adequate and comparable to endoprosthetic implants. Intramedullary devices scored an average of 21 of 30 with a range of 12–27, while endoprosthetic replacements averaged 24 with a range of 8–39 [66].

Endoprosthetic implants require a larger dissection and longer surgical time but have excellent outcomes. This is due to improvements of pain, physical function, and few complications. Guzik evaluated 64 endoprosthetic cases and found that all patients reported improvements in quality of life, decreases in VAS pain scale, and improvement in Karnofsky physical function score. All patients were able to ambulate with one ambulatory aid or less, and no patients had deep infections requiring implant removal at an average of 1.8 year follow-up [66]. A follow-up study evaluating a similar patient population by the same authors found similar pain and functional results with only two major complications [67]. Peterson et al. also evaluated functional results with long-stem hemiarthroplasty. Patients showed a change in MSTS score improved from 4.5 to 21, ECOG improved from 3.5 to 2, and KPS changed from 40 to 60 at the postoperative evaluation time. At 1 year, the surviving patients had continued improvements with MSTS average of 27, ECOG of 1, and KPS improved to 80. Patients who undergo treatment surgically benefit immediately postoperatively, and when patient survival extends, the benefits from intervention persist and even continue to improve [54]. Ultimately, the restoration of as much patient function as possible is an essential goal of the treatment of pathologic hip fractures.

Conclusion

Geriatric pathologic hip fractures represent a unique intersection of patient populations where the patient is metabolically at risk with low physiologic reserve. Treatment is focused on restoration of function and pain control, but it is important to fully evaluate the patient whether the pathologic fracture is in the setting of known neoplasm or a first symptom. Ultimately, with modern diagnosis, adjuvant and neoadjuvant therapy, geriatric patients with pathologic hip fractures have reasonable outcomes with internal fixation, arthroplasty, and endoprosthetic replacement. An understanding of the basic principles needed to arrive at a diagnosis prior to intervention is crucial to safely caring for patients with pathologic hip fractures.

Take-Home Points

- Metastatic carcinoma is the most common cause of pathologic hip fracture, but confirming the diagnosis is crucial because incorrectly assuming metastatic disease prior to surgical intervention can have devastating consequences.
- Treatment of pathologic hip fractures ranges from nonoperative and palliative care to endoprosthetic replacement. This largely depends on location of fracture and extent of destruction from the lesion.
- Adjuvant and neoadjuvant therapy are important in overall treatment of the patient, so multidisciplinary approach is a necessity.
- Delay of surgical intervention for diagnosis and medical optimization does not impact outcomes in pathologic fractures, and taking the time to arrive at the correct diagnosis is paramount.

References

1. Hage WD, Aboulafia AJ, Aboulafia DM. Incidence, location, and diagnostic evaluation of metastatic bone disease. Orthop Clin North Am. 2000;31(4):515–28.
2. Paget S. The distribution of secondary growths in cancer of the breast. 1889. Cancer Metastasis Rev. 1989;8(2):98–101.
3. Reich CD. Advances in the treatment of bone metastases. Clin J Oncol Nurs. 2003;7(6):641–6.
4. Stevens AR, Ewing J. Adenocarcinoma of the testis in the adult. Ann Surg. 1928;88(6):1074–8.
5. Weber KL, Randall RL, Grossman S, Parvizi J. Management of lower-extremity bone metastasis. J Bone Joint Surg. 2006;88(suppl_4):11–9.
6. Jacofsky DJ, Haidukewych GJ, Zhang H, Sim FH. Complications and results of arthroplasty for salvage of failed treatment of malignant pathologic fractures of the hip. Clin Orthop. 2004;427:52–6.
7. Schulman KL, Kohles J. Economic burden of metastatic bone disease in the U.S. Cancer. 2007;109(11):2334–42.
8. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2018: cancer statistics, 2018. CA Cancer J Clin. 2018;68(1):7–30.

9. Henley SJ, Ward EM, Scott S, Ma J, Anderson RN, Firth AU, et al. Annual report to the nation on the status of cancer, part I: national cancer statistics. Cancer. 2020;126(10):2225–49.
10. Hernandez RK, Wade SW, Reich A, Pirolli M, Liede A, Lyman GH. Incidence of bone metastases in patients with solid tumors: analysis of oncology electronic medical records in the United States. BMC Cancer. 2018;18(1):44.
11. Kumar N, Gupta B. Global incidence of primary malignant bone tumors. Curr Orthop Pract. 2016;27(5):530–4.
12. Yasuda H. RANKL, a necessary chance for clinical application to osteoporosis and cancer-related bone diseases. World J Orthop. 2013;4(4):207–17.
13. Renema N, Navet B, Heymann M-F, Lezot F, Heymann D. RANK-RANKL signalling in cancer. Biosci Rep 2016;36(4).
14. O'Carrigan B, Wong MH, Willson ML, Stockler MR, Pavlakis N, Goodwin A. Bisphosphonates and other bone agents for breast cancer. Cochrane Breast Cancer Group, editor. Cochrane Database Syst Rev [Internet]. 2017 Oct 30 [cited 2021 Mar 16]; Available from: http://doi.wiley.com/10.1002/14651858.CD003474.pub4.
15. Stopeck AT, Lipton A, Body J-J, Steger GG, Tonkin K, de Boer RH, et al. Denosumab compared with zoledronic acid for the treatment of bone metastases in patients with advanced breast cancer: a randomized, double-blind study. J Clin Oncol. 2010;28(35):5132–9.
16. Henry DH, Costa L, Goldwasser F, Hirsh V, Hungria V, Prausova J, et al. Randomized, double-blind study of denosumab versus zoledronic acid in the treatment of bone metastases in patients with advanced cancer (excluding breast and prostate cancer) or multiple myeloma. J Clin Oncol. 2011;29(9):1125–32.
17. Simon MA, Bartucci EJ. The search for the primary tumor in patients with skeletal metastases of unknown origin. Cancer. 1986;58(5):1088–95.
18. Clayer M, Duncan W. Importance of biopsy of new bone lesions in patients with previous carcinoma. Clin Orthop. 2006;451:208–11.
19. Yancik R. Population aging and cancer: a cross-national concern. Cancer J. 2005;11(6):437–41.
20. Kim SH, Shin K-H, Moon S-H, Jang J, Kim HS, Suh J-S, et al. Reassessment of alkaline phosphatase as serum tumor marker with high specificity in osteosarcoma. Cancer Med. 2017;6(6):1311–22.
21. Jin Y, Yuan M, Chen J, Zhang Y. Serum alkaline phosphatase predicts survival outcomes in patients with skeletal metastatic nasopharyngeal carcinoma. Clinics. 2015;70(4):264–72.
22. Lim SM, Kim YN, Park KH, Kang B, Chon HJ, Kim C, et al. Bone alkaline phosphatase as a surrogate marker of bone metastasis in gastric cancer patients. BMC Cancer. 2016;16(1):385.
23. Lawrenz JM, Gordon J, George J, Haben C, Rubin BP, Ilaslan H, et al. Does PET/CT aid in detecting primary carcinoma in patients with skeletal metastases of unknown primary? Clin Orthop. 2020;478(11):2451–7.
24. Traina F, Errani C, Toscano A, Pungetti C, Fabbri D, Mazzotti A, et al. Current concepts in the biopsy of musculoskeletal tumors: AAOS exhibit selection. J Bone Joint Surg Am. 2015;97(2):e7.
25. Clark CR, Morgan C, Sonstegard DA, Matthews LS. The effect of biopsy-hole shape and size on bone strength. J Bone Joint Surg Am. 1977;59(2):213–7.
26. Lane JM, Sculco TP, Zolan S. Treatment of pathological fractures of the hip by endoprosthetic replacement. J Bone Joint Surg Am. 1980;62(6):954–9.
27. Bauer HCF, Wedin R. Survival after surgery for spinal and extremity metastases: prognostication in 241 patients. Acta Orthop Scand. 1995;66(2):143–6.
28. Tokuhashi Y, Matsuzaki H, Oda H, Oshima M, Ryu J. A revised scoring system for preoperative evaluation of metastatic spine tumor prognosis. Spine. 2005;30(19):2186–91.
29. Hansen BH, Keller J, Laitinen M, Berg P, Skjeldal S, Trovik C, et al. The Scandinavian sarcoma group skeletal metastasis register survival after surgery for bone metastases in the pelvis and extremities. Acta Orthop Scand. 2004;75(sup311):11–5.
30. Forsberg JA, Sjoberg D, Chen Q-R, Vickers A, Healey JH. Treating metastatic disease: which survival model is best suited for the clinic? Clin Orthop. 2013;471(3):843–50.

31. Scurrah A, Shiner CT, Stevens JA, Faux SG. Regional nerve blockade for early analgesic management of elderly patients with hip fracture - a narrative review. Anaesthesia. 2018;73(6):769–83.
32. Mavrogenis AF, Angelini A, Vottis C, Pala E, Calabrò T, Papagelopoulos PJ, et al. Modern palliative treatments for metastatic bone disease: awareness of advantages, disadvantages, and guidance. Clin J Pain. 2016;32(4):337–50.
33. Biermann JS, Holt GE, Lewis VO, Schwartz HS, Yaszemski MJ. Metastatic bone disease: diagnosis, evaluation, and treatment. J Bone Joint Surg Am. 2009;91(6):1518–30.
34. Choy W-S, Kim KJ, Lee SK, Yang DS, Jeung SW, Choi HG, et al. Surgical treatment of pathological fractures occurring at the proximal femur. Yonsei Med J. 2015;56(2):460–5.
35. Reif TJ, Strotman PK, Kliethermes SA, Miller BJ, Nystrom LM. No consensus on implant choice for oligometastatic disease of the femoral head and neck. J Bone Oncol. 2018;12:14–8.
36. Alvi HM, Damron TA. Prophylactic stabilization for bone metastases, myeloma, or lymphoma: do we need to protect the entire bone? Clin Orthop. 2013;471(3):706–14.
37. Janssen SJ, Kortlever JTP, Ready JE, Raskin KA, Ferrone ML, Hornicek FJ, et al. Complications after surgical management of proximal femoral metastasis: a retrospective study of 417 patients. J Am Acad Orthop Surg. 2016;24(7):483–94.
38. Wedin R, Bauer HC, Rutqvist LE. Surgical treatment for skeletal breast cancer metastases: a population-based study of 641 patients. Cancer. 2001;92(2):257–62.
39. Takashi M, Takagi Y, Sakata T, Shimoji T, Miyake K. Surgical treatment of renal cell carcinoma metastases: prognostic significance. Int Urol Nephrol. 1995;27(1):1–8.
40. Fuchs B, Trousdale RT, Rock MG. Solitary bony metastasis from renal cell carcinoma: significance of surgical treatment. Clin Orthop. 2005;431:187–92.
41. van der Poel HG, Roukema JA, Horenblas S, van Geel AN, Debruyne FM. Metastasectomy in renal cell carcinoma: a multicenter retrospective analysis. Eur Urol. 1999;35(3):197–203.
42. Lin PP, Mirza AN, Lewis VO, Cannon CP, Tu S-M, Tannir NM, et al. Patient survival after surgery for osseous metastases from renal cell carcinoma. J Bone Joint Surg Am. 2007;89(8):1794–801.
43. Zacherl M, Gruber G, Glehr M, Ofner-Kopeinig P, Radl R, Greitbauer M, et al. Surgery for pathological proximal femoral fractures, excluding femoral head and neck fractures: resection vs. stabilisation. Int Orthop. 2011;35(10):1537–43.
44. Pazionis TJC, Papanastassiou ID, Maybody M, Healey JH. Embolization of hypervascular bone metastases reduces intraoperative blood loss: a case-control study. Clin Orthop. 2014;472(10):3179–87.
45. Townsend PW, Smalley SR, Cozad SC, Rosenthal HG, Hassanein RE. Role of postoperative radiation therapy after stabilization of fractures caused by metastatic disease. Int J Radiat Oncol Biol Phys. 1995;31(1):43–9.
46. Mirels H. Metastatic disease in long bones. A proposed scoring system for diagnosing impending pathologic fractures. Clin Orthop. 1989;249:256–64.
47. Tanaka R, Yonemori K, Hirakawa A, Kinoshita F, Takahashi N, Hashimoto J, et al. Risk factors for developing skeletal-related events in breast cancer patients with bone metastases undergoing treatment with bone-modifying agents. Oncologist. 2016;21(4):508–13.
48. Leng S, Chen Y, Tsai W-Y, Bhutani D, Hillyer GC, Lim E, et al. Use of bisphosphonates in elderly patients with newly diagnosed multiple myeloma. J Natl Compr Cancer Netw. 2019;17(1):22–8.
49. Lipton A, Theriault RL, Hortobagyi GN, Simeone J, Knight RD, Mellars K, et al. Pamidronate prevents skeletal complications and is effective palliative treatment in women with breast carcinoma and osteolytic bone metastases: long term follow-up of two randomized, placebo-controlled trials. Cancer. 2000;88(5):1082–90.
50. Coleman RE. Bisphosphonates: clinical experience. Oncologist. 2004;9(Suppl 4):14–27.
51. Molvik H, Khan W. Bisphosphonates and their influence on fracture healing: a systematic review. Osteoporos Int. 2015;26(4):1251–60.

52. Duckworth AD, McQueen MM, Tuck CE, Tobias JH, Wilkinson JM, Biant LC, et al. Effect of alendronic acid on fracture healing: a multicenter randomized placebo-controlled trial. J Bone Miner Res Off J Am Soc Bone Miner Res. 2019;34(6):1025–32.
53. Malawer MM, Link MP, Donaldson SS. Cancer: principles and practice of oncology. Philadelphia: Lippincott Williams and Wilkins Publishers; 2001.
54. Peterson JR, Decilveo AP, O'Connor IT, Golub I, Wittig JC. What are the functional results and complications with long stem hemiarthroplasty in patients with metastases to the proximal femur? Clin Orthop. 2017;475(3):745–56.
55. Cipriano CA, Arvanitis LD, Virkus WW. Use of the reamer-irrigator-aspirator may reduce tumor dissemination during intramedullary fixation of malignancies. Orthopedics. 2012;35(1):e48–52.
56. Henderson ER, Groundland JS, Pala E, Dennis JA, Wooten R, Cheong D, et al. Failure mode classification for tumor endoprostheses: retrospective review of five institutions and a literature review. J Bone Joint Surg Am. 2011;93(5):418–29.
57. Fu MC, Boddapati V, Gausden EB, Samuel AM, Russell LA, Lane JM. Surgery for a fracture of the hip within 24 hours of admission is independently associated with reduced short-term post-operative complications. Bone Joint J. 2017;99-B(9):1216–22.
58. Moja L, Piatti A, Pecoraro V, Ricci C, Virgili G, Salanti G, et al. Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. A meta-analysis and meta-regression of over 190,000 patients. PLoS One. 2012;7(10):e46175.
59. Shiga T, Wajima Z, Ohe Y. Is operative delay associated with increased mortality of hip fracture patients? Systematic review, meta-analysis, and meta-regression. Can J Anaesth. 2008;55(3):146–54.
60. Simunovic N, Devereaux PJ, Sprague S, Guyatt GH, Schemitsch E, Debeer J, et al. Effect of early surgery after hip fracture on mortality and complications: systematic review and meta-analysis. CMAJ. 2010;182(15):1609–16.
61. Varady NH, Ameen BT, Chen AF. Is delayed time to surgery associated with increased short-term complications in patients with pathologic hip fractures? Clin Orthop. 2020;478(3):607–15.
62. Kim JH, Seo SW, Chung CH. What factors are associated with early mortality in patients undergoing femur surgery for metastatic lung cancer? Clin Orthop. 2018;476(9):1815–22.
63. Chafey DH, Lewis VO, Satcher RL, Moon BS, Lin PP. Is a cephalomedullary nail durable treatment for patients with metastatic peritrochanteric disease? Clin Orthop. 2018;476(12):2392–401.
64. Steensma M, Boland PJ, Morris CD, Athanasian E, Healey JH. Endoprosthetic treatment is more durable for pathologic proximal femur fractures. Clin Orthop. 2012;470(3):920–6.
65. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. Clin Orthop. 1993;286:241–6.
66. Guzik G. Treatment outcomes and quality of life after the implantation of modular prostheses of the proximal femur in patients with cancer metastases. Ortop Traumatol Rehabil. 2016;18(3):231–8.
67. Pitera T, Guzik G, Biega P. Assessment of post-operative physical performance in patients after resection arthroplasty of the proximal femur. Ortop Traumatol Rehabil. 2017;19(4):333–40.

Chapter 9
Outcome Assessment and Quality Improvement for Geriatric Hip Fractures

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History of Geriatric Hip Fractures Outcome Assessment

Outcome assessment benefits patients, physicians, and hospitals, an idea that was recognized within orthopaedic surgery by Ernest Codman, who in 1921 emphasized the need "to follow up each patient [physicians] treat, long enough to determine whether the treatment given has permanently relieved the condition or symptoms complained of" [1]. Such a need may seem obvious to clinicians in the twenty-first century, but the idea was far from standard practice at the time. Codman saw three impediments to the widespread reporting and use of clinical outcomes. First, physicians were accustomed to determining outcomes based on anecdotal experience and did not desire a reporting system; second, the work of collecting and reporting outcomes was "time-consuming and difficult"; and third, hospitals did not have the financial resources or desire to pay for such work [1].

Fortunately, Codman's beliefs prevailed, and he proved to be ahead of his time. Outcomes were reported with increasing frequency after his landmark article, although problems with outcome assessment soon became apparent. In the mid-twentieth century, outcomes for geriatric hip fracture patients were particular to the hospital or research group reporting on them. The external validity and prognostic use of such outcomes were limited. For example, Dimon et al. in 1967 presented a series of 302 intertrochanteric fractures (average patient age of 70 years). They included the nebulous terms fracture union and "satisfactory" clinical results as two of the main outcomes, yet, do not specify what either term meant or how they were measured [2].

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By the 1970s, evidence-based medicine (EBM) changed the practice of medicine, with its emphasis on standardized outcomes and high-quality data as critical to clinical decision-making [3]. To ensure quality of evidence, guidelines for outcome reporting have become essential for research and outcome assessment and aid investigators in avoiding the pitfalls of clinical research of the previous decades. The Consolidated Standards of Reporting Trials (CONSORT), the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), and the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) are three important examples of guidelines whose goals are to improve the quality of prospective randomized trials, observational studies, and systematic reviews, respectively [4–6]. Despite these important strides, outcome research is continuously improving. It remains an imperfect science fraught with controversy.

Importantly, modern outcome research has changed specific treatments as well as treatment paradigms. The surgeon's goals may be fracture healing and pain-free mobility of the patient. The patient and family implicitly share these goals, but they may also value aspects of life unique to them. With this in mind, patient-reported outcomes were developed. An illustrative case is the fracture fixation in the operative management of hip fractures (FAITH) trial [7]. In the FAITH study, patients with femoral neck fractures undergoing treatment with either sliding hip screw (SHS) or cancellous screw fixation were compared using both radiographic and clinical outcomes. Patients in the SHS group had a significantly higher rate of radiographic avascular necrosis and a higher rate of reoperation for this problem. However, patient-reported outcomes did not differ between the two groups. Therefore, either treatment option may be adequate for the patient, when taking into account the patient's life as a whole.

Radiographic Outcome Assessment

Radiographic outcome assessment varies for geriatric hip fractures, which can make comparisons between studies difficult. Investigators have used a study Central Adjudication Committee to grade radiographic evidence of healing [8]. They have also used the criteria detailed in Table 9.1. These results were reported at various time points, which further confounds the assessment of radiographic outcomes following geriatric hip fractures. Such variability in radiographic outcome assessment can be mitigated with use of the Radiographic Union Score for Hip (RUSH), which is a ten-item grading system for femoral neck fracture healing developed in 2013 by Bhandari et al. [9] It assigns points to each of the following domains: anterior, posterior, medial, and lateral cortices; trabecular bone; and trabecular fracture line (Box 9.1). A score denoting perfect healing is 30. A score of 10 means there is no healing. In 2016, Frank et al. found that for femoral neck fractures, a RUSH of less than 18 was predictive of reoperation for nonunion [10]. Although RUSH was initially described for femoral neck fractures, Chiavaras et al. used the score to assess radiographic healing of intertrochanteric hip fractures [11].

Table 9.1 Radiographic criteria used to evaluate healing after hip fracture

Criteria
Lack of callus [8]
A new fracture line in a hip fracture that was initially diagnosed on magnetic resonance imaging (MRI) or computed tomography (CT) scan [8]
Persistent fracture line unchanged from injury radiograph [8]
Fracture displacement not consistent with type of fixation used [8]
Callous bridging the fracture site [12, 13]
Cortical continuity of at least three cortices [12]
Cortical continuity of at least two cortices [13]

Ultimately, radiographic grading of femoral neck and intertrochanteric fractures in geriatric patients need to be interpreted in the context of the patient's function and overall well-being. For example, patients with lower RUSH scores concerning for nonunion may still have good clinical outcomes, and patients with higher RUSH scores or with other radiographic evidence of healing may have persistent pain and require reoperation. The older binary standard of union versus nonunion as a sole predictor of outcome should remain a relic of the past.

Box 9.1 Radiographic Union Score for Hip (RUSH) Score, Adapted from Bhandari et al. [9]

- *Cortical Bridging*. For each of four cortices (anterior, posterior, medial, lateral), assign a score of 1 for no cortical bridging, 2 for some cortical bridging, and 3 for complete cortical bridging. Add this score (range 4–12).
- *Fracture Line*. For each of four cortices (anterior, posterior, medial, lateral), assign a score of 1 for visible fracture line, 2 for some evidence of fracture line, and 3 for no evidence of fracture line. Add this score (range 4–12).
- *Trabecular Consolidation*. Assign a score of 1 for no consolidation, 2 for some consolidation, and 3 for complete consolidation (range 1–3).
- *Trabecular Fracture Line*. Assign a score of 1 for fully visible trabecular fracture line, 2 for some evidence of trabecular fracture line, and 3 for no evidence of trabecular fracture line.
- The final score will range from 10 (no healing) and 30 (complete healing).

Clinical Outcome Assessment and Patient-Reported Outcome Measures

Similar to radiographic outcomes, clinical outcome methodology varies. Clinical outcomes can be either definite, objective endpoints, such as mortality, length of hospital stay, and complication rates, or they can be subjective assessments of a patient's general level of health and well-being (Box 9.2). Subjective assessments for geriatric hip fractures are most commonly derived from patient-reported outcomes (PROs), a heterogeneous collection of surveys whose commonality is that they ask a patient or patient's primary caregiver to report his or her own outcome (Box 9.3).

In response to the heterogeneity inherent in PROs, the World Health Organization (WHO) has emphasized the need to categorize subjective outcomes as they relate to three domains: *activity and participation*, *body function and structure*, and *external life factors* [14]. Hoang-Kim et al. used this WHO framework to grade the practicality and applicability of commonly used patient-reported outcomes. They concluded that the Harris hip score is practical for use in prospective trials for geriatric hip fractures with respect to examiner and respondent time burden [15]. Yet practicality itself is a subjective concept. Feinstein argues for an "enlightened common sense" when evaluating outcome scores [16]. The investigator and/or reader of a clinical trial has to have experience with a certain problem (in this case, the geriatric hip fracture patient) before applying outcome scores to practice. Furthermore, most outcome scales available are not specific to geriatric hip fracture patients and instead were developed for other injuries or procedures, such as acetabular fractures or total hip arthroplasty.

Certain clinical outcomes do combine objective clinical data with subjective data supplied by the patient. For example, the FRAIL Scale grades the Fatigue, Resistance, Aerobic capacity, Illnesses, and Loss of weight into a score that correlates with hospital length of stay and postoperative complication rate in geriatric fracture patients (hip fractures comprised 65.5% of fractures studied by FRAIL investigators) [14]. In sum, clinical outcomes for geriatric hip fractures cannot be completely understood with the use of one single instrument. A combination of objective and subjective clinical outcomes in the form of PROs is needed.

Box 9.2 Examples of Clinical Outcomes Used to Assess Geriatric Hip Fractures (Excluding Patient-Reported Outcomes)

- In-hospital mortality
- 30-day mortality
- 90-day mortality
- 1-year mortality
- Hospital length of stay
- Discharge disposition (home versus rehabilitation center)
- Readmission rate
- Reoperation rate
- Postoperative complications
  - Pneumonia
  - Deep vein thrombosis/pulmonary embolism
  - Cerebrovascular accident
  - Acute kidney injury

  - Postoperative delirium
  - Acute myocardial infarction

- Return to pre-injury ambulatory status
- Postoperative transfusion
- Timed up and go (TUG) test [17]
- Development of pressure ulcers [14]
- Use of physical restraint postoperatively [14]
- Anti-psychotic drug use [14]
- Knee flexor and extensor strength [18]

Box 9.3 Examples of Patient-Reported Outcomes Used to Assess Geriatric Hip Fracture Outcomes

- New Mobility Scale [19]
- EuroQol group-5 [19, 14]
- Barthel Index [19, 14]
- Traffic Light System Basic Activities of Daily Living (TLS-BasicADL) [20]
- Berg Balance Scale (BBS) [20]
- Harris Hip Score [21]
- Short Form 36 (SF-36) [14]
- Rapid Disability Rating Scale version 2 (RDRS-2) [16]
- Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [16]

Patient-Reported Outcomes Measurement Information System (PROMIS)

Though impossible to achieve in practice, the goal of any patient-reported outcome measure is to be perfectly valid and reliable. Valid means that a test measures what it intends to measure. Reliable means that the results of a given test are based on error-free measurement [22]. In 2002, the Patient-Reported Outcomes Measurement Information System (PROMIS) was developed by the National Institutes of Health (NIH) to improve patient-reported outcome measures by making them more valid and reliable. In developing PROMIS, the goal of the NIH was to create a standardized item bank that would measure patient-reported outcomes across many medical conditions and disease states, including disease and pathology of the musculoskeletal system. The NIH hypothesized that PROMIS, based in the logic of item response theory and computer adaptive testing, would allow easier administration and interpretation of clinical research and clinical outcomes compared to other patient-reported outcomes [23, 24].

Like any outcome measurement tool whose goal is to understand outcomes for an often heterogeneous patient population, PROMIS is imperfect. Critics cite its ceiling effects and its lack of validation for specific injuries and patients [25]. PROMIS has yet to be validated for the study of outcomes in geriatric patients who sustain low-energy hip fractures, which is an avenue for future clinical research. PROMIS has been used in the geriatric patient population for understanding outcomes following injury. For example, geriatric patients who sustain a low-energy injury such as a hip fracture have worse PROMIS physical function scores compared to geriatric patients who sustain high-energy injuries; these paradoxical results may indicate that a low-energy injury is a proxy for overall frailty and poor baseline health [26]. Another important application of PROMIS to geriatric patients is its reliability when administered to healthcare proxies. Alvarez-Nebreda et al. found that healthcare proxies are good informants of physical function after injury. However, they may underestimate a patient's level of pain [17]. Such an application of PROMIS is valuable as geriatric hip fracture patients often rely on family or non-family caregivers whose input can significantly influence care and outcomes after injury.

With regard to choosing an outcome measurement tool for the assessment of outcomes, we anticipate that the continued advance of itemized response theory and computer adaptive testing will drive the evolution of patient-reported outcomes. Thus, PROMIS can benefit any clinical researcher whose study design involves outcomes for patients who sustain geriatric hip fractures. Future research will include the validation of PROMIS for this patient population. It should be noted that validation of a patient-reported outcome does not have an ideal methodology and relies upon expert opinion of the patient-reported outcome survey design and comparison to a "gold standard" (often another patient-reported outcome) [27].

Understanding Levels of Evidence in Geriatric Hip Fracture Outcome Assessment

How we understand levels of evidence has evolved over time. A 1905 report concluded based on the authors' experience that union of an intracapsular hip fracture is not expected [28]. In 1957, Clawson assessed outcomes of a series of hip fracture patients using surgeon judgment of patient mobility and function as the primary endpoint [28]. In 2019, the HEALTH trial used (in part) validated patient-reported outcomes to assess the effects of treatment [29]. These three studies are exemplary of what has constituted the best or ideal evidence at different points in history. The early days of "healed or not" gave way to surgeon assessment of a patient outcome, which in turn was overtaken by patient-reported outcomes. Moreover, expert opinion sufficed in the early twentieth century. Today, the prospective comparative study is the cornerstone of clinical evidence. We grade evidence accordingly.

Knowing the level of evidence for a given study as established by the Oxford Center for Evidence-Based Medicine (OCEBM) is crucial to interpreting and applying reported outcomes [30, 31]. Evidence levels from the OCEBM and the Journal of Bone and Joint Surgery (JBJS), the most commonly used grading system for levels of evidence in orthopaedic surgery research, do vary somewhat [7]. For example, for a trial that investigates treatment benefits, the OCEBM grades only systematic reviews of randomized trials or n-of-1 trials as level I, whereas the JBJS system grades individual randomized trials as level I. Within research on geriatric hip fractures, the levels of evidence available range from level I to level V.

Systematic reviews are common, although the heterogeneity that comes with combining data makes interpretation of many systematic reviews difficult [32–34]. Randomized controlled trials have assessed a variety of outcomes including effects of different surgical treatment options, interdisciplinary home rehabilitation protocols, fall prevention, delirium reduction, home physical therapy, multi-specialty care protocols, and anesthesia techniques [35–42]. Randomized controlled trials of geriatric hip fracture patients are often level II, as patient and assessor blinding is not feasible. They are frequently under-powered as well, which leaves challenges and opportunities for future research [43].

In addition to systematic reviews and randomized controlled trials, database studies have contributed to our understanding of geriatric hip fractures. Such evidence is often level III (retrospective cohort study). The main benefit of database research is the large sample size and the geographic distribution of patients within a given sample, as databases typically draw patients from across a wide geographic area. Databases also often contain data over a timespan that allows for longitudinal analysis of outcomes. Examples of databases that have been used to answer questions about geriatric hip fracture care include the National Surgical Quality Improvement Program (NSQIP), the Trauma Quality Improvement Program (TQIP), the National Trauma Data Bank, and country-specific administrative databases such as the Manitoba Administrative Database and the Danish Fracture Database [44–47]. Database studies have their own set of limitations. Studies may lack external validity, since patients are grouped into cohorts, yet within a certain cohort, important differences may exist. For example, coronary artery disease (CAD) may increase mortality risk for a patient after sustaining a hip fracture. However, certain patients have more severe CAD than others, while some patients without a diagnosis of CAD but with clinically significant disease may be admitted to the hospital and undergo surgery without a physician ever having made the diagnosis or without a data entry clerk entering this diagnosis into the database.

Perhaps the greatest lesson from applying evidence-based medicine to the study of geriatric hip fractures is that while no study is perfect, we can gain and apply knowledge from them in useful ways. For example, in the early 2000s after certain data showed that earlier time to surgical treatment of geriatric hip fractures was associated with improved outcomes, the National Center for Trauma and Emergency Medicine Research in Tel-Hashomer, Israel, changed reimbursement patterns so that earlier treatment of geriatric hip fractures was reimbursed at a higher rate than later treatment [48–50]. The investigators found that with this new financial model, patients had shorter lengths of stay and a lower rate of in-hospital mortality [19].

Recommendations for Evaluating Outcomes

We have seen that geriatric hip fracture outcomes are based in radiographic and clinical data. We have also seen that many different radiographic and clinical outcomes have been used to quantify end results of treatment. The studies that contain these results can be stratified according to discrete levels of evidence. For the busy orthopaedic surgeon, the work of synthesizing and applying a large amount of data, some of which is conflicting, is not easy. In order to save time without sacrificing necessary depth of knowledge, the surgeon can follow a systematic approach to evaluating outcomes. We present one option below (Box 9.4). However, each individual can develop his or her own system. Once this is in place, successive iterations become easier and quicker.

Box 9.4 Case Study for a Systematic Approach to Outcome Assessment and Application Through an Analysis of the Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture (HEALTH) Trial [29]

Case: A 71-year-old independent woman with hypertension presents after a ground-level fall with a right displaced femoral neck fracture. Is she best treated with a total hip arthroplasty or hip hemiarthroplasty? The HEALTH trial was designed to answer this question [29]. The following systematic approach to evidence appraisal assists the treating surgeon in determining its applicability.

- *What is the level of evidence?* Level I (high-quality randomized trial).
- *Is the clinical question the same as the trial question?* Yes.
- *When was the study published?* 2019. Often, newer data is preferable as it reflects current treatment trends and incorporates prior evolution in treatment.
- *Are there any potential financial conflicts of interest?* No.
- *Is the study population the same as the patient under consideration?* Yes. Patients in the HEALTH trial were older than 50 years of age with a low-energy displaced femoral neck fracture who had been able to ambulate without assistance before the fracture occurred.
- *What are the primary and secondary outcomes (endpoints) of the trial, at what point were they recorded, and do these endpoints reflect the desired goals of treatment for the patient?* Primary outcome was an unplanned secondary hip procedure within 24 months after the initial surgery. Secondary outcomes were death, hip-related complications (e.g., hip dislo-

cation), serious adverse events, and health-related quality of life, function, and overall health measures (WOMAC, EQ-5D, SF-12, TUG). They were recorded at 2 years after surgery. Yes, these outcomes reflect desired goals of treatment.

- *Are statistical analyses transparent and adequate to answer the study question?* Yes.
- *How do the results apply to the patient?* There was no significant difference in the primary endpoint with regard to each treatment. With regard to secondary endpoints, patients in the total hip arthroplasty cohort were more likely to have a hip instability or dislocation compared to hemiarthroplasty. Patients in the total hip arthroplasty group had a statistically higher WOMAC score that did not meet a pre-specified minimal clinically important difference. These results suggest that a total hip arthroplasty and hemiarthroplasty may be equivalent for the patient in this case study.
- *Are there further intricacies with the results that may lead to another conclusion?* Yes. In the time-to-event analysis, patients with total hip arthroplasty were *more* likely to experience unplanned reoperation between surgery and 1 year after surgery, whereas patients with total hip arthroplasty were *less* likely to experience unplanned reoperation between years 1 and 2 after treatment. Only the difference after year 1 was statistically significant.
- *Are there any limitations of the study as it applies to the patient?* Yes. Outcomes were recorded at 2 years. After 2 years, the patient's clinical course cannot be predicted based on trial results.
- *Does the study provide an answer for best treatment option?* The study suggests that when considering the patient's outcome at 2 years after surgery, either a total or hip hemiarthroplasty arthroplasty provides similar benefit.

Quality Improvement in Geriatric Hip Fracture Care

Quality improvement refers to the process of identifying a problem, changing practice to solve the problem, and assessing the efficacy of the change in practice with evidence. The field of quality improvement has a vast scope that began to expand in earnest after the Institute of Medicine (now the National Academy of Medicine) published *To Err Is Human* in 1999; this seminal publication showed that medical errors result in preventable patient deaths [51]. Also in 1999 the non-profit, non-partisan National Quality Forum (NQF) was established with the mission "to be the trusted voice driving measureable health improvements" and the vision that "every person experiences high value care and optimal health outcomes" [52]. With respect to quality improvement for surgeons, the American College of Surgeons maintains the National Surgical Quality Improvement Program (NSQIP), which "provides participating hospitals with tools, analyses, and reports to make informed decisions about improving quality of care" [53]. In addition to administrative efforts, quality improvement means processes and results are shared through peer-reviewed publication. To organize these publications, experts in the "science of improvement" developed the Standards for Quality Improvement Reporting Excellence (SQUIRE) in 2008, which were revised in 2016 [54].

In caring for patients with geriatric hip fractures, orthopaedic surgeons and care teams have used the principles of quality improvement with encouraging results. Boddaert et al. showed a decrease in mortality at 6 months after injury for hip fracture patients admitted to a dedicated geriatric service compared to patients admitted before the service was established [55]. In terms of quality improvement, perhaps the most notable aspect of the work by Boddaert et al. is in the establishment of specific goals meant to improve care. Such goals were early alert from the emergency department, surgery if feasible within 24 h of admission, patient sitting within 24 h of admission and walking 48 h after admission, pressure ulcer prevention with mattresses designed for the purpose, and blood transfusion for hemoglobin of less than 10 grams per liter. This plan included input from the departments of Emergency Medicine, Anesthesiology, Critical Care, Geriatrics, Rehabilitation, Nutrition, and Orthopaedic Surgery. Although certain aspects of this model may be criticized (e.g., surgery within 24 h may not be necessary when compared to surgery within 48 h of admission), it does use principles of quality improvement to create meaningful change in practice.

Quality improvement in geriatric hip fracture care usually demands a coordinated, time-intensive approach to solving a problem. For example, Chuan et al. organized analgesia with fascia iliaca blocks administered in the emergency department by emergency department physicians as well as protocols for avoiding medication known to induce delirium. Their protocol included workshops on fascia iliaca blocks and protocol compliance audits. The results from their prospective study comparing patients who were treated under their protocol compared to a cohort who did not were a decrease in postoperative delirium as measured by the 3-Minute Confusion Assessment Method (3D-CAM) [53]. The lesson of many quality improvement endeavors is that a focused, goal-oriented program is time-intensive but worthwhile [56, 57]. One is reminded of Ernest Codman, who said that two of the main obstacles to undertaking quality improvement work similar to that performed by Chuan et al. are lack of time and financial resources [1]. The future of quality improvement in geriatric hip fracture care should be directed toward building support for the investment of time and money for the purpose of better care.

The Surgeon's Role in Using Outcome Research and in Quality Improvement

As the leader of the orthopaedic service, the surgeon must have a thorough understanding of clinical outcome research in order to understand and apply it judiciously. The geriatric hip fracture patient population is only superficially homogenous.

Significant heterogeneity exists among patients, which was demonstrated by Blankstein et al. in their assessment of the Fracture Fixation in the Operative Management of Hip Fractures (FAITH) randomized controlled trial and the Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture (HEALTH) randomized controlled trial [29, 41, 42]. Blankstein et al. demonstrated that although both large multicenter trials enrolled patients over the age of 50 years with low-energy femoral neck fractures, patients in the HEALTH trial were older, were less racially diverse, and had more comorbidities than patients in the FAITH trial [42]. This is one example that underscores the need to assess data critically. The treating surgeon must always know the patient at the bedside and the patients in a given study in order to understand the external validity of a reported outcome [58].

Beyond understanding and applying data, the clinician researcher has a unique position of straddling two worlds. He or she knows the challenges of seeing an individual hip fracture patient from emergency department to recovery at home or a rehabilitation center and therefore can provide the best input for study design. The past three decades have shown an improvement in the quality of literature as measured by level of evidence [30]. For this trend to continue, the surgeon has to be a central figure in clinical outcome research.

Finally, the surgeon must understand the principles of quality improvement in order to effect better care. Perhaps this is most important in the operating room, where quality must include patient safety. In 2013, Kuo et al. performed a literature review to identify common causes of preventable harm that occurred in the operating room as well as methods for avoiding preventable harm. Their data source was adverse surgical events reported to the Joint Commission from 1982 to 2012. The group identified six elements of surgical safety that can prevent these adverse events: (1) effective surgical team communication, (2) proper informed consent, (3) implementation and regular use of surgical checklists, (4) proper surgical site/procedure identification, (5) reduction of surgical team distractions, and (6) routine surgical data collection and analysis to improve the safety and quality of surgical patient care [20]. Consistent practice of these six elements of surgical safety starts with the surgeon, who inspires the service through exemplary leadership.

Conclusion

Careful analysis of outcomes for patients who sustain a geriatric hip fracture is critical for developing appropriate treatment plans. Such analysis requires an understanding of study design, the advantages and disadvantages of various outcome measures, the principles of quality improvement, and the necessity of physician leadership. Clinical researchers should adhere by research guidelines in order to report outcomes in the most thorough and organized way possible. Finally, investment of time and financial resources aids in improving care by providing hospitals with the means to execute quality improvement and other outcomes research.

References

1. Codman EA. The classic: a study in hospital efficiency: as demonstrated by the case report of first five years of private hospital. Clin Orthop Relat Res [Internet]. 2013; [cited 2020 Oct 28];471(6):1778–83. Available from: http://journals.lww.com/00003086-201306000-00011
2. Dimon JH, Hughston JC. Unstable intertrochanteric fractures of the hip. J Bone Joint Surg Am [Internet]. 1967; [cited 2020 Oct 28];49(3):440–50. Available from: https://pubmed.ncbi.nlm.nih.gov/6022353/
3. Djulbegovic B, Guyatt GH. Progress in evidence-based medicine: a quarter century on. Lancet. 2017;390:415–23. Lancet Publishing Group
4. Lepage L, Altman DG, Schulz KF, Moher D, Egger M, Davidoff F, et al. The revised CONSORT statement for reporting randomized trials: explanation and elaboration [Internet]. Vol. 134, Annals of Internal Medicine. American College of Physicians; 2001 [cited 2020 Oct 28]. p. 663–94. Available from: https://pubmed.ncbi.nlm.nih.gov/11304107/.
5. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344–9.
6. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ [Internet]. 2009 [cited 2020 Nov 9];339. Available from: https://pubmed.ncbi.nlm.nih.gov/19622552/.
7. JBJS, Inc. Journals Level of Evidence: JBJS [Internet]. [cited 2020 Dec 5]. Available from: https://journals.lww.com/jbjsjournal/Pages/Journals-Level-of-Evidence.aspx.
8. Bhandari M, Jin L, See K, Burge R, Gilchrist N, Witvrouw R, et al. Does teriparatide improve femoral neck fracture healing: results from a randomized placebo-controlled trial. Clin Orthop Relat Res [Internet]. 2016 May 1 [cited 2020 Oct 28];474(5):1234–44. Available from: /pmc/articles/PMC4814417/?report=abstract.
9. Bhandari M, Chiavaras M, Ayeni O, Chakraverrty R, Parasu N, Choudur H, et al. Assessment of radiographic fracture healing in patients with operatively treated femoral neck fractures. J Orthop Trauma [Internet]. 2013 [cited 2020 Oct 28];27(9):e213–9. Available from: https://pubmed.ncbi.nlm.nih.gov/23287749/.
10. Frank T, Osterhoff G, Sprague S, Garibaldi A, Bhandari M, Slobogean GP. The Radiographic Union Score for Hip (RUSH) identifies radiographic nonunion of femoral neck fractures. Clin Orthop Relat Res [Internet]. 2016 Jun 1 [cited 2020 Oct 28];474(6):1396–404. Available from: https://pubmed.ncbi.nlm.nih.gov/26728521/.
11. Bhandari M, Chiavaras MM, Parasu N, Choudur H, Ayeni O, Chakravertty R, et al. Radiographic union score for hip substantially improves agreement between surgeons and radiologists. BMC Musculoskelet Disord [Internet]. 2013 [cited 2020 Oct 28];14. Available from: https://pubmed.ncbi.nlm.nih.gov/23442540/.
12. Colón-Emeric C, Nordsletten L, Olson S, Major N, Boonen S, Haentjens P, et al. Association between timing of zoledronic acid infusion and hip fracture healing. Osteoporos Int [Internet]. 2011 Aug 9 [cited 2020 Oct 28];22(8):2329–36. Available from: https://link.springer.com/article/10.1007/s00198-010-1473-1.
13. Kim SJ, Park HS, Lee DW, Lee JW. Does short-term weekly teriparatide improve healing in unstable intertrochanteric fractures? J Orthop Surg [Internet]. 2018 Sep 1 [cited 2020 Oct 28];26(3):230949901880248. Available from: http://journals.sagepub.com/doi/10.1177/2309499018802485.
14. Berry SD, Rothbaum RR, Kiel DP, Lee Y, Mitchell SL. Association of clinical outcomes with surgical repair of hip fracture vs nonsurgical management in nursing home residents with advanced dementia. In: JAMA Internal Medicine [Internet]. American Medical Association; 2018 [cited 2020 Nov 15]. p. 774–80. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/29801122/.

15. Hoang-Kim A, Schemitsch E, Bhandari M, Kulkarni A V., Beaton D. Outcome assessment in hip fracture: evaluation of the practicality of commonly-used outcomes in hip fracture studies. Arch Orthop Trauma Surg [Internet]. 2011 Dec [cited 2020 Nov 15];131(12):1687–95. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/21805403/.
16. Boonen S, Autier P, Barette M, Vanderschueren D, Lips P, Haentjens P. Functional outcome and quality of life following hip fracture in elderly women: a prospective controlled study. Osteoporos Int [Internet]. 2004 Feb [cited 2020 Nov 15];15(2):87–94. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/14605799/.
17. Alvarez-Nebreda ML, Heng M, Rosner B, McTague M, Javedan H, Harris MB, et al. Reliability of proxy-reported patient-reported outcomes measurement information system physical function and pain interference responses for elderly patients with musculoskeletal injury. J Am Acad Orthop Surg [Internet]. 2019 Feb 15 [cited 2020 Nov 7];27(4):e156–65. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/30256341/.
18. Fischer K, Trombik M, Freystätter G, Egli A, Theiler R, Bischoff-Ferrari HA. Timeline of functional recovery after hip fracture in seniors aged 65 and older: a prospective observational analysis. Osteoporos Int [Internet]. 2019 Jul 1 [cited 2020 Nov 15];30(7):1371–81. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/30941485/.
19. Peleg K, Savitsky B, Yitzhak B, Avi I. Different reimbursement influences surviving of hip fracture in elderly patients. Injury [Internet]. 2011 [cited 2020 Nov 2];42(2):128–32. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/20417511/.
20. Kuo CC, Robb WJ. Critical roles of orthopaedic surgeon leadership in healthcare systems to improve orthopaedic surgical patient safety. In: Clinical orthopaedics and related research [Internet]. Springer New York LLC; 2013 [cited 2020 Nov 9]. p. 1792–800. Available from: https://pubmed.ncbi.nlm.nih.gov/23224770/.
21. Xing F, Li L, Chen W, Xiang Z. The effect of Parkinson's disease on Chinese geriatric patients with intertrochanteric fracture: A propensity score-matched analysis. Orthop Traumatol Surg Res [Internet]. 2020 Jun 1 [cited 2020 Nov 15];106(4):627–32. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/32029408/.
22. Scholtes VA, Terwee CB, Poolman RW. What makes a measurement instrument valid and reliable? Injury [Internet]. 2011 Mar [cited 2020 Nov 7];42(3):236–40. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/21145544/
23. Andres PL, Black-Schaffer RM, Ni P, Haley SM. Computer adaptive testing: A strategy for monitoring stroke rehabilitation across settings. Top Stroke Rehabil [Internet]. 2004 Mar [cited 2020 Nov 7];11(2):33–9. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/15118965/.
24. Hays RD, Morales LS, Reise SP. Item response theory and health outcomes measurement in the 21st century. Med Care [Internet]. 2000 [cited 2020 Nov 7];38(9 suppl. 2). Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/10982088/.
25. Gausden EB, Levack AE, Sin DN, Nwachukwu BU, Fabricant PD, Nellestein AM, et al. Validating the patient reported outcomes measurement information system (PROMIS) computerized adaptive tests for upper extremity fracture care. J Shoulder Elb Surg [Internet]. 2018 Jul 1 [cited 2020 Nov 7];27(7):1191–7. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/29567038/.
26. Shah J, Titus AJ, O'Toole R V., Sciadini MF, Boulton C, Castillo R, et al. Are geriatric patients who sustain high-energy traumatic injury likely to return to functional independence? J Orthop Trauma [Internet]. 2019 May 1 [cited 2020 Nov 7];33(5):234–8. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/30640296/.
27. SooHoo NF, McDonald AP, Seiler JG, McGillivary GR. Evaluation of the construct validity of the DASH questionnaire by correlation to the SF-36. J Hand Surg Am. 2002;27(3):537–41.
28. Intracapsular Fractures at the Hip. Hosp (Lond 1886) [Internet]. 1905 Oct 7 [cited 2020 Dec 5];39(993):5–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29812599.
29. Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture. N Engl J Med [Internet]. 2019 Dec 5 [cited 2020 Nov 7];381(23):2199–208. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/31557429/.

30. Scheschuk JP, Mostello AJ, Lombardi NJ, Maltenfort MG, Freedman KB, Tjoumakaris FP. Levels of evidence in orthopaedic trauma literature. J Orthop Trauma [Internet]. 2016 Jul 1 [cited 2020 Nov 2];30(7):362–6. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/27322200/.
31. OCEBM Levels of Evidence — Centre for Evidence-Based Medicine (CEBM), University of Oxford [Internet]. [cited 2020 Nov 2]. Available from: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence.
32. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in multidisciplinary team-based approach in geriatric hip fracture care: a systematic review. J Am Acad Orthop Surg [Internet]. 2019 May 30 [cited 2020 Nov 2];28(3):128–33. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31157757.
33. Chen DX, Yang L, Ding L, Li SY, Qi YN, Li Q. Perioperative outcomes in geriatric patients undergoing hip fracture surgery with different anesthesia techniques: a systematic review and meta-analysis. Med (United States). 2019;98(49):e18220.
34. Li S, Zhang J, Zheng H, Wang X, Liu Z, Sun T. Prognostic role of serum albumin, total lymphocyte count, and mini nutritional assessment on outcomes after geriatric hip fracture surgery: a meta-analysis and systematic review. Journal of Arthroplasty. 2019;34:1287–96. Churchill Livingstone Inc.
35. Berggren M, Karlsson Å, Lindelöf N, Englund U, Olofsson B, Nordström P, et al. Effects of geriatric interdisciplinary home rehabilitation on complications and readmissions after hip fracture: a randomized controlled trial. Clin Rehabil. 2019;33(1):64–73.
36. Scheffers-Barnhoorn MN, van Eijk M, van Haastregt JCM, Schols JMGA, van Balen R, van Geloven N, et al. Effects of the FIT-HIP intervention for fear of falling after hip fracture: a cluster-randomized controlled trial in geriatric rehabilitation. J Am Med Dir Assoc. 2019;20(7):857–865.e2.
37. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623–33.
38. Magaziner J, Mangione KK, Orwig D, Baumgarten M, Magder L, Terrin M, et al. Effect of a multicomponent home-based physical therapy intervention on ambulation after hip fracture in older adults: the CAP randomized clinical trial. J Am Med Assoc. 2019;322(10):946–56.
39. Karlsson Å, Berggren M, Gustafson Y, Olofsson B, Lindelöf N, Stenvall M. Effects of geriatric interdisciplinary home rehabilitation on walking ability and length of hospital stay after hip fracture: a randomized controlled trial. J Am Med Dir Assoc. 2016;17(5):464.e9–464.e15.
40. Marcantonio ER, Flacker JM, John Wright R, Resnick NM. Reducing delirium after hip fracture: a randomized trial. J Am Geriatr Soc. 2001;49(5):516–22.
41. Nauth A, Creek AT, Zellar A, Lawendy AR, Dowrick A, Gupta A, et al. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet. 2017;389(10078):1519–27.
42. Blankstein M, Schemitsch EH, Bzovsky S, Axelrod D, Poolman RW, Frihagen F, et al. The FAITH and HEALTH trials: are we studying different hip fracture patient populations? J Orthop Trauma 2020;34 S15-S21.
43. Bernstein J, Weintraub S, Morris T, Ahn J. Randomized controlled trials for geriatric hip fracture are rare and underpowered: a systematic review and a call for greater collaboration [Internet]. Vol. 101, J Bone Joint Surg Am Vol. Lippincott Williams and Wilkins; 2019 [cited 2020 Nov 2]. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/31567688/.
44. Cram P, Yan L, Bohm E, Kuzyk P, Lix LM, Morin SN, et al. Trends in operative and nonoperative hip fracture management 1990–2014: a longitudinal analysis of manitoba administrative data. J Am Geriatr Soc [Internet]. 2017 Jan 1 [cited 2020 Apr 14];65(1):27–34. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27861712.
45. Ottesen TD, McLynn RP, Galivanche AR, Bagi PS, Zogg CK, Rubin LE, et al. Increased complications in geriatric patients with a fracture of the hip whose postoperative weight-bearing is

restricted: An analysis of 4918 patients. Bone Joint J [Internet]. 2018 Oct 1 [cited 2020 Nov 2];100B(10):1377–84. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/30295535/.

46. Belmont PJ, Garcia EJ, Romano D, Bader JO, Nelson KJ, Schoenfeld AJ. Risk factors for complications and in-hospital mortality following hip fractures: A study using the National Trauma Data Bank. Arch Orthop Trauma Surg [Internet]. 2014 [cited 2020 Nov 2];134(5):597–604. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/24570142/.
47. Shelton T, Hecht G, Slee C, Wolinsky P. A Comparison of geriatric hip fracture databases. J Am Acad Orthop Surg [Internet]. 2019 Feb 1 [cited 2020 Nov 2];27(3):e135–41. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/30216245/.
48. Swanson CE, Day GA, Yelland CE, Broome JR, Massey L, Richardson HR, et al. The management of elderly patients with femoral fractures. A randomised controlled trial of early intervention versus standard care. Med J Aust [Internet]. 1998 Nov 16 [cited 2020 Apr 13];169(10):515–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/9861907.
49. Gdalevich M, Cohen D, Yosef D, Tauber C. Morbidity and mortality after hip fracture: the impact of operative delay. Arch Orthop Trauma Surg. 2004;124(5):334–40.
50. McGuire KJ, Bernstein J, Polsky D, Silber JH. The 2004 Marshall Urist award: delays until surgery after hip fracture increases mortality. Clin Orthop Relat Res [Internet]. 2004 Nov [cited 2020 Apr 15];(428):294–301. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15534555.
51. Kohn LT, Corrigan JM, Donaldson MS, editors. To Err Is Human [Internet]. Washington, DC: National Academies Press; 2000. [cited 2020 Nov 9]. Available from: http://www.nap.edu/catalog/9728
52. NQF: About Us [Internet]. [cited 2020 Nov 9]. Available from: http://www.qualityforum.org/About_NQF/.
53. ACS National Surgical Quality Improvement Program [Internet]. [cited 2020 Nov 9]. Available from: https://www.facs.org/quality-programs/acs-nsqip.
54. Ogrinc G, Davies L, Goodman D, Batalden P, Davidoff F, Stevens D. SQUIRE 2.0 - Standards for quality improvement reporting excellence - Revised publication guidelines from a detailed consensus process. J Am Coll Surg [Internet]. 2016 Mar 1 [cited 2020 Nov 8];222(3):317–23. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/26385723/.
55. Boddaert J, Cohen-Bittan J, Khiami F, Le Manach Y, Raux M, Beinis JY, et al. Postoperative admission to a dedicated geriatric unit decreases mortality in elderly patients with hip fracture. PLoS One [Internet]. 2014 Jan 15 [cited 2020 Nov 8];9(1). Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/24454708/.
56. Borade A, Kempegowda H, Tawari A, Suk M, Horwitz DS. Improvement in osteoporosis detection in a fracture liaison service with integration of a geriatric hip fracture care program. Injury [Internet]. 2016 Dec 1 [cited 2020 Nov 8];47(12):2755–9. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/27773370/.
57. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: A prospective, randomised, controlled trial. Lancet [Internet]. 2015 [cited 2020 Nov 8];385(9978):1623–33. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/25662415/.
58. Rothwell PM. Factors that can affect the external validity of randomised controlled trials. PLoS Clin Trials [Internet]. 2006 May 19 [cited 2020 Nov 7];1(1):e9. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/16871331/.

Chapter 10
Rehabilitation After Geriatric Hip Fractures

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History of Rehabilitation After Geriatric Hip Fracture

Orthopaedic surgeons have long recognized that the geriatric patient who sustains a hip fracture may experience a decrease in function or even complete loss of function after injury [1, 2]. In 1935, the American orthopaedic surgeon Kellogg Speed labeled it the “unsolved fracture” as poor healing and high mortality rates were common after both operative and non-operative treatment [3]. Meaningful recovery was often impeded by poor patient mobility to the extent that, by the 1950s, early ambulation was considered vital for patient survival [1]. Early ambulation as the cornerstone of recovery is now a well-established concept, with literature throughout the twentieth and into the twenty-first century supporting it [1, 4–12].

Our Approach to Rehabilitation After Geriatric Hip Fracture

The geriatric hip fracture patient is at the center of a numerous entities that influence her recovery (Fig. 10.1). In the current chapter, we address these entities, with the exception of medical care, which is addressed in Chaps. 3 and 11.

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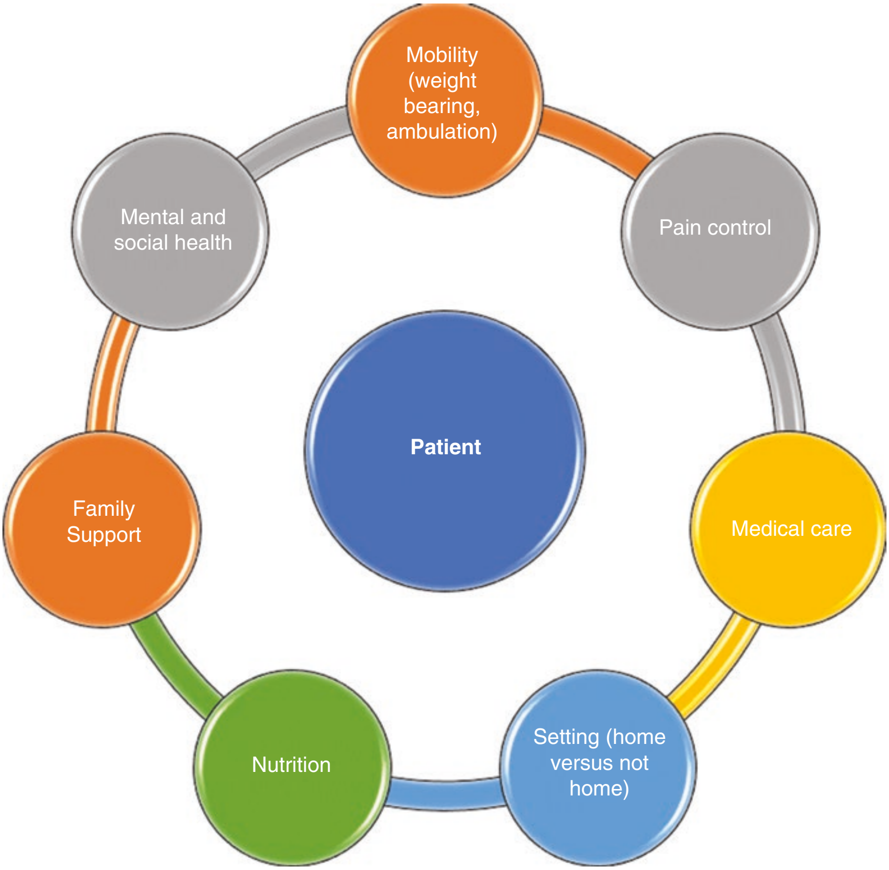

Fig. 10.1 A model of factors that determine patient recovery after geriatric hip fracture

Weight Bearing

For patients who undergo non-operative treatment of displaced intracapsular or extracapsular hip fractures, we recommend weight bearing as tolerated on the injured extremity, accepting the reality of a malunion or nonunion. We support weight bearing as tolerated because it does not restrict the mobility of a patient for whom immobilization would be detrimental, both in terms of physical function and in terms of medical complications such as venous thromboembolism and pneumonia. Patients with non-displaced fractures are made partial weight bearing on the injured extremity to decrease the risk of subsequent displacement. Patients should not remain bedbound. If pain prevents weight bearing, then patients should have assistance for transfer from bed to chair and should engage in passive and active range of motion exercises with physical therapy.

For patients undergoing operative treatment, the goal is early mobilization. Patients undergoing closed reduction and internal fixation of intracapsular hip fractures are made “toe touch” or “partial” weight bearing for 6 weeks in order to protect the fixation and allow time for fracture healing. We recommend communication between surgeon and therapist so that definitions of weight-bearing protocols are clear. For example, “toe touch” may be interpreted as more weight placed on the toes than is desirable. Patients treated with arthroplasty are made weight bearing as tolerated barring extenuating circumstances, such as intraoperative periprosthetic fracture. Range of motion restrictions to prevent dislocation is instituted at the surgeon’s discretion.

For patients undergoing closed or open reduction and internal fixation of extracapsular hip fractures, weight-bearing status depends on fracture pattern and fixation method. For stable fracture patterns stabilized with an intramedullary nail, weight bearing as tolerated is recommended. For unstable fracture patterns (e.g., reverse obliquity intertrochanteric fracture, or comminuted subtrochanteric fracture) whose fixation may fail under the strain of weight bearing, partial weight bearing or non-weight bearing may be proposed for some time.

Inpatient Physical Therapy

Before discharge, patients are immediately mobilized under the direction of a physical therapist. If surgery occurs early in the day, physical therapy may start on the day of surgery. Otherwise, therapy must start the day after surgery, assuming the patient’s medical status permits. The physical therapist will assist the patient in a variety of exercises including passive and active range of motion of both upper and lower extremities, transfer from bed to chair, and, of course, ambulation, both over flat surfaces and up and down stairs. The occupational therapist assists the patient in re-learning activities of daily living in the face of the new injury. These activities include brushing teeth, combing hair, using the toilet, bathing, and other activities if hospital resources permit, such as getting into and out of cars. Physical therapists and occupational therapists are invaluable in the patient’s path toward recovery.

In the inpatient setting, physical therapy helps prevent deconditioning, defined as functional loss following a period of decreased or no activity [13]. Deconditioning is caused by a loss in muscle mass (sarcopenia) that takes place during a period of inactivity. Younger patients with increased physiologic reserve can tolerate periods of inactivity with lower risk of sarcopenia compared to older patients in whom sarcopenia and deconditioning can develop rapidly [7]. Deconditioning is also associated with loss of balance. While poor balance may be a cause of the fall and resultant fracture, it is also a reason for loss of function after injury. Patients may lose confidence in their ability to maintain their balance, increasing their risk of falling again [14, 15]. Balance training has been associated with improvement in overall physical function [14].

Overall, deconditioning is a great frustration to the patient and physician alike, in part because of the seemingly unstoppable nature of its progression. Until we have a better understanding of the underlying mechanisms that contribute to deconditioning other than "old age," we will have at best semi-effective means of combating it.

Pain Control

The best summary for pain control in the geriatric hip fracture patient is the following: minimize the dose amount and lengthen the frequency between doses as much as possible for all narcotic medications including the three most commonly used classes – narcotics, benzodiazepines, and NMDA receptor antagonists (ketamine). Efforts to decrease the use of narcotics and therefore the incidence of delirium and other side effects such as constipation in hip fracture patients after surgery include use of neuraxial analgesia, local anesthesia, and intravenous acetaminophen [16–18].

We prefer a multi-modal approach to pain control including neuraxial anesthesia administered preoperatively by the anesthesiology service. Postoperatively we administer standing acetaminophen (650 mg every 6 h); low-dose oral oxycodone as needed (starting with 2.5 mg every 6 h for moderate pain and 5 mg every 6 h for severe pain); 0.2 mg of intravenous hydromorphone every 3 h for breakthrough pain; and ice and transdermal lidocaine (lidocaine patch) to the injured extremity. We add ibuprofen 600 mg standing every 6 h or its equivalent if there are no contraindications such as renal disease, concomitant administration of aspirin for venous thromboembolism prophylaxis, or history of gastrointestinal bleeding. For patients at higher risk of delirium, we encourage use of a bed located near a window and frequent time and date orientation from nursing and/or the patient's family members.

Patient Disposition: Rehabilitation Center Versus Home Discharge

Patients may be discharged from the hospital to a rehabilitation center or to home after surgery. A rehabilitation center is a site that provides complete care for a patient, including 24-hour nursing, physical therapy, occupational therapy, medication administration, meals, and bathing. The best candidate for discharge to a rehabilitation center is the patient who cannot care for him or herself at home. The presence of both occupational and physical therapy and the total duration of therapy may vary by institution [5, 19–21]. In the short term (6–12 months), the exact amount of therapy offered at a rehabilitation center may have little bearing on outcome, as long as some method for mobilizing patients exists [22, 23].

Some clinicians and investigators have differentiated between skilled nursing facilities (SNFs) and inpatient rehabilitation facilities (IRFs), with sicker patients being discharged to SNFs as opposed to IRFs. The important differentiator is not the name of the setting, but rather the activities offered at the setting [24–26]. As stressed throughout this chapter, the more activity a patient can perform, the better the outcome, regardless of the name or label applied to a given rehabilitation center.

Patients who can perform activities of daily living at home and/or have assistance for home living in the form of family or professional aides may be discharged home after surgery for hip fracture. If a patient can travel to physical therapy, he or she may attend therapy at an outpatient center. If a patient cannot or will not travel for therapy, home-based physical therapy is an option. Such home-based therapy can be with a visiting physical therapist or it can be self-directed, with patients performing exercises on their own. Both options have been shown to help patients regain ambulatory ability after injury [24, 27, 28].

Evidence suggests that home-based care is superior to care in a rehabilitation center for geriatric patients recovering from hip fracture [29, 30]. Some investigators disagree, arguing that no significant difference in recovery (defined as regaining functional independence) exists between patients discharged to a rehabilitation center and those discharged home [31]. While most clinicians and families favor discharge home, daily therapy at a rehabilitation center may be advantageous for a patient who otherwise would have less frequent therapy with home services. We use the simple criterion of ability to care for self at home as the main factor in determining discharge to home versus rehabilitation center.

Lastly, patient disposition may be determined in part by economics of care. For example, in the 1980s, following the federal government's implementation of the fixed-price prospective payment system (PPS), length of stay decreased and patients were discharged more frequently to nursing homes, which were more cost-effective than inpatient care. At the time, many orthopedists voiced concern that this change in management caused a decrease in quality of care [32]. Fitzgerald et al. found that, following the implementation of the PPS, patients were twice as likely to remain in a nursing home at 6 months after surgery [33]. Given the constantly changing reimbursement patterns for both Medicare and non-Medicare patients, orthopaedic surgeons must consider the various forces at play, including financial ones, when helping a patient and patient's family decide on discharge to home or a rehabilitation center.

Interdisciplinary Care: Who and to What Extent

The degree of involvement in acute perioperative care from the orthopaedic surgeon and internist is frequently a subject of controversy. For example, the primary service to which a patient is admitted may be the orthopaedic service or the internal medicine service, depending on institutional practice and patient medical status. Evidence supports the presence of an internist with training in geriatric medicine [34–36]. We recommend admission to a service that has the capacity to care for the patient's medical needs through daily rounding and execution of treatment plan. Whether that service is orthopaedic surgery with internal medicine as consultation or an internal medicine service with orthopaedic surgery in consultation is determined at the institutional, and frequently the individual physician, level.

Nutrition: Often Overlooked

Following surgery, patients are at risk for protein catabolism and malnutrition due to increased energy expenditure and inflammation and decreased protein intake. In turn, malnutrition compromises bone strength and structure, resulting in more challenging rehabilitation and putting patients at further risk for hip fracture [37–39]. Malnourishment is common among elderly patients presenting with hip fractures. It is a strong predictor of poor outcome, having been associated with gait impairment, increased mortality, worse mobility, worse physical function, poor cognition, and increased rates of rehospitalization [40–42].

Evidence shows that improved nutritional status is associated with better performance of activities of daily living among hip fracture patients and that weight loss is a predictor of decreased functional recovery [43–45]. Data also suggest that protein supplementation following hip fracture treatment reduces the chance of complication and decreases the hospital length of stay [39]. Increased protein intake may also be beneficial in the prevention of sarcopenia [46, 47].

Patients often have less than ideal access to proper nourishment during rehabilitation. They may even have difficulty feeding themselves, making staff or family assistance vital. Barriers to proper nutrition include lack of awareness of its importance, delayed or inadequate diagnosis, poor monitoring, and insufficient supplementation [48]. Thus, in order to address the increased morbidity and mortality associated with malnutrition, nutritional assessment and management should be included in care planning in both hospital and post-hospital rehabilitation [49]. Most hospitals have a nutrition service dedicated to assessing dietary needs.

Psychosocial Aspects of Rehabilitation: Mental Health and Family Support

Psychosocial factors such as fear of falling, self-efficacy (belief in one's capabilities), and coping strategies are crucial in the rehabilitation of the hip fracture patient [50]. Patients describe both physical and psychological restrictions after injury. These psychological restrictions include feeling tired and being concerned about falling again. Patients report that fear of falling and unsuccessful attempts at daily activities discourage them from functioning and bring about frustration and disappointment [51]. The efficacy of psychosocial intervention at improving outcomes after hip fracture is unclear, as quality of evidence is low [50].

Social support through family and/or friends is also critical to success. It has been shown to positively influence physical function recovery, mortality, pain, length of stay, and quality of life [52]. Auais et al. found that greater social support (interaction with others, outings, marital status, network size) increases patients' sense of self-efficacy, which is important because low self-efficacy can limit functioning and hinder rehabilitation [52].

Conclusions

Rehabilitation for the geriatric patient after hip fracture must take into account the myriad factors that contribute to successful – or unsuccessful – recovery. These factors include weight-bearing status, physical and occupational therapy, pain control, intelligent discharge planning, adequate nutrition, and good social and family support throughout recovery. A summary of our recommendations is presented in Box 10.1. A summary of evidence pertaining to various aspects of rehabilitation is presented in Table 10.1.

Box 10.1 Author's Recommendations for Effective Rehabilitation After Geriatric Hip Fracture

- Mobilize the patient as soon as possible after surgery (or after injury if treatment is non-operative).
- Use a multi-modal approach to pain control while minimizing or eliminating narcotic use.
- Ensure patient has good nutrition, which may require consultation with a nutritionist and family education to assist patient in eating and drinking.
- Be cognizant or psychosocial factors that may influence the patient's recovery (depression, lack of family or other social support, fear or further injury, fear of death).
- Ensure the patient has appropriate medical care with an internist (if possible an internist with training in geriatric medicine).

Table 10.1 Key studies in rehabilitation after geriatric hip fracture

Study	Year	Comment
Beckmann et al. [8]	2020	Exercise intervention started in the early phase of rehabilitation improved physical function, with no clear superior exercise type or setting
Auais et al. [52]	2020	Greater social support increases patients' sense of self-efficacy, which is important to maintain as low self-efficacy can limit functioning and hinder rehabilitation
Pol et al. [51]	2019	Patients appreciated support and coaching, as well as contact with other rehabilitants during their inpatient stay and maintaining those contacts during recovery
Nordstrom et al. [29]	2018	Rehabilitation involving interdisciplinary geriatric teams improved mobility and physical function when compared to standard care
Nishioka et al. [45]	2018	Improved nutritional status was associated with better performance on ADLs among malnourished hip fracture patients, and weight loss was a strong predictor of decreased functional recovery
Diong et al. [33]	2016	Exercise intervention within 1 year of injury led to small yet significant improvements in overall mobility
Niitsu et al. [45]	2016	Hip fracture patients receiving whey protein supplementation during the early postoperative period had greater bilateral muscle strength and better scores on ADLs
Edgren et al. [25]	2015	Patients receiving home-based rehabilitation may have a greater reduction in disability when compared to those patients who received just physical therapy education at the bedside
Boddaert et al. [31]	2014	Discharge within 48 h to a geriatric unit which focused on comorbidities and rehabilitation improved mortality and morbidity at 6 months
Li et al. [41]	2013	64% of hip fracture patients suffered from malnutrition, and those malnourished performed worse on ADLs when compared to those non-malnourished

Abbreviations: *ADLs* activities of daily living

References

1. Folman Y, Gepstein R, Assaraf A, Liberty S. Functional recovery after operative treatment of femoral neck fractures in an institutionalized elderly population. Arch Phys Med Rehabil. 1994;75(4):454–6.
2. Dr. Coale's prize dissertation on fractures. Bost Med Surg J [Internet]. 1845 Aug 27 [cited 2021 Feb 4];33(4):69–76. Available from: https://www.nejm.org/doi/full/10.1056/NEJM184508270330401.
3. Speed K. The unsolved fracture. Surg Gynecol Obs. 1935;60:371.
4. Hoenig H, Rubenstein LV, Sloane R, Horner R, Kahn K. What is the role of timing in the surgical and rehabilitative care of community-dwelling older persons with acute hip fracture? Arch Intern Med. 1997;157(5):513–20.
5. Jones GR, Miller TA, Petrella RJ. Evaluation of rehabilitation outcomes in older patients with hip fractures. Am J Phys Med Rehabil. 2002;81(7):489–97.
6. American Academy of Orthopedic Surgeons. OrthoGuidelines.
7. Suetta C, Magnusson SP, Rosted A, Aagaard P, Jakobsen AK, Larsen LH, et al. Resistance training in the early postoperative phase reduces hospitalization and leads to muscle hypertrophy in elderly hip surgery patients - a controlled, randomized study. J Am Geriatr Soc. 2004;52(12):2016–22.

8. Beckmann M, Bruun-Olsen V, Pripp AH, Bergland A, Smith T, Heiberg KE. Effect of exercise interventions in the early phase to improve physical function after hip fracture – a systematic review and meta-analysis. Physiother (UK). 2020;108:90–7.
9. Chesser TJS, Inman D, Johansen A, Belluati A, Pari C, Contini A, Voeten SC, Hegeman JH, Ponsen KJ, Montero-Fernández N, Delgado-Martínez A, Chana-Rodríguez F, Hip fracture systems—European experience, OTA International: The Open Access Journal of Orthopaedic Trauma, 3, 2020;e050.
10. Rojas LGP, Hernández SQ, Ávila JMJ, Cervantes REL, Enghelmayer RA, Pesciallo C, et al. Hip fracture care—Latin America. OTA Int Open Access J Orthop Trauma 2020;3:e064.
11. Oldmeadow LB, Edwards ER, Kimmel LA, Kipen E, Robertson VJ, Bailey MJ. No rest for the wounded: early ambulation after hip surgery accelerates recovery. ANZ J Surg. 2006;76(7):607–11.
12. Beliveau MM, Multach M. Perioperative care for the elderly patient. Med Clin North Am. 2003;87(1):273–89.
13. Pioli G, Bendini C, Pignedoli P. Post-operative management. In: Orthogeriatrics: the management of older patients with fragility fractures; 2020.
14. Lee SY, Jung SH, Lee SU, Ha YC, Lim JY. Effect of balance training after hip fracture surgery: a systematic review and meta-analysis of randomized controlled studies. J Gerontol Ser A Biol Sci Med Sci. 2019;74(10):1679–85.
15. Hadjistavropoulos T, Delbaere K, Fitzgerald TD. Reconceptualizing the role of fear of falling and balance confidence in fall risk. J Aging Health. 2011;23(1):3–23.
16. Girardot K, Hollister L, Zhu TH, Hoeppner S, Opoku D, Heisler J, et al. Effectiveness of multimodal pain therapy on reducing opioid use in surgical geriatric hip fracture patients. J Trauma Nurs [Internet]. 2020[cited 2021 Feb 4];27(4):207–15. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/32658061/.
17. Connolly KP, Kleinman RS, Stevenson KL, Neuman MD, Mehta SN. Delirium reduced with intravenous acetaminophen in geriatric hip fracture patients. J Am Acad Orthop Surg [Internet]. 2020[cited 2021 Feb 4];28(8):325–31. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/31393314/.
18. Poeran J, Cozowicz C, Zubizarreta N, Weinstein SM, Deiner SG, Leipzig RM, et al. Modifiable factors associated with postoperative delirium after hip fracture repair: an age-stratified retrospective cohort study. Eur J Anaesthe [Internet]. Lippincott Williams and Wilkins; 2020 [cited 2021 Feb 4]. p. 649–58. Available from: https://pubmed-ncbi-nlm-nih-gov.ezproxy.cul.columbia.edu/32251149/
19. Koval KJ, Chen AL, Aharonoff GB, Egol KA, Zuckerman JD. Clinical pathway for hip fractures in the elderly: the hospital for joint diseases experience. In: Clinical orthopaedics and related research. Philadelphia: Lippincott Williams and Wilkins; 2004. p. 72–81.
20. Cameron ID, Lyle DM, Quine S. Accelerated rehabilitation after proximal femoral fracture: a randomized controlled trial. Disabil Rehabil. 1993;15(1):29–34.
21. Swanson CE, Day GA, Yelland CE, Broome JR, Massey L, Richardson HR, et al. The management of elderly patients with femoral fractures. A randomised controlled trial of early intervention versus standard care. Med J Aust. 1998;169(10):515–8.
22. Koval KJ, Aharonoff GB, Su ET, Zuckerman JD. Effect of acute inpatient rehabilitation on outcome after fracture of the femoral neck or intertrochanteric fracture. J Bone Joint Surg Ser A. 1998;80(3):357–64.
23. Mendelsohn ME, Overend TJ, Petrella RJ. Effect of rehabilitation on hip and knee proprioception in older adults after hip fracture: a pilot study. Am J Phys Med Rehabil. 2004;83(8):624–32.
24. Kane RL, Chen Q, Finch M, Blewett L, Burns R, Moskowitz M. Functional outcomes of posthospital care for stroke and hip fracture patients under Medicare. J Am Geriatr Soc. 1998;46(12):1525–33.
25. Kramer AM, Steiner JF, Schlenker RE, Eilertsen TB, Hrincevich CA, Tropea DA, et al. Outcomes and costs after hip fracture and stroke: a comparison of rehabilitation settings. J Am Med Assoc. 1997;277(5):396–404.

26. Munin MC, Seligman K, Dew MA, Quear T, Skidmore ER, Gruen G, et al. Effect of rehabilitation site on functional recovery after hip fracture. Arch Phys Med Rehabil. 2005;86(3):367–72.
27. Tsauo JY, Leu WS, Chen YT, Sen YR. Effects on function and quality of life of postoperative home-based physical therapy for patients with hip fracture. Arch Phys Med Rehabil. 2005;86(10):1953–7.
28. Edgren J, Salpakoski A, Sihvonen SE, Portegijs E, Kallinen M, Arkela M, et al. Effects of a home-based physical rehabilitation program on physical disability after hip fracture: a randomized controlled trial. J Am Med Dir Assoc. 2015;16(4):350.e1–7.
29. Giusti A, Barone A, Oliveri M, Pizzonia M, Razzano M, Palummeri E, et al. An analysis of the feasibility of home rehabilitation among elderly people with proximal femoral fractures. Arch Phys Med Rehabil. 2006;87(6):826–31.
30. Kuisma R. A randomized, controlled comparison of home versus institutional rehabilitation of patients with hip fracture. Clin Rehabil. 2002;16(5):553–61.
31. Levi SJ. Posthospital setting, resource utilization, and self-care outcome in older women with hip fracture. Arch Phys Med Rehabil. 1997;78(9):973–9.
32. Cameron ID, Handoll HH, Finnegan TP, Madhok R, Langhorne P. Co-ordinated multidisciplinary approaches for inpatient rehabilitation of older patients with proximal femoral fractures. Cochrane Database Syst Rev 2009;3:1–36.
33. Fitzgerald JF, Fagan LF, Tierney WM, Dittus RS. Changing patterns of hip fracture care before and after implementation of the prospective payment system. JAMA. 1987;258(2):218–21.
34. Nordström P, Thorngren KG, Hommel A, Ziden L, Anttila S. Effects of geriatric team rehabilitation after hip fracture: meta-analysis of randomized controlled trials. J Am Med Dir Assoc. 2018;19(10):840–5.
35. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in multidisciplinary team-based approach in geriatric hip fracture care: a systematic review. J Am Acad Orthop Surg [Internet]. 2019 May 30 [cited 2020 Nov 2];28(3):128–33. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31157757.
36. Boddaert J, Cohen-Bittan J, Dé Ric Khiami F, Le Manach Y, Raux M, Beinis J-Y, et al. Postoperative admission to a dedicated geriatric unit decreases mortality in elderly patients with hip fracture. PLoS One. 2014;9(1):e83795.
37. Desborough JP. The stress response to trauma and surgery. Br J Anaesth. 2000;85(1):109–17.
38. Kaiser MJ, Bauer JM, Rämsch C, Uter W, Guigoz Y, Cederholm T, et al. Frequency of malnutrition in older adults: a multinational perspective using the mini nutritional assessment. J Am Geriatr Soc. 2010;58(9):1734–8.
39. Bonjour JP. Protein intake and bone health. Int J Vitam Nutr Res. 2011;81(2–3):134–42.
40. Gumieiro DN, Rafacho BPM, Gonçalves AF, Tanni SE, Azevedo PS, Sakane DT, et al. Mini Nutritional Assessment predicts gait status and mortality 6 months after hip fracture. Br J Nutr 2013;109:1657–61.
41. Li HJ, Cheng HS, Liang J, Wu CC, Shyu YIL. Functional recovery of older people with hip fracture: does malnutrition make a difference? J Adv Nurs. 2013;69(8):1691–703.
42. Hinton PS, Rector RS, Linden MA, Warner SO, Chockalingam A, Whaley-Connell AT, et al. Weight-loss-associated changes in bone mineral density and bone turnover after partial weight regain with or without aerobic exercise in obese women. Eur J Clin Nutr. 2012;66:606–12.
43. Nishioka S, Wakabayashi H, Momosaki R. Nutritional status changes and activities of daily living after hip fracture in convalescent rehabilitation units: a retrospective observational cohort study from the Japan rehabilitation nutrition database. J Acad Nutr Diet. 2018;118(7):1270–6.
44. Reider L, Hawkes W, Hebel JR, D'Adamo C, Magaziner J, Miller R, et al. The association between body mass index, weight loss and physical function in the year following a hip fracture. J Nutr Health Aging. 2013;17(1):91–5.
45. Niitsu M, Ichinose D, Hirooka T, Mitsutomi K, Morimoto Y, Sarukawa J, et al. Effects of combination of whey protein intake and rehabilitation on muscle strength and daily movements in patients with hip fracture in the early postoperative period. Clin Nutr. 2016;35(4):943–9.

46. González-Montalvo JI, Alarcón T, Gotor P, Queipo R, Velasco R, Hoyos R, 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.
47. Bauer JM, Verlaan S, Bautmans I, Brandt K, Donini LM, Maggio M, et al. Effects of a vitamin D and Leucine-enriched whey protein nutritional supplement on measures of sarcopenia in older adults, the PROVIDE study: a randomized, double-blind, placebo-controlled trial. J Am Med Dir Assoc. 2015;16(9):740–7.
48. Singh MAF. Exercise, nutrition and managing hip fracture in older persons. Curr Opin Clin Nutr Metab Care. 2014;17(1):12–24.
49. Tappenden KA, Quatrara B, Parkhurst ML, Malone AM, Fanjiang G, Ziegler TR. Critical role of nutrition in improving quality of care: an interdisciplinary call to action to address adult hospital malnutrition. J Acad Nutr Diet. 2013;113(9):1219–37.
50. Crotty M, Unroe K, Cameron ID, Miller M, Ramirez G, Couzner L. Rehabilitation interventions for improving physical and psychosocial functioning after hip fracture in older people. Cochrane Database Syst Rev. 2010;20(1):CD007624.
51. Pol M, Peek S, Van Nes F, Van Hartingsveldt M, Buurman B, Kröse B. Everyday life after a hip fracture: what community-living older adults perceive as most beneficial for their recovery. Age Ageing. 2019;48(3):440–7.
52. Auais M, Al-zoubi F, Matheson A, Brown K, Magaziner J, French SD, et al. Understanding the role of social factors in recovery after hip fractures: a structured scoping review. Health Soc Care Community. 2020;27(6):1375–87.

Chapter 11
Postoperative Bone Mineral Health Optimization in the Geriatric Patient

Ananya V. Kondapalli and Marcella D. Walker

Introduction

Hip fracture is the most devastating consequence of osteoporosis. Osteoporosis, a systemic skeletal disorder characterized by low bone mass and skeletal microarchitectural deterioration, leads to decreased bone strength and an increased risk of fragility fractures [1]. Unfortunately, osteoporosis is a silent condition and often goes undiagnosed until the sequela of fracture occurs. A hip fracture that occurs without trauma or occurs with only minimal trauma, defined as trauma equivalent to a fall from a standing height or less, is consistent with a fragility fracture. The occurrence of a fragility fracture is diagnostic of osteoporosis, regardless of bone mineral density (BMD) [2].

The measurement of BMD by dual-energy x-ray absorptiometry (DXA) can identify patients at risk for fracture before the first fracture occurs. Reduced BMD is a powerful risk factor for future fracture. Each standard deviation decrease in BMD increases the risk of future fracture by approximately two and one half fold. A BMD value (T-score) that is 2.5 standard deviations or more below the mean value for young healthy women is diagnostic of osteoporosis. While osteoporosis is under-diagnosed, its burden is enormous. In 2015, approximately 1.4 million Medicare fee-for-service beneficiaries suffered over 1.6 million osteoporotic fractures [3]. It is estimated that by 2025, the burden of osteoporosis in the United States will increase to over 3 million fractures and cost 25.3 billion dollars a year [4]. Estimates suggest that the incidence of hip fractures may rise to as much as 512,000 annually by 2040 [5].

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Osteoporotic fractures typically occur at the spine, hip, forearm, and proximal humerus but may occur at other skeletal sites as well. While all fractures cause morbidity, hip fractures are associated with the most significant morbidity and mortality. Hip fractures lead to prolonged hospitalizations, loss of independence, diminished quality of life, and increased mortality [6]. For example, mortality rate in the first year after a hip fracture can be as high as 25%, with increased age associated with higher mortality [7–9]. Multiple studies have shown that mortality rate can remain elevated compared to an age-matched population for at least 5–10 years, with one study suggesting increased risk of death up to 20 years after initial fracture [7].

Hip fractures are important not only due to their immediate consequences, but because their occurrence is associated with future fractures. Prior osteoporotic fracture at any site is a strong predictor for future fractures independent of bone mineral density [10]. Postmenopausal women with prior osteoporotic fracture have a two- to threefold increase in the risk of a future fracture compared to those without prior fractures [11, 12]. Studies that assessed risk of a second hip fracture after an index hip fracture found that up to 6–11% of patients suffered a second hip fracture; the Framingham Heart Study found 14.8% of patients with an index hip fracture had a second hip fracture over a 4.5 year period [13–15]. Despite recommendations to treat osteoporosis in patients who have sustained a fragility fracture, including a hip fracture, in order to prevent subsequent fractures, rates of treatment remain low with some studies showing continued declines over time [16]. This is thought to be primarily due to low rates of diagnosis and treatment initiation. Additionally, use of osteoporotic medications has recently decreased due to inflated patient-perceived concerns about very rare side effects. For example, a large, retrospective, observational study that included 147,199 patients hospitalized for hip fractures between 2002 and 2011 found that only 24% were started on osteoporosis medications within 12 months of fracture [9]. Another large, prospective, longitudinal study in primary care provider offices showed less than 20% of postmenopausal women with incident fracture were started on osteoporotic medications within the first year of follow-up [17]. A more recent report in Medicare recipients indicated that only 9% of female patients with osteoporotic fractures were referred for dual-energy x-ray absorptiometry (DXA) within 6 months after fracture [3]. Since 2006, use of bisphosphonates has plateaued and then, unfortunately, declined with oral medication use decreasing by >50% between 2008 and 2012 [18].

Fracture liaison services (FLS) have been established to increase recognition of osteoporotic fractures in the hospital, assist inpatient teams with basic evaluations for secondary causes of fracture, and coordinate outpatient follow-up and treatment. While data is limited and inconsistent with regard to whether use of an FLS reduces subsequent fracture risk, incorporation of a multi-specialty approach is attractive due to improvement in surrogate outcomes. Patients incorporated into an FLS were found to have increased rates of outpatient DXAs and improved non-pharmacologic measures but unfortunately no significant increase in osteoporotic medication use after hip fractures. Cost also remains a significant barrier to widespread implementation of FLS [19].

Because of the morbidity, mortality, cost, and risk of future fractures, secondary prevention of hip fractures is paramount. Risk for future fracture can be markedly reduced in patients who have sustained prior fractures, particularly hip fractures, with pharmacologic treatments that are safe and effective. Unfortunately, there remains a substantial gap between evidence-based recommendations for treatment of osteoporotic fractures and clinical practice.

Evaluation for Osteoporosis in the Hip Fracture Patient

Osteoporosis may be characterized as primary or secondary. The two main forms of primary osteoporosis include postmenopausal osteoporosis, which is related to estrogen deficiency, and senile osteoporosis related to loss of bone mass with age. Most patients with a hip fracture have primary osteoporosis. Secondary osteoporosis occurs in the setting of medications (Table 11.1) and other diseases that cause bone loss or increase the risk of fracture. Secondary osteoporosis may be seen in up to 20% of women and 30% of men [20]. Suspicion for secondary causes should be raised in those with hip fracture who are premenopausal, men below the age of 70, patients with multiple low trauma fractures, or patients with fractures while on osteoporosis therapy and patients without significant risk factors. Osteoporotic risk factors include female sex, advanced age, small body size, positive family history in a first-degree relative, vitamin D deficiency, low calcium intake, hyperthyroidism, hyperparathyroidism, malabsorption syndrome, smoking, excess alcohol use, premature menopause, and high doses and/or chronic lower doses of glucocorticoids [2].

Table 11.1 Major secondary causes of osteoporosis

Secondary causes	Most common fracture site[a]
Celiac Disease	Distal radius, vertebrae
Chronic Kidney Disease	Hip, vertebrae
Chronic Liver Disease	Vertebrae
Connective Tissue Disorders (osteogenesis imperfecta, hypophosphatasia)	Variable; hypophosphatasia – metatarsal stress fractures
Cushing's Syndrome	Vertebrae, ribs
Human Immunodeficiency Virus infection	Unknown
Hypercalciuria	Unknown, cortical sites
Hyperthyroidism	Hip
Hypogonadism in men	Distal radius, vertebrae
Medications (e.g., Glucocorticoids, Anti-epileptics)	Variable; glucocorticoid use – vertebrae
Multiple Myeloma	Vertebrae
Primary hyperparathyroidism	Distal radius, vertebrae
Systemic mastocytosis	Vertebrae

[a]Sheu and Diamond [62]

Initial assessment for all patients presenting with hip fracture should include a medical history, physical examination for signs of conditions associated with bone loss, risk factor evaluation, and laboratory evaluation. There is some disagreement as to the minimal necessary laboratory evaluation that is required prior to initiation of pharmacological therapy for osteoporosis. We advocate a biochemical evaluation (Table 11.2) that consists of a complete blood count, basic metabolic panel (electrolytes, creatinine, calcium), phosphorus, hepatic panel, 25-hydroxyvitamin D, and intact parathyroid hormone. This basic laboratory work up is needed to assess for

Table 11.2 Biochemical evaluation in patients with hip fracture and/or osteoporosis

Initial biochemical testing recommended in all patients	
Test	*Reason for test*
Basic metabolic panel	Anti-resorptives contraindicated in those with hypocalcemia
	IV bisphosphonates contraindicated in those with severe renal dysfunction
Complete blood cell count	Abnormal values (anemia, etc.) may indicate myeloma or malabsorption from various causes (e.g., celiac disease)
Hepatic panel	High alkaline phosphatase can indicate Paget's disease or osteomalacia, etc.
	Teriparatide contraindicated with high alkaline phosphatase
25-hydroxyvitamin D	Exclude vitamin D deficiency and assess need for repletion prior to treatment with pharmacologic therapy
Intact parathyroid hormone	Hyperparathyroidism
Serum phosphorus	Chronic hypophosphatemia may cause osteomalacia
Evaluation for Secondary Osteoporosis in Selected Patients	
Test	*Reason for test*
Tissue transglutaminase antibody with total IgA	Celiac Disease
24-hour urinary cortisol	Cushing's Syndrome
Medication History (glucocorticoids, anti-epileptics, etc.)	Drug-induced Osteoporosis
HIV Antigen/Antibody test	Human Immunodeficiency Virus infection
Thyroid-stimulating hormone	Hyperthyroidism
24-hour urinary calcium	Hypercalciuria
Total testosterone, follicle-stimulating hormone (FSH), luteinizing hormone (LH)	Hypogonadism in men
Magnesium	Hypomagnesemia leading to hypocalcemia and PTH resistance
Serum protein electrophoresis	Multiple Myeloma
Free kappa and lambda light chains	
Urinary histamine, tryptase, bone marrow biopsy	Systemic mastocytosis

other conditions that may accompany osteoporosis (vitamin D deficiency, hyperparathyroidism) and to exclude osteomalacia and evaluate for contraindications to particular osteoporosis therapies (e.g., unexplained high alkaline phosphatase). A more extensive laboratory evaluation (Table 11.2) may be appropriate in select settings depending on clinical suspicion. This may include measurement of serum magnesium, thyroid-stimulating hormone, tissue transglutaminase antibodies for celiac disease, serum protein electrophoresis and free kappa and lambda light chains for multiple myeloma, total testosterone and gonadotropins for hypogonadism, and 24-hour urinary calcium. In the right clinical setting, additional testing may be required for less common processes including mastocytosis, Cushing's disease, and collagen disorders [2].

Measuring BMD by DXA is recommended by national and international evidence-based guidelines from all expert groups, including but not limited to the National Osteoporosis Foundation, International Society for Clinical Densitometry [21, 22], and College of Rheumatology Guidelines for the Prevention and Treatment of Glucocorticoid-Induced Osteoporosis [23] for all women 65 and older, regardless of race or ethnicity; any woman over age 60 with risk factors for fracture as defined by evidence-based management (previous fracture, family history of osteoporosis or fracture, rheumatoid arthritis, glucocorticoid use, any other established secondary cause of osteoporosis); all men 70 and older, regardless of race or ethnicity; any man over age 65 with risk factors for fracture (previous fracture, family history of osteoporosis or fracture, hypogonadism, hormonal therapy for prostate cancer, glucocorticoid use, any other established secondary cause of osteoporosis); all men and women over age 50 who sustain low trauma fractures including spine, hip, forearm, humerus, and femur; all adults ≥40 receiving any dose of glucocorticoid chronically (duration 3 months or longer); and adults <40 receiving any dose of glucocorticoid chronically (duration 3 months or longer) who have other risk factors for fracture [24]. In patients with hip fractures in particular, DXA is recommended and can be used for monitoring the effectiveness of treatment; however, initiating therapy should not be delayed while awaiting DXA.

While most hip fractures occur in the setting of osteoporosis, hip fractures may be due to other metabolic diseases such as Paget disease of bone. Suspicion for these conditions may be raised by particular radiograph or lab abnormalities, such as an elevated serum alkaline phosphatase. Findings consistent with other metabolic bone disease besides osteoporosis should prompt referral to an endocrinologist or metabolic bone specialist.

Lifestyle Modifications

Lifestyle interventions such as smoking cessation, limiting alcohol intake, resistance and balance exercises, and adequate calcium and vitamin D intake are recommended and should be reinforced in all patients. Cigarette smoking has been linked to reduced BMD [25], and excess alcohol intake is associated with nutritional calcium deficiency, vitamin D deficiency due to chronic liver disease, and increased risk of falls [26]. Whether weight-bearing activity increases BMD or reduces risk of fracture has been controversial. The Study of Osteoporotic Fractures indicated that in nonblack women over 65 years old, increased physical activity and intensity can lead to significant reduction in hip fractures compared to non-active women [27]. Exercise also increases muscle mass and improves balance, which in turn can prevent falls [28]. A fall evaluation and instituting measures to prevent falls, such as physical and occupational therapy evaluation, home safety assessment, withdrawal of psychotropic medications, and correction of visual impairment, are also important. Discontinuation of medications that cause bone loss or increase risk of fracture should be considered if clinically appropriate.

The National Osteoporosis Foundation recommends a total daily intake of 1000–1200 mg of calcium (dietary and supplements) and 800–1000 international units of vitamin D in all postmenopausal women and men above 50 years old [29]. Older patients are especially at high risk for calcium and vitamin D deficiency due to decreased intestinal absorption of calcium that occurs due to advanced age, limited sun exposure, and low dietary intake of vitamin D. Whether calcium and vitamin D supplementation reduces risk of fractures remains controversial. A primary prevention study with over 3000 ambulatory, elderly women randomized to placebo versus vitamin D (800 IU) and calcium (1200 mg) supplementation showed 43% fewer hip fractures in the group allocated to calcium and vitamin D compared to those allocated to placebo [30]. In contrast, a secondary prevention study that included over 5000 ambulatory 70 years or older adults showed no significant difference between vitamin D and calcium supplementation versus placebo in preventing subsequent fractures [31]. Discrepancies between studies may be due to differences in supplement dosages or baseline intake. All studies, however, that have shown decreased risk of fractures with pharmacologic therapy include supplementation with calcium and vitamin D [28]. Additionally, some of the pharmacologic therapies for osteoporosis (described below) are contraindicated in patients with hypocalcemia or vitamin D deficiency. Further, vitamin D insufficiency and deficiency increase the risk of developing hypocalcemia while on therapy. In geriatric patients who are extremely high risk for fracture, the benefit from supplementation generally outweighs its risks (i.e., kidney stones). Whether calcium increases the risk of cardiovascular disease is controversial.

Pharmacologic Therapy

Pharmacologic treatment is recommended in all patients with an osteoporotic fracture to prevent subsequent fractures. Further, one may consider changing pharmacological treatment in those who sustain a fracture while on osteoporosis therapy. Pharmacologic options include anti-resorptive medications which decrease bone resorption by inhibiting osteoclast activity and anabolic agents which promote bone formation by activating osteoblasts [32]. Both classes of medications have been shown to decrease the risk of fractures and improve BMD (Table 11.3). While these medications have primarily been studied in postmenopausal women, there is evidence to support their use in men and patients with glucocorticoid-induced osteoporosis, particularly those with a history of hip fracture. The current FDA-approved pharmacologic therapies for prevention and treatment of osteoporosis include bisphosphonates, receptor activator of nuclear factor (RANK) ligand inhibitors, estrogen replacement therapy, selective estrogen receptor modulators, parathyroid hormone 1–34 analogs, parathyroid hormone-related peptide analogs, and an anti-sclerostin humanized monoclonal antibody [21].

Anti-resorptive Agents

Bisphosphonates

Bisphosphonates are considered, by many experts, to be the first-line treatment for osteoporosis in those who have sustained a hip fracture due to their efficacy to reduce fractures, ability to reduce mortality, low cost, and long-term safety data. Bisphosphonates are pyrophosphate analogs that deposit in bone, preferentially at sites of bone resorption. Within active skeletal remodeling sites, they are taken up by osteoclasts leading to inactivation and decreased bone resorption. Nitrogen-containing bisphosphonates including alendronate, risedronate, ibandronate, and zoledronic acid are more potent than non-nitrogen-containing bisphosphonates (i.e., etidronate) and preferentially used in clinical practice [33]. Non-nitrogen-containing bisphosphonates are rarely used except in specific circumstances.

Alendronate, risedronate, and ibandronate are the three available oral nitrogen-containing bisphosphonates in the United States. In a meta-analysis of over 3000 patients with initial hip fracture, use of bisphosphonates (zoledronic acid, alendronate, risedronate, etidronate) led to a significant decline in second hip fracture in the bisphosphonate group compared to those allocated to placebo [34]. Two large trials in postmenopausal women with vertebral fractures showed alendronate increases BMD at the lumbar spine, hip, and whole body and reduces risk of new vertebral fractures by 48% and new hip fractures by 50% compared to placebo [35, 36]. In women with a T-score less than −2.5 at the femoral neck and no vertebral fractures, treatment with alendronate for 4 years showed a 56% reduction in hip fractures compared to placebo [37].

Similar improvements in BMD and reduction in vertebral and non-vertebral fractures were seen with risedronate. In postmenopausal women with vertebral fractures, risedronate was found to improve BMD at lumbar spine, femoral neck, and femoral trochanter and reduce risk of vertebral fractures by 41% and non-vertebral fractures by 39% over a 3-year period [38]. Ibandronate is another bisphosphonate with both IV and PO formulations, which showed a significant reduction in

Table 11.3 Pharmacology therapy for prevention and treatment of osteoporosis

Drug class	Medication	Treatment dose	Indication			Fracture Risk Reduction			Percentage Increase in BMD (3 years)	Side effects
			PM	GC	Men	Hip	Vertebral	Non-Vertebral		
Anti-resorptives										
Bisphosphonates	Alendronate (PO)	70 mg weekly	✓	✓	✓	✓	✓	✓	LS: 6.2% TH: 4.7% FN: 4.1%	MSK pain, GI irritation rare: ONJ, AFF
	Risedronate (PO)	35 mg weekly or 150 mg monthly	✓	✓	✓	✓	✓	✓	LS: 5.4% FN: 1.6% FT: 3.3%	MSK symptoms, GI irritation rare: ONJ, AFF
	Ibandronate (IV or PO)	PO 2.5 mg daily, 150 mg monthly, or IV 3 mg q3 months	✓				✓		LS: 6.5% TH: 3.4% FN: 2.8%	MSK symptoms, GI irritation rare: ONJ, AFF
	Zoledronic Acid (IV)	5 mg yearly	✓	✓	✓	✓	✓	✓	LS: 6.71% TH: 6.02% FN: 5.06%	Acute phase reaction rare: ONJ, AFF
RANKL ligand Inhibitor	Denosumab (SQ)	60 mg every 6 months	✓	✓	✓	✓	✓	✓	LS: 9% TH: 6%	MSK pain, skin infections rare: ONJ, AFF
Selective Estrogen Receptor Modulators	Raloxifene (PO)	60 mg daily	✓				✓		LS: 2.6% FN: 2.1%	VTE, hot flashes peripheral edema, night sweats
Estrogens	Conjugated equine estrogen	0.15–1.25 mg daily	Prevention in postmenopausal osteoporosis			✓	✓	✓	LS: 5.1% TH: 2.3%	VTE, cardiovascular disease, breast cancer
Anabolic Agents										
PTH analog	Teriparatide (SQ)	20 μg daily	✓	✓	✓		✓	✓	LS: 9.7%[a] TH: 2.6% FN: 2.8%	Hypercalcemia, nausea, orthostatic hypotension

PTH-RP analog	Abaloparatide (SQ)	80 μg daily	✓				✓	✓	LS: 10.37%[b] TH: 4.18% FN: 4.01%	Hypercalcemia, nausea, orthostatic hypotension
Combination Anabolic and Anti-resorptive Agent										
Sclerostin Inhibitor	Romosozumab (SQ)	210 mg monthly	✓			✓	✓	✓	LS: 13.3%[c] TH: 6.9% FN: 5.9%	Arthralgia, headache, MSK pain

IV intravenous, *PO* per os (oral), *SQ* subcutaneous, *LS* lumbar spine, *TH* total hip, FN femoral neck, *FT* femoral trochanter, *MSK* musculoskeletal, *ONJ* osteonecrosis of the jaw, *AFF* atypical femoral fracture, *VTE* venous thromboembolism

[a]2 years

[b]18 months

[c]1 years

vertebral fractures and an increase in BMD at the lumbar spine and total hip. Ibandronate, in contrast to the other available oral bisphosphonates, did not show a significant reduction in non-vertebral fractures or hip fractures specifically. While this may be due to inadequate statistical power, ibandronate may be less preferable in this population for this reason [39, 40].

Zoledronic acid, an intravenous bisphosphonate, which is dosed annually, reduced the risk of vertebral and hip fractures by 70% and 41%, respectively, compared to placebo over a 3-year period [41]. There are data to show zoledronic acid has benefit specifically in patients with a history of hip fracture. Patients who received zoledronic acid within 90 days after surgical repair of a hip fracture had a 28% reduction in mortality and 35% risk reduction in new clinical fractures without any effect on fracture healing [42]. The latter along with the possibility that zoledronic acid may allow for better compliance compared to oral agents makes it an attractive option for patients with a hip fracture.

Bisphosphonates are generally very safe and effective, but a few contraindications and precautions must be considered. All bisphosphonates are contraindicated in patients with hypocalcemia. Intravenous bisphosphonates should be used with caution or avoided in certain circumstances such as severe renal dysfunction (creatinine clearance <35 mL/min) due to the possibility of transient renal dysfunction, hypocalcemia, and possible presence of renal osteodystrophy. 25-hydroxyvitamin D levels must be evaluated and, if deficient, repleted, prior to initiating therapy in order to prevent hypocalcemia that can occur after infusion. Oral bisphosphonates do not carry a risk of renal toxicity but can cause hypocalcemia to a lesser degree and may not be appropriate in patients with severe renal dysfunction due to renal osteodystrophy. Oral bisphosphonates are contraindicated in patients with significant esophageal disease including achalasia and strictures. The oral agents must be taken on an empty stomach, only with water, and separated from other medications or food by at least 30 min to maximize absorption. Patients should sit upright for at least 30–60 min after ingestion of oral bisphosphonates to avoid gastrointestinal irritation. Intravenous bisphosphonates have been associated with an acute phase reaction of flu-like symptoms within 3 days of the first infusion. Pre-treatment with acetaminophen can decrease the incidence and severity of reaction [28].

Two serious but extremely rare side effects associated with bisphosphonates include osteonecrosis of the jaw and atypical femoral fractures. Osteonecrosis of the jaw (ONJ) is defined as exposed bone that does not heal after 8 weeks of identification. Patients can present with no symptoms or may have pain, paresthesias, swelling, and soft tissue ulceration [43]. The majority of cases of ONJ were identified in patients receiving high doses of intravenous bisphosphonates (monthly) for underlying malignancy rather than osteoporosis [44]. Routine dental care and maintenance of good oral hygiene is recommended while on these medications to minimize the need for invasive dental procedures such as extractions and implants. In patients who are at high risk for fracture, impending dental work should not delay initiation of a bisphosphonate.

Atypical femoral fractures (AFFs) are stress-type fractures that occur in the subtrochanteric or shaft region of the femur. Patients typically experience a prodromal dull, aching pain in the thigh or groin, which may go unrecognized. While use of bisphosphonates for greater than 3–5 years may be associated with a small increment in the risk of AFFs, the absolute risk and incidence remain extremely low. It is estimated that for every 1 AFF, there are 265 hip fractures [45]. Given the rarity of these side effects, the benefit of using bisphosphonates in individuals with hip fracture generally outweighs these rare risks. Use of anti-resorptives is generally contraindicated in those with a history of AFF.

Denosumab

Denosumab, a human monoclonal antibody against receptor activator of nuclear factor-kB ligand (RANKL), is another attractive therapeutic option to consider in patients with a history of hip fracture, particularly those who may have contraindications to or who cannot tolerate bisphosphonates. Denosumab prevents binding of RANKL to its receptor on osteoclast precursors leading to decreased formation and activation of mature osteoclasts. The Fracture Reduction Evaluation of Denosumab in Osteoporosis Every 6 Months (FREEDOM) trial, a 36-month, large, international, randomized, controlled trial, compared denosumab to placebo in postmenopausal women with osteoporosis (T-score −2.5 to −4.0) at the total hip or lumbar spine. Denosumab increased BMD by 9% at the lumbar spine and 6% at the total hip. Risk of new vertebral and hip fractures was decreased by 68% and 40%, respectively [46]. Denosumab causes a rapid decrease in bone turnover markers, with near maximal reduction 3 days after initiation. While denosumab is effective, patients must be cautioned about abrupt discontinuation of therapy. Discontinuation of denosumab is associated with a rapid increase in bone turnover markers and loss of BMD at the lumbar spine and total hip within 12 months after stopping therapy. Case reports have described patients with multiple vertebral fractures after discontinuation of therapy. For this reason, drug holidays are not recommended with denosumab therapy, and patients must be carefully transitioned to alternative anti-resorptive medication [47]. Re-initiation of treatment with denosumab once again leads to improvement in BMD [48, 49].

Denosumab is contraindicated in patients with hypocalcemia. Unlike bisphosphonates, however, denosumab can be used in those with renal dysfunction due to the absence of renal toxicity, but such patients may be at significant risk for hypocalcemia. 25-hydroxyvitamin D levels must be checked and repleted prior to initiation of therapy. Denosumab has also been associated with a small risk of ONJ and AFF similar to bisphosphonates. The benefit of preventing subsequent fractures outweighs the extremely small risk of these adverse events in patients at risk of fracture.

Anabolic Agents

Parathyroid Hormone and Parathyroid Hormone-Related Peptide Analogs

Teriparatide is a PTH analog (PTH 1-34) that stimulates bone formation. Teriparatide is primarily used in patients at high risk of fracture such as those with history of fragility fracture, those with severe osteoporosis, or those who fracture while on anti-resorptive therapy. In a 21-month trial in postmenopausal women with vertebral fractures, teriparatide lowered risk of vertebral fractures by 65% and non-vertebral fractures by 35% but did not show significant reduction in hip fractures alone [50]. Despite this, it is still an appropriate treatment consideration in hip fracture patients, particularly those who have fractured on anti-resorptive therapies or have contraindications to other medications, due to its ability to reduce vertebral and non-vertebral fractures.

Abaloparatide is a parathyroid hormone-related peptide (PTHrP) analog, which activates the PTH1 receptor and leads to similar stimulation of bone formation. Abaloparatide significantly reduced new vertebral fractures (relative risk reduction 86%) and increased BMD at lumbar spine, total hip, and femoral neck compared to placebo [51]. Compared to teriparatide, abaloparatide was associated with a greater increase in hip, femoral neck, and lumbar spine BMD at 12 months and lower incidence of hypercalcemia [52]. Similar to teriparatide, while not shown specifically to reduce hip fractures, it can be considered in such patients as it reduces the risk of vertebral and non-vertebral fractures.

Teriparatide and abaloparatide are contraindicated in patients with a history of skeletal irradiation, open epiphyses, Paget's disease of bone, and unexplained elevated alkaline phosphatase due to the potential risk of osteosarcoma. This risk was demonstrated in rodent studies and dependent on dose and treatment duration. Teriparatide and abaloparatide have been historically approved for only up to 2 years of use, but the FDA has recently removed the black box warning related to osteosarcoma for teriparatide, potentially allowing extension of treatment to longer than 2 years.

Improvement in BMD can be lost rapidly after anabolic agents are discontinued. Treatment with an anti-resorptive immediately after stopping anabolic therapy has been shown to maintain or increase gains in BMD [53]. Several studies indicate that there is generally no benefit to concurrent treatment with anabolic agents and bisphosphonates [53]. However, the Denosumab and Teriparatide Administration (DATA) study showed a significant increase in BMD at the spine and hip with combined teriparatide and denosumab, compared to either medication alone, in postmenopausal women with osteoporosis. Given these findings, combination therapy can be considered in patients at high risk for fracture, though in practice, insurance coverage for combination therapy is limited [54].

Combination Anabolic/Anti-resorptive Agents

Romosozumab is the newest FDA-approved treatment for osteoporosis. It is a human monoclonal antibody against sclerostin, a protein produced by osteocytes that inhibits osteoblast bone formation. Administration of romosozumab leads to increased bone formation and decreased bone resorption [55]. In postmenopausal women with a T-score of –2.5 to −3.5 at the hip or femoral neck and no history of hip or multiple vertebral fractures, romosozumab for 12 months followed by denosumab showed a significant reduction in vertebral fractures at 12 and 24 months [56]. Romosozumab increased BMD at the lumbar spine, total hip, and femoral neck. In a second trial studying romosozumab versus alendronate in postmenopausal women, romosozumab reduced non-vertebral fractures and hip fractures by 19% and 38%, respectively.

Compared with alendronate, romosozumab was associated with a small but significant increase in cardiovascular events, leading to a black box warning that romosozumab should not be used in patients with recent myocardial infarction or stroke or those at high risk for cardiovascular (CV) events [57]. Its cost, shorter track record, and safety concerns make it a less attractive option for elderly patients with a hip fracture, but it may be considered if there are contraindications to other therapies.

Estrogen Replacement Therapy

Estrogen replacement therapy may be used in select patients for the prevention of osteoporosis; however, it is not FDA-approved for the treatment of osteoporosis. For this reason along with its potential side effects, it is generally not an appropriate choice in geriatric patients with hip fracture. In the Women's Health Initiative (WHI) trials, estrogen therapy led to significant reductions in rates of both hip fractures and vertebral fractures, but it increased risk of venous thromboembolism, myocardial infarction, stroke, and breast cancer. Therefore, estrogen is not considered first line for the treatment of osteoporosis. As most patients with hip fracture are frequently elderly, sedentary, and at increased risk for thromboembolic events and cardiovascular disease, the risks of estrogen do not outweigh its benefits in this population [58]. Its use is most appropriate in younger women who are recently postmenopausal without contraindications. Subsequent analyses of WHI data have shown that there was no increase in cardiovascular disease risk in those who started estrogen therapy within a few years of menopause.

Selective Estrogen Receptor Modulators

Selective estrogen receptor modulators or SERMs, such as raloxifene, bind to estrogen receptors to inhibit bone resorption but do not stimulate the uterine endometrium. While raloxifene is FDA-approved for both prevention and treatment of osteoporosis, it is a less attractive option for those with a history of hip fracture. In over 7000 postmenopausal women with osteoporosis, defined as low BMD or vertebral fracture, raloxifene was shown to decrease the risk of vertebral fracture by 30–50% and increase bone mineral density at the spine and femoral neck [59]. In this study, there was no significant reduction in the occurrence of non-vertebral fractures after 3 years. Specific risk reduction for hip fracture has not been shown. Raloxifene was associated with an increased incidence of venous thromboembolic events; rates were comparable to women receiving estrogen therapy and tamoxifen in other studies. Influenza syndrome, hot flashes, leg cramps, peripheral edema, and endometrial cavity fluid are other potential side effects.

Calcitonin

Calcitonin decreases bone resorption by inhibiting osteoclasts. A dose of 200 IU of intranasal calcitonin-salmon has been shown to reduce risk of vertebral fractures, although higher or lower doses did not show similar reduction and there was no reduction in non-vertebral fractures (i.e., hip fractures) [60]. While it is FDA-approved for treatment of postmenopausal osteoporosis, it is not recommended given conflicting data on efficacy and the availability of more effective treatments (as described above) for reducing fracture risk and increasing bone mineral density. Additionally, a meta-analysis of 21 trials showed an increased incidence of malignancy in patients receiving calcitonin-salmon for prolonged periods of time [24]. Its use in patients with hip fracture is not recommended.

Timing of Treatment

Once basic laboratory evaluation is completed, patients with hip fracture should be treated with pharmacologic therapy. Therapy is sometimes inappropriately delayed after hip fractures due to the concern that it may impair or delay fracture healing. This is, however, only a theoretical risk, and there are data to the contrary. Several studies show a benefit of early treatment in those with hip fracture. Patients treated with zoledronic acid within 2 weeks of an index hip fracture did not show delayed fracture healing [61]. Moreover, patients treated with IV bisphosphonate within 90 days of surgical repair hip of fracture had a reduction in mortality [42]. Thus, the benefit of initiating therapy in patients who have recently sustained a hip fracture in order to decrease mortality and prevent future fractures outweighs the theoretical risk of delayed fracture healing.

Summary

In summary, osteoporosis is an increasingly prevalent problem in the geriatric population. Osteoporotic fractures, especially hip fractures, are associated with significant morbidity and mortality. Hip fractures sustained with low-energy trauma are diagnostic of osteoporosis and a strong predictor for subsequent fractures, but the significance of a hip fracture and diagnosis of osteoporosis is under-recognized. Initiating treatment after a hip fracture or any osteoporotic fracture is critical. Pharmacologic therapy decreases fracture risk, improves bone mineral density, and reduces mortality. Treatment rates remain low due to the under-diagnosis of osteoporosis, as well as low rates of treatment initiation and decreased compliance because of concerns regarding very rare side effects. All patients with a history of hip fracture should be treated with pharmacological therapy that is FDA-approved for the treatment of osteoporosis. Serious side effects are exceedingly rare, and the benefits of preventing future fracture and reducing mortality outweigh these risks.

References

1. NIH consensus development panel on osteoporosis prevention D, therapy. Osteoporosis prevention, diagnosis, and therapy. JAMA. 2001;285(6):785–95.
2. Becker C. Clinical evaluation for osteoporosis. Clin Geriatr Med. 2003;19(2):299–320.
3. Dane Hansen CB, Pelizzari P, Pyenson B. Medicare cost of osteoporotic fractures. 2019 August. https://www.milliman.com/en/insight/medicare-cost-of-osteoporoticfractures.
4. Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, Tosteson A. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005-2025. J Bone Miner Res. 2007;22(3):465–75.
5. Cummings SR, Rubin SM, Black D. The future of hip fractures in the United States. Numbers, costs, and potential effects of postmenopausal estrogen. Clin Orthop Relat Res. 1990;252:163–6.
6. Lewiecki EM, Ortendahl JD, Vanderpuye-Orgle J, Grauer A, Arellano J, Lemay J, et al. Healthcare policy changes in osteoporosis can improve outcomes and reduce costs in the United States. JBMR Plus. 2019;3(9):e10192.
7. Abrahamsen B, van Staa T, Ariely R, Olson M, Cooper C. Excess mortality following hip fracture: a systematic epidemiological review. Osteoporos Int. 2009;20(10):1633–50.
8. Lu-Yao GL, Baron JA, Barrett JA, Fisher ES. Treatment and survival among elderly Americans with hip fractures: a population-based study. Am J Public Health. 1994;84(8):1287–91.
9. Solomon DH, Johnston SS, Boytsov NN, McMorrow D, Lane JM, Krohn KD. Osteoporosis medication use after hip fracture in U.S. patients between 2002 and 2011. J Bone Miner Res. 2014;29(9):1929–37.
10. Kanis JA, Johnell O, De Laet C, Johansson H, Oden A, Delmas P, et al. A meta-analysis of previous fracture and subsequent fracture risk. Bone. 2004;35(2):375–82.
11. Klotzbuecher CM, Ross PD, Landsman PB, Abbott TA 3rd, Berger M. Patients with prior fractures have an increased risk of future fractures: a summary of the literature and statistical synthesis. J Bone Miner Res. 2000;15(4):721–39.

12. van Staa TP, Leufkens HG, Cooper C. Does a fracture at one site predict later fractures at other sites? A British cohort study. Osteoporos Int. 2002;13(8):624–9.
13. Berry SD, Samelson EJ, Hannan MT, McLean RR, Lu M, Cupples LA, et al. Second hip fracture in older men and women: the Framingham study. Arch Intern Med. 2007;167(18):1971–6.
14. Schroder HM, Petersen KK, Erlandsen M. Occurrence and incidence of the second hip fracture. Clin Orthop Relat Res. 1993;289:166–9.
15. Melton LJ 3rd, Kearns AE, Atkinson EJ, Bolander ME, Achenbach SJ, Huddleston JM, et al. Secular trends in hip fracture incidence and recurrence. Osteoporos Int. 2009;20(5):687–94.
16. Desai RJ, Mahesri M, Abdia Y, Barberio J, Tong A, Zhang D, et al. Association of osteoporosis medication use after hip fracture with prevention of subsequent nonvertebral fractures: an instrumental variable analysis. JAMA Netw Open. 2018;1(3):e180826.
17. Greenspan SL, Wyman A, Hooven FH, Adami S, Gehlbach S, Anderson FA Jr, et al. Predictors of treatment with osteoporosis medications after recent fragility fractures in a multinational cohort of postmenopausal women. J Am Geriatr Soc. 2012;60(3):455–61.
18. Jha S, Wang Z, Laucis N, Bhattacharyya T. Trends in media reports, oral bisphosphonate prescriptions, and hip fractures 1996–2012: an ecological analysis. J Bone Miner Res. 2015;30(12):2179–87.
19. Geusens P, Bours SPG, Wyers CE, van den Bergh JP. Fracture liaison programs. Best Pract Res Clin Rheumatol. 2019;33(2):278–89.
20. Riggs BL, Melton LJ 3rd. Involutional osteoporosis. N Engl J Med. 1986;314(26):1676–86.
21. Cosman F, Lindsay R, LeBoff M, Jan de Beur S, Tanner B. Clinician's guide to prevention and treatment of osteoporosis 2013. Available from: http://www.saegre.org.ar/biblioteca/osteoporosis/nof%202013.pdf.
22. 2019 ISCD Official Positions 2019. Available from: https://iscd.app.box.com/s/5r713cfzvf4gr28q7zdccg2i7169fv86.
23. Buckley L, Guyatt G, Fink HA, Cannon M, Grossman J, Hansen KE, et al. American college of rheumatology guideline for the prevention and treatment of glucocorticoid-induced osteoporosis. Arthritis Rheumatol. 2017;69(8):1521–37.
24. Camacho PM, Petak SM, Binkley N, Clarke BL, Harris ST, Hurley DL, et al. American association of clinical endocrinologists and American college of endocrinology clinical practice guidelines for the diagnosis and treatment of postmenopausal osteoporosis - 2016—executive summary. Endocr Pract. 2016;22(9):1111–8.
25. Krall EA, Dawson-Hughes B. Smoking increases bone loss and decreases intestinal calcium absorption. J Bone Miner Res. 1999;14(2):215–20.
26. Laitinen K, Valimaki M. Alcohol and bone. Calcif Tissue Int. 1991;49(Suppl):S70–3.
27. Gregg EW, Cauley JA, Seeley DG, Ensrud KE, Bauer DC. Physical activity and osteoporotic fracture risk in older women. Study of osteoporotic fractures research group. Ann Intern Med. 1998;129(2):81–8.
28. Black DM, Rosen CJ. Clinical practice. Postmenopausal osteoporosis. N Engl J Med. 2016;374(3):254–62.
29. Ross AC, Taylor CL, Yaktine AL, Del Valle HB, editors. Dietary reference intakes for calcium and vitamin D. The National Academies Collection: reports funded by National Institutes of Health. Washington, DC: National Academies Press; 2011.
30. Chapuy MC, Arlot ME, Duboeuf F, Brun J, Crouzet B, Arnaud S, et al. Vitamin D3 and calcium to prevent hip fractures in elderly women. N Engl J Med. 1992;327(23):1637–42.
31. Grant AM, Avenell A, Campbell MK, McDonald AM, MacLennan GS, McPherson GC, et al. Oral vitamin D3 and calcium for secondary prevention of low-trauma fractures in elderly people (Randomised Evaluation of Calcium Or Vitamin D, RECORD): a randomised placebo-controlled trial. Lancet. 2005;365(9471):1621–8.
32. Haas AV, LeBoff MS. Osteoanabolic agents for osteoporosis. J Endocr Soc. 2018;2(8):922–32.
33. McClung MR. Bisphosphonates. Endocrinol Metab Clin N Am. 2003;32(1):253–71.

34. Peng J, Liu Y, Chen L, Peng K, Xu Z, Zhang D, et al. Bisphosphonates can prevent recurrent hip fracture and reduce the mortality in osteoporotic patient with hip fracture: a meta-analysis. Pak J Med Sci. 2016;32(2):499–504.
35. Liberman UA, Weiss SR, Broll J, Minne HW, Quan H, Bell NH, et al. Effect of oral alendronate on bone mineral density and the incidence of fractures in postmenopausal osteoporosis. The alendronate phase III osteoporosis treatment study group. N Engl J Med. 1995;333(22):1437–43.
36. Black DM, Cummings SR, Karpf DB, Cauley JA, Thompson DE, Nevitt MC, et al. Randomised trial of effect of alendronate on risk of fracture in women with existing vertebral fractures. Fracture intervention trial research group. Lancet. 1996;348(9041):1535–41.
37. Cummings SR, Black DM, Thompson DE, Applegate WB, Barrett-Connor E, Musliner TA, et al. Effect of alendronate on risk of fracture in women with low bone density but without vertebral fractures: results from the fracture intervention trial. JAMA. 1998;280(24):2077–82.
38. Harris ST, Watts NB, Genant HK, McKeever CD, Hangartner T, Keller M, et al. Effects of risedronate treatment on vertebral and nonvertebral fractures in women with postmenopausal osteoporosis: a randomized controlled trial. Vertebral efficacy with Risedronate therapy (VERT) study group. JAMA. 1999;282(14):1344–52.
39. Inderjeeth CA, Glendenning P, Ratnagobal S, Inderjeeth DC, Ondhia C. Long-term efficacy, safety, and patient acceptability of ibandronate in the treatment of postmenopausal osteoporosis. Int J Women's Health. 2015;7:7–17.
40. Chesnut CH 3rd, Skag A, Christiansen C, Recker R, Stakkestad JA, Hoiseth A, et al. Effects of oral ibandronate administered daily or intermittently on fracture risk in postmenopausal osteoporosis. J Bone Miner Res. 2004;19(8):1241–9.
41. Black DM, Delmas PD, Eastell R, Reid IR, Boonen S, Cauley JA, et al. Once-yearly zoledronic acid for treatment of postmenopausal osteoporosis. N Engl J Med. 2007;356(18):1809–22.
42. Lyles KW, Colon-Emeric CS, Magaziner JS, Adachi JD, Pieper CF, Mautalen C, et al. Zoledronic acid and clinical fractures and mortality after hip fracture. N Engl J Med. 2007;357(18):1799–809.
43. Khan AA, Morrison A, Hanley DA, Felsenberg D, McCauley LK, O'Ryan F, et al. Diagnosis and management of osteonecrosis of the jaw: a systematic review and international consensus. J Bone Miner Res. 2015;30(1):3–23.
44. Khosla S, Bilezikian JP, Dempster DW, Lewiecki EM, Miller PD, Neer RM, et al. Benefits and risks of bisphosphonate therapy for osteoporosis. J Clin Endocrinol Metab. 2012;97(7):2272–82.
45. Black DM, Abrahamsen B, Bouxsein ML, Einhorn T, Napoli N. Atypical femur fractures: review of epidemiology, relationship to bisphosphonates, prevention, and clinical management. Endocr Rev. 2019;40(2):333–68.
46. Cummings SR, San Martin J, McClung MR, Siris ES, Eastell R, Reid IR, et al. Denosumab for prevention of fractures in postmenopausal women with osteoporosis. N Engl J Med. 2009;361(8):756–65.
47. Camacho PM, Petak SM, Binkley N, Diab DL, Eldeiry LS, Farooki A, et al. American Association of Clinical Endocrinologists/American College of Endocrinology Clinical Practice Guidelines for the diagnosis and treatment of postmenopausal osteoporosis- 2020 update executive summary. Endocr Pract. 2020;26(5):564–70.
48. McClung MR, Lewiecki EM, Cohen SB, Bolognese MA, Woodson GC, Moffett AH, et al. Denosumab in postmenopausal women with low bone mineral density. N Engl J Med. 2006;354(8):821–31.
49. Miller PD, Bolognese MA, Lewiecki EM, McClung MR, Ding B, Austin M, et al. Effect of denosumab on bone density and turnover in postmenopausal women with low bone mass after long-term continued, discontinued, and restarting of therapy: a randomized blinded phase 2 clinical trial. Bone. 2008;43(2):222–9.
50. Neer RM, Arnaud CD, Zanchetta JR, Prince R, Gaich GA, Reginster JY, et al. Effect of parathyroid hormone (1-34) on fractures and bone mineral density in postmenopausal women with osteoporosis. N Engl J Med. 2001;344(19):1434–41.

51. Leder BZ, O'Dea LS, Zanchetta JR, Kumar P, Banks K, McKay K, et al. Effects of abaloparatide, a human parathyroid hormone-related peptide analog, on bone mineral density in postmenopausal women with osteoporosis. J Clin Endocrinol Metab. 2015;100(2):697–706.
52. Miller PD, Hattersley G, Riis BJ, Williams GC, Lau E, Russo LA, et al. Effect of abaloparatide vs placebo on new vertebral fractures in postmenopausal women with osteoporosis: a randomized clinical trial. JAMA. 2016;316(7):722–33.
53. Black DM, Bilezikian JP, Ensrud KE, Greenspan SL, Palermo L, Hue T, et al. One year of alendronate after one year of parathyroid hormone (1-84) for osteoporosis. N Engl J Med. 2005;353(6):555–65.
54. Tsai JN, Uihlein AV, Lee H, Kumbhani R, Siwila-Sackman E, McKay EA, et al. Teriparatide and denosumab, alone or combined, in women with postmenopausal osteoporosis: the DATA study randomised trial. Lancet. 2013;382(9886):50–6.
55. Lewiecki EM. Role of sclerostin in bone and cartilage and its potential as a therapeutic target in bone diseases. Ther Adv Musculoskelet Dis. 2014;6(2):48–57.
56. Cosman F, Crittenden DB, Adachi JD, Binkley N, Czerwinski E, Ferrari S, et al. Romosozumab treatment in postmenopausal women with osteoporosis. N Engl J Med. 2016;375(16):1532–43.
57. Saag KG, Petersen J, Brandi ML, Karaplis AC, Lorentzon M, Thomas T, et al. Romosozumab or alendronate for fracture prevention in women with osteoporosis. N Engl J Med. 2017;377(15):1417–27.
58. Rossouw JE, Anderson GL, Prentice RL, LaCroix AZ, Kooperberg C, Stefanick ML, et al. Risks and benefits of estrogen plus progestin in healthy postmenopausal women: principal results from the women's health initiative randomized controlled trial. JAMA. 2002;288(3):321–33.
59. Ettinger B, Black DM, Mitlak BH, Knickerbocker RK, Nickelsen T, Genant HK, et al. Reduction of vertebral fracture risk in postmenopausal women with osteoporosis treated with raloxifene: results from a 3-year randomized clinical trial. Multiple Outcomes of Raloxifene Evaluation (MORE) Investigators. JAMA. 1999;282(7):637–45.
60. Chesnut CH 3rd, Silverman S, Andriano K, Genant H, Gimona A, Harris S, et al. A randomized trial of nasal spray salmon calcitonin in postmenopausal women with established osteoporosis: the prevent recurrence of osteoporotic fractures study. PROOF Study Group. Am J Med. 2000;109(4):267–76.
61. Colon-Emeric C, Nordsletten L, Olson S, Major N, Boonen S, Haentjens P, et al. Association between timing of zoledronic acid infusion and hip fracture healing. Osteoporos Int. 2011;22(8):2329–36.
62. Sheu A, Diamond T. Secondary osteoporosis. Aust Prescr. 2016;39(3):85–7.

Chapter 12
Geriatric Hip Fracture Care in Low- and Middle-Income Countries

Hannah Elsevier, Sara Kiani, and Theodore Miclau

Introduction

The scope of this chapter is the epidemiology, management, and outcomes of geriatric hip fractures in low- and middle-income countries (LMICs). We define LMICs as those with World Bank designations of low, lower-middle, and upper-middle income, based on per capita gross national income (GNI) (Table 12.1) [1]. As a result of the aging global population, geriatric hip fractures have become increasingly common throughout the world and are anticipated to reach an estimated annual global incidence of 4.5 million in 2050 [2]. World Health Organization (WHO) estimations project that by 2050, 80% of the global elderly population will reside in LMICs [3]. With this increase in age comes increased incidence and burden of hip fractures. In addition to advanced age, risk factors for geriatric hip fracture include female gender, frailty, fragility, and prior fracture. Orthogeriatric co-management and early surgery can be difficult to accomplish in low-resource settings, but they have been shown to improve geriatric hip fracture outcomes. Barriers to surgery persist in LMICs, and non-operative treatment results in inferior outcomes and increased mortality. The literature on geriatric hip fracture management in LMICs is scarce but highlights efforts to minimize delays to surgery and improve access to affordable implants. International organizations have put forth guidelines and support networks to facilitate efforts to minimize complications,

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Table 12.1 World Bank 2021 classification of low-income, lower-middle income, and upper-middle income countries based on per capita GNI and subcategorized by region. (Created by authors with data from: World Bank Country and Lending Groups [Internet] [1])

Low income	Lower middle income	Upper middle income
East Asia and Pacific		
Korea, Dem. People's Rep.	Cambodia, Kiribati, Lao PDR, Micronesia, Mongolia, Myanmar, Papua New Guinea, the Philippines, Solomon Islands, Timor-Leste, Vanuatu, Vietnam	American Samoa, China, Fiji, Indonesia, Malaysia, Marshall Islands, Samoa, Thailand, Tonga, Tuvalu
Europe, and Central Asia		
Tajikistan	Kyrgyz Republic, Moldova, Ukraine, Uzbekistan	Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Georgia, Kazakhstan, Kosovo, Montenegro, North Macedonia, Russian Federation, Serbia, Turkey, Turkmenistan
Latin America and Caribbean		
Haiti	Bolivia, El Salvador, Honduras, Nicaragua	Argentina, Belize, Brazil, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Grenada, Guatemala, Guyana, Jamaica, Mexico, Paraguay, Peru, St. Lucia, St. Vincent and the Grenadines, Suriname, Venezuela
Middle East and North Africa		
Syrian Arab Republic, Yemen	Algeria, Djibouti, Egypt, Morocco, Tunisia, West Bank and Gaza	Iran, Islamic Rep., Iraq, Jordan, Lebanon, Libya
South Asia		
Afghanistan	Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka	Maldives
Sub-Saharan Africa		
Burkina Faso, Burundi, Central African Republic, Chad, Dem. Rep. Congo, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Somalia, South Sudan, Sudan, Togo, Uganda	Angola, Benin, Cabo Verde, Cameroon, Comoros, Congo, Côte d'Ivoire, Eswatini, Ghana, Kenya, Lesotho, Mauritania, Nigeria, São Tomé and Principe, Senegal, Tanzania, Zambia, Zimbabwe	Botswana, Equatorial Guinea, Gabon, Namibia, South Africa

prevent future falls, and achieve early mobilization. Geriatric hip fractures in LMICs present an opportunity to improve patient outcomes by investing in healthcare systems, education, and research.

Epidemiology

The Hip Fracture Epidemic: Aging Populations in LMICs

As the world's population ages, the incidence of geriatric hip fractures is anticipated to increase and shift from primarily impacting high-latitude, high-income countries (HICs) to disproportionately affecting LMICs. Throughout the world, there has been a trend toward increased life expectancy, which has, in turn, increased the incidences of geriatric illness and injuries faced by countries across the globe. Geriatric hip fractures represent a major source of global morbidity and mortality, more so than nearly any other age-related or osteoporotic injury [2]. As the burden of geriatric hip fractures shifts to lower resourced regions, a global effort must be made to better understand these trends and more effectively meet the needs of our global elderly population.

Estimates suggest that, worldwide, the number of people over 80 years of age will increase from 143 million in 2019 to 426 million in 2050 and 881 million by 2100 [2]. LMICs will have a more significant shift in their population pyramid as life expectancy improves more substantially in these regions compared to HICs, which have already made this transition. In 2019, 38% of the population over 80 years of age lived in Europe and North America, regions with a high proportion of HICs. This number is anticipated to decline to 26% in 2050 and 17% in 2100 as the population in LMICs ages due to advances leading to increased life expectancy [4]. On the other hand, the number of hip fractures in Asia will have more than doubled by 2050, accounting for nearly 50% of the world's hip fractures [5].

As these epidemiological transitions occur in Asia, Africa, and Latin America, particularly in the LMICs, the aging population will be accompanied with an increased prevalence of osteoporosis [6–8]. As a result, the largest growth in hip fracture incidence is expected to occur in these three continents, resulting in a high fracture burden that will have significant economic and social impacts. For example, among Asian Federation of Osteoporosis Societies (AFOS) countries, about half of which are classified as low- or middle–income countries, there is expected to be a 2.28-fold increase in hip fractures by 2050 as compared to 2018. China and India are expected to account for 79% of the total increase [5]. In Latin America, there is expected to be a 700% increase in hip fractures in individuals aged 65 or older [8]. Data from Mexico specifically estimated a fivefold increase in the number of hip fractures from 2005 to 2050, but this estimate likely underestimates the growth [9]. The projections in the literature are limited in their ability to provide a comprehensive understanding of the current and future burden of hip fractures in low- and middle-income countries, largely due to the lack of data from these countries and inconsistent methodology across studies.

Global Burden of Disease: Death and Disability

Globally, musculoskeletal injury led to more loss of productivity and life, as measured by disability adjusted life years (DALYs), than HIV, tuberculosis, and malaria combined, which are the better funded and more publicized global health initiatives [10]. Though the Global Burden of Disease (GBD) studies conducted by the World Health Organization (WHO) do not specify hip fractures within their illness and injury classification system, an analysis of DALYs attributable to falls in the population over age 70 provides an overview of the general trends (Fig. 12.1). Due to their large populations, the loss of productive years of life attributed to geriatric falls in India and China vastly outweighs that of much of the rest of the world. There have been suggestions that even this may be an underestimate of the true impact of fall-associated disability in these regions. The global assessment of DALYs does not adequately capture regional variations in societal burden, not only by the injury in isolation but also in the context of the local environment. For instance, a hip fracture in a region without

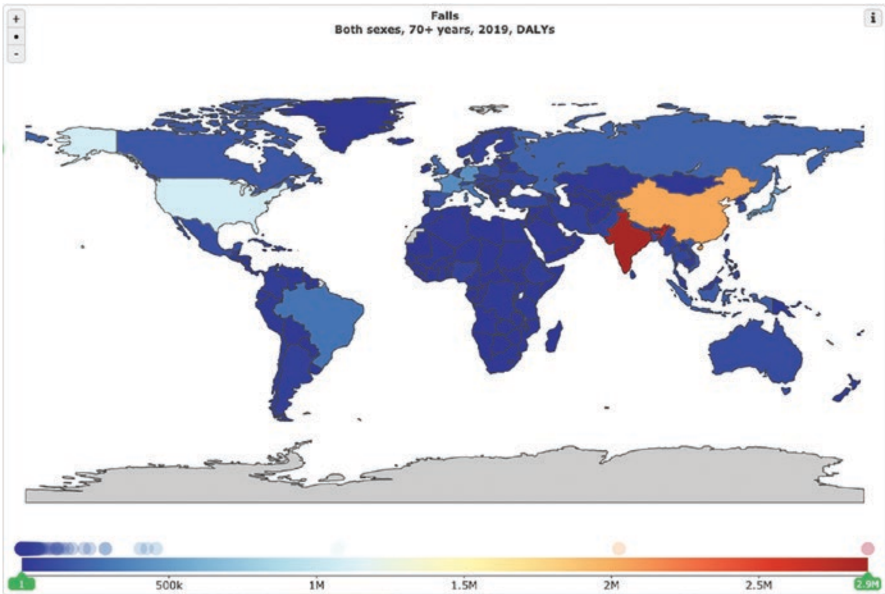

Fig. 12.1 Global number of disability adjusted life years (DALYs) attributed to falls in the elderly (>70 years of age)
China and India account for a disproportionate number of global DALYs attributed to falls in the elderly. (Reprinted with permission from: Institute for Health Metrics and Evaluation (IHME) [70])

wheelchairs, elevators, or paved surfaces may render an elderly patient completely homebound, while the same injury in a region with this infrastructure may be much less debilitating. Regional estimates of disability may provide more accurate assessments of the true impact of geriatric hip fractures, as they can better account for the impact of culture, infrastructure, and social support on the recovery process.

The individual factors affecting disability and quality of life (QOL) after hip fracture likely vary widely both across and within countries. QOL is impacted by injury factors, individual patient factors, and regional or societal factors. Hlaing et al. 2020 demonstrated that in Myanmar, the functional limitations following hip fracture led to a greater loss of QOL in women, who had less social support as a consequence of their gender [11]. Amphansap et al. in 2018 demonstrated that in Thailand, the initial sharp decline in QOL seen after hip fracture was diminished by nutritional supplementation and early surgery [12]. The duration of reduced QOL after hip fracture also varies on both individual and regional levels. While QOL in the patient population in the previously mentioned Thai study did not return to baseline a full year after injury, patients in a study out of Mexico showed similar initial reductions in QOL but that had nearly returned to baseline by 1 year [9].

Increased research is needed to understand the factors impacting hip fracture–related disability and QOL in LMICs in order to better understand and mitigate the long-term detrimental individual and societal impacts of hip fracture.

Economic Impact: Direct and Indirect, Individual and Societal

The direct and indirect economic impact of geriatric hip fractures can be felt on both individual and societal levels. Societal costs consider the economic burden to the country or region as a whole and are significantly impacted by the disability and death caused by geriatric hip fractures. Both direct costs of treatment and indirect costs related to lost productivity vary substantially across healthcare systems, countries, and cultures. Assessing indirect and societal costs is especially important in LMICs, where hip fracture patients are presenting at younger ages and living in cultures and economies that support or require work into the later years of life. The evaluations that go into assessing the economic burden attributed to geriatric hip fractures in HICs do not necessarily translate directly to evaluating those in LMICs.

The direct costs of hospitalization, surgery, and rehabilitation in LMICs may differ significantly from those seen in HICs. These costs are significant; for example, the expected increase in hip fractures in Latin America is projected to have a direct cost of 13 billion USD [8]. Within a single country, direct costs can vary widely across health systems and insurance models. It has been estimated that nearly 80% of the populations of low-income countries have no form of health care insurance [13]. As a consequence, prior to receiving treatment in many LMICs, hip fracture patients' families may be expected to purchase surgical supplies, including expensive implants, sutures, surgical gloves, fluids, and antibiotics [14]. This can lead to delayed surgery, longer hospital stays, and worse outcomes, which consequently increase the indirect cost felt by the patient and their support system. Even in settings where public or private health insurance systems are in place to reduce the individual financial burden, residual direct costs, and subsequent indirect costs can be devastating to patients and their families.

Indirect costs are not due to medical management of a disease specifically, but rather due to the lost wages, lost productivity, and additional costs patients would not otherwise experience. Missed days of work, both pre- and postoperative, can add to the financial burden, especially for those who work in agriculture or the informal sector. Families in LMICs struggle to cover non-medical costs, such as transportation and food, which can further the burden of hospitalization [14]. Many estimates of hip fracture costs focus primarily on direct medical costs, despite the magnitude of these indirect costs. A model that considers both direct and indirect costs of hip fractures in Turkey estimated the 2019 burden to be 455 million USD. The projected 5-year burden was estimated to be 2.42 billion USD, with 23% of the costs coming from patient productivity losses [15]. While there is clear evidence that hip fractures are a significant financial burden on individuals and society, the data quantifying the burden of geriatric hip fractures in LMICs is still limited and warrants further investigation.

Risk Factors

Non-modifiable Factors: Age and Sex

The risk factors for hip fractures in high-income countries are well understood and overlap with those seen in LMICs. Two significant non-modifiable patient factors include age and gender. Hip fractures disproportionately affect women, who tend to have longer life expectancies and lower bone mineral density (BMD) after menopause. Though estimates vary significantly throughout the world, it has been estimated that roughly three-quarters of elderly individuals suffering from hip fractures are women. For instance, in the São Paulo, Brazil Ageing and Health (SPAH) study, the age-standardized incidence of hip fractures was 421.2/100,000 person-years in women and 89.9/100,000 in men [16]. While in Sri Lanka, women accounted for 79% of crude hip fracture rates, with an incidence of 132.2/100,000 and 35.3/100,000 person-years in women and men, respectively [6]. The difference in elderly hip fracture incidence by gender is significant throughout most of the world and has been shown to widen with advancing age.

An exception to this otherwise universal trend can be seen in some local studies and may be a consequence of study design or social factors, leading to the underrepresentation of women. For example, some hospital-based studies in India have shown higher rates of hip fracture among men, who also tend to present at younger ages [17]. This divergence from the global trend may be a consequence of increased use of alcohol in men or an increased unmet need in women. Studies that calculate hip fracture incidence from hospital admissions or surgical intervention miss the portions of the population that never make it to the hospital or operating room. Accurately capturing the unmet surgical need of vulnerable populations in LMICs represents a major area of focus for future research and investment.

Modifiable Risks: Fragility, Frailty, and Falls

Modifiable patient factors are those that may be targeted by interventions in at-risk populations. Addressing these modifiable risk factors can drastically reduce the risk of hip fracture. The major modifiable risk factors for geriatric hip fractures are fragility (low bone mineral density/osteopenia/osteoporosis/prior fractures), frailty (poor nutrition and overall health), and susceptibility to falls.

Bone mineral density (BMD) decreases with age and low BMD has been shown to be associated with increased risk of hip fracture [16]. Osteopenia and osteoporosis are relative measures of BMD, defined by T-scores of −1 to −2.5 and <−2.5, respectively, with the T-score comparing BMD to that of a healthy young adult. In Brazil, decreased total hip BMD in the elderly has been shown to be predictive (RR 1.56, 95% CI 1.21–2.01) of non-vertebral fragility fractures, including hip fractures [16]. Bone mineral density in the geriatric populations of LMICs can be affected by a number of factors, including nutrition, medication use, and comorbid conditions.

Patients at risk of sustaining an osteoprotic hip fracture can be identified using country-specific FRAX models, which are based on clinical risk factors and BMD. In regions without access to densitometry, clinical risk factors alone can be used to predict fracture risk based on epidemiologic data. While this could potentially be a powerful tool in countries with limited resources, it relies on data that may be incomplete or absent. In LMICs that lack epidemiologic hip fracture data, the application of fracture rates from Sweden or other HICs with complete data thought to be representative of the population have been implemented [18]. It is hard to determine whether the method of using a surrogate population is an effective technique for estimating fracture risk in the absence of data. In LMICs that have some epidemiologic data, FRAX models may be constructed from local studies with geographic variability, low sample size, incomplete capture of cases, or short follow-up [16]. Studies on osteoporotic hip fracture epidemiology and risk factors in LMICs are needed to better understand, predict, and prevent geriatric hip fractures.

Both general nutritional and specific vitamin D deficiencies have been shown to be associated with increased risk of hip fractures. Vitamin D is a fat-soluble vitamin obtained through diet and exposure to sunlight. At present, hip fractures are more prevalent in higher latitude countries, further from the equator and direct sunlight. In China, research showed populations at higher latitudes were at increased risk of fracture, an association likely secondary to hypovitaminosis D [19]. While in Brazil, a country located mostly south of the equator, the southern regions, furthest from the equator, had the highest incidence of geriatric hip fracture [16]. However, even in regions with plentiful sunlight, hypovitaminosis D can be significant and is associated with hip fracture. A recent study in Thailand found that vitamin D deficiency

(<20 ng/mL) and insufficiency (20–30 ng/mL) were common, occurring in 46.3% and 32.1% of elderly hip fracture patients, respectively [20]. Similarly, in Myanmar, mean serum vitamin D was found to be significantly decreased in the older population [11]. In LMICs, where there is adequate daily sun, recommendations can be made to patients to get outside daily, especially elderly individuals recovering from hip fracture, who may not otherwise leave their homes. Dietary recommendations and vitamin D supplementation can be pursued in regions or for individuals where this is not an option.

Generalized nutritional deficiency is a significant risk factor for a fragility hip fracture and poor outcome after hip fracture surgery [21]. Inadequate nutrition contributes to anemia and frailty in the elderly, especially in countries with diminished food security [22]. Low body mass index (BMI) and associated malnutrition can be a significant problem in the elderly. This may be especially true in LMICs, where higher rates of poverty limit the ability to address nutritional needs. Targeted nutritional interventions are needed to address this risk factor, as elderly individuals may be unable to obtain adequate nutrition without family, community, or social support. Research in Thailand demonstrates that nutritional supplementation can blunt the initial sharp decline in quality of life after hip fracture [12].

With obesity on the rise throughout the world, the problems of malnutrition and fragility are not only found in patients with low BMI but also in those with obesity and diabetes. Diabetes has also increased the problem of end-stage renal disease (ESRD) and associated low bone mineral density. Research in Palestine has shown that 42.8% of ESRD patients had osteoporosis and 40.2% had osteopenia, with increasing incidence in those >60 years of age [23]. This puts those with ESRD at increased risk for hip fracture unless osteoporosis and osteopenia are addressed. Endocrine workups and long-term primary care follow-up for these patients should include nutritional optimization, treatment of low bone mineral density, and education on hip fracture risk reduction. Improving access to primary care in LMICs can reduce the impact of medical comorbidities, and public health campaigns can improve health literacy to improve nutrition, reduce chronic illness, and decrease the risk of hip fracture.

Elderly patients throughout the world experience physiologic changes that place them at increased risk of falling. Accumulation of medical comorbidities with age often results in increased use of prescription medications in the geriatric populations throughout the world. Seixas et al. demonstrated that in Brazil, nearly 30% of patients over the age of 80 are taking five or more medications, which is similar to rates seen in Europe [24]. Polypharmacy and use of potentially inappropriate medications (PIM) in the elderly can increase the risk of fall and fracture due to adverse effects such as orthostatic hypotension, delirium, and gait instability. Guidelines on PIMs vary throughout the world but perhaps the most well known is Beers Criteria, which was published in 1991 and has since been updated and modified by various national organizations to be inclusive of new medication classes and regional prescribing practices (Table 12.2) [25]. Country-specific modifications of Beers Criteria typically come from high-income nations with well-developed healthcare systems and ample geriatric pharmaceutical literature. The data on polypharmacy in the elderly in LMICs is scarce, but understanding prescribing practices and the impact on falls is a

Table 12.2 2019 American Geriatrics Society Beers Criteria® for potentially inappropriate medication use in older adults with a history of falls or fractures[a]

Drug(s)	Rationale	Recommendation	Quality of evidence	Strength of recommendation
Antiepileptics Antipsychotics[b] Benzodiazepines Non-benzodiazepine, benzodiazepine receptor agonist hypnotics Eszopiclone Zaleplon Zolpidem Antidepressants TCAs - tricyclic antidepressants SSRIs - Selective serotonin reuptake inhibitors SNRIs - Serotonin and norepinephrine reuptake inhibitors Opioids	May cause ataxia, impaired psychomotor function, syncope, additional falls; shorter-acting benzodiazepines are not safer than long-acting ones. If one of the drugs must be used, consider reducing use of other CNS-active medications that increase risk of falls and fractures (i.e., antiepileptics, opioid-receptor agonists, antipsychotics, antidepressants, non-benzodiazepine and benzodiazepine receptor agonist hypnotics, other sedatives/hypnotics) and implement other strategies to reduce fall risk. Data for antidepressants are mixed but no compelling evidence that certain antidepressants confer less fall risk than others.	Avoid unless safer alternatives are not available; avoid antiepileptics except for seizure and mood disorders Opioids: avoid except for pain management in the setting of severe acute pain (e.g., recent fractures or joint replacement)	Opioids: moderate All others: high	Strong

This table includes a shortened list of medications that are potentially inappropriate for use in older adults with a history of falls or fractures

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[a]The primary target audience is the practicing clinician. The intentions of the criteria include (1) improving the selection of prescription drugs by clinicians and patients, (2) evaluating patterns of drug use within populations, (3) educating clinicians and patients on proper drug usage, and (4) evaluating health outcome, quality of care, cost, and utilization data

[b]May be required to treat concurrent schizophrenia, bipolar disorder, and other selected mental health conditions but should be prescribed in the lowest effective dose and shortest possible duration

critical component of curbing the hip fracture epidemic. Simple, low-cost education programs in LMICs can help orthopaedic surgeons and primary care physicians reduce their elderly patients' risk of hip fracture by avoiding polypharmacy and PIMs.

In the elderly in LMICs, as in HICs, prior non-vertebral fracture is predictive of hip fracture [16]. Fracture liaison services (FLS) are designed to identify patients at risk of repeat fracture and provide structured standardized interventions that can be implemented in both high- and low-resource environments alike. FLSs are discussed in more depth in the postoperative management section of this chapter as a recommended component of postoperative care for all hip fracture patients. By identifying individuals at risk of fracture, optimizing bone mineral density, and completing falls risk assessments, physicians and surgeons can prevent the morbidity and mortality caused by a second osteoporotic fracture.

The major risk factors of hip fractures in LMICs are similar to those of HICs. Age and gender consistently are the most significant non-modifiable risk factors. Identifying the demographic most at risk allows LMICs to target interventions and increase impact while minimizing cost. Identifying modifiable risk factors is of increased importance, as they provide targets for intervention. Low BMD can be addressed by providing medications to treat low bone mass, addressing nutritional deficiencies, and treating comorbidities such as diabetes. Different approaches to hip fracture risk reduction are needed in regions with variable access to medications and other healthcare resources. Research and resources in LMICs can be directed toward improving access to primary care, reducing polypharmacy, and minimizing inappropriate medication prescribing in the elderly. Public health initiatives using simple community level education to improve overall nutrition, vitamin D, physical conditioning, and fall prevention are also low-cost steps that can be taken to reduce the risk of geriatric hip fractures in LMICs.

Preoperative Management

Orthogeriatric Co-management

Achieving streamlined multidisciplinary orthogeriatric co-management of hip fracture patients presents a challenge to healthcare systems in LMICs, which are strained by limited resources. A standardized multidisciplinary approach to the management of geriatric hip fractures and associated co-morbidities has been shown to improve outcomes and reduce mortality, though most available evidence of these gains comes from high-income countries with well-developed healthcare systems [26]. Across the globe, incorporation of comprehensive geriatric assessment (CGA) into preoperative hip fracture protocols varies significantly. Models range from completely integrated orthopaedic and geriatric co-management to primary management by one service, with the other following as a consultant [27]. Systems that rely on protocol-based co-management place shared responsibility on all team members and have shown great success; however, implementation is not always practical in low-volume or limited-resource settings [28].

Orthogeriatric hip fracture systems rely on numerous resources that are scarce in LMIC, most notably geriatricians and orthopaedic surgeons, which are absent from many hospitals across the globe. Furthermore, successful hip fracture protocols in high-income countries often include anesthesiologists, nurses, physical and occupational therapists, nutritionists, endocrinologists, and social workers [29]. Establishing orthogeriatric co-management is a cost-effective redistribution of available resources in well-established, well-resourced hospitals in HICs [30]. However, in LMICs, tertiary care centers are often so strained for resources that time to OR and patient outcomes are more dependent on hospital factors, such as bed, OR, X-ray, implant, and surgeon availability, than the efficient preoperative medical optimization targeted by orthogeriatric co-management programs [14, 31, 32].

International organizations have developed initiatives to bring standardized orthogeriatric care and hip fracture protocol best practices to all regions of the world, including LMICs. In 2018, the Fragility Fracture Network (FFN) published a global call to action urging the world's policy-makers to address the increased incidence and burden of fragility fractures worldwide with evidence-based multidisciplinary management best practices. The global call to action was endorsed and co-sponsored by professional organizations throughout the world and had special focus on LMICs [33]. To date, regional FFN care guidelines are only listed for high-income countries, with no published guidelines in FFN's Africa, Latin America, and Middle East regions [34]. This disparity between intention and implementation highlights the challenge of orthogeriatric care in LMICs.

To complement FFN's focus on policy, the AO Foundation's AO Trauma Orthogeriatrics initiatives focus on clinical education, including a free orthogeriatrics app, educational core competencies, and a series of best practice clinical summary documents [35]. With the aim of establishing improved assessment of orthogeriatric co-management models across the globe, AOTrauma published a set of standardized outcome parameters and timepoints [36]. Although experts from all regions of the world were invited to contribute and there was a focus on easy-to-assess parameters, the authors and regions represented in the literature used to create this tool are from HICs, potentially limiting its applicability in LMICs.

Prophylactic Antibiotics

Surgical site infections (SSI) complicate the postoperative course of geriatric hip fracture patients in both high- and low-income settings. Though there is limited SSI data specific to geriatric hip fracture surgery in LMICs, rates of SSIs after operative fixation of closed fractures have been shown to be nearly three times higher in LMICs than after comparable surgery in HICs [37]. Routine administration of appropriately timed prophylactic preoperative IV antibiotics, in conjunction with sterile operating procedures, has been shown to reduce the rate of SSIs, but patient and healthcare factors specific to LMICs may require alternative or multimodal SSI prophylaxis. In addition to standard administration of cephalosporins, supplemental approaches to minimize the rate of SSIs have been implemented in LMICs [38]. These include use of broad-spectrum IV antibiotics in high-risk patients, addition of antibiotics to cement for hip arthroplasties, and increased duration of postoperative antibiotics.

Many LMICs have been disproportionately affected by the HIV epidemic; thus, any discussion of minimizing postoperative SSIs in LMICs must involve consideration of HIV management. Variability in preoperative access and adherence to antiretroviral therapy (ART) leads HIV-positive patients to be at variable risk of SSIs. In Malawi, implementation of national and WHO guidelines ensures that preoperatively, in addition to IV cefuroxime, HIV-positive elective total hip arthroplasty patients also receive trimethoprim-sulfamethoxazole [38]. All patients in this study, regardless of HIV status, also had implants secured with antibiotic cement. Incorporating similar standardized antibiotic guidelines into national hip fracture protocols could improve the rates of postoperative surgical site infections in HIV-positive hip-fracture patients.

The resource limitations faced by many healthcare systems in LMICs can increase the risk of SSI. Lower extremity intramedullary nails have been shown to have slightly higher and notably variable rates of infection in LMICs, which has been attributed to operative technique considerations specific to these resource limitations [37]. Lack of fluoroscopy, for instance, necessitates open rather than closed reduction during intramedullary nailing of hip fractures, which can lead to increased operative time and extensile or multiple incisions, both known risk factors of SSIs. Implants such as SIGN Fracture Care International's SIGN Hip Construct (SHC), specifically designed for hip fracture fixation without fluoroscopy in LMICs and accompanied by an international registry, can help potentially reduce the impact of this risk factor for SSIs in LMICs.

It has been suggested that in hospitals in LMICs with delayed hip fracture presentation and operative intervention, longer duration of postoperative antibiotics may be beneficial; however, conclusive evidence is lacking [37]. More research on perioperative antibiotic prophylaxis in geriatric hip fracture surgery in LMICs is needed to better understand and reduce the risk of SSI. Despite rates of SSIs being higher in some LMICs than that reported by HICs, these data may still be an underestimate of the true incidence. While HICs generally have mandatory or standardized voluntary reporting of SSIs, LMICs SSI reporting is often limited to single tertiary care hospitals [39]. In the absence of mandatory or standardized reporting, in many hospitals, these infections likely remain unreported.

Anticoagulation and Anemia

Though guidelines exist for negotiating the risk of operating through anticoagulation in order to prioritize expedient surgery for hip fracture fixation or replacement, clinical decision-making in these circumstances remains a balancing act, which can be more challenging in LMICs. There is general consensus that rapidly correctable comorbidities, such as anemia, should not delay operative treatment of geriatric hip fractures [31]. However, in regions without ample access to safe blood products or anticoagulation reversal agents, the risk-benefit analysis of early surgery versus delay for medical optimization becomes more challenging. Anticoagulant medications frequently delay surgery in geriatric hip fracture patients [31].

While more aggressive initiatives for early surgery may be safer in regions where excess blood loss can be readily repleted, in many LMICs, blood products are in short supply. Only 27% of hospitals in low-income countries have an onsite blood bank, and many countries report that donated blood is not routinely tested for transfusion transmissible illnesses [14]. Inadequate nutrition contributes to anemia and frailty in the elderly, especially in LMICs with diminished food security [22]. As a consequence, patients in LMICs more frequently suffer from severe preoperative anemia [40]. A study of elective surgery patients in Republic of Congo and Madagascar demonstrated that severe preoperative anemia was associated with >8 times higher odds of postoperative complications, while mild preoperative anemia was associated with no such risk [41].

In LMICs, delays to surgery and intraoperative blood loss place geriatric hip fracture patients at increased risk of venous thromboembolic events (VTE) [42]. The use of VTE chemoprophylaxis has been shown to decrease the risk of VTE only when combined with prompt surgical treatment [43]. This has significant implications in LMICs where hip fracture surgery is frequently delayed [42]. Further research on preoperative management of anticoagulation medications, anemia, and VTE prevention in hip fracture patients in LMICs is needed.

Anesthesia and Pain Management

Lack of access to safe, affordable anesthesia is a major problem facing geriatric hip fracture patients in LMICs (Fig. 12.5) [14]. Studies show that roughly one in four hospitals in low-income countries lack reliable access to electricity, running water, and oxygen, while other anesthesia essentials such as pulse oximeters, laryngoscopes, and anesthesia machines are also largely unavailable [14]. Innovations to overcome these limitations include the development of durable low-cost pulse oximeters (Lifebox), inexpensive anesthesia machines that can operate through power outages (Glostavent and the Universal Anaesthesia Machine), and World Federation of Societies of Anaesthesiologists (WFSA) training fellowships to increase the number of anesthesiologists practicing in LMICs [14]. Increased investment in anesthesia infrastructure and training in LMICs is needed to meet the growing need for operative treatment of geriatric hip fractures in these countries.

Traditional approaches to anesthesia and pain management are challenging in geriatric hip fracture patients due to physiologic changes associated with aging and increased number of comorbidities [44]. Many medications, such as opioids, benzodiazepines, and muscle relaxants, which may be appropriate for younger patients with fractures, place geriatric patients at increased risk of delirium and subsequent falls (Table 12.2) [25]. Cognitive impairment, which is relatively common in elderly hip fracture patients, also poses a significant barrier to assessing pain and providing effective pain management [36]. Research in HICs has demonstrated that geriatric hip fracture patients benefit from the use of multimodal pain control, including regional blocks, to improve mobility and decrease systemic analgesia requirements [44]. The literature on anesthesia and pain management of geriatric hip fracture patients in LMICs is lacking.

Operative Intervention

Timely, appropriate operative treatment is critical to hip fracture management. Hip fractures can broadly be classified into two categories: intracapuslar (subcapital and transcervical femoral neck fractures) and extracapsular (basicervical fractures, intertrochanteric fractures, and subtrochanteric fractures). Operative management takes the form of either osteosynthesis or arthroplasty. Osteosynthesis involves fracture reduction and fixation. In the case of extracapsular trochanteric femur fractures, implants are typically cephalomedullary nails or sliding hip screws [7], while non-displaced or impacted intracapsular femoral neck fractures are secured using parallel implants. Displaced femoral neck fractures are treated with prosthetic replacement using either a total hip arthroplasty for younger, higher demand patients or hemiarthroplasty for older, lower demand patients. The femoral component of both types of arthroplasty can be either press-fit if the surrounding bone is of adequate quality or cemented into place in the case of osteoporotic, low-quality bone. Operative management of geriatric hip fractures in LMICs is complicated by delays to surgery, lack of affordable implants, and scarcity of resources.

Timing of Surgery

Patients in LMICs face delays to care that lead to an increased proportion of neglected or delayed hip fracture management and contribute to excess morbidity and mortality. Fracture fixation or arthroplasty performed within 48 hours has been shown to significantly reduce the morbidity and mortality associated with geriatric hip fractures [31]. Early operative treatment of hip fractures is widely accepted as the standard of care throughout the world. However, achieving timely surgery is more challenging in LMICs (Fig. 12.2).

To better understand delays in accessing timely surgical care, the Lancet Commission on Global Surgery established the Three Delays framework, which categorizes delays in seeking (First Delay), reaching (Second Delay), and receiving care (Third Delay) in low- and middle-income countries (Fig. 12.3) [32]. This framework can be used in LMICs to identify the source of delays and focus resource allocation to improve time to surgery and meet geriatric hip fracture best practice goals.

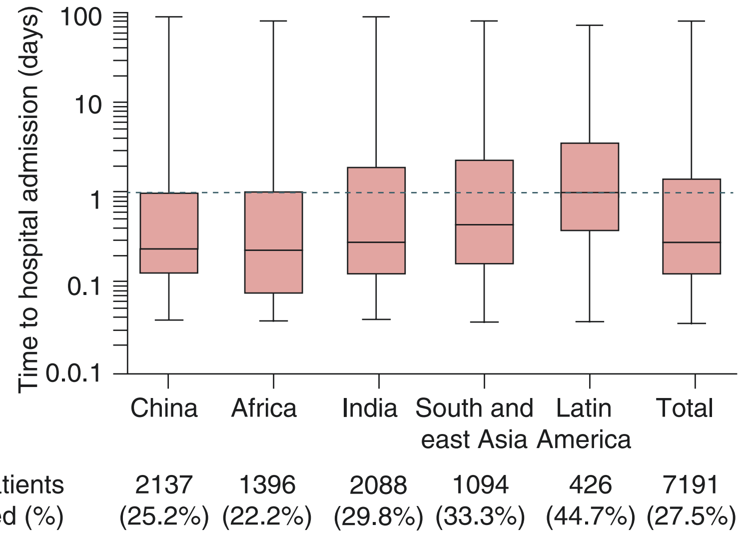

Fig. 12.2 Time from injury to admission to a treating hospital for patients with closed fractures, by region. The dotted line indicates 24 h delay. Box plots show median and IQR, with whiskers showing the full range. The proportion of patients delayed is reported in brackets. (Reprinted with permission from: Pouramin et al. [32])

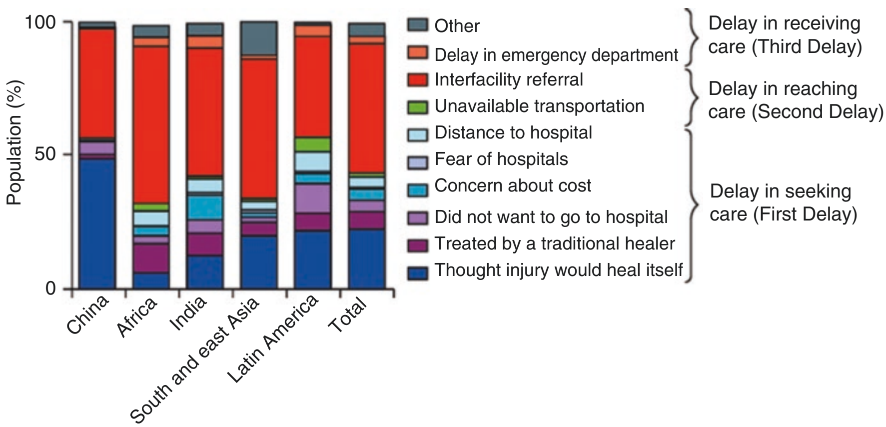

Fig. 12.3 Reasons patients with fractures had for delayed (>24 h) presentation to the hospital categorized according to the Lancet Commission on Global Surgery 2030 Three Delays framework. (Reprinted with permission from: Pouramin et al. [32])

First Delay – Seeking Care

Variations in the understanding or interpretation of injury as well as financial constraints can contribute to First Delays, with patients potentially turning to non-traditional healthcare systems or presuming their fracture will heal without operative intervention [45]. The type and severity of fracture impact a patient's impetus to seek treatment. Closed fractures incurred from a fall from standing, a mechanism for most geriatric hip fractures, are more likely to see a delay of >24 h than any other type of injury [32]. Community-based hip-fracture education initiatives to improve health literacy and familiarity with the healthcare system may represent a low-cost intervention to target the First Delay and reduce the time from injury to the time a patient seeks care.

Second Delay – Reaching Care

Patient demographic and socioeconomic factors as well as LMICs' regional infrastructure contribute to the ability of geriatric hip fracture patients to reach an adequately equipped hospital, accounting for the Second Delay. Elderly patients often have limited mobility at baseline and are likely to seek care at the closest regional medical center, which in many LMICs may not have the capability to manage hip fractures. Limited patient mobility and large distances between hospitals, in combination with limited access to pre- and inter-hospital transportation, can delay patients' presentation to a tertiary care center [32]. Delayed referral and transportation from other hospitals is common in many LMICs and has been shown to increase the risk of complications such as preoperative DVT [42]. Improving pre-hospital networks and streamlining the inter-hospital referral systems in LMICs can reduce the Second Delay, improving patients' ability to expediently reach care [31].

Third Delay – Receiving Care

Once geriatric hip fracture patients in LMICs reach a hospital capable of providing operative treatment, they may face prolonged wait times to be admitted and receive surgery, the Third Delay. Healthcare providers in LMICs have attributed Third Delays to inadequate resources and overcrowding. One study of three tertiary care hospitals in India showed that only 65% of geriatric hip fracture patients were admitted for treatment and, of those, only 30% received surgery within 48 h of admission. The remaining patients were treated within 39 days, with 3% expiring while awaiting treatment [17]. Unfortunately, these delays are not an uncommon occurrence in the over-burdened, under-resourced tertiary care hospitals of many LMICs, and allocation of surgical resources is not always fairly distributed. Women are shown to be at greater risk than men of receiving care delayed more than 24 h [32]. This potential gender bias in LMICs' health care systems has broad implications for women's health and human development. With hip fractures being more prevalent in women across the globe and expedient operative intervention acknowledged to reduce morbidity and mortality, addressing the Third Delay gender disparity is of paramount importance.

Non-operative Treatment

In addition to facing numerous delays, once geriatric hip fracture patients in LMICs do reach a healthcare facility, their fractures are more likely to be managed with non-operative treatment than patients in HICs due to a lack of resources. Non-operative treatment of geriatric hip fractures has been widely acknowledged as inappropriate apart from exceptional cases in which severe comorbidities and short life expectancy elevate the risk of surgical intervention beyond any palliative benefit the patient could reasonably expect from surgery [44]. Though HICs have improved outcomes by optimizing and standardizing operative management of geriatric hip fractures over the past few decades, they have done so with better infrastructure and more resources than are typically available in LMICs. Despite evidence of favorable outcomes of surgical intervention for hip fractures in LMICs, conservative treatment persists due to resource and system constraints. The number of surgeons providing musculoskeletal trauma care in LMICs is several folds lower than in HICs, with estimates ranging from 2.6 to 58.8 surgeons per one million inhabitants, respectively [13]. Less than 20% of the world's surgeons practice in the African, Eastern Mediterranean, and South-East Asian WHO regions, which have a high density of LMICs and account for nearly half of the world's population (Fig. 12.4) [46]. Studies drawing attention to the unacceptable rates of morbidity and mortality accompanying non-operative management in LMICs show that practices long ago abandoned in HICs remain inadequate in LMICs [47].

A large portion of the population of LMICs lack access to safe, affordable surgery and anesthesia (Fig. 12.5) [14]. Resources in LMICs need to be allocated to enable orthopaedic surgeons to treat the increasing number of elderly hip fracture patients to the globally accepted standard of care. In Sri Lanka, a case series of 180 patients with fragility hip fractures found that only 107 were managed operatively, and those receiving conservative management had greater than six times higher odds of death within 12 months [6]. In LMICs where the volume of operative trauma exceeds the capacity of the healthcare system, decisions about allocation of surgical resources are challenging. A study out of a high-demand, limited-resource public hospital in Uganda demonstrates that when resources are severely constrained, such as less than 60% of patients admitted with lower extremity fractures able to receive surgical care, these decisions are not always made based on clinic criteria. The study identified social capital as the strongest predictor of access to surgery in the >80% male patients admitted to the hospital with operative lower extremity fractures [48]. With the known morbidity and mortality associated with non-operative management or neglect of geriatric hip fractures, equitable access to surgery is a human rights issue. Systems that provide inferior care to women and the poor exacerbate preexisting social, health, and human development inequalities.

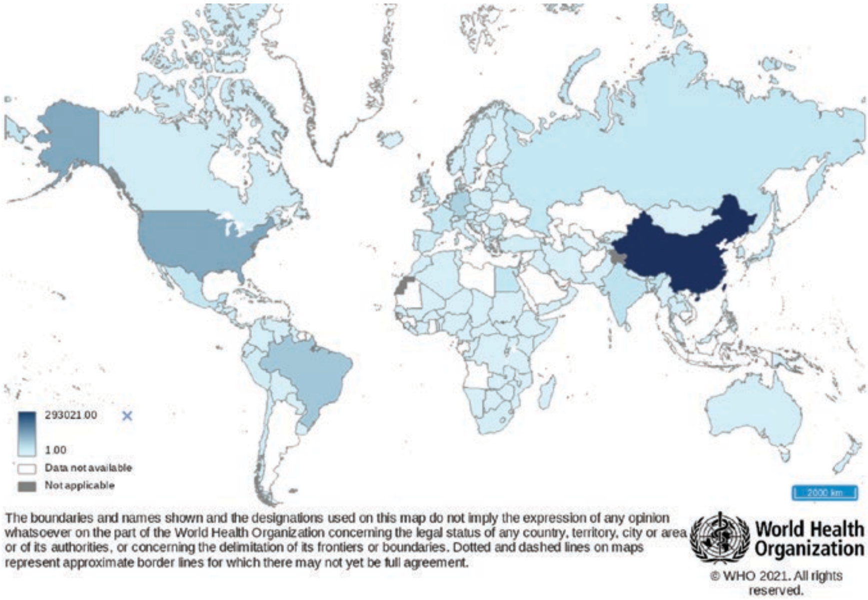

Fig. 12.4 Number of licensed surgeons of all specialties actively working, from the World Health Organization's (WHO) Global Health Observatory (GHO). (Reprinted with permission from: World Health Organization [46])

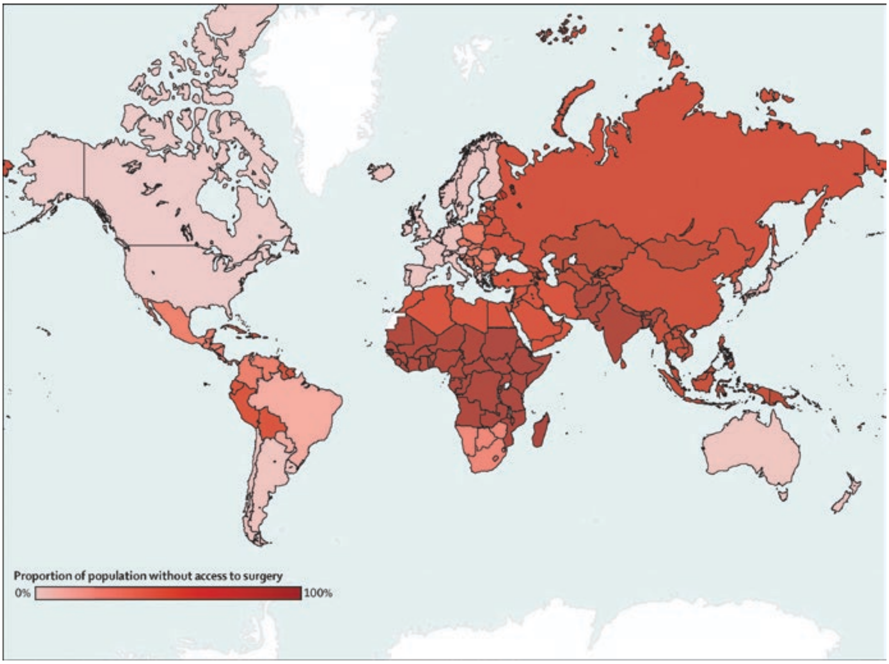

Fig. 12.5 Proportion of the population without access to safe, affordable surgery and anesthesia, from the Lancet report on Global Surgery 2030. (Reprinted with permission from: Meara et al. [14])

Osteosynthesis and Affordable Implants

Osteosynthesis involves fracture reduction and fixation. Non-displaced or valgus-impacted intracapsular femoral neck fractures can be secured using parallel screw fixation placed under fluoroscopic guidance. Extracapsular femur fractures typically require fluoroscopically guided closed reduction or open reduction with direct visualization and internal fixation. The implants most commonly used in HICs are cephalomedullary nails and sliding hip screws; however, their cost and absence of fluoroscopy can be prohibitive in LMICs [7].

Lack of funding for surgical implants in LMICs' hospitals and health systems can result in the cost of surgical implants falling on patients and their families [49]. The absence of disposable income in LMICs thus makes operative fracture care unattainable for many hip fracture patients. The alternative, non-operative care or delayed surgery results in prolonged hospitalization, inferior outcomes, and increased mortality. Investing in early hip fracture fixation and low-cost implants may ultimately provide both individual and societal cost savings when accounting for the direct and indirect costs associated with non-operative treatment of geriatric hip fracture.

Initiatives to bring low-cost implants to LMICs have shown success in improving outcomes. SIGN Fracture Care International's Hip Construct (SHC) is one such implant that was designed specifically for low-resource environments, without the use of fluoroscopy. The SHC is donated to hospitals that participate in the SIGN online database and thus can be provided at no cost to either the hospital or the patient's family. The structure of this program serves to overcome two common problems in LMICs – high implant costs and the absence of standardized hip fracture registry databases. Initial outcomes are promising, with implementation in Africa, Eastern Mediterranean, Western Pacific, Americas, and Southeast Asia (Fig. 12.6) [50].

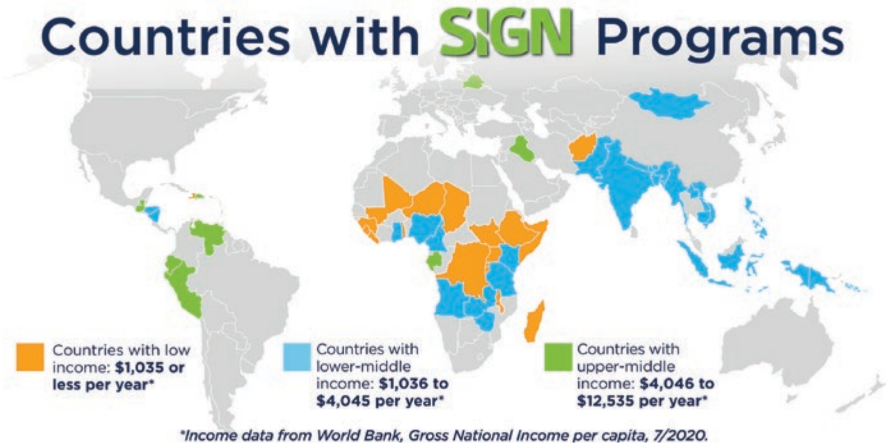

Fig. 12.6 Countries with SIGN Fracture Care International Programs. SIGN Fracture Care International has partnered with surgeons and hospitals in more than 50 LMICs, providing them with free orthopaedic education, implant systems, and surgical database access. (Reprinted with permission from: SIGN Fracture Care International [50])

The SHC has been used primarily in intertrochanteric and subtrochanteric fractures, but there have also been a few cases in which the construct has been used successfully in managing femoral neck fractures [51]. A case series of 68 hip fracture patients treated with the SHC in Tanzania showed promising outcomes [7]. The majority of patients were ambulatory by postoperative day three, and all who returned for follow-up at 6 weeks showed clinical signs of fracture healing. The few cases of major complications, one (1.5%) infection and eight (11.8%) cases of varus collapse, were favorable to the known unacceptable outcomes associated with non-operative management. The SHC has enabled operative fixation and early mobilization of hip fracture patients in LMICs in which resource scarcity or financial constraints would have otherwise prevented timely operative intervention.

Other steps that have been taken to overcome resource limitations in LMICs are consensus guidelines and recommendations on essential equipment required for appropriate operative treatment of hip fractures. Operative equipment guidelines can facilitate appropriate points of investment and intervention by governments and NGOs seeking to improve the capacity and quality of hip fracture care in LMICs. The publication of standardized equipment recommendations for various levels of care within the healthcare system can enable individual hospitals to assess their supplies and advocate for targeted funding. Essential equipment lists for fracture care in LMICs, specifically in sub-Saharan Africa, have been developed by a panel of experts as a means to guide resource allocation [52]. Importantly, the panels developing these recommendations are all from Africa with extensive experience working in LMICs. They specify that although their list may be helpful in other LMICs, it has not been widely tested and may not be completely translatable. Additionally, the panel highlights the frequent occurrence of inappropriately allocated resources burdening the healthcare systems of LMICs, with advanced equipment in basic care facilities being improperly used, maintained, or repaired. These issues not only represent waste of resources but also safety hazards. They illustrate the risk of applying potentially inappropriate HICs' guidelines in the absence of LMIC-specific data and needs-assessments. Further investment in research in LMICs is needed to generate appropriate regional guidelines and improve access to essential instruments and implants.

Arthroplasty

The standard treatment for displaced femoral neck fractures in the elderly is arthroplasty. Debate exists as to whether total hip arthroplasty (THA) or hemiarthroplasty (HA) is a more appropriate procedure for geriatric displaced femoral neck fracture management. HA is a less technically demanding procedure with lower cost implants and rates of dislocation, although it is typically used in older, lower demand patients with longevity and long-term function thought to be better in total hip arthroplasty. Recent research suggests that THA is not a cost-effective treatment as compared to HA with the exception of younger patients for whom greater gains in quality of life, shorter hospital stay, and fewer complications can be seen with THA [53]. Though this cost analysis comes from a HIC, the implications may be applicable to LMICs. Other studies have suggested that HA and THA result in similar complication profiles for up to 5 years, with no difference in outcomes or clinically significant difference in quality of life within 2 years [54, 55]. The limited clinical advantage of THA over HA may be a particularly important consideration in LMICs where THA may be unavailable or cost-prohibitive. There is a subset of literature from LMICs that reports the use of arthroplasty for unstable intertrochanteric femur fractures [56]. This use of arthroplasty for extracapsular hip fractures has not been supported by high-quality clinical, biomechanical, or cost-effectiveness studies.

The literature remains inconclusive regarding preferability of THA or HA for displaced femoral neck fractures in the elderly. Additional research on this topic from LMICs is needed, particularly with respect to cost-effectiveness and patient outcomes. Throughout the world, we need to prioritize improved access to low-cost, effective implants that can be safely used in low-resource settings. Regardless of whether surgeons in LMICs are using the SIGN hip construct for an intertrochanteric fracture or hemiarthroplasty for a displaced femoral neck fracture, early appropriate operative intervention and multidisciplinary perioperative management are cost-effective and improve patient outcomes.

Postoperative Management

Following operative treatment of geriatric hip fractures, there are three primary goals of postoperative management in both high- and low-income countries across the world: avoid postoperative complications, prevent future fractures, and restore mobility and function. Optimal postoperative care requires engagement of a multidisciplinary team that includes nurses, geriatricians, physical therapists, primary care physicians, social workers, family, and the patients' community.

Complications

Complications after hip fracture contribute significantly to morbidity and mortality. The adverse events seen in LMICs largely overlap with those seen in HICs, although the rates at which they occur may vary as a result of patient characteristics and local management practices. Some of the most commonly encountered and significant adverse events following geriatric hip fracture include mortality, infection, delirium, and thromboembolic events [36, 43]. More research on hip fracture morbidity and mortality in LMICs is needed to better understand and prevent these complications.

Mortality

Mortality rates after hip fracture are influenced by both healthcare factors and patient characteristics, which can vary significantly between and within countries. While 1-year mortality rates in HICs range from 12 to 20%, mortality rates in LMICs can be substantially higher [9]. A major risk factor for mortality is delayed surgery or non-operative treatment, which occur more frequently in LMICs. For instance, with only 13% of hip fracture patients in the Russian Federation receiving operative treatment, 1-year mortality can approach 50% [30]. In contrast, a hospital in Sri Lanka treating 60% of patients operatively reports a lower 1-year mortality rate of 18% [6]. Early surgery within 48 hours has been associated with a 20% lower 1-year mortality risk and fewer perioperative complications [31]. Patient factors such as preoperative comorbidities, baseline physical impairment, anemia, and older age have been associated with increased mortality in LMICs [6, 57]. Orthogeriatric collaboration has been shown to reduce in-hospital and long-term mortality for these patients [27]. Hospitals in LMICs with standardized multidisciplinary protocols may be better equipped to optimize care and prioritize resources to reduce mortality following geriatric hip fracture.

Thromboembolic Events

Patients with hip fractures are at high risk of venous thromboembolic events (VTE) such as deep venous thrombosis (DVT) and pulmonary emboli (PE). The use of chemoprophylaxis has shown to decrease this risk from a 50% rate of DVT and 1.4–7.5% rate of fatal PE to an overall rate of symptomatic VTE of just 1–2%. This low rate of VTE is dependent upon prompt operative fixation, with preoperative delays of more than 48 h increasing the VTE prevalence to 62% in spite of chemoprophylaxis [43]. This has significant implications in LMICs where hip fracture surgery is frequently delayed [42]. Although the type, dose, and duration of chemoprophylaxis are controversial, the use of aspirin – a low-cost, readily available oral medication – has been recommended for VTE prophylaxis after hip fracture surgery, with the caveat that it may be less effective than low molecular weight heparin (LMWH), a universally recommended but more expensive injectable medication [58]. Implementation of protocols that include affordable postoperative chemoprophylaxis, pneumatic compression devices, and most importantly early surgery may decrease VTE in LMICs.

Infections

Infections in geriatric hip fracture patients can occur at three timepoints: (1) prior to presentation to the hospital, (2) as a consequence of prolonged immobilization, and (3) as a complication of surgery. Preventing and treating these infections in LMICs can be challenging, as patients typically have less access to primary care preinjury and are more likely to experience delayed surgery and prolonged immobilization postinjury. Urinary tract and respiratory infections often coexist with frequent falls in the elderly [21]. Orthogeriatric co-management can facilitate the diagnosis and treatment of these infections [30]. Standardized hip fracture protocols that prioritize early surgery can reduce the risk of immobilization-associated pressure ulcer, urinary tract, and respiratory infections by facilitating hygiene, voiding, and pulmonary function. Postoperative surgical site infections are thought to occur at higher rates in LMICs than in HICs and frequently go unreported [37, 39]. Postoperative infections have been shown to lead to increased rates of mortality, longer hospital stays, and greater financial burden [39]. In LMICs where prompt operative intervention may not be feasible, it has been suggested that patients may benefit from a longer duration of postoperative antibiotics [37]. Additionally, in LMICs with higher rates of HIV, medical co-management of opportunistic infections and standardized hip surgery protocols including supplemental prophylactic IV antibiotics and antibiotic cement can minimize the rate of infections [38]. Standardized reporting and further research on infections associated with geriatric hip fractures in LMICs is needed.

Delirium

Delirium is a significant but often unreported complication in geriatric hip fracture patients [30]. It can occur as the sequelae of injury, hospitalization, and surgery in the elderly. Orthogeriatric co-management of hip fracture patients has been demonstrated to decrease delirium, improve function, and significantly reduce complications [27]. Avoiding potentially inappropriate medications such as opiates, benzodiazepines, and muscle relaxants can also help to reduce the incidence of delirium (Table 12.2) [25]. A review of fragility hip fractures in Mexico demonstrated that delirium was one of the most common complications, with rates comparable to those seen in the United States [59]. Standardized hip fracture protocols that include early continuous regional anesthesia can reduce opiate use, pain, and delirium in this vulnerable population [44]. Successful implementation of such protocols is resource dependent and not always feasible in LMICs. Research on delirium after hip fracture in LMICs is lacking. Future collaborative efforts should be directed at better understanding the burden of delirium after hip fracture in LMICs to identify areas for intervention.

Subsequent Fractures

Individuals who have sustained a fragility hip fracture are at significant risk of experiencing a subsequent fracture, especially in the first several months following their initial injury [33]. Worldwide, nearly half of patients presenting with hip fractures have suffered a prior fracture [60]. While population-wide osteoporosis screening, treatment, and fall prevention may not be cost-effective in the developing world, there is an obvious role for secondary prevention of fractures in hip fracture patients [33]. As the most expensive osteoporotic fracture to treat, hip fracture prevention represents great potential cost savings, yet many governments and health care systems in LMICs do not prioritize osteoporosis treatment and post-fracture care [18]. The majority of elderly fracture patients receive neither assessment nor treatment to reduce their risk of future fractures [60]. In Turkey, 75–90% of geriatric hip fracture patients did not receive post-fracture pharmacologic osteoporosis treatment [15]. Similarly, in Argentina, Brazil, Colombia, and Mexico, more than half of patients at risk of osteoporotic fracture do not receive treatment, and fewer than 10% of hospitals have Fracture Liaison Services [18]. Post-fracture care programs, or Fracture Liaison Services, provide multidisciplinary osteoporosis treatment and follow-up to hip fracture patient to reduce the risk of secondary fractures [33].

Fracture Liaison Services

In 2012, the International Osteoporosis Foundation (IOF) launched the Capture the Fracture Campaign to facilitate the global implementation of secondary fracture prevention programs to improve care and reduce cost worldwide (Fig. 12.7) [60]. They established the best practice framework (BPF), which has established international benchmarks through which Fracture Liaison Services (FLS) can be evaluated and improved throughout the world. Although FLS have the greatest representation in HICs, one of the five mentors listed on IOF's Capture the Fracture FLS mentoring page is from Russia, while China is one of the 19 countries represented in national audits and surveys. It has been estimated that universal implementation of FLS in Brazil, Mexico, Colombia, and Argentina, four of the largest LMICs in Latin America, would prevent over 31,000 fractures annually, avoiding hundreds of thousands of days bedbound, and saving over 58 million dollars [18]. These are incremental steps toward adequate representation of LMICs in the movement toward universal FLS implementation to close the secondary fracture gap.

Rehabilitation

Over the next 40 years, the global number of people living with disability due to hip fracture is expected to exceed 21 million, with the full extent of this burden likely underappreciated in LMICs [33]. Rather than being viewed as an essential component of healthcare, rehabilitation is often seen as an optional extra service and is therefore under-prioritized by resource-strained governments and health care systems.

The lack of human resources and infrastructure available for comprehensive inpatient and community-based rehabilitation can make recovery from hip fractures challenging in LMICs [8]. The World Health Organization's Rehabilitation 2030:

Fig. 12.7 The International Osteoporosis Foundation's (IOF) Capture the Fracture Best Practice Framework (BPF) map of 574 Fracture Liaison Service (FLS) programs in 48 countries. Each FLS is recognized with a rating of gold, silver, or bronze. New, not yet rated, FLS are denoted by blue stars. The UK's Royal Osteoporosis Society is denoted by maroon pins. (Reprinted with permission from: Capture the Fracture [60])

Call-to-Action draws attention to this profound unmet need in LMICs, which often have fewer than 10 rehabilitation practitioners per one million population [8]. Inadequate access to rehabilitation services for geriatric hip fracture patients in LMICs can lead to increased death, disability, and poor outcomes [8]. Research on rehabilitation following geriatric hip fractures in LMICs is scarce, but studies have shown that in Colombia, 64% of hip fracture patients are not evaluated by physiotherapists during their hospitalization and fewer than 10% of patients in China and India receive a fall-risk assessment [8]. The absence of rehabilitation following hip fracture in LMICs contributes not only to disability but also to death. In Sri Lanka, physical impairment was associated with a higher risk of mortality in patients with hip fractures [6]. In Brazil, in the first month after hip fracture surgery, falls are the leading cause of mortality, accounting for 43.5% of deaths [8].

Evidence from HICs supports the importance of geriatric hip fracture rehabilitation protocols with early postoperative mobilization and full weight bearing to minimize immobility-associated complications [13]. Implementation of evidence-based rehabilitation recommendations in LMICs is challenging due to clinical, structural, and social barriers, but necessary due to rapidly growing demand. Improving access to postoperative rehabilitation for geriatric hip fracture patients in LMICs will require investment in workforce, infrastructure, and governance through increased awareness, advocacy, and partnerships with HICs [8].

Interventions

There is both need and opportunity for education, research, capacity building, and multidisciplinary protocol-based interventions to improve hip fracture treatment and outcomes in LMICs. Things that you can do to contribute to the implementation of geriatric hip fracture best practices in LMICs include using international best practices in hip fracture care in your own institution, sharing your experience through open-access peer-reviewed publications, volunteering your time and expertise to the international organizations noted below, and establishing longitudinal bidirectional partnerships with stakeholders in LMICs to facilitate the exchange of knowledge and generate high-quality data, research, and publications so that we can all advocate for evidence-based change [61].

Education

In recent years, orthopaedic trainees have shown increased interest in experiencing orthopaedic surgery and fracture care in LMICs. In response to this demand, US orthopaedic residency programs have increased their global health opportunities by 92% over the past 5 years (Fig. 12.8) [63]. Orthopaedic trauma fellows, the trainees for whom hip fracture management is most relevant, likely share a similar degree of interest at this more focused stage of their training; yet, only a handful of US orthopaedic trauma fellowships offer structured global health programs [64].

In order for orthopaedic training partnerships to be mutually beneficial, the exchange of knowledge and experience must be reciprocal or bidirectional and the

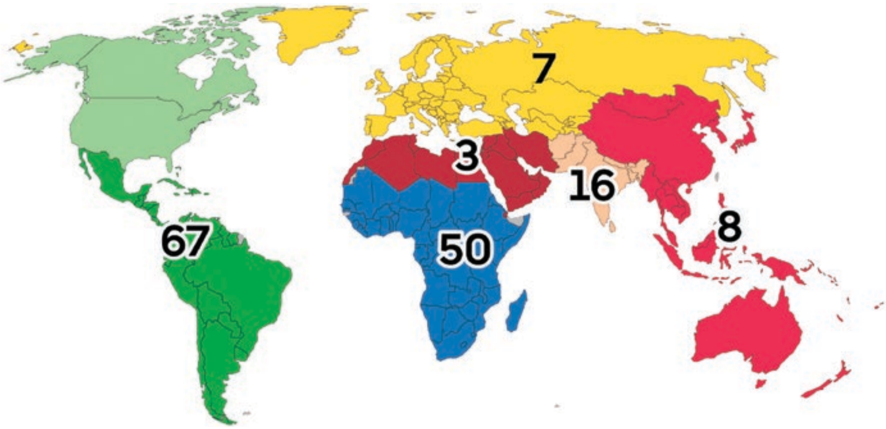

Fig. 12.8 Geographic distribution of international experiences for North American orthopaedic surgery residents. (Reprinted with permission from: Roberts et al. [62])

needs of LMICs' hosts must be prioritized [62, 65]. Unmet surgical need in LMICs poses a significant challenge to accomplishing hip fracture management best practices. US trainees participating in international rotations view addressing unmet surgical need as a major motivating factor, but it is important to note that host attending surgeons see more value in the educational exchange than the temporary provision of additional surgical personnel [62]. Though fully bidirectional partnerships have not yet been universally implemented, there are a number of opportunities for surgeons from LMICs to participate in orthopaedic observerships throughout North America (Fig. 12.9) [66]. Improving partnership, education, and training for young surgeons throughout the world can facilitate collaborations and opportunities to provide better care to geriatric hip fracture patients in LMICs.

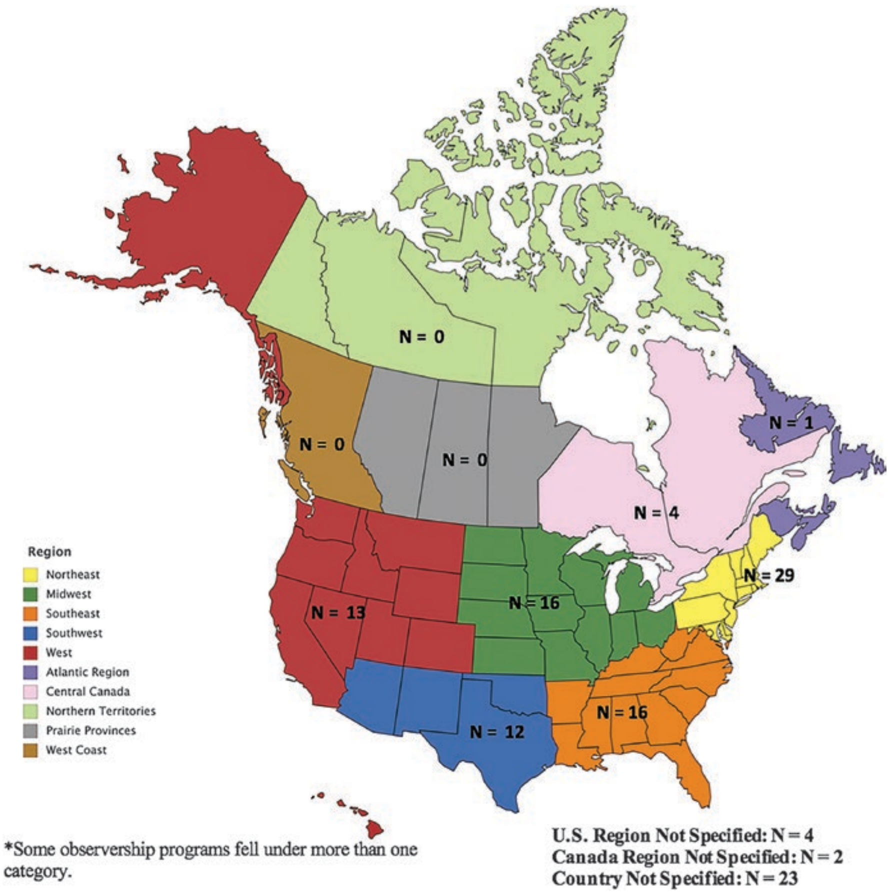

Fig. 12.9 Available North American orthopaedic observership programs for international surgeons, geared toward applicants from LMICs (16), non-LMICs (11), or unspecified (94). (Reprinted with permission from: Carrillo et al. [66])

Research

A defining theme of the literature on geriatric hip fracture management in LMICs has been the paucity of high-quality research. Although LMICs account for much of the global burden of geriatric hip fractures, the vast majority of the research on this topic has been performed in HICs. Scaling up research capacity in LMICs can be achieved by forming collaborations with health systems and academic institutions in HICs with robust research capacity. By providing access to research, education, and infrastructure, these collaborations can lead to a better understanding, improved allocation of scarce resources, and better overall care and outcomes for geriatric hip fractures in LMICs.

A recent research consortium composed of Latin-American leaders in orthopaedics highlighted the need for collaboration between LMICs and HICs in order to obtain the training and infrastructure needed to adequately address research questions impacting their communities. Several of the topics raised by this consortium are relevant to geriatric hip fractures: fragility fractures and osteometabolic disease, cost-effective implants, outcomes studies, and trauma burden [67]. The collaborations resulting from this and other similar working groups can serve as a model of global partnership for research capacity development in LMICs. One such model, which emerged from this aforementioned consortium, was the Asociación de Cirujanos Traumatólogos en las Américas (ACTUAR). ACTUAR, composed of more than 100 members from 20 countries, is dedicated to the development of research infrastructure in Latin America.

ACTUAR has collaborated on projects such as the International Orthopaedic Multicenter Study (INORMUS), coordinated by McMaster University Method Center in Canada, the George Institute of Global Health in Australia, and the Institute for Global Orthopaedics and Traumatology (IGOT) at University of California, San Francisco (UCSF), in the United States – has collaborated on projects such as the International Orthopaedic Multicenter Study (INORMUS). INORMUS is a cohort study of musculoskeletal trauma in Africa, Asia, and Latin America, which established a global research infrastructure to address the critical gap in our knowledge of the epidemiology, management, and outcomes of trauma in LMICs (Fig. 12.10) [68]. Additionally, the Consortium of Orthopaedic Academic Traumatologists (COACT), consisting of orthopaedic surgeon leaders from over 15 orthopaedic academic departments in the United States and Canada, was developed to promote the alignment of academic global health efforts in LMICs. The consortium works toward this goal through the sharing of best practices, mentorship opportunities, and resources for clinical exchange experiences, research projects, and surgical education initiatives. Similar research initiatives are needed to address the paucity of data on geriatric hip fractures in LMICs.

Research education has also demonstrated tremendous impact on the quality and quantity of research in LMICs. UCSF's IGOT International Research Symposium is an annual 1-day research course created to promote research initiatives by surgeons in LMICs. A 2-year follow-up study showed that the participants (from 10 LMICs) had increased research confidence, productivity, and recognition by international organizations like the Orthopaedic Trauma Association (OTA) [69]. By improving

Fig. 12.10 International Orthopaedic Multicenter Study in Fracture Care (INORMUS): participating sites: 50 hospitals in 17 countries. (Reprinted with permission from: Sprague et al. [68])

the quantity, quality, and visibility of research in LMICs, surgeons practicing in these environments can highlight successful implementation of geriatric hip fracture best practices and draw national and international attention to areas in need of resources or additional research.

The following is a selection of organizations that provide information, education, and opportunities to improve the care of geriatric hip fractures throughout the world.

Fragility Fracture Network
www.fragilityfracturenetwork.org
International Osteoporosis Foundation's Capture the Fracture
www.capturethefracture.org
American Orthopaedic Association's Own the Bone partnership with Project ECHO
www.ownthebone.org
hsc.unm.edu/echo/
AOTrauma's Orthogeriatrics
https://aotrauma.aofoundation.org/education/curricula/orthogeriatrics
Institute for Global Orthopaedics and Traumatology
www.igotglobal.org
SIGN
www.signfracturecare.org
Health Volunteers Overseas
www.hvousa.org
The George Institute for Global Health Scholarship: Managing hip fractures in resource poor settings
www.georgeinstitute.org/careers/scholarship-opportunity-managing-hip-fractures-in-resource-poor-settings

Conclusion

With the global population aging most rapidly in LMICs, geriatric hip fractures are anticipated to add significant burden to already strained systems. The economic and social effects of the geriatric hip fracture epidemic in LMICs are significant, but efforts to identify populations at risk and target modifiable risk factors can reduce the negative impact. Current geriatric hip fracture research and publications in LMICs are lacking. International collaborations that are focused on research and implementation of standardized orthogeriatric preoperative care, appropriate timely surgery, and postoperative monitoring and rehabilitation in LMICs can improve outcomes for geriatric hip fracture patients in LMICs.

References

1. World bank country and lending groups [Internet]. [cited 2020 Dec 27]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
2. Gullberg B, Johnell O, Kanis JA. World-wide Projections for Hip Fracture. Osteoporos Int. 1997;7(5):407–13.
3. World Health Organization. World report on ageing and health. World Health Organization; Geneva, Switzerland; 2015. https://apo.org.au/node/58203
4. UN DESA. World Population Prospects 2019. United Nations. Department of Economic and Social Affairs.
5. Cheung CL, Ang SB, Chadha M, Chow ES, Chung YS, Hew FL, Jaisamrarn U, Ng H, Takeuchi Y, Wu CH, Xia W. An updated hip fracture projection in Asia: the Asian Federation of Osteoporosis Societies study. Osteoporos sarcopenia. 2018;4(1):16–21.
6. Abeygunasekara T, Lekamwasam S, Lenora J, Alwis G. Current incidence and future projections of fragility hip fractures in Sri Lanka. Arch Osteoporos. 2020;15(1):1–6.
7. Haonga BT, Eliezer EN, Makupa JE, Shearer D, Liu MB, Wu H. SIGN hip construct: Achieving hip fracture fixation without using an image intensifier. EAOJ. 2016;10(1):7–10.
8. Dyer SM, Perracini MR, Smith T, Fairhall NJ, Cameron ID, Sherrington C, Crotty M. Rehabilitation following hip fracture. In: Falaschi P, Marsh D, editors. Orthogeriatrics. Practical issues in geriatrics. Cham: Springer; 2021. p. 183–222.
9. Guirant L, Carlos F, Curiel D, Kanis JA, Borgström F, Svedbom A, Clark P. Health-related quality of life during the first year after a hip fracture: results of the Mexican arm of the International Cost and Utility Related to Osteoporotic Fractures Study (MexICUROS). Osteoporos Int. 2018;29(5):1147–54.
10. World Health Organization. The world health report 2003: shaping the future. In: World Health Organization; 2003.
11. Hlaing WY, Thosingha O, Chanruangvanich W. Health-related quality of life and its determinants among patients with hip fracture after surgery in Myanmar. Int J Orthop Trauma Nurs. 2020;37:100752.
12. Amphansap T, Sujarekul P. Quality of life and factors that affect osteoporotic hip fracture patients in Thailand. Osteoporos Sarcopenia. 2018;4(4):140–4.
13. Miclau T, Hoogervorst P, Shearer DW, El Naga AN, Working ZM, Martin C, Pesántez R, Hüttl T, Kojima KE, Schütz M. International orthopaedic trauma study consortium. Current status of musculoskeletal trauma care systems worldwide. J Orthop Trauma. 2018;32:S64–70.

14. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, Bickler SW, Conteh L, Dare AJ, Davies J, Mérisier ED. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Lancet. 2015;386(9993):569–624.
15. Aziziyeh R, Perlaza JG, Saleem N, Kirazlı Y, Akalın E, McTavish RK, Duperrouzel C, Cameron C. The burden of osteoporosis in Turkey: a scorecard and economic model. Arch Osteoporos. 2020;15(1):1–9.
16. Domiciano DS, Machado LG, Figueiredo CP, Caparbo VF, Oliveira RM, Menezes PR, Pereira RM. Incidence and risk factors for osteoporotic non-vertebral fracture in low-income community-dwelling elderly: a population-based prospective cohort study in Brazil. The São Paulo Ageing and Health (SPAH) study. Osteoporos Int. 2020:1–1.
17. Rath S, Yadav L, Tewari A, Chantler T, Woodward M, Kotwal P, Jain A, Dey A, Garg B, Malhotra R, Goel A. Management of older adults with hip fractures in India: a mixed methods study of current practice, barriers and facilitators, with recommendations to improve care pathways. Arch Osteoporos. 2017;12(1):1–3.
18. Aziziyeh R, Perlaza JG, Saleem N, Guiang H, Szafranski K, McTavish RK. Benefits of fracture liaison services (FLS) in four Latin American countries: Brazil, Mexico, Colombia, and Argentina. Journal of Medical Economics. 2021;24(1):96–102.
19. Zhu Y, Xing X, Liu S, Chen W, Zhang X, Zhang Y. Epidemiology of low-energy wrist, hip, and spine fractures in Chinese populations 50 years or older: A national population-based survey. Medicine. 2020;99(5):e18531.
20. Phusunti S, Suthutvoravut W, Unnanuntana A, Chotiyarnwong P. The prevalence of hypovitaminosis D in patient with fragility hip fracture at a single institution in Thailand. J Med Assoc Thail. 2016;99(11):1233–8. PMID: 29901944
21. Han, T.S., Yeong, K., Lisk, R. et al. Prevalence and consequences of malnutrition and malnourishment in older individuals admitted to hospital with a hip fracture. Eur J Clin Nutr. 2021;75:645–52. https://doi.org/10.1038/s41430-020-00774-5.
22. Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in low-and middle-income countries. Ann N Y Acad Sci. 2019;1450(1):15.
23. Nazzal Z, Khader S, Zawyani H, Abdallah M, Sawalmeh O, Hamdan Z. Bone mineral density in Palestinian patients with end-stage renal disease and the related clinical and biochemical factors: Cross-sectional study. PLoS One. 2020;15(11):e0241201.
24. Seixas BV, Freitas GR. Polypharmacy among older Brazilians: prevalence, factors associated, and sociodemographic disparities (ELSI-Brazil). Pharm Pract. 2021 Jan;19:2168–1.
25. The 2019 American Geriatrics Society Beers Criteria® Update Expert Panel. The 2019 American Geriatrics Society Beers Criteria® for potentially inappropriate medication use in older adults. J Am Geriatr Soc. 2019. Published online January 31, 2019; https://doi.org/10.1111/jgs.15767.
26. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, Lydersen S, Halsteinli V, Saltnes T, Lamb SE, Johnsen LG. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623–33.
27. Grigoryan KV, Javedan H, Rudolph JL. Ortho-geriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. J Orthop Trauma. 2014;28(3):e49.
28. Meinberg E, Ward D, Herring M, Miclau T. Hospital-based Hip fracture programs: Clinical need and effectiveness. Injury. 2020;51:S2–4.
29. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in multidisciplinary team-based approach in geriatric hip fracture care: a systematic review. J Am Acad Orthop Surg. 2020;28(3):128–33.
30. Mitchell P, Åkesson K, Chandran M, Cooper C, Ganda K, Schneider M. Implementation of models of care for secondary osteoporotic fracture prevention and orthogeriatric models of care for osteoporotic hip fracture. Best Pract Res Clin Rheumatol. 2016;30(3):536–58.
31. Klestil T, Röder C, Stotter C, Winkler B, Nehrer S, Lutz M, Klerings I, Wagner G, Gartlehner G, Nussbaumer-Streit B. Impact of timing of surgery in elderly hip fracture patients: a systematic review and meta-analysis. Sci Rep. 2018;8(1):1–5.

32. Pouramin P, Li CS, Busse JW, Sprague S, Devereaux PJ, Jagnoor J, Ivers R, Bhandari M, Guyatt G, Petrisor B, Thabane L. Delays in hospital admissions in patients with fractures across 18 low-income and middle-income countries (INORMUS): a prospective observational study. Lancet Glob Health. 2020;8(5):e711–20.
33. Trafton PG. Fragility fractures in the developing world: A rising challenge. Curr Geriat Rep. 2018;7(4):278–87.
34. Fragility Fracture Network. Fragility Fracture Network [Internet]. FFN Central Office; [cited 2020 Jan 13]. Available from: https://www.fragilityfracturenetwork.org/global-regions/
35. AO Trauma. Orthogeriatrics [Internet]. AO Foundation; 2021 [cited 2021 Jan 14]. Available from: https://aotrauma.aofoundation.org/education/curricula/orthogeriatrics
36. Liem IS, Kammerlander C, Suhm N, Blauth M, Roth T, Gosch M, Hoang-Kim A, Mendelson D, Zuckerman J, Leung F, Burton J. Identifying a standard set of outcome parameters for the evaluation of orthogeriatric co-management for hip fractures. Injury. 2013;44(11):1403–12.
37. McQuillan TJ, Cai LZ, Corcoran-Schwartz I, Weiser TG, Forrester JD. Surgical site infections after open reduction internal fixation for trauma in low and middle human development index countries: a systematic review. Surg Infect. 2018;19(3):254–63.
38. Graham SM, Howard N, Moffat C, Lubega N, Mkandawire N, Harrison WJ. Total hip arthroplasty in a low-income country: Ten-year outcomes from the national joint registry of the Malawi Orthopaedic Association. JBJS Open Access. 2019 Oct;4(4).
39. Patel H, Khoury H, Girgenti D, Welner S, Yu H. Burden of surgical site infections associated with arthroplasty and the contribution of Staphylococcus aureus. Surg Infect. 2016;17(1):78–88.
40. Fowler AJ, Ahmad T, Abbott TE, Torrance HD, Wouters PF, De Hert S, Lobo SM, Rasmussen LS, Della Rocca G, Beattie WS, Wijeysundera DN. Association of preoperative anaemia with postoperative morbidity and mortality: an observational cohort study in low-, middle-, and high-income countries. Br J Anaesth. 2018;121(6):1227–35.
41. White MC, Longstaff L, Lai PS. Effect of pre-operative anaemia on post-operative complications in low-resource settings. World J Surg. 2017;41(3):644–9.
42. Zhang BF, Wei X, Huang H, Wang PF, Liu P, Qu SW, Li JH, Wang H, Cong YX, Zhuang Y, Zhang K. Deep vein thrombosis in bilateral lower extremities after hip fracture: a retrospective study of 463 patients. Clin Interv Aging. 2018;13:681.
43. Ricci WM, Broekhuyse H, Keating JF, Teague DC, White TO. Thromboprophylaxis an update of current practice: Can we reach a consensus? Ota Int. 2019;2(4):e027.
44. Elsevier H, Cannada LK. Management of pain associated with fractures. Curr Osteoporos Rep. 2020;18(3):130–7.
45. Tewari A, Pati S, Webster P, Rath S, Yadav L, Sahu KS, Sundari DS, Norton R. Care seeking behaviour of older adults with hip fracture in India: a qualitative study. J Pat Care. 2017;28:3(1).
46. World Health Organization. Surgical workforce: surgeons [Internet]. World Health Organization; 2021 [cited 2021 Jan 26]. Available from: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/number-of-licensed-qualified-surgeons-actively-working.
47. Chagomerana MB, Tomlinson J, Young S, Hosseinipour MC, Banza L, Lee CN. High morbidity and mortality after lower extremity injuries in Malawi: A prospective cohort study of 905 patients. Int J Surg. 2017;39:23–9.
48. Stephens T, Mezei A, O'Hara NN, Potter J, Mugarura R, Blachut PA, O'Brien PJ, Beyeza T, Slobogean GP. When surgical resources are severely constrained, who receives care? Determinants of access to orthopaedic trauma surgery in Uganda. World J Surg. 2017;41(6):1415–9.
49. Kramer EJ, Shearer D, Morshed S. The use of traction for treating femoral shaft fractures in low-and middle-income countries: a systematic review. Int Orthop. 2016;40(5):875–83.
50. SIGN Fracture Care International. SIGN Programs: building orthopaedic capacity around the world [Internet]. [cited 2021 Jan 26]. Available from: https://www.signfracturecare.org/programs
51. Roth J, Goldman B, Zirkle L Jr, Schlechter J, Ibrahim J, Shearer D. Early clinical cxperience with the SIGN hip construct: a retrospective case series. SICOT-J. 2018;4:5.
52. Chan Y, Banza L, Martin C Jr, Harrison WJ. Essential fracture and orthopaedic equipment lists in low resource settings: consensus derived by survey of experts in Africa. BMJ Open. 2018;8(9):e023473.

53. Axelrod D, Tarride JÉ, Ekhtiari S, Blackhouse G, Johal H, Bzovsky S, Schemitsch EH, Heels-Ansdell D, Bhandari M, Sprague SI. Total Hip Arthroplasty a Cost-Effective Option for Management of Displaced Femoral Neck Fractures? A Trial-Based Analysis of the HEALTH Study. J Orthop Trauma. 2020;34:S37–41.
54. Ekhtiari S, Gormley J, Axelrod DE, Devji T, Bhandari M, Guyatt GH. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fracture: a systematic review and meta-analysis of randomized controlled trials. JBJS. 2020;102(18):1638–45.
55. Health Investigators. Total hip arthroplasty or hemiarthroplasty for hip fracture. N Engl J Med. 2019;381(23):2199–208.
56. Elhadi AS, Gashi YN. Unstable intertrochanteric fracture in elderly patients: outcome of primary cemented bipolar hemiarthroplasty versus internal fixation. SA Orthopaedic J. 2018;17(4):22–6.
57. Atthakomol P, Manosroi W, Pipanmekaporn PP, Vaseenon T, Rojanasthien S. Prognostic Factors for All-Cause Mortality in Thai Patients with Fragility Fracture of Hip: Comorbidities and Laboratory Evaluations. Medicina. 2020;56(6):311.
58. Jenny JY, Pabinger I, Samama CM. European guidelines on perioperative venous thromboembolism prophylaxis: aspirin. Eur J Anaesth. 2018;35(2):123–9.
59. Viveros-García JC, Torres-Gutiérrez JL, Alarcón-Alarcón T, Condorhuamán-Alvarado PY, Sánchez-Rábago CJ, Gil-Garay E, González-Montalvo JI. Fractura de cadera por fragilidad en México:¿ En dónde estamos hoy?¿ Hacia dónde queremos ir? Acta Ortop Mex. 2019;32(6):334–41.
60. Capture the Fracture. What is Capture the Fracture? [Internet]. International Osteoporosis Foundation; 2021 [cited 2021 Jan 16]. Available from: https://www.capturethefracture.org
61. Wu HH, Liu M, Patel KR, Turner W, Baltus L, Caldwell AM, Hahn JC, Coughlin RR, Morshed S, Miclau T, Shearer DW. Impact of academic collaboration and quality of clinical orthopaedic research conducted in low- and middle-income countries. SICOT-J. 2017;3:6.
62. Roberts HJ, Albright PD, Shearer DW, Won N, MacKechnie MC, Coughlin RR, Miclau IIIT, Morshed S, Sabharwal S, Dawson J, Davis B. Motivations and impact of international rotations in low-and middle-income countries for orthopaedic surgery residents: Are we on the same page? Am J Surg. 2020;221(2):245–53.
63. Pfeifer J, Svec N, Are C, Nelson KL. Rising global opportunities among orthopaedic surgery residency programs. JAAOS Glob Res Rev. 2020;4(12):e20.00102.
64. Shaw J, Siy A, Dahm J, Lins L, Simske N, Whiting P. Limited availability of global health opportunities in US orthopaedic trauma fellowship programs. Ota Int. 2019;2(4):e031.
65. Pean CA, Premkumar A, Pean MA, Ihejirika-Lomedico R, Woolley PM, McLaurin T, Israelski R, Schwarzkopf R, Caplan A, Egol K. Global orthopaedic surgery: an ethical framework to prioritize surgical capacity building in low and middle-income countries. JBJS. 2019;101(13):e64.
66. Carrillo LA, Segarra B, Sabharwal S. Clinical observership opportunities in North America for international orthopaedic surgeons. JBJS. 2020;102(12):e60.
67. Chomsky-Higgins K, Miclau TA, Mackechnie MC, Aguilar D, Avila JR, Dos Reis FB, Balmaseda R, Barquet A, Ceballos A, Contreras F, Escalante I. Barriers to clinical research in Latin America. Front Public Health. 2017;5:57.
68. Sprague S, McKay P, Li CS, Ivers R, Moroz PJ, Jagnoor J, Bhandari M, Miclau T. International orthopaedic multicenter study in fracture care: coordinating a large-scale multicenter global prospective cohort study. J Orthop Trauma. 2018;32:S58–63.
69. Wu HH, Ibrahim J, Conway D, Liu M, Morshed S, Miclau T, Coughlin RR, Shearer DW. Clinical research course for international orthopaedic surgeons: 2-year outcomes. J Orthop Trauma. 2018;32:S35–7.
70. Institute for Health Metrics and Evaluation (IHME). GBD Compare [Internet]. Seattle: IHME, University of Washington; 2015. [updated 2019; cited 2021 Feb 01]. Available from: http://vizhub.healthdata.org/gbd-compare

Chapter 13
Geriatric Hip Fractures: Economics of Care

Carl L. Herndon

Introduction

Hip fractures are a very common injury in the geriatric trauma population and represent a major public health issue. More than 250,000 hip fractures occur annually in the United States, and this is expected to rise between 458,000 and 1 million by 2050 [1, 2]. The vast majority of these fractures occur in patients older than 65 years and are associated with significant morbidity, mortality, and expense to the healthcare system [3–5]. These fractures cost the US healthcare system $10.3–15.2 billion annually and continue to increase [6]. During their lifetime, 17% of white women and 6% of white men over the age of 50 years are predicted to suffer a hip fracture [7]. Additionally, geriatric hip fractures account for 14% of all fractures but represent 72% of fracture care costs [8]. Although in-hospital and immediate costs are a large portion of the overall expense of these injuries, data also suggests that there are increased costs even up to 1 year after surgery compared to non-fracture controls [9]. Given the commonness of this injury, the high morbidity, mortality, and high cost of these fractures, much has been published regarding best practices and ways to increase value of care. In this chapter, we will review the available literature of the economics of hip fracture care and attempt to inform surgeons on how to guide care that increases both quality and value.

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Risk Stratification and Protocolization

Before embarking on a discussion of how to provide value in the way we care for patients, we must first understand the patient factors that affect care. Studies have shown that patients with more medical comorbidities are at higher risk for medical complications after hip fracture surgery and require longer hospital stays [10, 11]. In a large cohort of almost 9000 patients, Lawrence et al. reported a 19% incidence of postoperative complications [12]. In order to identify patients at higher risk for complications, several risk stratification tools have been proposed.

A good surrogate for a patient's medical complexity is the American Society of Anesthesiologists (ASA) classification. Donegan et al. found that ASA score strongly correlated with medical problems in the perioperative period following hip fracture surgery, and ASA of 3 or 4 had a 3.8 or 7.4 times higher chance of having a postoperative medical complication respectively as patients with an ASA of 2 [11]. Michel et al. showed that patients with ASA 3 and 4 were nine times more likely to die within a year of injury compared to ASA 1 and 2 [13].

There is a myriad of other metrics to identify patients at risk for perioperative complications including the Charlson Comorbidity Index (CCI), Nottingham Hip Fracture Score (NHFS), Physiological and Operative Severity Score for the enumeration of Mortality and Morbidity (POSSUM), Estimation of Physiologic Ability and Surgical Stress (E-PASS), and others. In a systematic review, Marufu et al. evaluated 29 manuscripts assessing these various scores and concluded that the simpler models (ASA, CCI, and NHFS) were all easy to administer, inexpensive, and effective at predicting outcomes including hospital length of stay, morbidity, and mortality [14]. Other novel indices have also been shown to be effective in predicting morbidity and mortality following hip fracture surgery based on patient-specific preoperative factors [15–19]. At this time, most risk stratification models are derived from simple scores such as ASA or number of comorbidities.

High complication rates following hip fracture surgery are obviously devastating to both patients and clinicians. From an economic standpoint, these complications are also very expensive. Garcia et al. showed that an increase in ASA score of 1 correlated with an increased length of stay (LOS) of 2 days, which represented an increased direct hospitalization cost of $9300 at a large tertiary care center [20]. Schousboe et al. corroborated these findings and showed that patients with poor prefracture mobility, obesity, and multiple comorbidities all had costs of care ranging from 14% to 25% higher using a large Medicare fee for service dataset [21].

To combat this, authors have proposed specialized treatment protocols and algorithms for these patients in order to allow for early mobilization, avoid the complications of prolonged recumbency, and return patients to their highest possible level of functional activity [22]. Various institutional-specific models exist, but many seek to co-manage these complex patients between the orthopaedic and geriatric services ("orthogeriatric"), with an aim to reduce the time to the operating room, prevent medical complications, and streamline cost-effective care.

Co-management and Interdisciplinary Care

Combining the care and skills of geriatricians/internists and orthopaedic surgeons is not a novel approach, but one that has gained more attention in recent years, especially in light of recent emphasis on meaningful use of medical resources and value-based care models used by Medicare. The goal of these programs is to medically optimize patients as quickly as possible for operative intervention and allow them to mobilize postoperatively to reduce morbidity and mortality [23–26].

Traditionally, these patients were admitted to the orthopaedic service and the medicine team was asked to consult and provide guidance regarding medical optimization. Another alternative to that model is one in which the patient is admitted to the medicine service and the orthopedist is consulted for surgical management. A third, more recent model is one in which the patient is admitted to a joint "orthogeriatric" service where the care of the patient is shared equally between the surgical team medical team, with neither team signing off when their portion of the patient's care is completed. These teams also follow standardized assessments and protocols to streamline care. Many studies have been written regarding the benefits of a "hip fracture service" over the traditional model. In a recent systematic review, Patel et al. evaluated 17 trials comparing these models and found that time to surgery, hospital length of stay, and postoperative mortality were all reduced when using either a geriatrician-led or orthogeriatric service [23]. Using a large national database that included over 9000 hip fracture patients, Arshi et al. showed that patients receiving care from a co-managed standardized hip fracture program had lower rates of deep vein thrombosis (DVT), were less likely to be discharged on an inpatient rehabilitation setting, and had lower 30 day readmission rates [27].

In addition to improving patient care, these co-management models have also been shown to be cost-effective. In a large academic center, Miura et al. showed not only that outcomes were better but there was also a net savings to the hospital of nearly $2000 per patient when comparing 91 cases utilizing the hip fracture service compared to 72 controls the year prior to implementation of the fracture service [28]. Swart et al. corroborated this study using economic decision analysis. In their study, they weighed the economic consequences of what it would cost a hospital (or hospital system) either to hire a full-time hospitalist (along with a therapist and social worker) or reassign staff already on payroll, and further to determine the number of cases per year that the hospital would have to manage in order to A) break even and B) gain financial benefit. In their analysis, they showed that implementing a co-management team was cost-effective with a volume of 54 patients annually and created cost savings with 318 patients annually. Regardless of hiring new staff or reassigning existing staff, both models provided cost savings over traditional care [29].

Despite the potential cost savings and increase in quality of care, implementing these programs presents administrative and organizational challenges. Two strategies borne out of the business management literature are that of Lean and Six Sigma. Lean is a methodology developed by the Toyota Production system to eliminate unnecessary waste and Six Sigma was developed by Motorola to minimize errors to a Six Sigma level (3.4 defects per million opportunities) [30, 31]. Utilizing these quality improvement methodologies and principles, Sayeed et al. showed that implementing a hip fracture integrated care pathway reduced surgical delay >48 h, LOS, and hospital cost by nearly 10% [32].

Surgical Timing

Timing the surgical treatment of these injuries is a complex decision-making process that has many variables that have been studied from various points of view including care models, patient-specific factors, and hospital-specific factors [33]. One of the many benefits of a coordinated care model is that it has been shown to reduce the time from admission to the operating room [34–36]. Although data is heterogeneous and there are many confounders, reducing time to the operating room has been shown in many studies to reduce morbidity and mortality in elderly hip fracture patients. However, many of these patients are medically complex and require pre-operative optimization and/or require specialty surgeons or other operative teams. Generally speaking, the goal of treating physicians should be to definitively treat these fractures within 48 h of admission [37, 38]. In a review of the literature on timing of surgery, Lewis et al. concluded that for low-risk patients with relatively few comorbidities (ASA 1 and 2), surgery should be performed ideally within 12–48 h. For more complex patients (ASA 3 and 4), comorbidities that can be managed should be attempted to be managed, and a limited delay of up to 5 days may not increase mortality but may increase other complications such as pressure sores [39]. From an economic standpoint, Shabat et al. showed that performing surgery in the first 48 h was more cost-effective than delaying longer than 48 h in 191 patients [40]. Pincus et al. corroborated that finding on a broader scale, evaluating over 42,000 patients at 522 institutions in Canada and showed that patients who underwent surgery greater than 24 h after admission had an additional 1-year direct cost increase of $2638 compared to patients who underwent surgery within 24 h [41]. Delays can be due to in part to patient complexity. Sicker, more complex patients may require more pre-operative optimization, but there also may be institutional delays. One potential delay for patients to get the operating room is the inability of hospital systems to accommodate surgery in a timely manner. Concerns over cost and/or availability are often cited as reasons why teams cannot be made available (i.e., over a weekend). To counter this point, in a decision tree analysis to tabulate incremental costs and quality-adjusted life years (QALY), Dy et al. showed that dedicated on-call teams meant to expedite patient care and provide surgery within 48 h are cost-effective [42].

Postoperative Care and Disposition

There is debate on where these patients should be discharged to when their hospitalization ends. Although inpatient rehabilitation centers have been the mainstay historically, admission to such a facility does not come without cost, and sending patients home that are safe to do so is obviously cheaper. Often, frail patients require a higher level of care postoperatively and utilization of a post-acute care (PAC) institution may be necessary, which represents a large financial burden to the healthcare system. PAC use has been shown to be a significant portion of 90-day costs after hip fracture surgery [43–46]. Unfortunately, PAC discharge is also associated with increased rates of morbidity and mortality when compared with discharge to home [47, 48] and includes complications such as pressure ulcers, myocardial infarction, stroke, renal failure, pulmonary embolism, death, DVT, sepsis, shock, unplanned intubation, deep wound infection, and return to the operating room [49]. In total joint arthroplasty, it has been shown that in properly selected patients, discharge to the home saves cost without sacrificing patient safety [50]. In an attempt to predict PAC utilization in hip fracture patients, Arshi et al. did a retrospective review of the National Surgical Quality Improvement Program (NSQIP) database to identify 8133 hip fracture patients over 65 years of age and evaluate patient predictive factors of PAC utilization. Of these 8133 patients, 6670 (82%) were discharged to PAC and 2986 remained admitted to the PAC institution for more than 30 days postoperatively. Age, total dependence for activities of daily living (ADL), dementia, diabetes, and hospital length of stay were all independent risk factors for PAC discharge. Age, partial or total dependence in ADLs, ASA status, dementia, and hospital length of stay were all risk factors for stay in PAC for more than 30 days [43]. This data shows that the majority of all hip fracture patients are discharged to institutional PAC and helps predict which patients will require PAC and, conversely, may help identify patients that will be safe at home.

Modern Payment Models

In recent years, the Centers for Medicare and Medicaid Services (CMS) have implemented a series of alternative payment models to replace fee-for-service reimbursement in an effort to improve (and incentivize) quality of care and reduce cost [51]. Although mainly focused on total hip and total knee arthroplasty (THA and TKA), programs such as the Comprehensive Care for Joint Replacement (CJR) and the Bundled Payments for Care Improvement (BPCI) have generally been effective at reducing the PAC and total episode of care (EOC) costs following these procedures [52–54]. These models of reimbursement hold practitioners (hospitals and physicians) financially responsible for costs up to 90 days postoperatively. Claims are reconciled with a target price set by CMS. Providers participating in these models are required to repay CMS when the EOC costs exceed the benchmark and retain additional funds if their care costs less than the CMS set price [55].

Although these models have been implemented in THA and TKA, there is overlap with hip fractures as well. The procedures covered under these models are set by each diagnosis-related group (DRG) as defined by CMS, which groups patients undergoing THA and hemiarthroplasty (HA) for hip fracture with elective THA together in the same DRG. Unsurprisingly, patients undergoing THA or HA for fracture have been shown to have more medical comorbidities, higher complication rates, and increased EOC costs, including PAC utilization [56–59] compared to those undergoing elective primary THA. Despite this, these patients are included in the same DRG as elective primary THA patients. Due to physician advocacy efforts, CJR has separated fracture patients and assigned them a different cost, but this has not yet happened in the far more popular BPCI. The newest edition of this model, BPCI-Advanced, has attempted to factor this in by calculating the proportion of THA and HA done for fracture at each participating institution based on historical data. This creates a situation in which a small increase in the percentage of fracture patients treated at a participating institution may be financially ruinous [55]. Especially in light of the COVID-19 pandemic and the large-scale cancellation of elective primary cases across the country, many institutions had a drastic decrease in primary elective THA cases and therefore the proportion of THA and HA done for fracture was much greater.

In a retrospective review of over 4000 patients at a large academic center, Skibicki et al. showed that elective THA patients had lower EOC ($18,200 vs. $42,605 vs. $38,371) and PAC costs ($4477 vs. $28,093 vs. $23,217) than both HA and THA for fracture. Additionally, patients undergoing arthroplasty for fracture lost an average of $23,122 for the institution while elective THA earned the institution $1648 in profit. 91% of fracture cases EOC costs exceeded the CMS benchmark price compared to only 20% for elective THA [55]. This data highlights the need to reassign hip fracture patients undergoing arthroplasty into a different DRG than patients undergoing elective primary THA. In response to literature like this and other advocacy efforts by physician groups, CMS did create a new DRG for hip arthroplasty done for fracture for the 2021 fiscal year. Further research will need to be done to evaluate those changes and whether or not they are effective.

CMS planned to roll out mandatory bundled payment models for the treatment of all hip and femur fractures, termed the Surgical Hip & Femur Fracture Treatment (SHIFT) bundle in January 2018, but due to concerns voiced by physician advocacy groups, that rollout was scaled back and eventually cancelled. Reasons cited for the cancellation of the rollout were that bundled payment models are inefficient and ineffective at predicting payment plans for trauma and fracture cases [60]. The SHIFT bundle was set to calculate payments based on DRG and geographic location. In a review of historical Medicare data, Cairns et al. showed that simply stratifying by DRG and location was not sufficient to account for the differences in cost and strongly suggested that the proposed SHIFT bundle should also have more robust risk-adjustment methods to ensure that providers are fairly reimbursed and include age, comorbidities, demographics, location, and procedure rather than just

DRG [61]. Although the mandatory SHIFT bundle was cancelled, CMS continues to experiment with payment for fractures within the BPCI model, and further research will need to be done in the future as new payment schemes are enacted.

Clearly, as bundled payment models gain popularity, it is imperative to stratify patients and identify factors that increase costs in order to protect participating institutions and to appropriately weight the reimbursement for each patient. In a retrospective review of 615 patients at a large urban medical center, Johnson et al. showed that CCI correlated with increased LOS and increased cost. Patients with a CCI of 2 (compared to controls with a CCI of 0) stayed an average of 1.9 additional days, which costs an additional $8697 [62]. Other countries with centralized health systems have already implemented bundled payment models for hip fracture. A review of over 175,000 hip fracture patients treated in Taiwan, which switched to bundled payments for hip fractures in 2010, showed that unplanned readmission within 30 days of operation decreased following implementation of the novel payment model compared to historic controls [63], which does suggest, much like in the United States with THA and TKA, that these models can be effective at increasing value and quality of care.

Future directions that may help to predict higher-cost patients may be cost calculators such as that published by Konda et al. Using a proprietary risk assessment tool, Score for Trauma Triage in the Geriatric and Middle-Aged (STTGMA [Risk]) along with a novel cost-prediction tool (STTGMA [Cost]), the authors reviewed 361 operatively treated hip fractures at a single urban trauma center. The costliest 5% of patients in the cohort were considered “high cost,” and they sought to determine whether their model predicted which patients would fall into that group. They showed that their tool successfully identified nearly 90% of the highest cost patients [64]. As CMS continues to consider implementing bundled payments for hip fracture treatment, calculators such as this one will become pivotal in determining appropriate reimbursement to providers participating in these models.

Physician and patient advocacy groups must continue to lobby lawmakers so that these novel payment models are well planned, accommodate all patients, and not disincentivize hospitals for taking care of high-risk (and high-cost) patients to preserve access to care for all.

Author’s Recommendations

Based on the available literature, it is the opinion of this author that hip fracture patients should be treated in a collaborative, integrated care model that involves both orthopaedic surgeons and geriatricians in a protocolized manner. Patients should be promptly optimized for surgical intervention when possible and ideally treated within 48 h. When preexisting and modifiable patient comorbidities prevent urgent surgical fixation, those should be optimized and surgery should be performed expeditiously thereafter. To the best of our institutional abilities, logistical delays such as operating room, implant, surgeon, and staffing availability should not delay patients from undergoing surgery. Each of these interventions both increases the quality of care and decreases the financial burden of these fractures. Finally, in terms of future directions of payment models, as bundled payments gain popularity more research is needed to identify high-cost patients and stratify them as such, so that providers (especially ones at tertiary care centers caring for complex patients) are protected and access to care is not limited. Sub-dividing DRGs to account for baseline differences in patient complexity may be one strategy to achieve this. As these fractures become more common in the coming decades, surgeons must continue to advocate for positive change implementation to improve care and increase value both on the local and on national levels.

References

1. Brown CA, Starr AZ, Nunley JA. Analysis of past secular trends of hip fractures and predicted number in the future 2010–2050. J Orthop Trauma. 2012;26(2):117–22.
2. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. JAMA. 2009;302(14):1573–9.
3. Braithwaite RS, Col NF, Wong JB. Estimating hip fracture morbidity, mortality and costs. J Am Geriatr Soc. 2003;51(3):364–70.
4. Basu N, Natour M, Mounasamy V, Kates S. Geriatric hip fracture management: keys to providing a successful program. Eur J Trauma Emerg Surg. 2016;42(5):565–9.
5. Richmond J, Aharonoff GB, Zuckerman JD, Koval KJ. Mortality risk after hip fracture. J Orthop Trauma. 2003;17(8):S2–5.
6. Judd KT, Christianson E. Expedited operative care of hip fractures results in significantly lower cost of treatment. Iowa Orthop J. 2015;35:62.
7. Winner S, Morgan CA, Evans JG. Perimenopausal risk of falling and incidence of distal forearm fracture. Br Med J. 1989;298(6686):1486–8.
8. Friedman SM, Mendelson DA. Epidemiology of fragility fractures. Clin Geriatr Med. 2014;30(2):175–81.
9. Haentjens P, Autier P, Barette M, Boonen S. The economic cost of hip fractures among elderly women: a one-year, prospective, observational cohort study with matched-pair analysis. JBJS. 2001;83(4):493.
10. Khasraghi FA, Lee EJ, Christmas C, Wenz JF. The economic impact of medical complications in geriatric patients with hip fracture. Orthopaedics. 2003;26(1):49–53.
11. Donegan DJ, Gay AN, Baldwin K, Morales EE, Esterhai JL Jr, Mehta S. Use of medical comorbidities to predict complications after hip fracture surgery in the elderly. JBJS. 2010;92(4):807–13.
12. Lawrence VA, Hilsenbeck SG, Noveck H, Poses RM, Carson JL. Medical complications and outcomes after hip fracture repair. Arch Intern Med. 2002;162(18):2053–7.
13. Michel J-P, Klopfenstein C, Hoffmeyer P, Stern R, Grab B. Hip fracture surgery: is the preoperative American Society of Anesthesiologists (ASA) score a predictor of functional outcome? Aging Clin Exp Res. 2002;14(5):389–94.
14. Marufu TC, Mannings A, Moppett IK. Risk scoring models for predicting peri-operative morbidity and mortality in people with fragility hip fractures: qualitative systematic review. Injury. 2015;46(12):2325–34.
15. Traven SA, Reeves RA, Sekar MG, Slone HS, Walton ZJ. New 5-factor modified frailty index predicts morbidity and mortality in primary hip and knee arthroplasty. J Arthroplast. 2019;34(1):140–4.

16. Choi J-Y, Cho K-J, Kim S-w, Yoon S-J, Kang M-g, Kim K-i, Lee Y-K, Koo K-H, Kim C-H. Prediction of mortality and postoperative complications using the hip-multidimensional frailty score in elderly patients with hip fracture. Sci Rep. 2017;7:42966.
17. Bliemel C, Buecking B, Oberkircher L, Knobe M, Ruchholtz S, Eschbach D. The impact of pre-existing conditions on functional outcome and mortality in geriatric hip fracture patients. Int Orthop. 2017;41(10):1995–2000.
18. Konda SR, Lott A, Saleh H, Schubl S, Chan J, Egol KA. How does frailty factor into mortality risk assessment of a middle-aged and geriatric trauma population? Geriatr Orthop Surg Rehabil. 2017;8(4):225–30.
19. Maxwell M, Moran C, Moppett I. Development and validation of a preoperative scoring system to predict 30 day mortality in patients undergoing hip fracture surgery. Br J Anaesth. 2008;101(4):511–7.
20. Garcia AE, Bonnaig J, Yoneda ZT, Richards JE, Ehrenfeld JM, Obremskey WT, Jahangir AA, Sethi MK. Patient variables which may predict length of stay and hospital costs in elderly patients with hip fracture. J Orthop Trauma. 2012;26(11):620–3.
21. Schousboe JT, Paudel ML, Taylor BC, Kats AM, Virnig BA, Dowd BE, Langsetmo L, Ensrud KE. Pre-fracture individual characteristics associated with high total health care costs after hip fracture. Osteoporos Int. 2017;28(3):889–99.
22. Egol KA, Strauss EJ. Perioperative considerations in geriatric patients with hip fracture: what is the evidence? J Orthop Trauma. 2009;23(6):386–94.
23. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in multidisciplinary team-based approach in geriatric hip fracture care: a systematic review. J Am Acad Orthop Surg. 2020;28(3):128–33.
24. Bernstein J, Roberts FO, Wiesel BB, Ahn J. Preoperative testing for hip fracture patients delays surgery, prolongs hospital stays, and rarely dictates care. J Orthop Trauma. 2016;30(2):78–80.
25. Stitgen A, Poludnianyk K, Dulaney-Cripe E, Markert R, Prayson M. Adherence to preoperative cardiac clearance guidelines in hip fracture patients. J Orthop Trauma. 2015;29(11):500–3.
26. Lau T-W, Fang C, Leung F. The effectiveness of a geriatric hip fracture clinical pathway in reducing hospital and rehabilitation length of stay and improving short-term mortality rates. Geriatr Orthop Surg Rehabil. 2013;4(1):3–9.
27. Arshi A, Rezzadeh K, Stavrakis AI, Bukata SV, Zeegen EN. Standardized hospital-based care programs improve geriatric hip fracture outcomes: an analysis of the ACS NSQIP targeted hip fracture series. J Orthop Trauma. 2019;33(6):e223–8.
28. Miura LN, DiPiero AR, Homer LD. Effects of a geriatrician-led hip fracture program: improvements in clinical and economic outcomes. J Am Geriatr Soc. 2009;57(1):159–67.
29. Swart E, Vasudeva E, Makhni EC, Macaulay W, Bozic KJ. Dedicated perioperative hip fracture comanagement programs are cost-effective in high-volume centers: an economic analysis. Clin Orthop Relat Res. 2016;474(1):222–33.
30. Holden RJ. Lean thinking in emergency departments: a critical review. Ann Emerg Med. 2011;57(3):265–78.
31. Kubiak T, Benbow DW (2009) The certified six sigma black belt handbook- chapter 1. ASQ Quality Press. Milwaukee, WI.
32. Sayeed Z, Anoushiravani A, El-Othmani M, Barinaga G, Sayeed Y, Cagle P Jr, Saleh KJ. Implementation of a hip fracture care pathway using lean six sigma methodology in a level I trauma center. J Am Acad Orthop Surg. 2018;26(24):881–93.
33. Sheehan KJ, Sobolev B, Guy P. Mortality by timing of hip fracture surgery: factors and relationships at play. JBJS. 2017;99(20):e106.
34. Batsis JA, Phy MP, Joseph Melton IIIL, Schleck CD, Larson DR, Huddleston PM, Huddleston JM. Effects of a hospitalist care model on mortality of elderly patients with hip fractures. J Hosp Med. 2007;2(4):219–25.
35. Friedman SM, Mendelson DA, Bingham KW, Kates SL. Impact of a comanaged geriatric fracture center on short-term hip fracture outcomes. Arch Intern Med. 2009;169(18):1712–7.

36. Phy MP, Vanness DJ, Melton LJ, Long KH, Schleck CD, Larson DR, Huddleston PM, Huddleston JM. Effects of a hospitalist model on elderly patients with hip fracture. Arch Intern Med. 2005;165(7):796–801.
37. Shiga T, Zi W, Ohe Y. Is operative delay associated with increased mortality of hip fracture patients? Systematic review, meta-analysis, and meta-regression. Can J Anesth. 2008;55(3):146.
38. Anthony CA, Duchman KR, Bedard NA, Gholson JJ, Gao Y, Pugely AJ, Callaghan JJ. Hip fractures: appropriate timing to operative intervention. J Arthroplast. 2017;32(11):3314–8.
39. Lewis PM, Waddell JP. When is the ideal time to operate on a patient with a fracture of the hip? A review of the available literature. Bone Joint J. 2016;98(12):1573–81.
40. Shabat S, Heller E, Mann G, Gepstein R, Fredman B, Nyska M. Economic consequences of operative delay for hip fractures in a non-profit institution. Orthopaedics. 2003;26(12):1197–9.
41. Pincus D, Wasserstein D, Ravi B, Huang A, Paterson JM, Jenkinson RJ, Kreder HJ, Nathens AB, Wodchis WP. Medical costs of delayed hip fracture surgery. JBJS. 2018;100(16):1387–96.
42. Dy CJ, McCollister KE, Lubarsky DA, Lane JM. An economic evaluation of a systems-based strategy to expedite surgical treatment of hip fractures. JBJS. 2011;93(14):1326–34.
43. Arshi A, Iglesias BC, Zambrana LE, Lai WC, Zeegen EN, Sassoon AA, Stavrakis AI. Postacute care utilization in postsurgical orthogeriatric hip fracture care. J Am Acad Orthop Surg. 2020;28(18):743–9.
44. Nikitovic M, Wodchis W, Krahn M, Cadarette S. Direct health-care costs attributed to hip fractures among seniors: a matched cohort study. Osteoporos Int. 2013;24(2):659–69.
45. Pitzul KB, Wodchis WP, Kreder HJ, Carter MW, Jaglal SB. Discharge destination following hip fracture: comparative effectiveness and cost analyses. Arch Osteoporos. 2017;12(1):87.
46. Tessier JE, Rupp G, Gera JT, DeHart ML, Kowalik TD, Duwelius PJ. Physicians with defined clear care pathways have better discharge disposition and lower cost. J Arthroplast. 2016;31(9):54–8.
47. Bini SA, Fithian DC, Paxton LW, Khatod MX, Inacio MC, Namba RS. Does discharge disposition after primary total joint arthroplasty affect readmission rates? J Arthroplast. 2010;25(1):114–7.
48. Cameron I, Crotty M, Currie C, Finnegan T, Gillespie L, Gillespie W, Handoll H, Kurrle S, Madhok R, Murray G. Geriatric rehabilitation following fractures in older people: a systematic review. Health Technol Assess. 2000;4(2):i–iv, 1–111. PMID: 10702905.
49. Gillespie WJ. Hip fracture. BMJ. 2001;322(7292):968–75.
50. Tarity TD, Swall MM. Current trends in discharge disposition and post-discharge care after total joint arthroplasty. Curr Rev Musculoskelet Med. 2017;10(3):397–403.
51. Bundled Payments for Care Improvement (BPCI) Initiative: General Information. https://innovation.cms.gov/innovation-models/bundled-payments. Accessed 18 Jan 2021.
52. Bozic KJ, Ward L, Vail TP, Maze M. Bundled payments in total joint arthroplasty: targeting opportunities for quality improvement and cost reduction. Clin Orthop Relat Res. 2014;472(1):188–93.
53. Froimson MI, Rana A, White RE Jr, Marshall A, Schutzer SF, Healy WL, Naas P, Daubert G, Iorio R, Parsley B. Bundled payments for care improvement initiative: the next evolution of payment formulations: AAHKS bundled payment task force. J Arthroplast. 2013;28(8):157–65.
54. Rana AJ, Bozic KJ. Bundled payments in orthopaedics. Clin Orthop Relat Res. 2015;473(2):422–5.
55. Skibicki H, Yayac M, Krueger CA, Courtney PM. Target price adjustment for hip fractures is not sufficient in the bundled payments for care improvement initiative. J Arthroplast. 2020;36(1):47–53.
56. Le Manach Y, Collins G, Bhandari M, Bessissow A, Boddaert J, Khiami F, Chaudhry H, De Beer J, Riou B, Landais P. Outcomes after hip fracture surgery compared with elective total hip replacement. JAMA. 2015;314(11):1159–66.
57. Lombardi B, Paci M, Nannetti L, Moretti S, Maritato M, Benelli G. Total hip arthroplasty after hip fracture or osteoarthritis: are there differences in characteristics and outcomes in the early rehabilitative stage? Orthop Nurs. 2014;33(1):43–7.

58. Sassoon A, D'Apuzzo M, Sems S, Cass J, Mabry T. Total hip arthroplasty for femoral neck fracture: comparing in-hospital mortality, complications, and disposition to an elective patient population. J Arthroplast. 2013;28(9):1659–62.
59. Bordini B. CORR insights®: the frank stinchfield award: total hip arthroplasty for femoral neck fracture is not a typical DRG 470: a propensity-matched cohort study. Clin Orthop Relat Res. 2017;475(2):361–3.
60. Malik AT, Khan SN, Ly TV, Phieffer L, Quatman CE. The "hip fracture" bundle—experiences, challenges, and opportunities. Geriatr Orthop Surg Rehabil. 2020;11:2151459320910846.
61. Cairns MA, Ostrum RF, Clement RC. Refining risk adjustment for the proposed CMS surgical hip and femur fracture treatment bundled payment program. JBJS. 2018;100(4):269–77.
62. Johnson DJ, Greenberg SE, Sathiyakumar V, Thakore R, Ehrenfeld JM, Obremskey WT, Sethi MK. Relationship between the Charlson comorbidity index and cost of treating hip fractures: implications for bundled payment. J Orthop Traumatol. 2015;16(3):209–13.
63. Tung Y-C, Chang H-Y, Chang G-M. Impact of bundled payments on hip fracture outcomes: a nationwide population-based study. Int J Qual Health Care. 2018;30(1):23–31.
64. Konda SR, Lott A, Egol KA. Development of a value-based algorithm for inpatient triage of elderly hip fracture patients. J Am Acad Orthop Surg. 2020;28(13):e566–72.

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