The Impact of Perioperative Variables on Morbidity and Mortality of Elderly Hip Fractures

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ABSTRACT

With the aging United States population, there is a parallel increase in the number of patients presenting with hip fractures. These fractures in the elderly present unique challenges that arise from age and frailty. Improving perioperative management for these patients can enhance morbidity, mortality, and economic outcomes. Optimizing outcomes in elderly hip fracture repair relies on multidisciplinary collaboration to manage perioperative comorbidities.

KEY POINTS

- Elderly patients presenting for hip fracture repair are susceptible to postoperative complications of nearly all organ systems that frequently increase mortality risk.
- Preoperative conditions, including age, sex, frailty, comorbidities, ASA class, and type of fracture, all factor into postoperative risk of morbidity and mortality.
- Minimizing delays to surgery, a comprehensive preoperative cardiac and renal assessment, and administration of iron, erythropoietin, hemoglobin, albumin, and TXA may all help to decrease postoperative mortality.
- Pre- and postoperative troponin, BNP, and RRI monitoring may help with the early detection of postoperative complications.
- Dental hygiene, physical therapy, and incentive spirometry have been shown to decrease the incidence of postoperative pneumonia significantly.
- Intraoperative hypotension should be treated promptly.

KEYWORDS

Hip fracture, morbidity, mortality, postoperative complications, frailty, anesthesia management, geriatrics, elderly, fracture repair

INTRODUCTION

Hip fractures are the most common trauma-related injuries and the most common reason for elderly patients to undergo emergency surgery (1–3). The incidence of hip fractures is chronologically skewed, with 87% to 96% occurring in patients over 65 years and up to 75% of hip fractures occurring in women (4). Globally, about 18% of women and 6% of men, over their lifetime, will be impacted by such hip trauma (5).

There are over 300,000 hip fractures annually in the United States, generating approximately 19 billion dollars in healthcare costs. With life expectancy rising globally, hip fractures are a growing challenge worldwide (6). In 2017, France, Germany, Italy, Spain, the UK, and Sweden spent €37 billion on hip fracture care (7). In the USA, hip fractures account for 72% of fracture-related healthcare costs, representing only 14% of all osteoporotic fractures (8). The first six-month expenditure on medical care directly related to any hip fracture repair ranges between $34,509 and $54,054 (9). Thus, in a population with a growing proportion of elderly patients where fractures are becoming increasingly prevalent, hip fractures pose an increasing burden functionally and financially.

Hip fractures are associated with significant physical, psychological, and financial burdens, with up to half of patients unable to return to the same quality of life as before their injury (58). Nearly every organ system is negatively affected, with a considerable decline in cardiovascular, respiratory, renal, and cognitive function.

Type of Fractures

Hip fractures are classified by their anatomical location. They are generally divided into two categories: intracapsular, which occur in the region of the femoral head and neck within the joint capsule of the hip, and extracapsular, which occur anywhere outside the joint capsule (Figure 1) (12).

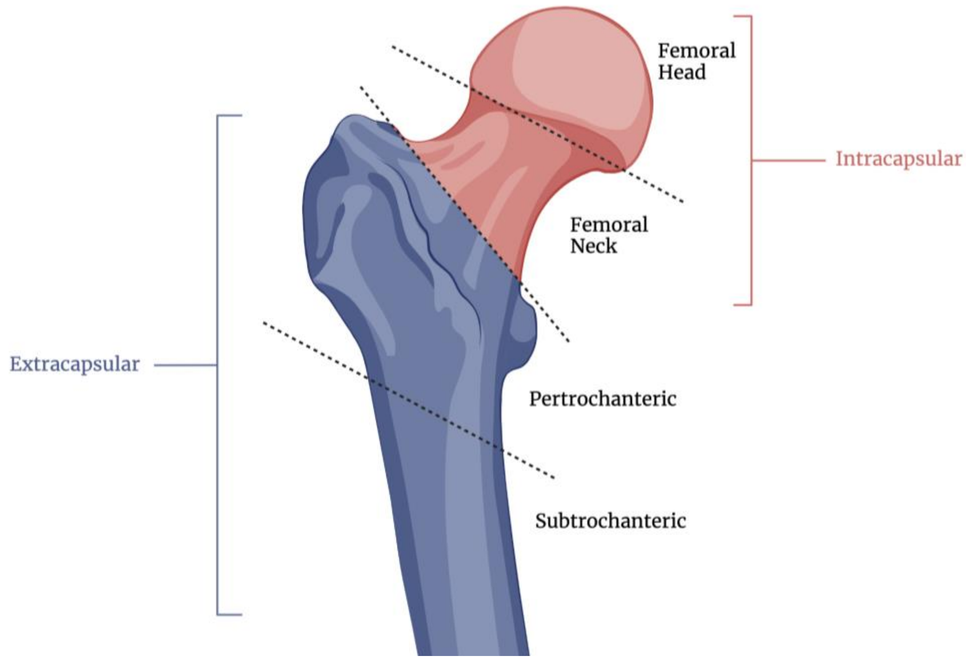


Figure 1: *Intracapsular fractures* affect the femoral head and neck, while *extracapsular fractures* are those located inferior to the femoral neck and outside the joint capsule.

Intracapsular fractures, particularly femoral neck fractures, are associated with a 77% greater risk of postoperative mortality when compared to extracapsular fractures (13–16), most likely due to the critical and vulnerable blood supply to the femoral neck and head resulting in worsened healing and increased susceptibility to necrosis (12).

Age and Sex

In addition to increased morbidity and substantial economic burdens, hip fractures are significantly linked to increased mortality in the geriatric population. Mortality after hip fracture occurs at a rate 3-fold higher than in an equivalent non-traumatized group (4). Unfortunately and significantly, one-fifth to one-third of patients will die within one year of their hip fracture (17). The risk of postoperative mortality is 68% higher in patients over 85 years(16). Although females are more likely to suffer from a hip fracture, males have a significantly higher mortality rate following hip fracture repair (4,18,19). Females are more likely to suffer from a hip fracture at a younger age than males, which may be due to postmenopausal osteoporosis and bone fragility. Thus, female patients, being younger, better handle the stress of fracture, subsequent surgery, and management (19,20). On the other hand, males tend to fracture their hip at a later age and, therefore, present in a state of greater frailty and have higher mortality from coexisting comorbidities (4,13,18,19).

Frailty

Frailty, arguably the most significant determinant of clinical outcomes in the elderly, is defined as increased vulnerability to external stressors. The degree of disability due to frailty can be quantified using numerous validated scales. The Clinical Frailty Scale (CFS) is one of the most used scales detailed in Table 1 (21,22).

Clinical Frailty Scale		
CFS	**Category**	**Description**
1	Very Fit	Robust, active, energetic, and motivated. Commonly exercise regularly. Fittest for their age.
2	Well	No severe disease symptoms but are less fit than category 1. Very active but only occasionally.
3	Managing Well	Well-controlled medical problems but are not regularly active beyond routine walking.
4	Living with Very Mild Frailty	While not dependent on others for daily help, symptoms often limit activities.
5	Living with Mild Frailty	Need help in higher-order instrumental activities of daily living such as finance, transportation, heavy housework, and medication management.
6	Living with Moderate Frailty	Need help with all outside activities and housekeeping. Inside often have problems with stairs, need help with bathing, and may need minimal assistance with dressing.
7	Living with Severe Frailty	Completely dependent on cognitive and physical personal care. Not at high risk of dying (within six months).
8	Living with Very Severe Frailty	Completely dependent on personal care and approaching the end of life. Typically, could not recover even from minor illnesses.
9	Terminally Ill	Approaching the end of life. Life expectancy of under six months who are not otherwise living with severe frailty.

Table 1. Clinical Frailty Scale (CFS) (21,22).

Associated 30-day mortality risks for the individual CFS scores in a retrospective observational study of emergency room patients requiring resuscitation who were subsequently admitted to intermediate care and intensive care units are shown in Table 2 (23).

Mortality Rates by CFS Score				
CFS	1-4	5	6	7-9
30-day mortality, n (%)	19 (8.4)	18 (14.2)	21 (21.0)	24 (26.4)
Unadjusted Analysis				
Risk Difference (95% CI), %	Reference	8.0 (−2.1 to 18.0)	15.9 (4.5 to 27.3)	21.8 (9.6 to 34.1)
Risk Ratio (95% CI), %	Reference	1.58 (0.96 to 2.61)	2.25 (1.42 to 3.56)	2.81 (1.81 to 4.35)
Adjusted Analysis				
Risk Difference (95% CI), %	Reference	6.3 (−3.4 to 15.9)	11.2 (0.4 to 22.0)	17.7 (5.3 to 30.1)
Risk Ratio (95% CI), %	Reference	1.45 (0.87 to 2.41)	1.85 (1.13 to 3.03)	2.44 (1.50 to 3.96)

Table 2. Mortality Rates by Clinical Frailty Score (23).

Not only is increased frailty associated with increased 30-day mortality and increased occurrence of one or more complications following hip fracture repair (15,24,25), the consequences of higher frailty secondary to comorbidities, polypharmacy, and osteoporosis have been strongly linked as precipitating factors for hip fractures themselves (25). Frailty scores have also been shown to predict discharge disposition, which may provide insight into the risk of morbidity and mortality following hip fracture repair. Specifically, discharge to skilled nursing facilities (SNFs) or assisted living facilities are associated with more excellent survival rates due to the emphasis on remobilization (defined as mobility in the first 24 to 48 hours after surgery) and re-enablement defined as resumption of activities of daily living (ADLs) within 3 to 5 days after surgery (4,26). Early ambulation within 96 hours of surgery and return to normal ADLs in elderly patients have been shown to improve long-term results by helping to decrease the risk of blood clots, pneumonia (PNA), disorientation, and deconditioning (19,27).

Comorbidities

With increased age comes an increased prevalence of comorbidities, including heart disease, diabetes, chronic obstructive pulmonary disease (COPD), renal dysfunction, and cognitive decline (28). The use of the American Society of Anesthesiologists (ASA) class as a proxy for comorbidities is well established, with the assumption that a higher ASA class (class III or more significant) correlates with a greater degree of worsened postoperative outcomes (29,30). The frequency of a higher ASA class in geriatric hip fractures varies between one-third to more than half of patients (27,31); this designation has also been linked to a higher risk for postoperative pulmonary complications (32). Higher ASA classes have been correlated with increased mortality rates postoperatively, with patients facing a 44% increased mortality risk (13,16,18,33).

The ASA classification is a systematic risk-stratification method whereby patients receive a class of 1 through 6 with examples of comorbidities shown in Table 3 (34):

ASA **Classification System**		
ASA Class	**Definition**	**Example**
ASA I	A normal healthy patient	Normal adult, non-smoker, minimal alcohol use
ASA II	A patient with mild systemic disease	Mild disease without functional impairment, current smoker, obese, well-controlled DM/HTN
ASA III	A patient with a severe systemic disease that is not life-threatening	Substantial function impairment, morbid obesity, poorly controlled DM/HTN, alcohol dependence, ESRD on dialysis, mildly reduced EF
ASA IV	A patient with a severe systemic disease that is a constant threat to life	MI, CVA, TIA, or stent placement within 3 months, cardiac ischemia, severely reduced EF, shock, sepsis, DIC, ESRD not on dialysis
ASA V	A moribund patient who is not expected to survive without operation	Ruptured aneurysm, massive trauma, ICH with mass effect, ischemic bowel with multi-organ dysfunction
ASA VI	A brain-dead patient whose organs are being removed to transplant into another patient	

Table 3. American Society of Anesthesiologists (ASA) Classification System (34).
DM: diabetes; HTN: hypertension; ESRD: end-stage renal disease; EF: ejection fraction; MI: myocardial infarction; CVA: cerebral vascular accident; TIA: transient ischemic attack; DIC: disseminated intravascular coagulation; ICH: intracranial hemorrhage.

Kidney Disease

Chronic kidney disease (CKD) is seen in 7.4 to 18.5% of hip fracture patients and poses a substantially increased risk for morbidity and mortality (5)**.** End-stage renal disease (ESRD) patients are between 4 to 17 times more susceptible to hip fractures (35). Patients with diabetic nephropathy are estimated to have a nearly 3-fold more significant risk of hip fracture (36). Numerous explanations for this increased risk in elderly patients with CKD have been proposed (Table 4) (35,37,38).

Increased risk in elderly patients with CKD
A creatinine clearance of <65 mL/min, in the setting of osteoporosis, increases the risk of traumatic falls and subsequent hip fracture in elderly patients.
Decreased neuromuscular function due to decreased Vitamin D concentrations.
Increased bone fragility due to dysfunctional bone and mineral metabolism and parathyroid hormone imbalances.

Table 4. Increased risk in elderly patients with Chronic Kidney Disease (35, 37, 38).

In elderly hip fracture patients, CKD increases two-fold the risk of postoperative cardiovascular events, pneumonia, respiratory failure, and gastrointestinal bleeding (5). The association between CKD and postoperative complications is even stronger in the face of concomitant underlying coronary vascular disease (39). Chronic kidney disease has also been associated with more extended stays (LOS) and higher hospital costs after hip fracture surgery (35).

Dialysis is associated with an increased risk of hip fractures and morbidity and mortality following postoperative repair (40). The risk of hip fracture increases with the length of time on dialysis, with a cumulative increase in risk by 2% for every month that the patient requires dialysis (36). Potential causes of this increased risk might be β2-microglobulin amyloidosis and chronic uremic osteodystrophy (41). The risk of MI within 30 days following hip fracture repair is two times greater in patients requiring dialysis (42). Dialysis patients taking adrenal cortical steroids, benzodiazepines, narcotics, or selective serotonin reuptake inhibitors (SSRIs) are shown to be at an increased risk for hip and other bone fractures (41). Needing immediate postoperative dialysis is associated with higher mortality in any fracture repair, even in patients who are on maintenance dialysis (43). Overall, in-hospital mortality of hip fracture patients on dialysis ranges from 7 to 17% (35,44).

The timing of dialysis before surgery may impact postoperative outcomes. General guidelines dictate when to dialyze a patient, though not specific to the geriatric populations, should be used as recommended (Table 5) (45,46).

When to Dialyze: General Guidelines
Dialysis should be done the day before surgery.
Surgery should not be scheduled on Monday if a patient is on a Tuesday, Thursday, or Saturday dialysis schedule.
If surgery is urgent and must be performed on the day of dialysis, holding heparin in the dialysate should be considered or surgery should be delayed 4 hours post-dialysis to allow heparin clearance.
Ideally, the patient should be euvolemic before surgery.

Table 5. General Guidelines for Dialysis (45,46).

Dialysis patients tend to bleed more because of uremic platelet dysfunction caused by excess uremia and elevated parathyroid hormone. Strategies to reduce bleeding in such patients include desmopressin or cryoprecipitate to improve platelet dysfunction. Waiting for four hours after dialysis is recommended before operating because heparin is frequently used during dialysis (45). A comprehensive assessment of glomerular filtration rate (GFR); potassium and hemoglobin levels; and acid-base and volume status should be performed before surgery to help avoid drugs or strategies that may negatively impact outcomes (Table 6).

Anesthetic Considerations in Dialysis Patients
Avoid succinylcholine in patients with elevated serum potassium.

Appropriate ventilatory settings to correct or compensate for acid-base disturbances.	
Use of fluids appropriate to the surgical procedure and perioperative volume status.	

Table 6. Anesthetic Considerations in Dialysis Patients (45).

Chronic Obstructive Pulmonary Disease

Like CKD, elderly patients with a history of COPD are at a higher risk of postoperative morbidity and mortality (42). Typically, regional anesthesia is preferred in COPD patients undergoing hip fracture repair to eliminate the risk of barotrauma and airway injury during endotracheal intubation. However, if general anesthesia is required, lung recruitment maneuvers and low tidal volume ventilation decreases intraoperative lung injury, decreasing postoperative pulmonary complications (42). Furthermore, intramedullary nailing of the fracture, as opposed to hip arthroplasty, is preferred due to decreased time under anesthesia and increased ability for remobilization (42).

Cognitive Impairment

Cognitive impairment (commonly caused by dementia, Alzheimer's disease, and Parkinson's disease) is significantly associated with postoperative mortality. Patients with cognitive impairment before admission face a 91% greater risk of death (16). In the preoperative scenario, this increased mortality may be due to the correlation between cognitive decline, advancing age, and declining overall health. Postoperative cognitive impairment (delirium or dementia) makes it challenging to comply with rehabilitation regimens, thereby increasing morbidity and mortality risk (16). Antidepressant use, positively correlated with comorbid conditions and increasing age, is also associated with increased fracture risk (47). SSRIs and tricyclic antidepressants (TCAs) have increased the risk of geriatric hip fractures (48). This risk is most significant within six weeks of starting antidepressant treatment. It is thought to be due to the inadvertent effect on serotonin transporters in osteocytes, osteoblasts, and osteoclasts (47). Additionally, in the initial stages of antidepressant therapy, balance is negatively affected, and elderly users are twice as likely to experience a clinically significant fall after starting this class of medication (49). Postural instability and reduced muscle strength are potential causal factors for the association between antidepressants and increased fall risk (47,50,51).

Infection

The association between viral infections and hip fracture incidence in elderly patients has been investigated. The influenza virus and other flu-like illnesses have increased the risk of hip fractures, particularly in nursing home residents (52,53). More recently, COVID-19 infection was seen in 21% of hip fracture patients (54) and is associated with an increased LOS, 30-day mortality, and a seven-fold increase in the risk of overall mortality following hip fractures (1). The leading causes of death include respiratory failure, COVID-19–associated pneumonia, and multi-organ failure (54). Moreover, there is also an increased risk of venous thrombotic events (VTE) secondary to COVID-19's inflammatory effect on endothelial cell dysfunction, fibrinolysis impairment, and excessive thrombin generation (1).

Causes of Mortality

The one-year mortality following surgically untreated hip fracture is 70%. Even when fracture repair is performed, one-year mortality is roughly 20% (10). For over eight years following the index injury, the mortality continues to be higher than baseline in all elderly patients (11). Any modifiable cause of mortality should be addressed proactively, recognizing that this patient subset already brings many nonmodifiable preoperative frailties.

Overall, short-term causes of death following hip fracture repair (in order of prevalence) are respiratory complications (bronchopneumonia and respiratory failure), cardiac complications (cardiac failure, myocardial infarction (MI), ischemic heart disease, pulmonary embolism (PE), and stroke), multi-organ failure, and septic shock (19,33).

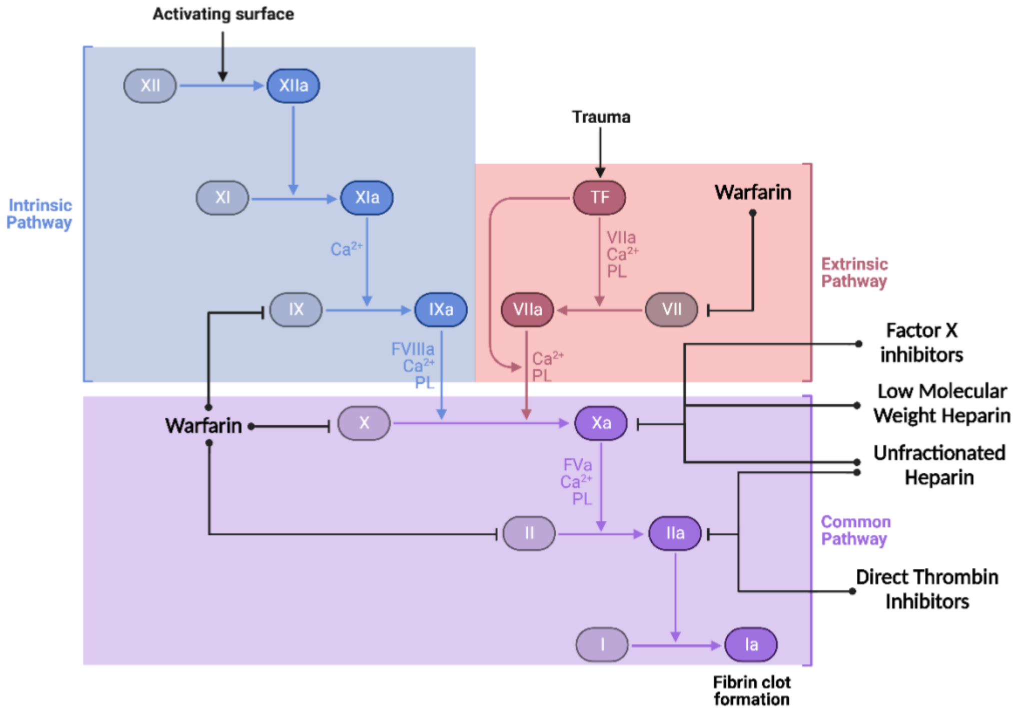
Sepsis and septic shock occur in roughly 2% of hip fracture surgeries. Still, they can increase the risk of 30-day mortality by three times and 11 times compared to patients without sepsis or septic shock, respectively. Urinary tract infections, pneumonia, and surgical site infections typically precede most cases of postoperative sepsis and septic shock. Risk factors for postoperative sepsis include long-term steroid use, congestive heart failure (CHF), and preoperative ventilator dependence. The link between ventilator use and septic shock is likely due to the risk of developing ventilator-associated pneumonia and subsequent progression to septic shock. Both anemia and hypoalbuminemia are also associated with an increased risk of sepsis and septic shock following hip fracture repair. Preoperative administration of iron supplements and erythropoietin, even with its known time lag to efficacy, may improve recovery times and reduce hospital LOS. Although intuitive and used frequently, it is yet to be statistically validated (55).

Both surgical repair within 24 hours following the initial injury and early mobilization have decreased the risk of bronchopneumonia and pulmonary embolism (56). The impact of time to hip fracture repair on postoperative mortality has been well studied, with delays over 48 hours resulting in 30-day postoperative mortality rising to 50% and one-year mortality increasing by 32% (7,13,26,32,57). Surgery within six hours has decreased overall hospital LOS and incidence of postoperative delirium (POD). Still, it has little effect on decreasing mortality or non-fatal complications such as MI, stroke, VTE, sepsis, and pneumonia (26).

Long-term causes of mortality include (in order of prevalence) cardiac complications, respiratory complications, dementia, and Alzheimer’s disease (4). Men are more likely to die from respiratory and circulatory disease following hip fracture fixation. This is speculated to be due to the increased prevalence of smoking and the earlier development of chronic heart disease in the male population resulting in a greater incidence of respiratory and cardiac diseases (4).

Cardiac Complications

Preoperative heart failure significantly correlates with longer length of stay (LOS) following surgery, increased risk of postoperative heart failure as a surgical complication, and increased one-year mortality (59). History of peripheral vascular disease (PVD), stroke, COPD, and cardiac disease are all significant predictors of postoperative cardiac events in all hip fracture patients (42). Patients with CKD double their risk of cardiovascular events, including pulmonary embolism, angina pectoris, MI, heart failure, arrhythmia, CVA, and death, following hip fracture surgery than those without CKD (5). Stress-induced hyperglycemia in nondiabetic patients is another predictor of postoperative MI (60). Elevated perioperative troponin levels effectively predict 30-day and long-term mortality from hip fractures (60). Between 30 to 70% of hip fracture patients present with an elevated troponin level at admission secondary to catecholamine surge and thrombotic processes in the setting of pain (60). It is difficult to assess a patient’s preoperative cardiac status due to a lack of pre-trauma cardiac data (61). Obtaining preoperative troponins, B-type natriuretic peptide (BNP) levels, and perioperative echocardiograms provides a valuable tool for risk assessment and helps guide intraoperative anesthetic management.



Vascular Complications

Venous thromboembolism (VTE), specifically deep venous thrombosis (DVT), is among the principal causes of perioperative morbidity and mortality following total hip arthroplasty (THA) (62,63). The prevalence of DVTs in hip replacements performed without anticoagulation prophylaxis can reach up to 75%, while that of pulmonary embolism ranges between 0.5 to 3.5% (64). When early surgical intervention and mobilization are challenging to achieve, thromboprophylaxis use can effectively reduce the risk of VTE by up to 60% (65). Numerous agents currently exist for thromboembolism prophylaxis (Figure 2).

Figure 2: Multiple therapeutic targets of the coagulation cascade

Fondaparinux, a selective factor Xa inhibitor in the coagulation cascade, is commonly used in hip fracture cases and considered one of the more effective prophylactic agents, shown to reduce the risk of VTE by as much as 56.4% (12). Heparin is another effective anticoagulant agent that rapidly works to block multiple factors in the coagulation cascade by augmenting the action of Antithrombin III (66). Available in two different preparations via intravenous injection, heparin exhibits different clearance mechanisms making each preparation better suited for specific patient populations (Table 7) (67).

Clearance of Heparins		
Mechanism	Saturable: clearance through reticuloendothelial system and endothelial cells	Non-saturable: clearance through renal excretion
Clearance	Rapidly increases at low doses, then plateaus	Increases linearly with dosage
Example	Low-Dose Unfractionated Heparin	High-Dose Unfractionated Heparin Low-Molecular Weight Heparin

Table 7. Clearance of Heparins (67).

LMWH, such as dalteparin and enoxaparin, may be preferable for some situations due to their better side effect profiles but should be avoided in patients with decreased renal function (12,68). Instead, LDUH is a safer option in patients with creatinine clearance <30 mL/min (12). Overall, perioperative heparin administration is significantly effective in reducing the incidence of DVT in hip fracture repair (69).

Mechanical calf/foot pumping devices and compression stockings are also proven to reduce DVT incidence during these surgeries (12,69). In addition, regional anesthesia has been shown to help lower the risk of VTE, likely due to increased peripheral vasodilation and the inhibition of platelet aggregation and stabilization of endothelial cells (70).

Before any injury, up to 40% of hip fracture patients are on anticoagulant or antiplatelet regimens. This proportion increases when considering the prevalence of long-term treatment of thrombotic conditions such as atrial fibrillation, acute coronary syndrome (ACS), intrinsic hypercoagulable states, previous VTE, and prolonged immobility in elderly patients (26,71). Thus, clinicians must balance decreasing the risk of intraoperative hemorrhage with an elderly patient's underlying hypercoagulable state (63).

Among the most common long-term anticoagulants used to prevent VTE are Vitamin K antagonists (VKAs), such as warfarin, which prevent the production of numerous factors in the coagulation cascade. Sufficient reversal of the effects of VKAs for hip fracture surgery, as measured by an International Normalized Ratio (INR) value of around 1.5, may take anywhere from 3 to 5 days (71–73). In urgent hip fracture surgery, where delayed repair is associated with adverse outcomes, omitting anticoagulating agents may not be enough to reverse antithrombotic effects. Considerations are shown in Table 8 (71-73).

IV infusion of Vitamin K and Halting VKAs	Administration of Prothrombin Complex Concentrate (PCC)
Effect within 12 to 36 hours of administration depending on the preoperative dose of Vitamin K.*	Has been shown to reverse INR values to an average of 1.3 from therapeutic levels within 30 minutes of administration.
INR < 1.8 under general anesthesia INR < 1.5 under spinal anesthesia	
Disadvantages: Anaphylaxis (dose-dependent) Acute Thrombosis Warfarin Resistance	Disadvantages: Allergic Reaction Heparin-Induced Thrombocytopenia Disseminated Intravascular Coagulopathy Thromboembolic Events High Cost

Table 8. Considerations for anticoagulant use in hip fractures (71-73).
*Additional research is necessary to elucidate the ideal utilization for VKA reversal in hip fracture repair.

Antiplatelet therapy, including aspirin (ASA), clopidogrel, and ticagrelor, is another anticoagulation treatment commonly used to prevent VTE. Platelet transfusion may be an effective reversal therapy for most antiplatelet regimens (72). Some studies have indicated that delays in surgery to reverse antiplatelet therapy from aspirin and clopidogrel are unnecessary, as no difference in bleeding complications, blood loss, or transfusion requirements was found when compared to patients, not on aspirin or clopidogrel (72). The risk of vertebral canal hematoma (VCH) with spinal anesthesia in hip fracture repair for patients on anticoagulant regimens is well known. However, recent guidelines have advised that this risk may be lower than general anesthesia or delaying repair (71).

Current recommendations for patients on anticoagulants undergoing hip fracture with spinal anesthesia can be seen in Figure 3.

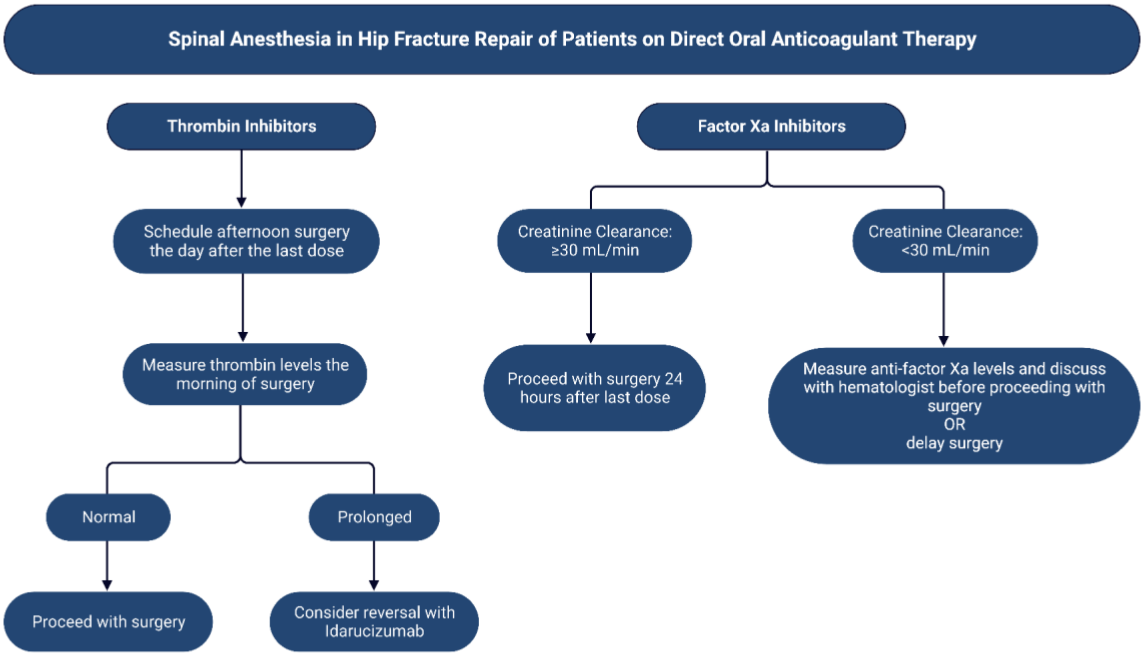


Figure 3: Decision-making for using spinal anesthesia in hip fracture repair for patients on direct oral anticoagulation therapy. Adapted, (71).

Bleeding is a common complication in hip fracture repair, with blood transfusion required in up to 30% of cases (74). There is some concern, however, that most of the blood loss associated with traumatic hip fractures occurred post-injury and before the repair itself, with an average hemoglobin decrease of 1.5 units and 2.0 units of blood for intracapsular and extracapsular hip fractures, respectively (75). Elderly patients undergoing hip fracture repair may present to the hospital already in a hypovolemic state due to chronic dehydration, blood loss after the initial trauma, or decreased ability to intake fluids due to fracture-related immobility, all of which emphasize the need for an assessment of preoperative volume status (75). Methods of measuring intraoperative blood loss are inaccurate. They cannot provide immediate feedback on patient volume status (76), requiring anesthesiologists to use their best judgment when deciding when to give blood or fluids based on alternate criteria such as heart rate, blood pressure, and pain control.

Tranexamic acid (TXA) is a pharmacologic agent that inhibits the normal breakdown of fibrin clots by preventing plasminogen activation (77). The administration of TXA in urgent hip fracture surgery should be used cautiously in an elderly patient population that is frequently hypercoagulable. However, some studies have shown that TXA administration for hip fracture repair is not associated with an increased risk of thromboembolic events, does not increase 90-day mortality, and decreases the need for blood transfusions by up to 42% (74,78). Reducing blood transfusions decreases the risk of transfusion reactions, infections, and anaphylaxis. Patients who had received TXA have also been shown to have higher hemoglobin concentrations postoperatively, further decreasing the risk of complications such as sepsis and acute kidney injury (AKI) (74).

Pulmonary Complications

Postoperative pneumonia is one of the most common complications following hip fracture resulting in severe morbidity and mortality due to altered immunity and susceptibility to infection in the elderly (Figure 4) (79–83). Advanced age is associated with an increased risk of pulmonary conditions and infections, such as pneumonia and atelectasis, due to numerous age-related factors (Table 9).

Age-Related Factors Predisposing for Pulmonary Complications
Impaired effective cough decreases airway clearance.
Increased alveolar dead space.
Decreased responsiveness to drugs.
Poor dental and oral hygiene.
Diminished ventilatory response to hypoxia and hypercapnia.
Weakened immunity.
Poor nutritional status.

Table 9. Age-Related Factors Predisposing for Pulmonary Complications.

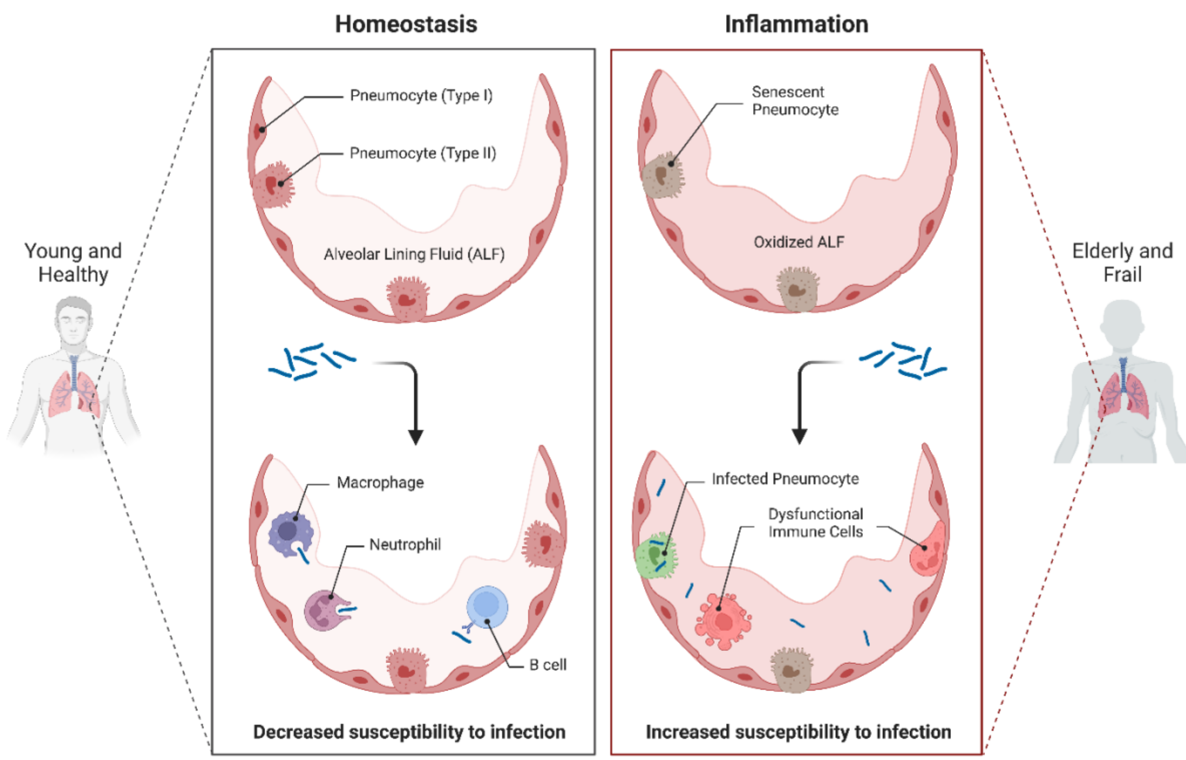


Figure 4: Difference in immune responsiveness between a healthy adult immune response and an elderly individual. Used with permission Biorender Graphics Library.

Elderly patients presenting for hip fracture repair with pre-operative atelectasis or pulmonary consolidation were shown to have a greater propensity for postoperative pulmonary complications (32). The incidence of such complications can be seen in up to a third of patients, prompting the need for preventative practices (Table 10) (32,84).

Methods of Decreasing Postoperative Pneumonia Incidence
The implementation of thorough oral care in daily nursing protocol and appropriate use of antibiotics can decrease the risk of aspirating bacterial microorganisms from the oral cavity and subsequent pulmonary infection.
Observing appropriate patient positioning for swallowing and preventing gastroesophageal reflux decrease the likelihood of aspiration.
Early remobilization through intense physiotherapy to promote mobility.
Postoperative chest physiotherapy using positive expiratory pressure devices and proper deep breathing techniques may help to improve oxygenation and facilitate mucous clearance.

Table 10. Methods of Decreasing Postoperative Pneumonia Incidence (32, 82, 84-86).

Prolonged bed rest is well-known to result in deterioration of muscle strength, insulin resistance, increased risk of thrombosis, and impaired respiration: all of which increase the risk of insufficient oxygenation and atelectasis (87).

In addition to an increased risk of hip fracture, osteoporosis also contributes to decreased chest wall expansion due to calcification of the osteochondral joints (80). The resultant decreased lung compliance leads to external cardiac compression and collapse of the inferior vena cava (IVC) as it passes through the diaphragm (88,89). The reduced venous return to the right heart causes decreases in left ventricular preload, stroke volume, and cardiac output (88,89). In insufficient physiologic compensation, the reduced venous return can increase the risk of hypotension in elderly patients, compounded by age-related increases in closing volume. Increased closing volumes result in hyperinflated lungs, while decreased lung compliance creates increased intrathoracic pressure, which directly compresses the heart, reduces cardiac compliance and performance, and contributes to an increased risk of perioperative hypotension in elderly patients. This increases the risk of hypoperfusion of end organs, increasing postoperative mortality and morbidity (89–91).

Renal Complications

The sudden drop in renal function, also known as acute kidney injury (AKI), following surgery occurs in up to 28% of hip fracture repairs and is associated with prolonged hospital LOS and increased rates of postoperative morbidity and mortality (92). The 30-day and one-year mortality of patients with AKI after hip fracture is higher than that of patients without AKI (7 and 3 times higher, respectively) (92). The development of postoperative AKI is multifactorial (Table 11) (92–96).

Preoperative	Intraoperative	Postoperative
Advanced Age	Hypotension Time	Hypoalbuminemia
Male	Hypotension Degree	Anemia
ASA > 3	Massive Bleed	Blood Transfusion**
History		
Peripheral Vascular Disease		
COPD		
Chronic Kidney Disease		
Diabetes Mellitus		
Congestive Heart Disease		
Tobacco Use		
Low Body Mass Index*		
Low GFR		
High Creatinine		
Use of Nephrotoxic Drugs		

Table 11. Risk Factors for Acute Kidney Injury in hip fracture patients (92-96).

COPD: chronic obstructive pulmonary disease; GFR, glomerular filtration rate; ASA

*Low BMIs may play a role in renal complications, although it is unclear what the role BMI plays in developing AKI

**Blood transfusions are usually a consequence of severe illness. The association between blood transfusion and AKI is likely due to acute illness in patients rather than AKI compounded by the blood transfusion itself.

Intraoperative hypotension is a significant concern for the development of AKI as each additional hour where mean arterial pressure (MAP) is less than 70-, 60-, and 50-mm Hg increases the risk of AKI by 2%, 5%, and 22% respectively (97). Postoperative hypoalbuminemia is a marker of decreased colloid osmotic pressure, which results in inadequate circulating volume and decreased glomerular filtration and renal function (98).

Studies have investigated using the renal resistive index (RRI) as a predictor for postoperative AKI and the early detection of renal microvascular damage following altered hemodynamics. The RRI is a non-invasive method of evaluating kidney perfusion, using Doppler waveforms at the level of arcuate or interlobar arteries (99). RRI is calculated as:

$$\text{RRI} = \frac{(peak\ systolic\ velocity - end\ diastolic\ velocity)}{peak\ systolic\ velocity}$$

Equation 1. Renal Resistive Index.

RRI is inversely related to MAP, diastolic blood pressure, and heart rate and directly related to pulse pressure (99). Regarding hip fracture repair, both preoperative and postoperative RRI are independent predictive factors of postoperative AKI. Postoperative RRI has shown value in detecting AKI up to a day earlier than serum creatinine levels or urine output (94,100). An RRI higher than a cut-off threshold of 0.71 has been shown to predict AKI following hip fracture surgery, while values less than 0.70 demonstrate improved renal outcomes (Table 12) (100,101). Current studies have emphasized the need for randomized control trials to better establish the value of RRI in managing AKI prevention.

	p-value
Preoperative RRI Values	0.014
No Perioperative AKI	0.68 (0.67 - 0.71)
Presence of Perioperative AKI	0.72 (0.70 - 0.73)
Postoperative RRI Values	< 0.0001
No Perioperative AKI	0.6 (0.58 - 0.68)
Presence of Perioperative AKI	0.74 (0.71 - 0.76)

Table 12. Renal Resistive Index can help predict AKI following hip fracture surgery (100,101).

Early fluid resuscitation, avoidance of nephrotoxic drugs, replenishment of albumin and hemoglobin, and strict maintenance of MAP above predetermined relative thresholds may all work to reduce the incidence of postoperative AKI.

Postoperative Delirium

Postoperative delirium is the most common complication, reported in up to a third of these patients (102). POD is also correlated with increased frailty, one-year mortality, LOS, discharge destination, sepsis, and rate of one-month readmission (3,16,20,24,102). The risk of six-month mortality increases by 10% with every additional day with POD (20,102). Risk factors for postoperative delirium are shown in Table 13 (20,24,32,103,104).

Preoperative Risk Factors	Intraoperative Risk Factors

ASA Class	Increased Time under Anesthesia
Male	Lability in Blood Pressure
COPD History	Blood Transfusion
High Frailty Scores	Late surgery*
Dementia History	
Anemia	

Table 13. Risk Factors for postoperative delirium in hip fracture patients (20,24,32,103,104).
*Observed particularly in patients with displaced femoral neck fractures, requiring Hip Bipolar Hemiarthroplasty.

Notably, the risk factors of POD are additive, stressing early recognition and prompt implementation of therapeutic measures (105). Patients with POD have hospital costs increased by 2.5-fold, causing an additional economic burden of $16,000 to $64,000 per patient year (106). Although the underlying mechanism behind POD has not yet been discerned, neurotransmitter imbalance, systemic inflammation, and electrolyte/metabolic derangements are speculated as causes of POD (20).

Multimodal pain control is effective in preventing and treating POD as it decreases the use of opioids and cholinesterase inhibitors (20). Other vital maneuvers include optimizing hemodynamic stability and acid-base status, providing adequate oxygenation, and minimizing electrolyte abnormalities (105). The choice of regional compared to general anesthesia does not change the incidence of POD (107). Overall, close collaboration with intensivists, hospitalists, geriatricians, and orthopedists is essential in minimizing the risk of POD and improving functional recovery (108).

General versus Regional Anesthesia

Whether general anesthesia is superior to regional anesthesia in the context of geriatric hip fracture repair is yet to be answered. Historically, the presence of multiple comorbidities in elderly patients makes it difficult to quantify the benefits of any mode of anesthesia over the other. However, hypotension is a significant concern in both modes due to impaired blood pressure regulation in elderly patients under anesthesia. Geriatric patients have decreased arterial compliance and cardiac cholinergic responsiveness, resulting in diminished responses to the acute changes in blood pressure caused by general or spinal anesthesia (68,109,110). Some studies find that regional anesthesia (including spinal anesthesia and nerve blocks) is correlated with better outcomes and decreased risk of morbidity than general anesthesia. However, this correlation has been subject to debate given conflicting reports by studies, flaws in study methodology, poorly defined measures of “outcome,” and varying times between inciting event (use of anesthesia) and measured outcome (30-day postoperative mortality) (7,18,26,29,32,103,104,109,111–113). General guidelines suggest that it is not the choice of anesthesia crucial to decreasing mortality but rather the provider's comfort with that mode of anesthesia (26).

Hypotension

Hypotension has been cited as a decisive factor in postoperative morbidity and mortality, including myocardial injury after non-cardiac surgery (MINS), stroke, AKI, MI, and POD in geriatric hip fracture repair (7,29,61,103,104,112,114,115). Intraoperative hypotension is seen in over 50% of elderly hip fracture surgeries. This is why 20% of patients fail to meet the remobilization performance indicator on the Nottingham Hip Fracture Score (NHFS). This is likely because intraoperative hypotension may lead to brain hypoperfusion and an increased risk of developing POD (3,20,26,112). Several preoperative risk factors for developing intraoperative hypotension include advanced age, pre-induction hypotension, chronic hypertension and antihypertensive drugs, ASA status, and hypovolemia (112). Historically, the lack of universally accepted perioperative blood pressure thresholds to define hypotension has made determining an optimal treatment plan difficult, with cut-offs utilizing multiple measurements (7,112,114) (Table 14).

Mean Arterial Pressure (MAP)	Systolic Blood Pressure (SBP)
Between 55 mm Hg - 75 mm Hg	Less than 100 mmHg
	20-30% decrease

Table 14. Suggested thresholds for defining hypotension (7,112,114).

Although no standardized definition of hypotension exists, increased cumulative time under any established hypotensive threshold is associated with an increased risk of postoperative morbidity and mortality, with organ injury occurring when MAP decreases <55 mm Hg for ≥10 min (7,103). The risk of AKI or MI increases as MAP drops below 65 mm Hg, while mortality risk is postulated to increase at a MAP of 80 mm Hg. These risks cumulatively increase as time and degree of hypotension increase (61). Mortality was significantly increased at 30 days, 60 days, and one-year marks after surgical repair when a patient received a vasopressor infusion for over 3 hours, possibly due to decreased myocardial perfusion resulting in increased oxygen demand and eventual MINS (103). Vasopressors that promote vasoconstriction may play a role in myocardial hypoperfusion and the development of MINS (103).

Risk stratification based on preoperative evaluation and early identification of hypotension is crucial in the timely and aggressive management of intraoperative hypotension. Absolute thresholds for hypotension may not be effective in geriatric populations as they assume all individuals within that category can autoregulate equally. There is a great degree of variation in autoregulatory ability amongst the geriatric population due to varying frailty, polypharmacy, and comorbidities (104). However, using relative thresholds using preoperative blood pressure readings as a reference may also be flawed due to the potential for artificial inflation of such values secondary to patient anxiety, stress, and pain (104). Nonetheless, anesthesiologists should be urged to decrease hypotensive duration by treating patients promptly on a relative threshold formed by preoperative conditions and trendlines, as opposed to absolute threshold criteria (114).

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